PHYSICS IN MANY-SHEETED SPACE-TIME: PART II

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0.1 PREFACE

This book belongs to a series of online books summarizing the recent state Topological Geometrodynamics (TGD) and its applications. TGD can be regarded as a unified theory of fundamental interactions but is not the kind of unified theory as so called GUTs constructed by graduate students at seventies and eighties using detailed recipes for how to reduce everything to group theory. Nowadays this activity has been completely computerized and it probably takes only a few hours to print out the predictions of this kind of unified theory as an article in the desired format. TGD is something different and I am not ashamed to confess that I have devoted the last 37 years of my life to this enterprise and am still unable to write The Rules.

If I remember correctly, I got the basic idea of Topological Geometrodynamics (TGD) during autumn 1977, perhaps it was October. What I realized was that the representability of physical space-times as 4-dimensional surfaces of some higher-dimensional space-time obtained by replacing the points of Minkowski space with some very small compact internal space could resolve the conceptual difficulties of general relativity related to the definition of the notion of energy. This belief was too optimistic and only with the advent of what I call zero energy ontology the understanding of the notion of Poincare invariance has become satisfactory. This required also the understanding of the relationship to General Relativity.

It soon became clear that the approach leads to a generalization of the notion of space-time with particles being represented by space-time surfaces with finite size so that TGD could be also seen as a generalization of the string model. Much later it became clear that this generalization is consistent with conformal invariance only if space-time is 4-dimensional and the Minkowski space factor of imbedding space is 4-dimensional. During last year it became clear that 4-D Minkowski space and 4-D complex projective space CP_2 are completely unique in the sense that they allow twistor space with Kähler structure.

It took some time to discover that also the geometrization of also gauge interactions and elementary particle quantum numbers could be possible in this framework: it took two years to find the unique internal space (CP_2) providing this geometrization involving also the realization that family replication phenomenon for fermions has a natural topological explanation in TGD framework and that the symmetries of the standard model symmetries are much more profound than pragmatic TOE builders have believed them to be. If TGD is correct, main stream particle physics chose the wrong track leading to the recent deep crisis when people decided that quarks and leptons belong to same multiplet of the gauge group implying instability of proton.

There have been also longstanding problems.

- Gravitational energy is well-defined in cosmological models but is not conserved. Hence the conservation of the inertial energy does not seem to be consistent with the Equivalence Principle. Furthermore, the imbeddings of Robertson-Walker cosmologies turned out to be vacuum extremals with respect to the inertial energy. About 25 years was needed to realize that the sign of the inertial energy can be also negative and in cosmological scales the density of inertial energy vanishes: physically acceptable universes are creatable from vacuum. Eventually this led to the notion of zero energy ontology (ZEO) which deviates dramatically from the standard ontology being however consistent with the crossing symmetry of quantum field theories. In this framework the quantum numbers are assigned with zero energy states located at the boundaries of so called causal diamonds defined as intersections of future and past directed light-cones. The notion of energy-momentum becomes length scale dependent since one has a scale hierarchy for causal diamonds. This allows to understand the non-conservation of energy as apparent.

  Equivalence Principle as it is expressed by Einstein's equations follows from Poincare invariance once it is realized that GRT space-time is obtained from the many-sheeted space-time of TGD by lumping together the space-time sheets to a regionof Minkowski space and endowing it with an effective metric given as a sum of Minkowski metric and deviations of the metrices of space-time sheets from Minkowski metric. Similar description relates classical gauge potentials identified as components of induced spinor connection to Yang-Mills gauge potentials in GRT space-time. Various topological inhomogenities below resolution scale identified as particles are described using energy momentum tensor and gauge currents.

- From the beginning it was clear that the theory predicts the presence of long ranged classical electro-weak and color gauge fields and that these fields necessarily accompany classical electromagnetic fields.

  It took about 26 years to gain the maturity to admit the obvious: these fields are classical correlates for long range color and weak interactions assignable to dark matter. The only possible conclusion is that TGD physics is a fractal consisting of an entire hierarchy of fractal copies of standard model physics. Also the understanding of electro-weak massivation and screening of weak charges has been a long standing problem, and 32 years was needed to discover that what I call weak form of electric-magnetic duality gives a satisfactory solution of the problem and provides also surprisingly powerful insights to the mathematical structure of quantum TGD.

  The latest development was the realization that the well- definedness of electromagnetic charge as quantum number for the modes of the induced spinors field requires that the CP_2 projection of the region in which they are non-vanishing carries vanishing W boson field and is 2-D. This implies in the generic case their localization to 2-D surfaces: string world sheets and possibly also partonic 2-surfaces. This localization applies to all modes except covariantly constant right handed neutrino generating supersymmetry and mplies that string model in 4-D space-time is part of TGD. Localization is possible only for Kähler-Dirac assigned with Kähler action defining the dynamics of space-time surfaces. One must however leave open the question whether W field might vanish for the space-time of GRT if related to many-sheeted space-time in the proposed manner even when they do not vanish for space-time sheets.

I started the serious attempts to construct quantum TGD after my thesis around 1982. The original optimistic hope was that path integral formalism or canonical quantization might be enough to construct the quantum theory but the first discovery made already during first year of TGD was that these formalisms might be useless due to the extreme non-linearity and enormous vacuum degeneracy of the theory. This turned out to be the case.

- It took some years to discover that the only working approach is based on the generalization of Einstein's program. Quantum physics involves the geometrization of the infinite-dimensional "world of classical worlds" (WCW) identified as 3-dimensional surfaces. Still few years had to pass before I understood that general coordinate invariance leads to a more or less unique solution of the problem and in positive energyontology implies that space-time surfaces are analogous to Bohr orbits. This in positive energy ontology in which space-like 3-surface is basic object. It is not clear whether Bohr orbitology is necessary also in ZEO in which space-time surfaces connect space-like 3-surfaces at the light-like boundaries of causal diamond CD obtained as intersection of future and past directed light-cones (with CP_2 factor included). The reason is that the pair of 3-surfaces replaces the boundary conditions at single 3-surface involving also time derivatives. If one assumes Bohr orbitology then strong correlations between the 3-surfaces at the ends of CD follow. Still a couple of years and I discovered that quantum states of the Universe can be identified as classical spinor fields in WCW. Only quantum jump remains the genuinely quantal aspect of quantum physics.

- During these years TGD led to a rather profound generalization of the space-time concept. Quite general properties of the theory led to the notion of many-sheeted space-time with sheets representing physical subsystems of various sizes. At the beginning of 90s I became dimly aware of the importance of p-adic number fields and soon ended up with the idea that p-adic thermodynamics for a conformally invariant system allows to understand elementary particle massivation with amazingly few input assumptions. The attempts to understand p-adicity from basic principles led gradually to the vision about physics as a generalized number theory as an approach complementary to the physics as an infinite-dimensional spinor geometry of WCW approach. One of its elements was a generalization of the number concept obtained by fusing real numbers and various p-adic numbers along common rationals. The number theoretical trinity involves besides p-adic number fields also quaternions and octonions and the notion of infinite prime.

- TGD inspired theory of consciousness entered the scheme after 1995 as I started to write a book about consciousness. Gradually it became difficult to say where physics ends and consciousness theory begins since consciousness theory could be seen as a generalization of quantum measurement theory by identifying quantum jump as a moment of consciousness and by replacing the observer with the notion of self identified as a system which is conscious as long as it can avoid entanglement with environment. The somewhat cryptic statement "Everything is conscious and consciousness can be only lost" summarizes the basic philosophy neatly.

The idea about p-adic physics as physics of cognition and intentionality emerged also rather naturally and implies perhaps the most dramatic generalization of the space-time concept in which most points of p-adic space-time sheets are infinite in real sense and the projection to the real imbedding space consists of discrete set of points. One of the most fascinating outcomes was the observation that the entropy based on p-adic norm can be negative. This observation led to the vision that life can be regarded as something in the intersection of real and p-adic worlds. Negentropic entanglement has interpretation as a correlate for various positively colored aspects of conscious experience and means also the possibility of strongly correlated states stable under state function reduction and different from the conventional bound states and perhaps playing key role in the energy metabolism of living matter.

If one requires consistency of Negentropy Mazimization Principle with standard measurement theory, negentropic entanglement defined in terms of number theoretic negentropy is necessarily associated with a density matrix proportional to unit matrix and is maximal and is characterized by the dimension n of the unit matrix. Negentropy is positive and maximal for a p-adic unique prime dividing n.

- One of the latest threads in the evolution of ideas is not more than nine years old. Learning about the paper of Laurent Nottale about the possibility to identify planetary orbits as Bohr orbits with a gigantic value of gravitational Planck constant made once again possible to see the obvious. Dynamical quantized Planck constant is strongly suggested by quantum classical correspondence and the fact that space-time sheets identifiable as quantum coherence regions can have arbitrarily large sizes. Second motivation for the hierarchy of Planck constants comes from bio-electromagnetism suggesting that in living systems Planck constant could have large values making macroscopic quantum coherence possible. The interpretation of dark matter as a hierarchy of phases of ordinary matter characterized by the value of Planck constant is very natural.

  During summer 2010 several new insights about the mathematical structure and interpretation of TGD emerged. One of these insights was the realization that the postulated hierarchy of Planck constants might follow from the basic structure of quantum TGD. The point is that due to the extreme non-linearity of the classical action principle the correspondence between canonical momentum densities and time derivatives of the imbedding space coordinates is one-to-many and the natural description of the situation is in terms of local singular covering spaces of the imbedding space. One could speak about effective value of Planck constant $h_{eff} = n \times h$ coming as a multiple of minimal value of Planck constant. Quite recently it became clear that the non-determinism of Kähler action is indeed the fundamental justification for the hierarchy: the integer n can be also interpreted as the integer characterizing the dimension of unit matrix characterizing negentropic entanglement made possible by the many-sheeted character of the space-time surface.

  Due to conformal invariance acting as gauge symmetry the n degenerate space-time sheets must be replaced with conformal equivalence classes of space-time sheets and conformal transformations correspond to quantum critical deformations leaving the ends of space-time surfaces invariant. Conformal invariance would be broken: only the sub-algebra for which conformal weights are divisible by n act as gauge symmetries. Thus deep connections between conformal invariance related to quantum criticality, hierarchy of Planck constants, negentropic entanglement, effective p-adic topology, and non-determinism of Kähler action perhaps reflecting p-adic non-determinism emerges.

  The implications of the hierarchy of Planck constants are extremely far reaching so that the significance of the reduction of this hierarchy to the basic mathematical structure distinguishing between TGD and competing theories cannot be under-estimated.

From the point of view of particle physics the ultimate goal is of course a practical construction recipe for the S-matrix of the theory. I have myself regarded this dream as quite too ambitious taking into account how far reaching re-structuring and generalization of the basic mathematical structure of quantum physics is required. It has indeed turned out that the dream about explicit formula is unrealistic before one has understood what happens in quantum jump. Symmetries and general physical principles have turned out to be the proper guide line here. To give some impressions about what is required some highlights are in order.

- With the emergence of ZEO the notion of S-matrix was replaced with M-matrix defined between positive and negative energy parts of zero energy states. M-matrix can be interpreted as a complex square root of density matrix representable as a diagonal and positive square root of density matrix and unitary S-matrix so that quantum theory in ZEO can be said to define a square root of thermodynamics at least formally. M-matrices in turn bombine to form the rows of unitary U-matrix defined between zero energy states.

- A decisive step was the strengthening of the General Coordinate Invariance to the requirement that the formulations of the theory in terms of light-like 3-surfaces identified as 3-surfaces at which the induced metric of space-time surfaces changes its signature and in terms of space-like 3-surfaces are equivalent. This means effective 2-dimensionality in the sense that partonic 2-surfaces defined as intersections of these two kinds of surfaces plus 4-D tangent space data at partonic 2-surfaces code for the physics. Quantum classical correspondence requires the coding of the quantum numbers characterizing quantum states assigned to the partonic 2-surfaces to the geometry of space-time surface. This is achieved by adding to the modified Dirac action a measurement interaction term assigned with light-like 3-surfaces.

- The replacement of strings with light-like 3-surfaces equivalent to space-like 3-surfaces means enormous generalization of the super conformal symmetries of string models. A further generalization of these symmetries to non-local Yangian symmetries generalizing the recently discovered Yangian symmetry of $\mathcal{N} = 4$ supersymmetric Yang-Mills theories is highly suggestive. Here the replacement of point like particles with partonic 2-surfaces means the replacement of conformal symmetry of Minkowski space with infinite-dimensional super-conformal algebras. Yangian symmetry provides also a further refinement to the notion of conserved quantum numbers allowing to define them for bound states using non-local energy conserved currents.

- A further attractive idea is that quantum TGD reduces to almost topological quantum field theory. This is possible if the Kähler action for the preferred extremals defining WCW Kähler function reduces to a 3-D boundary term. This takes place if the conserved currents are so called Beltrami fields with the defining property that the coordinates associated with flow lines extend to single global coordinate variable. This ansatz together with the weak form of electric-magnetic duality reduces the Kähler action to Chern-Simons term with the condition that the 3-surfaces are extremals of Chern-Simons action subject to the constraint force defined by the weak form of electric magnetic duality. It is the latter constraint which prevents the trivialization of the theory to a topological quantum field theory. Also the identification of the Kähler function of WCW as Dirac determinant finds support as well as the description of the scattering amplitudes in terms of braids with interpretation in terms of finite measurement resolution coded to the basic structure of the solutions of field equations.

- In standard QFT Feynman diagrams provide the description of scattering amplitudes. The beauty of Feynman diagrams is that they realize unitarity automatically via the so called Cutkosky rules. In contrast to Feynman's original beliefs, Feynman diagrams and virtual particles are taken only as a convenient mathematical tool in quantum field theories. QFT approach is however plagued by UV and IR divergences and one must keep mind open for the possibility that a genuine progress might mean opening of the black box of the virtual particle.

  In TGD framework this generalization of Feynman diagrams indeed emerges unavoidably. Light-like 3-surfaces replace the lines of Feynman diagrams and vertices are replaced by 2-D partonic 2-surfaces. The approximate localization of the nodes of induced spinor fields to 2-D string world sheets (and possibly also to partonic 2-surfaces) implies a stringy formulation of the theory analogous to stringy variant of twistor formalism with string world sheets having interpretation as 2-braids. In TGD framework fermionic variant of twistor Grassmann formalism leads to a stringy variant of twistor diagrammatics in which basic fermions can be said to be on mass-shell but carry non-physical helicities in the internal lines. This suggests the generalization of the Yangian symmetry to infinite-dimensional super-conformal algebras.

What I have said above is strongly biased view about the recent situation in quantum TGD. This vision is single man's view and doomed to contain unrealistic elements as I know from experience. My dream is that young critical readers could take this vision seriously enough to try to demonstrate that some of its basic premises are wrong or to develop an alternative based on these or better premises. I must be however honest and tell that 32 years of TGD is a really vast bundle of thoughts and quite a challenge for anyone who is not able to cheat himself by taking the attitude of a blind believer or a light-hearted debunker trusting on the power of easy rhetoric tricks.

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Neither TGD nor these books would exist without the help and encouragement of many people. The friendship with Heikki and Raija Haila and their family and Kalevi and Ritva Tikkanen and their family have been kept me in contact with the everyday world and without this friendship I would not have survived through these lonely 45 lonely years most of which I have remained unemployed as a scientific dissident. I am happy that my children have understood my difficult position and like my friends have believed that what I am doing is something valuable although I have not received any official recognition for it.

During the last decade Tapio Tammi has helped me quite concretely by providing the necessary computer facilities and being one of the few persons in Finland with whom to discuss my work. Pertti Kärkkäinen is my old physicist friend and has provided continued economic support for a long time. I have also had stimulating discussions with Samuli Penttinen who has also helped to get through the economical situations in which there seemed to be no hope. The continual updating of fifteen online books means quite a heavy bureaucracy at the level of bits and without a systemization one ends up with endless copying and pasting and internal consistency is soon lost. Tommi Ullgren has provided both economic support and encouragement during years. Pekka Rapinoja has offered his help in this respect and I am especially grateful to him for my Python skills.

During the last five years I have had inspiring discussions with many people in Finland interested in TGD. We have had video discussions with Sini Kunnas and had podcast discussions with Marko Manninen related to the TGD based view of physics and consciousness. Marko has also helped in the practical issues related to computers and quite recently he has done a lot of testing of chatGPT helping me to get an overall view of what it is. The discussions in a Zoom group involving Marko Manninen, Tuomas Sorakivi and Rode Majakka have given me the valuable opportunity to clarify my thoughts.

The collaboration with Lian Sidorov was extremely fruitful and she also helped me to survive economically through the hardest years. The participation in CASYS conferences in Liege has been an important window to the academic world and I am grateful for Daniel Dubois and Peter Marcer for making this participation possible. The discussions and collaboration with Eduardo de Luna and Istvan Dienes stimulated the hope that the communication of new vision might not be a mission impossible after all. Also blog discussions have been very useful. During these years I have received innumerable email contacts from people around the world. I am grateful to Mark McWilliams, Paul Kirsch, Gary Ehlenberg, and Ulla Matfolk and many others for providing links to possibly interesting websites and articles. We have collaborated with Peter Gariaev and Reza Rastmanesh. These contacts have helped me to avoid the depressive feeling of being some kind of Don Quixote of Science and helped me to widen my views: I am grateful for all these people.

In the situation in which the conventional scientific communication channels are strictly closed it is important to have some loop hole through which the information about the work done can at least in principle leak to the public through the iron wall of academic censorship. Without any exaggeration I can say that without the world wide web I would not have survived as a scientist nor as an individual. Homepage and blog are however not enough since only the formally published result is a result in recent day science. Publishing is however impossible without direct support from power holders- even in archives like arXiv.org.

Situation changed as Andrew Adamatsky proposed the writing of a book about TGD when I had already gotten used to the thought that my work would not be published during my lifetime. The Prespacetime Journal and two other journals related to quantum biology and consciousness - all of them founded by Huping Hu - have provided this kind of loophole. In particular, Dainis Zeps, Phil Gibbs, and Arkadiusz Jadczyk deserve my gratitude for their kind help in the preparation of an article series about TGD catalyzing a considerable progress in the understanding of quantum TGD. Also the viXra archive founded by Phil Gibbs and its predecessor Archive Freedom have been of great help: Victor Christianto deserves special thanks for doing the hard work needed to run Archive Freedom. Also the Neuroquantology Journal founded by Sultan Tarlaci deserves a special mention for its publication policy.

And last but not least: there are people who experience as a fascinating intellectual challenge to spoil the practical working conditions of a person working with something which might be called unified theory: I am grateful for the people who have helped me to survive through the virus attacks, an activity which has taken roughly one month per year during the last half decade and given a strong hue of grey to my hair.

For a person approaching his 73th birthday it is somewhat easier to overcome the hard feelings due to the loss of academic human rights than for an inpatient youngster. Unfortunately the economic situation has become increasingly difficult during the twenty years after the economic depression in Finland which in practice meant that Finland ceased to be a constitutional state in the strong sense of the word. It became possible to depose people like me from society without fear about public reactions and the classification as dropout became a convenient tool of ridicule to circumvent the ethical issues. During the period when the right wing held political power this trend was steadily strengthening and the situation is the same as I am writing this. In this kind of situation the concrete help from individuals has been and will be of utmost importance. Against this background it becomes obvious that this kind of work is not possible without the support from outside and I apologize for not being able to mention all the people who have helped me during these years.

Karkkila, August 30, 2023, Finland

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Chapter 1

Introduction

1.1 Basic Ideas of Topological Geometrodynamics (TGD)

Standard model describes rather successfully both electroweak and strong interactions but sees them as totally separate and contains a large number of parameters which it is not able to predict. For about four decades ago unified theories known as Grand Unified Theories (GUTs) trying to understand electroweak interactions and strong interactions as aspects of the same fundamental gauge interaction assignable to a larger symmetry group emerged. Later superstring models trying to unify even gravitation and strong and weak interactions emerged. The shortcomings of both GUTs and superstring models are now well-known. If TGD - whose basic idea emerged towards the end of 1977 - would emerge now it would be seen as an attempt to solve the difficulties of these approaches to unification.

The basic physical picture behind the geometric vision of TGD corresponds to a fusion of two rather disparate approaches: namely TGD as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model. After 1995 number theoretic vision started to develop and was initiated by the success of mass calculations based on p-adic thermodynamics. Number theoretic vision involves all number fields and is complementary to the geometric vision: one can say that this duality is analogous to momentum-position duality of wave mechanics. TGD can be also regarded as topological quantum theory in a very general sense as already the attribute "Topological" in "TGD" makes clear. Space-time surfaces as minimal surfaces can be regarded as representatives of homology equivalence classes and p-adic topologies generalize the notion of local topology and apply to the description of correlates of cognition.

1.1.1 Geometric Vision Very Briefly

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [K4].

The basic vision and its relationship to existing theories is now rather well understood.

1. Space-times are representable as 4-surfaces in the 8-dimensional embedding space $H = M^4 \times CP_2$, where M^4 is 4-dimensional (4-D) Minkowski space and CP_2 is 4-D complex projective space (see Appendix).

2. Induction procedure (a standard procedure in fiber bundle theory, see Appendix) allows to geometrize various fields. Space-time metric characterizing gravitational fields corresponds to the induced metric obtained by projecting the metric tensor of H to the space-time surface. Electroweak gauge potentials are identified as projections of the components of CP_2 spinor connection to the space-time surface, and color gauge potentials as projections of CP_2 Killing vector fields representing color symmetries. Also spinor structure can be induced: induced spinor gamma matrices are projections of gamma matrices of H and induced spinor fields just H spinor fields restricted to space-time surface. Spinor connection is also projected. The interpretation is that distances are measured in embedding space metric and parallel translation using spinor connection of embedding space.

Twistor lift of TGD means that one can lift space-time surfaces in H to 6-D surfaces a analogs of twistor space of space-time surface in the Cartesian product of the twistor spaces of M^4 and CP_2, which are the only 4-manifolds allowing twistor space with Kähler structure [?]. The twistor structure would be induced in some sense, and should coincide with that associated with the induced metric. Clearly, the 2-spheres defining the fibers of twistor spaces of M^4 and CP_2 must allow identification: this 2-sphere defines the S^2 fiber of the twistor space of the space-time surface. This poses a constraint on the embedding of the twistor space of space-time surfaces as sub-manifold in the Cartesian product of twistor spaces. The existence of Kähler structure allows to lift 4-D Kähler action to its 6-D counterparts and the 6-D counterpart of twistor space is obtained by its dimensional reduction so that one obtains a sphere bundle. This makes possible twistorialization for all space-time surfaces: in general relativity the general metric does not allow this.

3. A geometrization of quantum numbers is achieved. The isometry group of the geometry of CP_2 codes for the color gauge symmetries of strong interactions. Vierbein group codes for electroweak symmetries, and explains their breaking in terms of CP_2 geometry so that standard model gauge group results. There are also important deviations from the standard model: color quantum numbers are not spin-like but analogous to orbital angular momentum: this difference is expected to be seen only in CP_2 scale. In contrast to GUTs, quark and lepton numbers are separately conserved and family replication has a topological explanation in terms of topology of the partonic 2-surface carrying fermionic quantum numbers.

   M^4 and CP_2 are unique choices for many other reasons. For instance, they are the unique 4-D space-times allowing twistor space with Kähler structure. M^4 light-cone boundary allows a huge extension of 2-D conformal symmetries. M^4 and CP_2 allow quaternionic structures. Therefore standard model symmetries have number theoretic meaning.

4. Induced gauge potentials are expressible in terms of embedding space coordinates and their gradients and general coordinate invariance implies that there are only 4 field-like variables locally. Situation is thus extremely simple mathematically. The objection is that one loses linear superposition of fields. The resolution of the problem comes from the generalization of the concepts of particle and space-time.

   Space-time surfaces can be also particle like having thus finite size. In particular, space-time regions with Euclidian signature of the induced metric (temporal and spatial dimensions in the same role) emerge and have interpretation as lines of generalized Feynman diagrams. Particles in space-time can be identified as a topological inhomogeneities in background space-time surface which looks like the space-time of general relativity in long length scales.

   One ends up with a generalization of space-time surface to many-sheeted space-time with space-time sheets having extremely small distances of about 10^4 Planck lengths (CP_2 size). As one adds a particle to this kind of structure, it touches various space-time sheets and thus interacts with the associated classical fields. Their effects superpose linearly in good approximation and linear superposition of fields is replaced with that for their effects.

   This resolves the basic objection. It also leads to the understanding of how the space-time of general relativity and quantum field theories emerges from TGD space-time as effective space-time when the sheets of many-sheeted space-time are lumped together to form a region of Minkowski space with metric replaced with a metric identified as the sum of empty Minkowski metric and deviations of the metrics of sheets from empty Minkowski metric. Gauge potentials are identified as sums of the induced gauge potentials. TGD is therefore a microscopic theory from which the standard model and general relativity follow as a topological simplification, however forcing a dramatic increase of the number of fundamental field variables.

5. A further objection is that classical weak fields identified as induced gauge fields are long ranged and should cause large parity breaking effects due to weak interactions. These effects are indeed observed but only in living matter. The basic problem is that one has long ranged classical electroweak gauge fields. The resolution of the problem is that the quantum averages of induced weak and color gauge fields vanish due to the fact that color rotations affect both space-time surfaces and induced weak and color fields. Only the averages of

electromagnetic fields are nonvanishing. The correlations functions for weak fields are non-vanishing below Compton lengths of weak bosons. In living matter large values of effective Planck constant labelling phases of ordinary matter identified as dark matter make possible long ranged weak fields and color fields.

6. General coordinate invariance requires holography so that space-time surfaces are analogous to Bohr orbits for particles identified as 3-surfaces. Bohr orbit property would be naturally realized by a 4-D generalization of holomorphy of string world sheets and implies that the space-time surfaces are minimal surfaces apart from singularities. This holds true for any action as long as it is general coordinate invariant and constructible in terms of the induced geometry. String world sheets and light-like orbits of partonic 2-surfaces correspond to singularities at which the minimal surface property of the space-time surfaces realizing the preferred extremal property fails. Preferred extremals are not completely deterministic, which implies what I call zero energy ontology (ZEO) meaning that the Bohr orbits are the fundamental objects. This leads to a solution of the basic paradox of quantum measurement theory. Also the mathematically ill-defined path integral disappears and leaves only the well-defined functional integral over the Bohr orbits.

7. A string model-like picture emerges from TGD and one ends up with a rather concrete view about the topological counterpart of Feynman diagrammatics. The natural stringy action would be given by the string world sheet area, which is present only in the space-time regions with Minkowskian signature. Gravitational constant could be present as a fundamental constant in string action and the ratio $\hbar/G/R^2$ would be determined by quantum criticality conditions. The hierarchy of Planck constants $h_{eff}/h = n$ assigned to dark matter in TGD framework would allow to circumvent the objection that only objects of length of order Planck length are possible since string tension given by $T = 1/\hbar_{eff}G$ apart from numerical factor could be arbitrary small. This would make possible gravitational bound states as partonic 2-surfaces as structures connected by strings and solve the basic problem of superstring theories. This option allows the natural interpretation of M^4 type vacuum extremals with CP_2 projection, which is Lagrange manifold as good approximations for space-time sheets at macroscopic length scales. String area does not contribute to the Kähler function at all.

   Whether induced spinor fields associated with Kähler-Dirac action and de-localized inside the entire space-time surface should be allowed remains an open question: super-conformal symmetry strongly suggests their presence. A possible interpretation for the corresponding spinor modes could be in terms of dark matter, sparticles, and hierarchy of Planck constants.

It is perhaps useful to make clear what TGD is not and also what new TGD can give to physics.

1. TGD is *not* just General Relativity made concrete by using embeddings: the 4-surface property is absolutely essential for unifying standard model physics with gravitation and to circumvent the incurable conceptual problems of General Relativity. The many-sheeted space-time of TGD gives rise only at the macroscopic limit to GRT space-time as a slightly curved Minkowski space. TGD is *not* a Kaluza-Klein theory although color gauge potentials are analogous to gauge potentials in these theories.

   TGD space-time is 4-D and its dimension is due to completely unique conformal properties of light-cone boundary and 3-D light-like surfaces implying enormous extension of the ordinary conformal symmetries. Light-like 3-surfaces represent orbits of partonic 2-surfaces and carry fundamental fermions at 1-D boundaries of string world sheets. TGD is *not* obtained by performing Poincare gauging of space-time to introduce gravitation and is plagued by profound conceptual problems.

2. TGD is *not* a particular string model although string world sheets emerge in TGD very naturally as loci for spinor modes: their 2-dimensionality makes among other things possible quantum deformation of quantization known to be physically realized in condensed matter, and conjectured in TGD framework to be crucial for understanding the notion of finite measurement resolution. Hierarchy of objects of dimension up to 4 emerge from TGD: this obviously means analogy with branes of super-string models.

TGD is *not* one more item in the collection of string models of quantum gravitation relying on Planck length mystics. Dark matter becomes an essential element of quantum gravitation and quantum coherence in astrophysical scales is predicted just from the assumption that strings connecting partonic 2-surfaces are responsible for gravitational bound states.

TGD is *not* a particular string model although AdS/CFT duality of super-string models generalizes due to the huge extension of conformal symmetries and by the identification of WCW gamma matrices as Noether super-charges of super-symplectic algebra having a natural conformal structure.

3. TGD is *not* a gauge theory. In TGD framework the counterparts of also ordinary gauge symmetries are assigned to super-symplectic algebra (and its Yangian [?] [B22, B19, B20]), which is a generalization of Kac-Moody algebras rather than gauge algebra and suffers a fractal hierarchy of symmetry breakings defining hierarchy of criticalities. TGD is *not* one more quantum field theory like structure based on path integral formalism: path integral is replaced with functional integral over 3-surfaces, and the notion of classical space-time becomes an exact part of the theory. Quantum theory becomes formally a purely classical theory of WCW spinor fields: only state function reduction is something genuinely quantal.

4. TGD view about spinor fields is *not* the standard one. Spinor fields appear at three levels. Spinor modes of the embedding space are analogs of spinor modes characterizing incoming and outgoing states in quantum field theories. Induced second quantized spinor fields at space-time level are analogs of stringy spinor fields. Their modes are localized by the well-definedness of electro-magnetic charge and by number theoretic arguments at string world sheets. Kähler-Dirac action is fixed by supersymmetry implying that ordinary gamma matrices are replaced by what I call Kähler-Dirac gamma matrices - this something new. WCW spinor fields, which are classical in the sense that they are not second quantized, serve as analogs of fields of string field theory and imply a geometrization of quantum theory.

5. TGD is in some sense an extremely conservative geometrization of entire quantum physics: *no* additional structures such as gauge fields as independent dynamical degrees of freedom are introduced: Kähler geometry and associated spinor structure are enough. "Topological" in TGD should not be understood as an attempt to reduce physics to torsion (see for instance [B17]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of the everyday world represent non-trivial topology of space-time in the TGD Universe.

6. Twistor space - or rather, a generalization of twistor approach replacing masslessness in 4-D sense with masslessness in 8-D sense and thus allowing description of also massive particles - emerged originally as a technical tool, and its Kähler structure is possible only for $H = M^4 \times CP_2$. It however turned out that much more than a technical tool is in question. What is genuinely new is the infinite-dimensional character of the Kähler geometry making it highly unique, and its generalization to p-adic number fields to describe correlates of cognition. Also the hierarchy of Planck constants $h_{eff} = n \times h$ reduces to the quantum criticality of the TGD Universe and p-adic length scales and Zero Energy Ontology represent something genuinely new.

The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last 45 years to the realization of this dream and this has resulted in 26 online books about TGD and nine online books about TGD inspired theory of consciousness and of quantum biology.

A collection of 30 online books is now (August 2023) under preparation. The goal is to minimize overlap between the topics of the books and make the focus of a given book sharper.

1.1.2 Two Visions About TGD as Geometrization of Physics and Their Fusion

As already mentioned, TGD as a geometrization of physics can be interpreted both as a modification of general relativity and generalization of string models.

TGD as a Poincare Invariant Theory of Gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_\times CP_2$, where M^4 denotes Minkowski space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [?, ?, ?, ?].

The identification of the space-time as a sub-manifold [?, ?] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity.

It soon however turned out that sub-manifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

The choice of H is unique from the condition that TGD has standard model symmetries. Also number theoretical vision selects $H = M^4 \times CP_2$ uniquely. M^4 and CP_2 are also unique spaces allowing twistor space with Kähler structure.

TGD as a Generalization of the Hadronic String Model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

This decay vertex does not however correspond to a direct generalization of trouser vertex of string models. Indeed, the important difference between TGD and string models is that the analogs of string world sheet diagrams do not describe particle decays but the propagation of particles via different routes. Particle reactions are described by generalized Feynman diagrams for which 3-D light-like surface describing particle propagating join along their ends at vertices. As 4-manifolds the space-time surfaces are therefore singular like Feynman diagrams as 1-manifolds.

Quite recently, it has turned out that fermionic strings inside space-time surfaces define an exact part of quantum TGD and that this is essential for understanding gravitation in long length scales. Also the analog of AdS/CFT duality emerges in that the Kähler metric can be defined either in terms of Kähler function identifiable as Kähler action assignable to Euclidian space-time regions or Kähler action + string action assignable to Minkowskian regions.

The recent view about construction of scattering amplitudes is very "stringy". By strong form of holography string world sheets and partonic 2-surfaces provide the data needed to construct scattering amplitudes. Space-time surfaces are however needed to realize quantum-classical correspondence necessary to understand the classical correlates of quantum measurement. There is a huge generalization of the duality symmetry of hadronic string models.

The proposal is that scattering amplitudes can be regarded as sequences of computational operations for the Yangian of super-symplectic algebra. Product and co-product define the basic vertices and realized geometrically as partonic 2-surfaces and algebraically as multiplication for the elements of Yangian identified as super-symplectic Noether charges assignable to strings. Any computational sequences connecting given collections of algebraic objects at the opposite boundaries of causal diamond (CD) produce identical scattering amplitudes.

Fusion of the Two Approaches via a Generalization of the Space-Time Concept

The problem is that the two approaches to TGD seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there could be "vapor phase" that is a "gas" of particle like 3-surfaces and string like objects (counterpart of the "baby universes" of GRT) and the non-conservation of energy in GRT corresponds to the transfer of energy between different sheets of the space-time and possible existence vapour phase.

. What one obtains is what I have christened as many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig. ??** in the appendix of this book). One particular aspect is topological field quantization meaning that various classical fields assignable to a physical system correspond to space-time sheets representing the classical fields to that particular system. One can speak of the field body of a particular physical system. Field body consists of topological light rays, and electric and magnetic flux quanta. In Maxwell's theory the physical system does not possess this kind of field identity. The notion of the magnetic body is one of the key players in TGD inspired theory of consciousness and quantum biology. The existence of monopole flux tubes requiring no current as a source of the magnetic field makes it possible to understand the existence of magnetic fields in cosmological and astrophysical scales.

This picture became more detailed with the advent of zero energy ontology (ZEO). The basic notion of ZEO is causal diamond (CD) identified as the Cartesian product of CP_2 and of the intersection of future and past directed light-cones and having scale coming as an integer multiple of CP_2 size is fundamental. CDs form a fractal hierarchy and zero energy states decompose to products of positive and negative energy parts assignable to the opposite boundaries of CD defining the ends of the space-time surface. The counterpart of zero energy state in positive energy ontology is the pair of initial and final states of a physical event, say particle reaction.

At space-time level ZEO means that 3-surfaces are pairs of space-like 3-surfaces at the opposite light-like boundaries of CD. Since the extremals of Kähler action connect these, one can say that by holography the basic dynamical objects are the space-time surface connecting these 3-surfaces and identifiable as analogs of Bohr orbits. This changes totally the vision about notions like self-organization: self-organization by quantum jumps does not take for a 3-D system but for the entire 4-D field pattern associated with it.

General Coordinate Invariance (GCI) allows to identify the basic dynamical objects as space-like 3-surfaces at the ends of space-time surface at boundaries of CD: this means that space-time surface is analogous to Bohr orbit. An alternative identification of the lines of generalized Feynman diagrams is as light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian . Also the Euclidian 4-D regions can have a similar interpretation. The requirement that the two interpretations are equivalent, leads to a strong form of General Coordinate Invariance. The outcome is effective 2-dimensionality stating that the partonic 2-surfaces identified as intersections of the space-like ends of space-time surface and light-like wormhole throats are the fundamental objects. That only effective 2-dimensionality is in question is due to the effects caused by the failure of strict determinism of Kähler action. In finite length scale resolution these effects can be neglected below UV cutoff and above IR cutoff. One can also speak about a strong form of holography.

The understanding of the super symplectic invariance leads to the proposal that super symplectic algebra and other Kac-Moody type algebras labelled by non-negative multiples of basic conformal weights allow a hierarchy of symmetry breakings in which the analog of gauge symmetry breaks down to a genuine dynamical symmetry. This gives rise to fractal hierarchies of algebras and symmetry breakings. This breaking can occur also for ordinary conformal algebras if one restricts the conformal weights to be non-negative integers.

1.1.3 Basic Objections

Objections are the most powerful tool in theory building. The strongest objection against TGD is the observation that all classical gauge fields are expressible in terms of four embedding space coordinates only- essentially CP_2 coordinates. The linear superposition of classical gauge fields taking place independently for all gauge fields is lost. This would be a catastrophe without many-sheeted space-time. Instead of gauge fields, only the effects such as gauge forces are superposed.

Particles topologically condense to several space-time sheets simultaneously and experience the sum of gauge forces. This transforms the weakness to extreme economy: in a typical unified theory the number of primary field variables is countered in hundreds if not thousands, now it is just four.

Second objection is that TGD space-time is quite too simple as compared to GRT space-time due to the embeddability to 8-D embedding space. One can also argue that Poincare invariant theory of gravitation cannot be consistent with General Relativity. The above interpretation makes it possible to understand the relationship to GRT space-time and how the Equivalence Principle (EP) follows from Poincare invariance of TGD. The interpretation of GRT space-time is as effective space-time obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrics of the space-time sheets from Minkowski metric. Poincare invariance strongly suggests classical EP for the GRT limit in long length scales at least. One can also consider other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with a very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of the standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

Topological Field Quantization

Topological field quantization distinguishes between TGD based and more standard - say Maxwellian - notion of field. In Maxwell's fields created by separate systems superpose and one cannot tell which part of field comes from which system except theoretically. In TGD these fields correspond to different space-time sheets and only their effects on test particle superpose. Hence physical systems have well-defined field identifies - field bodies - in particular magnetic bodies.

The notion of magnetic body carrying dark matter with non-standard large value of Planck constant has become central concept in TGD inspired theory of consciousness and living matter, and by starting from various anomalies of biology one ends up to a rather detailed view about the role of magnetic body as intentional agent receiving sensory input from the biological body and controlling it using EEG and its various scaled up variants as a communication tool. Among other thins this leads to models for cell membrane, nerve pulse, and EEG.

1.1.4 Quantum TGD as Spinor Geometry of World of Classical Worlds

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and have been the following ones.

World of Classical Worlds

The notion of WCW reduces the interacting quantum theory to a theory of free WCW spinor fields.

1. Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude identified as WCW spinor in the configuration space CH ("world of classical worlds", WCW) consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included.

2. 4-D general coordinate invariance forces holography and replaces the ill-defined path integral over all space-time surfaces with a discrete sum over 4-D analogs of Bohr orbits for particles identified as 3-surfaces. Holography means that basic objects are these analogs of Bohr orbits. Since there is no quantization at the level of WCW, one has an analog of wave mechanics with point-like particles replaced with 4-D Bohr orbits.

3. One must geometrize WCW as the space of Bohr orbits. In an infinite-dimensional situation the existence of geometry requires maximal symmetries already in the case of loop spaces. Physics is unique from its mathematical existence.

   WCW is endowed with metric and spinor structure so that one can define various metric related differential operators, say Dirac operators, appearing in the field equations of the theory [1]

Identification of Kähler function

The evolution of these basic ideas has been rather slow but has gradually led to a rather beautiful vision. One of the key problems has been the definition of Kähler function. Kähler function is Kähler action for a preferred extremal assignable to a given 3-surface but what this preferred extremal is? The obvious first guess was as absolute minimum of Kähler action but could not be proven to be right or wrong. One big step in the progress was boosted by the idea that TGD should reduce to almost topological QFT in which braids would replace 3-surfaces in finite measurement resolution, which could be inherent property of the theory itself and imply discretization at partonic 2-surfaces with discrete points carrying fermion number.

It took long time to realize that there is no discretization in 4-D sense - this would lead to difficulties with basic symmetries. Rather, the discretization occurs for the parameters characterizing co-dimension 2 objects representing the information about space-time surface so that they belong to some algebraic extension of rationals. These 2-surfaces - string world sheets and partonic 2-surfaces - are genuine physical objects rather than a computational approximation. Physics itself approximates itself, one might say! This is of course nothing but strong form of holography.

1. TGD as almost topological QFT vision suggests that Kähler action for preferred extremals reduces to Chern-Simons term assigned with space-like 3-surfaces at the ends of space-time (recall the notion of causal diamond (CD)) and with the light-like 3-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian. Minkowskian and Euclidian regions would give at wormhole throats the same contribution apart from coefficients and in Minkowskian regions the $\sqrt{g_4}$ factorc coming from metric would be imaginary so that one would obtain sum of real term identifiable as Kähler function and imaginary term identifiable as the ordinary Minkowskian action giving rise to interference effects and stationary phase approximation central in both classical and quantum field theory.

   Imaginary contribution - the presence of which I realized only after 33 years of TGD - could also have topological interpretation as a Morse function. On physical side the emergence of Euclidian space-time regions is something completely new and leads to a dramatic modification of the ideas about black hole interior.

2. The way to achieve the reduction to Chern-Simons terms is simple. The vanishing of Coulomb contribution to Kähler action is required and is true for all known extremals if one makes a general ansatz about the form of classical conserved currents. The so called weak form of electric-magnetic duality defines a boundary condition reducing the resulting 3-D terms to Chern-Simons terms. In this way almost topological QFT results. But only "almost" since the Lagrange multiplier term forcing electric-magnetic duality implies that Chern-Simons action for preferred extremals depends on metric.

WCW spinor fields

Classical WCW spinor fields are analogous to Schrödinger amplitudes and the construction of WCW Kähler geometry reduces to the second quantization of free spinor fields of H.

[1] There are four kinds of Dirac operators in TGD. The geometrization of quantum theory requires Kähler metric definable either in terms of Kähler function identified as a the bosonic action for Euclidian space-time regions or as anti-commutators for WCW gamma matrices identified as conformal Noether super-charges associated with the second quantized modified Dirac action consisting of string world sheet term and possibly also modified Dirac action in Minkowskian space-time regions. These two possible definitions reflect a duality analogous to AdS/CFT duality.

1. The WCW metric is given by anticommutators of WCW gamma matrices which also have interpretation as supercharges assignable to the generators of WCW isometries and allowing expression as non-conserved Noether charges. Holography implies zero energy ontology (ZEO) meaning that zero energy states are superpositions of Bohr orbits connecting boundaries of causal diamond (CD). CDs form a fractal hierarchy and their space forming the spine of WCW is finite-dimensional and can be geometrized. The alternative interpretation is as a superposition of pairs of ordinary 3-D fermionic states assignable to the ends of the space-time surfaces.

2. There are several Dirac operators. WCW Dirac operator D_{WCW} appears in Super-symplectic gauge conditions analogous to Super Virasoro conditions. The algebraic variant of the H Dirac operator D_H appears in fermionic correlation functions: this is due to the fact that free fermions appearing as building bricks of WCW gamma matrices are modes of D_H. The modes of $_DH$ define the ground states of super-symplectic representations. There is also the modified Dirac operator D_{X^4} acting on the induced spinors at space-time surfaces and it is dictated by symmetry one the action fixing the space-time surfaces as Bohr orbits is fixed. D_H is needed since it determines the expressions of WCW gamma matrices as Noether charges assignable to 3-surfaces at the ends of WCW.

The role of modified Dirac action

1. By quantum classical correspondence, the construction of WCW spinor structure in sectors assignable to CDs reduces to the second quantization of the induced spinor fields of H. The basic action is so called modified Dirac action in which gamma matrices are replaced with the modified) gamma matrices defined as contractions of the canonical momentum currents of the bosonic action defining the space-time surfaces with the embedding space gamma matrices. In this way one achieves super-conformal symmetry and conservation of fermionic currents among other things and a consistent Dirac equation.

   Modified Dirac action is needed to define WCW gamma matrices as super charges assignable to WCW isometry generators identified as generators of symplectic transformations and by holography are needed only at the 3-surface at the boundaries of WCW. It is important to notice that the modified Dirac equation does not determine propagators since induced spinor fields are obtained from free second quantized spinor fields of H. This means enormous simplification and makes the theory calculable.

2. An important interpretational problem relates to the notion of the induced spinor connection. The presence of classical W boson fields is in conflict with the classical conservation of em charge since the coupling to classical W fields changes em charge.

   One way out of the problem is the fact that the quantum averages of weak and gluon fields vanish unlike the quantum average of the em field. This leads to a rather precise understanding of electroweak symmetry breaking as being due the fact that color symmetries rotate space-time surfaces and also affect the induced weak fields.

   One can also consider a stronger condition. If one requires that the spinor modes have well-defined em charge, one must assume that the modes in the generic situation are localized at 2-D surfaces - string world sheets or perhaps also partonic 2-surfaces - at which classical W boson fields vanish. Covariantly constant right handed neutrinos generating super-symmetries forms an exception. The vanishing of the Z^0 field is possible for Kähler-Dirac action and should hold true at least above weak length scales. This implies that the string model in 4-D space-time becomes part of TGD. Without these conditions classical weak fields can vanish above weak scale only for the GRT limit of TGD for which gauge potentials are sums over those for space-time sheets.

   The localization would simplify the mathematics enormously and one can solve exactly the Kähler-Dirac equation for the modes of the induced spinor field just like in super string models.

   At the light-like 3-surfaces the signature of the induced metric changes from Euclidian to Minkowskian so that $\sqrt{g_4}$ vanishes. One can pose the condition that the algebraic analog of the massless Dirac equation is satisfied by the modes of the modified-Dirac action assignable to the Chern-Simons-Kähler action.

1.1.5 Construction of scattering amplitudes

Reduction of particle reactions to space-time topology

Particle reactions are identified as topology changes [?, ?, ?]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. Classically this corresponds to a path of WCW leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

During years this naïve and very rough vision has of course developed a lot and is not anymore quite equivalent with the original insight. In particular, the space-time correlates of Feynman graphs have emerged from theory as Euclidian space-time regions and the strong form of General Coordinate Invariance has led to a rather detailed and in many respects un-expected visions. This picture forces to give up the idea about smooth space-time surfaces and replace space-time surface with a generalization of Feynman diagram in which vertices represent the failure of manifold property. I have also introduced the word "world of classical worlds" (WCW) instead of rather formal "configuration space". I hope that "WCW" does not induce despair in the reader having tendency to think about the technicalities involved!

Construction of the counterparts of S-matrices

What does one mean with the counterpart of S-matrix in the TGD framework has been a long standing problem. The development of ZEO based quantum measurement theory has led to a rough overall view of the situation.

1. There are two kinds of state function reductions (SFRs). "Small" SFRs (SSFRs) following the TGD counterpart of a unitary time evolution defines a sequence of SFRs, which is analogous to a sequence of repeated quantum measurements associated with the Zeno effect. In wave mechanics nothing happens in these measurements. In quantum optics these measurements correspond to weak measurements. In TGD SSFR affects the zero energy state but leaves the 3-D state at the passive boundary of CD unaffected.

2. In TGD framework each SSFR is preceded by a counterpart of a unitary time evolution, which means dispersion in the space of CDs and unitary time evolution in fermionic degrees of freedom such that the passive boundary of CDs and 3-D states at it are unaffected but a superposition of CDs with varying active boundaries in the space of CDs is formed. In SSFR a localization in the space of CDs occurs such that the active is fixed. In a statistical sense the size of the CD increases and the increasing distance between the tips of the CD gives rise to the arrow of geometric time.

3. Also "big" SFRS (BSFRs) can occur and they correspond to ordinary SFRs. In BSFR the roles of the active and passive boundary are changed and this means that the arrow of time is changed. Big SFR occurs when the SSFR corresponds to a quantum measurement, which does not commute with the operators, which define the states at the passive boundary of CD as their eigenstates. This means a radical deviation from standard quantum measurement theory and has predictions in all scales.

4. One can assign the counterpart of S-matrix to the unitary time evolution between two subsequent SSFRs and also to the counterpart of S-matrix associated with BSFR. At least in the latter case the dimension of the state space can increase since at least BSFRs lead to the increase of the dimension of algebraic extension of rationals assignable to the space-time surface by $M^8 - H$ duality. Unitarity is therefore replaced with isometry.

5. I have also considered the possibility that unitary S-matrix could be replaced in the fermionic degrees of freedom with Kähler metric of the state space satisfying analogs of unitarity conditions but it seems that this is un-necessary and also too outlandish an idea.

The notion of M-matrix

1. The most ambitious dream is that zero energy states correspond to a complete solution basis for the Dirac operators associated with WCWs associated with the spaces of CDs with fixed passive boundary: this would define an S-matrix assignable to SFR. Also the analog of S-matrix for the localizations of the states to the active boundary assignable to the BSFR changing the state at the passive boundary of CD is needed.

2. If one allows entanglement between positive and energy parts of the zero energy state but assumes that the states at the passive boundary are fixed, one must introduce the counterpart of the density matrix, or rather its square root. This classical free field theory would dictate what I have called M-matrices defined between positive and negative energy parts of zero energy states which form orthonormal rows of what I call U-matrix as a matrix defined between zero energy states. A biven M-matrix in turn would decompose to a product of a hermitian square root of density matrix and unitary S-matrix.

3. M-matrix would define time-like entanglement coefficients between positive and negative energy parts of zero energy states (all net quantum numbers vanish for them) and can be regarded as a hermitian square root of density matrix multiplied by a unitary S-matrix. Quantum theory would be in a well-defined sense a square root of thermodynamics. The orthogonality and hermiticity of the M-matrices commuting with S-matrix means that they span infinite-dimensional Lie algebras acting as symmetries of the S-matrix. Therefore quantum TGD would reduce to group theory in a well-defined sense.

4. In fact the Lie algebra of Hermitian M-matrices extends to Kac-Moody type algebra obtained by multiplying hermitian square roots of density matrices with powers of the S-matrix. Also the analog of Yangian algebra involving only non-negative powers of S-matrix is possible and would correspond to a hierarchy of CDs with the temporal distances between tips coming as integer multiples of the CP_2 time.

   The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to a representation matrix of scaling: $S(n) = S^n$, where S is unitary S-matrix associated with the minimal CD [K71]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

5. I have also considered the notion of U-matrix. U-matrix elements between M-matrices for various CDs are proportional to the inner products $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2} \lambda]$, where λ represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and H^i form an orthonormal basis of Hermitian square roots of density matrices. $\circ$ tells that S acts at the active boundary of CD only. I have proposed a general representation for the U-matrix, reducing its construction to that of the S-matrix.

1.1.6 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space ("world of classical worlds", WCW), p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. The fourth thread deserves the name "TGD as a generalized number theory". It involves three separate threads: the fusion of real and various p-adic physics to a single coherent whole by requiring number theoretic universality discussed already, the formulation of quantum TGD in terms of complexified counterparts of classical number fields, and the notion of infinite prime. Note that one can identify subrings such as hyper-quaternions and hyper-octonions as sub-spaces of complexified classical number fields with Minkowskian signature of the metric defined by the complexified inner product.

The Threads in the Development of Quantum TGD

The development of TGD has involved several strongly interacting threads: physics as infinite-dimensional geometry; TGD as a generalized number theory, the hierarchy of Planck constants interpreted in terms of dark matter hierarchy, and TGD inspired theory of consciousness. In the following these threads are briefly described.

1. Quantum T(opological) G(eometro)D(ynamics) as a classical spinor geometry for infinite-dimensional WCW, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness and of quantum biology have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

2. The discussions with Tony Smith initiated a fourth thread which deserves the name "TGD as a generalized number theory". The basic observation was that classical number fields might allow a deeper formulation of quantum TGD. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and rather fruitful revision of the basic views about what the final form and physical content of quantum TGD might be. Together with the vision about the fusion of p-adic and real physics to a larger coherent structure these sub-threads fused to the "physics as generalized number theory" thread.

3. A further thread emerged from the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and strongly suggested by the failure of strict determinism for the fundamental variational principle. The identification of hierarchy of Planck constants labelling phases of dark matter would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

The chronology based identification of the threads is quite natural but not logical and it is much more logical to see p-adic physics, the ideas related to classical number fields, and infinite primes as sub-threads of a thread which might be called "physics as a generalized number theory". In the following I adopt this view. This reduces the number of threads to three corresponding to geometric, number theoretic and topological views of physics.

TGD forces the generalization of physics to a quantum theory of consciousness, and TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations.

Number theoretic vision very briefly

Number theoretic vision about quantum TGD involves notions like adelic physics, M^8-H duality and number theoretic universality. A short review of the basic ideas that have developed during years is in order.

1. The physical interpretation of M^8 is as an analog of momentum space and M^8-H duality is analogous to momentum-position duality of ordinary wave mechanics.

2. Adelic physics means that all classical number fields, all p-adic number fields and their extensions induced by extensions of rationals and defining adeles, and also finite number fields are basic mathematical building bricks of physics.

   The complexification of M^8, identified as complexified octonions, would provide a realization of this picture and M^8-H duality would map the algebraic physics in M^8 to the ordinary physics in $M^4\times CP_2$ described in terms of partial differential equations.

3. Negentropy Maximization Principle (NMP) states that the conscious information assignable with cognition representable measured in terms of p-adic negentropy increases in statistical sense.

   NMP is mathematically completely analogous to the second law of thermodynamics and number theoretic evolution as an unavoidable statistical increase of the dimension of the algebraic extension of rationals characterizing a given space-time region implies it. There is no paradox involved: the p-adic negentropy measures the conscious information assignable to the entanglement of two systems regarded as a conscious entity whereas ordinary entropy measures the lack of information about the quantums state of either entangled system.

4. Number theoretical universality requires that space-time surfaces or at least their M^8-H duals in M_c^8 are defined for both reals and various p-adic number fields. This is true if they are defined by polynomials with integer coefficients as surfaces in M^8 obeying number theoretic holography realized as associativity of the normal space of 4-D surface using as holographic data 3-surfaces at mass shells identified in terms of roots of a polynomial. A physically motivated additional condition is that the coefficients of the polynomials are smaller than their degrees.

5. Galois confinement is a key piece of the number theoretic vision. It states that the momenta of physical states are algebraic integers in the extensions of rationals assignable to the space-time region considered. These numbers are in general complex and are not consistent with particle in box quantization. The proposal is that physical states satisfy Galois confinement being thus Galois singlets and having therefore total momenta, whose components are ordinary integers, when momentum unit defined by the scale of causal diamond (CD) is used.

6. The notion of p-adic prime was introduced in p-adic mass calculations that started the developments around 1995. p-Adic length scale hypothesis states that p-adic primes near powers of 2 have a special physical role (as possibly also the powers of other small primes such as $p=3$).

   The proposal is that p-adic primes correspond to ramified primes assignable to the extension and identified as divisors of the polynomial defined by the products of the root differences for the roots of the polynomial defining space-time space and having interpretation as values of, in general complex, virtual mass squared.

p-Adic TGD and fusion of real and p-adic physics to single coherent whole

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzles and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired "Universe as Computer" vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

In string model context one tries to reduces the physics to Planck scale. The price is the inability to say anything about physics in long length scales. In TGD p-adic physics takes care of this shortcoming by predicting the physics also in long length scales.

There were many interpretational and technical questions crying for a definite answer.

1. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *the* Physics? Should one perform p-adicization also at the level of the WCW? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations.
2. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question. Quite recently I however learned that the problem of making sense about p-adic integration has been for decades central problem in the frontier of mathematics and a lot of profound work has been done along same intuitive lines as I have proceeded in TGD framework. The basic idea is certainly the notion of algebraic continuation from the world of rationals belonging to the intersection of real world and various p-adic worlds.

Despite various uncertainties, the number of the applications of the poorly defined p-adic physics has grown steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

The key challenge is to fuse various p-adic physics and real physics to single larger structure. This has inspired a proposal for a generalization of the notion of number field by fusing real numbers and various p-adic number fields and their extensions along rationals and possible common algebraic numbers. This leads to a generalization of the notions of embedding space and space-time concept and one can speak about real and p-adic space-time sheets. One can talk about adelic space-time, embedding space, and WCW.

The corresponds of real 4-surfaces with the p-adic ones is induced by number theoretical discretization using points of 4-surfaces $Y^4 \subset M^8_c$ identifiable as 8-momenta, whose components are assumed to be algebraic integers in an extension of rationals defined by the extension of rationals associated with a polynomial P with integer coefficients smaller than the degree of P. These points define a cognitive representation, which is universal in the sense that it exists also in the algebraic extensions of p-adic numbers. The points of the cognitive representations associated with the mass shells with mass squared values identified as roots of P are enough since M^8-H duality can be used at both M^8 and H sides and also in the p-adic context. The mass shells are special in that they allow for Minkowski coordinates very large cognitive representations unlike the interiors of the 4-surfaces determined by holography by using the data defined by the 3-surfaces at the mass shells. The higher the dimension of the algebraic extension associated with P, the better the accuracy of the cognitive representation.

Adelization providing number theoretical universality reduces to algebraic continuation for the amplitudes from this intersection of reality and various p-adicities - analogous to a back of a book - to various number fields. There are no problems with symmetries but canonical identification is needed: various group invariant of the amplitude are mapped by canonical identification to various p-adic number fields. This is nothing but a generalization of the mapping of the p-adic mass squared to its real counterpart in p-adic mass calculations.

This leads to surprisingly detailed predictions and far reaching conjectures. For instance, the number theoretic generalization of entropy concept allows negentropic entanglement central for the applications to living matter (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). One can also understand how preferred p-adic primes could emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K67].

The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to “mind stuff”, the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably a brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

Infinite primes

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory.

After the realization that infinite primes can be mapped to polynomials possibly representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of complexified quaternions and octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

The infinite primes at the first level of hierarchy, which represent analogs of bound states, can be mapped to irreducible polynomials, which in turn characterize the algebraic extensions of rationals defining a hierarchy of algebraic physics continuable to real and p-adic number fields. The products of infinite primes in turn define more general algebraic extensions of rationals. The interesting question concerns the physical interpretation of the higher levels in the hierarchy of infinite primes and integers mappable to polynomials of $n > 1$ variables.

1.1.7 An explicit formula for $M^8 - H$ duality

$M^8 - H$ duality is a generalization of momentum-position duality relating the number theoretic and geometric views of physics in TGD and, despite that it still involves poorly understood aspects, it has become a fundamental building block of TGD. One has 4-D surfaces $Y^4 \subset M^8_c$, where M^8_c is complexified M^8 having interpretation as an analog of complex momentum space and 4-D spacetime surfaces $X^4 \subset H = M^4 \times CP_2$. M^8_c, equivalently E^8_c, can be regarded as complexified octonions. M^8_c has a subspace M^4_c containing M^4.

Comment: One should be very cautious with the meaning of "complex". Complexified octonions involve a complex imaginary unit i commuting with the octonionic imaginary units I_k. i is assumed to also appear as an imaginary unit also in complex algebraic numbers defined by the roots of polynomials P defining holographic data in M^8_c.

In the following $M^8 - H$ duality and its twistor lift are discussed and an explicit formula for the dualities are deduced. Also possible variants of the duality are discussed.

Holography in H

$X^4 \subset H$ satisfies holography and is analogous to the Bohr orbit of a particle identified as a 3-surface. The proposal is that holography reduces to a 4-D generalization of holomorphy so that X^4 is a simultaneous zero of two functions of complex CP_2 coordinates and of what I have called Hamilton-Jacobi coordinates of M^4 with a generalized Kähler structure.

The simplest choice of the Hamilton-Jacobi coordinates is defined by the decomposition $M^4 = M^2 \times E^2$, where M^2 is endowed with hypercomplex structure defined by light-like coordinates (u, v), which are analogous to z and $\overline{z}$. Any analytic map $u \to f(u)$ defines a new set of light-like coordinates and corresponds to a solution of the massless d'Alembert equation in M^2. E^2 has some complex coordinates with imaginary unit defined by i.

The conjecture is that also more general Hamilton-Jacobi structures for which the tangent space decomposition is local are possible. Therefore one would have $M^4 = M^2(x) \times E^2(x)$. These would correspond to non-equivalent complex and Kähler structures of M^4 analogous to those possessed by 2-D Riemann surfaces and parametrized by moduli space.

Number theoretic holography in M^8_c

$Y^4 \subset M^8_c$ satisfies number theoretic holography defining dynamics, which should reduce to associativity in some sense. The Euclidian complexified normal space $N^4(y)$ at a given point y of Y^4 is required to be associative, i.e. quaternionic. Besides this, $N^4(i)$ contains a preferred complex Euclidian 2-D subspace $Y^2(y)$. Also the spaces $Y^2(x)$ define an integrable distribution. I have assumed that $Y^2(x)$ can depend on the point y of Y^4.

These assumptions imply that the normal space $N(y)$ of Y^4 can be parameterized by a point of $CP_2 = SU(3)/U(2)$. This distribution is always integrable unlike quaternionic tangent space distributions. M^8-H duality assigns to the normal space $N(y)$ a point of CP_2. M^4_c point y is mapped to a point $x \in M^4 \subset M^4 \times CP_2$ defined by the real part of its inversion (conformal transformation): this formula involves effective Planck constant for dimensional reasons.

The 3-D holographic data, which partially fixes 4-surfaces Y^4 is partially determined by a polynomial P with real integer coefficients smaller than the degree of P. The roots define mass squared values which are in general complex algebraic numbers and define complex analogs of mass shells in $M^4_c \subset M^8_c$, which are analogs of hyperbolic spaces H^3. The 3-surfaces at these mass shells define 3-D holographic data continued to a surface Y^4 by requiring that the normal space of Y^4 is associative, i.e. quaternionic. These 3-surfaces are not completely fixed but an interesting conjecture is that they correspond to fundamental domains of tessellations of H^3.

What does the complexity of the mass shells mean? The simplest interpretation is that the space-like M^4 coordinates (3-momentum components) are real whereas the time-like coordinate (energy) is complex and determined by the mass shell condition. One would have $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3 when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as a time coordinate. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to an equation of mass shell when $\sqrt{(Re(E)^2 - Im(E)^2)}$, expressed in terms of $Re(E)$, is taken as new energy coordinate $E_{eff} = \sqrt{(Re(E)^2 - Im(E)^2)}$. Is this deformation of H^3 in imaginary time direction equivalent with a region of the hyperbolic 3-space H^3?

One can look at the formula in more detail. Mass shell condition gives $Re^2(E) - Im(E)^2 - p^2 = Re(m^2)$ and $2Re(E)Im(E) = Im(m^2)$. The condition for the real parts gives H^3, when $\sqrt{Re^2(E) - Im(E)^2}$ is taken as an effective energy. The second condition allows to solve $Im(E)$ in terms of $Re(E)$ so that the first condition reduces to a dispersion relation for $Re(E)^2$.

$$Re(E)^2 = \frac{1}{2}(Re(m^2) - Im(m^2) + p^2)(1 \pm \sqrt{1 + \frac{2Im(m^2)^2}{(Re(m^2) - Im(m^2) + p^2)^2}} . \qquad (1.1.1)$$

Only the positive root gives a non-tachyonic result for $Re(m^2) - Im(m^2) > 0$. For real roots with $Im(m^2) = 0$ and at the high momentum limit the formula coincides with the standard formula. For $Re(m^2) = Im(m^2)$ one obtains $Re(E)^2 \rightarrow Im(m^2)/\sqrt{2}$ at the low momentum limit $p^2 \rightarrow 0$. Energy does not depend on momentum at all: the situation resembles that for plasma waves.

Can one find an explicit formula for $M^8 - H$ duality?

The dream is an explicit formula for the $M^8 - H$ duality mapping $Y^4 \subset M^8_c$ to $X^4 \subset H$. This formula should be consistent with the assumption that the generalized holomorphy holds true for X^4.

The following proposal is a more detailed variant of the earlier proposal for which Y^4 is determined by a map g of $M^4_c \rightarrow SU(3)_c \subset G_{2,c}$, where $G_{2,c}$ is the complexified automorphism group of octonions and $SU(3)_c$ is interpreted as a complexified color group.

This map defines a trivial $SU(3)_c$ gauge field. The real part of g however defines a non-trivial real color gauge field by the non-linearity of the non-abelian gauge field with respect to the gauge potential. The quadratic terms involving the imaginary part of the gauge potential give an additional condition to the real part in the complex situation and cancel it. If only the real part of g contributes, this contribution would be absent and the gauge field is non-vanishing.

How could the automorphism $g(x) \subset SU(3) \subset G_2$ give rise to $M^8 - H$ duality?

1. The interpretation is that $g(y)$ at given point y of Y^4 relates the normal space at y to a fixed quaternionic/associative normal space at point y_0, which corresponds is fixed by some subgroup $U(2)_0 \subset SU(3)$. The automorphism property of g guarantees that the normal space is quaternionic/associative at y. This simplifies the construction dramatically.
2. The quaternionic normal sub-space (which has Euclidian signature) contains a complex sub-space which corresponds to a point of sphere $S^2 = SO(3)/O(2)$, where $SO(3)$ is the quaternionic automorphism group. The interpretation could be in terms of a selection of spin quantization axes. The local choice of the preferred complex plane would not be unique and is analogous to the possibility of having non-trivial Hamilton Jacobi structures in M^4 characterized by the choice of $M^2(x)$ and equivalently its normal subspace $E^2(x)$.

   These two structures are independent apart from dependencies forced by the number theoretic dynamics. Hamilton-Jacobi structure means a selection of the quantization axis of spin and energy by fixing a distribution of light-like tangent vectors of M^4 and the choice of the quaternionic normal sub-space fixes a choice of preferred quaternionic imaginary unit defining a quantization axis of the weak isospin.
3. The real part $Re(g(y))$ defines a point of $SU(3)$ and the bundle projection $SU(3) \rightarrow CP_2$ in turn defines a point of $CP_2 = SU(3)/U(2)$. Hence one can assign to g a point of CP_2 as $M^8 - H$ duality requires and deduce an explicit formula for the point. This means a realization of the dream.
4. The construction requires a fixing of a quaternionic normal space N_0 at y_0 containing a preferred complex subspace at a single point of Y^4 plus a selection of the function g. If M^4 coordinates are possible for Y^4, the first guess is that g as a function of complexified M^4 coordinates obeys generalized holomorphy with respect to complexified M^4 coordinates in the same sense and in the case of X^4. This might guarantee that the $M^8 - H$ image of Y^4 satisfies the generalized holomorphy.
5. Also space-time surfaces X^4 with M^4 projection having a dimension smaller than 4 are allowed. I have proposed that they might correspond to singular cases for the above formula: a kind of blow-up would be involved. One can also consider a more general definition of Y^4 allowing it to have a M^4 projection with dimension smaller than 4 (say cosmic strings). Could one have implicit equations for the surface Y^4 in terms of the complex coordinates of $SU(3)_c$ and M^4? Could this give for instance cosmic strings with a 2-D M^4 projection and CP_2 type extremals with 4-D CP_2 projection and 1-D light-like M^4 projection?

What could the number theoretic holography mean physically?

What could be physical meaning of the number theoretic holography? The condition that has been assumed is that the CP_2 coordinates at the mass shells of $M^4_c \subset M^8_c$ mapped to mass shells H^3 of $M^4 \subset M^4 \times CP_2$ are constant at the H^3. This is true if the $g(y)$ defines the same CP_2 point for a given component X^3_i of the 3-surface at a given mass shell. g is therefore fixed apart from a local $U(2)$ transformation leaving the CP_2 point invariant. A stronger condition would be that the CP_2 point is the same for each component of X^3_i and even at each mass shell but this condition seems to be unnecessarily strong.

Comment: One can o criticize this condition as too strong and one can consider giving up this condition. The motivation for this condition is that the number of algebraic points at the 3-surfaces associated with H^3 explodes since the coordinates associated with normal directions vanish. Kind of cognitive explosion would be in question.

$SU(3)$ corresponds to a subgroup of G_2 and one can wonder what the fixing of this subgroup could mean physically. G_2 is 14-D and the coset space $G_2/SU(3)$ is 6-D and a good guess is that it is just the 6-D twistor space $SU(3)/U(1) \times U(1)$ of CP_2: at least the isometries are the same.

The fixing of the $SU(3)$ subgroup means fixing of a CP_2 twistor. Physically this means the fixing of the quantization axis of color isospin and hypercharge.

Twistor lift of the holography

What is interesting is that by replacing $SU(3)$ with G_2, one obtains an explicit formula form the generalization of M^8-H duality to that for the twistorial lift of TGD!

One can also consider a twistorial generalization of the above proposal for the number theoretic holography by allowing local G_2 automorphisms interpreted as local choices of the color quantization axis. G_2 elements would be fixed apart from a local $SU(3)$ transformation at the components of 3-surfaces at mass shells. The choice of the color quantization axes for a connected 3-surface at a given mass shell would be the same everywhere. This choice is indeed very natural physically since 3-surface corresponds to a particle.

Is this proposal consistent with the boundary condition of the number theoretical holography mean in the case of 4-surfaces in M^8_c and $M^4\times CP_2$?

1. The selection of $SU(3)\subset G_2$ for ordinary M^8-H duality means that the $G_{2,c}$ gauge field vanishes everywhere and the choice of color quantization axis is the same at all points of the 4-surface. The fixing of the CP_2 point to be constant at H^3 implies that the color gauge field at $H^3\subset M^8_c$ and its image $H^3\subset H$ vanish. One would have color confinement at the mass shells H^3_i, where the observations are made. Is this condition too strong?
2. The constancy of the G_2 element at mass shells makes sense physically and means a fixed color quantization axis. The selection of a fixed $SU(3)\subset G_2$ for entire space-time surface is in conflict with the non-constancy of G_2 element unless G_2 element differs at different points of 4-surface only by a multiplication of a local $SU(3)_0$ element, that is local $SU(3)$ transformation. This kind of variation of the G_2 element would mean a fixed color group but varying choice of color quantization axis.
3. Could one consider the possibility that the local $G_{2,c}$ element is free and defines the twistor lift of M^8-H duality as something more fundamental than the ordinary M^8-H duality based on $SU(3)_c$. This duality would make sense only at the mass shells so that only the spaces $H^3\times CP_2$ assignable to mass shells would make sense physically? In the interior CP_2 would be replaced with the twistor space $SU(3)/U(1)\times U(1)$. Color gauge fields would be non-vanishing at the mass shells but outside the mass shells one would have G_2 gauge fields.

   There is also a physical objection against the G_2 option. The 14-D Lie algebra representation of G_2 acts on the imaginary octonions which decompose with respect to the color group to $1\oplus 3\oplus \overline{3}$. The automorphism property requires that 1 can be transformed to 3 or $\overline{3}$ to themselves: this requires that the decomposition contains $3\oplus\overline{3}$. Furthermore, it must be possible to transform 3 and $\overline{3}$ to themselves, which requires the presence of 8. This leaves only the decomposition $8\oplus 3\oplus\overline{3}$. G_2 gluons would both color octet and triplets. In the TDG framework the only conceivable interpretation would be in terms of ordinary gluons and leptoquark-like gluons. This does not fit with the basic vision of TGD.

The choice of twistor as a selection of quantization axes should make sense also in the M^4 degrees of freedom. M^4 twistor corresponds to a choice of light-like direction at a given point of M^4. The spatial component of the light-like vector fixes the spin quantization axis. Its choice together with the light-likeness fixes the time direction and therefore the rest system and energy quantization axis. Light-like vector fixes also the choice of M^2 and of E^2 as its orthogonal complement. Therefore the fixing of M^4 twistor as a point of $SU(4)/SU(3)\times U(1)$ corresponds to a choice of the spin quantization axis and the time-like axis defining the rest system in which the energy is measured. This choice would naturally correspond to the Hamilton-Jacobi structure fixing the decompositions $M^2(x)\times E^2(x)$. At a given mass shell the choice of the quantization axis would be constant for a given X^3_i.

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that

Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electro-weak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark Matter as Large $\hbar$ Phases

D. Da Rocha and Laurent Nottale [E87] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests that astrophysical systems are at some levels of the hierarchy of space-time sheets macroscopic quantum systems. The space-time sheets in question would carry dark matter.

Nottale's hypothesis would predict a gigantic value of h_{gr}. Equivalence Principle and the independence of gravitational Compton length on mass m implies however that one can restrict the values of mass m to masses of microscopic objects so that h_{gr} would be much smaller. Large h_{gr} could provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K93].

It is natural to assign the values of Planck constants postulated by Nottale to the space-time sheets mediating gravitational interaction and identifiable as magnetic flux tubes (quanta) possibly carrying monopole flux and identifiable as remnants of cosmic string phase of primordial cosmology. The magnetic energy of these flux quanta would correspond to dark energy and magnetic tension would give rise to negative "pressure" forcing accelerate cosmological expansion. This leads to a rather detailed vision about the evolution of stars and galaxies identified as bubbles of ordinary and dark matter inside magnetic flux tubes identifiable as dark energy.

Certain experimental findings suggest the identification $h_{eff} = n\times = h_{gr}$. The large value of h_{gr} can be seen as a way to reduce the string tension of fermionic strings so that gravitational (in fact all!) bound states can be described in terms of strings connecting the partonic 2-surfaces defining particles (analogous to AdS/CFT description). The values $h_{eff}/h = n$ can be interpreted in terms of a hierarchy of breakings of super-conformal symmetry in which the super-conformal generators act as gauge symmetries only for a sub-algebras with conformal weights coming as multiples of n. Macroscopic quantum coherence in astrophysical scales is implied. If also Kähler-Dirac action is present, part of the interior degrees of freedom associated with the Kähler-Dirac part of conformal algebra become physical. A possible is that tfermionic oscillator operators generate super-symmetries and sparticles correspond almost by definition to dark matter with $h_{eff}/h = n > 1$. One implication would be that at least part if not all gravitons would be dark and be observed only through their decays to ordinary high frequency graviton ($E = hf_{high} = h_{eff}f_{low}$) of bunch of n low energy gravitons.

Hierarchy of Planck Constants from the Anomalies of Neuroscience and Biology

The quantal ELF effects of ELF em fields on vertebrate brain have been known since seventies. ELF em fields at frequencies identifiable as cyclotron frequencies in magnetic field whose intensity is about 2/5 times that of Earth for biologically important ions have physiological effects and affect also behavior. What is intriguing that the effects are found only in vertebrates (to my best knowledge). The energies for the photons of ELF em fields are extremely low - about 10^{-10} times lower than thermal energy at physiological temperatures- so that quantal effects are impossible in the framework of standard quantum theory. The values of Planck constant would be in these situations large but not gigantic.

This inspired the hypothesis that these photons correspond to so large a value of Planck constant that the energy of photons is above the thermal energy. The proposed interpretation was as dark photons and the general hypothesis was that dark matter corresponds to ordinary matter with non-standard value of Planck constant. If only particles with the same value of Planck constant can appear in the same vertex of Feynman diagram, the phases with different value of Planck constant are dark relative to each other. The phase transitions changing Planck constant can however make possible interactions between phases with different Planck constant but these interactions do not manifest themselves in particle physics. Also the interactions mediated by classical fields should be possible. Dark matter would not be so dark as we have used to believe.

The hypothesis $h_{eff} = h_{gr}$ - at least for microscopic particles - implies that cyclotron energies of charged particles do not depend on the mass of the particle and their spectrum is thus universal although corresponding frequencies depend on mass. In bio-applications this spectrum would correspond to the energy spectrum of bio-photons assumed to result from dark photons by h_{eff} reducing phase transition and the energies of bio-photons would be in visible and UV range associated with the excitations of bio-molecules.

Also the anomalies of biology (see for instance [K85, K86, K83]) support the view that dark matter might be a key player in living matter.

Dark Matter as a Source of Long Ranged Weak and Color Fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics.

The recent view about the solutions of Kähler- Dirac action assumes that the modes have a well-defined em charge and this implies that localization of the modes to 2-D surfaces (right-handed neutrino is an exception). Classical W boson fields vanish at these surfaces and also classical Z^0 field can vanish. The latter would guarantee the absence of large parity breaking effects above intermediate boson scale scaling like h_{eff}.

1.1.9 Twistors in TGD and connection with Veneziano duality

The twistorialization of TGD has two aspects. The attempt to generalize twistor Grassmannian approach emerged first. It was however followed by the realization that also the twistor lift of TGD at classical space-time level is needed. It turned out that the progress in the understanding of the classical twistor lift has been much faster - probably this is due to my rather limited technical QFT skills.

Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K106]. The reason is that M^4 and CP_2 are completely exceptional in the sense that they are the only 4-D manifolds allowing twistor space with Kähler structure [?]. The twistor space of $M^4 \times CP_2$ is Cartesian product of those of M^4 and CP_2. The obvious idea is that space-time surfaces allowing twistor structure if they are orientable are representable as surfaces in H such that the properly induced twistor structure co-incides with the twistor structure defined by the induced metric.

In fact, it is enough to generalize the induction of spinor structure to that of twistor structure so that the induced twistor structure need not be identical with the ordinary twistor structure possibly assignable to the space-time surface. The induction procedure reduces to a dimensional reduction of 6-D Kähler action giving rise to 6-D surfaces having bundle structure with twistor sphere as fiber and space-time as base. The twistor sphere of this bundle is imbedded as sphere in the product of twistor spheres of twistor spaces of M^4 and CP_2.

This condition would define the dynamics, and the original conjecture was that this dynamics is equivalent with the identification of space-time surfaces as preferred extremals of Kähler action. The dynamics of space-time surfaces would be lifted to the dynamics of twistor spaces, which are sphere bundles over space-time surfaces. What is remarkable that the powerful machinery of complex analysis becomes available.

It however turned out that twistor lift of TGD is much more than a mere technical tool. First of all, the dimensionally reduction of 6-D Kähler action contained besides 4-D Kähler action also a volume term having interpretation in terms of cosmological constant. This need not bring anything new, since all known extremals of Kähler action with non-vanishing induced Kähler form are minimal surfaces. There is however a large number of embeddings of twistor sphere of space-time surface to the product of twistor spheres. Cosmological constant has spectrum and depends on length scale, and the proposal is that coupling constant evolution reduces to that for cosmological constant playing the role of cutoff length. That cosmological constant could transform from a mere nuisance to a key element of fundamental physics was something totally new and unexpected.

1. The twistor lift of TGD at space-time level forces to replace 4-D Kähler action with 6-D dimensionally reduced Kähler action for 6-D surface in the 12-D Cartesian product of 6-D twistor spaces of M^4 and CP_2. The 6-D surface has bundle structure with twistor sphere as fiber and space-time surface as base.

   Twistor structure is obtained by inducing the twistor structure of 12-D twistor space using dimensional reduction. The dimensionally reduced 6-D Kähler action is sum of 4-D Kähler action and volume term having interpretation in terms of a dynamical cosmological constant depending on the size scale of space-time surface (or of causal diamond CD in zero energy ontology (ZEO)) and determined by the representation of twistor sphere of space-time surface in the Cartesian product of the twistor spheres of M^4 and CP_2.

2. The preferred extremal property as a representation of quantum criticality would naturally correspond to minimal surface property meaning that the space-time surface is separately an extremal of both Kähler action and volume term almost everywhere so that there is no coupling between them. This is the case for all known extremals of Kähler action with non-vanishing induced Kähler form.

   Minimal surface property could however fail at 2-D string world sheets, their boundaries and perhaps also at partonic 2-surfaces. The failure is realized in minimal sense if the 3-surface has 1-D edges/folds (strings) and 4-surface 2-D edges/folds (string world sheets) at which some partial derivatives of the embedding space coordinates are discontinuous but canonical momentum densities for the entire action are continuous.

   There would be no flow of canonical momentum between interior and string world sheet and minimal surface equations would be satisfied for the string world sheet, whose 4-D counterpart in twistor bundle is determined by the analog of 4-D Kähler action. These conditions allow the transfer of canonical momenta between Kähler- and volume degrees of freedom at string world sheets. These no-flow conditions could hold true at least asymptotically (near the boundaries of CD).

   $M^8 - H$ duality suggests that string world sheets (partonic 2-surfaces) correspond to images of complex 2-sub-manifolds of M^8 (having tangent (normal) space which is complex 2-plane of octonionic M^8).

3. Cosmological constant would depend on p-adic length scales and one ends up to a concrete model for the evolution of cosmological constant as a function of p-adic length scale and other number theoretic parameters (such as Planck constant as the order of Galois group): this conforms with the earlier picture.

   Inflation is replaced with its TGD counterpart in which the thickening of cosmic strings to flux tubes leads to a transformation of Kähler magnetic energy to ordinary and dark matter. Since the increase of volume increases volume energy, this leads rapidly to energy minimum at some flux tube thickness. The reduction of cosmological constant by a phase transition however leads to a new expansion phase. These jerks would replace smooth cosmic expansion of GRT. The discrete coupling constant evolution predicted by the number theoretical vision could be understood as being induced by that of cosmological constant taking the role of cutoff parameter in QFT picture [L62].

Twistor lift at the level of scattering amplitudes and connection with Veneziano duality

The classical part of twistor lift of TGD is rather well-understood. Concerning the twistorialization at the level of scattering amplitudes the situation is much more difficult conceptually - I already mentioned my limited QFT skills.

1. From the classical picture described above it is clear that one should construct the 8-D twistorial counterpart of theory involving space-time surfaces, string world sheets and their boundaries, plus partonic 2-surfaces and that this should lead to concrete expressions for the scattering amplitudes.

   The light-like boundaries of string world sheets as carriers of fermion numbers would correspond to twistors as they appear in twistor Grassmann approach and define the analog for the massless sector of string theories. The attempts to understand twistorialization have been restricted to this sector.

2. The beautiful basic prediction would be that particles massless in 8-D sense can be massive in 4-D sense. Also the infrared cutoff problematic in twistor approach emerges naturally and reduces basically to the dynamical cosmological constant provided by classical twistor lift.

   One can assign 4-momentum both to the spinor harmonics of the embedding space representing ground states of super-conformal representations and to light-like boundaries of string world sheets at the orbits of partonic 2-surfaces. The two four-momenta should be identical by quantum classical correspondence: this could be seen as a concretization of Equivalence Principle. Also a connection with string model emerges.

3. As far as symmetries are considered, the picture looks rather clear. Ordinary twistor Grassmannian approach boils down to the construction of scattering amplitudes in terms of Yangian invariants for conformal group of M^4. Therefore a generalization of super-symplectic symmetries to their Yangian counterpart seems necessary. These symmetries would be gigantic but how to deduce their implications?

4. The notion of positive Grassmannian is central in the twistor approach to the scattering amplitudes in $calN = 4$ SUSYs. TGD provides a possible generalization and number theoretic interpretation of this notion. TGD generalizes the observation that scattering amplitudes in twistor Grassmann approach correspond to representations for permutations. Since 2-vertex is the only fermionic vertex in TGD, OZI rules for fermions generalizes, and scattering amplitudes are representations for braidings.

   Braid interpretation encourages the conjecture that non-planar diagrams can be reduced to ordinary ones by a procedure analogous to the construction of braid (knot) invariants by gradual un-braiding (un-knotting).

This is however not the only vision about a solution of non-planarity. Quantum criticality provides different view leading to a totally unexpected connection with string models, actually with the Veneziano duality, which was the starting point of dual resonance model in turn leading via dual resonance models to super string models.

1. Quantum criticality in TGD framework means that coupling constant evolution is discrete in the sense that coupling constants are piecewise constant functions of length scale replaced by dynamical cosmological constant. Loop corrections would vanish identically and the recursion formulas for the scattering amplitudes (allowing only planar diagrams) deduced in twistor Grassmann would involve no loop corrections. In particular, cuts would be replaced by sequences of poles mimicking them like sequences of point charge mimic line charges. In momentum discretization this picture follows automatically.

2. This would make sense in finite measurement resolution realized in number theoretical vision by number-theoretic discretization of the space-time surface (cognitive representation) as points with coordinates in the extension of rationals defining the adele [L41]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?

3. Maybe it is! The basic idea of behind the original Veneziano amplitudes (see http://tinyurl.com/yyhwvbqb) was Veneziano duality. This 4-particle amplitude was generalized by Yoshiro Nambu, Holber-Beck Nielsen, and Leonard Susskind to N-particle amplitude (see http://tinyurl.com/yyvkx7as) based on string picture, and the resulting model was called dual resonance model. The model was forgotten as QCD emerged. Later came superstring models and led to M-theory. Now it has become clear that something went wrong, and it seems that one must return to the roots. Could the return to the roots mean a careful reconsideration of the dual resonance model?

4. Recall that Veneziano duality (1968) was deduced by assuming that scattering amplitude can be described as sum over s-channel resonances or t-channel Regge exchanges and Veneziano duality stated that hadronic scattering amplitudes have representation as sums over s- or t-channel resonance poles identified as excitations of strings. The sum over exchanges defined by t-channel resonances indeed reduces at larger values of s to Regge form.

   The resonances had zero width, which was not consistent with unitarity. Further, there were no counterparts for the *sum* of s-, t-, and u-channel diagrams with continuous cuts in the kinematical regions encountered in QFT approach. What puts bells ringing is the u-channel diagrams would be non-planar and non-planarity is the problem of twistor Grassmann approach.

5. Veneziano duality is true only for s- and t- channels but not been s- and u-channel. Stringy description makes t-channel and s-channel pictures equivalent. Could it be that in fundamental description u-channels diagrams cannot be distinguished from s-channel diagrams or t-channel diagrams? Could the stringy representation of the scattering diagrams make u-channel twist somehow trivial if handles of string world sheet representing stringy loops in turn representing the analog of non-planarity of Feynman diagrams are absent? The permutation of external momenta for tree diagram in absence of loops in planar representation would be a twist of π in the representation of planar diagram as string world sheet and would not change the topology of the string world sheet and would not involve non-trivial world sheet topology.

   For string world sheets loops would correspond to handles. The presence of handle would give an edge with a loop at the level of 3-surface (self energy correction in QFT). Handles are not allowed if the induced metric for the string world sheet has Minkowskian signature. If the stringy counterparts of loops are absent, also the loops in scattering amplitudes should be absent.

   This argument applies only inside the Minkowskian space-time regions. If string world sheets are present also in Euclidian regions, they might have handles and loop corrections could emerge in this manner. In TGD framework strings (string world sheets) are identified to 1-D edges/folds of 3-surface at which minimal surface property and topological QFT property fails (minimal surfaces as calibrations). Could the interpretation of edge/fold as discontinuity of some partial derivatives exclude loopy edges: perhaps the branching points would be too singular?

A reduction to a sum over s-channel resonances is what the vanishing of loops would suggest. Could the presence of string world sheets make possible the vanishing of continuous cuts even at the continuum limit so that continuum cuts would emerge only in the approximation as the density of resonances is high enough?

The replacement of continuous cut with a sum of *infinitely* narrow resonances is certainly an approximation. Could it be that the stringy representation as a sum of resonances with *finite* width is an essential aspect of quantum physics allowing to get rid of infinities necessarily accompanying loops? Consider now the arguments against this idea.

1. How to get rid of the problems with unitarity caused by the zero width of resonances? Could *finite* resonance widths make unitarity possible? Ordinary twistor Grassmannian approach predicts that the virtual momenta are light-like but complex: obviously, the imaginary part of the energy in rest frame would have interpretation as resonance with.

   In TGD framework this generalizes for 8-D momenta. By quantum-classical correspondence (QCC) the classical Noether charges are equal to the eigenvalues of the fermionic charges in Cartan algebrable (maximal set of mutually commuting observables) and classical TGD indeed predicts complex momenta (Kähler coupling strength is naturally complex). QCC thus supports this proposal.

2. Sum over resonances/exchanges picture is in conflict with QFT picture about scattering of particles. Could *finite* resonance widths due to the complex momenta give rise to the QFT type scattering amplitudes as one develops the amplitudes in Taylor series with respect to the resonance width? Unitarity condition indeed gives the first estimate for the resonance width.

   QFT amplitudes should emerge in an approximation obtained by replacing the discrete set of finite width resonances with a cut as the distance between poles is shorter than the resolution for mass squared.

   In superstring models string tension has single very large value and one cannot obtain QFT type behavior at low energies (for instance, scattering amplitudes in hadronic string model are concentrated in forward direction). TGD however predicts an entire hierarchy of p-adic length scales with varying string tension. The hierarchy of mass scales corresponding roughly to the lengths and thickness of magnetic flux tubes as thickened cosmic strings and characterized by the value of cosmological constant predicted by twistor lift of TGD. Could this give rise to continuous QCT type cuts at the limit when measurement resolution cannot distinguish between resonances?

   The dominating term in the sum over sums of resonances in t-channel gives near forward direction approximately the lowest mass resonance for strings with the smallest string tension. This gives the behavior $1/(t-m_{min}^2)$, where m_{min} corresponds to the longest mass scale involved (the largest space-time sheet involved), approximating the $1/t$-behavior of massless theories. This also brings in IR cutoff, the lack of which is a problem of gauge theories. This should give rise to continuous QFT type cuts at the limit when measurement resolution cannot distinguish between resonances.

1.2 Bird's Eye of View about the Topics of the Book

This book is mostly devoted to what might be called classical TGD.

1. In a well-defined sense classical TGD defined as the dynamics of space-time surfaces determining them as kind of generalized Bohr orbits can be regarded as an exact part of quantum theory and assuming quantum classical correspondence has served as an extremely valuable guideline in the attempts to interpret TGD, to form a view about what TGD really predicts, and to guess what the underlying quantum theory could be and how it deviates from standard quantum theory.

2. The notions of many-sheeted space-time, topological field quantization and the notion of field/magnetic body, follow from simple topological considerations. The observation that space-time sheets can have arbitrarily large sizes and their interpretation as quantum coherence regions forces to conclude that in TGD Universe macroscopic and macro-temporal quantum coherence are possible in arbitrarily long scales. Also long ranged classical color and electro-weak fields are an unavoidable prediction.

3. It took a considerable time to make the obvious conclusion: TGD Universe is fractal containing fractal copies of standard model physics at various space-time sheets and labeled by the collection of p-adic primes assignable to elementary particles and by the level of dark matter hierarchy characterized partially by the value of Planck constant labeling the pages of the book like structure formed by singular covering spaces of the embedding space $M^4 \times CP_2$ glued together along a four-dimensional back. Particles at different pages are dark relative to each other since purely local interactions defined in terms of the vertices of Feynman diagram involve only particles at the same page.

4. The new view about energy and time justified by the notion of zero energy ontology (ZEO) means that the sign of inertial energy depends on the time orientation of the space-time sheet and that negative energy space-time sheets serve as correlates for communications to the geometric past. This alone leads to profoundly new views about metabolism, long term memory, and realization of intentional action.

1.2.1 The Implications Deriving From The Topology Of Space-Time Surface And From The Properties Of Induced Gauge Fields

1. The general properties of Kähler action, in particular its vacuum degeneracy and failure of the classical determinism in the conventional sense, have rather far reaching implications. Space-time surfaces as a generalization of Bohr orbit provide not only a representation of quantum states but also sequences of quantum jumps and thus contents of consciousness. Vacuum degeneracy implies spin glass degeneracy in 4-D sense reflecting quantum criticality which is the fundamental characteristic of TGD Universe.
2. The detailed study of the simplest extremals of Kähler action interpreted as correlates for asymptotic self organization patterns provides additional insights [K14] . CP_2 type extremals representing elementary particles, cosmic strings, vacuum extremals, topological light rays ("massless extremal", ME), flux quanta of magnetic and electric fields represent the basic extremals. Pairs of wormhole throats identifiable as parton pairs define a completely new kind of particle carrying only color quantum numbers in ideal case and I have proposed their interpretation as quantum correlates for Boolean cognition. MEs and flux quanta of magnetic and electric fields are of special importance in living matter.

This general picture serves as a cornerstone of also TGD inspired view about cosmology and astrophysics. For obvious reasons the newest ideas developed during last year and still developing (in particular, the vision about dark matter) are not discussed in full depth yet.

1.2.2 Many-Sheeted Cosmology

The many-sheeted space-time concept, the new view about the relationship between inertial and gravitational four-momenta, the basic properties of the paired cosmic strings, the existence of the limiting temperature, the assumption about the existence of the phase dominated by cosmic strings, and quantum criticality imply a rather detailed picture of the cosmic evolution, which differs from that provided by the standard cosmology in several respects but has also strong resemblances with inflationary scenario.

Basic deviations from standard cosmology

The most important differences between TGD based and standard cosmology are following.

1. Many-sheetedness implies cosmologies inside cosmologies Russian doll like structure with a spectrum of Hubble constants.
2. TGD cosmology is also genuinely quantal: each quantum jump in principle recreates each sub-cosmology in 4-dimensional sense: this makes possible a genuine evolution in cosmological length scales so that the use of anthropic principle to explain why fundamental constants are tuned for life is not necessary.
3. The new view about energy means that inertial energy is negative for space-time sheets with negative time orientation and that the density of inertial energy vanishes in cosmological length scales. Therefore any cosmology is in principle creatable from vacuum and the problem of initial values of cosmology disappears. The density of matter near the initial moment is dominated by cosmic strings approaches to zero so that big bang is transformed to a silent whisper amplified to a relatively big bang.
4. Dark matter hierarchy with dynamical quantized Planck constant $h_{eff} = nh_0$, where h_0 is the minimum value of Planck constant ($h = 6h_0$ is the proposal) implies the presence of dark space-time sheets which differ from non-dark ones in that they define multiple coverings of M^4. Quantum coherence of dark matter in the length scale of space-time sheet involved implies that even in cosmological length scales Universe is more like a living organism than a thermal soup of particles.
5. Sub-critical and over-critical Robertson-Walker cosmologies are fixed completely from the imbeddability requirement apart from a single parameter characterizing the duration of the period after which transition to sub-critical cosmology necessarily occurs. The fluctuations of the microwave background reflect the quantum criticality of the critical period rather than

amplification of primordial fluctuations by exponential expansion. This and also the finite size of the space-time sheets predicts deviations from the standard cosmology.

This picture can be criticized since it is based on Kähler action. Twistor lift however predicts that action contains a small volume term proportional to dynamical cosmological constant. This means that Robertson-Walker cosmologies are not possible as preferred extremals except at the limit of vanishing cosmological contant corresponds to infinitely large space-time sheets and is also possible in principle.

Cosmic strings

Cosmic strings belong to the basic extremals of the Kähler action. The string tension of the cosmic strings is $T \simeq .2 \times 10^{-6}/G$ and slightly smaller than the string tension of the GUT strings and this makes them very interesting cosmologically. Concerning the understanding of cosmic strings a decisive breakthrough came through the identification of gravitational four-momentum as the difference of inertial momenta associated with matter and antimatter and the realization that the net inertial energy of the Universe vanishes. This forced to conclude cosmological constant in TGD Universe is non-vanishing. p-Adic length fractality predicts that Λ scales as $1/L^2(k)$ as a function of the p-adic scale characterizing the space-time sheet. The recent value of the cosmological constant comes out correctly. The gravitational energy density described by the cosmological constant is identifiable as that associated with topologically condensed cosmic strings and of magnetic flux tubes to which they are gradually transformed during cosmological evolution.

p-Adic fractality and simple quantitative observations lead to the hypothesis that pairs of cosmic strings are responsible for the evolution of astrophysical structures in a very wide length scale range. Large voids with size of order 10^8 light years can be seen as structures containing knotted and linked cosmic string pairs wound around the boundaries of the void. Galaxies correspond to same structure with smaller size and linked around the supra-galactic strings. This conforms with the finding that galaxies tend to be grouped along linear structures. Simple quantitative estimates show that even stars and planets could be seen as structures formed around cosmic strings of appropriate size. Thus Universe could be seen as fractal cosmic necklace consisting of cosmic strings linked like pearls around longer cosmic strings linked like...

1.2.3 Dark Matter And Quantization Of Gravitational Planck Constant

The notion of gravitational Planck constant having gigantic value is perhaps the most radical idea related to the astrophysical applications of TGD. D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ $(\hbar = c = 1)$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

1.2.4 The organization of "Physics in Many-sheeted Space-time: Part II"

In this book many-sheeted-cosmology and astrophysics are summarized. The material is ordered along time-line of TGD, and the views of the earliest chapters are not necessarily completely consistent with the views of latest chapters. The book consists of 2 parts.

1. p-Adic and dark matter hierarchies imply that TGD inspired cosmology has a kind of Russian doll structure containing cosmologies within cosmologies. Cosmic strings and their deformations are basic objects of TGD inspired cosmology and of galactic physics - even astrophysics. They form a fractal hierarchy continuing down to the level of elementary particles representable as closed flux tubes carrying monopole flux.

   Very early cosmology would be dominated by cosmic strings with 2-D M^4 projection and one cay say that the GRT based cosmology with macroscopic space-time identifiable as small deformation of Minkowski space emerged during the analog of inflationary period leading to radiation dominated cosmology.

   In the chapters devoted TGD inspired cosmology the imbeddings of Robertson-Walker cosmology are studied. Both critical and over-critical cosmology are found to be unique apart from the parameter characterizing its duration. It must be emphasized that RW cosmologies make sense as preferred extremals only at the limit of vanishing cosmological constant.

2. The idea about dark matter hierarchy with levels labeled by the values of Planck constant was originally motivated by the observation that planetary orbits could be interpreted as Bohr orbits with enormous value of Planck constant (introduced originally by Nottale), whose value is fixed to a high degree by Equivalence Principle and which is assignable to the flux tubes mediating gravitational interaction. One ends up to a rather detailed view about macroscopically quantum coherent dark matter in astrophysics and cosmology. In particular, dark matter could be in anyonic phase at light-like 2-surfaces with complex topology and astrophysical size and visible matter would condense around it.

   Dark matter hierarchy allows to interpret critical cosmologies as correlates for the phase transitions increasing Planck constant and involving a relatively rapid expansion of space-time sheets. The quantum counterpart of the smooth cosmological expansion would be a series of phase transitions increasing the value of Planck constant and these phase transitions are predicted to take place also at planetary level, which provides a new theoretical basis for Expanding Earth hypothesis and suggests totally unexpected connections between biology and geology.

3. Twistor lift of TGD provides justification for the idea about cosmological constant depending on length scale. It replaces Kähler action with its sum with a volume term having interpretation in terms of dynamical cosmological constant, which depends on length scale and decreases like one over p-adic length scale squared. One can see cosmological evolution as a sequence of phase transitions reducing the value of cosmological constant followed by an expansion of the thickness of flux tubes reducing their Kähler magnetic energy but increasing volume energy until energy minimum is achieved.

   Twistor lift of TGD predicts that also the M^4 analog of Kähler action is present in the dimensionally reduced 6-D Kähler action. One can understand why the physical effects such as the violation of CP and T symmetries are small and an explanation for the small CP breaking effects of hadron physics and for the matter antimatter asymmetry emerges.

4. Long cosmic strings would develop galaxies as tangles with topology of dipole magnetic field (roughly) and these flux tubes of this tangles would in turn generate stars and planets as similar tangles. This hierarchy could continue to even smaller length scales. The thickening of cosmic strings and the sequence of phase transitions reducing cosmological constant would induce transformation of the magnetic and volume energy of cosmic strings to ordinary matter generating the visible matter of galaxies and also stars and planets. The decay of magnetic energy to ordinary matter during thickening period of flux tube would be analogous to the decay of inflaton field. The flat velocity spectrum of stars rotating around galaxies is predicted correctly without need for dark matter halo.

5. A new view about blackholes and white holes as tangles associated with cosmic strings suggests itself. For instance quasars could be white hole like objects created as Kähler magnetic tangle evolves from straight cosmic string and thickens by decays to ordinary matter. Blackhole would be time reversal of this process and indeed possible in ZEO predicting that "big" state function reductions inducing reversal of time arrow are possible even in astrophysical and cosmological scales.

1.3 Sources

The eight online books about TGD [K113, K107, K88, K77, K24, K72, K52, K96] and nine online books about TGD inspired theory of consciousness and quantum biology [K102, K18, K82, K16, K48, K61, K64, K95, K101] are warmly recommended for the reader willing to get overall view about what is involved.

My homepage (`http://tinyurl.com/ybv8dt4n`) contains a lot of material about TGD. In particular, a TGD glossary at `http://tinyurl.com/yd6jf3o7`).

I have published articles about TGD and its applications to consciousness and living matter in *Journal of Non-Locality* (`http://tinyurl.com/ycyrxj4o` founded by Lian Sidorov and in *Prespacetime Journal* (`http://tinyurl.com/ycvktjhn`), *Journal of Consciousness Research and Exploration* (`http://tinyurl.com/yba4f672`), and *DNA Decipher Journal* (`http://tinyurl.com/y9z52khg`), all of them founded by Huping Hu. One can find the list about the articles published at `http://tinyurl.com/ybv8dt4n`. I am grateful for these far-sighted people for providing a communication channel, whose importance one cannot overestimate.

1.4 The contents of the book

1.4.1 PART I: MANY-SHEETED COSMOLOGY

Cosmic strings

Cosmic strings belong to the basic extremals of the Kähler action. The upper bound for string tension of the cosmic strings is $T \simeq .5 \times 10^{-6}/G$ and in the same range as the string tension of GUT strings and this makes them very interesting cosmologically although TGD cosmic strings have otherwise practically nothing to do with their GUT counterparts.

1. Basic ideas

The understanding of cosmic strings has developed only slowly and has required dramatic modifications of existing views.

1. Zero energy ontology implies that the energy and all quantum numbers of the Universe vanishes and physical states are zero energy states decomposing into pairs of positive and negative energy states localizable to the light-like boundaries of causal diamonds defined as intersections of future and past directed light-cones. Positive energy ontology is a good approximation under certain assumptions.
2. Dark matter hierarchy whose levels are labeled by gigantic values of gravitational Planck constant associated with dark matter is second essential piece of the picture.
3. The second variation of Kähler action vanishes for preferred extremals - at least the second variations associated with dynamical symmetries. This guarantees that Noether currents assignable to the Kähler-Dirac action are conserved. The properties of the preferred extremals suggest a dimensional reduction providing formulations of quantum TGD in terms of possibly dual slicings of space-time surface by string word sheets and partonic 2-surfaces. The localization of the modes of the Kähler-Dirac equation to 2-D surfaces - string world sheets and possibly partonic 2-surfaces) suggests something similar although ot might be that both kind of objects are necessary for a full description.
4. GRT limit of can be understood as an outcome of the replacement of sheets of the many-sheeted space-time with single sheet endowed with effective metric given by the sum of Minkowski metric and deviations of the induced metrics of space-time sheets from Minkowski

metric. Gauge theory limit can be understood in an analogous manner. Equivalence Principle in Einsteinian sense follows from Poincare invariance of TGD. The additional assumption made before a real understanding of GRT limit was that the the most important GRT space-times can be represented as vacuum extremals of Kähler action. This assumption can be of course questioned.

5. The basic question whether one can model the exterior region of the topologically condensed cosmic string using General Relativity. The exterior metric of the cosmic string corresponds to a small deformation of a vacuum extremal assuming the identification of the most important GRT space-times as vacuum extremals of Kähler action. The angular defect and surplus associated with the exterior metrics extremizing curvature scalar can be much smaller than assuming vacuum Einstein's equations. The conjecture is that the exterior metric of galactic string conforms with the Newtonian intuitions and thus explains the constant velocity spectrum of distant stars if one assumes that galaxies are organized to linear structures along long strings like pearls in a necklace.

2. Critical and over-critical cosmologies involve accelerated cosmic expansion

In TGD framework critical and over-critical cosmologies are unique apart from single parameter telling their duration and predict the recently discovered accelerated cosmic expansion. Critical cosmologies are naturally associated with quantum critical phase transitions involving the change of gravitational Planck constant. A natural candidate for such a transition is the increase of the size of a large void as galactic strings have been driven to its boundary. During the phase transitions connecting two stationary cosmologies (extremals of curvature scalar) also determined apart from single parameter, accelerated expansion is predicted to occur. These transitions are completely analogous to quantum transitions at atomic level.

The proposed microscopic model predicts that the TGD counterpart of the quantity $\rho + 3p$ for cosmic strings is negative during the phase transition which implies accelerated expansion. Dark energy is replaced in TGD framework with dark matter indeed predicted by TGD and its fraction is .74 as in standard scenario. Cosmological constant thus characterizes phenomenologically the density of dark matter rather than energy in TGD Universe.

The sizes of large voids stay constant during stationary periods which means that also cosmological constant is piecewise constant. p-Adic length fractality predicts that Λ scales as $1/L^2(k)$ as a function of the p-adic scale characterizing the space-time sheet of void. The order of magnitude for the recent value of the cosmological constant comes out correctly. The gravitational energy density described by the cosmological constant is identifiable as that associated with topologically condensed cosmic strings and of magnetic flux tubes to which they are gradually transformed during cosmological evolution.

3. Cosmic strings and generation of structures

1. In zero energy ontology cosmic strings must be created from vacuum as zero energy states consisting of pairs of strings with opposite time orientation and inertial energy.
2. The counterpart of Hawking radiation provides a mechanism by which cosmic strings can generate ordinary matter. The splitting of cosmic strings followed by a "burning" of the string ends provides a second manner to generate visible matter. Matter-antimatter symmetry would result if antimatter is inside cosmic strings and matter in the exterior region. A justification for CP asymmetry comes from basic quantum TGD. One can add to Kähler function of the WCW an imaginary part defined by instanton term $J \wedge J$. This term does not affect Kähler metric but implies CP breaking.
3. Zero energy ontology has deep implications for the cosmic and ultimately also for biological evolution (magnetic flux tubes paly a fundamental role in TGD inspired biology and cosmic strings are limiting cases of them). The arrows of geometric time are opposite for the strings and also for positive energy matter and negative energy antimatter. This implies a competition between two dissipative time developments proceeding in different directions of geometric time and looking self-organization and even self-assembly from the point of view of each other. This resolves paradoxes created by gravitational self-organization contra second law of thermodynamics. So called super-symplectic matter at cosmic strings implies large p-adic entropy resolves the well-known entropy paradox.

4. p-Adic fractality and simple quantitative observations lead to the hypothesis that cosmic strings are responsible for the evolution of astrophysical structures in a very wide length scale range. Large voids with size of order 10^8 light years can be seen as structures cosmic strings wound around the boundaries of the void. Galaxies correspond to same structure with smaller size and linked around the supra-galactic strings. This conforms with the finding that galaxies tend to be grouped along linear structures. Simple quantitative estimates show that even stars and planets could be seen as structures formed around cosmic strings of appropriate size. Thus Universe could be seen as fractal cosmic necklace consisting of cosmic strings linked like pearls around longer cosmic strings linked like...

4. Cosmic strings, gamma ray bursts, and supernovae

During year 2003 two important findings related to cosmic strings were made.

1. A correlation between supernovae and gamma ray bursts was observed.
2. Evidence that some unknown particles of mass $m \simeq 2m_e$ and decaying to gamma rays and/or electron positron pairs annihilating immediately serve as signatures of dark matter. These findings challenge the identification of cosmic strings and/or their decay products as dark matter, and also the idea that gamma ray bursts correspond to cosmic fire crackers formed by the decaying ends of cosmic strings.

This forces the updating of the more than decade old rough vision about topologically condensed cosmic strings and about gamma ray bursts described in this chapter. According to the updated model, cosmic strings transform in topological condensation to magnetic flux tubes about which they represent a limiting case. Primordial magnetic flux tubes forming ferro-magnet like structures become seeds for gravitational condensation leading to the formation of stars and galaxies. The TGD based model for the asymptotic state of a rotating star as dynamo leads to the identification of the predicted magnetic flux tube at the rotation axis of the star as Z^0 magnetic flux tube of primordial origin. Besides Z^0 magnetic flux tube structure also magnetic flux tube structure exists at different space-time sheet but is in general not parallel to the Z^0 magnetic structure. This structure cannot have primordial origin (the magnetic field of star can even flip its polarity).

The flow of matter along Z^0 magnetic (rotation) axis generates synchrotron radiation, which escapes as a precisely targeted beam along magnetic axis and leaves the star. The identification is as the rotating light beam associated with ordinary neutron stars. During the core collapse leading to the supernova this beam becomes gamma ray burst. The mechanism is very much analogous to the squeezing of the tooth paste from the tube. The fact that all nuclei are fully ionized Z^0 ions, the Z^0 charge unbalance caused by the ejection of neutrinos, and the radial compression make the effect extremely strong so that there are hopes to understand the observed incredibly high polarization of 80 ± 20 per cent.

The W fields experienced by fundamental fermions at 2-D surfaces at which they are localized vanish by the well-definedness of em charge, and one can also require that Z^0 fields vanish at least above weak scale. The vanishing of effective weak fields is an obvious objection against the model unless one allows the possibility of large values of $h_{eff} = n \times h$ strongly suggested by the identification $h_{eff} = h_{gr}$, where $h_{gr}GMm/v_0$ is the gravitational Planck constant inspired by Nottale's considerations: here M and m would correspond to masses of supernova and of microscopic system.

TGD suggests the identification of particles of mass $m \simeq 2m_e$ accompanying dark matter as lepto-pions formed by color excited leptons, and topologically condensed at magnetic flux tubes having thickness of about lepto-pion Compton length. Lepto-pions would serve as signatures of dark matter whereas dark matter itself would correspond to the magnetic energy of topologically condensed cosmic strings transformed to magnetic flux tubes.

TGD and cosmology

A proposal for what might be called TGD inspired cosmology is made. The basic ingredient of this cosmology is the TGD counter part of the cosmic string. It is found that many-sheeted space-time concept, the new view about the relationship between inertial and gravitational four-momenta, the basic properties of the cosmic strings, zero energy ontology, the hierarchy of dark matter with levels labeled by arbitrarily large values of Planck constant: the existence of the limiting temperature (as in string model, too), the assumption about the existence of the vapor phase dominated by cosmic strings, and quantum criticality imply a rather detailed picture of the cosmic evolution, which differs from that provided by the standard cosmology in several respects but has also strong resemblances with inflationary scenario.

TGD inspired cosmology in its recent form relies on an ontology differing dramatically from that of GRT based cosmologies. Zero energy ontology (ZEO) states that all physical states have vanishing net quantum numbers so that all matter is creatable from vacuum. The hierarchy of dark matter identified as macroscopic quantum phases labeled by arbitrarily large values of Planck constant is second aspect of the new ontology. The values of the gravitational Planck constant assignable to space-time sheets mediating gravitational interaction are gigantic. This implies that TGD inspired late cosmology might decompose into stationary phases corresponding to stationary quantum states in cosmological scales and critical cosmologies corresponding to quantum transitions changing the value of the gravitational Planck constant and inducing an accelerated cosmic expansion.

1. Zero energy ontology

The construction of quantum theory leads naturally to ZEO stating that everything is creatable from vacuum. Zero energy states decompose into positive and negative energy parts having identification as initial and final states of particle reaction in time scales of perception longer than the geometro-temporal separation T of positive and negative energy parts of the state. If the time scale of perception is smaller than T, the usual positive energy ontology applies.

In ZEO inertial four-momentum is a quantity depending on the temporal time scale T used and in time scales longer than T the contribution of zero energy states with parameter $T_1 < T$ to four-momentum vanishes. This scale dependence alone implies that it does not make sense to speak about conservation of inertial four-momentum in cosmological scales. Hence it would be in principle possible to identify inertial and gravitational four-momenta and achieve strong form of Equivalence Principle. It however seems that this is not the correct approach to follow.

2. Dark matter hierarchy and hierarchy of Planck constants

Dark matter revolution with levels of the hierarchy labeled by values of Planck constant forces a further generalization of the notion of imbedding space and thus of space-time. One can say, that embedding space is a book like structure obtained by gluing together infinite number of copies of the embedding space like pages of a book: two copies characterized by singular discrete bundle structure are glued together along 4-dimensional set of common points. These points have physical interpretation in terms of quantum criticality. Particle states belonging to different sectors (pages of the book) can interact via field bodies representing space-time sheets which have parts belonging to two pages of this book. Dark matter hierarchy follows naturally from the non-determinism of Kähler action.

3. Quantum criticality

TGD Universe is quantum counterpart of a statistical system at critical temperature. As a consequence, topological condensate is expected to possess hierarchical, fractal like structure containing topologically condensed 3-surfaces with all possible sizes. Both Kähler magnetized and Kähler electric 3-surfaces ought to be important and string like objects indeed provide a good example of Kähler magnetic structures important in TGD inspired cosmology. In particular space-time is expected to be many-sheeted even at cosmological scales and ordinary cosmology must be replaced with many-sheeted cosmology. The presence of vapor phase consisting of free cosmic strings containing topologically condensed fermions is second crucial aspect of TGD inspired cosmology.

Quantum criticality of TGD Universe, which corresponds to the vanishing of second variation of Kähler action for preferred extremals - at least of the variations related to dynamical symmetries- supports the view that many-sheeted cosmology is in some sense critical. Criticality in turn suggests fractality. Phase transitions, in particular the topological phase transitions giving rise to new space-time sheets, are (quantum) critical phenomena involving no scales. If the curvature of the 3-space does not vanish, it defines scale: hence the flatness of the cosmic time=constant section of the cosmology implied by the criticality is consistent with the scale invariance of the critical phenomena. This motivates the assumption that the new space-time sheets created in topological phase transitions are in good approximation modelable as critical Robertson-Walker cosmologies for some period of time at least.

These phase transitions are between stationary quantum states having stationary cosmologies as space-time correlates: also these cosmologies are determined uniquely apart from single parameter.

4. Only sub-critical cosmologies are globally imbeddable

It should be made clear that TGD inspired cosmology involves a vulnerable asumption. It is assumed that single-sheeted space-time surface is enough to model the cosmology. This need not to be the case. GRT limit of TGD is obtained by lumping together the sheets of many-sheeted space-time to a piece of Minkowski space and endowing it with an effective metric, which is sum of Minkowski metric and deviations of the induced metrics of space-time sheets from Minkowski metric. Hence the proposed models make sense only if GRT limits allowing imbedding as a vacuum extremal of Kähler action have special physical role.

TGD allows global imbedding of subcritical cosmologies. A partial imbedding of one-parameter families of critical and overcritical cosmologies is possible. The infinite size of the horizon for the imbeddable critical cosmologies is in accordance with the presence of arbitrarily long range fluctuations at criticality and guarantees the average isotropy of the cosmology. Imbedding is possible for some critical duration of time. The parameter labeling these cosmologies is scale factor characterizing the duration of the critical period. These cosmologies have the same optical properties as inflationary cosmologies. Critical cosmology can be regarded as a "Silent Whisper amplified to Bang" rather than "Big Bang" and transformed to hyperbolic cosmology before its imbedding fails. Split strings decay to elementary particles in this transition and give rise to seeds of galaxies. In some later stage the hyperbolic cosmology can decompose to disjoint 3-surfaces. Thus each sub-cosmology is analogous to biological growth process leading eventually to death.

5. Fractal many-sheeted cosmology

The critical cosmologies can be used as a building blocks of a fractal cosmology containing cosmologies containing ... cosmologies. p-Adic length scale hypothesis allows a quantitative formulation of the fractality. Fractal cosmology predicts cosmos to have essentially same optic properties as inflationary scenario but avoids the prediction of unknown vacuum energy density. Fractal cosmology explains the paradoxical result that the observed density of the matter is much lower than the critical density associated with the largest space-time sheet of the fractal cosmology. Also the observation that some astrophysical objects seem to be older than the Universe, finds a nice explanation.

6. Cosmic strings as basic building blocks of TGD inspired cosmology

Cosmic strings are the basic building blocks of TGD inspired cosmology and all structures including large voids, galaxies, stars, and even planets can be seen as pearls in a cosmic fractal necklaces consisting of cosmic strings containing smaller cosmic strings linked around them containing... During cosmological evolution the cosmic strings are transformed to magnetic flux tubes with smaller Kähler string tension and these structures are also key players in TGD inspired quantum biology.

The observed large voids would contain galactic cosmic strings at their boundaries. These voids would participate cosmic expansion only in average sense. During stationary periods the quantum states would be modelable using stationary cosmologies and during phase transitions increasing gravitational Planck constant and thus size of the large void they critical cosmologies would be the appropriate description. The acceleration of cosmic expansion predicted by critical cosmologies can be naturally assigned with these periods. Classically the quantum phase transition would be induced when galactic strings are driven to the boundary of the large void. The mechanism forcing the phase transition could be repulsive Coulomb energy associated with dark matter at strings if cosmic strings generate net em charge as a consequence of CP breaking (antimatter could reside inside cosmic strings) or a repulsive gravitational acceleration. The large values of Planck constant are crucial for understanding of living matter so that gravitation would play fundamental role also in the evolution of life and intelligence.

Some sections are devoted to the TGD counterpart of inflationary cosmology. From the beginning it has been clear that quantum criticality implying flatness of 3-space and thus criticality is the TGD counterpart for inflationary cosmology. Only after the recent findings about evidence for the polarization of CMB I realized that critical cosmology contains a period of very fast accelerating expansion and that both inflation and accelerating expansion much later are special cases of criticality. This leads to a rather detailed view about how the temperature fluctuations could emerged in TGD framework. The predecessor of inflationary cosmology would be cosmic string gas in the light-cone of Minkowski space and critical period would mean the emergence of space-time as we know it.

More about TGD and cosmology

This chapter can be regarded as second part of the previous chapter and is develoted to various applications and problems of cosmology. Much of the text is written decade or two ago.

1. The anomalies of CMB are discussed as a natural continuation of discussion of the counterpart of inflationary cosmology in TGD framework.
2. Simulating Big Bang in laboratory is the title of the next section. The motivation comes from the observation that critical cosmology could serve as a universal model for phase transitions.
3. Some problems of existing cosmology are considered in TGD framework. Discussion includes certain problems of the cosmology such as the questions why some stars seem to be older than the Universe, the claimed time dependence of the fine structure constant, the generation of matter antimatter asymmetry, the problem of the fermion families, and the redshift anomaly of quasars. A mechanism for accelerated expansion of Universe is also considered. In the recent framework this reduces to the critical cosmology and cosmological constant can be assigned to the effective space-time defining GRT limit of TGD.
4. There is a section about matter-antimatter asymmetry, baryogenesis, leptogenesis and TGD discussing whether right-handed neutrino suggested to generate SUSY in TGD framework could be the key entity in fermiogenesis.
5. The remaining sections are devoted to Hogan's theory about quantum fluctuations as new kind of noise and the question whether hyperbolic 3-manifolds emerging naturally in Zero Energy Ontology might be useful in TGD inspired cosmology and explain some redshift anomalies.

Breaking of CP, P, and T in cosmological scales in TGD Universe

The twistor lift of TGD forces the analog of Kähler form for M^4. Covariantly constant sef-dual Kähler form $J(CD)$ depends on causal diamond of M^4 and defines rest frame and spin quantization axis. This implies a violation of CP, P, and T. By introducing a moduli space for the Kähler forms one avoids the loss of Poincare invariance. The natural question is whether $J(CD)$ could relate to CP breaking for K and B type mesons, to matter antimatter asymmetry and the large scale parity breaking suggested by CMB data.

The simplest guess for the coupling strength of $U(1)$ interaction associated with $J(CD)$ predicts a correct order of magnitude for CP violation for K meson and for the antimatter asymmetry and inspires a more detailed discussion. A general mechanism for the generation of matter asymmetry is proposed, and a model for the formation of disk- and elliptic galaxies is considered. The matter antimatter asymmetry would be apparent in the sense that the CP asymmetry would force matter-antimatter separation: antimatter would reside as dark matter (in TGD sense) inside magnetic flux tubes and matter outside them. Also the angular momenta of dark matter and matter would compensate each other.

TGD View about Coupling Constant Evolution

New results related to the TGD view about coupling constant evolution are discussed. The results emerge from the discussion of the recent claim of Atyiah that fine structure constant could be understood purely mathematically. The new view allows to understand the recently introduced TGD based construction of scattering amplitudes based on the analog of micro-canonical ensemble as a cognitive representation for the much more complex construction of full scattering amplitudes using real numbers rather than p-adic number fields. This construction utilizes number theoretic discretization of space-time surface inducing that of "world of classical worlds" (WCW) and makes possible adelization of quantum TGD.

The understanding of coupling constant evolution has been one of most longstanding problems of TGD and I have made several proposals during years.

Could number theoretical constraints fix the evolution? Adelization suffers from serious number theoretical problem due to the fact that the action exponentials do not in general exist p-adically for given adele. The solution of the problem turned out to be trivial. The exponentials disappear from the scattering amplitudes! Contrary to the first beliefs, adelization does not therefore seem to determine coupling constant evolution.

TGD view about cosmological constant turned out to be the solution of the problem. The formulation of the twistor lift of Kähler action led to a rather detailed view about the interpretation of cosmological constant as an approximate parameterization of the dimensionally reduced 6-D Kähler action (or energy) allowing also to understand how it can decrease so fast as a function of p-adic length scale. In particular, a dynamical mechanism for the dimensional reduction of 6-D Kähler action giving rise to the induction of the twistor structure and predicting this evolution emerges.

In standard QFT view about coupling constant evolution ultraviolet cutoff length serves as the evolution parameter. TGD is however free of infinities and there is no cutoff parameter. It turned out cosmological constant replaces this parameter and coupling constant evolution is induced by that for cosmological constant from the condition that the twistor lift of the action is not affected by small enough modifications of the moduli of the induced twistor structure. The moduli space for them corresponds to rotation group $SO(3)$. This leads to explicit evolution equations for α_K, which can be studied numerically.

The approach is also related to the view about coupling constant evolution based on the inclusions of hyper-finite factors of type II_1, and it is proposed that Galois group replaces discrete subgroup of $SU(2)$ leaving invariant the algebras of observables of the factors appearing in the inclusion.

Some Questions about Coupling Constant Evolution

In this chapter questions related to the hierarchy of Planck constants and p-adic coupling constant evolution (CCE) in the TGD framework are considered.

1. Is p-adic length scale hypothesis (PLS) correct in this recent form and can one deduce this hypothesis or its generalization from the basic physics of TGD defined by Kähler function of the "world of classical worlds" (WCW)? The fact, that the scaling of the roots of polynomial does not affect the algebraic properties of the extension strongly suggests that p-adic prime does not depend on purely algebraic properties of EQ. In particular, the proposed identification of p as a ramified prime of EQ could be wrong.

   Number theoretical universality suggests the formula $exp(\Delta K) = p^n$, where ΔK is the contribution to Kähler function of WCW for a given space-time surface inside causal diamond (CD).

2. The understanding of p-adic length scale evolution is also a problem. The "dark" CCE would be $\alpha_K = g_K^2/2h_{eff} = g_K^2/2nh_0$, and the PLS evolution $g_K^2(k) = g_K^2(max)/k$ should define independent evolutions since scalings commute with number theory. The total evolution $\alpha_K = \alpha_K(max)/nk$ would induce also the evolution of other coupling strengths if the coupling strenghts are related to α_K by Möbius transformation as suggested.

3. The formula $h_{eff} = nh_0$ involves the minimal value h_0. How could one determine it? p-Adic mass calculations for $h_{eff} = h$ lead to the conclusion that the CP_2 scale R is roughly $10^{7.5}$ times longer than Planck length l_P. Classical argument however suggests $R \simeq l_P$. If one assumes $h_{eff} = h_0$ in the p-adic mass calculations, this is indeed the case for $h/h_0 = (R(CP_2)/l_P)^2$. This ratio follows from number theoretic arguments as $h/h_0 = n_0 = (7!)^2$. This gives $\alpha_K = n_0/kn$, and perturbation theory can converge even for $n = 1$ for sufficiently long p-adic length scales. Gauge coupling strengths are predicted to be practically zero at

gravitational flux tubes so that only gravitational interaction is effectively present. This conforms with the view about dark matter.

4. Nottale hypothesis predicts gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ ($\beta_0 = v_0/c$ is velocity parameter), which has gigantic values. Gravitational fine structure constant is given by $\alpha_{gr} = \beta_0/4\pi$. Kepler's law $\beta^2 = GM/r = r_S/2r$ suggests length scale evolution $\beta^2 = xr_S/2L_N = \beta_{0,max}^2/N^2$, where x is proportionality constant, which can be fixed.

   Phase transitions changing β_0 are possible at $L_N/a_{gr} = N^2$ and these scales correspond to radii for the gravitational analogs of the Bohr orbits of hydrogen. p-Adic length scale hierarchy is replaced by that for the radii of Bohr orbits. The simplest option is that β_0 obeys a CCE induced by α_K.

   This picture conforms with the existing applications and makes it possible to understand the value of β_0 for the solar system, and is consistent with the application to the superfluid fountain effect.

1.4.2 PART II: MANY-SHEETED ASTROPHYSICS

TGD and Astrophysics

Astrophysics in TGD Universe is the basic topics of this chapter. The topics discussed are following.

1. p-Adic length scale hypothesis can be applied also in astrophysical length scales, and some examples of possible applications are discussed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

2. A model for the solar magnetic field as a bundle of topological magnetic flux tubes is constructed and a model of Sunspot cycle is proposed. This model is also shown to explain the mysteriously high temperature of solar corona and also some other mysterious phenomena related to the solar atmosphere. A direct connection with the TGD based explanation of the dark energy as magnetic and Z^0 magnetic energy of the magnetic flux tubes containing dark matter as ordinary matter, emerges. The matter in the solar corona is simply dark matter leaked from the highly curved portions of the magnetic flux tubes to the space-time sheets where it becomes visible. The generation of anomalous Z^0 charge caused by the runoff of dark neutrinos in Super Nova could provide a first principle explanation for the avoidance of collapse to black-hole in Super Nova explosion.

   The recent view about fermions is based on the condition that spinor modes have well-define em charge predicts that induced spinor fields are in the generic case localized to 2-D surfaces at which the classical W field vanishes as does also Z^0 field above weak scale (proportional to effective Planck constant h_{eff}). Hence fermions would feel weak Z^0 field only if they are at space-time sheets with large h_{eff}.

3. One section is devoted to some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly and Flyby anomaly.

4. The astrophysics of solar system involves also an anomaly related to the precession of equinoxes suggesting that Sun might have a companion. TGD suggests a model for anomalies as being due to interaction magnetic flux tube connecting Sun to its companion.

5. The TGD variant of the model of Nottale involved gravitational Planck constant h_{gr} is discussed in detail. Also further indications for large values of Planck constant are discussed and also the argument that $h_{gr} = GMm/v_0 = h_{eff} = n \times h$ holds true at least microscopiall. If so, the dependence of the effective Planck constant on particle mass can be predicted.

Quantum Astrophysics

In this chapter the topics relates to what might be called quantum astrophysics. Motivation comes from the model for Nottale's findings suggesting Bohr quantization of planetary orbits. The model leads to the introduction of gravitational Planck constant $h_{gr} = GMm/v_0$, where v_0 corresponds to a typical rotational velocity in two particle system. h_{gr} characterizes the interaction of masses

M and m and assigned to the magnetic flux tube connecting them and carrying the massless extremals mediating gravitational interaction. If m is planetary mass, the value of h_{gr} is gigantic. Since gravitational acceleration and gravitational Compton length do not depend on particle mass, one can however assume only that microscopic objects have gravitational flux tube connections to the central mass M. In this case the values of h_{gr} could be even identical to the corresponding values of $h_{eff} = n \times h$ in living matter and $h_{eff} = h_{gr}$ identification makes sense.

The topics discuss in this chapter are following.

1. An updated view about hierarchy of Planck constants is discussed and the connection $h_{eff} = h_{gr}$ is shown to be consistent with TGD inspired quantum biology. Quantum gravity would be in key role in biology as intuited also by Penrose.
2. Vision about formation of structures and quantum chaos is astrophysical scales is discussed. Also a speculative view about gravitational radiation based on h_{gr} is considered.
3. A simple model for gravitational radiation assuming that the emission occurs as dark gravitons is considered. $h \to h_{gr}$ implies that the energy of graviton is scaled from that in standard model by h_{gr}/h factor. Realistic model might correspond to h_{gr} for microscopic particles. The basic prediction is that gravitons would be detected as bunches of ordinary gravitons.
4. TGD suggests that cosmological evolution involves a series of phase transitions changing the value of h_{gr} occurring via periods of quantum criticality. The critical cosmology is fixed apart from its duration. This suggests a piecewise accelerated expansion. Also inflationary period would be example of this phenomenon as also accelerating expansion much later.
5. Expanding Earth model has been proposed for long time ago to explain why the continents seem to fit nicely to form a complete covering of the Earth's surface. The model however makes sense if the radius of Earth is one half of its recent value. TGD based interpretation for the expansion is is in terms of a phase transition increasing h_{gr} by factor 2.
6. Blackholes in TGD is the topic of the last two sections.

Magnetic Bubbles in TGD Universe: Part I

I received a link to a video summarizing the properties of the Local Bubble surrounding the solar system. The Local Bubble represents only one example of magnetic bubbles. The magnetic bubble carries a magnetic field with field lines along its surface. Star formation and interstellar gas seems to concentrate on the bubble.

It is believed that the Local Bubble has been formed in a burst of star formation in the center of the bubble. These stars would have died as supernovae and the matter from supernova explosions would have pushed gas and compressed it to form the Local Bubble.

These bubbles bring in mind the large voids, whose boundaries carry galaxies. I have discussed this from the TGD point of view already earlier. One ends up with a question, whether galaxies are formed at the surfaces of large voids and stars at the surfaces of the magnetic bubbles. Could also the formation of planets be understood in this way? TGD predicts that cosmic expansion takes place as rapid "jerks" and this view has application to the mystery of Cambrian Explosion. Could these local Big-Bangs give rise to a universal mechanism for the formation of structures? If so, then Earth and Moon must have the same composition. The finding that this is indeed the case, came as a total surprise.

The fusion of dark protons at monopole flux tubes to dark proton sequences identified as dark nuclei, which then transform to ordinary nuclei and liberate nuclei binding energy and in this way induce explosion, is the basic step in the formation of astrophysical objects. Dark fusion was originally proposed as a model of "cold fusion" but later generalized to a model for the first step in the formation of stars not yet involving ordinary fusion. The recently found candidates for population III stars could correspond to these prestellar objects.

Galactic blackholes have been recently found to receive a new contribution to their mass from dark energy identifiable as the energy of cosmic strings in the TGD framework. The second discovery is that galaxies, which should be the oldest ones on the basis of their distance, are oldest ones on the basis of their age: zero energy ontology explains this.

A detailed model emerges for the formation of a planetary system as a series of solar explosions as analogs of supernova explosions throwing out a layer of dark matter transforming to ordinary matter, possibly forming a planet. Both the generalization of Nottale's model for planetary orbits involving gravitational Planck constant and a generalization of the Expanding Earth model are involved. The model explains the composition differences between giant planets and Earth-like planets and also the Kuiper belt as a failed planet and is also applied to giant exoplanets.

Magnetic Bubbles in TGD Universe: Part II

Solar flares involving mass eruptions accompany sunspots and the reversal of the magnetic polarity of the solar magnetic field. The models however have several problems. For instance, it is believed that reconnections of magnetic field lines are essential for the process but the prediction for the rate of the process is by 13-14 orders of magnitude too low. The TGD view of space-time provides a new view of electromagnetic fields based on the notion of a field body. Dark matter as phases of ordinary matter with a large value of effective Planck constant is the second new idea and zero energy ontology (ZEO) provides a third new ingredient.

The recent advances in the understanding of the formation of astrophysical structures in various scales in the TGD framework inspire the attempt to understand the structure of the solar magnetic field and its dynamics involving solar cycle, solar flares, reconnections and reversal of the solar magnetic field. By fractality, the general vision leads to a concrete model for the solar cycle and strongly suggests a concrete analogy of the solar cycle with the basic rhythms appearing in biological systems and the identification of the counterparts of anabolism and catabolism at the fundamental level.

The general picture also leads to a model for the reversals of the Earth's magnetic field and to interesting speculations concerning their connection with the evolutionary leaps. In zero energy ontology, the reversal involves the decay and re-organization of the magnetic body in zero energy ontology. The decay is analogous to the decay of the biological body after death and induces it. This interpretation provides an understanding of the so-called Tukdam phenomenon.

LIGO and TGD

The recent detection of gravitational radiation from a merger of blackholes by LIGO detector initiated a new era in astronomy. The detection allows to sharpen the TGD based view about gravitational radiation, in particular to test the proposal that gravitons propagate as dark gravitons with very large value of Planck constant along magnetic flux tubes. Since classical (no dependence of $heff$) detection of gravitational waves rather than direct detection of gravitons is in question, it is not too surprising that the TGD picture survives. Also a gamma ray burst was observed .4 seconds after the merger and is very probably associated with it. In TGD framework the natural proposal is that this burst arrived as dark cyclotron radiation along the dark flux tubes carrying also the dark gravitons. The energy conserving transformation of the ordinary cyclotron radiation created in the ultra-strong magnetic field of the blackhole to dark photons could have generated the gamma ray pulse. The hypothesis allows to estimate the strength of magnetic field at magnetic flux tubes. The value is consistent with the order of magnitude for intergalactic magnetic fields.

TGD View about Quasars

The work of Rudolph Schild and his colleagues Darryl Letier and Stanley Robertson (among others) suggests that quasars are not supermassive blackholes but something else - MECOs, magnetic eternally collapsing objects having no horizon and possessing magnetic moment. Schild et al argue that the same applies to galactic blackhole candidates and active galactic nuclei, perhaps even to ordinary blackholes as Abhas Mitra, the developer of the notion of MECO proposes.

In the sequel TGD inspired view about quasars relying on the general model for how galaxies are generated as the energy of thickened cosmic strings decays to ordinary matter is proposed. Quasars would not be be blackhole like objects but would serve as an analog of the decay of inflaton field producing the galactic matter. The energy of the string like object would replace galactic dark matter and automatically predict a flat velocity spectrum.

TGD is assumed to have standard model and GRT as QFT limit in long length scales. Could MECOs provide this limit? It seems that the answer is negative: MECOs represent still collapsing objects. The energy of inflaton field is replaced with the sum of the magnetic energy of cosmic string and positive volume energy, which both decrease as the thickness of flux tube increases. The liberated energy transforms to ordinary particles and their dark variants in TGD sense. Time reversal of blackhole would be more appropriate interpretation. One can of course ask, whether the blackhole candidates in galactic nuclei are time reversals of quasars in TGD sense.

The writing of the article led also to a considerable understanding of two key aspects of TGD. The understanding of twistor lift and p-adic evolution of cosmological constant improved considerably. Also the understanding of gravitational Planck constant and the notion of space-time as a covering space became much more detailed in turn allowing much more refined view about the anatomy of magnetic body.

Solar Metallicity Problem from TGD Perspective

For ten years ago it was thought that Sun is a well-understood system but more precise computations demonstrated a problem. The metallicities deduced from the spectroscopic data deviate strongly from those deduced from helio-seismology and solar neutrino data.

The abundances used are determined from meteorites and these estimates are more accurate and consistent with the values determined by Asplund et al using 3-D modelling of solar surface used also to extrapolate the metallicities in core.

1. The metallicity of Sun deduced from spectroscopy by Asplund et al would be 1.3 per cent whereas the older model and also helio-seismology give 1.8 per cent metallicity. Is the metallicity indeed 1.3 per cent using standard model to extrapolate the spectroscopic data at surface? Or is it 1.8 per cent deeper in the interior in which case the extrapolation used to deduce metallicity in the interior would not be realistic.

2. There are also other discrepancies. The height of convective zone at which radiative energy transfer is replaced with convection is given by $R_{CZ} = .724R$. The predicted He abundance at surface is $Y_{surf} = .231$. These values are in conflict with $R_{CZ} = .713R$ and $Y_{surf} = .248$ deduced from helio-seismological data. Also density and sound velocity profiles deviate from those deduced from the helio-seismology. Ironically, the earlier model approximating solar surface as 2-D structure is in excellent accordance with the helio-seismological data.

When one has a paradox one must challenge the basic assumptions. Do the metallicities outside Sun and inside solar core really mean same thing? Dark matter identified as $h_{eff} = nh_0$ phases has become key player in TGD inspired new physics being now a crucial element of TGD based view about living matter. Dark nuclear fusion is proposed to provide the new physics allowing to understand "cold fusion". In the following it will be found that dark matter in TGD associated with solar core could provide an elegant solution also to the solar metallicity problem.

In TGD classical physics is an exact part of quantum physics. The tunnelling phenomenon essential for nuclear physics based model of solar nuclear fusion would correspond in TGD to a state function reduction creating a phase consisting of dark nuclei which can fuse without tunnelling due to the reduction of the binding energy scale. State function reduction to ordinary phase leads to the final state of the reaction. In ZEO "big" (ordinary) state function reduction (BFSR) would reverse the arrow of time so that if tunnelling phenomenon is assignable to BFSR rather than "small" state function reduction (SFSR) as TGD counterpart of "weak" measurement, ZEO would make possible nuclear fusion.

The missing nuclear matter inside core would be dark variants of nuclei associated with dark flux tubes. This would explain the conflict between the metallicities deduced from spectroscopic and meteoritic data on one hand and those derived from helio-seismic data. The reason is that sound waves and photons in the core couple to both ordinary and dark matter so that helio-seismology gives metallicities as sums of ordinary and dark metallicities. Using the estimate for the thickness of the dark flux tube coming from the TGD based model of "cold fusion", one can estimate the length of dark flux tube inside solar core and it turns out to fill about 30 per cent of its volume.

One can relate the model also to the model for the formation of galaxies, stars, and planets as tangles assignable to cosmic strings thickened to flux tubes implying the decay of their Kähler magnetic energy to ordinary matter in analogy with the decay of inflaton field and nice quantitative estimates follow. Also a connection with twistor lift of TGD predicting hierarchy of cosmological constants emerges and the radius of solar core turns out to corresponds to the value of cosmological constant implied by the amount of missing matter identified as dark matter at flux tubes.

The view about the role of new nuclear physics predicted by TGD in the model of solar interior gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles. One ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges.

The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature. The second thermodynamics is assignable to gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low. The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense. This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In zero energy ontology (ZEO) quasars and galactic blackholes can be seen as time reversals of each other.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years. Also "too" fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

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Comparing Electric Universe hypothesis and TGD

Electric Universe scenario in its extreme form postulates that electromagnetic fields are enough to explain gravitation and even nuclear fusion. From TGD viewpoint this vision is unrealistic. Wes Johnson however gave links to two Youtube videos related to Electric Universe telling about extremely interesting physical findings providing applications for TGD if take seriously. The first video was about the anomalies related to the craters of the Moon and second describe the claimed findings of SAFIRE team having a nice interpretation in TGD framework using the notions of monopole flux tubes and dark matter as hierarchy of phases of ordinary matter with non-standard value of Planck constant implying that electromagnetism has deep implications in arbitrarily long scales. The question in TGD is therefore not about whether electromagnetism (of gauge interactions in general) or gravitation is enough to understand cosmology and astrophysics: both are needed and in the sense of TGD.

Cosmic string model for the formation of galaxies and stars

The view about the role of new nuclear physics predicted by TGD in the model of solar interior gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles. One ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges.

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The cosmological time anomalies such as stars older than the Universe can be understood. In ZEO the time evolution for the zero energy states associated with causal diamonds (CDs) by sequences of small state function reductions (weak measurements) gives rise to conscious entity, self. Self dies and re-incarnates with an opposite arrow of time in big (ordinary) state function reduction reversing the arrow of time. These reincarnations define kind of universal Karma's cycle. If the Karma's cycle leaves the sizes of CDs bounded and their position in M^4 unaffected, quantum dynamics reduces to a local dynamics inside CDs defining sub-cosmologies. In particular, the age distributions and properties of stars depend only weakly on the value of cosmic time - stars older than the Universe become possible in standard view about time.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years. Also "too" fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

Could solar system be modelled as a miniature version of spiral galaxy?

The fractality of the TGD Universe motivates a model for planetary systems as miniature version of the model of spiral galaxy. The first two key elements are many-sheeted space-time, the notion of magnetic flux tubes - both monopole flux tubes and gravitational flux tubes without monopole flux - and the identification of dark matter as phases of ordinary matter labelled by effective Planck constant $h_{eff} = n \times h_0$ ($h = 6h_0$ is a good guess). Also the TGD generalization of Nottale's model for planetary system as analog of Bohr atom is in key role. A further key aspect is the prediction of twistor lift of TGD that cosmological constant is length scale dependent and characterizes various systems.

I did not originally end up with this model from general considerations. The first input were the problems related to the collision and accretion models for the formation of planets - TGD could replace these with quantal model. The discovery of "too" heavy blackholes and neutron stars by LIGO suggesting that TGD view about the formation of also planets could provide understanding about the role of angular momentum.

There are also problems related to the understanding of the entire planetary system: the dramatic difference between terrestrial and giant planets is not really understood. The problematic aspects of the Bohr orbit model together with the poorly understood differences between terrestrial and giant planets lead to a proposal that phase transition increasing the $\hbar_{gr}$ by factor 5 and accompanying a transition reducing the length scale dependent cosmological constant Λ could have scaled up the orbital radii of former inner planets. The transition could have also scaled up the radii of the former inner planets so that they became giant planets.

TGD View of the Engine Powering Jets from Active Galactic Nuclei

The identification of the energy source (central engine) explaining the energy loss associated with the jets from active galactic nuclei (AGNs) is a long-standing problem of astrophysics. In the model of Blandford and Znajek (BZ model) for the central engine as a blackhole, the Penrose process would provide the energy. The energy would come basically from the blackhole mass.

Empirical support for the BZ model emerges from the study of the supermassive blackhole associated with a galaxy known as Messier 87 (M87). The finding is that the magnetic field associated with the jet structure is tightly wound helical structure and so strong that it would control the dynamics of the matter from falling to blackhole except by occasional leakages. Electron-positron pairs created in the annihilation of photons would accelerate in the force-free helical electromagnetic field having also an electric component.

The TGD based model involves several aspects of the new physics predicted by TDG. TGD leads to a model of galaxies and other astrophysical structures. Inflaton decay is replaced with the thickening of cosmic strings to flux tubes liberating as ordinary matter. Hierarchy of Planck constants $h_{eff} = nh_0$, in particular Nottale's hypothesis predicts quantum coherence in the exterior of in scales at least of order Schwartschild radius of the blackhole-like entity. Zero energy ontology (ZEO) predicts that the arrow of time changes in ordinary state function reductions. TGD replaces black-holes with blackhole-like entities (BHs) and white-holes with their time reversals (WHs) allowed in ZEO.

BH (WH) would be a volume filling flux tube but with a relatively small value of h_{eff}. In the case of WH, it would provide "metabolic energy" for jets and take care that the value of h_{eff} is preserved (the analogy with living systems is very strong). The jets would be analogous to laser beams/supracurrents with a huge value of $h_{eff} = h_{gr}$. The model would also explain the ultrahigh energy cosmic rays. The force-free fields would be generalized Beltrami fields associated with flux tubes and identifiable as minimal surfaces in the Minkowskian regions of space-time surface. The absence of classical dissipation would be a correlate for the absence of dissipation for supra-currents and dark photon laser beams.

Part I

MANY-SHEETED COSMOLOGY

Chapter 2

Cosmic Strings

2.1 Introduction

Cosmic strings belong to the basic extremals of the Kähler action. These cosmic strings have nothing to do with the cosmic strings of GUTS [E254] but their string tension $T \simeq .52 \times 10^{-6}/G$ happens to be in the same range as that for the GUT strings and this makes them very interesting cosmologically. Indeed, string like objects play a fundamental role in TGD inspired cosmology and also provide TGD based models for the galaxy formation, galactic dark matter, and for the generation of the large voids. Therefore the study of the properties of cosmic strings deserves a separate chapter.

The progress in the understanding of the physics of cosmic strings has been slow due to the difficult interpretational problems.

1. Zero energy ontology implies that the energy and all quantum numbers of the Universe vanishes and physical states are zero energy states decomposing into pairs of positive and negative energy states localizable to the light-like boundaries of causal diamonds defined as intersections of future and past directed light-cones. Positive energy ontology is a good approximation under certain assumptions.
2. Dark matter hierarchy whose levels are labelled by gigantic values of gravitational Planck constant associated with dark matter is second essential piece of the picture.
3. The second variation of Kähler action vanishes for preferred extremals - at least the second variations associated with dynamical symmetries. This guarantees that Noether currents assignable to the Kähler-Dirac action are conserved. The properties of the preferred extremals suggest a dimensional reduction providing formulations of quantum TGD in terms of possibly dual slicings of space-time surface by string word sheets and partonic 2-surfaces. The localization of the modes of the Kähler-Dirac equation to 2-D surfaces - string world sheets and possibly partonic 2-surfaces) suggests something similar although ot might be that both kind of objects are necessary for a full description.
4. It is now clear that GRT space-time as region of Minkowski space with metric differing from flat Minkowski metric slightly follows as an approximation of many-sheeted space-time of TGD and that Equivalence Principle reflects Poincare invariance. Cosmic strings represent something not possible in GRT context. The very early cosmology described in terms of gas of cosmic strings in $M^4_+ \times CP_2$ corresponds to this kind of situation and inflationary period would correspond to a transition to radiation dominated cosmology.

2.1.1 Various Strings

TGD predicts two basic types of strings.

1. The analogs of hadronic strings correspond to deformations of vacuum extremals carrying non-vanishing induced Kähler fields. p-Adic thermodynamics for super-symplectic quanta condensed on them with additivity of mass squared yields without further assumptions stringy

mass formula. These strings are associated with various fractally scaled up variants of hadron physics.

2. Cosmic strings correspond to homologically non-trivial geodesic sphere of CP_2 (more generally to complex sub-manifolds of CP_2) and have a huge string tension. These strings are expected to have deformations with smaller string tension which look like magnetic flux tubes with finite thickness in M^4 degrees of freedom. The signature of these strings would be the homological non-triviality of the CP_2 projection of the transverse section of the string.

2.1.2 Correlation Between Super-Novae And Cosmic Strings

During year 2003 two important findings related to cosmic strings were made.

1. A correlation between supernovae and gamma ray bursts was observed.

2. Evidence that some unknown particles of mass $m \simeq 2m_e$ and decaying to gamma rays and/or electron positron pairs annihilating immediately serve as signatures of dark matter. These findings challenge the identification of cosmic strings and/or their decay products as dark matter, and also the idea that gamma ray bursts correspond to cosmic fire crackers formed by the decaying ends of cosmic strings. This forces the updating of the more than decade old rough vision about topologically condensed cosmic strings and about gamma ray bursts described in this chapter (old version is left essentially untouched in order to demonstrate how important the experimental input is for the evolution of ideas).

According to the updated model, cosmic strings transform in topological condensation to magnetic flux tubes about which they represent a limiting case. Primordial magnetic flux tubes forming ferro-magnet like structures become seeds for gravitational condensation leading to the formation of stars and galaxies. The TGD based model for the asymptotic state of a rotating star as dynamo [K111] leads to the identification of the predicted magnetic flux tube at the rotation axis of the star as Z^0 magnetic flux tube of primordial origin (flux tube carries also em field but could carry only Z^0 charge). Besides Z^0 magnetic flux tube structure also magnetic flux tube structure exists at different space-time sheet but is in general not parallel to the Z^0 magnetic structure. This structure cannot have primordial origin (the magnetic field of star can even flip its polarity).

The flow of matter along Z^0 magnetic (rotation) axis generates synchrotron radiation, which escapes as a precisely targeted beam along magnetic axis and leaves the star. The identification is as the rotating light beam associated with ordinary neutron stars. During the core collapse leading to the supernova this beam becomes gamma ray burst. The mechanism is very much analogous to the squeezing of the tooth paste from the tube.

TGD based models of nuclei [K97] and condensed matter [K39] suggests that the nuclei of dense condensed matter develop anomalous color and weak charges coupling to dark weak bosons having Compton length L_w of order atomic size. Also lighter copies of weak bosons can be important in living matter. This weak charge is vacuum screened above L_w and by dark particles below it. Dark neutrinos are good candidates for screening dark particles. The Z^0 charge unbalance caused by the ejection of screening dark neutrinos hinders the gravitational collapse. The strong radial compression amplifies the tooth paste effect in this kind of situation so that there are hopes to understand the observed incredibly high polarization of 80 ± 20 per cent [E79].

TGD suggests the identification of particles of mass $m \simeq 2m_e$ accompanying dark matter as lepto-pions [K109] formed by color excited leptons, and topologically condensed at magnetic flux tubes having thickness of about lepto-pion Compton length. Lepto-pions would serve as signatures of dark matter whereas dark matter itself would correspond to the magnetic energy of topologically condensed cosmic strings transformed to magnetic flux tubes..

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L7].

2.2 General Vision About Topological Condensation Of Cosmic Strings

In this section the basic properties of free cosmic strings are discussed and a general vision about topological condensation of cosmic strings is proposed. In the later sections the vision is developed at a more quantitative level.

2.2.1 Free Cosmic Strings

The free cosmic strings correspond to four-surfaces of type $X^2 \times S^2$, where S^2 is the homologically nontrivial geodesic sphere of CP_2 [L1] , [L1] and X^2 is minimal surface in M^4_+. As a matter fact, any complex manifold $Y^2 \subset CP_2$ is possible. In this section, a co-moving cosmic string solution inside the light cone $M^4_+(m)$ associated with a given m point of M^4_+ will be constructed.

Recall that the line element of the light cone in co-moving coordinates inside the light cone is given by

$$ds^2 = da^2 - a^2(\frac{dr^2}{1+r^2} + r^2 d\Omega^2) \ . \tag{2.2.1}$$

Outside the light cone the line element is given

$$ds^2 = -da^2 - a^2(-\frac{dr^2}{1-r^2} + r^2 d\Omega^2) \ , \tag{2.2.2}$$

and is obtained from the line element inside the light cone by replacements $a \to ia$ and $r \to -ir$.

Simplest solutions

Using the coordinates $(a = \sqrt{(m^0)^2 - r_M^2}, ar = r_M)$ for X^2 the orbit of the cosmic string is given by

$$\begin{aligned} \theta &= \frac{\pi}{2} \ , \\ \phi &= f(r) \ . \end{aligned} \tag{2.2.3}$$

Inside the light cone the line element of the induced metric of X^2 is given by

$$ds^2 = da^2 - a^2(\frac{1}{1+r^2} + r^2 f_{,r}^2)dr^2 \ . \tag{2.2.4}$$

The equations stating the minimal surface property of X^2 can be expressed as a differential conservation law for energy or equivalently for the component of the angular momentum in the direction orthogonal to the plane of the string. The conservation of the energy current T^α gives

$$\begin{aligned} T^\alpha_{,\alpha} &= 0 \ , \\ T^\alpha &= T g^{\alpha\beta} m^0_{,\beta} \sqrt{g} \ , \\ T &= \frac{1}{8\alpha_K R^2} \simeq .52 \times 10^{-6} \frac{1}{G} \ . \end{aligned} \tag{2.2.5}$$

The numerical estimate $TG \simeq .8.9 \times 10^{-6}$ for the string tension is upper bound and corresponds to a situation in which the entire area of S^2 contributes to the tension. It has been obtained using $\alpha_K \simeq 1/137$ and $R^2/G = 2.5 \times 10^7 G$ given by the most recent version of p-adic mass calculations (the earlier estimate was roughly by a factor 1/2 too small due to error in the calculation [K46, L62]). The string tension belongs to the range $TG \in [10^{-6} - 10^{-7}]$ predicted for GUT strings [E254]. WMAP data give the upper bound $TG \in [10^{-6} - 10^{-7}]$, which does not however hold true in the recent case since criticality predicts adiabatic spectrum of perturbations as in the inflationary scenarios.

The non-vanishing components of energy current are given by

$$\begin{aligned} T^a &= TUa \ , \\ T^r &= -T\frac{r}{U} \ , \\ U &= \sqrt{1+r^2(1+r^2)f_{,r}^2} \ . \end{aligned} \tag{2.2.6}$$

The equations of motion give

$$U = \frac{r}{\sqrt{r^2-r_0^2}} \ , \tag{2.2.7}$$

or equivalently

$$\phi_{,r} = \frac{r_0}{r\sqrt{(r^2-r_0^2)(1+r^2)}} \ , \tag{2.2.8}$$

where r_0 is an integration constant to be determined later. Outside the light cone the solution has the form

$$\phi_{,r} = \frac{r_0}{\sqrt{r^2+r_0^2}r\sqrt{1-r^2}} \ . \tag{2.2.9}$$

In the region inside the light cone, where the conditions

$$r_0 \quad << \quad r << 1 \tag{2.2.10}$$

hold, the solution has the form

$$\begin{aligned} \phi(r) &\simeq \phi_0 + \frac{v}{r} \ , \\ v &= \frac{r_0}{\sqrt{1+r_0^2}} \ , \end{aligned} \tag{2.2.11}$$

corresponding to the linearized equations of motion

$$f_{,rr} + \frac{2f_{,r}}{r} = 0 \ , \tag{2.2.12}$$

obtained most nicely from the angular momentum conservation condition.

Planck2013 bounds for the string tension of string like objects of various kinds

Planc2013 (see `http://tinyurl.com/ydegc4ry`) gives bounds on the string tension of cosmic strings. The bounds depend on the type of string considered: sone can consider Nambu-Goto strings, cosmic strings of gauge theories, string like objects of field theories, etc.... The upper bounds for TG are in the range $10^{-6} - 10^{-7}$.

One cannot of course directly compare these bounds to cosmic strings in TGD sense (not gauge theory strings but primordial 4-D string like objects). In TGD framework the string tension characterizes the density of Kähler magnetic energy of 4-D string like object with 2-D string world sheet as Minkowski space projection.

Cosmic string tension is inversely proportional to the square of CP_2 length scale R and to Kähler coupling strength α_K for which the most recent estimate is as equal to fine structure constant: $\alpha_K \simeq 1/137$. The value of R is fixed by p-adic mass calculations from the conditions that electron mass comes out correctly. The velocity spectrum of distance stars in galaxy gives the same estimate if the gravitational field created by long cosmic string along which galaxies are located like pearls in string, gives an estimate consistent with this value. The estimate (see `http://tinyurl.com/y8wbeo4q`) of cosmic string tension is $TG = 6.9 \times 10^{-7}$ and is therefore in the interval $10^{-6} - 10^{-7}$, where the upper bounds for other string tensions reside.

A comparison with string theory is in order. For Nambu-Goto strings the estimated upper bound for string tension is $GT < 1.5 \times 10^{-7}$ - not a good news since the Nambu-Goto string tension should satisfy $GT = 1$ in the original approach. The same holds true also for superstrings (see `http://tinyurl.com/yb7alzb9`) in the original sense of the word. Therefore the situation is not very promising for superstrings. In fact, it turned out very difficult to find anything concrete about the string tension of superstrings. I however found from web a ten year old estimate estimate (see `http://tinyurl.com/ycs2awy2`) $TG = 1/3000$ for superstring tension involving experimental input. Presumably the Planck 2013 results would lower this estimate by few orders of magnitude.

Cosmic string is stationary in comoving coordinates

In co-moving coordinates (in general the co-moving coordinates of sub-light-cone M^4_+!) the string is stationary. In Minkowski coordinates string rotates with an angular velocity inversely proportional to the distance from the origin

$$\omega \simeq \frac{v}{r_M} \qquad (2.2.13)$$

so that the orbital velocity of the string becomes essentially constant in this region. For very large values of r the orbital velocity of the string vanishes as $1/r$. Outside the light cone the variable r is in the role of time and for a given value of the time variable r strings are straight and one can regard the string as a rigidly rotating straight string in this region.

Inside the light cone, the solution becomes ill defined for the values of r smaller than the critical value r_0. Although the derivative $\phi_{,r}$ becomes infinite at this limit, the limiting value of ϕ is finite so that strings winds through a finite angle. The normal component T^r of the energy momentum current vanishes at $r = r_0$ identically, which means that no energy flows out at the end of the string. The coordinate variable r becomes however bad at $r = r_0$ (string resembles a circle at r_0) and this conclusion must be checked using ϕ as coordinate instead of r. The result is that the normal component of the energy current indeed vanishes.

Field equations are not however satisfied at the end of the string since the normal component of the angular momentum current (in z- direction) is non-vanishing at the boundary and given by

$$J^r = Tr^2a \ . \qquad (2.2.14)$$

This means that the string loses angular momentum through its ends although the angular momentum density of the string is vanishing. The angular momentum lost at moment a is given by

$$J = \frac{Tr^2a^2}{2} = \frac{Tr_M^2}{2} \ . \qquad (2.2.15)$$

This angular momentum is of the same order of magnitude as the angular momentum of a typical galaxy [E263].

In M^4 coordinates singularity corresponds to a disk in the plane of string growing with a constant velocity, when the coordinate m^0 is positive

$$\begin{aligned} r_M &= vm^0 \ , \\ v &= \frac{r_0}{\sqrt{1+r_0^2}} \ . \end{aligned} \qquad (2.2.16)$$

From the expression of the energy density of the string

$$\begin{aligned} T^a &= T\frac{ar}{\sqrt{r^2-r_0^2}} \ , \\ T &= \frac{1}{8\alpha_K R^2} \ , \end{aligned} \tag{2.2.17}$$

it is clear that energy density diverges at the singularity.

Energy of the cosmic string

As already noticed, the string tension is by a factor of order 10^{-6} smaller than the critical string tension $T_{cr} = 1/4G$ implying angle deficit of 2π in GRT so that there seems to be no conflict with General Relativity (unlike in the original scenario, in which the CP_2 radius was of order Planck length).

The energy of the string portion ranging from r_0 to r_1 is given by

$$E = T\sqrt{(r_1^2-r_0^2)a} = T\sqrt{\delta r_M^2} \ . \tag{2.2.18}$$

It should be noticed that M^4 time development of the string can be regarded as a scaling: each point of the string moves to radial direction with a constant velocity v.

One can calculate the total change of the angle ϕ from the integral

$$\Delta\phi = \sqrt{\frac{r_0^2}{1+r_0^2}}\int_{r_0}^{\infty} dr\frac{1}{r\sqrt{(r^2-r_0^2)(1+r^2)}} \ . \tag{2.2.19}$$

The upper bound of this quantity is obtained at the limit $r_0 \to 0$ and equals to $\Delta\phi = \pi/2$.

2.2.2 TGD Based Model For Cosmic Strings

The model for cosmic strings has forced to question all cherished assumptions including positive energy ontology, Equivalence Principle, and positivity of gravitational mass. The final outcome turned out to be rather conservative. Zero energy ontology is unavoidable, Equivalence Principle holds true universally but its general relativistic formulation makes sense only in long length scales, and gravitational mass has definite sign for positive/negative energy states. As a matter fact, all problems were created by the failure to realize that the expression of gravitational energy in terms of Einstein's tensor does not hold true in short length scales and must be replaced with the stringy expression resulting naturally by dimensional reduction of quantum TGD to string model like theory [K116, K46, L62]. Later much better understanding of the relationship between TGD and GRT and Equivalence Principle has emerged [K111].

Zero energy ontology and cosmic strings

There are two kinds of cosmic strings: free and topological condensed ones and both are important in TGD inspired cosmology.

1. Free cosmic strings are not absolute minima of the Kähler action (the action has wrong sign). In the original identification of preferred extremals as absolute minima of Kähler action proposed in positive energy ontology this was a problem. In zero energy ontology (ZEO) the preferred extremal property becomes obsolete for deterministic action principle since 3-surfaces correspond to pairs of 3-surfaces at opposite light-like boundaries of causal diamond (CD). This could be the case even in non-deterministic situation applying to Kähler action. The idea about Bohr orbit property as space-time correlate for the correlation of quantum states at opposite boundaries of CD suggests that the members of the pairs of 3-surfaces are not independent but there is a correlation between them expressible as preferred extremal property.

In the new formulation preferred extremals would correspond to quantum criticality identified as the vanishing of the second variation of Kähler action at least for the deformations defining (gauge) symmetries of Kähler action [K116, K46]. Criticality guarantees the conservation of the Noether charges assignable to the Kähler-Dirac action but does not guarantee their non-vanishing. Ideal cosmic strings are excluded because they fail to satisfy the conditions characterizing the preferred extremal as a space-time surface containing regions with both Euclidian and Minkowskian signature of the induced metric with light-like 3-surface separating them identified as orbits of partonic 2-surfaces carrying elementary particle quantum numbers. The topological condensation of CP_2 type vacuum extremals representing fermons generates negative contribution to the action and reduces the string tension and leaves cosmic strings still free.

2. If the topologically condensate of fermions has net Kähler charges as the model for matter antimatter asymmetry suggests, the repulsive interaction of the particles tends to thicken the cosmic string by increasing the thickness of its infinitely thin M^4 projection so that Kähler magnetic flux tubes result. These flux tubes are ideal candidates for the carriers of dark matter with a large value of Planck constant. The criterion for the phase transition increasing $\hbar$ is indeed the presence of a sufficiently dense plasma implying that perturbation theory in terms of $Z^2\alpha_{em}$ (Z is the effective number of charges with interacting with each other without screening effects) fails for the standard value of Planck constant. The phase transition $\hbar_0 \rightarrow \hbar$ reduces the value of $\alpha_{em} = e^2/4\pi\hbar$ so that perturbation theory works. This phase transition scales up also the transversal size of the cosmic string. Similar criterion works also for other charges. The resulting phase is anyonic if the resulting 2-surfaces containing almost spherical portions connected by flux tubes to each other encloses the tip of the causal diamond (CD). The proposal is that dark matter resides on complex anyonic 2-surfaces surrounding the tips of CDs.

3. The topological condensation of cosmic strings generates wormhole contacts represented as pieces of CP_2 type vacuum extremals identified as bosons composed of fermion-anti-fermion pairs. Also this generates negative action and can make cosmic string a preferred extremal of Kähler action. The earliest picture was based on dynamical cancelation mechanism involving generation of strong Kähler electric fields in the condensation whose action compensated for Kähler magnetic action. Also this mechanism might be at work. Cosmic strings could also form bound states by the formation graviton like flux tubes connecting them and having wormhole contacts at their ends so that again action is reduced.

4. One can argue that in long enough length and time scales Kähler action per volume must vanish so that the idealization of cosmology as a vacuum extremal becomes possible and there must be some mechanism compensating the positive action of the free cosmic strings. The general mechanism could be topological condensation of fermions and creation of bosons by topological condensation of cosmic strings to space-time sheets.

In this framework zero energy states correspond to cosmologies leading from big bang to big crunch separated by some time interval T of geometric time. Quantum jumps can gradually increase the value T and TGD inspired theory of consciousness suggests that the increase of T might relate to the shift for the contents of conscious experience towards geometric future. In particular, what is usually regarded as cosmology could have started from zero energy state with a small value of T.

Topological condensation of cosmic strings

In the original vision about topological condensation of cosmic strings I assumed that large voids represented by space-time sheets contain "big" cosmic string in their interior and galactic strings near their boundaries. The recent much simpler view is that there are just galactic strings which carry net fermion numbers (matter antimatter asymmetry). If they have also net em charge they have a repulsive interaction and tend to end up to the boundaries of the large void. Since this slows down the expansive motion of strings, the repulsive interaction energy increases and a phase transition increasing Planck constant and scaling up the size of the void occurs after which cosmic strings are again driven towards the boundary of the resulting larger void.

One cannot assume that the exterior metric of the galactic strings is the one predicted by assuming General Relativity in the exterior region. This would mean that metric decomposes as $g = g_2(X^2) + g_2(Y^2)$. $g(X^2)$ would be flat as also $g_2(Y^2)$ expect at the position of string. The resulting angle defect due to the replacement of plane Y^2 with cone would be large and give rise to lense effect of same magnitude as in the case of GUT cosmic strings. Lense effect has not been observed.

This suggests that General Relativity fails in the length scale of large void as far as the description of topologically condensed cosmic strings is considered. The constant velocity spectrum for distant stars of galaxies and the fact that galaxies are organized along strings suggests that these string generate in a good approximation Newtonian potential. This potential predicts constant velocity spectrum with a correct value velocity.

In the stationary situation one expects that the exterior metric of galactic string corresponds to a small deformation of vacuum extremal of Kähler action which is also extremal of the curvature scalar in the induced metric. This allows a solution ansatz which conforms with Newtonian intuitions and for which metric decomposes as $g = g_1 + g_3$, where g_1 corresponds to axis in the direction of string and g_3 remaining $1 + 2$ directions.

Dark energy is replaced with dark matter in TGD framework

The observed accelerating expansion of the Universe has forced to introduce the notion of cosmological constant in the GRT based cosmology. In TGD framework the situation is different.

1. The gigantic value of gravitational Planck constant implies that dark matter makes TGD Universe a macroscopic quantum system even in cosmological length scales. Astrophysical systems become stationary quantum systems which participate in cosmic expansion only via quantum phase transitions increasing the value of gravitational Planck constant.
2. Critical cosmologies, which are determined apart from a single parameter in TGD Universe, are natural during all quantum phase transitions, in particular the phase transition periods increasing the size of large voids and having interpretation in terms of an increase of gravitational Planck constant. Cosmic expansion is predicted to be accelerating during these periods. The mere criticality requires that besides ordinary matter there is a contribution $\Omega_\Lambda \simeq .74$ to the mass density besides visible matter and dark matter. In fact, also for the over-critical cosmologies expansion is accelerating.
3. In GRT framework the essential characteristic of dark energy is its negative pressure. In TGD framework critical and over-critical cosmologies have automatically effective negative pressure. This is essentially due to the constraint that Lorentz invariant vacuum extremal of Kähler action is in question. The mysterious negative pressure would be thus a signal about the representability of space-time as 4-surface in H and there is no need for any microscopic description in terms of exotic thermodynamics.

The interpretation of accelerated expansion and the values for the TGD counterpart of the cosmological constant

Dark energy characterized by cosmological constant provides a satisfactory description of the accelerated expansion in GRT framework and should have TGD counterpart.

1. If the accelerated expansion is due to the phase transitions changing the value of Planck constant, one can introduce a parameter characterizing the contribution of the dark mass to the mass density during critical periods and call it cosmological constant recalling however that the contribution does not correspond to dark energy in the standard sense. The negative pressure of the almost unique critical cosmology would be a space-time correlate for the phase transition increasing the Planck constant.
2. There is also an alternative interpretation. According to the earlier proposal, string like objects resulting as descendants of primordial cosmic string are carriers of the dark energy. If the string like objects correspond to space-time sheets mediating gravitational interaction and have a gigantic gravitational Planck constant $\hbar_{gr} = GMm/v_0$, with $v_0/c \leq 1$ holds true as proposed in [K93] ($v_0 = 2^{-11}$ for the 4 inner planets), one can indeed understand why dark

energy density is a constant in such an excellent approximation (Compton lengths of particles would be gigantic: Planck mass would correspond to Compton length of order Schwartschild radius for $\hbar_{gr} \sim GM^2/c$). The negative pressure assigned to dark energy would reflect the negative string tension of string like objects.

3. These two views a conform if the negative pressure of the critical cosmology is due to the presence of string like objects. Cosmological constant would be the natural parameter in GRT based description and replaced in TGD framework by the parameter characterizing the duration of the critical cosmology. In the purely classical description based on cosmological constant the accelerated expansion taking place as short jerks would be replaced by a continual accelerated expansion.

What is new that p-adic fractality predicts that Λ scales as $1/L^2(k)$ as a function of the p-adic scale characterizing the space-time sheet implying a series of phase transitions reducing Λ. The order of magnitude for the recent value of the cosmological constant comes out correctly. The gravitational energy density assignable to the cosmological constant is identifiable as that associated with topologically condensed cosmic strings and magnetic flux tubes to which they are gradually transformed during the cosmological evolution.

The naïve expectation would be the density of cosmic strings behaves as $1/a^2$ as function of M^4_+ proper time. The vision about dark matter as a phase characterized by gigantic Planck constant however implies that large voids do not expand in continuous manner during cosmic evolution but in discrete quantum jumps increasing the value of the gravitational Planck constant and thus increasing the size of the large void as a quantum state. Since the set of preferred values of Planck constant is closed under multiplication by powers of 2, p-adic length scales L_p, $p \simeq 2^k$ form a preferred set of sizes scales for the large voids.

Zero energy ontology provides a further view about the situation.

1. In zero energy ontology causal diamonds (CDs) defined as intersections of the future and past directed light-cones are the fundamental building blocks of the world of classical worlds (WCW) identified as a union of sub- WCW s assignable to CDs [K94]. Note that CDs contains CDs within CDs so that fractality results.

2. A particular CD is characterized by its position in M^4, by the value a of the Lorentz invariant distance a between its upper and lower tips, and by the Lorentz boost applied to get the CD from a standard representative. The moduli space for the CD is therefore the union of spaces $M^4 \times L(a)$ where $L(a)$ is Lobatchevski space, and a corresponds to an allowed value of a.

3. The hypothesis that $L(a)$ corresponds to the 3-space of Robertson-Walker cosmology in quantum cosmology with a having interpretation as cosmic time, is highly attractive. p-Adic length scale hypothesis follows if the values of a come as octaves of the CP_2 time scale. In this framework, the classical cosmology associated with CD representing accelerated expansion would serve as a smoothed out space-time correlate for the discrete quantum jump scaling the size of CD by 2.

A further work is required to find whether these different views about accelerated expansion are mutually consistent.

TGD cosmic strings are consistent with the fluctuations of CMB

GUT cosmic strings were excluded by the fluctuation spectrum of the CMB background [E6]. In GRT framework these fluctuations can be classified to adiabatic density perturbations and isocurvature density perturbations. Adiabatic density perturbations correspond to overall scaling of various densities and do not affect the vanishing curvature scalar. For isocurvature density fluctuations the net energy density remains invariant. GUT cosmic strings predict isocurvature density perturbations while inflationary scenario predicts adiabatic density fluctuations.

In TGD framework inflation is replaced with quantum criticality of the phase transition period leading from the cosmic string dominated phase to matter dominated phase. Since curvature scalar vanishes during this period, the density perturbations are indeed adiabatic.

2.3 More Detailed View About Topological Condensation Of Cosmic Strings

The purpose of this section is to represent in more detail the calculations behind the vision discussed in the previous section. As already noticed, free cosmic strings as such cannot correspond to the absolute minima of the action since their action is large and positive.

2.3.1 Topological Condensation Of A Positive Energy Cosmic String

It is however useful to build a model of exterior space-time of topologically condensed cosmic string as a solution of Einstein's equations. For a straight string this solution is flat except at the position of the string. What happens is that the 2-dimensional plane orthogonal to the string becomes a conical surface. The angular defect is given by

$$\Delta\phi = \frac{T}{T_{max}} \times 2\pi \ , \ T_{max} = \frac{1}{4G} \ . \tag{2.3.1}$$

Here the string tension T refers to the gravitational mass density of the string and this is not necessarily identical with the inertial mass density. Obviously $T_{max} = 1/4G$ represents an upper bound for the gravitational mass density of the string.

The metric can be written as

$$\begin{aligned} ds^2 &= dt^2 - dz^2 - \frac{d\rho^2}{k_1^2} - \rho^2 d\phi^2 \ , \\ k_1^2 &= 1 - 4GT \ . \end{aligned} \tag{2.3.2}$$

The embeddings of this metric as an induced metric are easy to find. The simplest embedding is obtained by considering a map $M^4 \to S^1$, where S^1 is a geodesic circle of CP_2. Denoting by Φ the angle coordinate of S^1, one has

$$\begin{aligned} \Phi &= k\rho \ , \\ 1 + R^2k^2 &= \frac{1}{k_1^2} \ . \end{aligned} \tag{2.3.3}$$

The geodesic lines associated with this metric are easy to find in Cartesian coordinates. In M^4 coordinates the geodesics are slightly curved, which is nothing but the lense effect [E59]. To see what happens consider geodesic lines in the plane; cut from the plane a sector corresponding to the deficit angle and bend it to form a cone; after this operation project the geodesic lines on the cone to the plane again to see how the geodesics look like in M^4 coordinates. The observation of this bending is possible if the coordinates used by the observers are actually M^4 coordinates rather than space-time coordinates.

The predicted lense effect would serve as a signature for the presence of strings with this kind of exterior metric and the experimental absence of this effect suggests that this metric is not a proper choice for the exterior metric but should be replaced with a metric inspired by Newtonian intuition.

2.3.2 Exterior Metrics Of Cosmic String As Extremal Of Curvature Scalar

Einstein action with induced metric in general gives also solutions for exterior metric which are not gravitational vacua. One might hope these solutions in the first approximation correspond to Newtonian expectations and give rise only to a small lense effect. One must of course keep in mind that Einstein's equations and their TGD variant hold true only in long length scales and their application in the scale of cosmic string might not be justified. Second point is that it is the inertial energy density of cosmic strings rather than the energy density associated with curvature scalar, which serves as the source term in TGD variant of the Einstein's equations.

The ansatz

A rather general ansatz implying radial induced gauge fields in the background space is given by the following expression in cylindrical coordinates for M^4_+

$$\begin{aligned} m^0 &= \Lambda t \ , \\ cos(\Theta) &= u(\rho) \ , \\ \Phi &= \omega t + k(\rho) + n\phi \ . \end{aligned} \tag{2.3.4}$$

The reason why this ansatz works is that the components of metric and thus also of curvature tensor depend only on ρ so that field equations reduce to two differential equations. One can get rid of the $g_{t\rho}$ component of the induced metric by assuming $m^0 = \Lambda t + h(\rho)$ as in case of Schwartschild metric.

The interesting components of the induced metric in the cylindrical coordinates are given by the expression

$$\begin{aligned} g_{tt} &= \Lambda^2 - \omega^2 A \ , \\ g_{\rho\rho} &= -1 - A\left[\partial_\rho k)^2 + (\partial_\rho u)^2 \frac{1}{(1-u^2)^2}\right] \ , \\ g_{\rho t} &= -\omega \partial_\rho k A \ , \\ g_{t\phi} &= -\omega n A \ , \\ g_{\rho\phi} &= -\partial_\rho k A \ , \\ A &= R^2\omega^2(1-u^2) \ , \\ \Lambda^2 - \omega^2 A(\infty) &= 1 \ . \end{aligned} \tag{2.3.5}$$

Note that the induced gauge fields are Abelian. Em and Z^0 fields are proportional to each other and classical color field is proportional to induced Kähler form and vanishes for vacuum extremals. This can be seen as a signature of color confinement.

Field equations as conservation laws

The conservation law for color charge corresponding to $\Phi \rightarrow \Phi + \epsilon$ gives the first differential equation:

$$\partial_\rho \left[(G^{\rho\rho}\partial_\rho k + \frac{G^{\rho\phi} n}{\rho} + G^{\rho t}\omega) sin^2(\Theta)\sqrt{g} \right] = 0 \ . \tag{2.3.6}$$

For $m^0 + \Lambda t + h(\rho)$ energy conservation one gets rid of the $G^{\rho t}$ term. This equation can be integrated to give

$$(G^{\rho\rho}\partial_\rho k + \frac{G^{\rho\phi} n}{\rho}) sin^2(\Theta)\sqrt{g} = C \ . \tag{2.3.7}$$

and states that the conserved radial flow of $U(1)$ color charge is non-vanishing. This current must flow along the string. Note that for $k = constant$ gives $C = 0$.

The second equation can be chosen to correspond to the momentum conservation in say x-direction and would give

$$\partial_\rho \left[(G^{\rho\rho} + \frac{G^{\phi\rho}}{\rho})\sqrt{g} \right] - G^{\phi\phi}\rho\sqrt{g} = 0 \ . \tag{2.3.8}$$

The resulting field equations are extremely non-linear ordinary differential equations for $\Theta(\rho)$ and $\Phi(\rho) = k(\rho)$ having a character of a hydrodynamical conservation law. For $n = 0$ one obtains effectively Einstein equations with purely geometric source terms.

$$\begin{aligned} G^{\rho\rho} &= \frac{C}{sin^2(\Theta)\partial_\rho k\sqrt{g}} \ , \\ G^{\phi\phi} &= \partial_\rho \left[\frac{C}{sin^2(\Theta)\partial_\rho k}\right] \frac{1}{\rho\sqrt{g}} \ . \end{aligned} \quad (2.3.9)$$

Linearization

The linearized expression of the Einstein tensor with respect to the deviation $h_{\alpha\beta}$ of the induced metric from flat metric should give a good approximation to the field equations and allow to decide whether the Newtonian picture holds true. The linearized Ricci tensor is given by

$$\begin{aligned} 2R_{\alpha\beta} &= D_\gamma D_\beta h^\gamma{}_\alpha + D_\gamma D_\alpha h^\gamma{}_\beta - D_\alpha D_\beta h - D_\gamma D^\gamma h_{\alpha\beta} \ , \\ R &= D_\alpha D_\beta h^{\alpha\beta} - D_\alpha D^\alpha h \ . \end{aligned} \quad (2.3.10)$$

The covariant derivatives are with respect to the flat M^4 metric.

Are field equations consistent with the Newtonian limit?

One can hope that the field equations are consistent with the Newtonian limit which implies $R_{tt} = g_{tt}R/2$ outside z-axis in the linear approximation. If this is true, the gravitational energy density of the exterior metric would remain vanishing in the linear approximation for the metric so that a minimal modification of the vacuum Einstein equations would be in question. That Newtonian limit makes sense could be due to the fact that Einstein tensor represents the action of a non-linear wave operator on metric. Hence metric should be expressible in terms of its sources and topologically condensed cosmic string defines such a source very naturally.

Newtonian limit corresponds to the approximation

$$g_{tt} - 1 = 2\Phi_{gr} \ , \quad \nabla^2\Phi_{gr} = -4\pi\rho_{gr} \ . \quad (2.3.11)$$

For string tension $T = dM/dl$, which corresponds to the density of inertial mass, one has $\Phi_{gr} = 2TGlog(\rho/\rho_0)$ as the 2-dimensional variant of Gauss law shows. This corresponds to the simplified ansatz

$$\begin{aligned} u &= u(\rho) \ , \ \Phi = \omega t + k(\rho) \ , \\ A - A(\infty) &= 2\Phi_{gr} = 4GT \times log(\frac{\rho}{\rho_0}) \ . \end{aligned} \quad (2.3.12)$$

This gives

$$\begin{aligned} u^2 &= u^2(\infty) - K \times log(\frac{\rho}{\rho_0}) \ , \\ K &= \frac{16GT}{R^2\omega^2} \ . \end{aligned} \quad (2.3.13)$$

The embedding ceases to exist at certain critical radii corresponding to

$$\begin{aligned} \frac{\rho_{max}}{\rho_0} &= exp(\frac{u^2(\infty)}{K}) \ , \\ \frac{\rho_{min}}{\rho_0} &= exp(\frac{u^2(\infty) - 1}{K}) \ , \\ \frac{\rho_{max}}{\rho_{min}} &= exp(\frac{1}{K}) \ , K = \frac{4GT}{R^2\omega^2} \ . \end{aligned} \quad (2.3.14)$$

This ansatz with suitably chosen $k_0(\rho)$ could be taken as the lowest order approximation to the solution and one can expand the solution as $X \equiv u^2 = X_0 + \epsilon X_1 + ...$ $k = k_0(\rho) + \epsilon_1 k_1 + ...$ and solve u_n and k_n by linearizing the field equations around $X = X_0 + ...\epsilon^n X_n$ and $k = k_0 + ...\epsilon^n k_n$ solving (X_{n+1}, k_{n+1}) from the linearized differential equations. One could also proceed by substituting to the right hand side n: th order approximation and linearized Einstein tensor to the left hand side using $n+1$: nt order approximation. Note that the ansatz makes sense also for negative gravitational energy.

The angle defect (or surplus) is given by

$$\Delta\Phi(\rho) = \frac{\sqrt{\rho^2 + R^2u^2n^2}}{\int_0^\rho \sqrt{g_{\rho\rho}}d\rho} \times 2\pi \ . \tag{2.3.15}$$

For small values of n the effect is expected to be small.

2.3.3 Geodesic Motion In The Exterior Metric Of Cosmic String

Writing the geodesic equations explicitly one finds that the conservation of energy and angular momentum give the conditions

$$\begin{aligned} \frac{dt}{ds} &= E \ , \\ \rho^2 k^2 \frac{d\phi}{ds} &= L \ . \end{aligned} \tag{2.3.16}$$

In the radial direction one obtains the equation of motion

$$\frac{d^2u}{ds^2} = \frac{u}{1-u^2} \times (\frac{du}{ds})^2 + \frac{L^2}{\rho_0^2}\frac{1-u^2}{u^3} \ . \tag{2.3.17}$$

The cosmic string induces besides ordinary centrifugal acceleration a radial repulsive acceleration

$$g = \frac{u}{1-u^2} \times (\frac{du}{ds})^2 \ . \tag{2.3.18}$$

The geodesic lines lead to the boundary of the cylindrical region. A possible interpretation is that this acceleration drives galactic cosmic strings with reduced string tension to the boundary of the large void.

The exterior solution does not represent co-moving matter which conforms with the idea that gravitational space-time sheets correspond to gigantic values of Planck constants implying that even astrophysical objects correspond to stationary quantum states following cosmic expansion only in average sense by quantum jumps leading to a reduction of Planck constant and rapid expansion of the space-time sheet. Classical picture would suggests that these jumps occur when the matter has ended up sufficiently near to the boundary of the large void.

Note that if one completes the space-time sheet by gluing "above" it second cosmic string with positive time orientation and positive gravitational mass the geodesic lines could turn around at the boundary so that the accelerated expansion of the matter would transform to compression.

It is easy to see that simple embeddings of almost everywhere flat metric do not exist so that the density of gravitational energy in the exterior region is unavoidable. The condition $g_{\rho\rho} = 1$ could be satisfied by assuming $m^0 = t + h(\rho)$ and choosing h properly. This generates however also $g_{t\rho}$ component to the induced metric and to compensate it one should have $\Phi = n\phi + \omega t + k(\rho)$ with k chosen properly. This however generates $g_{t\phi} \neq 0$ which cannot be canceled and would mean that the solution is rotating.

One obtains also vacuum extremals representing solutions for which gauge charges and angular momentum are non-vanishing by a very simple deformation $\Phi \rightarrow \Phi + \omega t$ of the proposed ansatz. Interestingly, non-vanishing gauge charges are necessarily accompanied by angular momentum and vice versa.

2.3.4 Matter Distribution Around Cosmic String

The distribution of stars in the vicinity of cosmic string can be modeled using kinetic model for the evolution of the distribution of stars. Assuming that stars have some average mass M and that the situation is non-relativistic the kinetic equation for the distribution of stars reads

$$\frac{dn}{dt} = \nabla \cdot (D\nabla n + \bar{w}n) \ . \tag{2.3.19}$$

The second term is the divergence of the current consisting of diffusion term and drift term caused by the Kähler force.

The drift velocity $\bar{w}$ is related to the Kähler force F_K

$$\bar{w} = b\bar{F}_K \ , \tag{2.3.20}$$

where b is the mobility of the star. Assuming that one can associate a well defined temperature parameter to the star distribution the mobility is related to the diffusion constant D by the Einstein relation $D = bT$. Kähler force is expressible in terms of Kähler gauge potential

$$\bar{F}_K = \nabla Q\Phi \ . \tag{2.3.21}$$

Here $\Phi = kT_sG\omega ln(\rho/\rho_0)$ is the gauge potential of the Kähler electric field. T_s denotes the string tension:

$$T_s \simeq .52 \ \times 10^{-6} \times \frac{\epsilon}{G} \ .$$

The lower bound for ϵ is about 10^{-7} from the previous considerations. Q is the average Kähler charge of the star: $Q \simeq \epsilon M\sqrt{G}$,

An order of magnitude estimate for diffusion constant is given by $D \simeq \langle v\rangle/n\sigma$, where $\langle v\rangle = \sqrt{(T/M)}$ is the average thermal velocity of star and σ is the collision cross section for collisions with other stars.

The equilibrium distribution corresponds to the cancelation of diffusion and drift currents

$$\frac{dn}{dr} \simeq -\frac{M\sqrt{G}\omega}{T}\partial_r\Phi n \ . \tag{2.3.22}$$

In isothermal case one obtains for the distribution of stars the following expression

$$\begin{aligned} n(\rho) &= n_0exp(-\frac{M\sqrt{G}\Phi_K\omega}{T}) = n_0(\frac{r}{r_0})^{\alpha} \ , \\ \alpha &= \frac{M\sqrt{G}T_sG\omega}{T} \ , \end{aligned} \tag{2.3.23}$$

so that a power law behavior results. Unfortunately, concerning the value of the temperature parameter there is nothing interesting to say.

The second alternative is based on the adiabaticity assumption

$$\frac{T}{T_0} = (\frac{n}{n_0})^{1-\gamma} \ , \tag{2.3.24}$$

where γ denotes adiabatic constant. In this case one obtains

$$\begin{aligned} n(r) &= n_0(Aln(\frac{r}{r_0}))^{\frac{1}{(1-\gamma)}} \ , \\ A &= (1-\gamma)M\sqrt{G}T_s\frac{G}{T_0} \ . \end{aligned} \tag{2.3.25}$$

for the distribution of stars.

2.3.5 Quantization Of The Cosmic Recession Velocity

The statistical analysis of the observational data about red shift of quasars [E176] shows that the distribution of emission line red shifts of quasars have a periodicity, which can be explained most nicely by assuming that the recession velocity v calculated from red shift is quantized so that one has, using the standard relation between the recession velocity and distance of the emitting object,

$$v = H_0(r_0 + nR) \ . \tag{2.3.26}$$

Here H_0 denotes the present value of Hubble constant. The order of magnitude for the parameter R is $R \simeq 10^8$ ly.

There is also a problem of the association between galaxies and quasars. There are indications that galaxies and quasars form correlated pairs but that the red shift of the quasar is much larger than the red shift of the galaxy [E74]. In case that the two systems are actually different physical systems, this implies that the red shift of the quasar member is of non-cosmological origin.

Various explanations for these effects have been proposed. For example, the idea that Universe is multiply connected has been put forward [E176]. According to this explanation the emission lines with different red shifts correspond to images of single object: the light emitted from the object can travel several times "around the world" before being detected and the distance to the observe is thus quantized: $r = r_0 + nL$, where L is the size of the non-simply connected Universe. Observations require that L is of the order of $L \simeq 10^8 - 10^9$ ly.

The TGD based explanation for the phenomenon is similar in spirit to this explanation (see **Fig. 2.1**). The original model for the phenomenon turned out to be inconsistent with the revised view about cosmic strings. The model however allows an obvious modification.

Original model for the quantization of red shifts

The original model was based on the idea is that null geodesic lines around the topologically condensed "big" strings ("big" meant that the parameter $K = \omega^2 R^2$ is not too far from unity) do not leave the 3-space surrounding "big" string in the center of large void of radius of order 10^8 ly and carrying strong Kähler electric field canceling its magnetic action: for the simplest geodesic the projection to the plane orthogonal to the string is just circle. Galaxies tend to be situated near the boundaries of the 3-space surrounding big string and the light emitted from quasar can travel several times around the string before being detected (see **Fig. 2.1**).

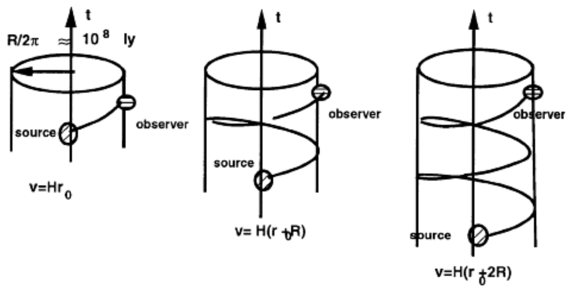

Figure 2.1: Quantization of the cosmic recession velocity.

A simplified situation is obtained, when the distance R of the emitting quasar and observer from the string is same ($R \simeq 10^8$ ly) and when the distance along string direction is L. In this case the projection of the light like geodesic on plane is circle and the motion in z-direction is along straight line. The distance traveled by light before its detection is given by the expression

$$r = \sqrt{L^2 + (r_0 + n2\pi R)^2} \ . \tag{2.3.27}$$

If observer and source are in same plane one obtains the previous formula for the quantized recession velocity. The size of the parameter R, which is fixed by the hypothesis that big void regions correspond to cosmic strings is indeed in accordance with the observational constraints.

It is not at all obvious that the orbit of photon can indeed be confined inside the outer critical radius ρ_+ associated with the string having $\omega R \sim 1$: the Kähler charge cannot obviously be all that matters since photons do not couple to it. For "big" strings however $\omega R \sim 1$ holds true. This is indeed the case: the physical reason is the extremely strong gravitational field caused by the big string. To see this consider the equations of motion for an orbit with circular projection in the plane orthogonal to the string. Orbit is characterized by energy conservation condition, momentum conservation condition in the direction of string, masslessness condition and the equation of motion in radial direction (essentially Kepler law)

$$\begin{aligned} \frac{dt}{ds} &= E \ , \\ \frac{dz}{ds} &= p \ , \\ E^2 g_{tt} - p^2 - \rho^2\omega_0^2 &= 0 \ , \\ \rho\omega_0^2 &= \frac{\partial_\rho g_{tt} E^2}{2} \ , \end{aligned} \tag{2.3.28}$$

The last equation forces the photon to a circular orbit if some additional consistency conditions are satisfied and obviously requires Kähler charged string. The expression for the time component of the metric is given by

$$\begin{aligned} g_{tt} &= 1 - R^2\omega^2(1-u^2) \ , \\ u &= cos(\Theta) = kln(\frac{\rho}{\rho_0}) \ , \\ k &= \frac{1}{ln(\frac{\rho_+}{\rho_0})} \ . \end{aligned} \tag{2.3.29}$$

Here $u = cos\Theta$ denotes the coordinate variable of the geodesic sphere S^2 as a function of the radial coordinate approaching value $u = -1$ at the boundary of the cylindrical region surrounding big string. These conditions boil down to the following condition fixing the value for the radius ρ of the circular orbit

$$cos(\Theta) = \frac{1}{\sqrt{K}}\sqrt{\frac{1-\frac{p^2}{E^2}-K}{1-\frac{Kk^2}{\omega_0^2\rho^2}}} \ . \tag{2.3.30}$$

This equation has real solutions provided the argument of the square root term is positive. In addition the condition $|cos\Theta| \leq 1$ must hold true.

If the longitudinal momentum of the photon vanishes, one has

$$cos(\Theta) = \frac{1}{\sqrt{K}}\sqrt{\frac{1-K}{1-\frac{Kk^2}{E^2}}} \ . \tag{2.3.31}$$

In the approximation $\frac{Kk^2}{E^2} \simeq 0$ this gives the bounds $1/2 < K < 1$. This condition is not consistent with the assumption that $K = R^2\omega^2$ is a small parameter given by

$$K = \frac{\epsilon}{2\alpha_K k} \ .$$

The small value of K is consistent with $p/E \simeq 1$ so that most of photons momentum is in the direction of string. The result means that the original model based on "big" strings in the center of the large void and explaining the observations must be given up.

Modified model for the quantization of red shifts

The modification of the previous model is obvious and much analogous to the topological model for the quantization. If closed galactic strings and torus like space-time sheets containing them and winding around the boundary of the large void are closed and are able to confine photons inside them and thus acting as cosmic wave guides, the photons from a distant star can rotate several times along these space-time sheets and same quantization of the red shift would result also now.

If the proposed explanation for the quantized red shift is correct, one can in principle observe the time development of single object from quasar to galaxy by a series of images, the time difference between two successive images being of the order of 10^8 ly. These images are observed on the same line of sight, when the light comes from a distant object.

2.4 Cosmic Evolution And Cosmic Strings

In this section a general vision about cosmic evolution based on zero energy ontology is discussed.

2.4.1 Cosmic Strings And Generation Of Structures

p-Adic fractality and simple quantitative observations lead to the hypothesis that cosmic strings are responsible for the evolution of astrophysical structures in a very wide length scale range. Large voids with size of order 10^8 light years can be seen as structures containing near their boundaries long cosmic strings at around which galaxies are organized linear structures like pearls in string. The original model contained big string in the center of void but it might well be possible to do without it. Galaxies would correspond to similar string like structure with smaller size and linked around the supra-galactic strings. This indeed conforms with the finding that galaxies tend to be grouped along linear structures. Simple quantitative estimates show that even stars and planets could be seen as structures formed around cosmic strings of appropriate size. Thus Universe could be seen as fractal cosmic necklace consisting of cosmic strings linked like pearls around longer cosmic strings linked like...

The observed quantization of the cosmic recession velocity [E176] supports the proposed view. The space-time sheet of large void containing galactic cosmic strings is closed structure. The photons from a distance astrophysical experience radial outwards acceleration and are drifted to the boundaries of the void but they cannot escape this space-time sheet. Hence these photons can be detected after having traversed several times around the closed loop and the red shift is proportional to the number of traversals. In case of larger void the order of magnitude for the quantization is predicted correctly.

2.4.2 Generation Of Ordinary Matter Via TGD Counterpart Of Hawking Radiation?

Cosmic strings can reduce their inertial masses by the analog of Hawking radiation involving the generation of fermion particle-antiparticle pairs, whose negative energy member remains inside string and annihilates there and positive energy member is radiated away. This mechanism can generate ordinary matter during initial stages of cosmic evolution and its temporal mirror image could give rise to a process analogous to the flow of ordinary matter to a black-hole during the final stages of the cosmic evolution. Highly tangled strings indeed within volume whose radius corresponds to black-hole radius indeed define a very general TGD based microscopic model of a black-hole. This “Hawking radiation” could generate at least part of the visible matter. The splitting of cosmic strings followed by a “burning” of the string ends provides a second manner to generate visible matter.

2.4.3 How Single Cosmic String Could Reduce Its Kähler StringTension?

The string tension of cosmic strings is due to Kähler action and has microscopic interpretation in terms of the mass of wormhole contacts having boson interpretation and fermions and super-symplectic bosons which correspond to topologically condensed CP_2 type vacuum extremals. The model of hadrons suggests that super-symplectic bosons could dominate the mass of cosmic string. If one accepts the general formula for the string tension in terms of Kähler coupling strength and quantum classical correspondence, one must conclude that the total contribution of matter to string tension equals to that of Kähler action.

One can imagine several mechanisms for how cosmic string could reduce its string tension. The topological condensation of CP_2 type vacuum extremals generates negative Kähler action so that string tension is reduced. The fact that Kähler action for the infinitely thin cosmic strings depends only on Kähler coupling strength suggests that the cosmic string transforms somehow in the process so that Kähler magnetic field flux remains constant but magnetic energy is reduced. This happens if the cosmic string develops finite transversal size in M^4 degrees of freedom since energy for magnetic flux tubes behaves as $1/S$, S the transversal thickness.

TGD predicts what I have used to call super-symplectic bosons and also their super-partners carrying having fermionic quantum numbers of right handed neutrino [K46]. These bosons have no electro-weak interactions and define a particular candidate for dark matter. Super-symplectic boson corresponds to single wormhole throat just like fermions and string like hadronic space-time sheets containing super-symplectic bosons and their super-partners connected by join along boundaries bonds to partonic space-time sheets have a key role in the recent model of hadrons. Also the model of black-hole as a gigantic hadron like entity relies on them. Two kinds of black-holes, "fermionic" and "bosonic" corresponding to strings and pairs of strings suggest themselves.

2.4.4 Zero Energy Ontology And Cosmic Strings

The combination of zero energy ontology with the cosmic evolution inspires concrete ideas about what the localization of contents of consciousness experience around narrow time interval identified as moment of subjective time could mean.

Zero energy ontology and cosmic evolution

Zero energy ontology means that all matter is creatable from vacuum as zero energy states which can be decomposed to positive and negative energy states whose space-time correlates correspond to partonic 2-surfaces in geometric past and future. This suggests strongly a picture about cosmic evolution beginning with TGD counterpart of Big Bang and ending with that of Big Crunch. It is however more appropriate to speak about "a silent whisper amplified to a big bang" since the amount of gravitational energy of cosmic strings in co-moving volume approaches zero at the limit of initial singularity.

This picture means genuine temporal non-locality and correlations over time interval T characterizing the distance between Bang and Crunch. It is however quite possible that T increases quantum jump by quantum jump and has been very small in past. The gradual shifting of the future end of zero energy state to the geometric future might relate directly to the arrow of subjective time. The usual identification of subjective time with geometric time can be understood if the arrow of subjective time corresponds to the gradual shift of the space-time volume from which the contents of conscious experience are to geometric future. TGD of course predicts a fractal hierarchy of cosmologies within cosmologies. Even elementary particle reactions have interpretation in terms of zero energy states identifiable as kind of mini-cosmologies.

If the main contribution to the contents of consciousness comes from the upper end of the zero energy state, and if T increases quantum jumps by quantum jump, this correlation could be understood and biological life cycle might have interpretation in terms of cosmology in human time scale at some level of dark matter hierarchy. Interestingly, the apparent increase of order suggests that the crunch phase might be experienced as a kind of Ω point. We could live all the subjective time at the Ω point which shifts to the geometric future quantum jump by quantum jump.

In the case of cosmic strings zero energy ontology would mean that cosmic strings are created in pairs of positive and negative energy cosmic strings. The mechanism could be non-local in the sense that the strings need not form tightly correlated pairs. An analogy with TGD based description of particle reaction would allow positive energy fermions from the geometric past and negative energy fermions from geometric future to meet somewhere in between. Bosons would correspond to tightly correlated pairs of positive and negative space-time sheets connected by wormhole contacts.

If the mechanism of generation of strings is local, "bosonic" strings formed by pairs of positive and negative inertial energy cosmic strings connected by connected by wormhole contacts would appear near the bang and crunch so that the density of inertial energy would vanish at this limit. With respect to geometric time single sub-cosmology would correspond to kind of vacuum polarization event for inertial energy. Locality assumption is however not necessary but would be consistent with the fact that Robertson Walker cosmology for which inertial mass density vanishes works so well.

The new view about second law

Quantum classical correspondence suggests negative and positive energy strings (in the sense of zero energy ontology) tend to dissipate backwards in opposite directions of the geometric time in their geometric degrees of freedom. Time reversed dissipation of negative energy states looks from the point of view of systems consisting of positive energy matter self-organization and even self assembly. The matter at the space-time sheet containing strings in turn consists of positive energy matter and negative energy antimatter and also here same competition would prevail.

This tension suggests a general manner to understand the paradoxical aspects of the cosmic and biological evolution.

1. The first paradox is that the initial state of cosmic evolution seems to correspond to a maximally entropic state. Entropy growth would be naturally due to the emergence of matter inside cosmic strings giving them large p-adic entropy proportional to mass squared [K46, L62]. As strings decay to ordinary matter and transform to magnetic flux tubes the entropy related to translation degrees of freedom increases.
2. The dissipative evolution of matter at space-time sheets with positive time orientation would obey second law and evolution of space-time sheets with negative time orientation its geometric time reversal. Second law would hold true in the standard sense as long as one can neglect the interaction with negative energy antimatter and strings.
3. The presence of the cosmic strings with negative energy and time orientation could explain why gravitational interaction leads to a self-assembly of systems in cosmic time scales. The formation of supernovae, black holes and the possible eventual concentration of positive energy matter at the negative energy cosmic strings could reflect the self assembly aspect due to the presence of negative energy strings. An analog of biological self assembly identified as the geometric time reversal for ordinary entropy generating evolution would be in question.
4. In the standard physics framework the emergence of life requires extreme fine tuning of the parameters playing the role of constants of Nature and the initial state of the Universe should be fixed with extreme accuracy in order to predict correctly the emergence of life. In the proposed framework situation is different. The competition between dissipations occurring in reverse time directions means that the analog of homeostasis fundamental for the functioning of living matter is realized at the level of cosmic evolution. The signalling in both directions of geometric time makes the system essentially four-dimensional with feedback loops realized as geometric time loops so that the evolution of the system would be comparable to the carving of a four-dimensional statue rather than approach to chaos.

2.4.5 A New Cosmological Finding Challenging General Relativity

Rachel Bean has published a cosmological finding which- if correct- challenges General Relativity or at least the cosmology based on cold dark matter. The title of the article [E229] is *A weak lensing detection of a deviation from General Relativity on cosmic scales*. Both Sean Carroll [E46] and Lubos Motl [E47] commented the finding. The article *Cosmological Perturbation Theory in the Synchronous and Conformal Newtonian Gauges* [E214] by C.P. Ma and E. Bertschinger allows to understand the mathematics related to the cosmological perturbation theory necessary for a deeper understanding of the article of Bean.

The message of the article is that under reasonable assumptions General Relativity leads to a wrong prediction for cosmic density perturbations in the scenario involving cold dark matter and cosmological constant to explain accelerated expansion. The following represents my first impressions after reading the article of Rachel Bean and the paper about cosmological perturbation theory.

Assumptions

"Reasonable" means at least following assumptions about the perturbation of the metric and of energy momentum tensor.

1. The perturbations to the Robertson-Walker metric contain only two local scalings parameterized as $d\tau^2 \rightarrow (1+2\Psi)d\tau^2$ and $dx^i dx_i \rightarrow (1-2\Phi)dx^i dx_i$. Vector perturbations and tensor perturbations (gravitational radiation classically) are neglected.
2. The traceless part (in 3-D sense) of the perturbation of energy momentum tensor vanishes. Geometrically this means that the perturbation does not contain a term for which the contribution to 3-curvature would vanish. In hydrodynamical picture the vanishing of this term would mean that the mass current for the perturbation contains only a term representing incompressible flow. During the period when matter and radiation were coupled this assumption makes sense. The non-vanishing of this term would mean the presence of a flow component - say radiation of some kind- which couples only very weakly to the background matter. Neutrinos would represent one particular example of this kind of contribution.
3. The model of cosmology used is so called ΛCDM (cosmological constant and cold dark matter).

These assumptions boil down to a simple equation

$$\eta \quad = \quad \Phi/\Psi = 1. \tag{2.4.1}$$

The results

The prediction can be tested and Rachel Bean indeed did it.

1. Ψ makes itself visible in the motion of massive objects such as galaxies since they couple to Newton's potential. This motion in turn makes itself visible as detected modifications of the microwave background from ideal. The so called Integrated Sachs-Wolfe effect [E32] is due to the redshift of microwave photons between last surface of scattering and Earth and caused by the gravitational fields of massive objects. Ordinary matter does not contribute to this effect but dark energy does.
2. η makes itself visible in the motion of light. The so called weak lensing effect [E43] distorts the images of the distant objects: apparent size is larger than the real one and there is also distortion of the shape of the object.

From these two data sources Rachel Bean is able to deduce that η differs significantly from the GRT value and concentrates around $\eta = 1/3$ meaning that the scaling of the time component of the metric perturbation is roughly 3 times larger than for spatial scaling.

What could be the interpretation of the discrepancy?

What $\eta = 1/3$ could mean physically and mathematically?

1. From [E214] one learns that for neutrinos causing shear stress one has $\Phi = (1 + 2R_\nu/5)\Psi$, where R_ν is the mass fraction of neutrinos: hence η should increase rather than decrease! If this formula generalizes, a negative mass fraction $R = -5/3$ would be present! Something goes badly wrong if one tries to interpret the result in terms of the perturbations of the density of matter - irrespective of whether it is visible or dark!
2. What about the perturbations of the density of dark energy? Geometrically $\eta = 1/3$ would mean that the trace of the metric tensor defined in terms of the background metric is not affected. This means conservation of the metric determinant for the deformations so that small four-volumes are not affected. As a consequence, the interaction term $T^{\alpha\beta}\delta g_{\alpha\beta}$ receives a contribution from $G^{\alpha\beta}$ but not from the cosmological term $\Lambda g^{\alpha\beta}$. This would suggest that

the perturbation is not that of matter but of the vacuum energy density for which one would have

$$\Lambda g^{\alpha\beta}\delta g_{\alpha\beta} = 0 \ . \quad (2.4.2)$$

The result would not challenge General Relativity (if one accepts the notion of dark energy) but only the assumption about the character of the density perturbation. Instead of matter it would be the density of dark energy which is perturbed.

TGD point of view

What TGD could say about this.

1. In TGD framework one has many-sheeted space-time, dark matter hierarchy represented by the book like structure of the generalized embedding space, and dark energy is replaced with dark matter at pages of the book with gigantic Planck constant so that the Compton lengths of ordinary particles are gigantic and the density of matter is constant in long scales so that one can speak about cosmological constant in General Relativity framework. The periods with vanishing 3-curvature are replaced by phase transitions changing the value of Planck constant at some space-time sheets and inducing lengthening of quantum scales: the cosmology during this kind of periods is fixed apart from the parameter telling the maximal duration of the period. Also early inflationary period would correspond to his kind of phase transition. Obviously, many new elements are involved so that it is difficult to say anything quantitative.
2. Quantum criticality means the existence of deformations of space-time surface for which the second variation of Kähler action vanishes. The first guess would be that cosmic perturbations correspond to this kind of deformations. In principle this would allow a quantitative modelling in TGD framework. Robertson-Walker metrics correspond to vacuum extremals of Kähler action with infinite spectrum of this kind of deformations (this is expected to hold true quite generally although deformations disappear as one deforms more and more the vacuum extremal).
3. Why the four-volumes defined by the Robertson-Walker metric should remain invariant under these perturbations as $\eta = 1/3$ would suggest? Are the critical perturbations of the energy momentum tensor indeed those for the dominating part of dark matter with gigantic values of Planck constant and having an effective representation in terms of cosmological constant in GRT so that the above mentioned equations implying conservation of four-volume result as a consequence?
4. The most natural interpretation for the space-time sheets mediating gravitation is as magnetic flux tubes connecting gravitationally interacting objects and thus string like objects of astrophysical size. For this kind of objects the effectively 2-dimensional energy momentum tensor is proportional to the induced metric. Could this mean -as I proposed many years ago when I still took seriously the notion of the cosmological constant as something fundamental in TGD framework- that in the GRT description based on the replacement string like objects with energy momentum tensor the resulting energy momentum tensor is proportional to the induced metric? String tension would explain the negative pressure preventing the identification of dark energy in terms of ordinary particles.
5. It is not clear whether the GRT based explanation of the accelerated expansion in terms of cosmological constant describing the presence of cosmic strings with large Planck constant conforms with the explanation in terms of phase transitions increasing Planck constant to which TGD assigns critical cosmology with negative string tension. Can one say that the presence of cosmic strings with gigantic Planck constant induces these phase transitions?
6. Note that the gigantic value of $\hbar_{gr}$ implies that for the energies usually assigned with gravitons the wave-length would be enormous so that these gravitons could correspond to string like objects connecting source and detector! Dark graviton with a frequency typically assignable to an astrophysical system would have enormous energy. Dark gravitons would decay to bunches of ordinary gravitons before arriving the detector [K111] so that the flux of ordinary gravitons would not be constant.

2.5 Cosmic String Model For Galaxies And Other Astrophysical Objects

The new view about the relationship between gravitational and inertial energy forces to modify the original model based of galaxy based on split cosmic strings. Splitting, although possible, might not be needed since Hawking radiation might replace it as a basic mechanism generating visible matter. By p-adic fractality the mechanism generalizes and provides a universal mechanism for the generation of astrophysical structures and universe can be seen as fractal necklace containing coiled pairs of cosmic strings linked around larger structures of similar kind linked...

2.5.1 Cosmic Strings And The Organization Of Galaxies Into Linear Structures

Astronomical observations suggest that galaxies form linear structures [E272]. This inspired the original TGD based model of galaxies as decay products of split cosmic strings forming kind of cosmic fire crackers. The required order of magnitude for the string tension was of order $10^{-6}/G$ the same as the string tension of the cosmic strings predicted by TGD (so that CP_2 radius would reflect itself directly in the galactic dynamics!). The model suggested also a solution of galactic dark matter problem since the net mass of a ball containing string is expected to depend linearly on the radius of the ball as indeed found.

One problem of this model was that galactic strings ought be in the plane of the galaxy. The galactic jets which one might expect to be parallel to the strings are however orthogonal to the galactic plane which suggests that visible matter condensed on certain points of a long string roughly orthogonal to the galactic plane.

The new view about the relationship between inertial and gravitational energy and the necessity of cosmological constant forces to modify this scenario.

1. The observation that galaxies are organized in linear structures can be understood if the basic structures cosmic strings with string tension determined by Kähler action and winding in a spaghetti like manner along the boundaries of large voids. Part of ordinary matter would results as a Hawking radiation from these strings but the very fact these strings are mostly invisible suggests that the matter emitted by them remains in the vicinity of strings. Visible jets orthogonal to the galactic plane usually interpreted in terms of black hole emissions could correspond to the emission of Hawking radiation from these structures. Galaxies are concentrations of visible matter around these strings and they are roughly orthogonal to the plane of galaxy.

2. The generation of positive and negative energy matter with zero net energy from vacuum does not contribute to the inertial energy in time scales longer than the scale of causal diamond (CD) involved. This has occurred already during string dominated critical period during which the density of gravitational mass behaves as $\rho \propto 1/a^2$ as a function of the light cone proper time and the mass per co-moving volume is proportional to a. The fractality of TGD inspired cosmology suggests that the creation pairs of positive and negative energy cosmic strings giving rise to cosmologies inside cosmologies has occurred also later in smaller length scales. In particular, galaxies and even smaller structures could be seen as cosmologies within cosmologies. Pairs of cosmic strings and magnetic flux tubes are not visible and are thus excellent candidates for the dark matter. The non-conservation of inertial and gravitational energy identified locally as energy associated with positive energy part of the local zero energy state supports this view.

   If the initial inertial and gravitational mass per unit length of these objects is same as that for a free string, the order of magnitude for the gravitational energy density of dark matter per volume is predicted correctly if the length L of string inside sphere R is proportional to its radius: $L \propto R$. Galaxies could be strongly knotted relatively short cosmic strings linked around the long cosmic strings like pearls in a necklace. Their shortness would mean that they do not contribute significantly to the mass of the void.

3. p-Adic fractality suggests that even smaller astrophysical structures might involve strings linked with larger strings linked with...., the cosmic necklace would be a fractal necklace. In the

case of Sun a string of length $L \sim 10^{11}$ m, which is not far from the distance $AU = 1.5 \times 10^{11}$ m between Earth and Sun, would be needed whereas the radius of Sun is $\sim 7 \times 10^8$ meters. Thus the magnetic flux tubes resulting form these strings could wind around solar system and bind the entire system into single coherent magnetic structure. For Earth one would have $L \sim 3 \times 10^5$ m, which is smaller than the radius $R = 6.4 \times 10^6$ m of Earth. What makes this interesting is that quite recently it has been announced that Earth contains a previously unidentified core region with size of 3×10^5 m [F36]. This picture suggest a universal mechanism for the evolution of the solar system replacing the existing Newtonian model based on the amplification of gravitational perturbations.

2.5.2 Cosmic Strings And Dark Matter Problem

Consider now the idea that the presence of cosmic strings might solve the dark matter puzzle [E223]. The presence of the dark matter is indicated by the velocity spectrum of the distant stars (at distance of few tens of kilo-parsecs from the center of the galaxy), which according to the recent observations [E123, E178] approaches to a constant depending on the galaxy in question and having the general order of magnitude $V \simeq 10^{-3}$.

One can estimate the velocity V of a distant star in galactic plane from Kepler law (the spherically symmetric model for galaxy suggests that this argument indeed applies)

$$\frac{V^2}{R} = \frac{GM(R)}{R^2} , \tag{2.5.1}$$

where $M(R)$ denotes the mass inside a sphere of radius R. Since the mass of the cosmic string dominates the mass inside a sphere of radius R one gets the following very rough estimate for the effective gravitational mass inside the sphere of radius R

$$M(R) \simeq n2TR , \tag{2.5.2}$$

where $n > 1$ accounts for the fact that straight string is not in question. From the known velocity V one obtains for the string tension the estimate

$$T \sim \frac{V^2}{4nG} \sim \frac{10^{-6}}{4nG} \sim v_D T_{free} . \tag{2.5.3}$$

This estimate is of the same order of magnitude as the lower bound of string tension obtained from the Jeans criterion. The result is also consistent with the assumption that, due to their gravitational binding to strings, stars rotate with the same velocity as strings.

Recall that an upper bound for the string tension of the TGD cosmic string is given by

$$T = \frac{1}{8\alpha_K R^2} \simeq .52 \times 10^{-6} \frac{1}{\hbar_0 G} .$$

This is roughly twice the required tension for $n = 1$ so that TGD is consistent with the experimental input. The effective string tension of the co-moving string also increases for $r \rightarrow r_0$ (see the general description of cosmic string solution) and diverges at $r = 0$. Furthermore, since the cosmic string is not straight there appears additional factor n making $M(R)$ larger than the simple estimate above.

On basis of these observations one has a strong temptation to think that the still existing cosmic strings, possibly thickened to magnetic flux tubes, correspond to galactic and extragalactic dark matter. At this stage one must leave open whether the naïve argument leads to a correct form for the velocity spectrum of stars. Whether or not true this prediction would have nice features in that it would relate the velocity spectrum directly to the size and age of the galaxy since the velocity v determines the recent size of the visible galaxy (if it corresponds to the recent distance of the string end from the center of galaxy): the older the galaxy with given size the smaller the rotational velocity v. Elliptic galaxies are older than spiral galaxies: rotational velocities for the elliptic galaxies are indeed smaller than for spiral galaxies [E178]. Furthermore, the rotational velocities increase with the size of the galaxy, when the age of the galaxy is kept constant: also this feature is in qualitative accordance with observed facts [E123, E178].

An interesting question is whether one could explain the angular momentum of galaxies in terms of the tidal forces acting between the galaxies [E72] at the opposite ends of a string (having length of order 10^5 light years. The idea is following. For free cosmic string there is a flux of angular momentum of order Tar^2 (using Robertson-Walker coordinates (a, r))) through the end of the string, which produces a correct order of magnitude for the galactic angular momentum at time a given by $J \sim Ta^2r^2 = Tr_M^2$, $r_M \sim 10^5\ ly$.

2.5.3 Estimate For The Velocity Parameters

The first task is to fix the value of the velocity parameter, to be denoted by V, appearing in the general solution describing one arm of the split cosmic string. In the region, where linearized equations of motion hold the orbital velocity V of the cosmic string is constant.

The radius of the singular region associated with cosmic string increases with some velocity v_D identifiable as the velocity with which the size of a typical galaxy (defined for example as the distance of spiral arm L from the center of galaxy) is about $L \simeq 10^4 - 10^5$ light years [E219, E175]. The condition $vT < L$, where $T \simeq 10^9 - 10^{10}$ years is the typical age of the galaxy, gives the estimate

$$v_D \quad < \quad 10^{-5} \ , \tag{2.5.4}$$

for the velocity v_D using the velocity of light as unit.

One can relate the velocity v_D to the string tension if one accepts the assumption that the relative motion of the string ends results from the shortening of strings, which in turn results from the decay of the string ends to elementary particles (some of them possibly exotics). A rough estimate for the velocity of the shortening of the string [E59] is based on the observation that the velocity

$$v \quad \simeq \quad TG \sim 10^{-6} \tag{2.5.5}$$

seems to set the time scale for the various dynamical processes leading to the decay of strings [E59]: for example, the shortening of loop with radius L via gravitational radiation as well as the shortening of the string connecting the monopole pair takes place with this velocity [E59]. This velocity is considerably smaller than the typical velocity $V \simeq 10^{-3}$ [E123, E178] of the distant stars moving in the galactic plane, which in turn can be understood using Kepler law.

The idea that the spiral arms of the spiral galaxy correspond to cosmic strings seems to be in accordance with the observational facts. In case of Milky Way [E219] the distance of spiral arms is about $L = 10^4 - 10^5$ light years from the center of the galaxy so that the order of magnitude for the velocity v_D is $v_D \sim 10^{-6} - 10^{-5}$. Furthermore, spiral arms are known to recede from the center of the Milky Way [E219].

The model suggests also an explanation for the observed bar like structure connecting the ends of the spiral arms of the spiral galaxies. The gravitational field is most intense near the string end so that the density of the ordinary matter is expected to be largest near the end of the string. On the other hand, the orbit of the string end is straight line so that "bar" like structure might be formed [E175], when the ends of the spiral arms recede from each other.

It should be stressed that the visible form of galaxies is not so closely related with the form of strings contrary to the original expectations (we used the term "spiral string"). This is clear from the observation that the total change of angle ϕ is smaller than $\pi/2$, which means that simplest cosmic strings are really not "spiral" like. Of course, this result holds for free strings and it might be that condensation in fact creates spiral structure somehow. A more conventional explanation is the generation of density waves with spiral structure [E263] and the presence of strings might have something to do with this phenomenon.

2.5.4 Galaxies As Split Cosmic Strings?

It is not clear whether the Hawking radiation from a coiled pair of cosmic strings is able to explain galactic visible matter. The reason is that the cosmic strings responsible for linear structures formed by galaxies are not visible along their entire length. One might argue that same applies also the knotted and linked galactic cosmic string pairs. If this is the case, the dark matter problem becomes visible matter problem. A possible solution of the problem is based on split cosmic strings with splitting possibly resulting in the collision of galactic strings with the long supra-galactic strings.

This scenario has indeed some attractive features (see **Fig. ??**).

1. The ends of the split cosmic string create strong gravitational fields and serve as seeds for the galaxy formation. Lense effect [E59] is predicted to be a signature of the string pairs. The fact that spiral galaxies have in general two arms, has a nice topological explanation.

2. One ends up to a rather simple scenario for the evolution of the galaxy.

   (a) The splitting occurs most probably during the string dominated phase for $t < L \sim 10^4\sqrt{G}$ (L is essentially CP_2 radius) and results most naturally from the collision of two strings.

   (b) The split strings begin to decay by emitting particles from their ends. The decay leads to a shortening of the split strings with constant velocity v so that the ends of the split strings recede from each other. This velocity can be identified with the velocity parameter $v \sim TG$ associated with the motion of the spiral arms. A correct size for the visible part of the galaxy is predicted.

   (c) Decaying cosmic string ends provide a model for the "central engines" associated with the galactic nuclei [E190]. The energy production by string decay turns out to be of same order of magnitude as the energy production in quasars assuming that the energy is produced in a narrow jet parallel to the string (momentum conservation favors this option). This was proposed as an explanation for the visible jets associated with the active galaxies as resulting from the interaction of the decay products with the ordinary matter. The fact that these jets are orthogonal to the galactic plane suggests Hawking radiation from supra-galactic string stimulated by the collision as an alternative explanation.

   (d) Co-moving cosmic strings happen to rotate with the same velocity as distant stars (relative to the center of galaxy) are found to rotate. The gravitational binding of stars by the average gravitational field created by cosmic strings would explain the rotational velocity spectrum.

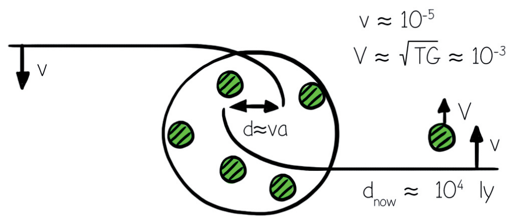

Figure 2.2: String model for galaxies.

In the following the model will be discussed in more detail to see whether it really works. The value for the velocity parameter v will be derived, Jeans criterion for the formation of the structures around a split cosmic string will be discussed, a simple toy model for a galaxy using spherically symmetric mass distribution will be constructed and the possibility that cosmic strings might provide a solution to the galactic dark matter problem will be studied.

Jeans criterion for the galaxy formation

It is not obvious that Jeans criterion for the generation of structures by gravitational interaction can be applied to galaxy formation in the recent situation differing so dramatically from Newtonian framework. One can however check what Jeans criterion would give in the case of split cosmic strings [E59].

1. The size L of the density fluctuation leading to the formation of a structure satisfies the inequality

$$l_J < L < l_H \ , \tag{2.5.6}$$

where the Jeans length l_J is given by [E59]

$$l_J \simeq 10 v_s t \ , \tag{2.5.7}$$

where v_s denotes the velocity of sound. Notice that the formation of structures is not possible at the radiation dominated era since Jeans length is larger than horizon: $l_H \simeq t < l_J \simeq 10t$ since the velocity of sound is of order 1.

2. When radiation and matter decouple from each other (corresponding to the value of about $a_{dec} = 10^8$ light years [E240]), the formation of galaxies becomes possible due to the lowering of the pressure, which leads also to the lowering of the sound velocity v_s from $v_s \simeq 1$ to $v_s \simeq 10^{-5}$ (thermal velocity of hydrogen). Jeans length shortens by a factor 10^{-5} and the formation of structures becomes possible.

In accordance with the idea that the split strings act as seeds for the galaxy formation, one can identify Jeans length as the minimal distance between the ends of the split string, which leads to a formation of galaxy

$$v_D a_{dec} > l_J \ . \tag{2.5.8}$$

Using the values for a_{dec} and l_J one obtains lower bounds for the velocity v_D between the ends of the galactic string and for the string tension of the galactic strings (accepting the proposed relationship between v_D and string tension)

$$\begin{aligned} v_D &> 10^{-6} \ , \\ T &> \frac{10^{-6}}{G} \ . \end{aligned} \tag{2.5.9}$$

One obtains also a lower bound for the recent size L_{now} of the galactic nuclei assuming that the decay of galactic strings continues with velocity v_D

$$L_{now} > 10^4 \ ly \ . \tag{2.5.10}$$

These numbers are in accordance with the estimate obtained for the string tension of a typical galactic strings and with what is known about recent sizes of the galaxies [E175].

Spherically symmetric model

The imbeddability requirement plays central role in TGD inspired cosmology and the galaxy model based on spherically symmetric mass ($M(r) = kr$) distribution is of some interest. This model could be regarded as a large length scale idealization of galaxy mass distribution. In case that galactic dark matter consists of the exotic decay products of the cosmic string the model might be even reasonably realistic. The line element for an energy momentum tensor characterized by energy density $\rho(r)$ and pressure $p(r)$ is given by the expression $ds^2 = A(r)dt^2 - B(r)dr^2 - r^2 d\Omega^2$

and to find an embedding for this metric one can use the general embedding ansatz introduced, when discussing the embedding of Reissner- Nordström metric.

Under rather general assumptions about the mass density the time component of the metric for a spherically symmetric mass distribution $M(r)$ (the mass inside the sphere of radius r) is given by the expression $g_{tt} = 1 - 2GM(r)/r$. In present case one would obtain $g_{tt} = constant$ so that some of the underlying assumptions must fail. The following form leads to a correct gravitational force

$$g_{tt} = 1 + 2Gkln(\frac{r}{r_0}) . \tag{2.5.11}$$

The gravitational force in the Newtonian limit is $2Gk/r = 2GM(r)/r^2$ and implies that Kepler law to be used later to derive velocity distribution of distant stars is indeed applicable.

The general expression for the metric component g_{tt} in terms of the embedding ($m^0 = \lambda t, \Theta = \Theta(r), \Phi = \omega t + f(r)$)

$$g_{tt} = \lambda^2 - R^2\omega^2 sin^2(\Theta) , \tag{2.5.12}$$

which gives

$$sin^2(\Theta) = \lambda^2 - 1 - \frac{2Gk}{R^2\omega^2} ln(\frac{r}{r_0}) . \tag{2.5.13}$$

Embedding fails for two critical radii r_{in} ($sin^2|(\Theta) = 1$) and r_{out} ($sin^2(\Theta) = 0$)

$$\begin{aligned} ln(\frac{r_{in}}{r_0}) &= \frac{(\lambda^2 - 1 - R^2\omega^2)}{2Gk} , \\ ln(\frac{r_{out}}{r_0}) &= \frac{(\lambda^2 - 1)}{2Gk} . \end{aligned} \tag{2.5.14}$$

An interesting question is whether one could relate the inner critical radii to the existence of the galactic nucleus having diameter of the order of 2 parsecs (.65 light years).

2.5.5 Cylindrically Symmetric Model For The Galactic Dark Matter

TGD allows also a model of the dark matter based on cylindrical symmetry. In this case the dark matter would correspond to the mass of a cosmic string orthogonal to the galactic plane and traversing through the galactic nucleus. The string tension would the one predicted by TGD. In the directions orthogonal to the plane of galaxy the motion would be free motion so that the orbits would be helical, and this should make it possible to test the model. In this kind of situation general theory of relativity would predict only an angle deficit giving rise to a lens effect. TGD predicts a Newtonian $1/\rho$ potential in a good approximation.

Spiral galaxies are accompanied by jets orthogonal to the galactic plane and a good guess is that they are associated with the cosmic strings. The two models need not exclude each other. The vision about astrophysical structures as pearls of a fractal necklace would suggest that the visible matter has resulted in the decay of cosmic strings originally linked around the cosmic string going through the galactic plane and creating $M(R) \propto R$ for the density of the visible matter in the galactic bulge. The finding that galaxies are organized along linear structures [E272] fits nicely with this picture.

2.5.6 New Information About The Distribution Of Galactic Dark Matter

The newest discovery relating to the galactic dark matter is described in the popular article "Milky Way Has a "Squashed Beachball" -Shaped Dark Matter Halo" [E228]. In more formal terms the title states that the orbit of the dwarf galaxy Sagittarius around Milky Way can be understood if the cold dark matter halo is not spherical but ellipsoid with different half axes in each three orthogonal directions. The dark matter distribution allowing the best fit is nearly orthogonal to the galactic plane and looks like a flattened sphere with height equal to one half of the diameter (see the illustration of the article [E228]).

The result is surprising since the most natural expectation is a complete spherical symmetry or ellipsoid with a rotational symmetry around the axes orthogonal to the galactic plane. The complete breaking of the rotational symmetry raises the question whether something might be wrong with the usual dark matter models. The following text is strongly updated version of the original one, which contained several errors and was badly organized.

Observations

Consider first in some detail what has been observed. Since the life span of the astronomers is not astronomical, they are not able to measure the orbit of the dwarf galaxy directly. The orbit of the dwarf galaxy can be however deduced from the stream of stars which Milky Way has ripped out from the dwarf galaxy.

Sagittarius is one of the 14 dwarf galaxies forming a gravitational bound state with Milky Way. It is an elliptic dwarf with a diameter of 10^4 light years (about size as the core of Milky Way). It has rotated about 1 My around Milky Way and already made about 10 full rotations. Now (in astronomical sense) Sagittarius is about to traverse the plane of Milky Way. During its motion Sagittarius experiences enormous tidal forces ripping out stars from it. The resulting stream of ripped out stars marks the orbit of Sagittarius. Obviously Sagittarius loses its mass to Milky Way and has already lost a considerable fraction. The ability of Sagittarius to maintain its coherence has been explained in terms of unusually high dark matter content.

The article states that the study of the paths for the parts of Sagittarius gives different parameters for the dark matter distribution. Maybe the "parts" refer to the four globular clusters of stars belonging to Sagittarius. In any case, a highly refined study of the structure of the star stream left behind by Sagittarius is carried out and one goal has been to find a gravitational potential allowing to fit the paths of the parts deduced from the star debris left behind by Sagittarius. The fact that Sagittarius has made several rotations around Milky Way explains why the "leading star debris" is present in the illustration of [E228]. The movie about the orbit of Sagittarius [E33] gives an artistic simulation about the situation. It seems that an illustration of the actual track from different angles in the galactic plane must be in question.

The basic observation is that the track is in a good approximation in plane. What one can conclude from this depends on what happens in the ripping out process. The star becomes part of Milky Way in some sense. The ripped out star experiences a free fall in the gravitational field of the Milky way. The question concerns what happens to the velocity of the star as it is ripped out.

1. The most natural guess is that the initial velocity is in a good approximation parallel to the velocity at the moment of ripping out.
2. A much stronger assumption is that the star eventually rotates with the same velocity as the distant stars of Milky Way around its center after the ripping out. If the dark matter is also rotating as it should be and forms a halo the gravitational interactions with it could force the hydrodynamic behavior. If one believe that dark matter in astrophysical length scales can have gigantic value of Planck constant, then hydrodynamics behavior looks natural.

Two models of dark matter

TGD allows to consider two alternative models for the dark matter. Contrary to the first guess both models are consistent if the ripping out process is interpreted in the first manner and need not therefore be hydrodynamic. Both models are consistent with the assumption that dark matter corresponds to particles at magnetic flux tubes, which are dark in the sense that they reside at different pages of the book like structure defined by the generalized embedding space with pages labeled by differed values of Planck constant. Magnetic flux tubes can be regarded as outcomes of cosmic expansion thickening the extremely thing cosmic strings and weakening the extremely strong magnetic fields inside them.

Classically dark matter corresponds to the magnetic energy of cosmic string. This interpretation is not locally consistent with the General Relativistic form of the Equivalence Principle if one considers a model for the string like object itself. Einstein's equations however make sense when one considers only the long range gravitational fields created by cosmic strings.

The two models are following.

1. The first model is very similar to the standard models of dark matter. If the galactic dark matter consists of decay products of a closed non-circular cosmic string approximately vertical to the galactic plane, a non-spherically symmetric distribution of dark matter is expected and there is qualitative consistency with the observed squeezed sphere character. If the ripping out leads rapidly to a hydrodynamic behavior the stream of the particles should rotate around Milky Way destroy the planarity of the debris stream. This would be like rocket in straight path through a rotating liquid: the used fuel would start to rotate with fluid.
2. In the second model galactic dark matter as matter resides at long cosmic string perpendicular to galactic plane. The matter in galactic plane could be also partially dark and visible matter could have resulted as decay products of the cosmic string transformed to magnetic flux tube. Galactic strings would have been linked around the long strings like pearls in necklace and this would explain the observed long strings of galaxies.

Consider next in detail the latter model. The very heavy cosmic string like object along the axis perpendicular to the galactic plane creates (in the Newtonian approximation) 2-D logarithmic potential forcing everything to rotate with a constant velocity around it. Besides this there is a weaker nearly vertical acceleration orthogonal to the plane created by the matter in the galactic plane. If the density of the matter in the galactic plane is approximated with a constant density, the motion of the individual star is a superposition of a free fall in the perpendicular direction and scattering in a logarithmic potential of form $Klog(\rho/\rho_0)$ in the approximation that the individual stars of the dwarf galaxy move completely independently. Second extreme would be a hydrodynamic flow.

Sagittarius rotates around the axis orthogonal to the plane of galaxy with the same velocity as the galactic matter identified as the velocity of the distant stars in the galactic plane (the constancy of this velocity led to the discovery of dark matter). Stating it differently, the motion of the stars of dwarf galaxy takes place in a a potential, which is sum of a potential $V_1(\rho)$ depending on the radial coordinate of the plane and a potential $V_2(z)$ depending on the vertical coordinate and created by the galactic matter.

The models differ from each other in several respects.

1. In the first model the simplest gravitational potential would be some function $V(r)$ of the 3-D radial coordinate and in the first approximation logarithmic. The rotation around the axes of Milky way takes place with a smaller velocity as in case of Milky Way and dark matter. The ripping out process is not consistent with the hydrodynamic behavior. The necessity to modify the spherically symmetric distribution of matter might reflect the fact the behavior is actually hydrodynamic.
2. In the second model galactic matter and Sagittarius itself would rotate with approximately the same velocity around the cosmic string and the ripping out process could be rather smooth since the velocity component in the galactic plane would not be affected in the ideal case. This model is consistent with the hydrodynamic behavior. In the optimal situation only the vertical gravitational forces due to the matter in the galactic plane would tend to rip out stars. This might relate to the fact that Sagittarius has been able to maintain its coherence so long. The article "Missing matter mystery of small galaxies" in New Scientist tells about mysterious missing dark matter [E230]. Roughly half of the dark matter predicted by theories is missing. The dark matter at the long cosmic strings would be the natural candidate for this missing dark matter if visible and dark matter in the plane of galaxy identifiable as decay products of galactic cosmic strings is responsible for the visible matter and already identified dark matter.

Some details related to the central string model

It is interesting to look in more detail the toy model based on cosmic string vertical to the galactic plane (also in this case matter in galactic plane could be decay remnants of a cosmic string). The energies for vertical and transverse motions are conserved separately as is also angular momentum component in vertical direction and one can solve the Newton's equations exactly. By Equivalence Principle one can speak about energy and angular momentum per unit mass: therefore notations e_z, e_T, l for the energies and angular momentum are natural.

1. Energy conservation in the vertical direction gives

$$v_z^2 + 2g_G \times z = 2e_z \quad , \tag{2.5.15}$$

   where g_G is the analog of gravitational acceleration at the Earth's surface and created by a constant density of the galactic matter in the galactic plane.

2. Angular momentum conservation gives

$$\rho^2 \omega = l \quad . \tag{2.5.16}$$

3. The conservation of energy in plane orthogonal to z-axis gives the third conservation law

$$(\frac{d\rho}{dt})^2 + \frac{l^2}{\rho^2} + 2Klog(\frac{\rho}{\rho_0}) = 2e_T \quad . \tag{2.5.17}$$

These conditions allow to solve the equations of motions for e_z, e_T, and l for each star involved and the mass of the star does not matter at all. In hydrodynamical model correlations between velocities of stars are forced by idealization as continuous matter. In this case the flow lines correspond to classical orbits with gradient of pressure added as an additional force to gravitational force. Energy and angular momentum are conserved along flow lines also now. Situation becomes more complex (and realistic) when one takes into account the gravitational forces between stars.

2.5.7 Cold Dark Matter In Difficulties

Cold dark matter scenario (see `http://tinyurl.com/lt6ul`) [E4] assumes that dark matter consists of exotic particles having extremely weak interactions with ordinary matter and which clump together gravitationally. These concentrations of dark matter would grow and attract ordinary matter forming eventually the galaxies.

Cold dark matter scenario (CDM) has several problems.

1. Computer simulations support the view that dark matter should be densely packed in galactic nuclei. This prediction is problematic since the constant velocity spectrum of distant stars rotting around galactic nucleus requires that the mass of dark matter within sphere of radius R is proportional to R so that the density of dark matter would decrease as $1/r^2$. This if one assumes that the distribution of dark matter is spherically symmetric.

2. Observations show that in the inner parts of galactic disk velocity spectrum depend linearly on the radial distance (see `http://tinyurl.com/yc4wzcgp`) [E266]. Dark matter density should be constant in good approximation (assuming spherical symmetry) whereas the cold dark matter model represent is strong peaking of the mass density in the galactic center. This is known as core/cusp problem.

3. CDM predicts also large number of dwarf galaxies with mass which would be about one thousandth of that for the Milky Way. They are not observed. This is known as missing satellites problem.

4. CDM predicts significant amounts of low angular momentum material which is not observed.

Already these problems suggest that CDM is somehow wrong. Quite recently a further problem related to dward galaxies has been identified as one learns from Science Daily article Dark Matter Mystery Deepens (see `http://tinyurl.com/np5pmt8`) [E8]. Dwarf galaxies are believed to contain 99 per cent of dark matter and are therefore ideal for the attempts to understand dark matter. They differ from ordinary ones in that stars inside them move like bees in beehive instead of moving along nice circular orbits. The observational data about the structure of dark matter in dwarf galaxies is in conflict with the predictions of cold dark matter scenario. New measurements about two dwarf galaxies tell that dark matter distribution is uniform over a region with diameter of several hundred light years which corresponds to the size scale of the galactic nucleus. For comparison purposes note that Milky Way has at its center a bar like structure with size between 3, 300-16, 000 ly. Notice also that also in ordinary galaxies empirical data support strongly constant density core (core/cusp problem) so that in the real world dwarf galaxies and ordinary galaxies need not be so different after all.

In TGD framework the simplest model for the galactic dark matter assumes that galaxies are like pearls in a necklace. Necklace would be long magnetic flux tube carrying dark energy identified as magnetic energy and galaxies would be bubbles inside the flux tube which would have thickened locally. Similar model would apply to start. The basic prediction is that the motion of stars along flux tube is free apart from the gravitational attraction caused by the visible matter. Constant velocity spectrum for distant stars follows from the logarithmic gravitational potential of the magnetic flux tube and cylindrical symmetry would be absolutely essential and distinguish the model from the cold dark matter scenario.

What can one say about the dwarf galaxies in TGD framework? The thickness of the flux tube is a good guess for the size scale in which dark matter distribution is approximately constant: this is true for any galaxy (recall that dark and ordinary matter would have formed as dark energy transforms to matter). The scale of hundred light years is roughly by a factor of 1/10 smaller than the size of the center of the Milky Way nucleus. If dark matter density equals to the density of dark energy (magnetic energy) which has given rise to the dark matter, dark matter distribution is naturally spherically symmetric and constant in this scale. This could be true also for ordinary galaxies. If so, the cusp/core problem would disappear and ordinary galaxies and dwarf galaxies would not differ in an essential manner as far as dark matter is considered. The problem would be essentially that of cold dark matter scenario.

2.5.8 Three Blows Against Standard View About Dark Matter

The standard view about dark matter is in grave difficulties.

1. The assumption is that galactic dark matter forms a spherical halo around the galaxy: with a suitable distribution this would explain constant velocity distribution of distant stars. Sometime ago NASA (see `http://tinyurl.com/7ypn8vr`) [E52] reported that Fermi telescope does not find support for dark matter in this sense in small faint galaxies that orbit our own.
2. Another blow (see `http://tinyurl.com/o7rjb2fr`) [E54] against standard view came now. A team using the MPG/ESO 2.2-metre telescope at the European Southern Observatory's La Silla Observatory, along with other telescopes, has mapped the motions of more than 400 stars up to 13, 000 light-years from the Sun. Also in this case the signature would have been the gravitational effects of dark matter. No evidence for dark matter has been found in this volume. The results will be published in an article entitled "Kinematical and chemical vertical structure of the Galactic thick disk II. A lack of dark matter in the solar neighborhood" by Moni-Bidin *et al.* to appear in The Astrophysical Journal.

These findings support the TGD based model for galactic dark matter (to be carefully distinguished from dark matter as large $\hbar$ phases appearing in much smaller amounts and essential for life in TGD inspired quantum biology). TGD based model for the galactic dark matter postulates that the dominating contribution is along long magnetic flux tubes resulting from these during cosmic expansion and containing galaxies around them like pearls in a necklace.

The distribution of dark matter would be concentrated around this string rather than forming a spherical halo around galaxy. This would give rise to a gravitational acceleration behaving like $1/\rho$, where ρ is transversal distance from the string, explaining constant velocity spectrum for distant stars. The killer prediction is that galaxies could move along the string direction freely. Large scale motions difficult to understand in standard cosmology has been indeed observed. It has been also known for a long time that galaxies tend to concentrate on linear structures.

The third blow (see `http://tinyurl.com/lk53s3v`) [E53] against the theory comes from the observation that Milky Way has a distribution of satellite galaxies and star clusters, which rotate around the Milky Way in plane orthogonal to Milky Way's plane. One can visualize the situation in terms of two orthogonal planes such that the second plane contains Milky Way and second one the satellite galaxies and globular clusters. The Milky Way itself has size scale of .1 million light years whereas the newly discovered structure extends from about 33, 000 light years to 1 million light years. The study is carried out by astronomers in Bonn University and will be published in journal Monthly Notices of the Royal Astronomical Society. The lead author is Ph. D. student Marcel Pawlowski.

According to the authors, it is not possible to understand the structure in terms of the standard model for dark matter. This model assumes that galactic dark matter forms a spherical halo around galaxy. The problem is the planarity of the newly discovered matter distribution. Not only satellite galaxies and star clusters but also the long streams of material left - stars and also gas - behind them as they orbit around Milky Way move in this plane. Planarity seems to be a basic aspect of the internal dynamics of the system. As a matter fact, quantum view (see `http://tinyurl.com/mha72yk`) about formation of also galaxies predicts planarity and this allows also to understand approximate planarity of solar system [K79]: common quantization axis of angular momentum defined by the direction of string like object in the recent case with a gigantic value of gravitational Planck constant defining the unit of angular momentum would provide a natural explanation for planarity.

The proposal of the researchers is that the situation is an outcome of a collision of two galaxies.

1. An amusing co-incidence is that the original TGD inspired model (see `http://tinyurl.com/y8wbeo4q`) for the formation of spiral galaxies [K31] assumed that they result when two primordial cosmic strings intersect each other. This would be nothing but the counterpart of closed string vertex giving also rise to reconnection of magnetic flux tubes. Later I gave up this assumption and introduced the model in which galaxies are like pearls in necklace defined by primordial cosmic strings which since then have thickened to magnetic flux tubes. These pearls could themselves correspond to closed string like objects or their decay products. Magnetic energy would transform to matter and would be the analog for the decay of inflaton field energy to particles in inflationary scenarios.

2. As already noticed, in TGD Universe galactic dark matter would correspond to the matter assignable to the magnetic flux tube defining the necklace creating $1/\rho$ gravitational accelerating explaining constant velocity spectrum of distant stars in galactic plane.

Could one interpret the findings by assuming two big cosmic strings which have collided and decayed after that to matter? Or should one assume that the galaxies existed before the collision?

1. The collision would have induced the decay of portions of these cosmic strings to ordinary and dark matter with large value of Planck constant. The magnetic energy of the cosmic strings identifiable as dark energy would have produced the matter. It is however not clear why the decay products would have remained in the planes orthogonal to the colliding orthogonal flux tubes. According to the researchers the planar structures must have existed before the collision.

2. This suggests that the two flux tubes pass near each other and the galaxies have moved along the flux tubes and collided and remained stuck to each other by gravitational attraction. The probability of this kind of galactic collisions depends on what one assumes about the distribution of string like objects. Due to their mutual gravitational attraction the flux tubes could be attracted towards each other to form web like structures forming a network of cosmic highways. Milky Way would represent on particular node at which two highways form a cross-road. In this kind of situation the collisions resulting s cross-road crashes could be more frequent than those resulting from encounters of randomly moving strings. The galaxies arriving to this kind of nodes would tend to form a bound state and remain in the node. It could also happen that the second galaxy continues its journey but leaves matter behind in the form of satellite galaxies and globular clusters.

It is encouraging that the TGD based explanation for galactic dark matter survives all these three discoveries meaning grave difficulties for the halo model.

2.6 Cosmic Strings And Energy Production In Quasars

One of the basic mysteries of astrophysics are so called "central engines" in the centers of the galaxies [E190]. These engines are very massive, have very small size of at most few light hours, their luminosity fluctuates in hour time scale, their electromagnetic spectrum is non-thermal and they are often accompanied by two jets in opposite directions. One should also understand why some galaxies are active (have a pair of jets) and others are not. A mysterious property of jets is their microstructure: main jets with length of order 10^6 light years are accompanied by short jets with length of order one light year and with directions parallel to the long jets.

In the standard model the central engine is a galactic black hole but the mechanism of the jet production is not well understood. In the following it is shown that decaying cosmic string ends provide a good candidate for the central engine. Note that in the standard picture jets are orthogonal to galactic plane whereas in the proposed model jets are parallel to the galactic plane. One could consider also the possibility that galaxies are formed in the splitting of cosmic strings orthogonal to galactic plane but this option will not be discussed here.

2.6.1 Basic Properties Of The Decaying Cosmic Strings

The rate for the shortening of a split galactic cosmic string can be deduced by an order of magnitude argument

$$\begin{aligned} v &\sim kTG \ , \\ T &\simeq \frac{2\times 10^{-7}}{G} \ . \end{aligned} \tag{2.6.1}$$

T is the string tension of the cosmic string. k is some numerical constant not too far from unity. The numerical study of the *ordinary* cosmic strings [E59] gives support for this order of magnitude estimate.

Taking the age of the Universe to be $a \sim 10^{11}$ years and assuming that the cosmic string is split in early phase of cosmology, the length of the portion of the decayed string is of the order

$$L \sim kTGa \simeq 2\times 10^4 k \ \text{light years} \ , \tag{2.6.2}$$

which is of the same order of magnitude as the typical size of the visible part of the galaxy.

An estimate for the rate of the energy production by single cosmic string is given by

$$P \sim Tv = kT^2G \sim \frac{4\times 10^{-14}k}{G} \sim 10^{47}k \times m(proton)/sec \ . \tag{2.6.3}$$

The energy production in quasars is roughly 10^{14} times larger than the energy production in Sun, which is about 10^{25} W: this gives $P \sim 10^{49} m_p/sec$. In order to have same order of magnitude one should have

$$k \sim 25 \ . \tag{2.6.4}$$

The required value of k looks suspiciously large and suggests that the energy flux from the decaying cosmic string could well be a jet directed to a narrow cone, which would increase the observed effective energy flux.

2.6.2 Decaying Cosmic String Ends As A Central Engine

It seems that the decaying cosmic string could explain elegantly the basic properties of the central engines. There are two alternative scenarios to be considered.

I) Galaxies are formed around the ends created in the splitting of a very long cosmic string.

II) Galaxies are formed by a decay of a piece of cosmic string. The decay of a finite piece of cosmic might explain the existence of some stellar objects accompanied by jet like structures.

In both cases the rate of the string decay gives a correct upper bound for the recent size of the visible part of the galaxies. Consider now the explanation of basic characteristics of active galaxies.

1. Visible jets are created by the energy beams

   The rate of the energy production in the decay of a cosmic string is few per cent about the estimated energy production in quasars assuming spherical symmetry. A correct rate for the observed energy flux from quasars is obtained if the energy from the decay of the string is liberated in a jet. Since two string ends are involved, the visible two-jet structure is an automatic consequence. The jets emerging from the active galactic nuclei are created by the interaction of the primary jets with the ordinary matter.

2. Quasars.

   Quasars differ from the ordinary galaxies only in that the energy jet from the cosmic string decay meets Earth. This explains the non-thermal nature of the spectrum and the absence of the atomic lines for the most intensive quasars (they are masked by the primary radiation). The rapid variations (a time scale of an hour) in the luminosity can be understood as resulting from the motion of the cosmic string inducing changes in the direction of the jet. Also the similarity between active and inactive galaxies is an automatic consequence.

3. Active-inactive distinction.

   For the option I possible explanation is that the galactic black hole has absorbed all matter around the galaxy and the jets coming from the decay of the cosmic strings have nothing with which to interact. It could however happen that the two jets interact with matter in very distant regions creating two tightly correlated jets but apparently originating from very distant sources. It could also occur that string ends are inside a galactic black hole for inactive galaxies so that the decay products remain inside the black hole and no visible jets are created. For the option II inactive galaxies without any jets, one can also consider the possibility that the piece of cosmic string has already decayed completely.

4. Dark matter halo.

   There are two alternative explanations for the velocity spectrum of the distant stars around the galaxy. The first, purely TGD based, explanation is that distant stars are gravitationally bound to the rotating cosmic string. Cosmic string indeed rotates with a correct velocity and, being Kähler charged, creates a genuine gravitational field unlike neutral cosmic string. The standard explanation is based on the assumption that galaxy is surrounded by a dark matter halo.

   An interesting possibility is that a halo of dark matter could result from the decay of the cosmic strings, perhaps in the form of ordinary and exotic neutrino like matter predicted by TGD. The decay could produce also part of the visible matter around the galactic nucleus. The jet model suggests that most of the decay products of the cosmic string escape the visible region of the galaxy but massive and Kähler charged particles with a proper sign of charge could remain bound to the cosmic string. Dark variants of ordinary elementary particles, in particular dark neutrinos, suffer classical Z^0 force below appropriate p-adic length scale. Clearly, Kähler force favors the generation of matter antimatter asymmetry. The average density in the halo would however be perhaps too small to explain the velocity spectrum.

5. Production mechanism for ultrahigh energy cosmic rays.

   The decay of the cosmic string should also give rise to ultrahigh energy cosmic rays. This production mechanism would provide an alternative for the production mechanisms based on the acceleration of the charged particles [it is difficult to conceive how any acceleration mechanism could lead to the generation of ultra high energy cosmic rays].

2.6.3 How To Understand The Micro-Jet Structure?

The long jets with length of roughly 10^6 light years have microstructure consisting of micro-jets with length of order one light year. This feature could be regarded as a shortcoming of the model. A possible TGD based explanation is based on lense effect on the gravitational field of the split cosmic string (scenario I).

In option I, a lense effect, caused by the strong gravitational field of the cosmic string itself, and creating multiple images could be involved. Since charged cosmic string is in question, the situation is more complicated than for the ordinary cosmic string. For instance, photon could rotate several times around the cosmic string before leaving the galactic region. The disappearance of the effect in distant regions (of length of order light year) could be understood if the energy jet were on the wrong side of the string at large distances or the distance between the jet and cosmic string would become so large that photons would not anymore circulate around the string.

2.6.4 Gamma-Ray Bursts And Cosmic Strings

Gamma ray bursters [E186] are now quite generally believed to have a cosmological origin. The energy flux from the gamma ray bursters (assuming spherical symmetry and cosmological origin and distance of order 10^8 ly) is about 10^{16} times the energy flux from Sun and by a factor of 10^2 larger than the total energy flux from the decaying cosmic string. The order of magnitude is same as for the energy flux of quasars. Typically the energy is produced in pulses lasting for a few seconds but also long lasting bursts consisting of a train of smaller pulses with a duration of order second are detected. It seems that the system emitting pulses is in some sense near criticality. The distribution of the gamma ray bursters is isotropic.

An interesting possibility is that decaying cosmic strings might explain also this phenomenon. The string would produce a continuous stream of energy, which fails slightly to meet Earth. Small perturbations causing the string end to oscillate (random oscillation of the direction of a flicker is a good analogy) imply that the beam of energy can meet the Earth at each period of oscillation and cause a sequence of pulses. A unique maximum intensity is predicted.

The shape of the pulse is predicted to reflect only the time development of the direction of the cosmic string rather than the actual intensity distribution of the pulse and this should make it possible to distinguish between TGD based and other explanations for the bursts. For instance, the typical bi-modality of the pulse could reflect directly to a perturbation taking string direction from the equilibrium position and bringing it back. The asymmetry of this perturbation caused by dissipative effects should explain the asymmetry of the two intensity peaks. The observed hardness-brightness correlation could be understood as following from the cosmic red shift and cosmic time dilatation increasing the observed duration of the pulse.

From the estimate that there are

$$\frac{dN}{dt} \sim 10^{-6}\ year^{-1}\ galaxy^{-1}$$

bursts per galaxy per year and taking the average duration t_P of the pulse to be

$$t_P \sim 1\ sec\ ,$$

one obtains a *very* rough estimate for the probability that a given galaxy acts as a gamma ray burster at a given moment as

$$P \sim t_P \times \frac{dN}{dt} \sim 10^{-13}.$$

One can estimate the solid angle Ω of the cone to which the energy of the decaying cosmic string is emitted: the probability P for galaxy being a burster, is simply the product of the probability $p(A)$ that galaxy is active multiplied with the probability $\Omega/(4\pi)$ that Earth happens to be in the solid angle Omega

$$P = \frac{p(A)\Omega}{4\pi} \sim 10^{-13}\ ,$$

which gives

$$\Omega \sim \frac{4\pi P}{p(A)} \sim \frac{10^{-12}}{p(A)}\ .$$

To proceed further an estimate for the probability of being active galaxy is needed. The value of Ω had better to be rather small since the oscillations in the direction of the cosmic string leading to fluctuations in the intensity of beam must be of the order of Ω and too large fluctuations are not expected (cosmic string is quite a heavy object!).

2.7 The Light Particles Associated With Dark Matter And The Correlation Between Gamma Ray Bursts And Supernovae

Both the model for dark matter identified as cosmic strings or their decay products and the model for gamma ray bursts identified as beams resulting in the fire cracker like decay of cosmic strings were constructed more than decade ago. During year 2003 came several astonishing observations, which at first seemed to be in a dramatic conflict with both the model of the dark matter and the model of gamma ray bursts.

It however turned out that these findings allow to relate, modify, and generalize as many as five models sketched at that time as the first applications of TGD. The subjects modeled were following:

1. The final state of a rotating star predicting flux tube like magnetic field along the symmetry axis [K111].
2. Dark matter identified as cosmic strings or their decay products.
3. Sunspots identified as the throats of magnetic flux tubes feeding magnetic flux to larger space-time sheet and behaving effectively as magnetic monopoles [K93]).
4. Gamma ray bursts explained as cosmic firecrackers resulting from the decay of split cosmic strings to elementary particles.
5. The anomalous e^+e^- pairs produced in the collisions of heavy nuclei at energy near the Coulomb wall as decay products of lepto-pions consisting of color excited leptons [K109].

2.7.1 Correlations Between Gamma Ray Bursts And Supernovae

The established correlation between gamma ray bursts and supernovae is certainly the cosmological discovery of the year 2003 [E88, E134].

1. The first indications for supernova gamma ray burst connection came 1998 when a supernova was seen few days after the gamma ray burst in the same region of sky. In this case the intensity of the burst was however by four orders of magnitude weaker than for the typical gamma ray bursts so that the idea about the correlation was not taken seriously. On 29 March, observers recorded a burst christened as GRB030329. On 6 April, theorists at the Technion Institute of Technology in Israel and CERN in Geneva predicted that there would be signs of a supernova in the visible light and infrared spectra on 8 April [E88]. On cue, two days later, observers picked up the telltale spectrum of a type Ic supernova in the same region of sky, triggered as the collapsing star lost hydrogen from its surface. It has now become clear that a large class of gamma ray bursts correlate with supernovae of type Ib and Ic [E57], and that they could thus be powered by the mere core collapse leading to supernova. Recall that supernovae of type II involve hydrogen lines unlike those of type I. Supernovae of type Ib shows Helium lines, and Ic shows neither hydrogen nor helium but intermediate mass elements instead. Supernovae of type Ib and Ic are thought to result as core collapse of massive stars.
2. One of the most enigmatic findings were the "mystery spots" accompanying supernova SN1987A at a distance of few light weeks at the symmetry axis at opposite sides of the supernova [E146]. Their luminosity was nearly 5 per cent of the maximal one. SN1987A was also accompanied by an expanding axi-symmetric remnant surrounded by three concentric rings.
3. The latest finding [E79] is that the radiation associated with the gamma ray bursts is maximally polarized. The polarization degree is the incredible 80 ± 20 per cent, which tells that it must be generated in an extremely strong magnetic field rather than in a simple explosion. The magnetic field must have a strong component parallel to the eye sight direction.

Do topologically condensed cosmic strings become co-moving magnetic flux tubes serving as seeds for the formation of stars and galaxies

According to the model for the formation of stars and galaxies proposed already fifteen years ago, topologically condensed pieces of cosmic strings perhaps resulting in the collision of long possibly knotted cosmic strings would serve as seeds making possible formation of lumps of matter forming later stars. The assumption that the pieces of cosmic strings result in the collision of cosmic strings leading to the splitting of them to pieces with some fractal length distribution perhaps concentrated around p-adic length scales would explain why the mass $M(R)$ of galactic dark matter inside a sphere of radius R is proportional to the radius: $M(R) \propto R$.

1. Topologically condensed cosmic strings as co-stretching magnetic flux tubes

I considered already 15 years ago a model for topological condensation of cosmic strings assuming that strong radial Kähler electric fields are generated to compensate the large positive magnetic action. Cosmic strings are actually a special case of magnetic flux tube solutions of field equations. This leads to a revised vision for what happens for topologically condensed cosmic strings. This model does not exclude the presence of the radial electric fields due to the charging of the cosmic strings.

Cosmic strings, which are in the ideal situation string like objects of type $X^2 \times Y^2$, X^2 string like object in M^4_+ and Y^2 geodesic sphere of CP_2 or a piece of it, generate an M^4_+ projection which increases in thickness so that the solution becomes increasingly thicker magnetic flux tube. In the topological condensation the open ends of the string disappear and thus no decay to elementary particles can occur. Thus the topological condensation would stabilize the cosmic strings against decay.

1. The simplest assumption is that the topologically condensed piece of a magnetic flux tube of finite length co-stretches with the expanding universe so that its length increases as $L \propto a$, a light cone proper time.
2. The requirement that magnetic flux is conserved and quantized implies $B \propto 1/S$, S the transverse area of the flux tube. The condition that magnetic energy is conserved, implies $S \propto L \propto a$ and $B \propto 1/a$. This of course applies both to the magnetic and Z^0 magnetic flux tubes.

The assumption that topologically condensed pieces of cosmic strings remain co-stretching forever is questionable, and it might be that when the thickness of the flux tube reaches a critical value corresponding to a Compton length of say pion or lepto-pion, expansion stops, and the flux tube freezes to a very long hadronic or lepto-hadronic (color) magnetic flux tube (a Kähler field giving rise to em or Z^0 field gives also rise to a classical color field).

"Wormhole magnetic fields" consist of pairs of magnetic flux tubes represented by space-time sheets with opposite time orientations and thus having opposite energies. These structures have zero energy and I have proposed that they play a key role in the physics of living matter. In particular, they could be generated by intentional action by first generating a p-adic variant of the wormhole magnetic field representing the intention to generate wormhole magnetic field, and then transforming it to its real counterpart in quantum jump. One cannot exclude the possibility that cosmic strings could also be generated as zero energy pairs of cosmic strings with opposite time orientation. This would make possible to intentionally create universe from nothing. This is actually the only possibility if one poses the boundary condition that no quantum numbers flow out of the future light cone at its boundary.

2. Stars and galaxies as gravitational condensates around fragments of cosmic strings

The gravitational condensation of matter around short parallel flux tubes topologically condensed at larger space-time sheets is a natural mechanism for generating structures like galaxies and stars. The pieces of magnetic flux tubes would form expanding ferro-magnet like structure in the self-consistent magnetic field defined by the by the return flux flowing at the space-time sheet at which strings have suffered topological condensation. The contribution of the magnetic flux tubes to the total mass of the star can be small and the ordinary matter can be seen as decay products of cosmic strings as in the earlier model. Similar mechanism with different initial length of topologically condensed cosmic strings and resulting in fragmentation in the collision of say two long cosmic strings could give rise to the birth of galactic nuclei.

According to the TGD based model of primordial critical cosmology, the transition from string dominated to radiation dominated cosmology should have occurred at $a_0 \sim 10^{-10}$ s, and one could argue that the topological condensation of the magnetic flux tubes should have started at this time. With this assumption the recent thickness of the magnetic flux tubes would be $d = (a/a_0)^{1/2} \times 10^4\sqrt{G} \sim 10^{-16}$ m for $a \sim 10^{11}$ years. This corresponds to a hadronic length scale. Quite generally, this would suggest that at light cone proper time a the fragments of long cosmic strings, which have survived the decay to elementary particles, have typical length $L \sim a$.

From the recent length of about light month associated with super nova SN1987A (identifying the mysterious light spots as ends of the flux tube), one can deduce that the length L_0 of the cosmic strings at a_0 would have been $L_0 \simeq 10^{-14}$ m, roughly the Compton length of pion. The corresponding magnetic field would be about 10^{16} Tesla and extremely strong. Fields of similar magnitude have been proposed to result in the core collapse of supernovae [E63]. It however seems that the flux tubes of the primordial magnetic fields cannot explain the highly polarized synchrotron radiation but that the temporary extremely strong Z^0 magnetic field induced by the core collapse are responsible for the polarization.

Magnetic and Z^0 magnetic flux tubes as templates for the formation of material structures is an idea borrowed from TGD inspired theory of consciousness and of bio-systems as macroscopic quantum systems [K102]. The TGD based quantum model for bio-matter assumes that the magnetic flux tubes of Earth serve as templates for the formation of bio-matter, and also define what I have called magnetic bodies controlling pre-biotic and biotic evolution [?]. Also the idea that magnetic flux tubes act as wave guides and make precisely targeted communications possible originates from TGD inspired theory of consciousness [?]. Thus magnetic flux tube structures could serve as templates for and even guide the evolution of matter in all length and time scales: this is certainly in spirit with the fractality of TGD Universe.

A mechanism producing gamma ray burst and polarized synchrotron radiation

The dynamo model for the final state of a rotating star leads to a model for gamma ray bursts consistent with ultrahigh polarization of the synchrotron radiation. The model is consistent with the standard model for the radiation beams from neutron stars.

1. Generalizing the dynamo model for the final state of rotating star

TGD based dynamo model for the final state of rotating star predicts that the rotation axis star contains extremely strong magnetic or Z^0 magnetic field. The field along the axis can also be helical and B_ϕ would naturally result from the rotation of the matter. While attempting to interpret the dynamo model I proposed that the axial field might somehow relate to a cosmic string. This might be indeed the case.

What I did not realize 15 years ago that many-sheeted space-time allows both magnetic and Z^0 magnetic dynamo fields and their symmetry axes of the fields need not coincide.

1. The atomic nuclei of even ordinary condensed matter can carry anomalous weak charges due to the presence of color bonds between nucleons having at their ends exotic quarks with mass of order electron mass and carrying also weak charges [K97, K39]. If some color bonds become charged they have also net weak charges. The Z^0 repulsion due to the weak bosons with Compton length of order atomic radius can explain the low compressibility of condensed matter and give rise to the repulsive term in van der Waals equation. Weak repulsion due to exotic weak bosons is expected to become important in the extremely dense phase of matter inside star.

2. There are good justifications for the assumption that Z^0 magnetic axis is parallel to the rotation axes- Z^0 magnetic field having neutron number as its source receives a large varying contribution dictated by the flow dynamics of the star. Hence Z^0 magnetic field is expected to be very strong, at least in the situations in which currents of different dark matter particle species do not cancel each other. In particular, the ejection of dark neutrinos during the formation of supernova is expected to generate a strong Z^0 charge due to the anomalous Z^0 charges of nuclei. This induces both Z^0 electric field and Z^0 magnetic fields. Since rotation

and Z^0 magnetic fields are so strongly coupled, the Z^0 magnetic and rotation axes should coincide.

3. The fact that the rotation axis of the star is rather stable is consistent with the primordial origin of the Z^0 magnetic field and suggests that Z^0 magnetic field as the primordial cause of the rotation.

4. Magnetic axis need not coincide with the rotation axis. The direction of the magnetic field of the star can be reversed (this is happening just now in case of Sun). This suggests that magnetic field does not have primordial origin and reflects the dynamics of the star.

5. TGD based variant for charged particle currents frozen to the magnetic field lines (assumed to have infinity conductivity in magnetohydrodynamics) are non-dissipative supra currents flowing along magnetic flux tubes of the magnetic and Z^0 magnetic fields. These currents in turn generate magnetic and/or Z^0 magnetic fields with field lines circulating around the rotation axes and thus make the magnetic field along symmetry axis helical.

6. Both in the case of magnetic or Z^0 magnetic field, the charged particles topologically condensed at the super-conducting flux tubes could be also spin polarized and amplify the field further.

In many-sheeted space-time topologically condensed magnetic flux tubes must feed their fluxes to larger space-time sheets so that a many-sheeted variant of the dipole field would result. The return fluxes would flow at larger space-time sheet and correspond to thicker flux tubes with weaker intensity of the magnetic flux. The regions, where the flux would be transferred between space-time sheets could correspond to flux tubes or wormhole contacts. In the latter case they would look like magnetic charges. As the in case of the sunspots, a fractal structure containing flux tubes inside flux tubes is expected [K93].

The mysterious light spots associated with SN1987A [E146] could correspond to flux tubes or the throats of the magnetic flux tubes of or primordial Z^0 magnetic flux tubes.

3. Synchrotron radiation in strong Z^0 magnetic field as a mechanism generating strong polarization

Usually the degree of polarization for the radiation from supernovae is around few per cent [E202]. The polarization associated with gamma ray burst GRB021206 is however incredibly high 80 ± 20 per cent and maximal polarization of the radiation [E79]. This requires extremely strong Z^0 magnetic field. The helical Z^0 magnetic field along the rotation axis can have flux quanta of astrophysical size and is ideal for accelerating dark charges flowing along the rotation axis and for producing dark photon synchrotron radiation leaking out in the direction of the rotating magnetic axis and transforming to ordinary photons by a mechanism analogous to decoherence of laser beams [K39, K37]. Gamma ray bursts could be seen as a particular case of this radiation resulting when an especially strong dark current (say dark electron current) flows along the rotational axis in an exceptionally strong dynamically generated Z^0 magnetic field, and induces a beam of synchrotron radiation along the rotating magnetic axis.

The radiation is linearly polarized with the polarization direction and intensity defined by the vector

$$\overline{n} \times (\overline{n} \times \overline{B}^Z) = \overline{B}^Z - B_z^Z cos(\theta)\overline{n} \ ,$$

where $\overline{n}$ is the direction of the observer in the direction of the axial magnetic flux tubes and characterized by the angle θ. The direction of polarization is constant during the observation period if the symmetry axis associated with B^Z coincides with the rotation axis. It is essential that magnetic and Z^0 magnetic fields are not parallel and reside at different space-time sheets. The intensity is proportional to the square of the polarization factor given by

$$(B^Z)^2 \times \left(1 - cos^2(\alpha)cos^2(\theta)\right) \ , \quad cos(\alpha) \equiv \frac{B_z^Z}{B^Z} \ .$$

If the Z^0 magnetic field has only z-component, the intensity is proportional to $(B^Z)^2 sin^2(\theta)$ and at minimum.

4. Radial compression as a mechanism producing strong Z^0 magnetic field

A sudden compression in radial directions orthogonal to the rotation axis at the core collapse could be seen as a process analogous to the squeezing of the tooth paste tube. A strong non-dissipative supra current along the axis of magnetic field is induced because this is the route of the lowest resistance. This current in turn generates a strong magnetic field component B_ϕ^Z, and the charges accelerated in the axial direction in this field emit synchrotron radiation with a direction of polarization tangential to the magnetic field component B_ϕ^Z. If all nuclei possess anomalous Z^0 charges, the matter flow along rotation axis can generate very strong Z^0 magnetic field so that there are good hopes of explaining the anomalously high value of polarization of the synchrotron radiation.

The three expanding ring like structures associated with SN1987A [E29] could be identified as being due to dark Z^0 currents rotating around the strong axial Z^0 magnetic field. Even the identification as torus like flux quanta of Z^0 magnetic field induced by the very strong Z^0 current along the z-axis is possible. This kind of Z^0 magnetic dark currents rotating around axial Z^0 magnetic field could be even responsible for the rings associated with planets like Saturnus and even with the ring current associated with Earth. This picture conforms with the model for the formation of solar system in which macroscopically quantum coherent dark matter serves as a template around which ordinary matter is condensed [K93, K37] as also with the explanation of tritium beta decay anomaly assuming that Earth's orbit is surrounded by dark neutrino belt [K97].

It is known that spherical and even axial symmetry is broken in case of SN1987A and this is consistent with the fact that magnetic and Z^0 magnetic axis are not parallel. Let L be the line of sight orthogonal to the plane S of sky, and R the projection of the ring to S. Let z-axis correspond to L and x- and y-axis to the directions of the minor and major axis of R. Denote by E_z and E_y the projections of ejecta to S and xz-plane. From the figure 2 of [E164] one can deduce that the plane of the ring forms an angle of 44 degrees with respect L. The symmetry axes of E_y resp. E_z forms an angle of 45 degrees resp. 15 degrees with respect to x-axis. From this one can conclude the polar and azimuthal angles of the symmetry axis of ejecta are $\theta = 45.4$ degrees and $\phi = 9$ degrees. A good guess is that this axis corresponds to the rotation axis and axis of Z^0 magnetic field tilted by 45.4 degrees with respect to the line of sight parallel to the magnetic axis. Mystery spots are known to be located at this axis too [E164] so that they could indeed correspond to sunspot like throats at which Z^0 magnetic flux is transferred between space-time sheets.

Magnetic flux tubes as wave guides

Magnetic flux tubes are ideal wave guides forcing the confined radiation to propagate in a precisely targeted manner along them. Topological light rays (MEs) accompany magnetic flux tubes involved and have interpretation as space-time correlates for a radiation propagating in the waveguide defined by the magnetic flux tube. They are accompanied by coherent light generated by light like vacuum currents associated with then. Topological light rays would couple to Alfven waves representing transversal oscillations of the magnetic flux tubes propagating also with light velocity.

The wave guide function of magnetic flux tubes suggests a generalization and modification of the model of gamma ray bursts. Gamma ray bursts would be generated by the synchrotron radiation generated in the acceleration of charges when they move along rotation axis with dynamically generated component B_ϕ^Z. Part of the resulting radiation would end up to a rotating magnetic flux tube bundle in the direction of the rotating magnetic axis. The initial channeling at the magnetic flux tubes would force synchrotron radiation to propagate to distant parts of the universe in a precisely targeted manner. This mechanism would explain the observed universal properties for the gamma ray [E186] [E86] difficult to understand in the models involving mergers, say collisions of white dwarf binaries [E57]. As already noticed, the model is consistent with the existing model for the ordinary radiation arriving from supernovae and thought of as involving a beam rotating with the supernova.

Gamma ray bursts as dark photons

In [K93] a model for dark graviton with a large value of Planck constant is developed. This yields also a model for the de-coherence of dark graviton and for what happens in the detection of dark gravitational radiation. The model applies also to dark gauge bosons.

1. The basic new element is that dark bosons are associated with topological light rays which are N-sheeted multiple coverings of M^4. The energy absorbed in the detection of a dark boson would be N-fold whereas the frequency for detections is expected to be $1/N$ times lower so that in average sense dark bosons would behave like normal ones. The events in which dark gravitons with large N are detected would be interpreted as noise. Same could apply to other dark bosons. Dark matter would be only apparently dark.

2. The propagation of of dark boson can be regarded as a sequential de-coherence in which pieces with smaller value of Planck constant and thus smaller energy are split off from the original dark boson. Frequency is not altered in this process.

   Gamma ray bursts could correspond to dark photons with very large value of N so that strongly targeted and very intense beam of ordinary photons results in the de-coherence process.

Gamma ray bursts as collective transitions of cosmic strings identified as scale up hadrons

According to the TGD based model [K74], hadrons consists of two kinds of matter. Valence quark space-time sheets have fused to single structure by color bonds, the "Pomeron" of the physics before QCD. This structure is in turn connected by bonds (possibly carrying the color of sea quarks) to string like hadronic space-time sheet characterized by Mersenne prime M_{107} and containing super-symplectic bosons giving the dominating contribution to the mass of light baryons.

The black-hole like characteristics of the hadronic space-time sheet, which conform with the experimental findings at RHIC, plus the general vision about the formation of neutron stars and quark stars via the fusion of hadronic space-time sheets encourage a generalization to a model for the microscopic structure of black-holes as highly tangled strings inside black-hole horizon. Black-hole would be kind of scaled up hadron.

The Mersenne primes characterizing the hadronic space-time sheet in the hierarchy extending from cosmic strings to hadrons would belong to the set $\{M_n|vertn = 2, 3, 5, 7, 13, 17, 19, 31, 61, 89, 107\}$. The quarks contained by cosmic string would be labeled by rather small p-adic primes. Cosmic strings would give rise to primordial black-holes decaying to ordinary matter and magnetic flux tubes with a lower string tension. Gamma ray bursts could result in collective quantum transitions of cosmic strings involving several steps with end products of final state at each step characterized by a smaller Mersenne prime. For gamma ray bursts produced by super-novae the value of Mersenne prime would be probably $k = 107$.

Note that ordinary hadrons need not define the lowest level of the hierarchy since also M_{127} copy of hadron physics appears in the TGD based model of nucleus. If Gaussian Mersennes are allowed then much more levels are possible: in particular, in length scale range especially relevant for living systems.

Gamma ray bursts and quantum phase transitions in the scale of string like object

The model of hadrons behind hadronic mass calculations leads to the vision that super-symplectic bosons are responsible for the most of hadronic mass [K74, K68]. This in turn leads to a microscopic model for neutron stars, quark stars, and black-holes as highly entangled hadronic strings resulting in the fusion of hadronic strings. Also cosmic strings would contain super-symplectic matter and separate from environment by black hole horizon.

All these objects would be macroscopic quantum systems and their quantum transitions could generate dark gamma rays, dark gravitons, and other dark particles decaying to ordinary particles in de-coherence phase transition.

A model for dark graviton emission assignable to the gravitational quantum transition of astrophysical objects characterized by gigantic gravitational Planck constant is discussed in [K111]. Dark gravitons would correspond to pulses of ordinary gravitons resulting in de-coherence rather than continuous flow of gravitons. These pulses might be dismissed as noise in measurement philosophy based on standard quantum mechanics.

2.7.2 Lepto-Pions As A Signature Dark Matter?

The identification of cosmic strings as the ultimate source of both visible and dark matter does not exclude the possibility that a considerable portion of topologically condensed cosmic strings have decayed to some light particles. In particular, this could be the situation in the galactic nuclei. On the other hand, if some fraction of cosmic strings evolve to magnetic flux tubes, these flux tubes identifiable as dominant part of the dark matter can carry phases of some exotic particles serving as signatures of the dark matter. Quite recent experimental findings [E111] suggest that these exotic particles could be lepto-hadrons predicted by TGD [K109].

Two anomalies

The idea that lepto-hadrons might have something to do with the dark matter has popped up now and then during the last decade but for some reason I have not taken it seriously. Situation changed towards the end of the year 2003. There exist now detailed maps of the dark matter in the center of galaxy and it has been found that the density of dark matter correlates strongly with the intensity of monochromatic photons with energy equal to the rest mass of electron [E111].

The only explanation for the radiation is that some yet unidentified particle of mass very nearly equal to $2m_e$ decays to an electron positron pair or directly to gamma pair. Electron and positron are almost at rest and this implies a high rate for the annihilation to a pair of gamma rays. A natural identification for the particle in question would be as a lepto-pion. By their low mass lepto-pions, just like ordinary pions, would be produced in high abundance, in lepto-hadronic strong reactions and therefore the intensity of the monochromatic photons resulting in their decays would serve as a measure for the density of the lepto-hadronic matter. Also the presence of lepto-pionic condensates can be considered. Lepto-pions decay directly to both gamma pairs and electron-positron pairs. Indeed, galaxy is for long time known to be a source of positrons and there is no generally accepted mechanism producing them [E111].

The second anomaly was the microwave interstellar medium emission observed by WMAP used to map the anistropy of cosmic microwave spectrum [E92]. Unfortunately, the anomaly reached my attention for more than 4 years later. Anomalous lines at frequencies $f = 23; 33, 41, 61, 94$ GHz have been observed. In good approximation they correspond to harmonics of single frequency of f= 10 GHz. For the cyclotron transitions of electron the required magnetic field would be about 0.36 Tesla. The identification would be in terms of cyclotron transitions of dark electrons or of their Cooper pairs residing at magnetic flux tubes of galactic magnetic fields and characterized by so large value of Planck constant that cyclotron energy is above thermal energy. The emitted cyclotron radiation would decay into bunches of ordinary photons with same frequency but much smaller energy.

Lepto-hadron as explanation of gamma ray anomaly?

In the chapter [K109] I have discussed the TGD based explanation for the anomalous production of electron positron pairs in the collisions of heavy nuclei at energies corresponding to the height of Coulomb wall. The effect was observed for more than fifteen years ago [C14] but after string model revolution has been forgotten by theorists like many other anomalies of particle physics. The hypothesis is that so called lepto-pions are produced in the strong, non-orthogonal, and rapidly varying electric and magnetic fields of the colliding nuclei. Lepto-hadrons are color bound states of colored excitations of leptons predicted by TGD defining an asymptotically non-free QCD. Actually an entire hierarchy of non-asymptotically free QCD: s are allowed in TGD Universe.

These findings force to take seriously either the identification

a) of the dark matter as lepto-hadrons or

b) of lepto-pions as a signature of dark matter, which itself would be basically magnetic energy associated the with cosmic strings transformed to magnetic flux tubes in topological condensation. Of course, lepto-pions could correspond to only a small fraction of dark matter and one can quite well imagined that they are created in strong interactions of leptobaryons.

In fact, lepto-pions are not the only possibility. The TGD based model for tetra-neutrons [C13] [K97] is based on the hypothesis that mesons made of scaled down versions of quarks corresponding to Mersenne prime M_{127} (ordinary quarks correspond to $k = 107$) and having masses around one MeV could correspond to the color electric flux tubes binding the neutrons to form a tetra-neutron. The same force would be also relevant for the understanding of alpha particles.

Why lepto-hadrons cannot directly correspond to dark matter?

The identification of lepto-hadrons as dark matter raises several questions leading to the conclusion that lepto-pions are most probably only a signature of dark matter.

1. Why the ratio of the lepto-hadronic mass density to the mass density of the ordinary hadrons would be so high, of order 7? Could an entire hierarchy of asymptotically non-free QCDs be responsible for the dark matter so that lepto-hadrons would explain only a small portion of the dark matter? Is even the hierarchy of QCD: s enough?
2. Under what conditions one can regard lepto-hadronic matter as a dark matter? Could short life-times of lepto-hadrons make them effectively dark matter in the sense that there would be no stable enough atom like structures consisting of say charged lepto-baryons bound electromagnetically to the ordinary nuclei or electrons? But what would be the mechanism producing lepto-hadrons in this case (nuclear collisions produce lepto-pions only under very special conditions)?
3. What would be the role of the many-sheeted space-time: could lepto-hadrons and atomic nuclei reside at different space-time sheets so that lepto-baryons could be long-lived? Could dark matter quite generally correspond to the matter at different space-time sheets and thus serve as a direct signature of the many-sheeted space-time topology? Magnetic flux tubes are excellent candidates for the space-time sheets accommodate the dark matter but there are good reasons to believe that magnetic energy is considerably higher than the energy of particles condensed on magnetic flux tubes so that magnetic energy is the best candidate for dark matter.

These objections suggest that lepto-pions serve only as a signature of dark matter. The recent vision about dark matter suggests that all particles can appear as dark variants and reside at magnetic flux tubes and lepto-pions could be only particular kind of dark matter. Of course, dark matter itself could correspond also to the magnetic energy of the magnetic flux tubes and cosmic strings.

Lepto-pions topologically condensed on magnetic flux tubes as a signature of dark matter?

Lepto-pions and other lepto-hadrons producing copiously lepto-pions could reside at magnetic of Z^0 magnetic flux tubes of thickness of order Compton length of lepto-pion. These strings could be seen as kind of very long lepto-hadronic strings. Also long hadronic flux tubes carrying coherent states of ordinary pions are possible and Z^0 flux tubes beaming the gamma ray bursts could correspond to them.

One could identify the lepto-hadronic magnetic flux tubes as structures generated later in the cosmic evolution, when the magnetic flux of hadronic flux tubes flow to larger space-time sheets. The transversal length scales of the flux tubes would be in ratio m_e/m_p and the magnetic field would be by a factor of about 10^{-6} weaker, about 10^{10} Tesla whereas the magnetic field of supernovae are around 10^9 Tesla. If the thickness of the magnetic flux tube at the moment of the annihilation of lepto-pion is of the order of Compton length of electron, one obtains an estimate for its thickness at the moment when the transition to the radiation dominated phase occurred.

If the strength of the magnetic field is of order $eB \sim m_e^2 \sim 10^9$ Tesla, the cyclotron frequency would be of same order as electron mass $eB/m_e \sim m_e$ and in gamma ray region. For $eB \sim m_p^2$ the field strength would be 10^{15} Tesla and cyclotron energy would be of order proton mass. Harmonics of this line might serve as a signature for the strength of the magnetic field. The monochromatic gamma lines at electron mass could also result in cyclotron transitions of electrons if the magnetic field at magnetic flux tubes that $eB = m_e^2$ holds true in high precision.

One can imagine two mechanisms of lepto-pion production.

1. The magnetic and Z^0 magnetic fields associated with the magnetic flux tubes give rise to classical color fields, which suggest that one could regard the flux tubes as macroscopic color

magnetic and possibly also color electric flux tubes carrying lepto-hadrons, which produce copiously lepto-pions in their reactions.

2. In heavy ion collisions lepto-pion production is caused by the presence of the rapidly varying non-orthogonal electric and magnetic fields of colliding nuclei, whose "instanton density" $E \cdot B$ is non-vanishing (this means that the magnetic flux tube has higher than 2-dimensional CP_2 projection). The amplitude for lepto-pion production as a decay of the coherent state is proportional to the Fourier component of the "instanton density". The mechanism could be at work also now if magnetic flux tubes carry strong charges and generate radial electric fields. Lepto-pions would serve as signature for rapid changes of the magnetic and electric fields induced by rapid deformations of the magnetic flux tubes.

Solar X-ray halo and scaled up QCDs at magnetic flux tubes

Quite recently New Scientist told about an explanation proposed by Kostantin Zioukas and his colleagues [E171] for the X-ray halo of Sun in terms of axions, one of the many candidates for the dark matter [E44]. The X-ray halo of Sun was detected at 1940. The halo extends from the surface of Sun (free path for photons increases at the surface). The X-ray intensity decays exponentially and extends several solar radii from the surface. The energy range of X-rays is $3 - 15$ keV. The origin of the X-ray halo has remained a mystery.

The axions in the required mass range are predicted by certain higher-dimensional theories [E171]. The axions would be produced in the solar core and because of their extremely long lifetime they would propagate to the surface of Sun and some fraction of non-relativistic axions would remain bound in the solar gravitational field where they would decay. The estimated mean distance of the proposed axion population from the solar surface is about 6.2 solar radii. Zioukas and his colleagues are able to deduce the value of the coupling constant $g_{A\gamma\gamma}$ characterizing the rate of axion decay and the interaction cross section of axion with matter from the fact that the X-ray luminosity must be proportional to $g^4_{A\gamma\gamma}$. The resulting lifetime of the axion is about 10^{21} s to be compared with the lifetime of ordinary pion about 10^{-16} s.

TGD suggests an alternative explanation based on a non-asymptotically free exotic QCD at a magnetic flux tube corresponding to a p-adic length scale $L(k)$ for which the scaled down value of pion mass corresponds to mass of about 3 keV. Assuming that pion corresponds to $k = 107$ ($k = 109$ is the second candidate) this gives $2^{(k-107)/2} \sim m_{\pi(107)}/m_{\pi(k)}$. The lower limit for the energy spectrum would favor the p-adic length scale $L(139)$ giving $m_{\pi(139)} \simeq 2.2$ keV. The lifetime of lepto-pion would be scaled up by a factor 2^{16} so that one would have $\tau \sim 10^{-11}$ s. One cannot exclude the presence of several scaled up QCDs with $k = 139, 137$ and $k = 131$ being the most favored ones in the energy range of about 3 octaves spanned by the X-ray spectrum.

In the recent case the intensity of the X-ray halo from a given spherical volume V of the halo defining the pixel is determined by the density $dn(\pi)/dl$ of the exotic pions per unit length of the magnetic flux tube and the length $l(V)$ of the magnetic flux tube inside the volume, which is expected behave as $l(V) \sim V^{1/3}$. A rough estimate is

$$I(V) \sim \frac{dn(\pi)}{dl} \times l(V) \times \Gamma \times \langle E(\pi)\rangle \Delta\Omega \ ,$$

where $\Delta\Omega = A/4\pi R^2$ is the solid angle defined spanned by the active detection area A of the measuring instrument at a given point of the magnetic flux tube and R is the distance of Earth from Sun. In principle this allows to estimate the density of exotic pions per unit length of the magnetic flux tube.

The exponential decay of the intensity with distance from the surface of the Sun would suggest that magnetic flux tubes might be regarded as threads extending from the solar surface and returning back to it, and that the probability of a path of given length decreases exponentially with its length. If the probability for the appearance of a thread of given length is proportional to the Boltzmann weight $exp(-E_B/T)$, where E_B is magnetic energy of the thread and T is temperature parameter, this indeed holds true.

The intensity of the magnetic field at the flux tubes can be estimated from the nominal value $B_E = .5 \times 10^{-4}$ Tesla of the Earth's magnetic field at the space-time sheet $k = 169$. By scaling one would obtain $B = 2^{169-139} B_E = 5 \times 10^4$ Tesla. The field is extremely strong and could be perhaps assigned to remnants of primordial cosmic strings. Note that also Z^0 magnetic field could be in question in which case dark matter coupling to scaled down copies of electro-weak bosons would be in question [?, K39].

Do the length scale ratios for astrophysical objects reflect Compton length ratios of elementary particles?

The ratio for the size $L_l \sim 10^5$ light years of a galactic nucleus to the distance $L_h \sim 1$ light month between the light spots of super nova gives an estimate for the ratio of the lengths of the lepto-hadronic and hadronic magnetic flux tubes. This would predict $L_l/L_h \sim 10^6$ and that the ratio of transverse thicknesses $d_l/d_h = 10^3$, which is the ratio of lepto-pion Compton length scale scale to proton Compton length. This would suggests that the length scale hierarchy for astrophysical objects could represent a scaled up version of the p-adic length scale hierarchy associated with elementary particles.

Frequency cutoff for zero point frequencies as a test for many-sheeted space-time?

For a quantum system mode lable in terms of harmonic oscillators (say photon field) the frequency spectrum in the thermal equilibrium obeys Planck distribution. Besides this the system exhibits zero point fluctuations whose energy density is given by $\rho_0(f) = 8\pi^2 f^3$ ($\hbar = c = 1$) in the 3-dimensional case. Zero point fluctuations appear in many models of physical phenomena such as X-ray scattering in solids, Lamb shift, Casimir effect, and the interpretation of the Aharonov Bohm effect (for references see [E70]).

The zero point fluctuations are predicted to appear also in electronic systems, and the experimentally measured spectral density of the current noise measured by Koch [E196] in Josephson junctions provides a direct support for this prediction. The fluctuations have been observed up to the frequency of $f = .6$ THz which corresponds to a microwave wavelength of .5 mm.

It has been proposed by Beck and Mackey [E70] that if these fluctuations are associated with the vacuum energy, the total vacuum energy density associated with these fluctuations cannot exceed the recently measured dark energy density of the Universe: this leads to a cutoff frequency of $f_c = (1.69 \pm .05)$ THz for the measured frequency spectrum.

In TGD framework dark matter is ordinary matter at larger space-time sheets. First of all, the finite size of the space-time sheet poses an IR cutoff. p-Adic length scale hierarchy suggests that there is also UV cutoff that corresponds to the next p-adic length scale in the hierarchy. Hence the frequencies above the UV cutoff would correspond to oscillations at smaller space-time sheets. The interpretation would be in terms of de-coherence.

Thus a given space-time sheet would contain half octave of frequencies between the frequency cutoffs $f_{low}(k) = c/L(k) \propto 2^{-k/2}$ and $f_{up}(k) = c/L(k+1)$. Cutoff frequencies would come as half octaves for k integer as predicted by the most general form of the p-adic length scale hypothesis. The stronger form of the hypothesis favors prime values of k. Note that for $k = 179$ (prime) the predicted cutoff frequency would be $f_c(179) \simeq 1.74$ THz, which happens consistent with the prediction of [E70] deduced from the estimate for the dark matter density. This need not be an accident. According to the TGD based model explaining the finding that neutrino mass depends on the environment, neutrinos can condense on several space-time sheets and neutrinos in dense matter travel along $k = 179$ space-time sheet [K63].

The problem is that the spectral density would be same at every space-time sheet. One might however hope that the shift of the spectrum from a space-time sheet to another one manifests itself as some kind of structure at half-integer octaves of a basic frequency. By using a suitable arrangement one might be even able to eliminate some space-time sheet so that a gap would result. An interesting question is how the measurement instrument could be constructed to detect only the frequencies associated with a space-time sheet corresponding to a fixed value of k.

Chapter 3

TGD and Cosmology

3.1 Introduction

TGD inspired cosmology in its recent form relies on an ontology differing dramatically from that of GRT based cosmologies. Zero energy ontology (ZEO) states that all physical states have vanishing net quantum numbers so that all matter is creatable from vacuum. The hierarchy of dark matter identified as macroscopic quantum phases labeled by arbitrarily large values of Planck constant is second aspect of the new ontology. The values of the gravitational Planck constant assignable to space-time sheets mediating gravitational interaction are gigantic unless the second interacting particle is microscopic, in which case the identification $h_{gr} = GMm/v_0 = h_{eff} = n \times h$ makes sense. This implies that TGD inspired late cosmology might decompose into stationary phases corresponding to stationary quantum states in cosmological scales and critical cosmologies corresponding to quantum transitions changing the value of the gravitational Planck constant and inducing an accelerated cosmic expansion.

3.1.1 Zero Energy Ontology

In zero energy ontology one replaces positive energy states with zero energy states with positive and negative energy parts of the state at the boundaries of future and past direct light-cones forming a causal diamond. All conserved quantum numbers of the positive and negative energy states are of opposite sign so that these states can be created from vacuum. "Any physical state is creatable from vacuum" becomes thus a basic principle of quantum TGD and together with the notion of quantum jump resolves several philosophical problems (What was the initial state of universe?, What are the values of conserved quantities for Universe, Is theory building completely useless if only single solution of field equations is realized?).

At the level of elementary particle physics positive and negative energy parts of zero energy state are interpreted as initial and final states of a particle reaction so that quantum states become physical events. Equivalence Principle would hold true in the sense that the classical gravitational four-momentum of the vacuum extremal whose small deformations appear as the argument of configuration space spinor field is equal to the positive energy of the positive energy part of the zero energy quantum state.

Zero energy states decompose into positive and negative energy parts having identification as initial and final states of particle reaction in time scales of perception longer than the geometro-temporal separation T of positive and negative energy parts of the state. If the time scale of perception is smaller than T, the usual positive energy ontology applies.

In zero energy ontology inertial four-momentum is a quantity depending on the temporal time scale T used and in time scales longer than T the contribution of zero energy states with parameter $T_1 < T$ to four-momentum vanishes. This scale dependence alone implies that it does not make sense to speak about conservation of inertial four-momentum in cosmological scales. Hence it would be in principle possible to identify inertial and gravitational four-momenta and achieve strong form of Equivalence Principle. It however seems that this is not the correct approach to follow.

Negative energy virtual gravitons represented by topological quanta having negative time orientation and hence also negative energy. The absorption of negative energy gravitons by photons could explain the gradual red-shifting of the microwave background radiation. Negative energy virtual gravitons give also rise to a negative gravitational potential energy. Quite generally, negative energy virtual bosons build up the negative interaction potential energy. An important constraint to TGD inspired cosmology is the requirement that Hagedorn temperature $T_H \sim 1/R$, where R is CP_2 size, is the limiting temperature of radiation dominated phase.

3.1.2 GRT And TGD

The relationship between TGD and GRT was understood quite recently (2014). GRT space-time as effective space-time obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrices of space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical form of Equivalence Principle (EP) for the GRT limit in long length scales at least expressed in terms of Einstein's equations in given resolution scale with space-time sheets with size smaller than resolution scale represented as external currents.

One can consider also other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

3.1.3 Vacuum Extremals As Models For Cosmologies

The vacuum extremals are absolutely essential for the TGD based view about long length scale limit about gravitation. Effective GRT space time would be imbeddable as a vacuum extremal to H. This is just assumption albeit coming first in mind - especially so when one has not yet understood how GRT space-time emerges from TGD!

Already the Kähler action defined by CP_2 Kähler form J allows enormous vacuum degeneracy: any four-surface having Lagrangian sub-manifold of CP_2 as its CP_2 projection is a vacuum extremal. The dimension of these sub-manifolds is at most two. Robertson-Walker cosmologies correspond to vacua with respect to inertial energy and in fact with respect to all quantum numbers. They are not vacua with respect to gravitational charges defined as Noether charges associated with the curvature scalar. Also more general imbeddings of Einstein's equations are typically vacuum extremals with respect to Noether charges assignable to Kähler action since otherwise one ends up with conflict between imbeddability and dynamics. This suggests that physical states have vanishing net quantum numbers quite generally. The construction of quantum theory [K46, K28] indeed leads naturally to zero energy ontology stating that everything is creatable from vacuum.

3.1.4 Dark Matter Hierarchy And Hierarchy Of Planck Constants

The idea about hierarchy of Planck constants relying on generalization of the embedding space was inspired both by empirical input (Bohr quantization of planetary orbits) and by the mathematics of hyper-finite factors of type II_1 combined with the quantum classical correspondence.

Quantum classical correspondence suggests that Jones inclusions [A1] have space-time correlates [K115, K42]. There is a canonical hierarchy of Jones inclusions labeled by finite subgroups of SU(2) [?] This leads to a generalization of the embedding space obtained by gluing an infinite number of copies of H regarded as singular bundles over $H/G_a \times G_b$, where $G_a \times G_b$ is a subgroup of $SU(2) \times SU(2) \subset SL(2,C) \times SU(3)$. Gluing occurs along a factor for which the group is same. The generalized embedding space has clearly a book like structure with pages of books intersecting along 4-D sub-manifold $M^2 \times S^2$, S^2 a geodesic sphere of CP_2 characterizing the choice of quantization axes. Entire configuration space is union over "books" corresponding to various choices of this sub-manifold.

The groups in question define in a natural way the direction of quantization axes for for various isometry charges and this hierarchy seems to be an essential element of quantum measurement theory. Ordinary Planck constant, as opposed to Planck constants $\hbar_a = n_a\hbar_0$ and $\hbar_b = n_b\hbar_0$

appearing in the commutation relations of symmetry algebras assignable to M^4 and CP_2, is naturally quantized as $\hbar = (n_a/n_b)\hbar_0$, where n_i is the order of maximal cyclic subgroup of G_i. The hierarchy of Planck constants is interpreted in terms of dark matter hierarchy [K42]. What is also important is that $(n_a/n_b)^2$ appear as a scaling factor of M^4 metric so that Kähler action via its dependence on induced metric codes for radiative corrections coming in powers of ordinary Planck constant: therefore quantum criticality and vanishing of radiative corrections to functional integral over WCW does not mean vanishing of radiative corrections.

G_a would correspond directly to the observed symmetries of visible matter induced by the underlying dark matter [K42]. For instance, in living matter molecules with 5- and 6-cycles could directly reflect the fact that free electron pairs associated with these cycles correspond to $n_a = 5$ and $n_a = 6$ dark matter possibly responsible for anomalous conductivity of DNA [K42, K19] and recently reported strange properties of graphene [D5]. Also the tetrahedral and icosahedral symmetries of water molecule clusters could have similar interpretation [K39]. [D7].

A further fascinating possibility is that the observed indications for Bohr orbit quantization of planetary orbits [E87] could have interpretation in terms of gigantic Planck constant for underlying dark matter [K93] so that macroscopic and -temporal quantum coherence would be possible in astrophysical length scales manifesting itself in many way: say as preferred directions of quantization axis (perhaps related to the CMB anomaly) or as anomalously low dissipation rates.

Since the gravitational Planck constant is proportional to the product of the gravitational masses of interacting systems, it must be assigned to the field body of the two systems and characterizes the interaction between systems rather than systems themselves. This observation applies quite generally and each field body of the system (em, weak, color, gravitational) is characterized by its own Planck constant.

In the gravitational case the order of G_a is gigantic and at least GM_1m/v_0, $v_0 = 2^{-11}$ the favored value. The natural interpretation is as a discrete rotational symmetry of the gravitational field body of the system having both gravimagnetic and gravi-electric parts. The subgroups of G_a for which order is a divisor of the order of G_a define broken symmetries at the lower levels of dark matter hierarchy, in particular symmetries of visible matter.

The number theoretically simple ruler-and-compass integers having as factors only first powers of Fermat primes and power of 2 would define a physically preferred sub-hierarchy of quantum criticality for which subsequent levels would correspond to powers of 2: a connection with p-adic length scale hypothesis suggests itself. Ruler and compass hypothesis implies that besides p-adic length scales also their 3- and 5- multiples should be important.

A crucially important implication of dark matter hierarchy is macroscopic quantum coherence in astrophysical scales. This means that astrophysical systems tend to retain their M^4 size during cosmic expansion and change their size only during quantum jumps increasing the value of Planck constant. Cosmological quantum states can be modeled in terms of stationary Robertson-Walker cosmologies, which are extremals of curvature scalar. These cosmologies are determined apart from single parameter and string dominated having infinite horizon size.

Quantum phase transitions between stationary cosmologies are modellable in terms of quantum critical cosmologies which are also determined apart from single parameter. They correspond to accelerated cosmic expansion having interpretation in terms of increase of quantum scale due to the increases of gravitational Planck constant.

3.1.5 Quantum Criticality And Quantum Phase Transitions

TGD Universe is quantum counterpart of a statistical system at a critical temperature. As a consequence, topological condensate is expected to possess hierarchical, fractal like structure containing topologically condensed 3-surfaces with all possible sizes. Both Kähler magnetized and Kähler electric 3-surfaces ought to be important and string like objects indeed provide a good example of Kähler magnetic structures important in TGD inspired cosmology. In particular space-time is expected to be many-sheeted even at cosmological scales and ordinary cosmology must be replaced with many-sheeted cosmology. The possible presence of vapor phase consisting of free cosmic strings and possibly also elementary particles is second crucial aspects of TGD inspired cosmology.

Quantum criticality of TGD Universe supports the view that many-sheeted cosmology is in some sense critical, at least during quantum phase transitions. Criticality in turn suggests fractality. Phase transitions, in particular the topological phase transitions giving rise to new space-time sheets, are (quantum) critical phenomena involving no scales. If the curvature of the 3-space does not vanish, it defines scale: hence the flatness of the cosmic time=constant section of the cosmology implied by the criticality is consistent with the scale invariance of the critical phenomena. This motivates the assumption that the new space-time sheets created in topological phase transitions are in good approximation modellable as critical Robertson-Walker cosmologies for some period of time at least. It turns out that the critical cosmologies are naturally assignable to phase transitions and quantum criticality.

3.1.6 Critical And Over-Critical Cosmologies Are Highly Unique

Any one-dimensional sub-manifold of CP_2 allows global imbeddings of subcritical cosmologies whereas for a given 2-dimensional Lagrange manifold of CP_2 critical and overcritical cosmologies allow only one-parameter family of partial imbeddings.

The infinite size of the horizon for the imbeddable critical cosmologies is in accordance with the presence of arbitrarily long range fluctuations at criticality and guarantees the average isotropy of the cosmology. Imbedding is possible for some critical duration of time. The parameter labeling these cosmologies is a scale factor characterizing the duration of the critical period. These cosmologies have the same optical properties as inflationary cosmologies but exponential expansion is replaced with logarithmic one.

Cosmic expansion is accelerated for critical cosmologies. This gives good hopes of avoiding the introduction of cosmological constant and exotic forms of matter such as quintessence. Critical cosmologies might be completely universal and assignable to any quantum phase transitions in proper length scale. Dark matter hierarchy realized in terms of gigantic values of gravitational Planck constant predicts that even astrophysical systems are macroscopic quantum systems at the level of dark matter. This means that their M^4 size remains constant during cosmic expansion and can change only in quantum jump increasing the value of Planck constant. Critical cosmologies would be assigned to this kind of phase transitions occurring for large voids [K31].

Critical cosmology can be regarded as a “Silent Whisper amplified to Bang” rather than “Big Bang” and transformed to hyperbolic cosmology before its imbedding fails. Split strings decay to elementary particles in this transition and give rise to seeds of galaxies. In some later stage the hyperbolic cosmology can decompose to disjoint 3-surfaces. Thus each sub-cosmology is analogous to biological growth process leading eventually to biological death.

Critical and stationary cosmologies for which gravitational charges are conserved can be used as a building blocks of a fractal cosmology containing cosmologies containing... cosmologies. p-Adic length scale hypothesis allows a quantitative formulation of the fractality [K93]. Fractal cosmology predicts cosmos to have essentially same optical properties as inflationary scenario but avoids the prediction of unknown vacuum energy density. Fractal cosmology explains the paradoxical result that the observed density of the matter is much lower than the critical density associated with the largest space-time sheet of the fractal cosmology. Also the observation that some astrophysical objects seem to be older than the Universe, finds a nice explanation.

The key difference between inflationary and quantum critical cosmologies relates to the interpretation of the fluctuations of the microwave background. In the inflationary option fluctuations are amplified to long length scale fluctuations during inflationary expansion. In quantum critical cosmology the fluctuations be assigned to the quantum critical period accompanying macroscopic quantum fluctuations of the dark matter appearing in very long length scales during the phase transition so that no inflationary expansion is needed. Sub-critical cosmology is predicted after the inflationary period.

3.1.7 Cosmic Strings As Basic Building Blocks Of TGD Inspired Cosmology

Cosmic strings are the basic building blocks of TGD inspired cosmology and all structures including large voids, galaxies, stars, and even planets can be seen as pearls in a cosmic fractal necklaces consisting of cosmic strings containing smaller cosmic strings linked around them containing... During cosmological evolution the cosmic strings are transformed to magnetic flux tubes with smaller Kähler string tension and these structures are also key players in TGD inspired quantum biology.

Cosmic strings are of form $X^2 \times Y^2 \subset M^4 \times CP_2$, where X^2 corresponds to string orbit and Y^2 is a complex sub-manifold of CP_2. The gravitational mass of cosmic string is $M_{gr} = (1-g)/4G$, where g is the genus of Y^2. For $g = 1$ the mass vanishes. When Y^2 corresponds to homologically trivial geodesic sphere of CP_2 the presence of Kähler magnetic field is however expected to generate inertial mass which also gives rise to gravitational mass visible as asymptotic behavior of the metric of space-time sheet at which the cosmic string has suffered topological condensation. The corresponding string tension is in the same range that for GUT strings and explains the constant velocity spectrum of distant stars around galaxies.

For $g > 1$ the gravitational mass is negative. This inspires a model for large voids as space-time regions containing $g > 1$ cosmic string with negative gravitational energy and repelling the galactic $g = 0$ cosmic strings to the boundaries of the large void.

These voids would participate cosmic expansion only in average sense. During stationary periods the quantum states would be modellable using stationary cosmologies and during phase transitions increasing gravitational Planck constant and thus size of the large void they critical cosmologies would be the appropriate description. The acceleration of cosmic expansion predicted by critical cosmologies can be naturally assigned with these periods. Classically the quantum phase transition would be induced when galactic strings are driven to the boundary of the large void by the antigravity of big cosmic strings with negative gravitational energy. The large values of Planck constant are crucial for understanding of living matter so that gravitation would play fundamental role also in the evolution of life and intelligence.

3.1.8 Topics Of The Chapter

In the following this scenario is described in detail.

1. Basic ingredients of TGD inspired cosmology are introduced. The consequences of the imbeddability requirement are analyzed. The basic properties of cosmic strings are summarized and simple model for vapor phase as consisting of critical density of cosmic strings are introduced. Additional topics are thermodynamical aspects of cosmology, in particular the new view about second law and the consequences of Hagedorn temperature. Non-conservation of gravitational momentum is considered.
2. The evolution of the fractal cosmology is described in more detail.
3. TGD inspired cosmology is compared to inflationary scenario: in particular, the TGD based explanation for the recently observed flatness of 3-space and a possible solution to the Hubble constant controversy are discussed. Also the latest BICEP results providing claimed to demonstrate the presence of graviton interactions with CMB are discussed.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L7].

3.2 Basic Ingredients Of TGD Inspired Cosmology

In this section the general principles and ingredients of the TGD inspired cosmology are discussed briefly.

3.2.1 Many-Sheeted Space-rime Defines A Hierarchy Of Smoothed Out Space-times

The notion of quantum average space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) obtained by smoothing out details below the scale of resolution was inspired by renormalization group philosophy and for long time I regarded as the counterpart of GRT space-time. The rough idea was that quantum average effective space-times correspond to the preferred extremals of the Kähler action associated with the maxima of the Kähler function. Therefore the dynamics of the quantum average effective space-time is fixed and the stationarity requirement for the effective action should only select some physically preferred maxima of the Kähler function. The topologically trivial space-time of classical GRT cannot directly correspond to the topologically highly nontrivial TGD space-time but should be obtained only as an idealized, length scale dependent and essentially macroscopic concept. This allows the possibility that also the dynamics of the effective smoothed out space-times is determined by the effective action.

The space-time in length scale L would be obtained by smoothing out all topological details (particles) and by describing their presence using various densities such as energy momentum tensor $T_{\#}^{\alpha\beta}$ and Yang Mills current densities $J_{a\#}^{\alpha}$ serving as sources of classical electro-weak and color gauge fields (see **Fig. 3.1**). It is important to notice that the smoothing out procedure eliminates elementary particle type boundary components in all length scales: this suggests that the size of a typical elementary particle boundary component sets lower limit for the scale, where the smoothing out procedure applies.

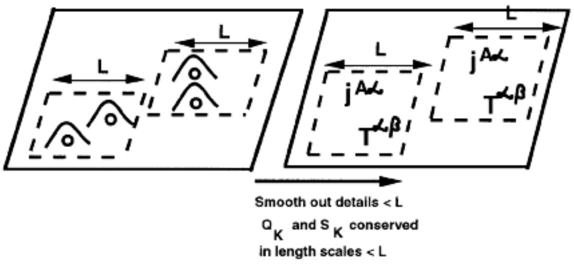

Figure 3.1: Intuitive definition of length scale dependent space-time

This notion can be critized.

1. The identification of smoothed out space-time as an extremal of Kähler action - most naturally vacuum extremal - is perhaps too strong. In particular, single sheetedness is too strong assumption if one assumes that the effective metric is induced metric. The identification also implicitly assumes single-sheetedness above the cutoff length scale.

2. The full realization that space-time of TGD Universe is many-sheeted in all scales led to the idea that GRT space-time is obtained by replacing the sheets of the many-sheeted space-time with Minkowski space endowed with effective metric which is sum of flat Minkowski metric and deviations of the metrics of the space-time sheets from Minkowski metric. This is the metric which defines the force experienced by test particle. It is of course possible that vacuum extremals are good approximations for the effective metric in asymptotic regions: typically in situations in which single sheet dominates.

3. The resulting picture would look like follows. Finite length scale resolution implies that the topological inhomogenities (space-time sheets and other topological inhomogenities) are treated as point-like objects and described in terms of energy momentum tensor of matter and various currents coupling to effective YM fields and effective metric important in length scales above the resolution scale. Einstein's equations with coupling to gauge fields and matter relate these currents to the Einstein tensor and metric tensor of the effective metric of M^4. Einstein's equations express Equivalence Principle and reduce it to Poincare invariance. For preferred extremals representable as graphs for map from $M^4 \rightarrow CP_2$ vanishing of the divergence of energy momentum tensor is highly suggestive and would in GRT framework lead to Einstein's equations: for preferred extremals this need not be the case but cannot excluded. The topological inhomogenities below cutoff scale serve determine the curvature of the effective metric. Gravitational constant and cosmological constant are predictions.

If one accepts (as I did for long time) the conjecture that effective metric can be expressed as induced metric for vacuum extremals one ends up with rather interesting vision. The smoothing out of details might not only activity of a theoretician, but that the many-sheeted space-time itself can be said to perform renormalization theory.

1. In TGD framework classical space-time is much more than a fiction produced by the stationary phase approximation. The localization in the so called zero modes, which corresponds to state function reduction in TGD, which occurs in each quantum jump (the delicacies due to macro-temporal quantum coherence will not be discussed here) means that the superposition of space-time surfaces in the final state of quantum jump, consists of space-time surfaces equivalent from the point of view of observer.
2. The notion of many-sheeted space-time predicts a hierarchy of space-time sheets labeled by p-adic primes $p \simeq 2^k$, k integer with primes and prime powers being in preferred role. The space-time sheets at a given level of hierarchy play a role of particles topologically condensed at larger space-time sheets. Hence the physics at larger space-time sheets is quite concretely a smoothed out version of the physics at smaller space-time sheets. Many-sheeted space-time itself performs renormalization group theory, and p-adic primes characterizing the sizes of the space-time sheets correspond to the fixed points of the renormalization group evolution.
3. There are good reasons to expect that the Kähler action vanishes for large enough space-time sheets, and that space-time sheets result as small deformations of the vacuum extremals at the long length scale limit. The equations derived from Einstein-Hilbert action for the induced metric can be posed as an additional constraint on stationary vacuum extremals for which the gravitational four momentum current is conserved. It must be however emphasized that the structure of Einstein tensor as a source of the wave equation for the metric is enough to guarantee that gravitational masses make themselves visible in the asymptotic behavior of the metric.

   An important difference to the standard view is that energy momentum tensor is defined by the Einstein tensor (plus possible contribution of metric rather than vice versa. EYM equations cannot in general be satisfied by induced metric without the introduction of particle currents. This conforms with the view that Einstein's equations relate to a statistical description of matter in terms of both particle densities and classical fields. The imbeddability to $H = M^4_+ \times CP_2$ means a rich spectrum of predictions not made by GRT. TGD inspired cosmology and TGD based model for the final state of the star are good examples of these predictions, and are consistent with experimental facts. One must however emphasize that the imbeddability of the effective GRT space-time might be un-necessarily strong assumption.

   Of course, already the postulate that microscopic theory behind TGD is based on TGD space-time is extremely powerful since the space-time surfaces as preferred extremals are extremely simple. One can even hope that the existing preferred extremals define a considerable fraction of the most interesting extremals (note however that explicit solutions representing Kähler magnetic and electric flux quanta are not known). The complexity would emerge only when one lumps the space-time sheets together.
4. Quantum measurement theory with a finite measurement resolution formulated in terms of Jones inclusions replacing effectively complex numbers as coefficient field of Hilbert space with non-commutative von Neumann algebra is the most recent formulation for the finite measurement resolution and leads to the rather fascinating vision about quantum TGD [K115, K42]. This formulation should have also a counterpart at space-time level and combined with number theoretical vision it leads to the emergence of discretization at space-time level realized in terms of number theoretical braids.

Dark matter hierarchy whose levels are labeled by the values of Planck constant brings in also something genuinely new.

1. Dark matter hierarchy means multi-sheetedness of space-time surfaces but single-sheetedness of 3-surfaces at the ends of space-time surfaces located at the boundaries of causal diamonds. [K46, K42]. This multi-sheetedness is essentially due to the non-determinism of Kähler action. Planck constant actually gives the number of sheets or more precisely, conformal equivalence classes of them, resulting from the failure of complete determinism. This kind of non-determinism is expected for the "field bodies" mediating various interactions and gravitational field bodies have a gigantic value of Planck constant.

2. The description of this hierarchy at the level of embedding space means the replacement of the effectie embedding space with a book like structure whose pages are copies of embedding space endowed with a finite and singular bundle projection corresponding to the group $Z_{n_a} \times Z_{n_b} \subset SO(3) \times SU(3)$. These groups act as discrete symmetries of field bodies.
3. The choice of these discrete subgroups realizes the choice of angular momentum and color quantization axes at the level of embedding space and thus realizes quantum classical correspondence. Any two pages of this book with 8-D pages intersect along common at most 4-D sub-manifold and the partonic 2-surfaces in the intersection can regarded as quantum critical systems in the sense that they correspond to a critical point of a quantum phase transition in general changing the value of Planck constant. Field bodies are four-surfaces mediating interactions between four-surfaces at different pages of this book.
4. The value of Planck constant makes itself visible in the scaling of M^4 part of the metric of H appearing in Kähler action. The scaling factor of M^4 metric m_{kl} equals to $(\hbar/\hbar_0)^2 = (n_a/n_b)^2$ as is clear from the fact that the Laplacian part of Schrödinger equation is at same time proportional to the contravariant metric and to $1/\hbar^2$. This means that radiative corrections are coded by the nonlinear dependence of the Kähler action on the induced metric. This means that all radiative corrections assignable to functional integral defined by exponent of Kähler function can vanish for preferred values of Kähler coupling strength. Number theoretic arguments require this.

Robertson-Walker cosmologies are the basic building block of standard cosmologies and sub-critical R-W cosmologies have a very natural place in TGD framework as Lorentz invariant cosmologies. Inflationary cosmologies are replaced with critical cosmologies being parameterized by a single parameter telling the duration of the critical cosmology. Over-critical cosmologies are also possible and have the same form as critical cosmologies and finite duration.

Why Robertson-Walker cosmologies?

Robertson Walker cosmology, which is a vacuum extremal of the Kähler action, is a reasonable idealization only in the length scales, where the density of the Kähler charge vanishes. Since (visible) matter and antimatter carry Kähler charges of opposite sign this means that Kähler charge density vanishes in length scales, where matter-antimatter asymmetry disappears on the average. This length scale is certainly very large in present day cosmology: in the proposed model for cosmology its present value is of the order of 10^8 light years: the size of the observed regions containing visible matter predominantly on their boundaries [E272]. That only matter is observed could be understood if it resides dominantly outside cosmic strings and antimatter inside cosmic strings.

Robertson Walker cosmology is expected to apply in the description of the condensate locally at each condensate level and it is assumed that the GRT based criteria for the formation of "structures" apply. In particular, the Jeans criterion stating that density fluctuations with size between Jeans length and horizon size can lead to the development of the "structures" will be applied.

Imbeddability requirement for RW cosmologies

Standard Robertson-Walker cosmology is characterized by the line element [E240]

$$ds^2 = f(a)da^2 - a^2(\frac{dr^2}{1-kr^2} + r^2 d\Omega^2) \ , \tag{3.2.1}$$

where the values $k = 0, \pm 1$ of k are possible.

The line element of the light cone is given by the expression

$$ds^2 = da^2 - a^2(\frac{dr^2}{1+r^2} + r^2 d\Omega^2) \ . \tag{3.2.2}$$

Here the variables a and r are defined in terms of standard Minkowksi coordinates as

$$\begin{aligned} a &= \sqrt{(m^0)^2 - r_M^2} \ , \\ r_M &= ar \ . \end{aligned} \tag{3.2.3}$$

Light cone clearly corresponds to mass density zero cosmology with $k = -1$ and this makes the case $k = -1$ is rather special as far embeddings are considered since any Lorentz invariant map $M^4_+ \to CP_2$ defines embedding

$$s^k = f^k(a) \ . \tag{3.2.4}$$

Here f^k are arbitrary functions of a.

$k = -1$ requirement guarantees imbeddability if the matter density is positive as is easy to see. The matter density is given by the expression

$$\rho = \frac{3}{8\pi G a^2}(\frac{1}{g_{aa}} + k) \ . \tag{3.2.5}$$

A typical embedding of $k = -1$ cosmology is given by

$$\begin{aligned} \phi &= f(a) \ , \\ g_{aa} &= 1 - \frac{R^2}{4}(\partial_a f)^2 \ . \end{aligned} \tag{3.2.6}$$

where ϕ can be chosen to be the angular coordinate associated with a geodesic sphere of CP_2 (any one-dimensional sub-manifold of CP_2 works equally well). The square root term is always positive by the positivity of the mass density and the embedding is indeed well defined. Since g_{aa} is smaller than one, the matter density is necessarily positive.

Critical and over-critical cosmologies

TGD allows the embeddings of a one-parameter family of critical over-critical cosmologies. Critical cosmologies are however not inflationary in the sense that they would involve the presence of scalar fields. Exponential expansion is replaced with a logarithmic one so that the cosmologies are in this sense exact opposites of each other. Critical cosmology has been used hitherto as a possible model for the very early cosmology. What is remarkable that this cosmology becomes vacuum at the moment of "Big Bang" since mass density behaves as $1/a^2$ as function of the light cone proper time. Instead of "Big Bang" one could talk about "Small Whisper amplified to bang" gradually. This is consistent with the idea that space-time sheet begins as a vacuum space-time sheet for some moment of cosmic time.

As an imbedded 4-surface this cosmology would correspond to a deformed future light cone having its tip inside the future light cone. The interpretation of the tip as a seed of a phase transition is possible. The embedding makes sense up to some moment of cosmic time after which the cosmology becomes necessarily hyperbolic. At later time hyperbolic cosmology stops expanding and decomposes to disjoint 3-surfaces behaving as particle like objects co-moving at larger cosmological space-time sheet. These 3-surfaces topologically condense on larger space-time sheets representing new critical cosmologies.

Consider now in more detail the embeddings of the critical and overcritical cosmologies. For $k = 0, 1$ the imbeddability requirement fixes the cosmology almost uniquely. To see this, consider as an example of $k = 0/1$ embedding the map from the light cone to S^2, where S^2 is a geodesic sphere of CP_2 with a vanishing Kähler form (any Lagrage manifold of CP_2 would do instead of S^2). In the standard coordinates (Θ, Φ) for S^2 and Robertson-Walker coordinates (a, r, θ, ϕ) for future light cone (, which can be regarded as empty hyperbolic cosmology), the embedding is given as

$$\begin{aligned} sin(\Theta) &= \frac{a}{a_1} \ , \\ (\partial_r\Phi)^2 &= \frac{1}{K_0}\left[\frac{1}{1-kr^2}-\frac{1}{1+r^2}\right] \ , \\ K_0 &= \frac{R^2}{4a_1^2} \ , \ \ k=0,1 \ , \end{aligned} \tag{3.2.7}$$

when Robertson-Walker coordinates are used for both the future light cone and space-time surface.

The differential equation for Φ can be written as

$$\partial_r\Phi = \pm\sqrt{\frac{1}{K_0}\left[\frac{1}{1-kr^2}-\frac{1}{1+r^2}\right]} \ . \tag{3.2.8}$$

For $k=0$ case the solution exists for all values of r. For $k=1$ the solution extends only to $r=1$, which corresponds to a 4-surface $r_M = m^0/\sqrt{2}$ identifiable as a ball expanding with the velocity $v = c/\sqrt{2}$. For $r \rightarrow 1$ Φ approaches constant Φ_0 as $\Phi - \Phi_0 \propto \sqrt{1-r}$. The space-time sheets corresponding to the two signs in the previous equation can be glued together at $r=1$ to obtain sphere S^3.

The expression of the induced metric follows from the line element of future light cone

$$ds^2 = da^2 - a^2(\frac{dr^2}{1-kr^2} + r^2d\Omega^2) \ . \tag{3.2.9}$$

The imbeddability requirement fixes almost uniquely the dependence of the S^2 coordinates a and r and the g_{aa} component of the metric is given by the same expression for both $k=0$ and $k=1$.

$$\begin{aligned} g_{aa} &= 1-K \ , \\ K &\equiv K_0\frac{1}{(1-u^2)} \ , \\ u &\equiv \frac{a}{a_1} \ . \end{aligned} \tag{3.2.10}$$

The embedding fails for $a \geq a_1$. For $a_1 \gg R$ the cosmology is essentially flat up to immediate vicinity of $a = a_1$. Energy density and “pressure” follow from the general equation of Einstein tensor and are given by the expressions

$$\begin{aligned} \rho &= \frac{3}{8\pi G a^2}(\frac{1}{g_{aa}}+k) \ , \ \ k=0,\pm 1 \ , \\ \frac{1}{g_{aa}} &= \frac{1}{1-K} \ , \\ p &= -(\rho + \frac{a\partial_a\rho}{3}) = -\frac{\rho}{3} + \frac{2}{3}K_0u^2\frac{1}{(1-K)(1-u^2)^2}\rho_{cr} \ , \\ u &\equiv \frac{a}{a_1} \ . \end{aligned} \tag{3.2.11}$$

Here the subscript “cr” refers to $k=0$ case. Since the time component g_{aa} of the metric approaches constant for very small values of the cosmic time, there are no horizons associated with this metric. This is clear from the formula

$$r(a) = \int_0^a \sqrt{g_{aa}}\frac{da}{a}$$

for the horizon radius.

g_{aa} vanishes at the limit $a \rightarrow a_f = a_1\sqrt{1-K_0}$. One has $a_f \simeq a_1$ in excellent approximation for cosmic values of a_1 as is clear from the definition of K_0. For $a = a_f$ the signature of the metric transforms to Euclidian. The relationship between cosmic proper time $t = \int \sqrt{g_{aa}}da$ and a is given in excellent approximation $a = t$ so that the situation is very much like for empty Minkowski space. 3-space is flat but there is no expansion with exponential rate as in the case of inflationary cosmologies. The expansion is accelerating since the counterpart of pressure is negative.

The mass density associated with these cosmologies behaves as $\rho \propto 1/a^2$ for very small values of the M^4_+ proper time. The mass in a co-moving volume is proportional to $a/(1-K)$ and goes to zero at the limit $a \rightarrow 0$. Thus, instead of Big Bang one has "Silent Whisper" gradually amplifying to Big Bang. The embedding fails at the limit $a \rightarrow a_1$. At this limit energy density becomes infinite. This cosmology can be regarded as a cosmology for which co-moving strings ($\rho \propto 1/a^2$) dominate the mass density as is clear also from the fact that the "pressure" becomes negative at big bang ($p \rightarrow -\rho/3$) reflecting the presence of the string tension. The natural interpretation is that cosmic strings condense on the space-time sheet which is originally empty.

The facts that the embedding fails and gravitational energy density diverges for $a = a_1$ necessitates a transition to a hyperbolic cosmology. For instance, a transition to radiation or matter dominated hyperbolic cosmology can occur at the limit $\theta \rightarrow \pi/2$. At this limit $\phi(r)$ must transform to a function $\phi(a)$. The fact, that vacuum extremals of Kähler action are in question, allows large flexibility for the modelling of what happens in this transition. Quantum criticality and p-adic fractality suggest the presence of an entire fractal hierarchy of space-time sheets representing critical cosmologies created at certain values of cosmic time and having as their light cone projection sub-light cone with its tip at some a=constant hyperboloid.

More general embeddings of critical and over-critical cosmologies as vacuum extremals

In order to obtain embeddings as more general vacuum extremals, one must pose the condition guaranteeing the vanishing of corresponding the induced Kähler form (see the Appendix of this book). Using coordinates $(r, u = cos(\Theta), \Psi, \Phi)$ for CP_2 the surfaces in question can be expressed as

$$\begin{aligned} r &= \sqrt{\frac{X}{1-X}} \ , \\ X &= D|k+u| \ , \\ u &\equiv cos(\Theta) \ , \ D = \frac{r_0^2}{1+r_0^2} \times \frac{1}{C} \ , \quad C = |k + cos(\Theta_0)| \ . \end{aligned} \tag{3.2.12}$$

Here C and D are integration constants.

These embeddings generalize to embeddings to $M^4 \times Y^2$, where Y^2 belongs to a family of Lagrange manifolds described in the Appendix of this book with induced metric

$$\begin{aligned} ds^2_{eff} &= \frac{R^2}{4}[s^{eff}_{\Theta\Theta} d\Theta^2 + s^{eff}_{\Phi\Phi} d\Phi^2] \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ . \end{aligned} \tag{3.2.13}$$

For $k \neq 1$ $u = \pm 1$ corresponds in general to circle rather than single point as is clear from the fact that $s^{eff}_{\Phi\Phi}$ is non-vanishing at $u = \pm 1$ so that u and Φ parameterize a piece of cylinder. The generalization of the previous embedding is as

$$sin(\Theta) = ka \quad \rightarrow \quad \sqrt{s^{eff}_{\Phi\Phi}} = ka \ . \tag{3.2.14}$$

For Φ the expression is as in the previous case and determined by the requirement that g_{rr} corresponds to $k = 0, 1$.

The time component of the metric can be expressed as

$$g_{aa} = 1 - \frac{R^2k^2}{4}\frac{s^{eff}_{\Theta\Theta}}{\frac{d\sqrt{s^{eff}_{\Phi\Phi}}}{d\Theta}} \tag{3.2.15}$$

In this case the $1/(1-k^2a^2)$ singularity of the density of gravitational mass at $\Theta = \pi/2$ is shifted to the maximum of $s^{eff}_{\Phi\Phi}$ as function of Θ defining the maximal value a_{max} of a for which the embedding exists at all. Already for $a_0 < a_{max}$ the vanishing of g_{aa} implies the non-physicality of the embedding since gravitational mass density becomes infinite.

The geometric properties of critical cosmology change radically in the transition to the radiation dominated cosmology: before the transition the CP_2 projection of the critical cosmology is two-dimensional. After the transition it is one-dimensional. Also the isometry group of the cosmology changes from $SO(3)\times E^3$ to $SO(3,1)$ in the transition. One could say that critical cosmology represents Galilean Universe whereas hyperbolic cosmology represents Lorentzian Universe.

String dominated cosmology

A particularly interesting cosmology string dominated cosmology with very nearly critical mass density. Assuming that strings are co-moving the mass density of this cosmology is proportional to $1/a^2$ instead of the $1/a^3$ behavior characteristic to the standard matter dominated cosmology. The line element of this metric is very simple: the time component of the metric is simply constant smaller than 1:

$$g_{aa} = K < 1 \ . \tag{3.2.16}$$

The Hubble constant for this cosmology is given by

$$H = \frac{1}{\sqrt{K}a} \ , \tag{3.2.17}$$

and the so called acceleration parameter [E240] k_0 proportional to the second derivative $\ddot{a}$ therefore vanishes. Mass density and pressure are given by the expression

$$\rho = \frac{3}{8\pi G K a^2}(1-K) = -3p \ . \tag{3.2.18}$$

What makes this cosmology so interesting is the absence of the horizons. The comparison with the critical cosmology shows that these two cosmologies resemble each other very closely and both could be used as a model for the very early cosmology.

Stationary cosmology

An interesting candidate for the asymptotic cosmology is stationary cosmology for which gravitational four-momentum currents (and also gravitational color currents) are conserved. This cosmology extremizes the Einstein-Hilbert action with cosmological term given by $\int(kR+\lambda)\sqrt{g}d^4x + \lambda$ and is obtained as a sub-manifold $X^4 \subset M^4_+ \times S^1$, where S^1 is the geodesic circle of CP_2 (note that embedding is now unique apart from isometries by variational principle).

For a vanishing cosmological constant, field equations reduce to the conservation law for the isometry associated with S^1 and read

$$\partial_a(G^{aa}\partial_a\phi\sqrt{g}) = 0 \ , \tag{3.2.19}$$

where ϕ denotes the angle coordinate associated with S^1. From this one finds for the relevant component of the metric the expression

$$g_{aa} = \frac{(1-2x)}{(1-x)} ,$$
$$x = (\frac{C}{a})^{2/3} . \quad (3.2.20)$$

The mass density and "pressure" of this cosmology are given by the expressions

$$\rho = \frac{3}{8\pi G a^2}\frac{x}{(1-2x)} ,$$
$$p = -(\rho + \frac{a\partial_a \rho}{3}) = -\frac{\rho}{9}\left[3 - \frac{2}{(1-2x)}\right] . \quad (3.2.21)$$

The asymptotic behavior of the energy density is $\rho \propto a^{-8/3}$. "Pressure" becomes negative indicating that this cosmology is dominated by the string like objects, whose string tension gives negative contribution to the "pressure". Also this cosmology is horizon free as are all string dominated cosmologies: this is of crucial importance in TGD inspired cosmology.

It should be noticed that energy density for this cosmology becomes infinite for $x = (C/a)^{2/3} = 1/2$ implying that this cosmology doesn't make sense at very early times so that the non-conservation of gravitational energy is necessary during the early stages of the cosmology.

Stationary cosmologies could define space-time correlates for macroscopic quantum states in cosmological length scales predicted by the hypothesis for the values of gravitational Planck constant [K46]. Together with critical cosmologies serving as space-time correlates for cosmic quantum jumps increasing gravitational Planck constant they could define basic building blocks for late cosmologies in TGD Universe.

Non-conservation of gravitational energy in RW cosmologies

In RW cosmology the gravitational energy in a given co-moving sphere of radius r in local light cone coordinates (a, r, θ, ϕ) is given by

$$E = \int \rho g^{aa}\partial_a m^0 \sqrt{g} dV . \quad (3.2.22)$$

The rate characterizing the non-conservation of gravitational energy is determined by the parameter X defined as

$$X \equiv \frac{(dE/da)_{vap}}{E} = \frac{(dE/da + \int |g^{rr}| p \partial_r m^0 \sqrt{g} d\Omega)}{E} , \quad (3.2.23)$$

where p denotes the pressure and $d\Omega$ denotes angular integration over a sphere with radius r. The latter term subtracts the energy flow through the boundary of the sphere.

The generation of the pairs of positive and negative (inertial) energy space-time sheets leads to a non-conservation of gravitational energy. The generation of pairs of positive and negative energy cosmic strings would be involved with the generation of a critical sub-cosmology. "Fermionic" pairs would have time-like separation and "bosonic" pairs would consist of parallel stringy space-time sheets connected by wormhole contacts.

For RW cosmology with subcritical mass density the calculation gives

$$X = \frac{\partial_a(\rho a^3/\sqrt{g_{aa}})}{(\rho a^3/\sqrt{g_{aa}})} + \frac{3pg_{aa}}{\rho a} . \quad (3.2.24)$$

This formula applies to any infinitesimal volume. The rate doesn't depend on the details of the embedding (recall that practically any one-dimensional sub-manifold of CP_2 defines a huge family of subcritical cosmologies). Apart from the numerical factors, the rate behaves as $1/a$ in the most physically interesting RW cosmologies. In the radiation dominated and matter dominated cosmologies one has $X=-1/a$ and $X=-1/2a$ respectively so that gravitational energy decreases in radiation and matter dominated cosmologies. For the string dominated cosmology with $k=-1$ having $g_{aa}=K$ one has $X=2/a$ so that gravitational energy increases: this might be due to the generation of dark matter due to pairs of cosmic strings with vanishing net inertial energy.

For the cosmology with exactly critical mass density Lorentz invariance is broken and the contribution of the rate from 3-volume depends on the position of the co-moving volume. Taking the limit of infinitesimal volume one obtains for the parameter X the expression

$$\begin{aligned} X &= X_1+X_2 \ , \\ X_1 &= \frac{\partial_a(\rho a^3/\sqrt{g_{aa}})}{(\rho a^3/\sqrt{g_{aa}})} \ , \\ X_2 &= \frac{pg_{aa}}{\rho a}\times \frac{3+2r^2}{(1+r^2)^{3/2}} \ . \end{aligned} \tag{3.2.25}$$

Here r refers to the position of the infinitesimal volume. Simple calculation gives

$$\begin{aligned} &X = X_1+X_2 \ , \\ &X_1 = \frac{1}{a}\left[1+3K_0u^2\frac{1}{1-K}\right] \ , \\ &X_2 = -\frac{1}{3a}\left[1-K-\frac{2K_0u^2}{(1-u^2)^2}\right]\times\frac{3+2r^2}{(1+r^2)^{3/2}} \ , \\ &\qquad K=\frac{K_0}{1-u^2} \ , \quad u=\frac{a}{a_0} \ , \quad K_0=\frac{R^2}{4a_0^2} \ . \end{aligned} \tag{3.2.26}$$

The positive density term X_1 corresponds to increase of gravitational energy which is gradually amplified whereas pressure term ($p<0$) corresponds to a decrease of gravitational energy changing however its sign at the limit $a\rightarrow a_0$.

The interpretation might be in terms of creation of pairs of positive and negative energy particles contributing nothing to the inertial energy but increasing gravitational energy. Also pairs of positive energy gravitons and negative anti-gravitons are involved. The contributions of all particle species are determined by thermal arguments so that gravitons should not play any special role as thought originally.

Pressure term is negligible at the limit $r\rightarrow\infty$ so that topological condensation occurs all the time at this limit. For $a\rightarrow 0, r\rightarrow 0$ one has $X>0\rightarrow 0$ so that condensation starts from zero at $r=0$. For $a\rightarrow 0, r\rightarrow\infty$ one has $X=1/a$ which means that topological condensation is present already at the limit $a\rightarrow 0$.

Both the existence of the finite limiting temperature and of the critical mass density imply separately finite energy per co-moving volume for the condensate at the very early stages of the cosmic evolution. In fact, the mere requirement that the energy per co-moving volume in the vapor phase remains finite and non-vanishing at the limit $a\rightarrow 0$ implies string dominance as the following argument shows.

Assuming that the mass density of the condensate behaves as $\rho\propto 1/a^{2(1+\alpha)}$ one finds from the expression

$$\rho\propto\frac{(\frac{1}{g_{aa}}-1)}{a^2} \ ,$$

that the time component of the metric behaves as $g_{aa}\propto a^{\alpha}$. Unless the condition $\alpha<1/3$ is satisfied or equivalently the condition

$$\rho < \frac{k}{a^{2+2/3}} \tag{3.2.27}$$

is satisfied, gravitational energy density is reduced. In fact, the limiting behavior corresponds to the stationary cosmology, which is not imbeddable for the small values of the cosmic time. For stationary cosmology gravitational energy density is conserved which suggests that the reduction of the density of cosmic strings is solely due to the cosmic expansion.

3.2.2 Cosmic Strings And Cosmology

The model for cosmic strings has forced to question all cherished assumptions including positive energy ontology, Equivalence Principle, and positivity of gravitational mass. The final outcome turned out to be rather conservative. Zero energy ontology is unavoidable, Equivalence Principle holds true universally but its general relativistic formulation makes sense only in long length scales, and gravitational mass has definite sign for positive/negative energy states. As a matter fact, all problems were created by the failure to realize that the expression of gravitational energy in terms of Einstein's tensor does not hold true in short length scales and must be replaced with the stringy expression resulting naturally by dimensional reduction of quantum TGD to string model like theory [K116, K46, L62].

The realization that GRT is only an effective description of many-sheeted space-time as Minkowski space M^4 endowed with effective metric whose deviation from flat metric is the sum of the corresponding deviations for space-time sheets in the region of M^4 considered resolved finally the problems and allowed to reduced Equivalence Principle to its form in GRT. Similar description applies also to gauge interactions.

TGD is therefore a microscopic theory and the physics for single space-time sheet is expected to be extremely simpler, much simpler than in gauge theory and general relativity already due to the fact that only four bosonic variables (4 embedding space coordinates) defined the dynamics at this level.

Zero energy ontology and cosmic strings

There are two kinds of cosmic strings: free and topological condensed ones and both are important in TGD inspired cosmology.

1. Free cosmic strings are not absolute minima of the Kähler action (the action has wrong sign). In the original identification of preferred extremals as absolute minima of Kähler action this was a problem. In the new formulation preferred extremals correspond to quantum criticality identified as the vanishing of the second variation of Kähler action at least for the deformations defining symmetries of Kähler action [K116, K46]. The symmetries very probably correspond to conformal symmetries acting as or almost as gauge symmetries. The number of conformal equivalence classes of space-time sheets with same Kähler action and conserved charges is expected to be finite and correspond to n in $h_{eff} = n \times h$ defining the hierarchy of Planck constants labelling phases of dark matter (see **Fig.** `http://tgdtheory.fi/appfigures/planckhierarchy.jpg` or **Fig. ??** in the appendix of this book).

   Criticality guarantees the conservation of the Noether charges assignable to the Kähler-Dirac action. Ideal cosmic strings are excluded because they fail to satisfy the conditions characterizing the preferred extremal as a space-time surface containing regions with both Euclidian and Minkowskian signature of the induced metric with light-like 3-surface separating them identified as orbits of partonic 2-surfaces carrying elementary particle quantum numbers. The topological condensation of CP_2 type vacuum extremals representing fermons generates negative contribution to the action and reduces the string tension and leaves cosmic strings still free.

2. If the topologically condensate of fermions has net Kähler charges as the model for matter antimatter asymmetry suggests, the repulsive interaction of the particles tends to thicken the cosmic string by increasing the thickness of its infinitely thin M^4 projection so that Kähler magnetic flux tubes result. These flux tubes are ideal candidates for the carriers of dark matter with a large value of Planck constant. The criterion for the phase transition increasing $\hbar$ is indeed the presence of a sufficiently dense plasma implying that perturbation theory in terms of $Z^2\alpha_{em}$ (Z is the effective number of charges with interacting with each other without screening effects) fails for the standard value of Planck constant. The phase transition $\hbar_0 \rightarrow \hbar$

reduces the value of $\alpha_{em} = e^2/4\pi\hbar$ so that perturbation theory works. This phase transition scales up also the transversal size of the cosmic string. Similar criterion works also for other charges. The resulting phase is anyonic if the resulting 2-surfaces containing almost spherical portions connected by flux tubes to each other encloses the tip of the causal diamond (CD). The proposal is that dark matter resides on complex anyonic 2-surfaces surrounding the tips of CDs.

3. The topological condensation of cosmic strings generates wormhole contacts represented as pieces of CP_2 type vacuum extremals identified as bosons composed of fermion-anti-fermion pairs. Also this generates negative action and can make cosmic string a preferred extremal of Kähler action. The earliest picture was based on dynamical cancelation mechanism involving generation of strong Kähler electric fields in the condensation whose action compensated for Kähler magnetic action. Also this mechanism might be at work. Cosmic strings could also form bound states by the formation graviton like flux tubes connecting them and having wormhole contacts at their ends so that again action is reduced.
4. One can argue that in long enough length and time scales Kähler action per volume must vanish so that the idealization of cosmology as a vacuum extremal becomes possible and there must be some mechanism compensating the positive action of the free cosmic strings. The general mechanism could be topological condensation of fermions and creation of bosons by topological condensation of cosmic strings to space-time sheets.

In this framework zero energy states correspond to cosmologies leading from big bang to big crunch separated by some time interval T of geometric time. Quantum jumps can gradually increase the value T and TGD inspired theory of consciousness suggests that the increase of T might relate to the shift for the contents of conscious experience towards geometric future. In particular, what is usually regarded as cosmology could have started from zero energy state with a small value of T.

Topological condensation of cosmic strings

In the original vision about topological condensation of cosmic strings I assumed that large voids represented by space-time sheets contain "big" cosmic string in their interior and galactic strings near their boundaries. The recent much simpler view is that there are just galactic strings which carry net fermion numbers (matter antimatter asymmetry). If they have also net em charge they have a repulsive interaction and tend to end up to the boundaries of the large void. Since this slows down the expansive motion of strings, the repulsive interaction energy increases and a phase transition increasing Planck constant and scaling up the size of the void occurs after which cosmic strings are again driven towards the boundary of the resulting larger void.

One cannot assume that the exterior metric of the galactic strings is the one predicted by assuming General Relativity in the exterior region. This would mean that metric decomposes as $g = g_2(X^2) + g_2(Y^2)$. $g(X^2)$ would be flat as also $g_2(Y^2)$ expect at the position of string. The resulting angle defect due to the replacement of plane Y^2 with cone would be large and give rise to lense effect of same magnitude as in the case of GUT cosmic strings. Lense effect has not been observed.

This suggests that General Relativity fails in the length scale of large void as far as the description of topologically condensed cosmic strings is considered. The constant velocity spectrum for distant stars of galaxies and the fact that galaxies are organized along strings suggests that these string generate in a good approximation Newtonian potential. This potential predicts constant velocity spectrum with a correct value velocity.

In the stationary situation one expects that the exterior metric of galactic string corresponds to a small deformation of vacuum extremal of Kähler action which is also extremal of the curvature scalar in the induced metric. This allows a solution ansatz which conforms with Newtonian intuitions and for which metric decomposes as $g = g_1 + g_3$, where g_1 corresponds to axis in the direction of string and g_3 remaining $1 + 2$ directions.

Dark energy is replaced with dark matter in TGD framework

The observed accelerating expansion of the Universe has forced to introduce the notion of cosmological constant in the GRT based cosmology. In TGD framework the situation is different.

1. The gigantic value of gravitational Planck constant implies that dark matter makes TGD Universe a macroscopic quantum system even in cosmological length scales. Astrophysical systems become stationary quantum systems which participate in cosmic expansion only via quantum phase transitions increasing the value of gravitational Planck constant.
2. Critical cosmologies, which are determined apart from a single parameter in TGD Universe, are natural during all quantum phase transitions, in particular the phase transition periods increasing the size of large voids and having interpretation in terms of an increase of gravitational Planck constant. Cosmic expansion is predicted to be accelerating during these periods. The mere criticality requires that besides ordinary matter there is a contribution $\Omega_\Lambda \simeq .74$ to the mass density besides visible matter and dark matter. In fact, also for the over-critical cosmologies expansion is accelerating.
3. In GRT framework the essential characteristic of dark energy is its negative pressure. In TGD framework critical and over-critical cosmologies have automatically effective negative pressure. This is essentially due to the constraint that Lorentz invariant vacuum extremal of Kähler action is in question. The mysterious negative pressure would be thus a signal about the representability of space-time as 4-surface in H and there is no need for any microscopic description in terms of exotic thermodynamics.

The values for the TGD counterpart of cosmological constant

One can introduce a parameter characterizing the contribution of dark mass to the mass density during critical periods and call it cosmological constant recalling however that the contribution does not correspond to dark energy. The value of this parameter is same as in the standard cosmology from mere criticality assumption.

What is new that p-adic fractality predicts that Λ scales as $1/L^2(k)$ as a function of the p-adic scale characterizing the space-time sheet implying a series of phase transitions reducing Λ. The order of magnitude for the recent value of the cosmological constant comes out correctly. The gravitational energy density assignable to the cosmological constant is identifiable as that associated with topologically condensed cosmic strings and magnetic flux tubes to which they are gradually transformed during cosmological evolution.

The naïve expectation would be the density of cosmic strings would behave as $1/a^2$ as function of M^4_+ proper time. The vision about dark matter as a phase characterized by gigantic Planck constant however implies that large voids do not expand in continuous manner during cosmic evolution but in discrete quantum jumps increasing the value of the gravitational Planck constant and thus increasing the size of the large void as a quantum state. Since the set of preferred values of Planck constant is closed under multiplication by powers of 2, p-adic length scales L_p, $p \simeq 2^k$ form a preferred set of sizes scales for the large voids.

TGD cosmic strings are consistent with the fluctuations of CMB

GUT cosmic strings were excluded by the fluctuation spectrum of the CMB background [E6]. In GRT framework these fluctuations can be classified to adiabatic density perturbations and isocurvature density perturbations. Adiabatic density perturbations correspond to overall scaling of various densities and do not affect the vanishing curvature scalar. For isocurvature density fluctuations the net energy density remains invariant. GUT cosmic strings predict isocurvature density perturbations while inflationary scenario predicts adiabatic density fluctuations.

In TGD framework inflation is replaced with quantum criticality of the phase transition period leading from the cosmic string dominated phase to matter dominated phase. Since curvature scalar vanishes during this period, the density perturbations are indeed adiabatic.

Matter-antimatter asymmetry and cosmic strings

Despite huge amount of work done during last decades (during the GUT era the problem was regarded as being solved!) matter-antimatter asymmetry remains still an unresolved problem of cosmology. A possible resolution of the problem is matter-antimatter asymmetry in the sense that cosmic strings contain antimatter and their exteriors matter. The challenge would be to understand the mechanism generating this asymmetry. The vanishing of the net gauge charges of cosmic string allows this symmetry since electro-weak charges of quarks and leptons can cancel each other.

The challenge is to identify the mechanism inducing the CP breaking necessary for the matter-antimatter asymmetry. Quite a small CP breaking inside cosmic strings would be enough.

1. The key observation is that vacuum extremals as such are not physically acceptable: small deformations of vacuum extremals to non-vacua are required. This applies also to cosmic strings since as such they do note present preferred extremals. The reason is that the preferred extremals involve necessary regions with Euclidian signature providing four-dimensional representations of generalized Feynman diagrams with particle quantum numbers at the light-like 3-surfaces at which the induced metric is degenerate.
2. The simplest deformation of vacuum extremals and cosmic strings would be induced by the topological condensation of CP_2 type vacuum extremals representing fermions. The topological condensation at larger space-time surface in turn creates bosons as wormhole contacts.
3. This process induces a Kähler electric fields and could induce a small Kähler electric charge inside cosmic string. This in turn would induce CP breaking inside cosmic string inducing matter antimatter asymmetry by the minimization of the ground state energy. Conservation of Kähler charge in turn would induce asymmetry outside cosmic string and the annihilation of matter and antimatter would then lead to a situation in which there is only matter.
4. Either galactic cosmic strings or big cosmic strings (in the sense of having large string tension) at the centers of galactic voids or both could generate the asymmetry and in the recent scenario big strings are not necessary. One might argue that the photon to baryon ratio $r \sim 10^{-9}$ characterizing matter asymmetry quantitatively must be expressible in terms of some fundamental constant possibly characterizing cosmic strings. The ratio $\epsilon = G/\hbar R^2 \simeq 4\times 10^{-8}$ is certainly a fundamental constant in TGD Universe. By replacing R with $2\pi R$ would give $\epsilon = G/(2\pi R)^2 \simeq 1.0 \times 10^{-9}$. It would not be surprising if this parameter would determine the value of r.

The model can be criticized.

1. The model suggest only a mechanism and one can argue that the Kähler electric fields created by topological condensates could be random and would not generate any Kähler electric charge. Also the sign of the asymmetry could depend on cosmic string. A CP breaking at the fundamental level might be necessary to fix the sign of the breaking locally.
2. The model is not the only one that one can imagine. It is only required that antimatter is somewhere else. Antimatter could reside also at other p-adic space-time sheets and at the dark space-time sheets with different values of Planck constant.

The needed CP breaking is indeed predicted by the fundamental formulation of quantum TGD in terms of the Kähler-Dirac action associated with Kähler action and its generalization allowing include instanton term as imaginary part of Kähler action inducing CP breaking [K116, K81] .

1. The key idea in the formulation of quantum TGD in terms of modified Dirac equation associated with Kähler action is that the Dirac determinant defined by the generalized eigenvalues assignable to the Dirac operator D_K equals to the vacuum functional defined as the exponent of Kähler function in turn identifiable as Kähler action for a preferred extremal, whose proper identification becomes a challenge. In ZEO (ZEO) 3-surfaces are pairs of space-like 3-surfaces assignable to the boundaries of causal diamond (CD) and for deterministic action principle this suggests that the extremals are unique. In presence of non-determinism the situation changes.
2. The huge vacuum degeneracy of Kähler action suggests that for given pair of 3-surfaces at the boundaries of CD there is a continuum of extremals with the same Kähler action and conserved charges obtained from each other by conformal transformations acting as gauge symmetries and respecting the light-likeness of wormhole throats (as well as the vanishing of the determinant of space-time metric at them). The interpretation is in terms of quantum criticality with the hierarchy of symmetries defining a hierarchy of criticalities analogous to the hierarchy defined by the rank of the matrix defined by the second derivatives of potential function in Thom's catastrophe theory.

3. The number of gauge equivalence classes is expected to be finite integer n and the proposal is that it corresponds to the value of the effective Planck constant $h_{eff} = n \times h$ so that a connection with dark matter hierarchy labelled by values of n emerges [K42].

4. This representation generalizes - at least formally. One could add an imaginary instanton term to the Kähler function and corresponding Kähler-Dirac operator D_K so that the generalized eigenvalues assignable to D_K become complex. The generalized eigenvalues correspond to the square roots of the eigenvalues of the operator $DD^\dagger = (p^k\gamma_k + \Gamma^n)(p^k\gamma_k + \Gamma^n)^\dagger$ acting at the boundaries of string world sheets carrying fermion modes and it seems that only space-like 3-surfaces contribute. Γ^n is the normal component of the vector defined by Kähler-Dirac gamma matrices. One can define Dirac determinant formally as the product of the eigenvalues of $DD^\dagger$.

   The conjecture is that the resulting Dirac determinant equals to the exponent of Kähler action and imaginary instanton term for the preferred extremal. The instanton term does not contribute to the WCW metric but could provide a first principle description for CP breaking and anyonic effects. It also predicts the dependence of these effects on the page of the book like structure defined by the generalized embedding space realizing the dark matter hierarchy with levels labeled by the value of Planck constant.

5. In the case of cosmic strings CP breaking could be especially significant and force the generation of Kähler electric charge. Instanton term is proportional to $1/h_{eff}$ so that CP breaking would be small for the gigantic values of h_{eff} characterizing dark matter. For small values of h_{eff} the breaking is large provided that the topological condensation is able to make the CP_2 projection of cosmic string four-dimensional so that the instanton contribution to the complexified Kähler action is non-vanishing and large enough. Since instanton contribution as a local divergence reduces to the contributions assignable to the light-like 3-surfaces X_l^3 representing topologically condensed particles, CP breaking is large if the density of topologically condensed fermions and wormhole contacts generated by the condensation of cosmic strings is high enough.

CP breaking at the level of CKM matrix

The CKM matrix for quarks contains CP breaking phase factors and this could lead to different evaporation rates for baryons and anti-baryons are different (quark cannot appear as vapor phase particle since vapor phase particle must have vanishing color gauge charges and in the recent vision about quantum TGD CP_2 type vacuum extremal which has not suffered topological condensation represents vacuum). The CP breaking at the level of CKM matrix would be implied by the instanton term present in the complexified Kähler action and Kähler-Dirac operator. The mechanism might rely on hadronic Kähler electric fields which are accompanied by color electric gauge fields proportional to induced Kähler form.

The topological condensation of quarks on hadronic strings containing weak color electric fields proportional to Kähler electric fields should be responsible for its string tension and this should in turn generate CP breaking. At the parton level the presence of CP breaking phase factor $exp(ikS_{CS})$, where $S_{CS} = \int_{X^4} J \wedge J + boundary\ term$ is purely topological Chern Simons term and naturally associated with the boundaries of space-time sheets with at most $D = 3$-dimensional CP_2 projection, could have something to do with the matter antimatter asymmetry. Note however that TGD predicts no strong CP breaking as QCD does [L62].

Development of strings in the string dominated cosmology

The development of the string perturbations in the Robertson Walker cosmology has been studied [E59] and the general conclusion seems to be that all the details smaller than horizon are rapidly smoothed out. One must of course take very cautiously the application of these result in TGD framework.

In present case, the horizon has an infinite size so that details in all scales should die away. To see what actually happens consider small perturbations of a static string along z-axis. Restrict the consideration to a perturbation in the y-direction. Using instead of the proper time coordinate t the "conformal time coordinate" τ defined by $d\tau = dt/a$ the equations of motion read [E59]

$$
\begin{aligned}
(\partial_\tau + \frac{2\dot{a}}{a})(\dot{y}U) &= \partial_z(y'U) \ , \\
U &= \frac{1}{\sqrt{1+(y')^2-\dot{y}^2}} \ .
\end{aligned} \tag{3.2.28}
$$

Restrict the consideration to small perturbations for which the condition $U \simeq 1$ holds. For the string dominated cosmology the quantity $\dot{a}/a = 1/\sqrt{K}$ is constant and the equations of motion reduce to a very simple approximate form

$$
\ddot{y} + \frac{2}{\sqrt{K}}\dot{y} - y'' = 0 \ . \tag{3.2.29}
$$

The separable solutions of this equation are of type

$$
\begin{aligned}
y &= g(a)(C\sin(kz) + D\cos(kz)) \ , \\
g(a) &= (\frac{a}{a_0})^r \ .
\end{aligned} \tag{3.2.30}
$$

where r is a solution of the characteristic equation $r^2 + 2r/\sqrt{K} + k^2 = 0$:

$$
r = -\frac{1}{\sqrt{K}}(1 \pm \sqrt{1-k^2K}) \ . \tag{3.2.31}
$$

For perturbations of small wavelength $k > 1/\sqrt{K}$, an extremely rapid attenuation occurs; $1/\sqrt{K} \simeq 10^{27}$! For the long wavelength perturbations with $k << 1/\sqrt{K}$ (physical wavelength is larger than t) the attenuation is milder for the second root of above equation: attenuation takes place as $(a/a_0)^{\sqrt{K}k^2/2}$. The conclusion is that irregularities in all scales are smoothed away but that attenuation is much slower for the long wave length perturbations.

The absence of horizons in the string dominated phase has a rather interesting consequence. According to the well known Jeans criterion the size L of density fluctuations leading to the formation of structures [E59] must satisfy the following conditions

$$
l_J < L < l_H \ , \tag{3.2.32}
$$

where l_H denotes the size of horizon and l_J denotes the Jeans length related to the sound velocity v_s and cosmic proper time as [E59]

$$
l_J \simeq 10v_st \ . \tag{3.2.33}
$$

For a string dominated cosmology the size of the horizon is infinite so that no upper bound for the size of the possible structures results. These structures of course, correspond to string like objects of various sizes in the microscopic description. This suggests that primordial fluctuations create structures of arbitrary large size, which become visible at much later time, when cosmology becomes string dominated again.

3.2.3 Thermodynamical Considerations

The new view about energy challenging the universal applicability of the second law of thermodynamics, the existence of "vapor phase" consisting mainly of cosmic strings and critical temperature equal to Hagedorn temperature are basic characteristics of TGD inspired cosmology. The recent view about preferred extremals cspin, newviews requires that cosmic strings are accompanied by a topological condensate of fermions (and possibly also super-symplectic bosons) represented by CP_2 type vacuum extremals. The corresponding light-like 3-surfaces define generalized Feynman diagram associated with the state.

New view about second law: first trial

Quantum classical correspondence suggests negative and positive energy strings (in the sense of zero energy ontology) tend to dissipate backwards in opposite directions of the geometric time in their geometric degrees of freedom. Time reversed dissipation of negative energy states looks from the point of view of systems consisting of positive energy matter self-organization and even self assembly. The matter at the space-time sheet containing strings in turn consists of positive energy matter and negative energy antimatter and also here same competition would prevail.

This tension suggests a general manner to understand the paradoxical aspects of the cosmic and biological evolution.

1. The first paradox is that the initial state of cosmic evolution seems to correspond to a maximally entropic state. Entropy growth would be naturally due to the emergence of matter inside cosmic strings giving them large p-adic entropy proportional to mass squared [K46, L62]. As strings decay to ordinary matter and transform to magnetic flux tubes the entropy related to translation degrees of freedom increases.
2. The dissipative evolution of matter at space-time sheets with positive time orientation would obey second law and evolution of space-time sheets with negative time orientation its geometric time reversal. Second law would hold true in the standard sense as long as one can neglect the interaction with negative energy antimatter and strings.
3. The presence of the cosmic strings with negative energy and time orientation could explain why gravitational interaction leads to a self-assembly of systems in cosmic time scales. The formation of supernovae, black holes and the possible eventual concentration of positive energy matter at the negative energy cosmic strings could reflect the self assembly aspect due to the presence of negative energy strings. An analog of biological self assembly identified as the geometric time reversal for ordinary entropy generating evolution would be in question.
4. In the standard physics framework the emergence of life requires extreme fine tuning of the parameters playing the role of constants of Nature and the initial state of the Universe should be fixed with extreme accuracy in order to predict correctly the emergence of life. In the proposed framework situation is different. The competition between dissipations occurring in reverse time directions means that the analog of homeostasis fundamental for the functioning of living matter is realized at the level of cosmic evolution. The signalling in both directions of geometric time makes the system essentially four-dimensional with feedback loops realized as geometric time loops so that the evolution of the system would be comparable to the carving of a four-dimensional statue rather than approach to chaos.
5. The apparent creation of order by the gravitational interactions is a mystery in the standard cosmology. A naïve application of the second law of thermodynamics suggests that in GRT based cosmology the most probable end state corresponds to a black hole dominated Universe since the entropy of the black hole is much larger than the entropy of a typical star with the same mass. TGD allows to consider several alternative solutions of this puzzle.
   (a) One might think that the hierarchy of Planck constants and the proportional of the black hole entropy to $\hbar$ could make black holes entropic so that they would not be favored final states of evolution. This argument turned out to be wrong. If black holes are dark black holes with a gigantic gravitational Planck constant the sheets of the blackhole surface for C-C option - which can be understood as a consequence of basic TGD- are not entropic since the entropy for single sheet of the covering is scaled down by $1/n_an_b$. For the entire covering one however obtains just the standard black-hole entropy since the number of sheets equals to $\hbar/\hbar_0$. This would suggest that entropy serves as a control variable in the sense that when it exceeds the threshold value, the partonic 2-surfaces at the ends of CD split to a surfaces in the covering. In the Bohr orbit model for solar system the value of Planck constant for the space-time sheets mediating gravitational interaction has the gigantic value $\hbar_{gr} = GM_1M_2/v_0$, where $v_0 = 2^{-11}$ holds true for inner planets. If $\hbar_{gr} = GM^2/v_0$ holds true for black holes, black hole entropy for single sheet of covering would be of order $1/v_0$. For $v_0 = 1/4$ this entropy would be of order single bit and Schwartshild radius would be equal to the scaled up Planck length $l_P = \sqrt{\hbar_{gr}}M$.

(b) The new view about second law inspires the view that gravitational self-organization corresponds to the temporal mirror image of dissipative time evolution for space-time sheets with negative time orientation competing with thermalization. In this situation negative energy dark black holes with small entropy are possible. The formation of black hole would look like breaking of second law from the point of view of observed with standard arrow of geometric time. The self organizing tendency of negative energy cosmic strings would compete with the opposite tendency of positive energy strings and ordinary matter could give rise to kind of gravitational homeostasis. Although black-hole like structures would result as outcome of gravitational self-organization they would not be sinks of information but have complex internal information carrying structure.

(c) It is also possible that elementary particles take the role of black holes in TGD framework. CP_2 type extremals are the counterparts of the black holes in TGD. Hawking-Bekenstein area law generalizes and states that elementary particles are carriers of p-adic entropy. Thus this p-adic entropy associated with the thermodynamics of Virasoro generator L_0 could be the counterpart of black hole entropy and the decay of the free cosmic strings to elementary particles would thus generate "invisible" entropy. The upper bound for the p-adic entropy depends on p-adic condensation level as $log(p)$ so that the generation of the new space-time sheets with increasing size (and thus p) generates new entropy since the particles, which are topologically condensed on these sheets, can have entropy of order $log(p)$.

New view about second law: second trial

The proposed new view about second law can be criticized of involving un-necessary assumptions about the details of dynamics. The real understanding of what second law inspired by TGD inspired theory of consciousness [K65] and zero energy ontology indeed allows to resolve the paradox without making this kind of assumptions.

The TGD inspired proposal is based on zero energy ontology and new view about the relationship between subjective and geometric time. In zero energy ontology causal diamonds (CDs) defined as intersections of future and past light-cones of Minkowski space define basic building blocks of world of classical worlds. CDs are thought to have position in M^4 characterized by tips of the light-cones: this guarantees Poincare invariance broken for individual CD. The world of classical worlds is union of sub-worlds of classical worlds defined by space-time surfaces inside given CD. CDs also define a fractal structure: CDs within CDs are possible and the assumption that the temporal distance between tips comes in powers of 2 implies p-adic length scale hypothesis. The hypothesis assigns to elementary particles time scale. For electron this time scale is.1 seconds, which corresponds to 10 Hz biorhythm associated with living systems. p-Adic length scale $L(193) = 2.1$ cm corresponds to $T(193) = 2.4 \times 10^{11}$ years, which gives order of magnitude for the age of the Universe. $L(193) = 2.1$. $L(199) = 16.7$ cm (length scale defined by human brain) corresponds to $T(199) = 1.5 \times 10^{13}$ years which could be regarded as an upper bound for the age of the Universe. Maybe brain hemispheres correspond to cosmological CD.

In TGD inspired theory of consciousness CDs serve as correlates for selves and CD can be identified as perceptive field of self defining the contents of consciousness of self. One can understand the arrow of psychological time emerging as apparent arrow of geometric time [K8]. Also the localization of sensory mental experiences to a narrow time interval instead of entire CD can be understood using same argument. Memories are however distributed to entire CD and this leads to a new view about what memories are.

Consider now the argument.

1. It is *subjective* time with respect to which second law holds true. It corresponds to the geometric time of observer *only locally.*

2. One can apply second law only for to what happens inside 4-D causal diamond (CD) corresponding to the time scale of observations: in positive energy ontology second law is applied at fixed value of geometric time and this leads to problems. In cosmology the relevant CD extends from the moment of big bang and to the recent time or even farther to geometric future. The idea that entropy grows as a function of cosmic time is simply wrong if you accept zero energy ontology.

More concrete picture would look like follows.

1. In each quantum jump re-creating entire 4-D Universe the entire geometric *future* and *past* changes.
2. Initial state of big bang in geometric sense- the zero energy states associated with small CDs near the light-cone boundary corresponding to Big Bang- are replaced by a new one at every moment of subjective time. Hence the "subjectively recent" initial state of Big Bang can be assumed to have maximum entropy as also states after that when the time scale of observations (size of CD) is the age of the universe. Gradually the entire geometric past ends up to a maximum entropy state in time scales below the time scale characterizing the time scale of observations. Thermal equilibrium in 4-D sense rather than 3-D sense results and the paradox disappears.

Note that the breaking of strict classical determinism of Kähler action allowing CDs within CDs picture is essential mathematical prerequisite: otherwise this picture does not make sense. It makes possible also space-time correlates for quantum jump sequence rather than only for quantum states.

Vapor phase

The structure of $M^4_+ \times CP_2$ suggests kinematic constraints on the cosmology: for the very small values of the M^4_+ proper time a the allowed 3-surfaces are necessarily CP_2 type surfaces or string like objects rather than pieces of M^4. As a consequence, topological evaporation should take place so that the space-time resembles enormous stringy diagram containing inside itself generalized Feynman diagram rather than continuous "classical" space-time. It indeed turns out that although the condensate could be present also in the primordial stage, the dominant contribution to the energy density is in the vapor phase during the primordial cosmology (and as it turns out, also in recent cosmology unless one takes into account the fact that at each level of condensate cosmic expansion is only local!).

The properties of the critical cosmology suggest that space-time sheets representing critical sub-cosmologies are generated only after some value $a_0 \sim R$ of light cone proper time, where $R \sim 10^{3.5}$ Planck times corresponds is CP_2 time. Before this moment there would be no macroscopic space-time but only vapor phase consisting of cosmic strings containing topologically condensed fermions and having purely geometric contact interactions. Thus the idea about primordial cosmology as a stage preceding the formation of space-time in the sense of General Relativity seems to be correct in TGD framework.

The key object of the TGD inspired cosmology is cosmic string with string tension $T \simeq .2 \times 10^{-6}/G$ of same order as the string tension of the GUT strings but with totally different physical and geometric interpretation. Cosmic strings play a key role in the very early string dominated cosmology, they could generate the matter antimatter asymmetry, they would lead to the formation of the large voids and galaxies, they would give rise to the galactic dark matter and also dominate the mass density in the asymptotic cosmology. Vapor phase cosmic strings containing dark might be present also in the cosmology of later times and correspond closely to the vacuum energy density of inflationary cosmologies: now however dark matter rather than dark energy would be in question.

For critical cosmology the gravitational energy of the co-moving volume is proportional to a at the limit $a \rightarrow 0$ and vanishes so that "Silent Whisper" amplifying to "Big Bang" is in question. The assumption that also vapor phase gravitational energy density (that is density in embedding space) behaves in similar manner implies the absence of initial singularities also at vapor phase level. Thus the condition

$$\rho \propto \frac{1}{a^2} , \tag{3.2.34}$$

and hence the string dominated primordial cosmology both in vapor phase and space-time sheets is an attractive hypothesis mathematically. The simplest hypothesis suggested by dimensional considerations is that the mass density of the vapor phase near $a = 0$ behaves as

$$\rho = n\frac{3}{8\pi Ga^2} \ . \tag{3.2.35}$$

Here n is numerical factor of order one. This hypothesis fixes the total energy density of the universe and sets strong constraints on energetics of the cosmology. At later stages topological condensation of the strings reduces the mass density in vapor phase and replaces n by a decreasing function of a. A very attractive hypothesis is that the value of of n is

$$n = 1 \ . \tag{3.2.36}$$

This gravitational energy density is same as that of critical cosmology at the limit of flatness and can be interpreted as TGD counterpart for the basic hypothesis of inflationary cosmologies. In inflationary cosmologies 70 per cent of the critical mass density is in form of vacuum energy deriving from cosmological constant. In TGD the counterpart of vacuum energy could be the mass density of cosmic strings in vapor phase in these sense that it topologically condensed on string like objects. By quantum classical correspondence it however corresponds to dark matter rather than genuine dark energy.

One can criticize the assumption as un-necessarily strong. There is no absolute necessity for the density of gravitational four-momentum of strings in M^4_+ to be conserved and one can consider the possibility that zero inertial energy string pairs are created from vacuum everywhere inside future light cone.

Long range interactions in the vapor phase are generated only by the exchange of particle like 3-surfaces and the long range interactions mediated by the exchange of the boundary components are impossible. The exchange of CP_2 type vacuum extremals has geometric cross section and the same is expected to be true for the other exchanges of the particle like surfaces. This would mean that the interaction cross sections are determined by the size of the particle of the order of CP_2 radius: $\sigma \simeq l^2 \sim 10^8 G$. In this sense the asymptotic freedom of gauge theories would be realized in the vapor phase. It should be emphasized that this assumption might be wrong and that the gauge interactions between two particles belonging to vapor phase and condensate respectively are certainly present and topological condensation can be indeed seen as this interaction. It should be noticed that the expansion of the Universe in vapor phase is slower than in condensed phase: the ratio of the expansion rates of the universe in vapor and condensed phases is given by the velocity of light in the condensed phase ($c_{\#} = \sqrt{g_{aa}}$).

Also the cross sections for the purely geometric contact interactions of free cosmic strings are extremely low. This suggests that vapor phase is in essentially in temperature zero string dominated state and that the energy density of strings behaves as $1/a^2$.

Limiting temperature

Since particles are extended objects in TGD, one expects the existence of the limiting temperature T_H (Hagedorn temperature as it is called in string models) so that the primordial cosmology is in Hagedorn temperature. A special consequence is that the contribution of the light particles to the energy density becomes negligible: this is in accordance with the string dominance of the critical mass cosmology. The value of T_H is of order $T_H \sim \hbar/R$, where R is CP_2 radius of order $R \sim 10^{3.5}\sqrt{G}$ and thus considerably smaller than Planck temperature. Note that T_H increases with Planck constant and one can wonder whether this increase continues only up to $T_H = \hbar_{cr}/R = \sqrt{\hbar_{cr}/G}$, which corresponds to the critical value $\hbar_{cr} = R^2/G$. The value $R^2/G = 3 \times 20^{23}\hbar_0$ is consistent with p-adic mass calculations and is favored by by number theoretical arguments [K46, L62].

The existence of limiting temperature gives strong constraint to the value of the light cone proper time a_F when radiation dominance must have established itself in the critical cosmology which gave rise to our sub-cosmology. Before the moment of transition to hyperbolic cosmology critical cosmology is string dominated and the generation of negative energy virtual gravitons builds up gradually the huge energy density density, which can lead to gravitational collapse, splitting of the strings and establishment of thermal equilibrium with gradually rising temperature. This temperature cannot however become higher than Hagedorn temperature T_H, which serves thus as the highest possible temperature of the effectively radiation dominated cosmology following the critical period. The decay of the split strings generates elementary particles providing the seeds of galaxies.

If most strings decay to light particles then energy density is certainly of the form $1/a^4$ of radiation dominated cosmology. This is not the only manner to obtain effective radiation dominance. Part of the thermal energy goes to the kinetic energy of the vibrational motion of strings and energy density $\rho \propto 1/a^2$ cannot hold anymore. The strings of the condensate is expected to obey the scaling law $\rho \propto 1/a^4$, $p = \rho/3$ [E59]. The simulations with string networks suggest that the energy density of the string network behaves as $\rho \propto 1/a^{2(1+v^2)}$, where v^2 is the mean square velocity of the point of the string [E71]. Therefore, if the value of the mean square velocity approaches light velocity, effective radiation dominance results even when strings dominate [E253]. In radiation dominated cosmology the velocity of sound is $v = 1/\sqrt{3}$. When v lowers to sound velocity one obtains stationary cosmology which is string dominated.

An estimate for a_F is obtained from the requirement that the temperature of the radiation dominated cosmology, when extrapolated from its value $T_R \simeq .3\text{eV}$ at the time about $a_R \sim 3\times 10^7$ years for the decoupling of radiation and matter to $a = a_F$ using the scaling law $T \propto 1/a$, corresponds to Hagedorn temperature. This gives

$$\begin{aligned} a_F &= a_R\frac{T_R}{T_H} \ , \\ T_H &= \frac{n}{R} \ , \qquad a_R \sim 3\times 10^7 \ y \ , \quad T_R = .27 \ eV \ . \end{aligned} \tag{3.2.37}$$

This gives a rough estimate $a_F \sim 3\times 10^{-10}$ seconds, which corresponds to length scale of order 7.7×10^{-2} meters. The value of a_F is quite large.

The result does not mean that radiation dominated sub-cosmologies might have not developed before $a = a_F$. In fact, entire series of critical sub-cosmologies could have developed to radiation dominated phase before the final one leading to our sub-cosmology is actually possible. The contribution of sub-cosmology i to the total energy density of recent cosmology is in the first approximation equal to the fraction $(a_F(i)/a_F)^4$. This ratio is multiplied by a ratio of numerical factors telling the number of effectively massless particle species present in the condensate if elementary particles dominate the mass density. If strings dominate the mass density (as expected) the numerical factor is absent.

For some reason the later critical cosmologies have not evolved to the radiation dominated phase. This might be due to the reduced density of cosmic strings in the vapor phase caused by the formation of the earlier cosmologies which does not allow sufficiently strong gravitational collapse to develop and implies that critical cosmology transforms directly to stationary cosmology without the intervening effectively radiation dominated phase. Indeed, condensed cosmic strings develop Kähler electric field compensating the huge positive Kähler action of free string and can survive the decay to light particles if they are not split. The density of split strings yielding light particles is presumably the proper parameter in this respect.

p-Adic length scale hypothesis allows rather predictive quantitative model for the series of sub-cosmologies [K93] predicting the number of them and allowing to estimate the moments of their birth, the durations of the critical periods and also the durations of radiation dominated phases. p-Adic length scale hypothesis allows also to estimate the maximum temperature achieved during the critical period: this temperature depends on the duration of the critical period a_1 as $T \sim n/a_1$, where n turns out to be of order 10^{30}. This means that if the duration of the critical period is long enough, transition to string dominated asymptotic cosmology occurs with the intervening decay of cosmic strings leading to the radiation dominated phase.

The existence of the limiting temperature has radical consequences concerning the properties of the very early cosmology. The contribution of a given massless particle to the energy density becomes constant. So, unless the number of the effectively massless particle families $N(a)$ increases too fast the contribution of the effectively massless particles to the energy density becomes negligible. The massive excitations of large size (string like objects) are indeed expected to become dominant in the mass density.

What about thermodynamical implications of dark matter hierarchy?

The previous discussion has not mentioned dark matter hierarchy labeled by increasing values of Planck constants and predicted macroscopic quantum coherence in arbitrarily long scales. In TGD Universe dark matter hierarchy means also a hierarchy of conscious entities with increasingly long span of memory and higher intelligence [K102, K38].

This forces to ask whether the second law is really a fundamental law and whether it could reflect a wrong view about existence resulting resulting when all these dark matter levels and information associated with conscious experiences at these levels is neglected. For instance, biological evolution difficult to understand in a universe obeying second law relies crucially on evolution as gradual progress in which sudden leaps occur as new dark matter levels emerge.

TGD inspired consciousness suggests that Second Law holds true only for the mental images of a given self (a system able to avoid bound state entanglement with environment [K102]) rather than being a universal physical law. Besides these mental images there is irreducible basic awareness of self and second law does not apply to it. Also the hierarchy of higher level conscious entities is there. In this framework second law would basically reflect the exclusion of conscious observers from the physical model of the Universe.

3.2.4 Structure Of WCW In Zero Energy Ontology And Robertson-Walker Cosmology

Zero energy ontology has meant a real quantum leap in the understanding of the exact structure of the world of classical worlds (WCW). There are however still open questions and interpretational problems. The following comments are about a quantal interpretation of Robertson-Walker cosmology provided by zero energy ontology.

1. The light-like 3-surfaces -or equivalently corresponding space-time sheets- inside a particular causal diamond (CD) is the basic structural unit of world of classical worlds (WCW)). CD (or strictly speaking $CD \times CP_2$) is characterized by the positions of the tips for the intersection of the future and past directed light-cones defining it. The Lorentz invariant temporal distance a between the tips allows to characterize the CDs related by Lorentz boosts and $SO(3)$ acts as the isotropy group of a given CD. CDs with a given value of a are parameterized by Lobatchevski space -call it $L(a)$- identifiable as $a^2 = constant$ hyperboloid of the future light-cone and having interpretation as a constant time slice in TGD inspired cosmology.
2. The moduli space for CDs characterized by a given value of a is $M^4 \times L(a)$. If one poses no restrictions on the values of a, the union of all CDs corresponds to $M^4 \times M^4_+$, where M^4_+ corresponds to the interior of future light-cone. F-theorist might get excited about dimension 12 for $M^4 \times M^4_+ \times CP_2$: this is of course just a numerical co-incidence.
3. p-Adic length scale hypothesis follows if it is assumed that a comes as octaves of CP_2 time scale: $a_n = 2^n T_{CP_2}$. For this option the moduli space would be discrete union $\cup_n M^4 \times L(a_n)$. A weaker condition would be that a comes as prime multiples of T_{CP_2}. In this case the preferred p-adic primes $p \simeq 2^n$ correspond to $a = a_n$ and would be natural winners in fight for survival. If continuum is allowed, p-adic length scale hypothesis must be be a result of dynamics alone. Algebraic physics favors quantization at the level of moduli spaces.
4. Also unions of CDs are possible. The proposal has been that CDs form a fractal hierarchy in the sense that there are CDs within CDs but that CDs to not intersect. A more general option would allow also intersecting CDs.

Consider now the possible cosmological implications of this picture. In TGD framework Robertson-Walker cosmologies correspond to Lorentz invariant space-time surfaces in M^4_+ and the parameter a corresponds to cosmic time.

1. First some questions. Could Robertson Walker coordinates label CDs rather than points of space-time surface at deeper level? Does the parameter a labeling CDs really correspond to cosmic time? Do astrophysical objects correspond to sub-CDs?
2. An affirmative answer to these questions is consistent with classical causality since the observer identified as -say- upper boundary of CD receives classical positive/negative energy

signals from sub-CDs arriving with a velocity not exceeding light-velocity. $M^4 \times L(a)$ decomposition provides also a more precise articulation of the answer to the question how the non-conservation of energy in cosmological scales can be consistent with Poincare invariance. Note also that the empirically favored sub-critical Robertson-Walker cosmologies are unavoidable in this framework whereas the understanding of sub-criticality is one of the fundamental open problems in General Relativity inspired cosmology.

3. What objections against this interpretation can one imagine?

    (a) Robertson-Walker cosmology reduces to future light-cone only at the limit of vanishing density of gravitational mass. One could however argue that the scaling factor of the metric of $L(a)$ need not be a^2 corresponding to M^4_+ but can be more general function of a. This would allow all Robertson-Walker cosmologies with sub-critical mass density. This argument makes sense also for $a = a_n$ option.

    (b) Lorentz invariant space-time surfaces in CD provide an elegant and highly predictive model for cosmology. Should one give up this model in favor of the proposed model? This need not to be the case. Quantum classical correspondence requires that also the quantum cosmology has a representation at space-time level.

4. What is then the physical interpretation for the density of gravitational mass in Robertson-Walker cosmology in the new framework? A given CD characterized by a point of $M^4 \times L(a)$, has certainly a finite gravitational mass identified as the mass assignable to positive/negative energy state at either upper or lower light-like boundary or CD. In zero energy ontology this mass is actually an average over a superposition of pairs of positive and negative energy states with varying energies. Since quantum TGD can be seen as square root of thermodynamics the resulting mass has only statistical meaning. One can assign a probability amplitude to CD as a wave function in $M^4 \times L(a)$ as a function of various quantum numbers. The cosmological density of gravitational mass would correspond to the quantum average of the mass density determined by this amplitude. Hence the quantum view about cosmology would be statistical as is also the view provided by standard cosmology.

5. Could cosmological time be really quantized as $a = a_n = 2^n T(CP_2)$? Note that other values of a are possible at the pages of the book like structure representing the generalized embedding space since a scales as $r = \hbar/\hbar_0$ at these pages. All rational multiples of a_n are possible for the most general option. The quantization of a does not lead to any obvious contradiction since M^4 time would correspond to the time measured in laboratory and there is no clock keeping count about the flow of a and telling whether it is really discrete or continuous. It might be however possible to deduce experimental tests for this prediction since it holds true in all scales. Even for elementary particles the time scale a is macroscopic. For electron it is.1 seconds, which defines the fundamental bio-rhythm.

6. The quantization for a encourages also to consider the quantization for the space of Lorentz boosts characterized by $L(a)$ obtained by restricting the boosts to a subgroup of Lorentz group. A more concrete picture is obtained from the representation of $SL(2, C)$ as Möbius transformations of plane [A13].

    (a) The restriction to a discrete subgroup of Lorentz group $SL(2, C)$ is possible. This would allow an extremely rich structure. The most general discrete subgroup would be subgroup of $SL(2, Q_C)$, where Q_C could be any algebraic extension of complex rational numbers. In particular, discrete subgroups of rotation group and powers L^n of a basic Lorentz boost $L = exp(\eta_0)$ to a motion with a fixed velocity $v_0 = tanh(\eta_0)$ define lattice like structures in $L(a)$. This would effectively mean a cosmology in 4-D lattice. Note that everything is fully consistent with the basic symmetries.

    (b) The alternative possibility is that all points of $L(a)$ are possible but that the probability amplitude is invariant under some discrete subgroup of $SL(2, Q_C)$. The first option could be seen as a special case of this.

    (c) One can consider also the restriction to a discrete subgroup of $SL(2, R)$ known as Fuschian groups Fuschian. This would mean a spontaneous breaking of Lorentz symmetry since only boosts in one particular direction would be allowed. The modular group $SL(2, Z)$ and its subgroups known as congruence subgroups [?] define an especially interesting hierarchy of groups if this kind: the tessellations of hyperbolic plane provide a concrete representation for the resulting hyperbolic geometries.

(d) Is there any experimental support for these ideas. There are indeed claims for the quantization of cosmic recession velocities of quasars [E176] discussed in [K31] in terms of TGD inspired classical cosmology. For non-relativistic velocities this means that in a given direction there are objects for which corresponding Lorentz boosts are powers of a basic boost $exp(\eta_0)$. The effect could be due to a restriction of allowed Lorentz boosts to a discrete subgroup or to the invariance of the cosmic wave function under this kind of subgroup. These effects should take place in all scales: in particle physics they could manifest themselves as a periodicity of production rates as a function of η closely related to the so called rapidity variable y.

7. The possibility of CDs would mean violent collisions of sub-cosmologies. One could consider a generalized form of Pauli exclusion principle denying the intersections.

3.2.5 Is Cosmic Expansion A Mere Coordinate Effect?

There is a very interesting article about cosmic expansion or rather a claim about the possible absence of cosmic expansion (`http://tinyurl.com/o6vyb9g`).

The argument based on the experimental findings of a team of astrophysicists led by Eric Lerner goes as follows. In non-expanding cosmology and also in the space around us (Earth, Solar system, Milky Way), as similar objects go further away, they look fainter and smaller. Their surface brightness remains constant. In Big Bang theory objects actually should appear fainter but bigger. Therefore the surface brightness- total luminosity per area - should decrease with distance. Besides this cosmic redshift would be dimming the light.

Therefore in expanding Universe the most distant galaxies should have hundreds of times dimmer surface brightness since the surface are is larger and total intensity of light emitted more or less the same. Unless of course, the total luminosity increases to compensate this: this would be of course total adhoc connection between dynamics of stars and cosmic expansion rate.

This is not what observations tell [E205]. Therefore one could conclude that Universe does not expand and Big Bang theory is wrong.

The conclusion is of course wrong. Big Bang theory certainly explains a log of things. I try to summarize what goes wrong.

(a) It is essential to make clear what time coordinate one is using. When analyzing motions in Solar System and Milky Way, one uses flat Minkowski coordinates of Special Relativity. In this framework one observes no expansion.

(b) In cosmology one uses Robertson-Walker coordinates (a, r, θ, ϕ). a and r are the relevant ones. In TGD inspired cosmology R-W coordinates relate to the spherical variant (t, r_M, θ, ϕ) of Minkowski coordinates by formulas

$$a^2 = t^2 - r_M^2, r_M = a \times r \ .$$

The line element of metric is

$$ds^2 = g_{aa}da^2 - a^2[dr^2/(1 + r^2) + r^2 d\Omega^2] \ .$$

and at the limit of empty cosmology one has $g_{aa} = 1$.

In these coordinates the light-cone of empty Minkowski space looks like expanding albeit empty cosmology! a is just the light-cone proper time. The reason is that cosmic time coordinate labels the a=constant hyperboloids (hyperbolic spaces) rather than M^4 time=constant snapshots. This totally trivial observation is extremely important concerning the interpretation of cosmic expansion. Often however trivial observations are the most difficult ones to make.

Cosmic expansion would to high extend a coordinate effect but why should one then use R-W coordinates in cosmic scales? Why not Minkowski coordinates?

(a) In Zero Energy Ontology (ZEO) - something very specific to TGD - the use of these coordinates is natural since zero energy states are pairs of positive and negative energy states localized about boundaries of causal diamonds (CD), which are intersections of future and past directed light-cones having pieces of light-cone boundary as their boundaries. The geometry of CD suggests strongly the use of R-W coordinates associated with either boundary of CD. The question “Which boundary?” would lead to digression to TGD inspired theory of consciousness [K8].

(b) Thus the correct conclusion is that local objects such as stars and galaxies and even large objects do not participate in the expansion when one looks the situation in local Minkowski coordinates - which by the way are uniquely defined in TGD framework since space-time sheets are surfaces in $M^4 \times CP_2$. In General Relativity the identification of the local Minkowski coordinates could be highly non-trivial challenge.

In TGD framework local systems correspond to their own space-time sheets and Minkowski coordinates are natural for the description of the local physic since space-time sheet is by definition a space-time region allowing a representation as a graph of a map from M^4 to CP_2. The effects caused by the CD inside which the space-time surfaces in question belong to the local physics are negligible. Cosmic expansion is therefore not a mere coordinate effect but directly reflects the underlying ZEO.

(c) In General Relativity one cannot assume imbeddability of the generic solution of Einstein's equations to $M^4 \times CP_2$ and this argument does not work. The absence of local expansion have been known for a long time and Swiss Cheese cosmology has been proposed as a solution. Non-expanding local objects of constant size would be the holes of Swiss Cheese and the cheese around them would expand. In TGD framewor the holes of cheese would correspond to space-time sheets. All space-time sheets can be in principle non-expanding and they have suffered topological condensation to large space-time sheets.

One should also make clear GRT space-time is only an approximate concept in TGD framework.

(a) Einstein-Yang-Mills space-time is obtained from the many-sheeted space-time of TGD by lumping together the sheets and describing it as a region of Minkowski space endowed with an effective metric which is sum of flat Minkowski metric and deviations of the metrics of sheets from Minkowski metric. Same procedure is applied to gauge potentials.

(b) The motivation is that test particle topologically condenses at all space-time sheets present in given region of M^4andthe effects of the classical fields at these sheets superpose. Thus superposition of fields is replaced with superposition of their effects and linear superposition with set theoretic union of space-time sheets. TGD inspired cosmology *assumes* that the effective metric obtained in this manner allows embedding as vacuum extremal of Kähler action. The justification of this assumption is that it solves several key problems of GRT based cosmology.

(c) The number of field patterns in TGD Universe is extremely small - given by preferred extremals - and the relationship of TGD to GRT and YM theories is like that of atomic physics to condensed matter physics. In the transition to GRT-Yang-Mills picture one gets rid of enormous topological complexity but the extreme simplicity at the level of fields is lost. Only four CP_2 coordinates appear in the role of fields in TGD framework and at GRT Yang-Mills limit they are replaced with a large number of classical fields.

This quantum view about cosmology will not be discussed further in this chapter most of which is written much before the emergence of zero energy ontology.

3.3 TGD Inspired Cosmology

Quantum criticality suggests strongly quantum critical fractal cosmology containing cosmologies inside cosmologies such that each sub-cosmology is critical before transition to hyperbolic phase. The general conceptual framework represented in the previous section give rather strong constraints on fractal cosmology. There are reasons to believe that the scenario to be represented, although by no means the final formulation, contains several essential features of what might be called TGD inspired cosmology.

Some remarks about interpretation are in order.

1. Equivalence Principle is assumed to hold true quite generally and the expression of gravitational four-momentum in terms of Einstein tensor is assumed to make sense in long length scales.

2. Robertson-Walker cosmology is taken as a statistical description replacing the many-sheeted space-time with single space-time sheet. The vanishing of density of inertial energy would be due to the smoothing out of the topological condensate of CP_2 type vacuum extremals and cosmic strings (carrying also these condensates) and giving to the inertial four-momentum a contribution expressible in terms of Einstein tensor in statistical description.

3. TGD inspired cosmology has the structure of Russian doll. Dark matters at various pages of the Big Book defined by the hierarchy of Planck constants defines one hierarchy of cosmologies. There is also a hierarchy of causal diamonds (CDs) defined as the intersection of future and past directed light-cones. Zero energy state associated with CDs could be interpreted as not so big bang followed by not so big crunch as the time scale of CD becomes long enough. In short time scales the interpretation would be in terms of particle reaction. Sub-cosmologies can be generated from vacuum spontaneously so that one has a p-adic hierarchy of cosmologies within cosmologies. If the size of CD is assumed to come as power of 2 as the geometry of CD suggests, p-adic length scale hypothesis follows.

4. The understanding of the non-conservation of gravitational energy associated with a co-moving volume has been a long standing issue in TGD. The conservation of four-momentum is an un-necessarily strong assumption in statistical description since in zero energy ontology four-momentum is conserved only inside causal diamond (CD). The rate for change of the gravitational energy in a given co-moving volume could be interpreted to reflect this statistical non-conservation. The original interpretation for the non-conservation of gravitational energy was in terms of topological evaporation and condensation of space-time sheets and cosmic strings carrying topological condensate of particles, and more generally, in terms of the transfer of energy between different space-time sheets. One cannot exclude the presence of also these mechanisms.

In the following discussion only a sub-cosmology associated with a given CD is discussed and the considerations assume that the time scale of observations is short as compared with the time scale of CD so that positive energy ontology is a good approximation.

3.3.1 Primordial Cosmology

TGD inspired cosmology has primordial phase in which only vapor phase containing only cosmic strings containing topological condensate of fermions is present and lasting to $a \sim R$. During this period it is not possible to speak about space-time in the sense of General Relativity. The energy density and "pressure" of cosmic strings in vapor phase (densities in $M^4_+ \times CP_2$ are assumed to be

$$\begin{aligned} \rho_V &= \frac{3}{8\pi G a^2} \ , \\ p &= -\frac{\rho}{3} \ . \end{aligned} \tag{3.3.1}$$

This assumption would mean that gravitational energy and various gravitational counterparts of the classical charges associated with the isometries of H are conserved during vapor phase period. This assumption guarantees consistency with the critical cosmology and by the requirement that the mass per co-moving volume vanishes at the limit $a \rightarrow 0$ so that the Universe is apparently created from nothing. The interactions between cosmic strings are pure contact interactions and extremely weak and it seems natural to assume that the temperature of the vapor phase is zero.

3.3.2 Critical Phases

The mere finiteness of Kähler action does not allow vapor phase to endure indefinitely since the Kähler magnetic action of the free cosmic string is positive and infinite at the limit of infinite duration. The topological condensate of fermions necessarily present reduces this action. Second manner to reduce it is creation of space-time sheets at which cosmic strings condense on them and generate Kähler electric fields compensating the positive Kähler magnetic action. Individual cosmic string can however stay as free cosmic string for arbitrarily long time since the finite magnetic Kähler action can be compensated by the correspondingly larger electric Kähler action. In principle cosmic strings can be created as pairs of positive and negative inertial energy cosmic strings from vacuum in vapor phase.

In accordance with this primordial phase is followed by the generation of critical cosmologies as "Silent Whispers" amplifying to "Big Bangs" basically by emission of ordinary matter by Hawking radiation, and possibly by gravitational heating made possible by the emission of negative energy virtual gravitons as "acceleration radiation" as matter gains strong inertial energies in gravitational fields. p-Adic length scale hypothesis allows to deduce estimates for the typical time for the creation of a critical cosmology, the duration of the critical phase, the temperature achieved during the critical phase and the duration of the hyperbolic expanding phase possibly following it and transforming to a phase in which cosmic expansion ceases and space-time surface behaves like a particle.

What is of extreme importance is that the deceleration parameter q associated with critical and over-critical cosmologies is negative. It is given by

$$q = -K_0 \frac{K_0 u^2}{1-u^2-K_0} < 0 \ , \ \ u = a/a_1 \ , \tag{3.3.2}$$

where K_0 and a_1 are the parameters appearing in $g_{aa} = 1-K$, $K = K_0/(1-u^2)$.

The rate of change for Hubble constant is

$$\frac{dH/ds}{H^2} = -(1+q) \ , \tag{3.3.3}$$

so that one must have $q < -1$ in order to have acceleration. This holds true for $a > \sqrt{(1-K_0)/(1+K_0)}a_1$. This allows to understand the recently discovered acceleration of late cosmology as assignable to a quantum critical phase transition increasing cosmological constant and thus leading to an increase of the size of the large void.

This model is discussed in detail in [K31] and shown to explain the observed jerk about 13 billion years changing deceleration to acceleration. The recently observed cold spot in cosmic microwave background [E1] can be understood as a presence of large void with size of about 10^8 ly already about 10^{10} years ago. This conforms with the hypothesis that large voids increase their size in phase transition like manner rather than participating in cosmic expansion in continuous manner.

3.3.3 Radiation Dominated Phases

p-Adic length scale hypothesis suggests that the typical moments of birth $a_0(k)$ and durations $a_1(k)$ for the critical cosmologies satisfy $a_0(k) \sim L(k)$ and $a_1(k) \sim L(k)$, where k prime or power of prime, $L(k) = l \times 2^{k/2}$, $l = R \simeq 10^{3.5}$ Planck lengths, and n is a numerical factor. p-Adic length scale hypothesis suggest that the temperature just after the transition to the effectively radiation dominated phase is

$$\begin{aligned} T(k) &= \tfrac{n}{L(k)} \ , && \text{for } k > k_{cr} \ , \\ T(k) &= T_H \sim \tfrac{1}{R} \ , && \text{for } k \leq k_{cr} \ . \end{aligned} \tag{3.3.4}$$

Here n is rather large numerical factor. Since $a_F \sim 2.7 \times 10^{-10}$ seconds which corresponds to length scale $L \simeq .08$ meters roughly to p-adic length scale $L(197) \simeq .08$ meters (which by the way corresponds to the largest p-adic length scale associated with brain, a cosmic joke?!), should correspond to the establishment of Hagedorn temperature, one has the conditions

$$\begin{aligned} k_{cr} &= 197 \ , \\ n &\simeq 2^{197/2} \sim 10^{30} \sim \frac{m_{CP_2}^2}{m_p^2} \ . \end{aligned}$$

Thus n is in of same order of magnitude as the ratio of the CP_2 mass squared ($m_{CP_2} \simeq 10^{-3.5}$ Planck masses) to proton mass squared.

Dimensional considerations suggest also that the energy density in the beginning of the radiation dominated phase (in case that it is achieved) is

$$\rho = nT^4(k) \ , \tag{3.3.5}$$

where n a numerical factor of order one. n does not count for the number of light particle species since the thermal energy of strings could give rise to the effective radiation dominance. Furthermore, if ordinary matter is created by Hawking radiation and by radiation generated by the ends of split strings, the large mass and Hagedorn temperature as a limiting temperature could make impossible the generation of particle genera higher the three lowest ones (see [K26] for the argument why $g > 2$ particle families (g denotes the genus of partonic 2-surface) have ultra heavy masses). Thus it seems that the infinite number of fermion families cannot lead to an infinite density of thermal energy and why their presence leaves no trace in present day cosmology.

When the time parameter a_1 of the critical cosmology grows too large, it cannot anymore generate radiation dominated phase since the temperature remains too low. Previous considerations suggest that the maximum value of a_1 is roughly $a_1(max) = a_F \sim 3 \times 10^{-10}$. After this critical sub-cosmologies would transform directly to the stationary cosmologies.

Radiation dominated phase transforms to matter dominated phase and possibly decomposes to disjoint 3-surfaces with size of order horizon size at the same time. p-Adic length scale hypothesis suggests that the duration of the radiation dominated phase with respect to the proper time of the space-time sheet is or order

$$s_2 \equiv \int_{a_1}^{a_1+a_2} \sqrt{g_{aa}} da \sim L(k) \ . \tag{3.3.6}$$

In case of "our" radiation dominated cosmology this gives correct estimate for the moment of time when transition to matter dominated phase occurs since one has $L(k) \sim a_F$ in this case.

That the decomposition to disjoint 3-surfaces occurs after the transition to matter dominated phase is suggested by simple arguments. First of all, the decomposition into regions has obviously interpretation as a formation of visible structures around hidden structures formed by pairs of cosmic strings thickened to magnetic flux tubes. Secondly, of decomposition occurs, the photons coming from distant objects "drop" to the space-time sheets representing later critical cosmologies. This explains why the optical properties of the Universe seem to be those of a critical cosmology.

3.3.4 Matter Dominated Phases

The transition to the matter dominated phase followed by the decoupling of the radiation and matter makes possible the formation of structures. This is expected to involve compression of matter to dense regions and to lead to at least a temporary decomposition of the matter dominated cosmology to disjoint 3-surfaces condensed on larger space-time surfaces. The reason is that Jeans length becomes smaller than the size of the horizon. A galaxy model based on the assumption that the region around the two curved ends of a split cosmic string serve as a seed for galaxy formation has been considered in [K31]. In particular, it was found that Jeans criterion leads to a lower bound for the string tension of the galactic strings of same order of magnitude as the string tension of the cosmic strings.

If one assumes that matter dominated regions continue cosmological expansion so that the radius of region equals to the horizon size $R = a^{1/2}$, the fraction of the volume occupied by matter dominated regions grows as $\epsilon(a) = (a/a_R)\epsilon(a_R)$. In recent cosmology the regions have joined together for $\epsilon(a_R) > 10^{-3}$ which would suggest that ultimately asymptotic string dominated cosmology results. One could however argue that matter dominated cosmology does not expand. Taking into account the horizon size of about 5×10^5 light years at the time of the transition to matter dominance, this would mean that galaxies do not participate in cosmic expansion but move as particles on background cosmology.

TGD allows an entire sequence of matter dominated cosmologies associated with the radiation dominated cosmologies labeled by p-adic primes allowed by p-adic length scale hypothesis. Forgetting the delicacies related to nucleo-synthesis, the matter densities associated with these matter dominated cosmologies are scaled down like $(a_1(k)/a_F)^3$ where $a_1(k)\sin L(k)$ is the moment at which the corresponding critical cosmology was created. Thus the latest matter dominated cosmology gives the dominating contribution to the matter density.

Sooner or later matter dominated cosmology becomes string dominated. A good guess is that the transition to string dominance occurs if cosmic expansion of the space-time sheet indeed continues. To see what is involved consider the bounds on the total length of string per large void with size of order $a_* \sim 10^8$ light years. This length can be parameterized as $L = nL(void)$. The requirement that the mass density of the strings is below the critical density gives, when applied to the large void with size of $a_* \simeq 10^8$ light years at recent time a, gives

$$\frac{3}{4\pi}\frac{nT}{a_*^2} < \rho_s = \frac{3}{8\pi G a^2} \quad . \tag{3.3.7}$$

Here one has $T \simeq .22 \times 10^{-6}\frac{1}{G}$. This gives roughly

$$n < 2 \times 10^6 \times (\frac{a_*}{a})^2 \quad . \tag{3.3.8}$$

The second constraint is obtained from the requirement that the ratio of the string mass per void to the mass of the ordinary matter per void is not too large at present time. Using the expression

$$\rho_m \simeq \frac{3}{32\pi G}\frac{a_*}{a^3} \quad ,$$

with $a_* \sim 10^8$ years (time of recombination) and the expression for the string mass per void one has

$$\frac{\rho_s(a)}{\rho_m a(a)} = n \times 1.8 \times 10^{-6}(\frac{a}{a_*})^3 \quad . \tag{3.3.9}$$

for the ratio of the densities. For $a = 10^{10+1/2}$ ly the two conditions give

$$\begin{aligned} n &< 20 \quad , \\ \frac{\rho_s(a)}{\rho_m} &\simeq n \times 18 \times \sqrt{10} \quad . \end{aligned} \tag{3.3.10}$$

These equations suggest that n cannot be much larger than one and suggest the simple picture in which the Kähler charges associated with the "big" string in the interior of the large void and with the galactic strings on the boundaries of the void cancel each other. The minimal value of n is clearly $n = 4$ corresponding to a straight string in the interior of the void. It must be however emphasized that these estimates are rough.

The rate $dlog(E_{gr})/dlog(a)$ for the change of gravitational energy in co-moving volume at present moment in the matter dominated cosmology is determined by

$$\frac{(d\rho_c/da)}{\rho_c} = -\frac{1}{2a} \sim 10^{-11}\frac{1}{year} \quad . \tag{3.3.11}$$

The rate is of the same order of magnitude as the rate of energy production in Sun [E240] so that the rates dE_{I+}/da and dE_{I-}/da for the change of positive and negative contributions to the inertial energy would be of same order of magnitude and sum up to dE_{gr}/da.

3.3.5 Stationary Cosmology

The original term was asymptotic cosmology but stationary cosmology is a better choice if one accepts the notion of quantal cosmology. In this kind of situation expects that stationary cosmologies correspond to stationary quantum states during which topologically condensed space-time sheets do not participate the cosmic expansion but co-move as point like particles.

During stationary cosmology one has $dE_{gr}/da = 0$. In zero energy ontology the interpretation is that the apparent non-conservation of gravitational (=inertial) energy due to the change of time scale characterizing typical causal diamond (CD) is not present anymore. The following argument suggests that asymptotic cosmology is equivalent with the assumption that the cosmic expansion of the space-time sheets almost halts. The expression for the horizon radius for the cosmology decomposing into critical, radiation and matter dominated and asymptotic phases. The expression for the radius reads as

$$R = \int_0^a \sqrt{g_{aa}}\frac{da}{a} = R_0 + R_{as} \ ,$$

where R_0 corresponds from the cosmology before the transition to the asymptotic cosmology and R_{as} gives the contribution after that. Formally this expression is infinite since the contribution to R_{as} from the critical period is infinite. Since one has $g_{aa} \to 1$ asymptotically R_{as} is in good approximation equal to $R_{as} = log(a/a_{as})$, where a_{as} denotes the time for the transition to asymptotic cosmology. This means that the growth of the horizon radius becomes logarithmically slow: $dR(a)/da = 1/a$. A possible interpretation is that the sizes of various structures during asymptotic cosmology are almost frozen. One can however consider the possibility that the disjoint structures formed during the period of matter dominated phase expand and fuse together so that the there is basically single structure of infinite size formed by the join along boundaries condensate of various matter carrying regions.

From the known estimates [E272] for the total length of galactic string per void one obtains estimate for the needed string tension of the galactic strings. The resulting string tension is indeed of the order of GUT string tension $T \sim 10^{-6}/G$. It will be found later that Jeans criterion gives same lower bound for the string tension of the galactic strings. The resulting contribution to the mass density is smaller than the critical mass density so that no inconsistencies result.

The simplest mechanism generating galactic strings is the splitting of long strings to pieces resulting from the collisions of the strings during very early string dominated cosmology. This mechanism implies that galaxies should form linear structures: this seems indeed to be the case [E272].

The recent mass density of the strings is considerably larger than that associated with the visible matter. This implies string dominance sooner or later. There are two possible alternatives for the string dominated cosmology.

1. Cosmology with co-moving strings.
2. Stationary cosmology, which seems a natural candidate for the asymptotic cosmology.

Consider first the co-moving string dominated cosmology. The mass density for the string dominated Robertson-Walker cosmology (necessarily smaller than critical density now) is given by the expression

$$\begin{aligned} \rho &= \frac{3}{8\pi G a^2}(\frac{1}{K}-1) \ , \\ H^2 &= \frac{1}{Ka^2} \ , \end{aligned} \tag{3.3.12}$$

and is a considerable fraction of the critical mass density unless the parameter K happens to be very close to 1. Sub-criticality gives the condition

$$c_\# = \sqrt{K} > \frac{1}{\sqrt{2}} \ .$$

The requirement that the gravitational force dominates over the Kähler force implies that the value of $g_{aa} = K$ differs considerably from unity. The recent value of the quantity Ka^2 can be evaluated from the known value of the Hubble constant. By the previous argument, the ratio of the string mass density to the matter mass density for the recent time $a \sim 10^{10+1/2}$ years is about $\rho_s/\rho_m \sim 50$. This gives the estimates for the light velocity in the condensate and the ratio of the density to the critical density

$$\begin{aligned} c_\# &= \sqrt{K} \simeq .93 \ , \\ \Omega \equiv \frac{\rho}{\rho_{cr}} &\simeq .16 \ . \end{aligned} \tag{3.3.13}$$

One also obtains an estimate for the time a_1, when the transition to string dominated phase has occurred

$$\begin{aligned} \rho_{m0} &= \rho_m(\frac{a}{a_1})^3 = \rho_s = \rho_{s0}(\frac{a}{a_1})^2 \ , \\ a_1 &= \frac{\rho_m}{\rho_s} a \sim 6 \times 10^8 \ \text{ly} \ . \end{aligned} \tag{3.3.14}$$

The fraction of the total mass density about the critical mass density is about 4 per cent an perhaps two small.

Consider next the stationary cosmology. The relevant component of the metric and mass density are given by the expressions

$$\begin{aligned} g_{aa} &= \frac{(1-2x)}{(1-x)} \ , \\ \rho &= \frac{3}{8\pi G a^2}\frac{x}{(1-2x)} \ , \\ x &= (\frac{a_1}{a})^{2/3} \ . \end{aligned} \tag{3.3.15}$$

Asymptotically the mass density for this cosmology behaves as
$\rho \simeq 1/a^{2(1+v^2)}$, $v^2 = 1/3$ and "pressure" ($p \simeq -1/9\rho$) is negative indicating that strings indeed dominate the mass density. The results from the numerical simulation of the GUT cosmic strings suggest the interpretation of v^2 as mean square velocity for a long string [E71]: the relative velocities of the big strings seem rather large.

The transition to the stationary cosmology must take place at some finite time since the energy density

$$\rho = \frac{3}{8\pi G a^2}\frac{(\frac{a_1}{a})^{2/3}}{(1-2(\frac{a_1}{a})^{2/3})} \ , \tag{3.3.16}$$

is negative, when the condition $a < a_1(1/2)^{-3/2}$ holds true. An estimate for the parameter a_1 is obtained by requiring that the ratio of the mass density to the recent density of the ordinary matter is of order $r \sim 200$ at time $a \sim 10^{10.5}$ ly (this requires $n = 4$, which corresponds to the lower bound for the length of cosmic string per void): $\frac{\rho}{\rho_m}(a) = r$. This gives for the parameter x, the time parameter a_1, the velocity of light in the condensate and for the fraction of the mass density about the critical mass density the following estimates:

$$\begin{aligned} x &= \frac{\frac{r}{4}\frac{a_*}{a}}{1+\frac{r}{2}\frac{a_*}{a}} \simeq .16 \ , \\ a_1 &\simeq 2 \times 10^9 \ \text{ly} \ , \\ c_\# &\simeq .93 \ , \\ \Omega &\simeq .16 \ . \end{aligned} \tag{3.3.17}$$

Apart from the value of the transition time, the results are essentially the same as for the string dominated cosmology. By increasing the amount of a string per void one could reduce the value of the light velocity in the condensate. The experimental lower bound on Ω is $\Omega > .016$ and the favored value is $\Omega \sim .3$. The latter value would require $n \simeq 6.8$ instead of the lower bound $n = 4$ and give $c_{\#} \simeq .87$

If the proposed physical interpretation for dE_{gr}/da in terms of the energy production inside the stars is correct, then stationary cosmology should be a good idealization for the cosmology provided that the rate of the energy production of stars is negligibly small as compared with the total energy density. This is expected to case, when the energy density of the string like objects begins to dominate over the ordinary matter.

String dominated and stationary cosmologies have certain common characteristic features:

1. Horizons are absent. This implies that the formation of the structures of arbitrarily large size should be possible at this stage and in certain sense the formation of these structures can be regarded as a manifestation of the structures already formed during the very early string dominated cosmology.
2. The so called acceleration parameter q_0 vanishes asymptotically for the stationary cosmology and identically for string dominated cosmology: The deceleration parameter

$$q = \frac{1}{3}\frac{x}{(1-2x)(1-x)} \ . \tag{3.3.18}$$

The value of q is positive and conforms with the identification of stationary cosmology as counterpart of stationary state in which topologically condensed space-time sheets co-move but do not expand.

For the matter dominated cosmology the value of this parameter is $q_0 = 1/2$ and positive ($a \simeq t^{2/3}$). The earlier attempts made to evaluate the value of this parameter from the observations are consistent with the value $q_0 = 0$ as well as with the value $q_0 = 1/2$ [E240]. Quite recent determinations of the parameter [E152] are consistent with $q_0 \leq 0$ but exclude large negative values of q_0 typical for the inflationary scenarios with a large value of the cosmological constant.

3.4 Inflationary Cosmology Or Quantum Critical Cosmology?

The measurements [E68] allow to deduce information about the curvature properties of the space-time in cosmological scales. These experimental findings force the conclusion that cosmological time= constant sections are essentially flat after the decoupling of the em radiation from matter which occurred roughly one half million years after the Big Bang. The findings allowed to build a much more detailed model for the many-sheeted cosmology leading also to a considerable increase in the understanding of the general principles of TGD inspired cosmology. In the following the observational facts are discussed first and then TGD based explanation relying on the many-sheeted cosmology is briefly discussed. One ends up to a cosmological realization of quantum criticality in terms of a fractal cosmology having Russian doll like structure. The cosmologies within cosmologies are critical cosmologies before transition to hyperbolicity followed by an eventual decay to disjoint non-expanding 3-surfaces.

Critical cosmologies can be regarded as "Silent Whispers" amplifying to Big Bangs and are generated from vacuum by the gradual condensation of cosmic strings to initially empty and flat space-time sheets. The transition to hyperbolicity involves topological condensation of the remnants of the earlier sub-cosmologies. Hyperbolic period is followed by a decay to disjoint non-expanding 3-surfaces, remnants of the sub-cosmology. There is thus a strong analogy with biological evolution involving growth, metabolism and death. Sub-cosmologies are characterized by three parameters: moment of birth and durations of the critical period and hyperbolic periods. p-Adic length scale hypothesis makes model quantitative by providing estimates for the moments of cosmic time when the phase transitions generating new critical sub-cosmologies occur and fixes the number of the phase transitions already occurred. What is especially remarkable, that the time for the generation of CMB is predicted correctly from p-adic fractality and from the absence of the second acoustic peak in the spectrum of CMB fluctuations.

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It must be emphasized that in TGD framework critical cosmology reflects quantum criticality and the presence of two kinds of two-dimensional conformal symmetries acting at the level of embedding space and space-time [K116]. Thus the correlation function for the fluctuations of the mass density at the surface of a sphere of fixed radius is dictated by conformal invariance and by quantal effects the naïve scaling dimension predicted by the scaling invariance can be modified to an anomalous dimension. The implications of replacing scaling invariance with conformal invariance for the correlation function of density fluctuations is discussed at the general level in [E65].

3.4.1 Comparison With Inflationary Cosmology

TGD differs from GRT in several respects. Many-sheeted space-time concept forces fractal cosmology containing cosmologies within cosmologies. A p-adic hierarchy of long ranged electro-weak and color physics assignable to dark matter at various space-time sheets is predicted if one interprets the unavoidable long ranged classical gauge fields as space-time correlates of corresponding quantum fields. Confinement (weak) length scales associated with these physics correspond to p-adic length scales characterizing the sizes of the space-time sheets of corresponding hadrons (weak bosons). Topological condensation involves a formation of # contacts identifiable as parton-antiparton pairs defining a particular instance of dark matter. Infinite variety of dark matters, or more precisely partially dark matters with respect to each other, is predicted.

Z^0 force competes with gravitational force and it will be found that the role of this force could be crucial in understanding the formation of the observed large void regions (with recent size of order 10^8 light years) containing ordinary matter predominantly on their boundaries. Einstein's equations provide only special solutions of the field equations for the length scale dependent space-time of TGD. For instance, in case of strongly Kähler charged cosmic strings it seems better to regard the strings as sources of the Kähler electric field rather than gravitational field. Vapor phase containing at least cosmic strings is the crucial element of TGD inspired cosmology.

The proposed scenario for cosmology deserves a comparison with the inflationary scenarios [E62, E60].

1. In inflationary cosmologies exponentially expanding phase corresponds to a symmetry non-broken phase and de-Sitter cosmology follows from the vacuum energy density for the Higgs field. The vacuum energy of the Higgs field creates "negative pressure" giving rise to the exponential expansion. The string tension of the topologically condensed cosmic strings creates

the "negative pressure" in TGD context.

In TGD framework the period with Minkowskian signature of induced metric is analogous to inflationary period. This can be seen by solving proper time t in terms of M^4_+ proper time a from the equation

$$\frac{dt}{da} = \sqrt{g_{aa}} = \sqrt{1 - \frac{R^2k^2}{4}\frac{1}{1-k^2a^2}} \ . \tag{3.4.1}$$

From this expression one sees that the dt/da evolves from very small and finite value to zero at $ka = kR/2$ so that da/dt is infinite at the end of Minkowskian period. The value of da/dt approach infinity for radiation dominated cosmology with $t \propto a^2$ so that a good guess is that space-time sheets with radiation dominated cosmology begin to be generated.

2. In the inflationary scenarios the exponential expansion destroys inhomogenuities and implies the isotropy of 3 K radiation and the decay of the Higgs field to radiation creates entropy. In TGD string dominance implies the absence of horizons. There are no horizons associated with the vapor phase neither since it obeys light cone cosmology. Also critical, string dominated and asymptotic cosmologies are horizon free.

3. In inflationary scenarios the transition to the radiation dominated phase corresponds to the transition from the symmetric phase to a symmetry broken phase. In TGD something analogous happens. Cosmic strings are free at primordial stage but unstable against decay to elementary particles because their action has wrong sign. Some of these strings achieve stability by topologically condensing and generating large Kähler electric charge to cancel their Kähler magnetic action. Light particles of matter in turn suffer a gradual condensation around Kähler electric strings. The Kähler charge of the string induces automatically a slight matter-antimatter asymmetry in the exterior space-time. Or vice versa: the surrounding vacuum extremal must suffer a slight deformation to non-vacuum extremal and this requires Kähler electric field and simplest field of this kind is radial one forcing cosmic string to generate small Kähler charge. At the limit $a \to 0$ the contribution of the condensate to the energy of a given co-moving volume vanishes and in this sense condensate can be regarded as a seed of the symmetry broken phase.

4. In inflationary scenarios the critical mass density is reached from above and final state corresponds to a cosmology with a critical mass density. In TGD scenario in its simplest form, the mass density is exactly critical before the transition to the "radiation dominated phase" and overcritical mass density resides in the vapor phase. In a well defined sense vapor phase makes possible sub-critical cosmology. The mysterious vacuum energy density of the inflationary cosmologies could corresponds in TGD framework to the dark matter density at cosmic strings part of which could be in vapor phase.

Also critical cosmology involves a rapid expansion and one can imagine what this means in TGD framework if one takes p-adic length scale hypothesis and the hierarchy of Planck constants seriously. This point will be discussed in separate section.

3.4.2 Balloon Measurements Of The Cosmic Microwave Background Favor Flat Cosmos

Inflationary scenario has been one of the dominating candidates for cosmology. The basic prediction of the inflationary cosmology is criticality of the mass density which means that cosmic time=constant sections are flat. Observations about the density of known forms of matter are not consistent with this and the only possible manner to get critical mass density is to assume that there exist some hitherto unknown form of vacuum energy density contributing roughly 70 percent to the energy density of the universe. This vacuum energy density is believed to cause the observed acceleration of the cosmic expansion.

The basic geometrical prediction of the inflationary scenario is that cosmic time=constant sections are flat Euclidian 3-spaces. This prediction has been now tested experimentally and it seems that the predictions are consistent with the observations. The test is based on the study of non-uniformities of the cosmic microwave background (CMB). CMB was created about half million years after the moment of Big Bang when opaque plasma of electrons and ions coalesced into transparent gas of neutral hydrogen and helium. Thermal photons decoupled from matter to form cosmic microwave background and have been propagating practically freely after that. The fluctuations of the temperature of the cosmic microwave background reflect the density fluctuations of the universe at the time when this transition occurred. The prediction is that the relative fluctuations of temperature are proportional to the relative fluctuations of mass density and are few parts to 10^5.

Happily, it is possible to estimate the size spectrum for the regions of unusually high and low density theoretically and compare the predictions with the experimentally determined distribution of hot and cold spots in CMB. Since the light from hot and cold spots propagates through the intervening curved space, its intrinsic geometry reflects itself in the properties of the observed spectrum of CMB fluctuations. Hence it becomes possible to experimentally determine whether the 3-space (cosmic time=constant section) is negatively curved (expansion forever), positively curved and closed (big crunch) or flat.

The acoustic properties of the plasma help in the task of determining the spectrum of CBM fluctuations. The competition between gravity and radiation pressure during radiation dominated period produced regions of slow, attenuated oscillatory contraction and expansion. The maximum size of over-dense region that could have shrunk coherently during the half million years before the plasma became transparent was limited by the velocity of sound which is $c/\sqrt{3}$ in radiation dominated plasma. This gives $R = 5/\sqrt{3} \times 10^5$ light years which is about 300 thousand light years for the maximal size of the hot spot. The observed position and size of the first acoustic peak corresponding to the largest hot spots and its observed position depends on the presence or absence of the distorting cosmic curvature. If the intervening 3-space is positively (negatively) curved the parallel rays coming from hot spot diverge and hot spots look larger (smaller) than they actually are: also distances between hot spots look larger (smaller).

To abstract cosmological details from the observations one calculates the power spectrum of the thermal fluctuations by fitting the CMB temperature map to a spherical harmonic series. The absolute square of the fitted amplitude for l: th order spherical-harmonic component is essentially the mean-square point-to-point temperature fluctuation of the CMB on angular scale about π/l radians. The observed fluctuation power spectrum as function of l has maximum at $l = 200$. This is consistent with flat intervening 3-space and inflationary scenario. The next maximum of power spectrum as function of l corresponds to the second acoustic peak (recall that acoustic oscillations are in question) with smaller size of hot spot and should be observed at $l = 500$ according to inflationary scenario. In fact this peak has not been observed. This might be due to the small statistics or due to the fact that the scale free prediction of the inflationary scenario for the spectrum of fluctuations is quite not correct but that fluctuations have cutoff at some length scale larger than the size of the size of the hot spot associated with the second acoustic peak.

In standard cosmology the result means that 3-space has remained flat for most of the time after the moment when CMB was generated. Of course, the cosmology can have changed hyperbolic after that since the small mass density of the recent day universe implies that the effects of the curvature on the optical properties of the universe are small. Inflationary scenario predicts this if one repeats the biggest blunder of Einstein's life by adding to Einstein's equations cosmological constant, which means that vacuum energy density of an unknown origin contributes about 70 per cent to the mass density of the universe. Besides this one must assume that primordial baryon density is about 50 per cent higher than standard expectation. Thus inflationary model survives the test but not gracefully.

3.4.3 Quantum Critical Fractal Cosmology As TGD Counterpart Of The Inflationary Cosmology

In TGD framework Einstein's equations are structural equations relating the energy momentum tensor of topologically condensed matter to the geometry of the space-time surface rather than fundamental equations derivable from a variational principle. Furthermore, the solutions of Einstein's equations are only a special case of the equations characterizing the macroscopic limit of the theory. The simplest assumption is however that Einstein's equations hold true for each sheet of the many-sheeted space-time and is made in TGD inspired cosmology.

Does quantum criticality of TGD imply criticality and fractality of TGD based cosmology?

Quantum criticality of the TGD Universe supports the view that many-sheeted cosmology is in some sense critical. Criticality in turn suggests p-adic fractality. Phase transitions, in particular the topological phase transitions giving rise to new space-time sheets, are (quantum) critical phenomena involving no scales. If the curvature of the 3-space does not vanish, it defines scale: hence the flatness of the cosmic time=constant section of the cosmology implied by the criticality is consistent with the scale invariance of the critical phenomena. This motivates the assumption that the new space-time sheets created in topological phase transitions are in good approximation modellable as critical Robertson-Walker cosmologies for some period of time at least.

Neither inflationary cosmologies nor overcritical cosmologies allow global embeddings. TGD however allows the embedding of a one-parameter family of critical and overcritical cosmologies. Embedding is possible for some critical duration of time. The parameter labeling these cosmologies is a scale factor characterizing the duration of the critical period. The infinite size of the horizon for the imbeddable critical cosmologies is in accordance with the presence of arbitrarily long range fluctuations at criticality and guarantees the average isotropy of the cosmology. These cosmologies have the same optical properties as inflationary cosmologies.

The critical cosmologies can be used as a building blocks of a fractal cosmology containing cosmologies containing... cosmologies. p-Adic length scale hypothesis allows a quantitative formulation of the fractality. Fractal cosmology provides explanation for the balloon experiments and also for the paradoxical result that the observed density of the matter is much lower than the critical density associated with the largest space-time sheet of the fractal cosmology. Also the observation that some astrophysical objects seem to be older than the Universe, finds a nice explanation.

Cosmic strings and vapor phase

En essential element of TGD inspired cosmology is the presence of vapor phase consisting dominantly of cosmic strings. For the values of light cone proper time a smaller than CP_2 time R, space-time does not exist in sense as it is defined in General Relativity. Instead, very early Universe consists of a primordial soup of cosmic strings. General arguments lead to the hypothesis that the density of the cosmic strings in vapor phase in in this period is

$$\rho_V = \frac{3}{8\pi G a^2} . \tag{3.4.2}$$

The expression of the density is formally same as the critical density of flat critical cosmology (note that future light cone is hyperbolic vacuum cosmology). The topological condensation of free cosmic strings could be forced by the absolute minimization of Kähler action (free cosmic strings have infinite positive Kähler magnetic action) to critical space-time sheets leads to fractal hierarchy of critical cosmologies and reduces the density of vapor phase. Obviously the energy density in vapor phase is very much analogous to the vacuum energy density needed in inflationary cosmologies. Note however that absolute minimization is only one of the many interpretation for what preferred extremaly property could mean.

What happens when criticality becomes impossible?

Given critical sub-cosmology is created at the moment $a = a_0$ of the light cone proper time. The imbeddability of the critical cosmology fails for $a = a_1$. The question is what happens for the space-time sheet before this occurs. A natural assumption is that when the value of the cosmic time for which imbeddability fails is approached, cosmology is transformed to hyperbolic cosmology. One can imagine several scenarios but the following one involving two transitions is the most plausible one. The first step is the transition of the critical cosmology to a hyperbolic cosmology which is either matter or radiation dominated or to a stationary cosmology for which gravitational energy density is conserved. The next step is possible decomposition of $a = constant$ 3-surface of hyperbolic cosmology to disjoint non-expanding 3-surfaces topologically condensing on critical cosmology created later. This process in turn could induce the transition of the critical cosmology to hyperbolicity: when critical sub-cosmology eats the remnants of earlier sub-cosmology it could become hyperbolic itself. Of course, this is not the only mechanism. This scenario resembles to high degree the lifecycle of a biological organism involving gradual growth, metabolism and death.

1. Transition to matter or radiation dominated phase

The critical cosmology is transformed to a hyperbolic cosmology with sub-critical mass density. This option is very general and means that criticality is gradually shifted to increasingly longer length scales when it breaks down in short length scales. The continuity condition in the transformation to hyperbolic cosmology with $\theta = \pi/2$ and $\phi = \phi(a)$ for g_{aa} reads as

$$\begin{aligned} \frac{1}{g^H_{aa}} - 1 &= \frac{1}{1-K} \equiv \epsilon \ , \\ K &\equiv \frac{R^2}{4a_1^2}\frac{1}{(1-(\frac{a}{a_1})^2)} \ . \end{aligned} \tag{3.4.3}$$

The light cone projection of the sub-cosmology is sub-ligtcone of M^4_+. a denotes light cone proper time for this sub-light cone: its value is obviously smaller than the value of M^4_+ proper time. Upper index "H" refers to the metric of the hyperbolic cosmology. The value of the parameter ϵ must deviate considerably from unity and and since R/a_1 is extremely small number, the transformation to hyperbolic cosmology must happen very near to $a = a_1$: for all practical purposes this fixes the moment of transition to be $a = a_1$. Critical cosmology is also flat in excellent approximation up to $a = a_1$. The mass density of the hyperbolic cosmology behaves during the matter (radiation) dominated phase as

$$\rho = \frac{3}{8\pi G}\epsilon\frac{a_1^{1+n}}{a^{3+n}} \ . \tag{3.4.4}$$

Here $n = 0$ corresponds to matter dominance and $n = 1$ to radiation dominance.

2. Decomposition of $a = constant$ surface to disjoint non-expanding components

p-Adic length scale hypothesis suggests that hyperbolic sub-cosmology ceases to participate in the cosmic expansion sooner or later and that $a = constant$ 3-surface decomposes to disjoint particle like non-expanding objects topologically condensing at and comoving on the sub-cosmologies generated later. A possible mechanism causing the decomposition of a hyperbolic sub-cosmology into disjoint space-time sheets is the intersection of the sub-light cones defined by the sub-cosmologies initiated at same $a = constant$ hyperboloid. The transition to non-expanding phase has certainly occurred for stellar objects.

The disjoint 3-surfaces generated in this process are topologically condensed at (or are "metabolized" by) younger critical cosmologies and the simplest assumption is that this condensation process changes the newer cosmology to matter dominated hyperbolic cosmology. This assumption is consistent with the fact that the mass density of the critical cosmologies is very small before the transformation to the matter dominated phase so that they cannot contain topologically condensed matter. Before the condensation process the condensation of free cosmic strings gives rise to the gradual increase of the mass density of the critical cosmology.

This picture implies that cosmic expansion occurs only above some length scale and that the long length scale optical properties of the universe are determined by the competion of sub-cosmologies in hyperbolic and critical stages since photons travel along space-time sheets of both type.

p-Adic fractality

p-Adic fractality suggests that all cosmological phase transitions giving rise to the generation of new space-time sheets should be describable using the same universal Robertson-Walker cosmology during their critical period so that cosmology would contain cosmologies containing cosmologies... like Russian doll contains Russian dolls inside it. The light cone projection of each sub-cosmology is sub-light cone. Lorentz invariance requires that the probability distribution for the position the tip of the sub-light cone is constant along $a = constant$ hyperboloid.

Sub-cosmology is characterized by three parameters a_0, a_1 and a_2. a_0 characterizes the moment of birth for sub-cosmology, a_1 characterizes in excellent approximation the value of the sub-light cone proper time for which the transition from critical to hyperbolic sub-cosmology occurs. a_1+a_2 in turn characterizes the sub-light cone proper time for the decay of the hyperbolic sub-cosmology to comoving non-expanding surfaces. p-Adic length scale hypothesis allows to make educated guesses for the values of a_0, a_1 and a_2 so that TGD inspired cosmology becomes highly predictive.

Since a_0 characterizes the moment of birth for sub-cosmology, it is not expected to reflect in any manner the dynamics of earlier sub-cosmologies. In contrast to this, a_1 and a_2 characterize the internal dynamics of sub-cosmology involving gravitational time dilation effects in an essential manner and this suggests that the fundamental parameters are the values of the proper times s_1 and s_2 for sub-cosmologies to which a_1 and a_2 are related in simple manner.

More quantitatively, the proper time s of the space-time surface representing cosmology is defined as

$$s = \int_0^a \sqrt{g_{aa}}da \quad .$$

The relationship between light cone proper time and proper time of the critical cosmology implies the relationship

$$\begin{aligned} s_1 &= \int_0^{a_1} \sqrt{1-K}da \quad , \\ K &\equiv \frac{R^2}{4a_1^2}\frac{1}{(1-(\frac{a}{a_1})^2)} \quad . \end{aligned} \tag{3.4.5}$$

between a_1 and s_1. Up to $a \simeq a_1$ the value of the parameter K is nearly vanishing so that $s \simeq a$ holds in a good approximation during the critical period. This means that the values of s_1 and a_1 are in excellent approximation identical:

$$s_1 \simeq a_1 \quad .$$

The relationship between s_2 and a_1 and a_2 is

$$s_2 = \int_{a_1}^{a_1+a_2} \sqrt{g_{aa}}da \quad . \tag{3.4.6}$$

The gravitational dilation effects for hyperbolic cosmology are large and s_2 and a_2 can differ by orders of magnitude.

p-Adic length scale hypothesis states two things.

1. Each p-adic prime p corresponds to p-adic length scale $L_p = \sqrt{p}\times l$, where $l \simeq 10^{3.5}$ Planck lengths is CP_2 "radius".
2. The primes $p \simeq 2^k$, k prime or power of prime are physically preferred so that one has

$$L_p \equiv L(k) \simeq 2^{k/2}\times l \quad .$$

p-Adic fractality allows to make educated guesses for the most plausible values of the parameters a_0, a_1 and a_2 characterizing the evolution of the sub-cosmologies.

1. Moments of birth of sub-cosmologies

It seems that the generation of new sub-cosmologies is a process having nothing to do with the internal dynamics of sub-cosmologies themselves. Therefore p-adic fractality suggests that the dips of the sub-light cones associated with the critical cosmologies are concentrated in good approximation at the hyperboloids

$$a_0(k) = x_0 L(k)$$

of the light cone M^4_+ where x_0 is some numerical constant: note that a_0 refers to the proper time of the light cone M^4_+ rather than sub-light cone. The number of primes k in the interval $[2, ..., 401]$ (see Table 2) is rather small which implies that the number of sub-cosmologies created after Big Bang is smaller than 100.

2. Moments for the transition to hyperbolicity

The natural guess is that the embedding for the cosmology characterized by $p \simeq 2^k$ fails for $a \simeq a_1$ (in excellent approximation) when sub-cosmology also starts to metabolize the remnants of earlier sub-cosmologies. p-Adic length scale hypothesis gives the estimate

$$s_1(k) \simeq a_1(k) = x_1 L(k) \ ,$$

where x_1 is numerical constant of order unity. The most natural interpretation is that transition to radiation or matter dominated cosmology occurs. It is natural to assume that topological condensation of 3-surfaces resulting from earlier cosmology accompanies this transition. One can also say that cosmological metabolism causes transition to hyperbolicity.

3. Moments of death for sub-cosmologies

The death of the sub-cosmology means decay to disjoint 3-surfaces. The simplest assumption is that this occurs when the age of sub-cosmology measured with respect to sub-cosmological proper time s exceeds p-adic time scale defined by the next p-adic prime in the hierarchy. Thus one has

$$s_1 + s_2 \simeq a_1 + s_2 = x_2 L(k(next))$$

giving

$$s_2 = x_2 L(k(next)) - x_1 L(k) \ . \tag{3.4.7}$$

From this one can relate the parameter a_2 with the p-adic length scales $L(k(next)$ and $L(k)$. $L(k)$ gives the size scale of the 3-surfaces resulting when the connected space-time sheet $a_2 = constant$ decomposes to pieces. Due to gravitational time dilation s_2 can be smaller than a_2 by several orders of magnitude so that the duration of the hyperbolic period when measured using sub-light cone proper time is lengthened by gravitational time dilation and topological condensation of the remnants of sub-cosmology can take place to a critical cosmology having $k > k(next)$.

4. Temperature and energy density of the critical cosmology at the moment of transition to hyperbolicity.

p-Adic length scale hypothesis suggest that the temperature just after the transition to the effectively radiation dominated phase is

$$\begin{aligned} T(k) &= \frac{n}{L(k)} \ , \quad \text{for } k > k_{cr} \ , \\ T(k) &= T_H \sim \frac{1}{R} \ , \quad \text{for } k \leq k_{cr} \ . \end{aligned} \tag{3.4.8}$$

Here n is rather large numerical factor. Since $a_F \sim 2.7 \times 10^{-10}$ seconds which corresponds to length scale $L \simeq .08$ meters roughly to p-adic length scale $L(197) \simeq .08$ meters (which by the way corresponds to the largest p-adic length scale associated with brain, cosmic joke?), should correspond to the establishment of Hagedorn temperature, one has the conditions

$$\begin{aligned} k_{cr} &= 197 \ , \\ n &\simeq 2^{197/2} \sim 10^{30} \sim \frac{m^2_{CP_2}}{m^2_p} \ . \end{aligned}$$

Thus n is in of same order of magnitude as the ratio of the CP_2 mass squared ($m_{CP_2} \simeq 10^{-3.5}$ Planck masses) to proton mass squared.

k	127	131	137	139	149
$L_p/10^{-10}m$	.025	.1	.8	1.6	50
k	151	157	163	167	169
$L_p/10^{-8}m$	1	8	64	256	512
k	173	179	181	191	193
$L_p/10^{-4}m$	.2	1.6	3.2	100	200
k	197	199	211	223	227
L_p/m	.08	.16	10	640	2560

Table 3.1: p-Adic length scales $L_p = 2^{k-151}L_{151}$, $p \simeq 2^k$, k prime, possibly relevant to astro- and biophysics. The last 3 scales are included in order to show that twin pairs are very frequent in the biologically interesting range of length scales. The length scale $L(151)$ is take to be thickness of cell scale, which is 10^{-8} meters in good approximation.

k	227	229	233	239	241
L_p/m	$2.3E+3$	$4.6E+3$	$1.9E+4$	$1.5E+5$	$3.0E+5$
k	251	257	263	269	271
L_p/m	$.96E+7$	$7.7E+7$	$6.0E+8$	$4.8E+9$	$.9E+10$
k	277	289	293	307	311
L_p/m	$7.7E+10$	$5.0E+12$	$2.0E+13$	$2.5E+15$	$1.0E+16$
k	313	317	329	331	337
L_p/ly	2.2	$5.4E+2$	$1.0E+3$	2.2E+3	$8.4E+3$
k	347	349	353	359	367
L_p/ly	$2.8E+5$	$5.6E+5$	$2.2E+6$	$1.8E+7$	$2.9E+8$
k	373	379	381	391	397
L_p/ly	$2.2E+9$	$1.9E+10$	3.8 E+10	1.2E+12	.96E+13

Table 3.2: p-Adic length scales $L_p = 2^{(k-127)/2}L_{127}$, $p \simeq 2^k$, k prime, possibly relevant to large scale astrophysics. The definition of the length scale involves an unknown factor r of order one and the requirement $L(151) \simeq 10^{-8}$ meters, the thickness of the cell membrane, implies that this factor is $r \simeq 1.1$.

Dimensional considerations suggest also that the energy density in the beginning of the radiation dominated phase (in case that it is achieved) is

$$\rho = nT(k)^4 \ , \tag{3.4.9}$$

where n a numerical factor of order one. n does not count for the number of light particle species since the thermal energy of strings gives rise to the effective radiation dominance. This explains why infinite number of fermion families does not lead to infinite density of thermal energy and why their presence leaves no trace in present day cosmology.

When the time parameter a_1 of the critical cosmology becomes too high, it cannot anymore generate radiation dominated phase since the temperature remains too low. Previous considerations suggest that the maximum value of a_1 is roughly $a_1(max) = a_F \sim 3 \times 10^{-10}$. After this critical sub-cosmologies transform directly to the stationary cosmologies.

These estimates fix the structure of the fractal cosmology to rather high degree. Note that the expanding space-time surfaces associated with the new critical cosmologies created in the phase transition can fuse since corresponding light cones can intersect. The number of the phase transitions occurred after the light cone proper time corresponding to electron Compton length is roughly forty. The tables below give the p-adic length scales in the range extending from electron Compton radius to 10^{10} light years.

3.4.4 The Problem Of Cosmological Missing Mass

In inflationary cosmology the basic problem is related to the missing mass. The experimentally determined recent density of the ordinary matter is about 4 per cent of the critical mass density and it seems that ordinary sources (other than vacuum energy density) can contribute about 30 percent of the critical mass density in inflationary scenarios. In TGD framework the situation is different as following arguments show.

1. Criticality does not force missing mass in TGD framework.

There is no absolute need for vacuum energy density since the mass densities of critical cosmologies present in condensate are extremely low before the transition to the hyperbolicity. In TGD framework the observed mass density corresponds to the mass density at "our" cosmological space-time sheet condensed to some larger space-time sheet... condensed on the largest space-time sheet present in the topological condensate now. If the vapor phase density equals to the critical density of flat critical cosmology, the net energy density of the entire topological condensate is bound to be smaller than the critical density. This is in accordance with experimental facts. In fact, vapor phase energy density corresponds closely to the vacuum energy density of inflationary scenarios. By the conservation of energy the total energy density at various space-time sheets is indeed equal to "critical" vapor phase density apart from effects caused by different expansion rates. The possibility of negative energy virtual gravitons however makes possible for a given space-time sheet to have energy density much larger than the energy density of the vapor phase.

2. The observed optical properties of the Universe require that photons travel in critical cosmologies for a sufficiently long fraction of time.

The photons coming from a distant source must propagate along a space-time sheet of a critical cosmology for a sufficiently long fraction of time during their travel to detector. If the period of the matter dominance is too long, photons spend too long time fraction in matter dominated phase and the spectrum of anisotropies is seriously affected. This is avoided if the period between the initiation of the matter dominance and decomposition into disjoint 3-surfaces is sufficiently short. Generation of lumps of matter could in fact involve gravitational collapse leading to the decomposition of the 3-surface to pieces. Second possibility is that the topological condensation of photons is more probable on critical and essentially flat cosmologies (present always) than on matter dominated cosmologies. The large rate of topological evaporation from radiation and matter dominated cosmologies is consistent with this. An alternative explanation in terms of zero energy ontology is that topological evaporation is only effective.

3. The mass density of later matter dominated cosmologies should be larger than that of previous matter dominated cosmologies.

Assume that previous cosmology have made transition to non-expanding phase and behaves as comoving matter with density $\rho(p_1)$ on the next expanding matter dominated cosmology with density $\rho(p_2)$. Under this assumption the condition

$$\rho(p_1) \equiv p\rho(1) < \rho(p_2)$$

implies

$$a_1(p_1)\epsilon(p_1)\frac{1}{a^3(p_1)} = p \times a_1(p_2)\epsilon(p_2)\frac{1}{a^3(p_2)} \quad .$$

The larger the space-time sheet, the later it is created, and therefore one has $a(p_1) > a(p_2)$ as well as $a_1(p_1) < a_1(p_2)$. For large values of $a(p_1)$ and $a(p_2)$ one has $a(p_1) \sim a(p_2)$ in good approximation and one has

$$a_1(p_1)\epsilon(p_1) = p \times a_1(p_2)\epsilon(p_2) \quad . \tag{3.4.10}$$

The parameters ϵ are of order unity in recent day cosmology.

If one assumes the relationship $s_1 \simeq a_1 = xL(k)$, one obtains

$$\frac{\epsilon(k_1)}{\epsilon(k_2)} = p \times 2^{(k_2-k_1)/2} \quad . \tag{3.4.11}$$

It is possible to satisfy this constraint for $p < 1$.

The assumption about cosmologies inside cosmologies implies distribution of ages of the Universe and provides a natural explanation for why the observed mass density is subcritical. Cosmic strings topologically condensed at the larger space-time sheet could correspond to the missing mass. The age of the space-time sheet of an astrophysical object can be much longer than the age of the largest space-time sheet: this could explain the paradoxical observation that some stars seem to be older than the Universe.

3.4.5 TGD Based Explanation Of The Results Of The Balloon Experiments

TGD based model explaining the results of balloon experiments relies on the notion of the fractal cosmology.

Under what conditions Universe is effectively critical?

TGD based model explaining the results of balloon experiments relies on the notion of the fractal cosmology. If $a = constant$ sections of hyperbolic cosmologies decompose to disjoint 3-surfaces after sufficiently short matter dominated period, the photons propagating along these space-time sheets must "drop" on the critical space-time sheets so that situation stays effectively critical and model yields same predictions as inflationary cosmology. The decoupling of radiation from matter involved a topological phase transition leading to a generation of new expanding space-time sheets along which the CMB radiation could propagate.

The following argument shows under what conditions the total duration of the matter dominated periods is negligible as compared with the total duration of the critical periods. The ratio of the observed angular separation $\Delta\phi_{obs}$ between hot spots to real angular separation $\Delta\phi_r$ between them can be deduced from

$$\begin{aligned} \Delta\phi_{obs} \simeq tan(\Delta\phi_{obs}) &= \frac{\sqrt{g_{\phi\phi}}\Delta\phi_r}{R(r)} \quad , \\ R(r) &= \int \sqrt{g_{aa}}da = \int \sqrt{g_{rr}}\frac{dr}{da}da \end{aligned} \tag{3.4.12}$$

$R(r)$ is the Euclidian distance calculated along the light like geodesic associated with photon and depends on the curvature properties of the intervening space. Flat cosmology serves as a natural reference and the ratio

$$\begin{aligned} \frac{\Delta\phi_{obs}}{\Delta\phi_{obs}(flat)} &= \frac{R(r,flat)}{R(r)} \\ &= \frac{a-a_1}{\int_{a_1}^{a}\sqrt{g_{aa}}da} \end{aligned} \tag{3.4.13}$$

measures the effect of the intervening space to the observed angular distance between hot spots of CMB. Note that the integral must be expressed in terms of the initial values of the coordinate r.

When photons travel along critical cosmology, $g_{aa} \simeq 1$ holds true and this corresponds to flat situation. For a fixed value of r one has the following approximate expressions in various cosmologies

$$\begin{aligned} a - a_1 = r - r_1 \ , & \quad \text{(critical cosmology with } g_{aa} = 1) \ , \\ a - a_1 \sim log(\tfrac{r}{r_1}) \ , & \quad \text{(hyperbolic cosmology with } g_{aa} = 1) \ , \\ \tfrac{2}{3}ka((\tfrac{a}{a_R})^{1/2} - (\tfrac{a_1}{a_R})^{1/2}) & \\ = log(\tfrac{r}{r_1}) \ , & \quad \text{(matter dominance with } g_{aa} = k(\tfrac{a}{a_R})^{1/2}) \ . \end{aligned} \tag{3.4.14}$$

From these expressions one finds that same increment of r gives rise to much smaller increment of a in hyperbolic cosmology than in critical cosmology. Thus the fractions of r spent in critical cosmology gives the dominating contribution to the integral unless this fraction happens to be especially small. From these expressions one finds that for a given distance r the red shift in approximately flat (no horizon) hyperbolic cosmology is exponentially larger than in critical cosmology. The arrival of photons along hyperbolic cosmology could thus explain why their ages when derived from the red shift seem to be larger than the age of the Universe derived assuming that photons travel along critical cosmology.

During periods of matter dominance g_{aa} behaves as $g_{aa} = k\frac{a}{a_2}$ and gives smaller contribution than critical period. Integral can be expressed as sum of critical and matter dominated contributions as

$$\int_{a_2}^{a} \sqrt{g_{aa}} da = \sum_i [\Delta a_0(i) + s_2(i)] \ . \tag{3.4.15}$$

Here the durations of periods are of order $L(k_i)$ and last period gives the dominant contribution. If the last propagation has occurred along critical cosmology for a sufficiently long time, the contribution of the earlier matter dominated periods to the integral are small and the last critical period can dominate in the integral. If the last critical period corresponds to $k = 379$ preceded by $k = 373$, then the ratio for angle separations does not differ more than about 10 per cent from the value guaranteeing ideal criticality.

What the absence of the second acoustic peak implies?

The absence of the second acoustic peak (which might be also a statistical artefact) fixes the TGD based model to a very high degree.

1. By quantum criticality scale free spectrum for the size L of the density fluctuations is a natural assumption when L is above the p-adic length scale $L(k(prev))$ characterizing the size of the remnants of the previous cosmology condensing to the critical space-time sheets in the transition to hyperbolic cosmology. Below this size ($L < L(k(prev))$) the spectrum for fluctuations has however natural cutoff. This cutoff could also correspond to the length of the cosmic strings giving rise to large voids containing cosmic strings inside them in TGD based model of galaxy formation and to the recent size of large voids containing galaxies at their boundaries. The space-time sheets of large voids should have been born in the phase transition generating CMB if this picture is correct.
2. The first acoustic maximum corresponds to $l = 200$ and $L(k_R)$. The second acoustic maximum corresponds to $l = 500$ and has thus size which is 2/5 of the size of the first hot spot. $L(k_R(prev)$ defines the lower bound for the size of the density and temperature fluctuations as the minimum size of topologically condensed space-time sheets. Therefore, if second acoustic maximum is present, the size of the corresponding hot spot must be larger than $L(k_R(prev))$. Thus the condition for the absence of the second acoustic maximum is

$$\frac{L(k_R(prev))}{L(k_R)} < \frac{2}{5} \ .$$

Thus the experimental absence of the second maximum requires that k_R and $k_R(prev)$ form twin pair ($k_R(prev) = k_R - 2$) so that one has $L(k_R(prev)) = L(k_R)/2$.

There are two candidates for the twin pairs in question: the twin pairs are $(347, 349)$ and $(359, 381)$ (see table 2 for the values of corresponding p-adic length scales). Only the first pair is consistent with the previous considerations related to p-adic fractality.

1. The pair ($k_R(prev) = 347, k_R = 349$) corresponds to the p-adic length scales $L(347) = 2.8E{+}5$ ly and $L(349) = 5.6E + 5$ ly. $L(347)$ clearly corresponds to the minimum size of the first acoustic peak. Rather remarkably, the length scale $L(347)$, which corresponds also to the size of the typical spatial structures frozen in the transition to matter dominated cosmology, corresponds rather closely to the estimated time $s_R \sim 5E + 5$ years for the transition to matter dominance and also to the typical size of galaxies. In consistency with the general picture, the estimate

$$s_R = s_1 + s_2 = x_2 L(349)$$

gives $s_R = 5.8E + 5$ years for $x_2 = 1$.

2. If one takes seriously the order of magnitude estimate $s = s_R = 5 \times 10^5$ light years for the age of the cosmology when CMB was created, and assumes that hyperbolic cosmology was radiation dominated before s_R, one can estimate the value of light cone proper time a at this time using the formula

$$\begin{aligned} s_R &= \int_{a_1}^{a_R} \sqrt{g_{aa}} da \ , \\ g_{aa} &\simeq 10^{-3} \frac{a^2}{a_R^2} \ . \end{aligned} \quad (3.4.16)$$

This gives $a_R \sim 3.3 \times 10^7$ light years: this corresponds to the p-adic length scale $L(359)$. Thus gravitational time dilatation implies that topological condensation does not occur to $L(353)$ next to $L(349)$ but to $L(259)$. 5 new cosmologies corresponding to $k = 353, 359, 367, 373$ and 379 should have emerged after the transition to matter dominated cosmology and could correspond to cosmological structures. Large voids are certainly this kind of structures and correspond to the p-adic length scale $L(367) \sim 2.9E{+}8$ ly. The predicted age of the Universe is about $L(381) \sim 1.9E + 10$ years in this scenario.

Fluctuations of the microwave background as a support the notion of many-sheeted space-time

The fluctuations of the microwave background temperature are due to the un-isotropies of the mass density: enhanced mass density induces larger red shift visible as a local lowering of the temperature. Hence the fluctuations of the microwave temperatures spectrum provide statistical information about the deviations of the geometry of the 3-space from global homogenuity. The symmetries of the fluctuation spectrum can also provide information about the global topology of 3-space and for over-critical topologies the presence of symmetries is easily testable [E232].

The first year Wilkinson microwave anisotropy probe observations [E107] allow to deduce the angular correlation function. For angular separations smaller the 60 degrees the correlation function agrees well with that predicted by the inflationary scenarios and deriving essentially from the assumption of a flat 3-space (due to quantum criticality in TGD framework). For larger angular separations the correlations however vanish, which means the existence of a preferred length scale. The correlation function can be expressed as a sum of spherical harmonics. The $J = 1$ harmonic is not detectable due to the strong local perturbation masking it completely. The strength of $J = 2$ partial wave is only 1/7 of the predicted one whereas $J = 3$ strength is about 72 per cent of the predicted. The coefficients of higher harmonics agree well with the predictions based on infinite flat 3-space.

Later some interpretational difficulties have emerged: there is evidence that the shape of spectrum might reflect local conditions. There are differences between northern and southern galactic hemispheres and largest fluctuations are in the plane of the solar system. In TGD framework these anomalies could be interpreted as evidence for the presence of galactic and solar system space-time sheets.

1. Dodecahedral cosmology?

The WMAP result means a discrepancy with the inflationary scenario and explanations based on finite closed cosmologies necessarily having $\Omega > 1$ but very near to $\Omega = 1$ have been proposed. In [E144] Poincare dodecahedral space, which is globally homogenous space obtained by identifying the points of S^3 related by the action of dodecahedral group, or more concretely, by taking a dodecahedron in S^3 (12 faces, 20 vertices, and 30 edges) and identifying opposite faces after 36 degree rotation, was discussed. It was found to fit quadrupole and octupole strengths for $1.012 < \Omega < 1.014$ without an introduction of any other parameters than Ω.

However, according to [E163] the quadrupole and octupole moments have a common preferred spatial axis along which the spectral power is suppressed so that dodecahedron model seems to be excluded. The analysis of [E121] led to the same result. According to the article of Luminet [E191], the situation is however not yet completely settled, and there is even some experimental evidence for the predicted icosahedral symmetry of the thermal fluctuations.

The possibility to imbed also a very restricted family of over-critical cosmologies raises the question whether it might be possible to develop a TGD based version of the dodecahedral cosmology. The dodecahedral property could have two interpretations in TGD framework.

1. Space-time sheet with boundaries could correspond to a fundamental dodecahedron of S^3. If temperature fluctuations are assumed to be invariant under the so called icosahedral group, which is subgroup of $SO(3)$ leaving the vertices of dodecahedron invariant as a point set, the predictions of the dodecahedral model result.
2. An alternative interpretation is that the temperature fluctuations for S^3 decomposing to 120 copies of fundamental dodecahedron are invariant under the icosahedral group.

For neither option topological lensing phenomenon is present since icosahedral symmetry is not due to the identification of points of 3-space in widely different directions but due to symmetry which is not be strict. An objection against both options is that there is no obvious justification for the G invariance of the thermal fluctuations. The only justification that one can imagine is in terms of quantum coherent dark matter.

The finding of WMAP that the ratio Ω of the mass density of the Universe to critical mass density is $\Omega = 1 + g_{aa} = 1 + \epsilon$, $\epsilon = 0.02 \pm 02$. This is consistent with critical cosmology. If only slightly overcritical cosmology is realized, there must be a very good reason for this.

The WMAP constraint implies that the value of a which corresponds to the value of cosmic time a_s which characterizes the thermal fluctuations must be such that $g_{aa} = \epsilon$ holds true. The inspection of the explicit form of g_{aa} deduced in the subsection "Critical and over-critical cosmologies" requires that a_s is extremely near to the value a_0 of cosmic time for which $g_{aa} = 0$ holds true: the deviation of a from a_0 should be of order $(R/_0)R$ and most of the thermal radiation should have been generated at this moment.

Since gravitational mass density approaches infinity at $a \to a_0$ one can imagine that the spectrum of thermal fluctuations reflects the situation at the transition to sub-criticality occurring for $\Omega = 1 + \epsilon$. Thermal fluctuations would be identifiable as long ranged quantum critical fluctuations accompanying this transition and realized as a hierarchy of space-time sheets inducing the formation of structures. The scaling invariance of the fluctuation spectrum generalizes in TGD framework to conformal invariance. This means that the correlation function for fluctuations can have anomalous scaling dimension [E65]. The hadron physics analogy would be the transition from hadronic phase to quark gluon plasma via a critical phase discussed in section "Simulating Big Bang in laboratory".

The transition $k = 1 \to 0 \to -1$ would involve the change in the shape of the $S^2 \subset CP_2$ angle coordinate Φ as a function $f(r)$ of radial coordinate of RW cosmology. The shape is fixed by the value of $k = 1, 0, -1$. In particular, Φ would become constant in the transition to subcriticality. $k = 1 \to 0$ phase transition would be accompanied by the increase of the maximal size of space-time sheets to infinite in accordance with the emergence of infinite quantum coherence length at criticality. Whether this could be regarded as the TGD counterpart for the exponential expansion during inflationary period is an interesting question. In the transition to subcriticality also the shape of Θ as function of a necessarily changes since $sin(\Theta(a > a_0)) > 1$ would be required otherwise.

2. Hyperbolic cosmology with finite volume?

Also hyperbolic cosmologies allow infinite number of non-simply connected variants with 3-space having finite volume. For these cosmologies the points of $a = constant$ hyperboloid are identified under some discrete subgroup G of $SO(3,1)$. Also now fundamental domain determines the resulting space and it has a finite volume.

It has been found that a hyperbolic cosmology with finite-sized 3-space based on so called Picard hyperbolic space [E101, E236] , which in the representation of hyperbolic space H^3 as upper half space $z > 0$ with line element $ds^2 = (dx^2+dy^2+dz^2)/z^2$ can be modeled as the space obtained by the identifications $(x,y,z) = (x+ma, y+nb, z)$. This space can be regarded as an infinitely long trumpet in z-direction having however a finite volume. The cross section is obviously 2-torus. This metric corresponds to a foliation of H^3 represented as hyperboloid of M^4 by surfaces $m^3 = f(\rho)$, $\rho^2 = (m^1)^2+(m^2)^2$ with f determined from the requirement that the induced metric is flat so that x, y correspond to Minkowski coordinates (m^1, m^2) and z a parameter labeling the flat 2-planes corresponds to m^3 varying from ∞ to ∞.

This model allows to explain the small intensities of the lowest partial waves as being due to constraints posed by G invariance but requires $\Omega = .95$. This is not quite consistent with $\Omega = 1.02 \pm .02$.

Also now two interpretations are possible in TGD framework. Thermal photons could originate from a space-time sheet identifiable as the fundamental domain invariant under G. Alternatively, $a = constant$ hyperboloid could have a lattice-like structure having fundamental domain as a lattice cell with thermal fluctuations invariant under G. The shape of the fundamental domain interpreted as a surface of M^4 is rather weird and one could argue that already this excludes this model.

Quantum criticality and the presence of quantum coherent dark matter in arbitrarily long length scales could explain the invariance of fluctuations. If Ω reflects the situation after the transition to subcriticality, one has $\Omega = g_{aa}-1 = .95$. This gives $g_{aa} = 1.95$ which is in conflict with $g_{aa} < 1$ holding true for the embeddings of all hyperbolic cosmologies. Thus Ω must correspond to the critical period and one should explain the deviation from $\Omega = 1$. A detailed model for the temperature fluctuations possibly fixed by conformal invariance alone would be needed in order to conclude whether many-sheeted space-time might allow this option.

3. Is the loss of correlations due to the finite size of the space-time sheet?

One can imagine a much more concrete explanation for the vanishing of the correlations at angles larger than 60 degrees in terms of the many-sheeted space-time. Large angular separations mean large spatial distances. Too large spatial distance, together with the fact that the size of the space-time sheet containing the two astrophysical objects was smaller than now, means that they cannot belong to the same space-time sheet if the red shift is large enough, and cannot thus correlate. The size of the space-time sheet defines the preferred scale. The preferred direction would be most naturally defined by cosmic string(s) in the length scale of the space-time sheet. For instance, closed cosmic string would define an expanding 3-space with torus topology and thus having symmetries. This option would explain also the WMAP anomalies suggesting local effects as effects due to galactic and solar space-time sheets.

Empirical support for the hyperbolic period

TGD inspired cosmology predicts that critical cosmology is followed by a hyperbolic cosmology. A natural question is whether the travel of microwave photons through the negative curvature cosmology might induce some signatures in microwave background. This is indeed the case.

The geodesics in negative curvature 3-space diverge exponentially. The divergence of the nearly parallel light-like geodesic lines is due to the negative curvature making 2-dimensional sections of 3-space analogous to saddle surfaces. The scatterings during the travel of light induce geodesic mixing so that light from regions with differing temperature mix. Hence negative curvature tends to smooth out the anisotropies of the temperature distribution.

Negative curvature has also a more dramatic signature. Gurzadyan [E180, E256] has developed a very refined argument involving algorithmic information theory and complexity theory to show that in the hyperbolic cosmology the hot and cold spots of the temperature distribution of the cosmic microwave radiation look elongated. The direction of elongation is random but the shape of the ellipse is characterized by the curvature of 3-space and does not depend on temperature or size of the spot. For a flat or positively curved space this kind of elongation does not occur.

The emergence of a preferred direction in a Lorentz invariant cosmology looks highly counter-intuitive. My humble understanding is that a scattering of photons from a large geometric structure must be involved somehow. The elongation should relate to what happens at the last scattering surface whose position together with the positions of observer and previous scattering surface define a plane whose normal defines the preferred direction, which would presumably correspond to the shorter axis of the ellipse. In TGD framework the transfer of photons from a larger space-time sheet to that of observer might correspond to this scattering process. Scattering surface would correspond to the boundary of the space-time sheet of the observer whereas scattering would correspond to refraction at the boundary.

The analysis of BOOMERanG, COBE and WMAP CMB maps indeed shows that the spots have elliptic shape with ellipticity parameter ~ 2 whereas the prediction for hyperbolic RW cosmology is 1.4. [E132]. This would suggest that some additional effect is involved and TGD inspired bet have been already described.

Universe as a dodecahedron?: two decades later

I encountered a link to a popular article in Physics World with the title "Is the Universe a dodecahedron" (`https://physicsworld.com/a/is-the-universe-a-dodecahedron/`) telling about the proposal of Luminet et al that the Universe has a geometry of dodecahedron. I have commented on this finding almost 20 years ago. A lot has happened during these two decades and it is interesting to take a fresh TGD inspired view.

In the TGD framework, one can imagine two starting points concerning the explanation of the findings.

1. Could there be a connection with the redshift quantization along the lines (God's fingers) proposed by Halton Arp? In TGD cosmic=time constant surface corresponds to hyperbolic 3-space H^3 of Minkowski space in TGD. H^3 allows an infinite number of tessellations (lattice-like structures).

   I have proposed an explanation for the redshift quantization in terms of tessellations of H^3. The magnetic bodies(MBs) of astrophysical objects and even objects themselves could tend to locate at the unit cells of the tessellation.

2. Icosa-tetrahedral tessellation (lattice-like structure in hyperbolic space H^3) plays a key role in the TGD model of genetic code ([L103] suggested to be universal. Lattice-like structures make possible diffraction if the incoming light has a wavelength, which is of the same order as the size of the unit cell.

In the sequel I will consider only the latter option.

In X ray diffraction, the diffraction pattern reflects the structure of the dual lattice: the same should be true now. Only the symmetries of the unit cell are reflected in diffraction. If CMB is diffracted in the tessellation, the diffraction pattern reflects the symmetries of the dual of the tessellation and does not depend on the value of the effective Planck constant h$_eff.LargevaluesofPlanckconstantmakepossiblelarg$ $likestructuresrealizedaspartofthemagneticbodyhavinglargeenoughsize, nowrealizedatthemagneticbody(MB)$.

Icosa-tetrahedral tessellation plays a key role in the TGD inspired model of the genetic code. Dodecahedron is the dual of icosahedron and tetrahedron is self-dual! [Note however that also the octahedron is involved with the unit cell although "icosa-tetrahedral" does not reflect its presence. Cube is the dual of the octahedron.]

So: could the gravitational diffraction of CMB on a local crystal having the structure of icosa-tetrahedral tessellation create the illusion that the Universe is a dodecahedron?

Could the possible dark part of the CMB radiation diffract in local tessellations assigned with the local MBs?

1. In diffraction, the wavelength of diffracted radiation must correspond to the size of the unit cell of the lattice-like structure involved. The maximum wavelength of CMB intensity as function of wavelength corresponds to a wavelength of about .5 cm. Can one imagine a tessellation with the unit cell of size about .5 cm?

2. The gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$, where M is large mass and m a small mass, say proton mass [K93, K80] [L50, L101, L119, L121]. Both masses are assignable to the monopole flux tubes mediating gravitational interaction. $\beta_0 = v_0/c$ is velocity parameter and near to unity in the case of Earth.

3. The size scale of the unit cell of the dark gravitational crystal would be naturally given by $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0$ and would be depend on M only and would be rather large and depend on the local large mass M, say that of Earth. Λ_{gr} does not depend on m (Equivalence Principle).

4. For Earth, the size scale of the unit cell would be of the order of $\Lambda_{gr} = GM_E/\beta_0 \sim .45$ cm, where $\beta_0 = 0 = v_0/c \sim 1$ is near unity from the experimental inputs emerging from quantum hydrodynamics [?] and quantum model of EEG [L101] and quantum gravitational model for metabolism [L121, L119]. Λ_{gr} could define the size of the unit cell of the icosa-tetrahedral tessellation. Note that Earth's Schwartschild radius $r_S = 2GM \sim .9$ cm.

   Encouragingly, the wavelength of CMB intensity as a function of wavelength around .5 cm to be compared with $\Lambda_{gr} \sim .45$ cm! Quantum gravitational diffraction might take place for dark CMB and give rise to the diffraction peaks!

5. Diffraction pattern would reflect astroscopic quantum coherence, and the findings of Luminet et al could have an explanation in terms of the geometry of local gravitational MB rather than the geometry of the Universe! Diffraction could also explain the strange deviations of CMB correlation functions from predictions for large values of the angular distance.

   It might be also possible to understand the finding that CMB seems to depend on the features of the local environment of Earth, which is in a sharp conflict with the cosmological principle. According to Wikipedia article (`https://cutt.ly/YZXJ7ao`), Even in the COBE map, it was observed that the quadrupole ($l = 2$, spherical harmonic) has a low amplitude compared to the predictions of the Big Bang. In particular, the quadrupole and octupole ($l = 3$) modes appear to have an unexplained alignment with each other and with both the ecliptic plane and equinoxes.

6. Could the CMB photon transform to a gravitationally dark photon in the diffraction? This would be a reversal for the transformation of dark photons to ordinary photons interpreted as biophotons. Also in quantum biology the transformation of ordinary photons to dark ones takes place. If so the wave length for a given CMB photon would be scaled up by the factor $\hbar_{gr}/\hbar = (GM_Em/\beta_0)/\hbar \simeq 3.5 \times 10^{12}$ for proton. This gives $\Lambda_{gr} = 1.75 \times 10^7$ km, to be compared with the radius of Earth about 6.4×10^6 km.

3.5 Inflation and TGD

The comparison of TGD with inflationary cosmology combined with new results about TGD inspired cosmology provides fresh insights to the relationship of TGD and standard approach and shows how TGD cures the lethal diseases of the eternal inflation. Very roughly: the replacement of the energy of the scalar field with magnetic energy replaces eternal inflation with a fractal quantum critical cosmology allowing to see more sharply the TGD counterpart of inflation and accelerating expansion as special cases of criticality. Wikipedia gives a nice overall summary inflationary cosmology (see `http://tinyurl.com/yka2wce`) [E5] and I recommend it to the non-specialist physics reader as a way to refresh his or her memory.

3.5.1 Brief Summary Of The Inflationary Scenario

Inflationary scenario relies very heavily on rather mechanical unification recipes based on GUTs. Standard model gauge group is extended to a larger group. This symmetry group breaks down to standard model gauge group in GUT scale which happens to correspond to CP_2 size scale. Leptons and quarks are put into same multiplet of the gauge group so that enormous breaking of symmetries occurs as is clear from the ratio of top quark mass scale and neutrino mass scale. These unifiers want however a simple model allowing to calculate so that neither aesthetics nor physics does not matter. The instability of proton is one particular prediction. No decays of proton in the predicted manner have been observed but this has not troubled the gurus. As a matter fact, even Particle Data Tables tell that proton is not stable! The lobbies of GUTs are masters of their profession!

One of the key features of GUT approach is the prediction Higgs like fields. They allow to realize the symmetry breaking and describe particle massivation. Higgs like scalar fields are also the key ingredient of the inflationary scenario and inflation goes to down to drain tub if Higgs is not found at LHC. It is looking more and more probable that this is indeed the case. Inflation has endless variety of variants and each suffers from some drawback. In this kind of situation one would expect that it is better to give up but it has become a habit to say that inflation is more that a theory, it is a paradigm. When superstring models turned out to be a physical failure, they did not same thing and claimed that super string models are more like a calculus rather than mere physical theory.

The problems that inflation was proposed to solve

The basic problems that inflation was proposed to solve are magnetic monopole problem, flatness problem, and horizon problem. Cosmological principle is a formulation for the fact that cosmic microwave radiation is found to be isotropic and homogenous in an excellent approximation. There are fluctuations in CMB believed to be Gaussian and the prediction for the spectrum of these fluctuations is an important prediction of inflationary scenarios.

1. Consider first the horizon problem. The physical state inside horizon is not causally correlated with that outside it. If the observer today receives signals from a region of past which is much larger than horizon, he should find that the universe is not isotropic and homogenous. In particular, the temperature of the microwave radiation should fluctuate wildly. This is not the case and one should explain this.

   The basic idea is that the potential energy density of the scalar field implies exponential expansion in the sense that the "radius" of the Universe increases with an exponential rate with respect to cosmological time. This kind of Universe looks locally like de-Sitter Universe. This fast expansion smooths out any inhomogenuities and non-isotropies inside horizon. The Universe of the past observed by a given observer is contained within the horizon of the past so that it looks isotropic and homogenous.

2. GUTs predict a high density of magnetic monopoles during the primordial period as singularities of non-abelian gauge fields. Magnetic monopoles have not been however detected and one should be able to explain this. The idea is very simple. If Universe suffers an exponential expansion, the density of magnetic monopoles gets so diluted that they become effectively non-existent.

3. Flatness problem means that the curvature scalar of 3-space defined as a hyper-surface with constant value of cosmological time parameter (proper time in local rest system) is vanishing in an excellent approximation. de-Sitter Universe indeed predicts flat 3-space for a critical mass density. The contribution of known elementary particles to the mass density is however much below the critical mass density so that one must postulate additional forms of energy. Dark matter and dark energy fit the bill. Dark energy is very much analogous to the vacuum energy of Higgs like scalar fields in the inflationary scenario but the energy scale of dark energy is by 27 orders of magnitude smaller than that of inflation, about 10^{-3} eV.

Evolution of inflationary models

The inflationary models developed gradually more realistic.

1. Alan Guth was the first to realize that the decay of false (unstable) vacuum in the early universe could solve the problem posed by magnetic monopoles. What would happen would

be the analog of super-cooling in thermodynamics. In super-cooling the phase transition to stable thermodynamical phase does not occur at the critical temperature and cooling leads to a generation of bubbles of the stable phase which expand with light velocity.

The unstable super-cooled phase would locally correspond to exponentially expanding de-Sitter cosmology with a non-vanishing cosmological constant and high energy density assignable to the scalar field. The exponential expansion would lead to a dilution of the magnetic monopoles and domain walls. The false vacuum corresponds to a value of Higgs field for which the symmetry is not broken but energy is far from minimum. Quantum tunnelling would generate regions of true vacuum with a lower energy and expanding with a velocity of light. The natural hope would be that the energy of the false vacuum would generate radiation inducing reheating. Guth however realized that nucleation does not generate radiation. The collisions of bubbles do so but the rapid expansion masks this effect.

2. A very attractive idea is that the energy of the scalar field transforms to radiation and produces in this manner what we identify as matter and radiation. To realize this dream the notion of slow-roll inflation was proposed. The idea was that the bubbles were not formed at at all but that the scalar field gradually rolled down along almost flat hill. This gives rise to an exponential inflation in good approximation. At the final stage the slope of the potential would come so steep that reheating would took place and the energy of the scalar field would transform to radiation. This requires a highly artificial shape of the potential energy. There is also a fine tuning problem: the predictions depend very sensitively on the details of the potential so that strictly speaking there are no predictions anymore. Inflaton should have also a small mass and represent new kind of particle.

3. The tiny quantum fluctuations of the inflaton field have been identified as the seed of all structures observed in the recent Universe. These density fluctuations make them visible also as fluctuations in the temperature of the cosmic microwave background and these fluctuations have become an important field of study (WMAP).

4. In the hybrid model of inflation there are two scalar fields. The first one gives rise to slow-roll inflation and second one puts end to inflationary period when the first one has reached a critical value by decaying to radiation. It is of course imagine endless number of speculative variants of inflation and Wikipedia article summarizes some of them.

5. In eternal inflation the quantum fluctuations of the scalar field generate regions which expand faster than the surrounding regions and gradually begin to dominate. This means that there is eternal inflation meaning continual creation of Universes. This is the basic idea behind multiverse thinking. Again one must notice that scalar fields are essential: in absence of them the whole vision falls down like a card house.

The basic criticism of Penrose against inflation is that it actually requires very specific initial conditions and that the idea that the uniformity of the early Universe results from a thermalization process is somehow fundamentally wrong. Of course, the necessity to assume scalar field and a potential energy with a very weird shape whose details affect dramatically the observed Universe, has been also criticized.

3.5.2 Comparison With TGD Inspired Cosmology

It is good to start by asking what are the empirical facts and how TGD can explain them.

What about magnetic monopoles in TGD Universe?

Also TGD predicts magnetic monopoles. CP_2 has a non-trivial second homology and second geodesic sphere represents a non-trivial element of homology. Induced Kähler magnetic field can be a monopole field and cosmic strings are objects for which the transversal section of the string carries monopole flux. The very early cosmology is dominated by cosmic strings carrying magnetic monopole fluxes. The monopoles do not however disappear anywhere. Elementary particles themselves are string like objects carrying magnetic charges at their ends identifiable as wormhole throats at which the signature of the induced metric changes. For fermions the second end of the string carries neutrino pair neutralizing the weak isospin. Also color confinement could involve magnetic confinement. These monopoles are indeed seen: they are essential for both the screening of weak interactions and for color confinement!

The origin of cosmological principle

The isotropy and homogenuity of cosmic microwave radiation is a fact as are also the fluctuations in its temperature as well as the anomalies in the fluctuation spectrum suggesting the presence of large scale structures. Inflationary scenarios predict that fluctuations correspond to those of nearly gauge invariant Gaussian random field. The observed spectral index measuring the deviation from exact scaling invariance is consistent with the predictions of inflationary scenarios.

Isotropy and homogenuity reduce to what is known as cosmological principle. In general relativity one has only local Lorentz invariance as approximate symmetry. For Robertson-Walker cosmologies with sub-critical mass density one has Lorentz invariance but this is due to the assumption of cosmological principle - it is not a prediction of the theory. In inflationary scenarios the goal is to reduce cosmological principle to thermodynamics but fine tuning problem is the fatal failure of this approach.

In TGD inspired cosmology [K94] cosmological principle reduces sub-manifold gravity in $H = M^4 \times CP_2$ predicting a global Poincare invariance reducing to Lorentz invariance for the causal diamonds. This represent extremely important distinction between TGD and GRT. This is however not quite enough since it predicts that Poincare symmetries treat entire partonic 2-surfaces at the end of CD as points rather than affecting on single point of space-time. More is required and one expects that also now finite radius for horizon in very early Universe would destroy the isotropy and homogenuity of 3 K radiation. The solution of the problem is simple: cosmic string dominated primordial cosmology has infinite horizon size so that arbitrarily distance regions are correlated. Also the critical cosmology, which is determined part from the parameter determining its duration by its imbeddability, has infinite horizon size. Same applies to the asymptotic cosmology for which curvature scalar is extremized.

The hierarchy of Planck constants [K42] and the fact that gravitational space-time sheets should possess gigantic Planck constant suggest a quantum solution to the problem: quantum coherence in arbitrary long length scales is present even in recent day Universe. Whether and how this two views about isotropy and homogenuity are related by quantum classical correspondence, is an interesting question to ponder in more detail.

3-space is flat

The flatness of 3-space is an empirical fact and can be deduced from the spectrum of microwave radiation. Flatness does not however imply inflation, which is much stronger assumption involving the questionable scalar fields and the weird shaped potential requiring a fine tuning. The already mentioned critical cosmology is fixed about the value value of only single parameter characterizing its duration and would mean extremely powerful predictions since just the imbeddability would fix the space-time dynamics almost completely.

Exponentially expanding cosmologies with critical mass density do not allow embedding to $M^4 \times CP_2$. Cosmologies with critical or over-critical mass density and flat 3-space allow embedding but the embedding fails above some value of cosmic time. These embeddings are very natural since the radial coordinate r corresponds to the coordinate r for the Lorentz invariant a=constant hyperboloid so that cosmological principle is satisfied.

Can one imbed exponentially expanding sub-critical cosmology? This cosmology has the line element

$$ds^2 = dt^2 - ds_3^2 \ \ , \ \ ds_3^2 = sinh^2(t)d\Omega_3^2 \ \ ,$$

where ds_3^2 is the metric of the $a = constant$ hyperboloid of M^4_+ (future light-cone).

1. The simplest embedding is as vacuum extremal to $M^4 \times S^2$, S^2 the homologically trivial geodesic sphere of CP_2. The embedding using standard coordinates (a, r, θ, ϕ) of M^4_+ and spherical coordinates (Θ, Φ) for S^2 is to a geodesic circle (the simplest possibility)

$$\Phi = f(a) \ , \ \Theta = \pi/2 \ .$$

2. $\Phi = f(a)$ is fixed from the condition

$$a = sinh(t) \ ,$$

giving

$$g_{aa} = (dt/da)^2 = \frac{1}{cosh^2(t)}$$

and from the condition for the g_{aa} as a component of induced metric tensor

$$g_{aa} = 1 - R^2(\frac{df}{da})^2 = \frac{1}{cosh^2(t)} \ .$$

3. This gives

$$\frac{df}{da} = \pm\frac{1}{R} \times tanh(t)$$

giving $f(a) = (cosh(t) - 1)/R$. Inflationary cosmology allows embedding but this embedding cannot have a flat 3-space and therefore cannot make sense in TGD framework.

Replacement of inflationary cosmology with critical cosmology

In TGD framework inflationary cosmology is replaced with critical cosmology. The vacuum extremal representing critical cosmology is obtained has 2-D CP_2 projection- in the simplest situation geodesic sphere. The dependence of Φ on r and Θ on a is fixed from the condition that one obtains flat 3- metric

$$\frac{a^2}{1+r^2} - R^2 sin^2(\Theta)(\frac{d\Phi}{dr})^2 = a^2 \ .$$

This gives

$$sin(\Theta) = \pm ka \ , \ \frac{d\Phi}{dr} = \pm\frac{1}{kR}\frac{r}{\sqrt{1+r^2}} \ .$$

The embedding fails for $|ka| > 1$ and is unique apart from the parameter k characterizing the duration of the critical cosmology. The radius of the horizon is given by

$$R = \int \frac{1}{a}\sqrt{1 - \frac{R^2k^2}{1-k^2a^2}}$$

and diverges. This tells that there are no horizons and therefore cosmological principle is realized. Infinite horizon radius could be seen as space-time correlate for quantum criticality implying long range correlations and allowing to realize cosmological principle. Therefore thermal realization of cosmological principle would be replaced with quantum realization in TGD framework predicting long range quantal correlations in all length scales. Obviously this realization is a in well-defined sense the diametrical opposite of the thermal realization. The dark matter hierarchy is expected to correspond to the microscopic realization of the cosmological principle generating the long range correlations.

Critical cosmology could describe the phase transition increasing Planck constant associated with a magnetic flux tube leading to its thickening. Magnetic flux would be conserved and the magnetic energy for the thicknened portion would be reduced via its partial transformation to radiation giving rise to ordinary and dark matter.

Fractal hierarchy of cosmologies within cosmologies

Many-sheeted space-time leads to a fractal hierarchy of cosmologies within cosmologies. In zero energy ontology the realization is in terms of causal diamonds within causal diamonds with causal diamond identified as intersection of future and past directed light-cones. One can say that everything can be created from vacuum. The temporal distance between the tips of CD is given as an integer multiple of CP_2 time in the most general case and boosts of CDs are allowed. The are also other moduli associated with CD and discretization of the moduli parameters is strong suggestive.

Critical cosmology corresponds to negative value of “pressure” so that it also gives rise to accelerating expansion. This suggests strongly that both the inflationary period and the accelerating expansion period which is much later than inflationary period correspond to critical cosmologies differing from each other by scaling. Continuous cosmic expansion is replaced with a sequence of discrete expansion phases in which the Planck constant assignable to a magnetic flux quantum increases and implies its expansion. This liberates magnetic energy as radiation so that a continual creation of matter takes place in various scales.

This fractal hierarchy is the TGD counterpart for the eternal inflation. This fractal hierarchy implies also that the TGD counterpart of inflationary period is just a scaled up invariant of critical cosmologies within critical cosmologies. Of course, also radiation and matter dominated phases as well as asymptotic string dominated cosmology are expected to be present and correspond to cosmic evolutions within given CD.

Vacuum energy density as magnetic energy of magnetic flux tubes and accelerating expansion

TGD allows a more microscopic view about cosmology based on the vision that primordial period is dominated by cosmic strings which during cosmic evolution develop 4-D M^4 projection meaning that the thickness of the M^4 projection defining the thickness of the magnetic flux tube gradually increases [K94]. The magnetic tension corresponds to negative pressure and can be seen as a microscopic cause of the accelerated expansion. Magnetic energy is in turn the counterpart for the vacuum energy assigned with the inflaton field. The gravitational Planck constant assignable to the flux tubes mediating gravitational interaction nowadays is gigantic and they are thus in macroscopic quantum phase. This explains the cosmological principle at quantum level.

The phase transitions inducing the boiling of the magnetic energy to ordinary matter are possible. What happens that the flux tube suffers a phase transition increasing its radius. This however reduces the magnetic energy so that part of magnetic energy must transform to ordinary matter. This would give rise to the formation of stars and galaxies. This process is the TGD counterpart for the re-heating transforming the potential energy of inflaton to radiation. The local expansion of the magnetic flux could be described in good approximation by critical cosmology since quantum criticality is in question.

One can of course ask whether inflationary cosmology could describe the transition period and critical cosmology could correspond only to the outcome. This does not look very attractive idea since the CP_2 projections of these cosmologies have dimension D=1 and D=2 respectively.

In TGD framework the fluctuations of the cosmic microwave background correspond to mass density gradients assignable to the magnetic flux tubes. An interesting question is whether the flux tubes could reveal themselves as a fractal network of linear structures in CMB. The prediction is that galaxies are like pearls in a necklace: smaller cosmic strings around long cosmic strings. The model discussed for the formation of stars and galaxies discussed in the previous section gives a more detailed view about this.

What is the counterpart of cosmological constant in TGD framework?

In TGD framework cosmological constant emerge when one asks what might be the GRT limit of TGD [K111], [L5] (see `http://tinyurl.com/hzkldnb`). Space-time surface decomposes into regions with both Minkowskian and Euclidian signature of the induced metric and Euclidian regions have interpretation as counterparts of generalized Feynman graphs. Also GRT limit must allow space-time regions with Euclidian signature of metric - in particular CP_2 itself - and this requires positive cosmological constant in this regions. The action principle is naturally Maxwell-Einstein action with cosmological constant which is vanishing in Minkowskian regions and very large in

Euclidian regions of space-time. Both Reissner-Nordström metric and CP_2 are solutions of field equations with deformations of CP_2 representing the GRT counterparts of Feynman graphs. The average value of te cosmological constant is very small and of correct order of magnitude since only Euclidian regions contribute to the spatial average. This picture is consistent with the microscopic picture based on the identification of the density of magnetic energy as vacuum energy since Euclidian particle like regions are created as magnetic energy transforms to radiation.

Dark energy and cosmic consciousness

The hierarchy of Planck constants makes possible macroscopic quantum coherence in arbitrarily long scales. Macroscopic quantum coherence is essential for life and the notion of magnetic body is central in TGD inspired biology. For instance, the braiding of flux tubes making possible topological quantum computation like processes [K5]. The findings of Peter Gariaev [I8, I9, I13] provide support for the notion of magnetic body containing dark matter [K1]. The notion of magnetic body also inspires science fictive ideas like remote replication of DNA [K121] for which there is also some support and which could be essential for understanding water memory [I10, I11].

The gravitational Planck constant $\hbar_{gr} = GM_1M_2/v_0$ (v_0 is dimensionless parameter in units for which $c = 1$ but has interpretation as velocity) assumed in the model of planetary system based on Bohr orbitology [K93, K79] is assigned to the magnetic flux quanta mediating gravitational interaction between objects with masses M_1 and M_2 ($M_1 = M_2$ for self gravitation). For these values of Planck constant the quantum scales are gigantic. Even for gravitational magnetic flux tubes connecting electron with Sun, the Compton length would be of the order of the radius of Sun. If there are ordinary particles at these flux tubes, their Compton length is enormous and their density is essentially constant.

The fractality of TGD Universe and of the magnetic flux tube hierarchy forces to ask whether intelligent consciousness could be possible in cosmic scales and be based on the Indra's net of the magnetic flux tubes. This cosmic nervous system would carry dark energy as magnetic energy with magnetic tension responsible for the negative "pressure" causing accelerated expansion. This Indra's web would act as super-intelligence taking the role of God by creating stars and galaxies by transforming magnetic energy to radiation and matter in phase transitions increasing the Planck constant and driving the evolution of this cosmic intelligence. In inflationary scenario inflaton field would have similar role. In zero energy ontology there is no deep reason preventing for the creation of entire sub-cosmologies from vacuum.

3.5.3 CBM cold spot as problem of the inflationary cosmology

The existence of large cold spot in CMB (see `http://tinyurl.com/hxgck9r`) is a serious problem for the inflationary cosmology. The distance r of the cold spot is in the range .6-1 Gly at redshift $z \sim 1$ with uncertainty coming from that for Hubble constant in the formula $z = r/Hc$.

Remark: The uncertainty in distance corresponds to the ratio 3/2 for the upper and lower ends for the range of H. TGD predicts that both cosmological constant and Hubble constant obey p-adic length scale evolution and that the smallest increment of Hubble constant is by factor $\sqrt{2}$ [L61].

The root mean square fluctuation of CMB temperature is $T = 2.7$ K is $\Delta T_{CMB} = 18$ μK: $\Delta T_{CMB}/T \sim .7 \times 10^{-5}$. The temperature fluctuation in the cold spot reduces average temperature by 70 μK corresponding to $\Delta_{spot}T/T \sim 2.6 \times 10^{-5}$. The ratio of these 2 fluctuations is $\Delta T_{CMB}/\Delta T_{spot} = 3.9$. In standard cosmological scenario density fluctuations $\Delta\rho/\rho$ is predicted to be proportional to $\Delta T/T$ and would have same order of magnitude but fluctuation in so long scale about .5-1 Gly is not plausible. That a region with lower temperature has also a lower density (not much!) is natural since density fluctuations and temperature fluctuations are proportional to each other in the standard view about the formation of structures.

This comment was inspired as a reaction to probably the most adventurous explanation for the cold spot as resulting from a collision of two Universes (see `http://tinyurl.com/ycl65svs`). At this moment multiverse exists only in the imagination of theoreticians. The cold spot is however there very concretely and cries for an explanation. It would be nice to say something interesting about it also in TGD framework.

Could the cold spot be apparent and due to supervoid and integrated Sachs-Wolfe effect?

A more conventional explanation is in terms of large voids (see `http://tinyurl.com/jyqcjhl`). These regions contain very few galaxies and the density is about 10 per cent about the density. Therefore the $\Delta/T \propto \Delta\rho/\rho$ rule cannot hold true in these regions. These regions would give rise to a reduction of the energy of the CMB photons travelling through them, which would imply an apparent reduction of CMB temperature. This effect is due to a gravitational redshift and known as integrated Sachs-Wolfe effect (ISW) (see `http://tinyurl.com/y9hd73ms`).

There is indeed evidence for a supervoid with radius of 1.8 Gly centered at distance of 3 Gly in the direction of Eridani and thus in the direction of the cold spot. According to the Wikipedia article the supervoid explaining the hot spot should have distance of 6-10 Gly and diameter about 1 Gly.

There are arguments against the explanation of hot spot in terms of large voids along the line of sight (see `http://tinyurl.com/yb5dr8w3`). According to the abstract of the article, there are voids at z = 0.14, 0.26 and 0.30 but they are interspersed with small over-densities but that the scale of these voids is insufficient to explain the Cold Spot through the ΛCDM ISW. Therefore the reduction of the temperature should have primodial origin. Second problem - at least for me - is that I do not know whether there is any convincing explanation for why the dark matter should concentrate at filaments, which in turn are found to concentrate at 2-D surfaces of large voids.

TGD inspired explanation

In TGD framework one considers flux tube network, and the formation of structures is based on different mechanism. The correlation between density and temperature fluctuations remains true in the scales in which mass density can be regarded as constant.

1. Dark mass and energy dominate over the mass density and are concentrated along cosmic strings - as knots as the simplest option proposed. It is indeed known that dark matter is distributed along filamentary structures and the outcome is a kind of honeycomb structure with most of the dark matter at the surfaces of the cells and intermediate regions formed by large voids. The average of the mass density must be taken in a scale longer than that of large voids which is in the range of .1-1 Gly.

2. Cosmic strings - flux tubes containing dark matter - would generate the visible matter both by a transformation of dark matter to ordinary matter by h_{eff} reducing phase transition and by condensation of ordinary matter around knots of cosmic strings. Long strings could form knots via temporary reconnections giving rise to spiral and elliptic galaxies (for these reconnection would form a separate closed flux tube). Stars could be formed as sub-knots of galactic knots in the same manner. One can wonder this formation mechanism is able to explain large regions with slightly lower density?

To get an idea about the possible TGD based explanation of the cold spot, one must ask what is new in TGD cosmology preceding radiation dominated phase as compared to GRT based inflationary cosmology.

1. In TGD the counterpart of pre-inflationary period is the period during, which cosmic strings dominated [K31, K94, K66, L22]. During this period there was no space-time in the conventional sense of the word - that is as a space-time surfaces having 4-D M^4 projection in $M^4 \times CP_2$. Rather, cosmic strings had 2-D string world sheets as M^4 projections. Space-time in the conventional sense emerged during the inflationary period as the thickness of M^4 projection of the originally infinitely thin) flux tubes started to increase as a response to the perturbations caused by other flux tubes and the huge magnetic fields along flux tubes started to get weaker. After the transition to radiation dominated phase it became convenient to speak about space-time in the conventional sense. Radiation was produced in the decay of cosmic string energy to radiation.

   The conservation of monopole flux of the cosmic strings (monopole flux is possible by CP_2 topology) led to the reduction of the magnetic field as $1/S$, S the area of flux tube and also energy density. There is present a volume term proportional to the cosmological constant. How the net density of the dark energy of flux tube behaved depends on how the ratio of these densities evolved but on dimensional grounds one can make the guess that the dark energy per unit length reduced as $1/L(k)^2$ where $L(k) \propto k^{-1/2}$ is the p-adic length scales assignable to $p \simeq 2^k$ and increasing during cosmic evolution as proportional to the Hubble radius.

2. The basic prediction is that the analog of the inflationary period need neither begin nor end at precisely the same time - call the latter time t_{end} - everywhere. There are fluctuations in the value of t_{end}. If the transition occurs for a given region earlier than for the environment, cosmic expansion also starts earlier, and the density of matter at later times and also temperature is lower than in the surrounding regions for the same value of M^4_+ time (light-cone proper time a, which defines the scale factor a^2 of the Robertson-Walker metric). By cosmic expansion also the scale of the large voids in these regions would be larger than in environment. This explanation would differ form the explanation in terms of supervoid in the sense that the temperature fluctuation would be real and primordial rather than apparent and caused by gravitational redshift in super-voids (ISW effect). The concentration of dark matter and energy to flux tubes would also explain super-voids. Super voids would not induce apparent temperature reduction. Rather, both super voids and temperature fluctuation would have a common primordial origin.

   Note that the fluctuations of ΔT correspond by $T/T_0 = a_0/a$ fluctuations of same size for $t_{end} = a_{end}$ (a is light-cone proper time defining the scale factor of RW metric as induced metric of space-time surface) so that the cold spot would have $\Delta a/a_{now} \sim 2.6 \times 10^{-5}$. $g_{aa} < 1$ implying $a_{now} > t_{now}$ gives $a_{now} > 13.8$ Gy. This gives $\Delta a_{now} > (\Delta T/T)a_{now} > 3.6 \times 10^5$ y.

   The basic unanswered question is whether the the typical size scale for the fluctuation for the time t_{end} is larger than the typical size scale of the density fluctuation in standard cosmology.

3. One should also have an explanation for the concentration of flux tube structures at the surfaces of large voids. I have proposed for decades ago a model of large voids based on extremals of Kähler action. The void would have long cosmic string in the center and the return would come along the surface of the large void. One would have an analog of a dipole magnetic field. Galaxies would be knots along the flux tubes of the return flux. These dipole field like structures would arrange to a kind of lattice analogous to ferromagnet or anti-ferromagnet. At the boundaries between neighboring cells there would be pairs of flux tubes arriving from different cells and carrying parallel or antiparallel fluxes.

   Classically various magnetization effects are not possible since they involve exchange interaction of spins. One can recklessly speculate that magnetized phases with parallel spins could exist at dark flux tubes as macroscopic quantum phases. Also cyclotron BE condensates would be possible. Could these make the flux tubes to behave like spins with very large $h_{eff} = n \times h = h_{gr}$ serving as a unit of spin (in renormalization group approach to statistical physics one indeed combines spins to larger block spins)? Could one speak of exchange forces between the spins at different flux tubes arising from entanglement? If so, there would be quantum coherence in cosmological scales made possible by very large values of the effective Planck constant $h_{eff} = n \times h = h_{gr}$ at flux tubes [K93, K79, L22, K80].

3.6 About the TGD counterpart of the inflationary cosmology

The question of Marko Manninen related to the inflation theory (see this) inspired the following considerations related to the TGD counterpart of the inflationary period assumed to precede the radiation dominated phase and to produce ordinary matter in the decay of the inflaton fields. I have considered the TGD analog of inflation already 12 years ago [L4] [K94] and the recent discussion brings in the progress in the understanding that occurred during these years.

Recall that inflation theory was motivated by several problems of the standard model of cosmology: the almost constancy of the temperature of the cosmic microwave background; the nearly flatness of 3-space implying in standard cosmology that the mass density is very nearly critical; and the empirical absence of magnetic monopoles predicted by GUTs. The proposal solving these problems was that the universe had critical mass density before the radiation dominated cosmology, which forced exponential expansion and that our observable Universe defined by the horizon radius corresponds to a single coherent region of 3-space.

The critical mass density was required by the model and exponential expansion implying approximate flatness. The almost constant microwave temperature would be due to the exponential decay of temperature gradients and diluted monopole density. The model also explained the temperature fluctuations as Gaussian fluctuations caused by the fluctuations of the mass density. The generation of matter from the decay of the energy density of vacuum assigned with the vacuum expectation values of the inflaton fields was predicted to produce the ordinary matter. There was however also a very severe problem: the prediction of a multiverse: there would be an endless number of similar expanded coherence regions with different laws of physics.

A very brief summary of the recent view of the TGD variant of the inflation theory proposed earlier [L4] is in order before going into the details.

1. The TGD view is based on a new space-time concept: space-time surfaces are at the fundamental level identified as 4-D surfaces in $H = M^4 \times CP_2$. They have rich topologies and they are of finite size. The Eisteinian space-time of general relativity as a small metric deformation of empty Minkowski space M^4 is predicted at the long length scale limit as an effective description. TGD however predicts a rich spectrum of space-time topologies which mean deviation from the standard model in short scales and these have turned out to be essential not only for the understanding of primordial cosmology but also the formation of galaxies, stars and planets.

2. In TGD, the role of the inflaton fields decaying to ordinary matter is taken by what I call cosmic strings, which are 3-D extremely thin string-like objects of form $X^2 \times Y^2 \subset M^4 \times CP_2$, have a huge energy density (string tension) and decay to monopole flux tubes and liberate ordinary matter and dark matter in the process. That cosmic strings and monopole flux tubes form a "gas" in $M^4 \times CP_2$ solves the flatness problem: M^4 is indeed flat!

   TGD also involves the number theoretic vision besides geometric vision: these visions are related by what I call $M^8 - H$ duality, see for instance [L91, L92] for the odyssey leading to its recent dramatically simplified form [L145]. The basic prediction is a hierarchy of Planck constants $h_{eff} = nh_0$ labelling phases of ordinary matter behaving like dark matter: these phases explain missing baryonic matter whereas galactic dark matter corresponds to dark energy as the energy of monopole flux tubes.

   Quantum coherence becomes possible in arbitrarily long scales and in cosmic scales gravitational quantum coherence replaces the assumption that the observed universe corresponds to an exponentially expanding coherence region and saves it from the multiverse. This solves the problem due to the constancy of the CMB background temperature.

3. In the TGD framework, cosmic strings thickened to monopole flux tubes are present in the later cosmology and would define the TGD counterpart of critical mass density in the inflationary cosmology but not at the level of space-time but in $M^4 \subset M^4 \times CP_2$. The monopole flux tubes are always closed: this solves the problem posed by the magnetic monopoles in GUTs. Monopole flux tubes also explain the stability of long range magnetic fields, which are a mystery in standard cosmology even at the level of planets such as Earth.

4. The fluctuations of CMB temperature would be due to the density fluctuations. In inflation theory they would correspond to the fluctuations of the inflaton field vacuum expectation values. In TGD, the density fluctuations would be associated with quantum criticality explaining the critical mass density ρ_{cr}. The fluctuations $\delta\rho_{cr}$ of the critical mass density for the monopole flux tubes would be due to the spectrum for the values of effective Planck constant h_{eff}: one would have $\delta T/T \propto \delta h_{eff}/h_{eff}$. This would give a direct connection between cosmology and quantum biology where the phases with large h_{eff} are in a fundamental role.

3.6.1 Some basic notions of TGD

Cosmic strings and monopole flux tubes

In the TGD Universe space-times are 4-D surfaces in $H = M^4 \times CP_2$.

1. Cosmic strings [K31, K94] are 3-D string like objects which have 2-D M^4 projection and do not have any counterpart in GRT. They are of the form $X^2 \times Y^2 \subset M^4 \times CP_2$, where X^2 is a string world sheet and Y^2 is a complex submanifold of CP_2, say geodesic sphere. They can be arbitrarily long and have length measured even in billions of light years. They are not possible in string models or in GUTs.

2. Cosmic string world sheets are unstable against the thickening of their 2-D M^4 projection making it 4-dimensional. This thickening creates what I call Einsteinian space-time. The thickening reduces the string tension and liberates energy as ordinary matter and the TGD counterpart of galactic dark matter. This decay process is the TGD counterpart of inflaton field decay.

   This process repeats itself as a similar process for monopole flux tubes but the liberated energy decreases. The recent accelerating period of expansion could correspond to this kind of phase transition. The thickening *need not* involve an exponential expansion of these space-time surfaces. This decay would lead from the cosmic string dominated phase to a radiation dominated phase and generate Einsteinian space-time and cosmology.

3. The energy of the cosmic strings generates a transversal $1/\rho$ gravitational field and cosmic strings orthogonal to galactic planes explain galactic dark matter yielding the flat velocity spectrum of stars in the galactic plane. No dark matter halo is needed as in ΛCDM model. Galactic dark matter as dark energy would not form a halo but a string-like structure. The prediction is that galaxies are formed as tangles of thickened cosmic strings along these very long cosmic strings. Zeldowich discovered these linear structures formed by galaxies decades ago [E272] but they have been "forgotten".

$M^8 - H$ duality

Before proceeding, one must say something about $M^8 - H$ duality.

1. In the earlier versions of $M^8 - H$ duality [L35, L36, L37, L91, L92, L138], the integer n appearing in $h_{eff} = nh_0$ corresponds to a dimension of an algebraic extension of rationals assignable to a single octonion polynomial $P(o)$ with integer coefficients defined in the space of complexified octonions O_c. The polynomials would have as roots possibly complex mass shells in $M^4_c \subset M^8_c$ and these would partially define the 3-D data of number theoretic holography in M^8.

2. It turns out that a correct spectrum of fluctuations is predicted if one has $n = n_1 n_2$ where n_i are identical or nearly identical. One can consider several variants for the composition of n to a product of integers. For instance, for the polynomials defined as functional composites of polynomials P_i have dimension of extension which is product $\prod_i n_i$ of the dimensions n_i for the polynomials P_i. The decomposition of n to the product could physically correspond to various interactions.

   The factors in the product could also correspond to M^4 and CP_2 degrees of freedom and this option suggested by the recent view of $M^8 - H$ duality [L145]. As a matter of fact, I proposed this kind of decomposition in the beginning of $M^8 - H$ adventure but gave it up.

3. The most recent formulation of $M^8 - H$ duality [L145] is dramatically simpler than the earlier ones. Complexified octonsions $O_c = M^8_c$ are replaced with octonions O allowing naturally a Minkowskian number theoretic norm $Re(o^2)$ making O effectively M^8. The holography = holomorphy principle at the level of H together with $M^8 - H$ duality fixes the number theoretic holography at the level of M^8 (normal space of 4-surface is associative and contains 2-D commutative subspace there is no need to define number theoretic holography

using polynomials $P(o)$ in M_c^8. It seems that all nice features of the earlier proposal apply also to this proposal.

The vanishing of 2 holomorphic functions of 4 generalized complex coordinates of H defines 4-D space-time surfaces in H [L132, L141]. These holomorphic functions naturally form a hierarchy of pairs of polynomials P_i, $i = 1, 2$, and one can assign toP_i an extension of rationals with dimension n_i, $i = 1, 2$. Could one identify $h = h_{eff}/h_0 = n$ as the product $n = n_1 n_2$? Note that n_1 and n_2 can also factorize to primes.

Number theoretic vision forces the increase of algebraic complexity meaning the increase of h_{eff} during cosmic evolution. $h_{eff} = h_0$ would be the simplest option in the primordial phase, where things are as simple as possible.

Hierarchies of p-adic length scales and effective Planck constants

The number theoretic vision of TGD implies hierarchies of p-adic length scales labelled by powers of p-adic primes p. Each p-adic hierarchy is accompanied by a hierarchy of dark scales and a hierarchy of phases behaving like dark matter. p-Adic length scale hypothesis, motivated by p-adic mass calculations [K63, K26], states that primes near some powers of 2 are physically preferred p-adic primes strengthens this hypothesis.

1. For a given prime p there exists entire hierarchy of p-adic length scales $L_{p,n} = p^{(n-1)/2)} L_p$, where one has $L_p = sqrtpR$, where R equals to the radius of CP_2 apart from a numerical constant.
2. The hierarchy of Planck constants $h_eff = nh_0$, where h_0 is the minimal value of effective Planck constant defines a hierarchy of phases of ordinary matter behaving like dark matter. This hierarchy solves the missing baryon problem whereas the energy of cosmic strings explains the galactic dark matter. The dark scales are given by $L_{p,n}^{dark} = \hbar_{eff} L_{p,n}$.
3. These two hierarchies are not independent since a given extension of rationals determining $h_{eff}/h_0 = n$ as its dimension defines also a set of p-adic primes p as a ramified prime for a polynomial defining the extension. The largest p-adic prime p_{max} is in a special physical role. The phase transitions changing the extension of rationals and the value of h_{eff} are possible and change the length scale of the monopole flux tube. Reconnections of the flux tubes define their topological dynamics and are in a central role in TGD inspired quantum chemistry and explain the basic mysteries of biocatalysis. Simple calculations show that p_{max} can be exponentially larger than n_0 [L140].
4. The ramified primes are bounded if one assumes that the coefficients of polynomials P are smaller than their degrees and imply that the number of polynomials with a smaller degree is finite for a given degree: this forces a number theoretic evolution in a very strong sense.

Zero energy ontology

In the TGD framework, zero energy ontology (ZEO) [L84] [K119] is the central element of quantum measurement theory and provides additional insights to the situation.

1. ZEO ontology involves as a basic concept the notion of causal diamond (CD) [L139, L145] as an interaction of future and past directed light-cones. CD is characterized by its size identifiable as the distance between its tips. The sizes of CDs form scaling hierarchies labelled by $h_{eff}/h_0 = n$ and p-adic length scales L_p. At least L_p, $L_{p,2} = \sqrt{p} L_p$, and the dark scales nL_p and $nL_{p,2}$ are fundamental scales. The p-adic primes p correspond to the ramified primes assignable to the polynomials defining the extension and p_{max} is in a preferred position.
2. The interpretation of CD is as the perceptive field of a conscious entity: CD could correspond to the part of the Universe perceivable to corresponding conscious entity and CD size would serve as the analog for horizon radius. The size of CD would naturally define the scale of quantum coherence and would increase during the cosmic evolution as n increases. It could be however arbitrarily long already in the primordial phase if rational polynomials are allowed.

3.6.2 The TGD view of primordial cosmology

I have already considered primordial cosmology in the TGD framework [L4] [K94].

Primordial cosmology and the almost constant temperature of the CMB

Primordial cosmology preceding the radiation dominated phase corresponds in the TGD framework to a "gas" like phase formed by a network of cosmic strings, which could be arbitrarily long and are always closed. Reconnection is the basic topological reaction for them. This phase has no counterpart in Einstein's theory.

A natural assumption is that there is a quantum coherence along the string. This means a hierarchies of quantum coherence scales assignable to cosmic strings and monopole flux tubes, which in the number theoretic vision of TGD would correspond to p-adic length scales and to a hierarchy of dark scales assignable to the h_{eff} a hierarchy of phases behaving like dark matter.

1. The p-adic length scales L_p could characterize the thickness of the monopole flux tubes and, as it turns out, $L_{p,2}$ could characterize the lengths of strings and flux tubes.

2. The dark length scales $nL_{p,n}$, $n = h_{eff}/h_0$ would be associated with the dark variants of the strings and monopole flux tubes. p would correspond to a ramified prime for a polynomial P defining an extension of rationals with dimension n and there is a large number of polynomials of this kind. The maximal p-adic prime for given P and n is in a physical special role and defines the maximal thickness and length of the flux tube in this case.

What about the p-adic length scales associated with the primordial phase? Assume the holography=holomorphy vision [L141, L146] so that a pair of polynomials defines the space-time surface and these polynomials define extension rationals assignable to M^4 and CP_2 degrees of freedom.

One can consider two options.

1. The simplest option is that cosmic strings correspond to $p = 1$ for which the flux tube is infinitely thin and the extension of rationals is trivial ($n = 0$). This would mean that flux tubes would have the same minimal length defined by CP_2 radius R. Primordial quantum coherence would be possible only in CP_2 scale.

2. There is also a more complex option.

   (a) The transversal scale of the cosmic string corresponds to CP_2 length scale R and is minimal. The CP_2 projection Y^2 as a complex surface can however have several sizes. One could however argue that they do not correspond to p-adic length scales and $p = 1$ corresponding to linear polynomials of CP_2 coordinates allowing only a homologically non-trivial geodesic sphere is possible.

   (b) What about M^4 degrees of freedom? Could one allow the reduction of the polynomials of 4 four complex (or hypercomplex) variables to non-irreducible polynomials when 3 complex variables are fixed to rational values (say put equal to zero). These would also allow rational roots. If all roots are rational, $n = 0$ is true. Does it make sense to identify the ramified primes as prime factors of the determinant identified as the square of the product of root differences ($b^2 - 4ac$ for a second order polynomial). If so, one could have p-adic primes $p \geq 2$ also in the primordial phase. Strings could have arbitrary long lengths also in this phase but no dark phases would be present.

   For this option a primordial quantum coherence would be possible in arbitrarily long p-adic length scales. Only the dark phases would emerge during evolution. This option conforms with the recent view of TGD.

In ZEO causal diamond (CD=cd$\times CP_2$) defines the perceptive field of a conscious entity. cd is analogous to an empty cosmology as a big bang followed by big crunch.

1. What determines the size of the CD in the recent cosmology? The ratio of CP_2 radius to Planck length is in the range 10^3-10^4 from p-adic mass calculations. Could the recent mean value $h_{eff}=h=n_0h_0$ correspond to CP_2 length scale R perhaps identifiable as the length scale of M^4 projection of monopole flux tube? The value of n_0 is in the range 10^7-10^8.

2. The scale defined as the geometric mean of Planck length and the length scale L defined by cosmological constant Λ defines the size scale of a large neuron around $L_m\sim 10^{-4}$ m. One can think that $_m$ is for "meso": L_m is the fundamental biological scale determined as a geometric mean of two scales: Planck length for microcosmos and Hubble radius for macroscoscosmos. The basic scale of biological systems would correspond to the geometric mean of horizons scale and Planck scale. The geometric mean property implies that L_m and L can be expressed as $L_n=xL_0$ and $L=x^2L_0$ which strongly suggests that these scales are primary and secondary length scales for some prime p.

3. In the twistor lift of TGD [K106, L43] [L116, L117], the cosmological constant Λ appears as the coefficient of the 4-volume term in the dimensionally reduced Kähler action determining as its preferred extemals 6-D twistor space as 6-surface in the product of 6-D twistor spaces of M^4 and CP_2 having two-sphere S^2 as a fiber and the space-time surface $X^4\subset H$ as the base space. The only spaces having a twistor space with Kähler structure are M^4 and CP_2 [?] so that TGD is unique.

4. Twistor lift suggests that $L_m=xL_P$, $x\equiv L_m/L_P=\sqrt{L/l_P}\sim 10^{31}/1.65$, defines the maximal thickness of a typical monopole flux tube in the recent cosmos. The scale x^2L_P in turn could define the scaling factor giving the maximal length L of the cosmic string determining the size scale of the CD. The natural identification would be as Hubble length $\hbar/H_0$, which is determined by the cosmological constant Λ. There are two scales: do they correspond to scales assignable to ordinary matter and dark matter at the highest possible level of the magnetic body of the system?

Could one understand the value of x number theoretically? Certainly it cannot correspond to the ratio $n_0=h/h_0\in[10^7-10^8]$. Much larger values are required.

1. Number theoretical approach predicts besides dark scales also p-adic length scales. The primary p-adic length scale L_p and secondary p-adic length $L_{2,p}=\sqrt{p}L_p$ and possibly also higher p-adic length scales forming a hierarchy in powers of $\sqrt{p}$. Could x and x^2 correspond to the dark primary length scale $nL_p\propto n\sqrt{p}R$ and to the dark secondary p-adic length scale $nL_{p,2}=npR$? p would be a ramified prime determined by the extensions of rationals determined by the value of h_{eff}.

   There are two options. In the recent universe either a) L_p or b) nL_p could correspond to a p-adic length scale assignable to neurons. For option a) nL_p would correspond to a scale in the range 10^3-10^4 m. For option b) L_p would correspond to a length scale in the range $10^{-12}-10^{-11}$ m (electron Compton length is 2.4×10^{-12} m).

   Secondary p-adic length scale $L_{2,p}$ would correspond to the horizon radius $\hbar/H_0$ and $nL_{2,p}$ to the radius of dark horizon assignable to the field body of cosmos perceivable to us.

2. During the primordial phase, the size of CD could correspond to Planck length or to CP_2 radius R. One could have $l_P=R$ for $h_{eff}=h_0$. In the recent situation one would $h=n_0h_0$ and $R_{eff}^2=n_0R^2=n_0\sqrt{G}$, perhaps identifiable as the scale of the M^4 projection of cosmic string (see below). n_0 would correspond to the dimension of extension of rationals and the p-adic prime p to a ramified prime of extension. There would be at least two CD sizes defined by $L_m=xL_P$ and $L=x^2L_P$, where one has $x=\sqrt{p/2}$ and p is a ramified prime of the extension of rationals considered.

Do quantum fluctuations replace the thermal fluctuations of inflation theory?

If long length scale quantum coherence is possible in the length scale of cosmic strings, one ends up with the following questions.

1. Does gravitational quantum coherence due to long cosmic strings explain the almost constant value of the CMB temperature? One has $\rho \propto T^4$, which gives $\delta\ T/T \propto 4\delta\ \rho/\rho$.

   One can imagine two options.

   (a) If arbitrarily long cosmic strings are possible in the primordial phase (rational polynomials are allowed), quantum coherence could be present in all scales already in the primordial phase with $h_{eff} = h_0$. This option conforms with the original proposal.

   (b) If the lengths of cosmic strings are bounded in the primordial phase so that they are proportional too h_{eff}, long cosmic strings must be created later by reconnection in phase transitions increasing the value of h_{eff} allowing larger p-adic primes defining p-adic lengths scales. These phase transitions would also increase the length of cosmic strings.

2. In the inflation model, the fluctuations of CMB temperature are due to the density fluctuations $\delta\ \rho/\rho$. Could these density fluctuations be reduced to the fluctuations of the density in the phase formed by the cosmic strings in the primordial phase and later in the phase formed by the monopole flux tubes (magnetic bodies) characterized by the value of h_{eff}?

3. Inflationary cosmology is critical in the sense that mass density $\rho_{cr} = 3H_0^2/8\pi G$, where H_0 is the Hubble constant, is critical. In the TGD framework, this formula holds true at the level of future light-cone $M^4_+ \subset M^4 \subset H = M^4 \times CP_2$ representing empty standard cosmology rather than at space-time level as in inflation theory. Therefore exponential expansion is not needed for this formula. The quantum criticality would naturally apply to the phase formed by ordinary particles at monopole flux tubes characterized by the values h_{eff}.

4. Quantum criticality means a spectrum of the values of $h_{eff} = nh_0$. How do the fluctuations of h_{eff} imply the density fluctuations?

   The dimension of G is $[L^2]/[h]$. In TGD the only dimensional parameter is CP_2 length scale R and this suggests the formula $G = R^2/\hbar$, which generalizes to the formula $G = R^2/\hbar_{eff}$. One must have $\hbar \sim (10^7 - 10^8)\hbar_0$ to explain CP_2 radius fixed by electron mass from p-adic mass calculations.

   Again one can consider several options.

   (a) R is a fundamental constant and the value of $G_{eff} = R^2/h_{eff}$ varies and is different in the dark phases and decreases with h_{eff}. This looks strange but since we cannot yet observe dark matter, one cannot exclude this option. For this option one would have for the dark matter $\rho_{cr} = 3H_0^2/4\pi G_{eff} = 3\hbar_{eff}H_0^2/4\pi R^2$. A natural assumption is that H_0 corresponds to a p-adic length scale that is $H_0 \propto 1/L_{p,2}$.

   (b) $G = R^2/\hbar_0$ is a fundamental constant and the effective radius squared $R^2_{eff} = \hbar_{eff}R^2/\hbar_0$ of CP_2 varies. It could geometrically correspond to the size of the M^4 projection of the cosmic string, or more precisely the thickening of $Y^2 \subset CP_2$. CP_2 scale would correspond to the Planck scale. For this option one would have $\rho = 3\hbar_0 H_0^2/8\pi R^2_{eff} = 3\hbar_{eff}/8\pi L^2_{p,2}$.

   (c) For both options the density of dark matter would increase with $\hbar_{eff}$. One can however consider also the possibility that H_0 corresponds to the inverse of the dark p-adic length scale $H_0 \propto 1/L_p(dark)$, $L_p(dark) = nL_p$. This would give $rho_{crit} \propto 1/nL^2_{p,2}$.

Consider now what quantum criticality predicts.

1. Criticality means that one has $\rho = \rho_{cr} = 3H_0^2/8\pi G$ so that the fluctuations would correspond to fluctuations of Hubble constant and $\hbar_{eff}$: $\delta\rho/\rho = \delta\hbar_{eff}/\hbar + 2\Delta H_0/H_0$. This means fluctuations and long range correlations since quantum coherence scales are typically proportional to h_{eff} and even h^2_{eff} as in atomic physics.

2. Depending on option, one can write the fluctuations of H_0 in terms of fluctuations of p-adic length scale $L_{p,2}$ or of dark p-adic length scale $L_{p,2}(dark) = nL_{p,2}$.

(a) For the $L_H = L_p$ option, one has $\Delta H_0/H_0 = \delta L_{p_2}/L_{p,2}$ which is extremely small in cosmic scales. This gives $\delta\rho/\rho \sim \delta\hbar_{eff}/\hbar = \delta n/n$.

(b) For the $L_H = L_p(dark) = nL_p$ option one has $\Delta H_0/H_0 = -2\delta n/n + \delta L_{p_2}/L_{p,2} \simeq -2/\delta n/n$. This gives $\delta\rho/\rho \sim \delta - \hbar_{eff}/\hbar = -\delta n/n$.

One therefore obtains $\delta H_0/H_0 \sim \epsilon\delta n/n$, where $\epsilon = \pm 1$ depending on option. The thermal fluctuations are induced by the fluctuations of $\hbar_{eff}/h_0 = n$ and depend extremely weakly on the polynomial defining the extension of rationals with dimension n.

For the first option the scale $L_m \sim 10^{-4}$ m would correspond too L_p and for the second option to the scale $L_p(dark) = n_0 L_p$. In the latter case one would have $L_p \in [10^{-12}, 10^{-11}]$, the p-adic length scale $L_{M_{127}} \simeq \sqrt{5}L_c = 5.4\times 10^{-12}$ m is highly suggestive. This would correspond to $n_0 \simeq 1.85\times 10^7$.

What can one say about the p-adic prime p assignable to an extension as a ramified prime?

1. Suppose that $p = p_{max}(P_{|n})$, that is the largest ramified prime assignable to a polynomial P defining the extension of rationals with dimension n. Several extensions can have dimension n exist and several polynomials P could in principle define an extension with a given value of n and the same value of $p_{max} = p$.

2. For an extension with a given value of n, one can allow fluctuations defined by polynomials with different values of p_{max}. This gives a rough estimate $\delta H_0/H_0 = -(\delta n/n - dL_{p_{max}}/L_{p_{max}})$. The term $dL_{p_{max}}/L_{p_{max}} = \delta p_{max}/p_{max}$ is very small for large p-adic primes, and one would have $\delta H_0/H_0 \sim -\delta n/n$ giving $\delta H_0/H_0 \sim 1/n$ for $|\delta n| = 1$.

$$\frac{\delta T}{T} = \frac{1}{2}\frac{\delta\ \rho_{cr}}{\rho_{cr}} = 2\frac{\delta H_0}{H_0} = -2\ \frac{\delta n}{n}\ . \tag{3.6.1}$$

3. The temperature fluctuations of CMB would reveal the fluctuations of $n = \hbar_{eff}/h_0$ in turn inducing fluctuations of padic length scale $L_{p_{max},2}$ defining H_0.

The fluctuations of CMB would be a number theoretic phenomenon. Does this proposal conform with the observations?

1. Density fluctuations are in the range $\delta\ T/T \in [10^{-4}, 10^{-5}]$. The nominal value of $\delta\ T/T$ is $10^{-4}/3$ (see this). This corresponds to $\delta\ \rho_{cr}/\rho_{cr} = 4\delta\ T/T =\ 1.3\times 10^{-4}$.

2. If the fluctuation corresponds to a single extension of rationals, or more generally, n is not a product of two or more statistically independent factors, one has $|\delta n| \geq 1$ and the $|\delta T|/T \sim\ (1/2)|\delta n|/n$. If one uses the estimate $n = R^2/G \in [10^7 - 10^8]$, one obtains $|\delta T|/T = (1/2)\sum_k p(|\delta|\ n = k)k/n$, which in the first approximation gives $|\delta T/T| = p(1)x/2$, $x \in [10^{-7}, 10^{-8}]$. The estimate is too small.

3. If one assumes that the decomposition $h_{eff}/h_0 = n_1 n_2$, where n_i are assumed to be statistically independent, one obtains $|\delta\ h_{eff}|/h_{eff} = |\delta n_1|/n_1 + |\delta n_2|/n_2$. If only $|\delta n_1| = 1$ and $|\delta n_2| = 1$ contribute significantly, and one has $|\delta|T/T = p(1)/n_1 + p(2)/n_2]/2$. Assuming $n_1 = n_2 \sim \sqrt{n} \in [10^{3.5}, 10^4]$, and $p_1 = p_2 = P$ one has very naive estimate $2P/\sqrt{n}$, $n \in [10^{-3.5}, 10^{-4}]$. The order of magnitude is correct.

4. The justification for the decomposition comes from the holography=holomorphy hypothesis, which implies that the two polynomials defining the space-time surface as a complex surface in generalized sense gives rise to two extensions of rationals with dimensions n_1 and n_2. These extensions can be assigned to M^4 degrees of freedom (string world sheets X^2) and to CP_2 degrees of freedom (partonic 2-surfaces Y^2). One can also consider the possibility that internal consistency requires the extensions to have the same dimension $n_1 = n_2$.

For the cold spot of CMB (see this), the temperature fluctuation of CMB is 70 μK and 4 times higher than on the average. Could one understand this number theoretically? For instance, could this could be due to $n_1 \rightarrow 8n_1$ and $n_2 = n_1 \rightarrow n_1/8$ in $n \rightarrow n_1 n_2 \sim n_1^2$ giving for $\delta\ n_1 = deltan_2 = 1$ the outcome $\delta\ n/n = 1/(8n_1) + 8/n_1 \simeq 8/n_1$ so that the fluctuation is 4 times larger.

About the problem of two Hubble constants

The usual formulation of the problem of two Hubble constants is that the value of the Hubble constant seems to be increasing with time. There is no convincing explanation for this. But is this the correct way to formulate the problem? In the TGD framework one can start from the following ideas discussed already earlier [K66].

1. Would it be better to say that the measurements in short scales give slightly larger results for H_0 than those in long scales? Scale does not appear as a fundamental notion neither in general relativity nor in the standard model. The notion of fractal relies on the notion but has not found the way to fundamental physics. Suppose that the notion of scale is accepted: could one say that Hubble constant does not change with time but is length scale dependent. The number theoretic vision of TGD brings brings in two length scale hierarchies: p-adic length scales L_p and dark length scale hierarchies $L_p(dark) = nL_p$, where one has $h_{eff} = nh_0$ of effective Planck constants with n defining the dimension of an extension of rationals. These hierarchies are closely related since p corresponds to a ramified prime (most naturally the largest one) for a polynomial defining an extension with dimension n.

2. I have already earlier considered the possibility that the measurements in our local neighborhood (short scales) give rise to a slightly larger Hubble constant? Is our galactic environment somehow special?

Consider first the length scale hierarchies.

1. The geometric view of TGD replaces Einsteinian space-times with 4-surfaces in $H = M^4 \times CP_2$. Space-time decomposes to space-time sheets and closed monopole flux tubes connecting distant regions and radiation arrives along these. The radiation would arrive from distant regions along long closed monopole flux tubes, whose length scale is L_H. They have thickness d and length L_H. d is the geometric mean $d = sqrt(l_P L_H)$ of Planck length L_P and length L_H. d is of about 10^{-4} meters and size scale of a large neuron. It is somewhat surprising that biology and cosmology seem to meet each other.

2. The number theoretic view of TGD is dual to the geometric view and predicts a hierarchy of primary p-adic length scales $L_p \propto \sqrt{p}$ and secondary p-adic length scales $L_{2,p} = \sqrt{p}L_p$. p-Adic length scale hypothesis states that p-adic length scales L_p correspond to primes near the power of 2: $p \simeq 2^k$. p-adic primes p correspond to so-called ramified primes for a polynomial defining some extension of rationals via its roots.

   One can also identify dark p-adic length scales

$$L_p(dark) = nL_p \ , \tag{3.6.2}$$

   where $n = h_{eff}/h_0$ corresponds to a dimension of extension of rationals serving as a measure for evolutionary level. h_{eff} labels the phases of ordinary matter behaving like dark matter explain the missing baryonic matter (galactic dark matter corresponds to the dark energy assignable to monopole flux tubes).

3. p-Adic length scales would characterize the size scales of the space-time sheets. The Hubble constant H_0 has dimensions of the inverse of length so that the inverse of the Hubble constant $L_H \propto 1/H_0$ characterizes the size of the horizon as a cosmic scale. One can define entire hierarchy of analogs of L_H assignable to space-time sheets of various sizes but this does not solve the problem since one has $H_0 \propto 1/L_p$ and varies very fast with the p-adic scale coming as a power of 2 if p-adic length scale hypothesis is assumed. Something else is involved.

One can also try to understand also the possible local variation of H_0 by starting from the TGD analog of inflation theory. In inflation theory temperature fluctuations of CMB are essential.

1. The average value of h_{eff} is $\langle h_{eff}\rangle = h$ but there are fluctuations of h_{eff} and quantum biology relies on very large but very rare fluctuations of h_{eff}. Fluctuations are local and one has $\langle L_p(dark)\rangle = \langle h_{eff}/h_0\rangle L_p$. This average value can vary. In particular, this is the case for the p-adic length scale $L_{p,2}$ ($L_{p,2}(dark) = nL_{2,p}$), which defines the Hubble length L_H and H_0 for the first (second) option.

2. Critical mass density is given by $3H_0^2/8\pi G$. The critical mass density is slightly larger in the local environment or in short scales. As already found, for the first option the fluctuations of the critical mass density are proportional to $\delta n/n$ and for the second option to $-\delta n/n$. For the first (second) option the experimentally determined Hubble constant increases when n increases (decreases). The typical fluctuation would be $\delta h_{eff}/h \sim 10^{-5}$. What is remarkable is that it is correctly predicted if the integer n decomposes to a product $n_1 = n_2$ of nearly identical integers.

   For the first option, the fluctuation $\delta h_{eff}/h_{eff} = \delta n/n$ in our local environment would be positive and considerably larger than on the average, of order 10^{-2} rather than 10^{-5}. h_{eff} measures the number theoretic evolutionary level of the system, which suggests that the larger value of $\langle h_{eff}\rangle$ could reflect the higher evolutionary level of our local environment. For the second option the variation would correspond to $\delta n/n \leq 0$ implying lower level of evolution and does not look flattering from the human perspective. Does this allow us to say that this option is implausible? The fluctuation of h_{eff} around h would mean that the quantum mechanical energy scales of various systems determined by $\langle h_{eff}\rangle = h$ vary slightly in cosmological scales. Could the reduction of the energy scales due to smaller value of h_{eff} for systems at very long distance be distinguished from the reduction caused by the redshift. Since the transition energies depend on powers of Planck constant in a state dependent manner, the redshifts for the same cosmic distance would be apparently different. Could this be tested? Could the variation of h_{eff} be visible in the transition energies associated with the cold spot.

3. The large fluctuation in the local neighbourhood also implies a large fluctuation of the temperature of the cosmic microwave background: one should have $\Delta T/T \simeq \delta n/n \simeq \delta H_0/H_0$. Could one test this proposal?

3.7 Bicep2 Might Have Detected Gravitational Waves

BICEP2 team (see http://tinyurl.com/pg7n9eu) [E251] has announced a detection of gravitational waves via the effects of gravitational waves on the spectrum on polarization of cosmic microwave background (CMB). What happens that gravitational waves (or possibly some other mechanism) transforms so called E modes which correspond the curl free part of polarization field expressible as gradient to B modes responsible for the divergenceless part of polarization field expressible as curl of vector field.

Interaction of photons with gravitons would induce this polarization changing transformation: this is discussed in the earlier post by Lubos Motl (see http://tinyurl.com/ybdc3gvy). The signal is unexpectedly strong constraints on possible models, in particular to the inflationary models which are currently in fashion. The map produced by BICEP describes the vorticity of the polarization field (see http://tinyurl.com/ydgazhsh) at the sky and one can clearly see it. There has been a lot of pre-hype about the finding as proof for inflation, which it is not. Even Scientific American (see http://tinyurl.com/y8x4mo9k) falls in the sin of inflationary hyping: inflationary theory is only the dominating theory which might be able to explain the finding.

In the sequel the findings are discussed in the framework of TGD based cosmology in which the flatness of 3-space is interpreted in terms of quantum criticality rather than inflation. The key role is played by gradually thickening cosmic strings carrying magnetic monopole flux, dark energy as magnetic energy and dark matter as large h_{eff} phases at cosmic strings. Very thin cosmic strings dominate the cosmology before the emergence of space-time as we know it and quantum criticality is associated with the phase transition between these two phases. Later cosmic strings serve as seeds of various cosmological structures by decaying partially to ordinary matter somewhat like inflaton fields in inflationary cosmology. Cosmic strings also explain the presence of magnetic fields in cosmos difficult to understand in standard approch. The crucial point is that

- in contrast to ordinary magnetic fields - monopole fluxes do not require for their creation any currents coherent in long scales.

3.7.1 Liam Mcallister's Summary About The Findings Of Bicep2 Team

Liam McAllister from Cornell University has written an excellent posting about the discovery and its implications in Lubos Motl's blog (see http://tinyurl.com/ybnd7oct) [E201]. McAllister discusses the finding from several points of view. Can one trust that the finding is real? How should one interpret the result? What are its implications? A brief summary is in order before going to details.

1. Consideration is restricted to inflationary scenarios but it is made clear that they are not the only option. It is emphasized that a huge amount of inflationary parameter space is excluded by the unexpectedly high strength of the effect. Also the general problems of inflationary models are made explicit - a great favor for those who are not inflationary enthusiasts and might have something else in mind.

2. Also other than gravitonic mechanisms transforming E modes to B modes can be imagined. For instance, the signal might not be primordial but caused by polarized foreground sources: BICEP claims that these contributions have been eliminated.

3. The most important conclusion is of course that a direct detection of gravitational waves - maybe even quantal ones - has been achieved. Earlier gravitational radiation has been detected only a slowing down of rotation rate of pulsars (Hulse-Taylor binary pulsar).

3.7.2 Comparison Of Inflationary Models And TGD

Further conclusions depend on the cosmological model adopted and McAllister considers the situation in the framework of inflationary models and lists the basic aspects of inflationary model.

1. The Universe on large scales should be approximately homogenous, isotropic and flat.

2. The primordial scalar density perturbations should be correlated on super-horizon scales and be approximately Gaussian, adiabatic, and approximately scale-invariant.

In TGD framework inflationary cosmology is replaced with a cosmology fixed almost uniquely by the criticality of the mass density when combined with imbeddability to $N^4 \times CP_2$ as Lorentz invariant 4- surface [K111, K94]. The only free parameter is the finite duration τ of the critical period. This kind of critical - it seems even quantum critical - periods are predicted to appear in various scales so that Russian doll cosmology is strongly suggested as in case of inflationary models. Scalar fields (inflaton fields) are replaced with cosmic strings, which evolve by thickening their M^4 projections from string world sheets to 4-D ones. Magnetic energy replaces dark energy and has interpretation as counterpart for the energy of inflation field. Dark matter at magnetic flux tubes corresponds to large $\hbar$ phases [K42, K93, K79].

1. In TGD framework the long range correlations would be due to quantum criticality rather than extremely rapid expansion during inflationary period. The Universe in large scales should be also now homogenous, isotropic, and flat.

2. The primordial density perturbations reflect the presence of cosmic strings before the phase transition period. These cosmic strings have 2-D M^4 projection, which is minimal surface, so that these object behave for all practical purposes like strings, and CP_2 projection is e 2-D holomorphic surface in CP_2. During primordial period cosmic strings dominate and the mass density behaves like $1/a^2$, where a is proper time coordinate of the light-cone. The mass per comoving volume goes to zero at the moment of big bang so that initial singularity is smoothed out and big bang transforms to "a silent whisper amplified to big bang". For radiation dominated cosmology mass density would behave as $1/a^4$ giving rise to infinite energy per comoving volume at the moment of Big Bang.

3. Cosmic strings gradually thicken their M^4 projections and the huge primordial magnetic fields carrying quantized monopole flux weaken. These fields differ crucially from the ordinary magnetic fields in that no current is needed to create them - this is due the fact that CP_2 Kähler form defines a self-dual magnetic monopole (instanton). Amazingly, even the magnetic fields penetrating to super-conductors could be this kind and perhaps even those associated with ferromagnets.

   This can explain why primordial and recent Universe is full of magnetic fields in length scales, where they should not exist since the currents creating them cannot exist in long scales. The thickening of the remnants of cosmic strings would give rise to birth of galaxies organised like pearls in necklace along big cosmic strings: galaxies are indeed known to be organized into long string like structures and density perturbations would correspond to these strings.

   No vacuum expectations of Higgs like scalar fields are needed. Even in elementary particle physics Higgs expectation is replaced with string tension assignable to string like structures accompanying elementary particles.

   Cosmic strings would carry dark energy as magnetic energy and dark matter as phases with large values of Planck constant coming as integer multiple of ordinary Planck constant. Ordinary matter would be formed when cosmic strings and dark matter "burn" to ordinary matter: this would be the TGD counterpart for the decay of inflaton field to ordinary matter.

4. Cosmic strings would define the density perturbations having correlations on super-horizon scales. In the first approximation they are certainly Gaussian. Whether they are adiabatic (no exchange of heat with environment) is an interesting question: if they correspond to large values of Planck constant, this is certainly what one expects. The perturbations would be approximately scale invariant: p-adic length scale hypothesis would formulate this quantitatively by replacing continuum of scales with a hierarchy of discrete p-adic length scales coming as powers of square root of 2 (half octaves).

5. One can of course ask about spectrum of Planck constant coming as integer multiples of ordinary Planck constant: could it realize the presence of large number of length scales characterizing criticality? Could the spectrum of length scales implied by spectrum of Planck constants be the TGD counterpart for the inflationary expansion? Does the average value of Compton length or flux tube length proportional to h_{eff} increase with exponential rate during quantum criticality as larger and larger Planck constants emerge?

It seems that at this qualitative level TGD survives basic tests at qualitative level but without assuming inflation fields and exponentially fast expansion since quantum criticality predicting flat 3-space (dimensional parameters such as curvature of 3-space vanish). Cosmic strings would represent the long range fluctuations. A further bonus is that cosmic strings explain dark energy and dark matter, and also the presence of long range magnetic fields in cosmos.

3.7.3 Fluctuations Of Gravitational Field

McAllister gives a nice overall summary about the physics involved if given by inflationary models.

1. It is not yet fully clear whether the fluctuations of gravitational field are quantum mechanical or classical. In TGD framework quantum classical correspondence suggests that quantal and classical identifications might be equivalent.

2. Just as the quantum fluctuations of inflaton field would give rise to the density fluctuations visible as temperature anisotropies and large scale structures, the quantum fluctuations of gravitational field would give rise to the observed B modes in inflationary scenario. The correlation functions of gravitons in the background metric would tell everything. The problem is that we do not yet have quantum theory of gravitation allowing to really calculate everything except in QFT approximation.

3. In TGD framework the fluctuations should physically correspond to cosmic strings and the question is whether gravitons can be identified as massless modes for the cosmic strings so that string like objects would give all. In fact, elementary particles are in TGD framework

identified as string like objects! Ironically, TGD as generalization of string model realizes stringy dream in all scales and even for ordinary elementary particles!

Since gravitons couple to energy the formula for the energy density at which inflationary period begins should determine the spectrum of gravitational waves. Inflationary models predict this energy scale as the fourth root of the energy density in the beginning of inflation: the formula is given by in the article of McAllister. This formula contains single dimensionless parameter called r, and BICEP measurements give a rather large value $r = .2$ for it.

The natural expectation is that any theory explaining the findings in terms of gravitons produces similar prediction but with the energy density of scalar field replaced with something else. In TGD the energy density assignable to cosmic strings so that the square root of the energy density of cosmic string multiplied by some numerical factor should be the relevant parameter now.

3.7.4 Inflation Should Begin At Gut Mass Scale

The first implication of the findings is that if inflation explains the findings, it should have begun in GUT scale 10^{16} GeV, which is very high. The findings cut off a gigantic portion of the parameter space of inflationary models and leaves only inflation potentials that are approximately translationally invariant.

In TGD framework one expects that the energy scale corresponds to that in which quantum critical period begins after string dominated primordial period. This scale should be given by CP_2 mass scale apart from some numerical factor. CP_2 mass corresponds to $m(CP_2) = \hbar/R(CP_2)$, where $R(CP_2)$ is CP_2 radius. p-Adic mass calculations predict the value of electron mass and assign to electron the largest Mersenne prime M_{127} having the property that the p-adic length scales $\sqrt{p}R(CP_2)$ is not completely super-astronomical. This fixes $R(CP_2)$ and $m(CP_2)$. The outcome is $m(CP_2) \sim 5.7 \times 10^{14}$ GeV. One has $m(CP_2)/m_P = 2.4 \times 10^{-4}$.

A numerical constant can be present in the estimate for the energy scale at which quantum critical period begins. In particular, the factor $1/\alpha_K^{1/4}$ should be present since Kähler action is proportional to $1/\alpha_K$, which by simple argument is in excellent approximation equal to the inverse of the fine structure constant equal to 137. This would rise the estimate for the energy scale to about 10^{16} GeV if the same formula for it is used also in TGD (which might of course be wrong!). With a considerable dose of optimism one could say that TGD allows to understand why the measured value of r is what it is.

3.7.5 Difficulties Of The Inflationary Approach

What is nice that McAllister discusses also so the difficulties of inflationary approach.

1. So called Lyth bound gives lower bound for the distance that inflaton's vacuum expectation must move in field space in order to generate detectably large primordial waves: that is the duration of the inflationary expansion. The lower bound is given by Planck mass M_p: $\Delta\Phi > M_p$.

2. There is however a problem. This distance should be not larger than the cutoff scale Λ of the quantum field theory. But if standard wisdom is taken granted, Λ should be smaller than Planck mass M_p giving $\Delta\Phi < M_p$!

3. One can certainly invent all kinds of tricky mechanisms to circumvent the problem: the proposal considered by McAllister is that the couplings of Φ are suppressed to heavy degrees of freedom so that the UV theory respects the approximate shift symmetry $\Phi \to \Phi + \Delta\Phi$. This is true for massless scalar field but this field does not develop vacuum expectation value. McAllister mentions that for $V = m^2\Phi^2/2$ the approximate shift symmetry is true. Maybe it is for small enough values of m: exact symmetry would require $m = 0$.

4. The physical interpretation of masslessness implied by strict shift invariance would be in terms of conformal invariance. In TGD framework quantum criticality implies conformal invariance also in 2-D sense and quantum criticality corresponds to the absence of dimensional parameters from Higgs potential making Higgs mechanism impossible.

To my humble opinion, this difficulty means a strong blow against the idea about Higgs mechanism as source of vacuum energy density in cosmology. As already mentioned, the decay of the dark energy identifiable as magnetic energy and large h_{eff} dark matter associated with the evolving primordial cosmic strings would produce ordinary matter in TGD Universe.

Also the ordinary Higgs mechanism is plagued by the loss of naturalness and predictivity by the fact that the Higgs particle has too low mass and SUSY has not been found in low enough mass scales to stabilize Higgs mass. In TGD framework the string tension of string like objects assignable to elementary particles would give the dominating contribution to gauge boson masses and p-adic thermodynamics in its original form the dominating contribution to fermion masses [K63]. The couplings of fermions to Higgs are gradient couplings and the coupling is same for all fermions in accordance with naturality and universality [K50].

3.7.6 Could TGD Allow Inflationary Cosmology?

A natural question is whether TGD could allow inflationary cosmology. In the lowest order this would require embedding of the De Sitter space [?]. De Sitter space allows two basic coordinate slicings.

1. The first one corresponds to a stationary metric having interpretation in terms of interior of an object with constant mass density. The line element reads

$$\begin{aligned} ds^2 &= Adt^2 - Bdr^2 - r^2 d\omega^2 \ , \\ A &= 1 - (\frac{r}{l})^2 \ , \ B = \frac{1}{A} \ . \end{aligned} \quad (3.7.1)$$

   l has natural interpretation as outer boundary of the object in question. It will be found that TGD suggests 2-fold covering of this metric.

2. Second coordinatization has interpretation as simplest possible inflationary cosmology having flat 3-space:

$$ds^2 = d\hat{t}^2 - e^{2\frac{\hat{t}}{l}} dr^2 - \hat{r}^2 d\omega^2 \ . \quad (3.7.2)$$

3. The two coordinatizations are related to each other by the formulas deducible from the general transformation property of metric tensor:

$$\begin{aligned} t &= \hat{t} + \frac{1}{2} log[1 + (\frac{\hat{r}}{l})^2 e^{2\frac{\hat{t}}{l}}] \ , \\ r &= e^{\frac{\hat{t}}{l}} \hat{r} \ . \end{aligned} \quad (3.7.3)$$

In TGD framework also the embedding of space-time as surfaces matters besides the metric which is purely internal property. The most general ansatz for the embedding of De Sitter metric into $M^4 \times CP_2$ is as a vacuum extremal for for Kähler action with the understanding that small deformation carries energy momentum tensor equal to Einstein tensor so that Einstein's equations would old true in statistical sense.

1. The general ansatz for the stationary form of the metric is of same general form as that for Schwartchild metric. One can restrict the consideration to a homologically trivial geodesic sphere S^2 of CP_2 with vanishing induced Kähler form and standard spherical metric. This means that CP_2 is effectively replaced with S^2. This embedding is a special one but gives a good idea about what is involved.

Denoting by (m^0, r_M, θ, ϕ) the coordinates of M^4 and by (Θ, Φ) the coordinates of S^2, a rather general ansatz for the embedding is

$$\begin{aligned} m^0 &= t + h(r) \ , \ \ r_M = r \ , \\ R\omega \times sin(\Theta(r)) &= \pm\frac{r}{l} \ \ , \Phi = \omega t + k(r) \ . \end{aligned} \tag{3.7.4}$$

2. The functions $h(r)$, $k(r)$, and $\Theta(r)$ can be solved from the condition that the induced metric is the stationary metric. For Schwartschild metric $h(r)$ and $k(r)$ are non-vanishing so that the embedding cannot be said to be stationary at the level of embedding space since $t = constant$ surfaces correspond to $m_0 - h(r_M) = constant$ surfaces.

   De Sitter metric is however very special. In this case one can assume $h(r) = k(r) = 0$ for $R\omega = 1$. The embedding reduces simply to an essentially unique embedding

$$sin(\Theta(r)) = \pm\frac{r}{l} = \frac{r_M}{l} \ \ , \ \ \Phi = \frac{t}{R} = \frac{m^0}{R} \ . \tag{3.7.5}$$

   This embedding is certainly very natural and would describe stationary non-expanding cosmology with constant mass density. Not that the embedding is defined only for $r_M < l$. Unless one allows 3-space to have boundary, which for non-vacuum extremals does not seem plausible option, one must assume double covering

$$sin(\Theta(r)) = sin(\pi - \Theta(r)) = \pm\frac{r_M}{l} \ . \tag{3.7.6}$$

   Stationarity implies that there is no Big Bang.

3. The transition to the inflationary picture looks in TGD framework very much like a trick in which one replaces radial Minkowski coordinate with $\hat{r} = exp(-\hat{t}/l)r_M$ and in these new coordinates obtains Big Bang and exponential expansion as what looks like a coordinate effect at the level of embedding space. Also the transition to radiation dominated cosmology for which the hyperbolic character of M^4_+ metric $ds^2 = da^2 - a^2(dr^2/(1+r^2) + r^2d\Omega^2)$ is essential, is difficult to understand in this framework. The transition should correspond to a transition from a stationary cosmology at the level of embedding space level to genuinely expanding cosmology.

The cautious conclusion is that sub-manifold cosmology neither excludes nor favors inflationary cosmology and that critical cosmology [K94] is more natural in TGD framework. In TGD Universe de Sitter metric looks like an ideal model for the interior of a stationary star characterized by its radius just like blackhole is characterized by its radius. It seems that TGD survives the new findings at qualitative and even partially quantitative level.

3.7.7 Quantum Critical Cosmology Of TGD Predicts Also Very Fast Expansion

TGD inspired critical cosmology [K94] relies on the identification of 3-space as $a = constant$ section, where a is Lorentz invariant cosmological time defined by the light-cone proper time $a = \sqrt{(m^0)^2 - r_M^2}$, and from the assumption that (quantum) criticality corresponds to a vanishing 3-curvature meaning that 3-space is Euclidian.

The condition that the induced metric of the $a = constant$ section is Euclidian, fixes the critical cosmology apart from its duration a_0 from the existence of its vacuum extremal embedding to $M^4 \times S^2$, where S^2 homologically trivial geodesic sphere:

$$\begin{aligned} ds^2 &= g_{aa}da^2 - a^2(dr^2 + r^2d\Omega^2) \ , \\ g_{aa} &= (\frac{dt}{da})^2 = 1 - \frac{\epsilon^2}{1-u^2} \ , \ u = \frac{a}{a_0} \ , \ \epsilon = \frac{R}{a_0} \ . \\ sin(\Theta) &= \pm u \ , \ \Phi = f(r) \ , \\ \frac{1}{1+r^2} &- \epsilon^2(\frac{df}{dr})^2 = 1 \ . \end{aligned} \tag{3.7.7}$$

From the expression for dt/da one learns that for the small values of a it is essentially constant equal to $dt/da = \sqrt{1-\epsilon^2}$. When a/a_0 approaches to $\sqrt{1-\epsilon^2}$, dt/da approaches to zero so that the rate of expansion becomes infinite. Therefore critical cosmology is analogous to inflationary cosmology with exponential expansion rate. Note that the solution is defined only inside future or past light-cone of M^4 in accordance with zero energy ontology.

After this a transition to Euclidian signature of metric happens (also a transition to radiation dominated cosmology is possible): this is something completely new as compared to the general relativistic model. The expansion begins to slow down now since dt/da approaches infinity at $a/a_0 = 1$. In TGD framework the regions with Euclidian signature of induced metric are good candidates for blackhole like objects. This kind of space-time sheets could however accompany all physical systems in all scales as analogs for the lines of generalized Feynman diagrams. For $sin(\Theta) = 1$ at $a/a_0 = 1$ the embedding ceases to exist. One could consider gluing together of two copies of this cosmology together with $sin(\Theta) = sin(\pi - \Theta) = a/a_0$ to get a closed space-time surface. The first guess is that the energy momentum tensor for the particles defined by wormhole contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig. ??** in the appendix of this book) connecting the two space-time sheets satisfies Einstein's equations with cosmological constant.

Quantum criticality would be associated with the phase transitions leading to the increase of the length and thickness of magnetic flux tubes carrying Kähler magnetic monopole fluxes and explaining the presence of magnetic fields in all length scales. Kähler magnetic energy density would be reduced in this process, which is analogous to the reduction of vacuum expectation value of the inflation field transforming inflaton vacuum energy to ordinary and dark matter.

At the microscopic level one can consider two phase transitions. These phase transitions are related to the hierarchy of Planck constants and to the hierarchy of p-adic length scales corresponding to p-adic primes near powers of 2.

1. The first phase transition increases Planck constant $h_{eff} = nh$ in a step-wise manner and increases the length and width of the magnetic flux tubes accordingly but conserves the total magnetic energy so that no magnetic energy is dissipated and one has adiabaticity. This sequence of phase transitions would be analogous to slow roll inflation in which the vacuum expectation of inflation field is preserved in good approximation so that vacuum energy is not liberated. The flux tubes contain dark matter.

2. Second phase transition increases the p-adic length scale by a power of $\sqrt{2}$ and increases the length and width of magnetic flux tubes so that the value of the magnetic field is reduced by flux conservation (magnetic flux tubes carry monopole fluxes made possible by CP_2 homology). This phase transition reduces zero point kinetic energy and in the case of magnetic fields magnetic energy transforming to ordinary and dark matter.

3. The latter phase transition can be accompanied by a phase transition reducing Planck constant so that the length of the flux tubes is preserved. In this transition magnetic energy is liberated and dark matter is produced and possibly transformed to ordinary matter. This kind of phase transitions could take place after the inflationary adiabatic expansion and produce ordinary matter. As a matter fact, I have originally proposed this kind of phase transition to be the basic phase transition involved with the metabolism in living matter [K84], which suggests that the creation of ordinary matter from dark magnetic energy could be seen as kind of metabolism in cosmological scales.

In zero energy ontology one can ask whether one could assign to the Minkowskian and Euclidian periods a sequence of phase transitions increasing Planck constants but proceeding in opposite time directions.

4. During the inflationary period the size scale of the Universe should increase by a factor of order 10^{26} at least. This corresponds to 2^{87} - that is 87 2-foldings, which is a more natural notion than e-folding now. If the size of the sub-Universe is characterized by a p-adic length scale, this would correspond in the final state to $p \sim 2^{174}$ at least: this p-adic length scale is about 4×10^{-5} meters roughly and thus of order cell size.

5. How the transition to radiation dominated cosmology takes place is an interesting question. The decay of the magnetic energy to ordinary matter should take place during the Euclidian period initiating therefore the radiation dominated period. For the radiation dominated cosmology the scale factor behaves as $t \propto a^2$ so that dt/da approaches zero. Since this occurs also when the Euclidian period starts, the guess is that space-time sheets with radiation dominated sub-cosmologies assignable to sub-CDs (CD is shorthand for causal diamond) begin to be created.

Although this picture is only an artist's vision and although one can imagine many alternatives, I have the feeling that the picture might contain the basic seeds of truth.

3.7.8 Still Comments Abount Inflation In TGD

Quantum criticality is the TGD counterpart of the inflation and the flatness of 3-space follows from the condition that no local dimensional quantities are present in 3-geometry. Also the imbeddability fo M^4 is an important piece of story and restricts the set the parameters of imbeddable cosmologies dramatically.

One can try to understand the situation microscopically in terms of the cosmic strings which gradually develop higher than 2-D M^4 projection during cosmic evolution and become magnetic flux tubes carrying magnetic monopole fluxes explaining the presence of magnetic fields in cosmology.

At microscopic level magnetic flux tubes are the key structural elements. The phase transitions increasing Planck constant for the matter associated with flux tubes and thus also the lengths of magnetic flux tubes should be important as also the phase transitions increasing p-adic prime and reducing Planck constant originally emerged in the modelling of TGD inspired quantum biology are highly suggestive. First transitions would mean adiabatic expansion with no heat generation and latter transitions would liberate magnetic field energy since flux conservation forces field strength to be reduced and leads to liberation of magnetic energy producing ordinary matter and dark matter. Dark energy in turn is identifiable as magnetic energy.

The key question concerns the mechanism causing the isotropy and homogeny of the cosmology. There are two possible identifications.

1. According to two decades old proposal [K94], primordial cosmology before the emergence of space-time sheets could be regarded as string gas in $M^4_+ \times CP_2$ at Hagedorn temperature determined by CP_2 radius: $T_H \sim \hbar/R_{CP_2}$. This phase could be present also after the transition to radiation dominated cosmology and consist of strings, whose thickness is gradually increasing and which contain carry dark energy and dark matter. The horizon radius is infinite for this cosmology thus providing at least partial explanation for the homogeny and isotropy and visible matter would represent deviations from it.

2. The accelerating expansion period towards the end of the critical period could smooth out inhomogenities and thus provide an additional mechanism leading to homogenous and isotropic Big Bang. This for given space-time sheet representing R-W cosmology: in many-sheeted cosmology one can imagine distribution of parameters for the cosmology. The rapid expansion period could however also develop large fluctuations! Indeed, the time $a_F < a_1$ (density would be infinite for a_1) for its end - and therefore local mass density - must have a distribution after the rapid expansion ends. This expansion would generate separate smoothed out radiation dominated space-time sheets with slightly different mass densities and cosmic temperatures. A splitting to smooth radiation dominated sub-cosmologies would take place.

Therefore TGD scenario could be very different from inflationary scenario. The problem is to decide which option is the most feasible one.

The formulas used to make back of the envelope(http://tinyurl.com/y92pvrbe) calculations in inflation theory discussed in a quest posting in Lubos Motl's blog given some idea about TGD counterpart for the generation of gravitons. Inflationary period is replaced with essentially unique critical cosmology containing only its duration as a free parameter. The fluctuations in the duration of this parameter explain scalar temperature fluctuations assoiated with CMB.

How the local polarization of CMB is generated?

There is a nice discussion about the mechanism leading to the generation of CMB polarization (http://tinyurl.com/y7cssjz7). The polarization is generated after the decoupling of CMB photons from thermal equilibrium and is due to the scattering of photons on free electrons during decoupling. This scattering is known as Thomson scattering. The page in question contains schematic illustrations for how the polarization is generated. The scattering from electrons polarizes the photons in direction orthogonal to the scattering plane. In thermal equilibrium the net polarization of scattered radiation vanishes. If however the scattered photons from two perpendicular directions have different intensities a net polarization develops.

Polarized photons could be produced only during a short period during recombination scattering from free electrons was still possible and photons could diffuse between regions with different temperature. Polarized photons were generated when electrons from hot and cold regions where scattering on same electrons. CMB polarization indeed varies over sky but not in long length scales since photons could not diffuse for long lengths.

So called quadrupole anisotropy of CMB temperature contains information about the polarization. There are http://tinyurl.com/ycfqvcz5polar4.htmlthree contributions: scalar, vector, and tensor.

1. Scalar contributions is due to density fluctuations reflecting themselves as temperature fluctuations and does not distinguish between polarizations: this is what has been studied mostly hitherto. A natural TGD mechanism for their generation would be different time for the end of the critical period leading to splitting of critical cosmology to radiation dominated cosmologies with slightly different temperatures.

2. There is also so called vorticity distribution due to the flow which has vorticity and would due to defects/string like objects present also in TGD. The simplified situation corresponds to are region in which one has two flows in opposite direction locally. Depending on whether the scattering photons are upstream or down stream they are blue-shifted or red-shifter so that the temperatures are slightly different in up-stream and down.The flows in opposite direction give rise to a situation in which photons with different temperatures scatter and produce polarization. The effects of vorticity are expected to disappear during the fast expansion period. Probably because the gradients of velocity giving rise to vorticity are smoothed out.

3. The third contribution is tensor contribution and due to gravitons generating stretching and squeezing of space in two orthogonal directions defining polarization tensor. Stretching increases wavelengths and decreases temperature. Squeezing does the opposite. Therefore temperature differences distinguishing between the two directions are generated and the outcome is polarization of the CMB background much later. This corresponds to the so called E and B modes. One can decompose polarization as vector field to two parts: the first one - the E-mode - is gradient and thus irrotational and second is curl and thus rotational and with vanishing divergence (incompressible liquid flow is a good concrete example).

How the polarization anisotropies could be generated in TGD Universe?

One can try to understand microscopically how the polarization anisotropies are generated in TGD framework using poor man's arguments.

1. One can introduce a vision vision about fractal 3-D network of cosmic strings forming a kinds of grids with nodes in various scales. These grids would be associated with different levels

of the hierarchy of space-time sheets associated with many-sheeted space-time. Coordinate grid is of course an idealization since three coordinate lines would meet in single node. A weaker form of grid would involve meeting of two coordinate lines at given node. There is data about our own galactic nucleus understood if it correspond to the node at which two magnetic flux tubes meet. Ordinary visible matter would be generated in nodes. One might say that galaxies are due to traffic accidents in which dark matter arriving along two cosmic strings collides in the crossing of the roads. Flux tubes would be attracted together by gravitational attraction so from the crossing.

2. Amusingly, the notion grid emerged also TGD inspired quantum biology as a proposal for how living system codes morphogenetic position information. Flux tubes carry dark matter and ordinary matter is associated with the nodes at which coordinate lines meet each other. This web can give rise to a generalization of topological quantum computation using 2-braids. Coordinate lines define strings which can be knotted in 3-dimensions and define braids making possible topological quantum computation using macroscopic quantum phases defined by the dark matter. The time evolutions of coordinate lines defines string world sheets and in 4-D space-time the string world sheets can be knotted and braided so that also higher level TQC becomes possible with string reconnection and going above or below the other define two bits in each node.

3. The presence of grid could also explain the honeycomb like structure of Universe with the recent typical size of honeycomb about 10^8 ly.

4. In this framework the illustrations for how the gravitational waves induce the polarization of CMB. The radiation beams entering from opposite directions can be assigned with two magnetic flux tubes meeting at the node and in slightly different temperatures due to the interaction with gravitons much earlier. The gravitons can be regarded as larger space-time sheets at which the two flux tubes had contacts so that space associated with the flux tubes was forced to stretch or squeeze. This in turn increased of reduced photon wavelength so that photon temperature at flux tubes was different and the difference were preserved during subsequent evolution.

Back on the envelope calculations in TGD framework

One can modify the back on the envelope calculations of John Preskill (`http://tinyurl.com/y7vuh9xp`.html) in Lubos Motl's blog to see what could happen in TGD framework. Now one however starts from the critical cosmology fixed apart from its duration and looks what it gives rather than starting from Higgs potential for inflaton field. The obvious counterpart for inflaton scalar field would be magnetic field intensity having same dimension but one should avoid too concrete correspondences.

The key question is whether the critical period generates the rapid expansion smoothing out inhomogenities or whether it generates them. The original guess that it smooths them out turns out be wrong in closer examination.

1. The basic equation in inflationary model is given by

$$(\frac{\dot{a}}{a)})^2 = \frac{V}{m_p^2}$$

If V is small this has as solution $a(t) = a(0)exp(Ht)$ if $G = \sqrt{V}/m_p$ is constant. De Sitter cosmology allows partial embedding in TGD but the embedding is naturally static and has interpretation as black-hole interior with constant mass density. One can find coordinates in which the solution looks like expanding cosmology without Big Bang but these coordinates are not natural from the view of embedding space.

2. In TGD the expression for $\dot{a}$ for critical cosmology is

$$\dot{a} = \sqrt{\frac{a_0^2 - a^2}{a_0 2^- R^2 - a^2}} \quad .$$

a_0 is roughly the duration of cosmology and R is CP_2 radius of order $10^{3.5}$ Planck lengths. The almost uniqueness follows from the condition that the embedding is such that the induced metric at the 3-surfaces defined by intersections with hyperboloids of M^4_+ is flat rather than hyperbolic. This cosmology differs from de-Sitter cosmology.

3. For $a \to 0$ one has

$$\dot{a} \simeq \frac{a_0^2}{a_0^2 - R^2} \simeq 1 \ .$$

so that one has $\dot{a} \simeq 1$ and $a \simeq t$ for small values of a in accordance with the replacement of Big Bang with a "silent whisper amplified to a Big Bang" (density of matter goes as $1/a^2$) Hubble constant goes like $H \propto 1/a$ so that Hubble radius divergence. This does not guarantee that horizon radius becomes infinite. Rather, the horizon is finite and given in good accuracy by the duration $a_1 = \sqrt{a_0^2 - R^2}$ of the period. One can however explain the isotropy and homogenity of the string gas in M^4_+ carrying flux tubes carrying dark matter and energy in terms of the infinite horizon of M^4.

There is no exponential time evolution at this period since one has $a \simeq t$ in good approximation for $a/a_0 << 1$. The TGD counterpart of V would behave like $1/a^2$ which conforms with the idea that V corresponds to energy density.

4. As the limit $a \to a_1 = \sqrt{a_0^2 - R^2}$ is approached, the expansion rate approaches infinite and for $a > a_1$ at the latest one expects radiation dominated cosmology: otherwise a region of Euclidian signature of the induced metric results. The expectation is that a transition to radiation dominated cosmology takes place before $a = a_1$ at which also energy density would diverge. The question is whether this period means smoothing out of inhomogenities or generation of them or both.

Consider now what could happen near the end of the Minkowskian period of critical cosmology.

1. Although it is not clear whether rapidly accelerating expansion is needed to smooth out homogenities, one can just find what conditions this would give on the parameters. For $a_i = kR$ at which phase transition began the condition that a was increased at least by factor $e^{50} \sim 5 \times 10^{21}$ (50 e-folds) this would give $a_1 \simeq a_0 > e^{50}kR$. For $k \sim 1$ this gives something like 10^{-18} seconds, which happens to correspond atomic length scale. Below it will be found that this period more naturally corresponds to the period during which large fluctuations in density distribution and metric are generated.

2. The earlier estimate for the emergence of radiation dominated cosmology discussed in [K94] assumed that the transition to radiation dominated cosmology takes place at CP_2 temperature defining Hagedorn temperature at which temperature of the string gas cannot be raised anymore since all the energy goes to the generation of string excitations rather than to kinetic energy, gives $a_F \sim 10^{-10}$ seconds, which is by factor 10^8 larger. If this were true, the fast expansion period a_F would increase the scale factor to about 68 e-folds equivalent to 98 2-folds. p-Adic prime $p \simeq 2^{196}$ would correspond to p-adic length scale about $L(196) \sim .1$ meters. The crucial assumption would be that the time a_f at which the expansion ends is same everywhere. There is no reason to assume this and this would mean that the period in question generates inhomogenities and isotropies of mass distribution and temperature distribution.

Note that if the distribution of the time $a_F < a_1$ at which the critical period ends is responsible for the CMB fluxtuations then the number of foldings characterizes the smoothness of given local radiation dominated cosmology and could be rather large.

3. The rapid accelerating expansion occurs as g_{aa} approaches zero. Indeed, for

$$a \to a_1 = \sqrt{a_0^2 - R^2}$$

a very rapid expansion occurs and $\dot{a}$ approaches infinite value. Near to a_1 one can write $a/a_1 = 1-\delta$ and solve δ approximately as function of t as

$$\delta = (\frac{3R^2}{4a_1^2})^{2/3}(\frac{t-t_1}{a_1})^{2/3} \ , \ t_1 = \int_0^{a_1} \frac{(1-\frac{a^2}{a_1^2})^{1/2}}{(1-\frac{a^2}{a_1^2})^{1/2}} \ .$$

Hubble constant behaves as

$$H \equiv \frac{\dot{a}}{a} = \frac{R^2}{2a_1^3}\delta^{-1/2} \ .$$

4. What is interesting is that applying the naïve dimensional estimate for the amplitude of gravitational fluctuations to be $\delta h_T^2 \sim H^2/m_P^4$. This would mean that at the limit $a \to a_F < a_1$ gravitational fluctuations become very strong and generate the strong graviton background. Same applies to fluctuations in mass density.

Summary

The possibility of very rapid expansion near $a = a_F < a_1$ leading to radiation dominated cosmology should have some deep meaning. The following tries to catch this meaning.

1. The explosive period could lead to a radiation dominated cosmologies from string dominated cosmology with Hagedorn temperature. It could involve h_{eff} increasing phase transitions for string gas during the initial period and liberation of magnetic energy during the end period as massless particles: this would explain why the mass density of the space-time sheet increases dramatically. The critical cosmology could correspond to a phase transition from a phase with Hagedorn temperature identified as $T_H \propto \hbar/R_H$ to radiation dominated cosmology.

2. The cooling of string gas would lead to the generation of hierarchy of Planck constants and liberation of the magnetic energy of strings as massless particles during the end of critical period topologically condensing to space-time sheets such as massless extremals. This process could correspond to the rapid increase of energy density towards the end of the critical period.

3. Isotropy and homogenity appear both at the level of embedding space and space-time sheets. The infinite horizon of M^4_+ would explain the isotropy and homogenity of string gas in H both before and after the emergence of space-time sheets at Hagedorn temperature around $a \sim R_{CP_2}$. In particular, the smoothness of the cosmology of dark matter and dark energy would find explanation. The rapid expansion would in turn smooth out inhomogenities of individual space-time sheets.

4. The Hubble scale $1/H$ approaches to zero as $a = a_F < a_1$ is approached. The rapid expansion destroys anisotropies and inhomogenities of radiation dominated space-time sheet corresponding to particular value of a_F. The distribution for values of a_F in turn explains CMB scalar fluctuations since the energy density in final state is highly sensitive to the precise value of a_F. This distribution would be Gaussian in the first approximation. One can say that the fluctuation spectrum for inflaton field is replaced with that for a_F.

5. Also the generation of gravitational radiation and its decoupling from matter could take place during the same end period. After this gravitational fields would be essentially classical and assignable to space-time sheets. Essentially formation of gravitationally bound states would be in question analogous to what happens photons decouple from matter much later. The reduction of the temperature of string gas below Hagedorn temperature could generate also the massless graviton phase decoupling from matter and inducing the temperature fluctuations and polarization during decoupling.

   Gravitons and also other particles would topological condense at "massless extremals" (MEs, topological light rays) and particles - in particular photons - would interact with gravitons by generating wormhole contacts to gravitonic MEs. The interaction between MEs assignable to gravitational radiation and photons would have caused the fluctuations of CMB temperature.

To sum up, if the TGD inspired picture is correct then Penrose (http://tinyurl.com/kuxh3ac) would have been correct in the identification of string theory as fashion and inflationary cosmology as fantasy (for the strong reaction of Lubos Motl see http://tinyurl.com/ycvn9y74). Also the fact that inflationary cosmology is at the verge of internal contradiction due the fact that the assumption of field theoretic description is in conflict with the large graviton background suggests that inflationary cosmology is not for long with us anymore.

3.7.9 Could The Polarization Be Due To The Dark Synchrotron Radiation?

I have commented in several postings (http://tinyurl.com/yaqmo9za, http://tinyurl.com/ydco4qog, http://tinyurl.com/yaoy6lfa, and http://tinyurl.com/yafpspgw) the BICEP claim of having detected primordial B-modes in the polarization of cosmic microwave background (CMB). The claim was that effect was produced by the interaction of microwave photons from the effects caused by primordial gravitons on the space-time geometry caused by the presence of the gravitons. The effect was unexpectedly large and challenges quantum field theoretic description used in inflation paradigm: note that inflation paradigm postulates the existence of Higgs like particle called inflaton.

Now Jester (http://tinyurl.com/y7hdo9ls) tells in his blog that there are rumours that BICEP2 group might have underestimated the effect of galactic foreground. There is also a little article in Science Now about the situation (http://tinyurl.com/lyysmqv).

BICEP signal is taken only at single frequency: 150 GHz. Planck has published a polarization at 353 GHz demonstrating that there may be a significant foreground emission from the galactic dust in the parts of sky studied by BICEP. The Planck collaboration has masked the results in BICEP patch: this does not certainly help BICEP team in their work. It is a pity that competition between research groups leads to this kind of secrecy.

Whether or not the BICEP finding is correct does not affect much neither inflationary models or TGD model. In inflationary approach there are so many variants to consider that one can always find candidate models. The reduction of B-mode contribution would be actually wellcome since it would allow to get rid of the internal consistency problem. In TGD framework there is also rapid accelerating expansion analogous to that of inflationary expansion but the no inflatons are needed. Quantum criticality implies vanishing 3-curvature and this fixes the cosmology apart from the duration of the critical phase. The model is not quantum field theoretic anymore: gas of cosmic strings inside Minkowski space light-cone prevails before the inflationary period which is critical period for the phase transition to a radiation dominated cosmology. The problem is that one (more precisely, I) cannot really calculate precise prediction for the size of the effect.

The B-mode contribution should be disentangled from two foreground contributions from synchrotron radiation and galactic dust. The problems with BICEP are possibly related to the latter one. I cannot of course say anything interesting about the experimental side of the problem.

One can however ask TGD might predict new kind of synchrotron contribution. In TGD Universe magnetic flux tubes in various scales are basic objects and essential also in the model for temperature fluctuations and polarization of CMB resulting from slightly different temperatures for the two polarization of CMB. The magnetic flux tubes carry monopole fluxes making their existence possible without currents generating then. Their magnetic energy can be identified as dark energy. They carry also dark variants of ordinary particles identified as phases with Planck constant coming as integer multiple of the ordinary one. Could the charged particles - in particular electrons - rotating at cyclotron orbits at these flux tubes produce cyclotron radiation at CMB frequencies and thus giving rise to its apparent polarization?

Concerning cyclotron radiation one can consider relativistic/non-relativistic and classical/quantal situations.

1. In Wikipedia there is article about classical model for cyclotron radiation (http://tinyurl.com/mb2lv). One expects that the qualitative aspects remain the same in quantal treatment. For planar motion around magnetic field the radiation has dipole pattern around the axis of motion in non-relativistic situation. In relativistic situation it is strongly peaked around the direction of motion at frequency of order γ^3/ρ where γ is the relativistic time dilation factor and ρ is the radius of the orbit which gradually decreases. Most of the radiation is in the

plane orthogonal to the orbit and the polarization in the plane of the orbit is parallel to the plane and orthogonal to the line of sight.

2. Quantum model might be relevant if the charged particles are in large h_{eff} phase at magnetic flux tubes and emit dark photons with scaled up energies. Dark photons would later transform to bunches of ordinary photons and if their energies are in the region corresponding to CMB they might produces additional contribution.

   In quantum case the charged particles behaves like a 2-D harmonic oscillator in degrees of freedom orthogonal to the magnetic field and energy is quantized as multiples of the cyclotron energy $E = n \times h_{eff}\omega$, $\omega = ZeB/m$. Note the upwards scaling of energy by h_{eff}. The frequencies of the emitted radiation come a multiples of the cyclotron frequency and can be rather high. The Bohr radii of the orbits are quantized and the spiral orbit with decreasing radius is replaced with a sequence of circular orbits with instantaneous jumps to orbit with smaller radius. One expects that the general polarization characteristics are same as in the classical case and that classical description is a good approximation also now.

Could this kind of dark radiation give an apparent contribution to CMB? The following very naïve scaling estimate is an attempt to answer the question.

1. The local direction of the vector field defined by the local polarization of CMB photons should be equal to the local direction of magnetic flux tubes in question so that the polarization map would give a map of flux tubes carrying dark matter. This would be of course extremely nice.

2. The condition that the radiation is in CMB range implies that the frequency is of order 100 GHz. Electron or electron Cooper is the best candidate for the dark charged particle in question. The cyclotron frequency of electron is $f = 6 \times 10^5$ Hz in the magnetic field of.2 Gauss (familiar to me from TGD inspired quantum biology!). From this one deduces that a magnetic fields in question should be in Tesla range if they are to affect the CMB background.

3. If one requires quantization of the flux then minimal flux quantum for ordinary value of Planck constant would have a minimal thickness of order $R = 10$ nm. By naïve scaling the flux quantum is proportional to h_{eff} so that by a naïve scaling the minimal radius of flux tube would scale like $h_{eff}^{1/2}$ and be thus larger than 10 nm lower bound.

   Macroscopic situation would correspond to very large thickness scaling as $n^{1/2}$, where integer n characterizes the quantized flux. Macroscopic effective thickness is of course required by data. Very large values of h_{eff} or n would be required to give realistic values for the flux tube radius. In the fractal Universe of TGD a fractal hierarchy of flux tubes within flux tubes picture is expected and one could have bunches of flux tubes with thickness $h_{eff}^{1/2} \times R$.

I leave it for the reader to guess whether this contribution could mimic the CMB polarization detected by BICEP.

3.8 Cyclic cosmology from TGD perspective

The motivation for this piece of text came from a very inspiring interview of Neil Turk by Paul Kennedy in CBS radio (see `http://tinyurl.com/hzw8k68`). The themes were the extreme complexity of theories in contrast to exrteme simplicity of physics, the mysterious homegeny and isotropy of cosmology, and the cyclic model of cosmology developed also by Turok himself. In the following I will consider these issues from TGD viewpoint.

3.8.1 Extreme complexity of theories *viz.* extreme simplicity of physics

The theme was the incredible simplicity of physics in short and long scales *viz.* equally incredible complexity of the fashionable theories not even able to predict anything testable. More precisely, super string theory makes predictions: the prediction is that every imaginable option is possible.

Very safe but not very interesting. The outcome is the multiverse paradigm having its roots in inflationary scenario and stating that our local Universe is just one particular randomly selected Universe in a collection of infinite number of Universes. If so then physics has reached its end.

This unavoidably brings to my mind the saying of Einstein: "Any intelligent fool can make things bigger, more complex, and more violent. It takes a touch of genius – and a lot of courage – to move in the opposite direction.".

Turok is not so pessimistic and thinks that some deep principle has remained undiscovered. Turok's basic objection against multiverse is that there is not a slightest thread of experimental evidence for it. In fact, I think that we can sigh for relief now: multiverse is disappearing to the sands of time, and can be seen as the last desperate attempt to establish super string theory as a respectable physical theory.

Emphasis is now in the applications of AdS/CFT correspondence to other branches of physics such as condensed matter physics and quantum computation. The attempt is to reduce the complex strongly interaction dynamics of conformally invariant systems to gravitational interaction in higher dimensional space-time called bulk. Unfortunately this approach involves the effective field theory thinking, which led to the landscape catastrophe in superstring theory. Einstein's theory is assumed to describe low energy gravitation in AdS so that higher dimensional blackholes emerge and their interiors can be populated with all kinds of weird entities. For TGD view about the situation see [L21].

One can of course criticize Turok's view about the simplicity of the Universe. What we know that *visible* matter becomes simple both at short and long scales: we actually know very little about dark matter. Turok also mentions that in our scales - roughly the geometric mean of shortest and longest scales for the known Universe - resides biology, which is extremely complex. In TGD Universe this would due to the fact that dark matter is the boss for living systems and the complexity of visible matter reflects that of dark matter. It could be that dark matter levels corresponding to increasing values of h_{eff}/h get increasingly complex in long scales and complexity increases. We just do not see it!

3.8.2 Why the cosmology is so homogenous and isotropic?

Turok sees as one of the deepest problems of cosmology the extreme homogeny and isotropy of cosmic microwave background implying that two regions with no information exchange have been at the same temperature in the remote past. Classically this is extremely implausible and in GRT framework there is no obvious reason for this. Inflationary scenario is one possible mechanism explaining this: the observed Universe would have been very small region, which expanded during inflationary period and all temperature gradients where smoothed out. This paradigm has several shortcomings and there exists no generally accepted variant of this scenario.

In TGD framework one can also consider several explanations.

1. One of my original arguments for $H = M^4 \times CP_2$ was that the imbeddability of the cosmology to H forces long range correlations [K31, K94, K66]. The theory is Lorentz invariant and standard cosmologies can be imbedded inside future light-cone with its boundary representing Big Bang. Only Roberton-Walker cosmologies with sub-critical or critical mass are allowed by TGD. They are Lorentz invariant and therefore a very natural option [K94]. One would have automatically constant temperature. Could the enormous reduction of degrees of freedom due to the 4-surface property force the long range correlations? Probably not. 4-surface property is a necessary condition but very probably far from enough.

2. The primordial TGD inspired cosmology is cosmic string dominated: one has a gas of string like objects, which in the ideal case are of form $X^2 \times Y^2 \subset M^4 \times CP_2$, where X^2 is minimal surface and Y^2 complex surface of CP_2. The strings can be arbitrarily long unlike in GUTs. The conventional space-time as a surface representing the graph of some map $M^4 \rightarrow CP_2$ does not exist during this period. The density goes like $1/a^2$, a light-cone proper time, and the mass of co-moving volume vanishes at the limit of Big Bang, which actually is reduced to "Silent Whisper" amplified later to Big Bang.

   Cosmic string dominated period is followed by a quantum critical period analogous to inflationary period as cosmic strings start to topologically condense at space-time sheets becoming magnetic flux tubes with gradually thickening M^4 projections. Ordinary space-time is formed: the critical cosmology is universal and uniquely fixed apart from single parameter determining the duration of this period.

After that a phase transition to the radiation dominated phase takes place and ordinary matter emerges in the decay of magnetic energy of cosmic strings to particles - Kähler magnetic energy corresponds to the vacuum energy of inflaton field. This period would do analogous to inflationary period. Negative pressure would be due to the magnetic tension of the flux tubes.

Also the asymptotic cosmology is string dominated since the corresponding density of energy goes like $1/a^2$ as for primordial phase whereas for matter dominated cosmology it goes like $1/a^3$. This brings in mind the ekpyrotic phase of the cyclic cosmology.

3. This picture is perhaps over-simplified. Quite recently I proposed a lift of Kähler action to its 6-D twistorial counterpart [L20]. The prediction is that a volume term with positive coefficient representing cosmological constant emerges from the 6-D twistorial variant of Kähler action via dimensional reduction. It is associated with the S^2 fiber of M^4 twistor space and Planck length characterizes the radius of S^2. Volume density and magnetic energy density together could give rise to cosmological constant behind negative pressure term. Note that cosmological term for cosmic strings reduces to similar form as that from Kähler action and depending on the value of cosmological constant only either of them or both are important. TGD suggest strongly that cosmological constant Λ has a spectrum determined by quantum criticality and is proportional to the inverse of p-adic length scale squared so that both terms could be important. If cosmological constant term is small always the original explanation for the negative pressure applies.

   The vision about quantum criticality of TGD Universe would suggest that the two terms has similar sizes. For cosmic strings the cosmological term does not give pressure term since it come from the string world sheet alone. Thus for cosmic strings Kähler action would define the negative pressure and for space-time sheets both. If the contributions could have opposite signs, the acceleration of cosmic expansion would be determined by competing control variables. To my best understanding the signs of the two contributions are same (my best understanding does snot however guarantee much since I am a numerical idiot and blundering with numerical factors and signs are my specialities). If the signs are opposite, one cannot avoid the question whether quantum critical Universe could be able to control its expansion by cosmic homeostasis by varying the two cosmological constants. Otherwise the control of the difference of accelerations for expansion rates of cosmic strings and space-time sheets would be possible.

4. A third argument explaining the mysterious temperature correlations relies on the hierarchy of Planck constants $h_{eff}/h = n$ labelling the levels of dark matter hierarchy with quantum scales proportional to n. Arbitrary large scales would be present and their presence would imply a hierarchy of arbitrary large space-time sheets with size characterized by n. The dynamics in given scale would be homogenous and isotropic below the scale of this space-time sheet.

   One could see the correlations of cosmic temperature as a signature of quantum coherence in cosmological scales involving also entanglement is cosmic scales [L21]. Kähler magnetic flux tubes carrying monopole flux requiring no currents to generate the magnetic fields inside them would serve as correlates for the entanglement just as the wormholes serve as a correlate of entanglement in ER-EPR correlations. This would conform with the fact that the analog of inflationary phase preserves the flux tube network formed from cosmic strings. It would also explain the mysterious existence of magnetic fields in all scales.

3.8.3 The TGD analog of cyclic cosmology

Turok is a proponent of cyclic cosmology [E226, E252, E69] (see `http://tinyurl.com/hrlzdkp`) combining so called ekpyrotic cosmology and inflationary cosmology. This cosmology offers a further solution candidate for the homogeny/isotropy mystery. Contracting phase would differ from the expanding phase in that contraction would be much slower than expansion and only during the last state there would be a symmetry between the two half-periods. In concrete realizations inflaton type field is introduced. Also scenarios in which branes near each other collide with each other cyclically and generate in this manner big crunch followed by big bang is considered. I find difficult to see this picture as a solution of the homogeny/isotropy problem.

I however realized it is possible to imagine a TGD analog of cyclic cosmology in Zero Energy Ontology (ZEO). There is no need to assume that this picture solves the homogeny/isotropy problem and cyclicity would correspond to kind of biological cyclicity or rather sequence of re-incarnations in the sense of TGD inspired theory of consciousness.

1. In ZEO the basic geometric object is causal diamond (CD), whose M^4 projection represents expanding spherical light-front, which at some moment begis to contract - this defines an intersection of future and past directed light-cones. Zero energy states are pairs of positive and negative energy states at opposite light-like boundaries of CD such that all conserved quantum numbers are opposite. This makes it possible to satisfy conservation laws. ZEO, in particular CDs, are forced by the finiteness of the dimensionally reduced 6-D Kähler action for the twistor lift of space-time containing also volume term diverging for infinitely large space-time surfaces.

2. CD is identified as 4-D perceptive field of a conscious entity in the sense that the contents of conscious experiences are from CD. Does CD is represent only the perceptive field of an observer getting sensory representation about much larger space-time surface continuing beyond the boundaries of CD or does the geometry of CD imply cosmology, which is Big Bang followed by a Big Crunch. Or do the two boundaries of CD define also space-time boundaries so that space-time would end there.

   The conscious entity defined by CD cannot tell whether this is the case. Could a larger CD containing it perhaps answer the question? No! For larger CD the CD could represent the analog of quantum fluctuation so that space-time of CD would not extend beyond CD.

3. The geometry of CD brings in mind Big Bang - Big Crunch cosmology. Could this be forced by boundary conditions at future and past boundaries of CD meeting along the large 3-sphere forcing Big Bang at both ends of CD but in opposite directions. If CD is independent geometric entity, one could see it as Big Bang followed by Big Crunch in some sense but not in a return back to the primordial state: this would be boring and in conflict with TGD view about cosmic evolution.

4. To proceed some TGD inspired theory of consciousness is needed. In ZEO quantum measurement theory extends to a theory of consciousness. State function reductions can occur to either boundary of CD and Negentropy Maximization Principle (NMP) dictates the dynamics of consciousness [K67].

   Zeno effect generalizes to a sequence of state function reductions leaving second boundary of CD and the members of zero energy states at it unchanged but changing the states at opposite boundary and also the location of CD so that the distance between the tips of CD is increasing reduction by reduction. This gives rise to the experienced flow of subjective time and its correlation with the flow of geometric time identified as the increase of this distance.

   The first reduction to opposite boundary is forced to eventually occur by NMP and corresponds to state function reduction in the usual sense. It means the death of the conscious entity and its re-incarnation at opposite boundary, which begins to shift towards opposite time direction reduction by reduction. Therefore the distance between the tips of CD continues to increase. The two lifes of self are lived in opposite time directions.

5. Could one test this picture? By fractality CDs appear in all scales and are relevant also for living matter and consciousness. For instance, mental images should have CDs as correlates in some scale. Can one identify some analogy for the Big Bang-Big Crunch cosmology for them? I have indeed considered what time reversal for mental images could mean and some individuals (including me) have experienced it concretely in some altered states of consciousness.

The question that I am ready to pose is easy to guess by a smart reader. Could this sequence of life cycles of self with opposite directions of time serve as TGD analog for cyclic cosmology?

1. If so, the Universe could be seen a gigantic organism dying and re-incarnating and quantum coherence even in largest scales would explain the long range correlations of temperature in terms of entanglement - in fact negentropic entanglement, which is basic new element of TGD based generalization of quantum theory.

2. Big Crunch to primordial cosmology destroying all achievements of evolution should not occur at any level of dark matter hierarchy. Rather the process leading to biological death would involve the deaths of various subsystems with increasing scale and eventually the death in the largest scale involved.

3. The system would continue its expansion and evolution from the state that it reached during the previous cycle but in opposite time direction. What would remain from previous life would be the negentropic entanglement at the evolving boundary fixed by the first reduction to the opposite boundary, and this conscious information would correspond to static permanent part of self for the new conscious entity, whose sensory input would come from the opposite boundary of CD after the re-incarnation. Birth of organism should be analogous to Big Bang - certainly the growth of organism is something like this in metaphoral sense. Is the decay of organism analogous to Big Crunch?

4. What is remarkable that both primordial and asymptotic cosmology are dominated by string like objects, only their scales are different. Therefore the primordial cosmology would be dominated by cosmic strings thickened to cosmic strings also for the reversed cycle. Even more, the accelerated expansion could rip the space-time - this is one of the crazy looking predictions of accelerating expansion - and one would have free albeit thickened cosmic strings. In rough enough resolution they would look like ideal cosmic strings.

   The re-cycling would not be trivial and boring (dare I say stupid) repeated return to the same primordial state in conflict with NMP implying endless evolution. It would involve scaling up at each rebirth. The evolution would be like a repeated zooming up of Mandelbrot fractal! Breathing is a good metaphor for this endless process of re-creation: God is breathing! Or Gods, since the is fractal hierarchy of CDs within CDs.

5. There is however a trivial problem that I did not first notice. The light-cone proper times $a_\pm$ assignable to the two light-cones $M^4_\pm$ defining CD are not same. If future directed light-cone M^4_+ corresponds to $a_+^2 = t^2 - r_M^2$ with the lower tip of CD at $(t, r_M) = (0, 0)$, the light-cone proper time associated with M^4_- corresponds $a_-^2 = (t-T)^2 - r_M^2 = a_+^2 - 2tT + T^2 = a_+^2 - 2\sqrt{a_+^2 + r_M^2}T + T^2$. The energy density would behave near the upper tip like $\rho \propto 1/a_+^2$ rather than $\rho \propto 1/a_-^2$. Does this require that a Big Crunch occurs and leads to the phase where one has gas of cosmic strings in M^4_-? This does not seem plausible. Rather, the gas of presumably thickened cosmic strings in M^4_- is generated in the state function reduction to the opposite boundary. This state function reduction would be very much like the end of world and creation of a new Universe.

To sum up, single observation - the constancy of cosmic temperature - gives strong support for extremely non-trivial and apparently completely crazy conclusion that quantum coherence is present in cosmological scales and also that Universe is living organism. This should prove how incredibly important the interaction between experiment and theory is.

3.9 Conformal cyclic cosmology of Penrose and zero energy ontology based cosmology

This text was inspired by a popular article "Weird circles in the sky may be signs of a universe before ours" (see `http://tinyurl.com/ycme7xg4` telling about the conformal cyclic cosmology (CCC) proposed by Penrose (see `http://tinyurl.com/ydbq32`) predicting low variance concentric circles in cosmic microwave background (CMB) [E64] (see `https://arxiv.org/abs/1808.01740`) .

1. 2011 Penrose and V.G. Gurzadyan claimed that CMB indeed contains concentric circles with a low variance. The significance of the finding was told to be 6-sigma (see http://tinyurl.com/ydbz587d.

2. Three groups have independently attempted to reproduce these results, but found that the detection of the concentric anomalies was not statistically significant, in that no more concentric circles appeared in the data than in Lambda-CDM simulations (see https://arxiv.org/abs/1012.1268, https://arxiv.org/abs/1012.1305, and https://arxiv.org/abs/1012.1656). The reason for the disagreement was tracked down to an issue of how to construct the simulations that are used to determine the significance (see https://arxiv.org/pdf/1012.1486.pdf): Wikipedia article (see http://tinyurl.com/jnnwnwv) tells that the three independent attempts to repeat the analysis all used simulations based on the standard Lambda-CDM model, while Penrose and Gurzadyan used an undocumented non-standard approach.

3. The recent paper by An, Meissner and Penrose [E64] (see https://arxiv.org/abs/1808.01740) the earlier claims are repeated and it is also noticed that the B-mode location found by BICEP 2 corresponds to a singular point to which one assign concentric circles of low variance in CMB.

The idea of CCC is mathematically rather refined. The vision is that Universe can be seen as a sequence of cosmologies (aeons as Penrose calls them) obtained by gluing them together. The Robertson-Walker metric of given cosmology would differ from the previous cosmology by a conformal factor Ω^2 approaching zero at smooth space-like conformal boundary, which I understand as the surface at which cosmic time coordinate approaches infinity.

Remark: In the case of M^4 light-cone this conformal boundary could correspond to the limit of the hyperboloid $a = \sqrt{t^2 - r^2} = constant \rightarrow \infty$, where a is proper time coordinate of the light-cone. Symmetry of CD in TGD framework suggests that the conformal boundaries correspond to opposite boundaries of CD. It is interesting that the metric restricted at the either boundary of CD becomes formally zero ($ds^2 = da^2 - a^2(d\Omega^2 \rightarrow da^2)$ in analogy with conformal scaling factor going to zero.

The presence of the conformal factor would mean that the lengths in the new metric is scaled down by a factor Ω approaching zero. Gluing would not be isometric and infinite shrinking of the scales would take place in the transition. This looks questionable. Penrose justifies conformal gluing by 4-D conformal invariance. But how could physics realize this shrinking of scales? This remains a mystery.

Could CCC be tested?

1. This would require that the previous aeon leaves some memories about itself to the next aeon. These memories should originate from the physical state at the conformal boundary. The view is following. The end of the previous aeon gives rise to a formation of blackholes and in the beginning of the next aeon these blackholes suffer Hawking evaporation as photons. This assumption is claimed to follow from general consistency conditions implying that all fermionic matter must transform to bosonic matter whereas radiation could survive the transition.

2. For instance, the evaporation of galactic blackhole would give rise to enormous pulse of Hawking radiation defining expanding spherical wave front. The photons associated with these wave fronts would modify CMB and give rise to circles with low variance. It is essential that circles are in question and Penrose and Gurzadyan claim that elliptic and triangle like curves with low variance are not found in CMB. Several concentric circles could be seen as evidence for several aeons before the recent one.

3. If the circles really exist, they would have revolutionary implications. The reason is that they have cosmic size scale of the order of the time scale when inflationary period ended and changed to radiation dominance with radiation coming from the energy of inflaton field.

The proposal CCC is highly interesting from TGD point of view. In TGD framework the time scale for the setting of radiation dominated phase would correspond to the time when cosmic string dominated period ended and space-time surfaces with 4-D M^4 projection modellable in terms of radiation dominated cosmology emerged. The thickening of cosmic strings would have reduced string tension and the liberated energy would have transformed to ordinary particles [K31, K94, K66].

The view is that cosmic strings condensed at the newly formed space-time surfaces and began to thicken as magnetic flux tubes. In zero energy ontology (ZEO) the radiation (ordinary particles) emitted by cosmic strings would be absorbed at the opposite boundary of CD meaning essentially time reversal of the analog of inflationary transition.

CD serves as a correlate for a conscious entity [L44]- self - even in cosmic length scales. Self corresponds to a sequence of state function reductions - analogs of weak measurements - changing only the members of zero energy states assignable to the active (changing) boundary of CD. The death and reincarnation of self means the first state function reduction - "big" reduction in which the roles of passive (unchanging) and active boundaries of CD are changed. In cosmology this would mean re-incarnation of cosmology as cosmology with opposite arrow of time since the former passive boundary becomes the active boundary receding from the passive boundary. The question is whether the process transforming energy of cosmic strings to radiation consisting of ordinary matter during very early CD cosmology can cause spherical radiation pulses and whether these spherical surfaces are preserved as memories from earlier life cycles of cosmic self. I have discussed this idea earlier in [K94] and [L19].

3.9.1 ZEO based cosmology as sequence of deaths and reincarnations of cosmology as a conscious entity

TGD inspired theory of consciousness based on zero energy ontology (ZEO) [L44] leads to a quantum variant about sequence of cosmologies.

1. Zero energy states are pairs of quantum states at active and passive boundary and the members of states pairs at passive boundary are not affected whereas those at active boundary change in state function reductions following unitary evolutions. Also the temporal distance between passive and active boundary changes and defines a clock time in correspondence with the subjective time identified as sequence of state function reductions defining moments of consciousness for the conscious entity associated with the CD. One can say that one has Zeno effect for the passive boundary of CD.

2. One can interpret the sequence of state function reductions as weak quantum measurements and argue that if the number of observables to be measure is infinite, eventually the situation in which no state function reduction is possible anymore. What should the conscious entity do. Just repeat the measurement of observables already measured - kind of enlightened state freed from the cycle of Karma - or perform the first state function reduction not leaving the states at the passive boundary invariant. This "big" state function reduction - analogous to ordinary state function reduction in elementary particle physics - would change the roles of the active and passive boundary. Self would die and reincarnate as as self with opposite arrow of clock time. CD would now increase in opposite time direction.

3. CDs can have arbitrarily large sizes and form an infinite hierarchy. Sub-CD corresponds to mental image at the level of conscious experience. Even Universe - or rather hierarchy of Universe - could be seen as a conscious entity. Cosmologies are assignable to causal diamonds (CDs) for which second -passive - boundary remains invariant under a sequence of state function reductions at second - active - boundary analogous to weak measurements.

4. If cosmological selves are part of this "Karma's cycle", one would have the analog of Penrose's CCC. The conformal gluing of space-times would be replaced by the "big" state function reduction replacing zero energy state with a given arrow of time with a state with opposite arrow of time. T symmetry is broken both in physics (neutral kaon and B meson). T is broken also in TGD Universe by the necessity to have generalized Kähler structure for M^4: this gives rise to small CP and T breaking interaction distinguishing between time evolution and its time reversal so that even classically cosmic evolution and its reversal are not same.

More precise view about ZEO based cosmology

Consider now in more detail ZEO based (sub-)cosmology as conscious entity.

1. One can start from TGD inspired theory of consciousness. Can we remember our lives as meditators claim? One can used the fractality of self hierarchy to reformulate the question. Our mental images have finite lifetime: for sensory mental images this life time is measured in fraction of second. We know the phenomenon of after image: the same mental image -say visual mental image - dies and re-incarnates again and again. Could it be that the period between the two mental images corresponds to time reversal of the corresponding sub-self? Could it be that at some level of the personal self hierarchy I died at the evening, slept the night living in opposite time direction, and woke up at the morning as a reincarnation in the original time direction. I indeed remember things about yesterday and even days before that!

2. Could also cosmic memories be possible? Could recent cosmology remember some dramatic events about its previous life cycle? Penrose considers Hawking evaporation as an event of this kind. In the case of galactic blackhole evaporation near conformal boundary would create a huge pulse of Hawking radiation and these pulses from the previous cosmologies would be responsible for the concentric circles.

   In TGD framework the analogs of these radiation pulses could also be generated as the dark matter and energy inside cosmic strings transforms to ordinary particles at the passive boundary of CD. At the active boundary the reversal of this process would occur as cosmic strings would absorb all the ordinary matter. This process is TGD counterpart for the transformation of the energy of inflaton field to elementary particles particles and would lead to radiation dominated period and give rise to ordinary space-time.

Zero energy states are superpositions of classical space-time surfaces associated with the zero energy states. A natural expectation is that the space-time surfaces very near the passive boundary are in reasonable approximation free cosmic strings and then make transition to radiation dominated RW cosmology. Same should hold true also at the active boundary.

1. If this occurs in strict sense, the magnetic flux tubes - thickened cosmic strings - serving as correlates for the linear structures formed by galaxies and having galaxies as local knots in turn having stars as local knots would transform back to free cosmic strings containing magnetic and dark energy plus dark matter as $h_{eff} = nh_0$ phases [?, K80]. This would require very special boundary conditions near the boundaries of CD demanding ing that the elementary particles generated by partial evaporation of cosmic strings during the analog of the inflationary period would be absorbed by cosmic strings to which magnetic flux tubes would be contracted.

2. This process would be analogous to the formation of blackholes as a reversal of their evaporation and of inflationary period near the passive boundary. The process thinning the cosmic strings would also resemble Penrose's downwards conformal scaling of distances by factor $\Omega \rightarrow 0$. It must be emphasized that in CCC the blackholes would evaporate and leave only radiation at the future conformal boundary. Here TGD picture would differ radically from the view of Penrose.

3. Boundary conditions at the boundaries of CD stating that near both boundaries of CD one has gas of cosmic strings in CD would force this kind of reversal of the arrow of classical time evolution happen say around $a = T/2$, where T is the distance between tips of CD (which itself increases in every weak measurement). Could these boundary conditions be forced by the preferred extremal property, which is extremely powerful condition indeed. The proposal is that the only allowed extremals are minimal surfaces except at points having interpretation as reaction vertices. These boundary conditions should imply a rough analog of time reflection symmetry with respect to $a = T/2$ (perhaps in statistical sense)

   Remark: In Wikipedia article about CCC (see `http://tinyurl.com/jnnwnwv`) it is mentioned that the existence of smooth conformal horizons in GRT is an extremely powerful condition.

If this contraction of flux tubes to cosmic strings happens, the beginning of the time reversed cosmic evolution would be rather similar to the previous evolution. In reversed time direction the contraction process would look like the analog of the inflationary period. The process is quantum process, and one might also ask whether the "big" state function reduction could occur with maximal probability to the time reversed space-time surfaces, which are cosmic strings near the active boundary of CD. For this option boundary conditions would be needed.

4. Could cosmic string dominance be the only possible mathematically acceptable option? In GRT picture, radiation dominance implies that the GRT based energy density diverges like $1/a^4$ and the energy of co-moving volume diverges like $1/a$: this looks non-sensical. For cosmic string dominance the energy density in CD would behave like $1/a^2$ and the energy of a co-moving volume vanishes like a: cosmology would be a "silent whisper amplified to relatively big bang": one can hardly demand anything smoother if one accepts GRT description. Matter dominance would give finite energy per co-moving volume.

   It however turns out that in TGD framework very early cosmology is even simpler. The energy density remains finite near the boundaries of CD and this possible due to that fact that many-sheeted space-time having GRT as an approximate description is replaced with a gas of cosmic strings.

   Remark: Second option is that one obtains in the cosmic re-incarnation only scaled up variants of flux tubes looking cosmic strings in resolution defined by a longer length scale. I have earlier regarded this option as a more realistic one [K94] [L19].

Some comments and questions are in order.

1. CDs form a hierarchy and it is quite possible that one obtains this kind of almost-predictions in all scales.

2. Could the CDs with no outgoing legs be in preferred position and the proposed boundary conditions hold true only for them? One can also ask whether the particles could simply travel through the active boundary out as external particles so that the boundary of CD would contain only the cosmic strings. This would not conform with the idea that the thickening of cosmic strings reducing their string tension generates ordinary matter in analogy with inflation.

3. An essential point is whether one allows CDs to have external legs analogous to incoming particles of particle reaction. These are possible and would give rise to a construction of scattering diagrams analogous to that applied in twistor Grassmannian approach. But zero ZEO also allows to have "irreducible" CDs with not external legs and analogous to vacuum fluctuations in QFT context. These states would be something genuinely new not allowed by ordinary ontology.

4. In the more recent view about dynamics inside CDs I have returned to the original proposal that the minimal surface property of space-time sheets does not hold only true outside CDs for external particles but also inside CDs and that it breaks down only in reaction vertices located at partonic 2-surface [L57]. At these points there is energy transfer between volume term and Kähler action proportional to delta function. Feynman/twistor graph like representation of scattering amplitudes would be realized at classical space-time level. Cosmic strings are the simplest minimal surfaces and come as two kinds and would be the analogs of blackholes in TGD framework. Note that TGD allows the possibility of blackhole like states too but blackhole interior would contain highly tangled cosmic string.

How the TGD description differs from GRT description near the boundaries of CD

The first questions concern the conservation laws near the boundaries of CD. One expects that GRT cosmology fails near the boundaries of CD as the appearance of singularity suggests. I have indeed proposed the description of very early cosmology in terms of gas of cosmic strings in M^4. How the GRT based picture about early cosmology differs from TGD based picture in which one has genuine conservation laws? Can one find some justification for the dominance of cosmic strings?

1. Before going to the mathematical details it must be made clear that GRT based cosmology emerges in TGD framework as QFT-GRT limit of TGD. Gauge potentials and gravitational field as deviation of metric from M^4 metric emerge as sums of corresponding induced gauge fields over different space-time sheets with 4-D space-time projection.

   In fact, in TGD inspired cosmology one assumes that cosmic expansion takes place as rapid phase transitions. This picture is suggested both by the solutions of field equations and the empirical fact that astrophysical objects do not expand in smooth manner but might do so in jerks. This leads to TGD variant expanding Earth model motivated by some strange geological findings and applied to Cambrian explosion.

2. Light-cone can be thought of as empty Robertson-Walker cosmology formally. In R-W coordinates for light-cone one has $ds^2 = da^2 - a^2(dr^2/(1+r^2) + r^2\Omega^2)$. These coordinates become singular at light-cone boundary $a = 0$ and formally the metric reduces 1-D $ds^2 = da^2$. Non-vanishing values of the ordinary Minkowski radial coordinate $r_M = ar$ requires that r $r = r_M/a$ approaches ∞. The hyperbolic angle η in $r = sinh(\eta)$ must approach to $\eta = \infty$ for $a \rightarrow 0$.

   Robertson-Walker coordinates are not suitable in TGD framework since they are singular at light-cone boundary and to see what happens it is best to use light-cone coordinates $(u = t - r_M, v = t + r_M, \theta, \phi)$, where $u = 0$ corresponds to light-cone boundary and $v = 2r_M$, where r_M is radial M^4 coordinate at light-cone boundary. M^4_+ metric is $2dudv - ((u-v)^2/4)d\Omega^2$. One can use for space-time surfaces with 4-D M^4 projection these coordinates.

One can consider several descriptions.

Space-time description in TGD framework:

1. One can deduce conserved energy momentum currents in TGD framework and one can assign to the ends of space-time surface conserved four-momenta unlike in GRT. The conserved 4-momentum currents contractions $j^\alpha_A = (T^{\alpha_beta}\partial_\beta h^l h_{kl} jAk\sqrt{g_4}$, where j^K_k is vector field defining of isometry. T is determined by the action which is sum of volume and Kähler terms. The four-momentum in given volume is obtained by integrating momentum density over 3-surface at the boundary of CD.

2. For space-time surfaces it is easy to see that for 3-surfaces the energy-momentum currents determined by the action (Kähler action plus volume term) and therefore conserved momenta remain finite since the induced metric is invertible in the generic case. Energy momentum for a volume corresponding to a finite value of $r = r_M/a = (v-u)/2\sqrt{uv} \sim \sqrt{v/u}$ however vanishes since v must approach to zero like u and integration over v gives zero at this limit.

GRT description as cosmic string dominated cosmology:

1. The assumption that mass density in $T^{aa} = g^{aa}\rho$ of the ordinary R-W cosmology satisfies $\rho \propto 1/a^n$: $n = 4, 3, 2$ for radiation -, matter -, and cosmic string dominated cosmology. In Minkowski cosmology this would imply even for $n = 2$ that the component $T^{aa} = g^{aa}\rho$ behaves like g^{aa}/a^2. The integral of ρ over co-moving volume $\propto a^3$ would behave like a for string dominated cosmology one $\rho \propto 1/a^2$. Note that the mass defined in this manner is the best that one can achieve in GRT and would be finite form for a co-moving sphere with any finite value of r so that the mass density is singular and energy as Noether charge would diverge for finite values of M^4 radius r_M.

2. One could see the singularity as failure of GRT description at the limit light-cone boundary and being due to the wrong assumption that M^4 projections of space-time surfaces are 4-D: this in turn implies that the tota mass density diverges for infinite number of space-time sheets.

Description as gas of cosmic strings in M^4: Suppose that it make sense to speak about conserved energy momentum tensor in M^4_+ as the picture about gas of cosmic strings in M^4_+ suggests. By isometries of M^4_+ this energy momentum tensor - if suitably defined, gives rise to conserved quantities. What one obtains if one assumes that the energy momentum currents remains finite at light-cone boundary?

1. After the transition to radiation dominated cosmology in which M^4_+ projections of the space-time surfaces are 4-D and one can speak about many-sheetedness. If the number of space-time sheets becomes large as is expected to happen after transition to radiation dominance, the sum of metrics would at GRT limit give an metric for which Einstein tensor and metric gives an energy density behaving like in GRT based cosmology.

2. Could very early cosmology be modelled as a gas of cosmic strings in M^4_+? Assume that four-momentum in the model for a gas of cosmic strings in M^4_+ is finite for finite M^4 volume. Assume that energy momentum tensor in M^4_+ is $T^{uv} = kg^{uv}$: this guarantees vanishing of covariant divergence. One can also consider the possibility that the energy momentum tensor is proportional to M^4_+ metric (Einstein tensor of M^4_+ vanishes). This conforms with the assumption of string dominance in which 2 degrees of freedom of space-time surfaces correspond to either geodesic sphere of CP_2. If k is constant the divergence of energy momentum tensor vanishes.

3. The energy-momentum densities are given by $j^{Au} = kg^{uv}\partial_v m^k \sqrt{g_4}$, $\sqrt(g_4) = r_M^2 sin(\theta) = (u-v)^2 sin(\theta)/2$. These currents are conserved and define conserved charged for fixed M^4 sphere with radius $r_M = ar$. This volume *does not* correspond to co-moving volume with constant r appearing GRT framework. GRT and TGD pictures differ for very early times for the reasons already explained. The most important implication is that initial singularity disappears in TGD framework.

3.9.2 Does ZEO based cosmology predict the concentric circles?

Can one imagine signatures of ZEO cosmology analogous to those proposed by Penrose?

1. The evaporation of galactic blackholes or cosmic strings thickening the into flux tubes would generate a pulse of Hawking radiation travelling with average velocity $v \leq c$ to the active boundary of CD. One has actually $v < c$ due to interaction with matter so that the path of photon is not quite light-like. The photons would be absorbed by flux tubes and suffer time reflection in the "big" state function reduction. In statistical sense they would reflect back in time with opposite four-momentum in the "big" state function reduction. Conservation of total quantum numbers does not require that photon momentum changes sign but this is expected to be true in good approximation in statistical sense. For $v = c$ photon would return exactly to the position where it started from.

   $v < c$ however means that pulse absorbed by flux tubes and arrives after "big" state function reduction back along different route. By looking what happens during several aeons, one finds that one obtains sequences of 2-surfaces as reflection surfaces at the boundary of CD (which also increase during sequence of state function reductions). Could these spheres give rise to a sequence of concentric circles as intersection of a 3-D light-cone associated with observer with these spheres?

2. One can also consider the analog of pulses of Hawking radiation from magnetic flux tubes containing dark matter and generating the ordinary elementary particles as analog of inflation. Quasars and gamma ray bursts (GRBs) could be analogs of these processes and there is sub-pulse structure in the pulses but in time scale varying from millisecond to 100 seconds and therefore totally different order of magnitude than the age of the Universe. Could the pulses of radiation from these objects assignable to different aeons give rise to concentric circles?

3.10 Is inflation theory simply wrong?

I listened a very nice (see `http://tinyurl.com/ycvbk79t`) about inflation by Steinhardt, who was one of the founders of inflation theory and certainly knows what he talks. Steinhardt concludes that inflation is simply wrong. He discusses three kind of flexibilities of inflationary theory, which destroy its ability to predict and makes it non-falsifiable and therefore pseudoscience.

Basically cosmologists want to understand the extreme simplicity of cosmology. Also particle physics has turned to be extremely simple whereas theories have during last 4 decades become so complex that they cannot predict anything.

1. CMB temperature is essentially constant. This looks like a miracle. The constant cosmic temperature is simply impossible due to the finite horizon size in typical cosmology making impossible classical communications between distant points so that temperature equalization cannot take place.

2. One must also understand the almost flatness of 3-space: the value of curvature scalar is very near to zero.

Inflation theories were proposed as a solution of these problems.

The great vision of inflationists is that these features of the universe result during an exponentially fast expansion of cosmos - inflationary period - analogous to super-cooling. This expansion would smooth out all inhomogenities and an-isotropies of quantum fluctuation and yield almost flat universe with almost constant temperature with relative fluctuations of temperature of order 10^{-5}.

The key ingredient of recent inflation theories is a scalar field known as inflaton field (actually several of them are needed). There are many variants of inflationary theory (see `http://tinyurl.com/ycvyx2oh`).

Inflaton models are characterized by the potential function $V(\Phi)$ of the inflaton field Φ analogous to potential function used in classical mechanics. During the fast expansion $V(\Phi)$ would vary very slowly as a function of the vacuum expectation value of Φ . Super cooling would mean that Φ does not decay to particles during the expansion period.

1. In "old inflation" model cosmos was trapped in a false minimum of energy during expansion and by quantum tunneling ended up to true minimum. The liberated energy decayed to particles and reheated the Universe. No inflaton field was introduced yet. This approach however led to difficulties.

2. In "new inflation" model the effective potential $V_{eff}(\Phi, T)$ of inflaton field depending on temperature was introduced. It would have no minimum above critical temperature and super-cooling cosmos would roll down the potential hill with a very small slope. At critical temperature the potential would change qualitatively: a minimum would emerge at critical temperature and the inflaton field fall to the minimum and decay to particles and causes reheating. This is highly analogous to Higgs mechanism emerging as the temperature reduces below that defined by electroweak mass scale.

3. In "chaotic inflation" model there is no phase transition and the inflaton field rolls down to true vacuum, where it couples to other matter fields and decays to particles. Here it is essential that the expansion slows down so that particles have time to transform to ordinary particles. Universe is reheated.

3.10.1 Objections of Steinhardt against inflation

Consider now the objections of Steinhardt against inflation. As non-specialist I can of course only repeat the arguments of Steinhardt, which I believe are on very strong basis.

1. The parameters characterizing the scalar potential of inflaton field(s) can be chosen freely. This gives infinite flexibility. In fact, most outcomes based on classical inflation do not predict flat 3-space in recent cosmology! The simplest one-parameter models are excluded empirically. The inflaton potential energy must be very slowly decreasing function of Φ: in other words, the slope of the hill along which the field rolls down is extremely small. This looks rather artificial and suggests that the description based on scalar field could be wrong.

2. The original idea that inflation leads from almost any initial conditions to flat universe, has turned out to be wrong. Most initial conditions lead to something very different from flat 3-space: another infinite flexibility destroying predictivity. To obtain a flat 3-space must assume that 3-space was essentially flat from beginning!

3. In the original scenario the quantum fluctuations of inflaton fields were assumed to be present only during the primordial period and single quantum fluctuation expanded to the observer Universe. It has however turned out that this assumption fails for practically all inflationary models. The small quantum fluctuations of the inflationary field still present are amplified by gravitational backreaction. Inflation would continue eternally and produce all possible universes. Again predictivity would be completely lost. Multiverse has been sold as a totally new view about science in which one gives up the criterion of falsifiability.

Steinhardt discusses Popper's philosophy of science centered around the notions of provability, falsifiability, and pseudoscience. Popper state that in natural sciences it is only possible to prove that theory is wrong. A toy theory begins with a bold postulate "All swans are white!". It is not possible to prove this statement scientifically because it should be done for all values of time and everywhere. One can only demonstrate that the postulate is wrong.

Soon one indeed discovers that there are also some black swans. The postulate weakens to "All swans are white except the black ones!". As further observations accumulate, one eventually ends up with not so bold postulate "All swans have some color.". This statement does not predict anything and is a tautology. Just this has happened in the case of inflationary theories and also in the case of superstring theory.

Steinhardt discusses the "There is no viable alternative" defense, which also M-theorists have used. According to Steinhardt there are viable alternatives and Steinhardt discusses some of them. The often heard excuse is also that superstring theory is completely exceptional theory because of its unforeseen mathematical beauty: for this reason one should give up the falsifiability requirement. Many physicists, including me, however are unable to experience this heavenly beauty of super strings: what I experience is the disgusting ugliness of the stringy landscape and multiverse.

3.10.2 The counterpart of inflation in TGD Universe and twistor lift of Kähler action

The TGD variant of very early cosmology [K94] differs considerably from inflationary scenario but has also some common features.

The basic challenges are following.

1. One should understand the constancy of CMB temperature.

   Hint: String dominated cosmology with matter density behaving like $1/a^2$, a light-cone proper time defining the scaling factor of 3-D part of Friedman metric. This makes classical communications over infinitely long ranges possible and equalization of the temperature. At the moment of big-bang - second boundary of causal diamond (CD), which is part of boundary of light-cone - the distance between points in light-like radial direction vanishes. This could be the geometric correlate for the possibility of communications and long range quantum entanglement.

2. One should understand the flatness of 3-space.

   Hint: (Quantum) criticality predicts the absence of length scales. The curvature scalar of 3-space is dimensional quantity must vanish - hence flatness. TGD Universe is indeed quantum critical! This fixes the value spectrum of various coupling parameters.

The original TGD inspired answers to the basic questions would be following.

1. What were the initial conditions? In TGD Universe the primordial phase was a gas of cosmic strings in vicinity of the boundary of very big causal diamond (for the observer in recent cosmology). The boundary of CD - having M^4 given by the intersection of future and past directed light-cones - consists of two pieces of light-cone boundary with points replaced with CP_2). The gas is associated with the second piece of the boundary.

   Horizon size for M^4 light-cone is infinite and the hierarchy of Planck constants allows quantum coherence in arbitrarily long scales for the gas of cosmic strings forming the primordial state. This could explain constant cosmic temperature both in classical and quantum sense (both explanations are needed by quantum classical correspondence).

2. Inflationary period is replaced with the phase transition giving to space-time sheets with 4-D Minkowski space projection: the space-time as we know it. The basic objects are magnetic flux tubes which have emerged from cosmic strings as the M^4 projection has thickened from string world sheet to 4-D region. These cosmic strings decay partially to elementary particles at the end of the counterpart of inflationary period. Hence Kähler magnetic energy replaces the energy of the inflaton field. The outcome is radiation dominated cosmology.

3. The GRT limit of TGD replaces the many-sheeted space-time with a region of M^4 made slighly curved. Could one model this GRT cosmology using as a model single space-time sheet? This need not make sense but one can try.

   Criticality states that mass density is critical as in inflationary scenario. Einstein's equations demand that the curvature scalar for Lorentz invariant RW cosmology vanishes. It turns out that one can realize this kind of cosmology as vacuum extremal of Kähler action. The resulting cosmology contains only single free parameter: the duration of the transition period. 3-space is flat and has critical mass density as given by Einstein tensor.

   One might hope that this model could describe quantum criticality in all scales: not only the inflationary period but also the accelerating expansion at much later times. There is an exponentially fast expansion but it need not smooth out fluctuations now since the density of cosmic strings and temperature are essentially constant from beginning. This is what also inflationary models according to Steinhardt force to conclude although the original idea was that inflation produces the smoothness.

4. The energy of inflaton field is in this scenario replaced with the magnetic energy of the magnetic flux tubes obtained from cosmic strings (2-D M^4 projection). The negative "pressure" of the critical cosmology would microscopically corresponds to the magnetic tension along flux tubes.

5. Quantum fluctuations are present also in TGD framework but quantum coherence made possible by $h_{gr} = h_{eff} = n \times h$ dark matter saves the situation in arbitrary long scales. Dark matter as large $\hbar$ phases replaces the multiverse. Dark matter exists! Unlike multiverse!

Consider now the twistor lift of this picture. The twistor lift of the Kähler action adds by dimensional reduction to the 4-D Kähler action a volume term proportional to dimensional constant and one expects breaking of criticality and indeed the critical vacuum extremal of Kähler action fails to be a minimal surface as one can verify by a simple calculation. The value of cosmological constant is very small in the recent cosmology but the Kähler action of its vacuum extremal vanishes. What ways out of the difficulty can one imagine?

1. Should one just give up the somewhat questionable idea that critical cosmology for single space-time sheet allows to model the transition from the gas of cosmic strings to radiation dominated cosmology?

2. Should one consider small deformations of the critical vacuum extremal and assume that Kähler action dominates over the volume term for them so that it one can speak about small deformations of the critical cosmology is a good approximation? The average energy density associated with the small deformations - say gluing of smaller non-vacuum space-time sheetes to the background - would be given by Einstein tensor for critical cosmology.

3. Or could one argue as follows? During quantum criticality the action cannot contain any dimensional parameters - this at least at the limit of infinitely large CD. Hence the cosmological constant defining the coefficient of the volume term must vanish. The corresponding (p-adic) length scale is infinite and quantum fluctuations indeed appear in arbitarily long scales as they indeed should in quantum criticality. Can one say that during quantum critical phase transition volume term becomes effectively vanishing because cosmological constant as coupling constant vanishes.

   One can argue that this picture is an over-idealization. It might however work at GRT limit of TGD where size scale of CD defines the length scale assignable to cosmological constant and is taken to infinity. Thus vacuum extremal would be a good model for the cosmology as described by GRT limit.

As already described, there is also second problem. One has two explanations for the vacuum energy and negative pressure. First would come from the Kähler magnetic energy and magnetic tension and second from cosmological constant associated with the volume term. I have considered the possibility that these explanations are equivalent. The first one would apply to the magnetic flux tubes near to vacuum extremals and carrying vanishing magnetic monopole flux. Second one would apply to magnetic flux tubes far from vacuum extremals and carrying non-vanishing monopole flux. One can consider quantum criticality in the sense that these two flux tubes correspond to each other in 1-1 manner meaning that their M^4 projections are identical and they have same string tension.

3.10.3 The problems leading to and created by inflation and their solution in TGD framework

The following is essentially a blogpost response comparing the most recent view about TGD inspired cosmology with inflationary cosmology.

The Wikipedia article about inflationary cosmology (see `http://tinyurl.com/odlpyg8`) gives a good summary of inflation theory and its problems. What is nice that inflation theory is a solution to real problems. What is not nice is that it leads to new problems.

1. Horizon problem: temperature constant in extreme accuracy. There is no time to equilibrate if this process occurs by classical interactions propagating with light velocity.

2. Flatness problem: 3-space is unexpectedly flat suggesting critical 3-space so that 3-curvature vanishes. Here inflation theorists should have though a second though. Criticality suggests criticality in thermodynamical and even in quantum sense.

3. Monopole problem of GUTs. Monopoles are not observed. This is a problem of GUTs and thus all theories that are based on GUTs as QFT limit.

This is a nice starting point. The inflationary solution of the problems would be a rapid expansion. Inflation theory relies on GUT paradigm and proposes exponentially fast expansion due to a decay of false vacuum with non-vanishing energy density decaying to particles. Horizon size becomes large. The fluctuations of the curvature of 3-space get extremely small and 3-space flattens. Monopole density goes to zero. Observed universe would correspond to the content of single horizon.

It has however turned out that there are problems - Steinhardt is one of the critical voices. In particular, one cannot avoid fine tuning after all. Inflation theory remains qualitative. There is no empirical evidence for inflaton fields, and Russian doll cosmology is strongly suggestive leading to multiverse.

TGD provides an alternative solution. First TGD very briefly.

1. TGD emerges as a solution of energy problem of GRT and also as generalization of string models replacing string world sheets with space-time surfaces. TGD provides a new view about space-time. Space-times are 4-D surfaces in $M^4 \times CP_2$. M^4 and CP_2 are fixed uniquely by the existence of twistor lift of TGD requiring that the twistor spaces involved have Kähler structure.

   6-D Kähler action dimensionally reduces to a sum of a volume term - cosmological constant having a spectrum- and the analog of Maxwell action action. Preferred extremals are minimal surfaces - geometric analogs for massless fields - and extremals of also Maxwell action simultaneously but having 2-D string world sheets as singularities at which there is charge transfer between the two action terms. String like objects thicken to magnetic fluxes as their M^4 projection thickens. The action is essentially generalization of the action of point like charge in Maxwell field obtained by replacing point like particle with 3-D surface.

2. New view about quantum theory based on what I call zero energy ontology (ZEO) and number theoretical vision involving extension of physics to adelic physics with p-adic sectors of the theory describing cognition. Effective Planck constant is predicted to have hierarchy with values $h_{eff} = n \times h_0$, n the dimension of algebraic extension of rationals to which

parameters of extremals belong. This hierarchy of phases has interpretation as dark matter. Quantum coherence in even astrophysical and cosmic scales becomes possible. In biology the implications are dramatic.

Consider now the TGD solution to problems motivating inflation and also many other problems.

1. The problem of cosmological constant. Twistor lift replaces space-time surface with the analog of its twistor space - an S^2 bundle with twistor structure induced from the product of twistor spaces of M^4 and CP_2. *Length scale dependent* cosmological constant is the outcome of dimensional reduction of 6-D surfaces to S^2 bundle with space-time surface as base-space.

   Cosmological constant decreases in stepwise during cosmological evolution in phase transitions. During the expansion periods following the reduction of cosmological constant the Kähler magnetic energy of expanding flux tube transforms to particles but eventually the expansion halts since volume term increases and one reaches energy minimum. This process produces matter.

2. The solution to the problem of dark energy. The interpretation of the energy of monopole flux tubes having flux and return flux at different space-time sheets connected by tiny wormhole contacts is as dark energy: the reason is that test particle between the sheets experiences no classical forces. Long range gravitational fields are however created. Also the recent accelerating phase in the recent cosmology might correspond to such a transition. What is amazing that there is direct connection with biological scales.

3. What before possible rapidly expanding period leading to radiation dominated phase? There was no space-time in the usual sense - that is as 4-surfaces with 4-D M^4 projection - but cosmic strings with 2-D M^4 projections. String like objects dominated.

4. Was there a period of rapid inflationary expansion? The stepwise variation of cosmological constant in phase transitions means increase of the thickness of the flux tubes assignable naturally to cosmological expansion at QFT limit. The transition from string dominated to radiation dominated phase creating space-time in GRT sense would be one example. There would be entire series of this kind of fast expansions during which cosmological constant would be reduced. The recent accelerated expansion of the Universe would be also example of this kind of phase transition.

   Quantum criticality provides second perspective. The phase transition from cosmic string dominated phase to radiation dominated phase is the first transition of this kind and one expects approximate flatness of 3-space at QFT limit since criticality does not allow dimensional parameters. Vanishing 3 curvature is highly plausible at the quantum field theory limit in which space-time sheets are replaced with a slightly curved deformation of M^4 and fields are identified as sums of purely geometrically determined induced fields at various space-time sheets. This requires very fast expansion and at the limit of vanishing cosmological constant -infinitely large space-time sheets - one theory allows vacuum extremals representing very fast expansion

5. Why the constancy of the cosmic temperature? The cosmic string phase would have been *quantum coherent* in long scales or at least scales corresponding to the recent horizon size. The general prediction of quantum coherence even in astrophysical scales in the recent Universe and this revolutionizes the vision about astrophysics. The network formed by cosmic strings/flux tubes is like a nervous system and long range correlations between astrophysics of distant objects are predicted. The "Axis-of-Evil" - one of the problems of inflation - is an excellent example of this. Flux tubes replace wormholes in ER-EPR correspondence and make possible long range quantum entanglement.

6. Solution of the initial singularity problem. The energy density in cosmic string dominated phase behaved like $1/a^2$ (a the proper time coordinate of M^4 light-cone). Energy per comoving volume went to zero. No initial singularity: silent whisper amplified to relatively big bang.

7. Solution of the monopole problem. Cosmic strings can carry monopole flux but there are no magnetic charges. This is due to geometry of CP_2 - Kähler form is monopole field in homological sense.

8. Magnetic field problem: how there can be magnetic fields in all scales in the recent cosmology?- currents creating them are not possible in early cosmology. Monopole magnetic fields require no currents to create them. Monopole flux tubes are in central role in the model for the formation of galaxies, stars, even planets, even magnetic fields of Sun and Earth. Even in biology, and down to elementary particles physics. String like objects are accompanied by genuine fermionic strings associated with singularities of minimal surfaces seem to populate the entire physics in sharp contrast to superstrings.

Chapter 4

More about TGD and Cosmology

4.1 Introduction

This chapter can be regarded as second part of the previous chapter [K94] and is develoted to various applications and problems of cosmology. Much of the text is written decade or two ago.

1. The anomalies of CMB are discussed as a natural continuation of discussion of the counterpart of inflationary cosmology in TGD framework.

2. Simulating Big Bang in laboratory is the title of the next section. The motivation comes from the observation that critical cosmology could serve as a universal model for phase transitions.

Some problems of existing cosmology are considered in TGD framework. Discussion includes certain problems of the cosmology such as the questions why some stars seem to be older than the Universe, the claimed time dependence of the fine structure constant, the generation of matter antimatter asymmetry, the problem of the fermion families, and the redshift anomaly of quasars. A mechanism for accelerated expansion of Universe is also considered. In the recent framework this reduces to the critical cosmology and cosmological constant can be assigned to the effective space-time defining GRT limit of TGD.

There is a section about matter-antimatter asymmetry, baryogenesis, leptogenesis and TGD discussing whether right-handed neutrino suggested to generate SUSY in TGD framework could be the key entity in fermiogenesis.

The remaining sections are devoted to Hogan's theory abot quantum fluctuations as new kind of noise and the question whether hyperbolic 3-manifolds emerging naturally in Zero Energy Ontology might be useful in TGD inspired cosmology and explain some redshift anomalies.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L7].

4.2 About The Anomalies Of The Cosmic Microwave Background

Depending on one's attitudes, the anomalies of the fluctuation spectrum of the cosmic microwave background (CMB) can be seen as a challenge for people analyzing the experiments or that of the inflationary scenario. I do not pretend to be deeply involved with CMB. What interests me is whether the replacement of inflation with quantum criticality and $\hbar$ changing phase transitions could provide fresh insights about fluctuations and the anomalies of CMB. In the following I try first to explain to myself what the anomalies are and after that I will consider some TGD inspired crazy (as always) ideas. My motivations for commuting these ideas are indeed strong: the consideration of the anomalies led to a generalization of the notion of conformal QFT to what might be called symplectic QFT having very natural place also in quantum TGD proper.

4.2.1 Background

Consider first some background.

1. The fluctuations of CMB reflect directly the fluctuations of energy density (acoustic waves) responsible for the formation of various structures: this follows from the proportionality $\rho \propto T^4$: one has $\Delta T/T \propto \Delta\rho/\rho \propto \Phi$, Φ is gravitational potential created by the density fluctuations. The spectrum reflects the situation as thermal photons decoupled from matter and the matter became transparent to photons. The radiation comes from the sphere of last scattering S^2, which corresponds to the setting on of transparency and only Thomson scattering can affect the radiation after that time. For short angular distances the 2-point correlation functions at S^2 for the fluctuations are suppressed: this is due to a rapid increase of photon free path during the transition making possible exponential damping of the fluctuations of energy density for angular separation $\theta < 1$ degree at which the amplitude is maximum. Quite generally, at the maxima of correlation function the photons almost decouple from the acoustic fluctuations.

2. The analysis of fluctuation spectrum of CMB in general relativistic context requires a solution of Einstein's equations for small perturbations of Robertson Walker metric in presence of matter. It is convenient to decompose the perturbation of the metric Robertson-Walker coordinates using representations of rotation group [E35]. The perturbation of g_{tt} is scalar, the perturbation of g_{ti} decomposes to a gradient of a scalar and rotor of a vector, and the perturbation of g_{ij} corresponds to a scaling of the 3-metric represented by a scalar, double gradient of scalar, and genuinely tensorial part corresponding to classical gravitational radiation. From the four scalar modes two can be eliminated as mere coordinate changes without actual physical content. It is believed that only the scalar perturbations and tensor perturbation are significant. For the WMAP data only scalar perturbations matter.

3. Scalar fluctuations can be divided to two classes. For adiabatic fluctuations the fluctuation of the energy density for a given particle species is proportional to the energy density associated with the species with a common constant of proportionality. When curvature scalar vanishes these fluctuations do not affect the curvature scalar. Inflationary scenario predicts adiabaticity. For iso-curvature fluctuations the sum of the fluctuations associated with different particles vanishes: cosmic strings predict this kind of spectrum. The detailed spectrum of the peaks for 2-point correlation functions is consistent with adiabaticity and excludes cosmic strings in sense of GUTs.

4. The predictions of the inflationary scenario follow from the assumption that fluctuations correspond to primordial quantum fluctuations of inflaton field which expanded with an exponential rate to macroscopic fluctuations during the inflationary period. The spectrum of perturbations is assumed to be Gaussian and to obey approximate scale invariance [E5]. Gaussianity holds true in 3-D momentum space and states that correlation function for the fluctuations of the energy density is proportional to 3-D delta function in momentum space. In other words, the Fourier components of the density perturbation are statistically independent. The coefficient of delta function can depend on the magnitude of 3-momentum. For exact scale invariance it would be constant. This invariance is however broken and the multiplying function is a power k^{1-n_s} of the length of the wave vector, where n_s is so called spectral index. Spectral index has been deduced from WMAP data been measured and differs slightly from unity: $n_s = .960 \pm .0014$. Gaussian distribution contains as a free parameter the scale r of the perturbations and the observed amplitude $r = \Delta T/T \simeq 10^{-5}$ of fluctuations would reflect primordial initial conditions in energy scale about 10^{-3} times Planck mass, which has interpretation as gauge unification scale in GUTs. I am not sure whether the theories can really predict the value of r.

4.2.2 Anomalies Of CMB

There are several anomalies associated with CMB corresponding to the power spectrum of fluctuations and 2-point correlation function as a function of the angle difference θ between points of the sphere of last scattering. There is also some evidence for the failure of Gaussianity reflecting itself as a non-vanishing of 3-point correlation functions.

Consider first fluctuation spectrum, or formally 1-point correlation functions for what is essentially gravitational potential due to fluctuations in Newtonian gauge.

1. There is dipole term in the spectrum identifiable in terms of motion of the galaxy cluster containing Milky Way relative to the reference frame of the CMB. The cluster appears to be moving with velocity 627 ± 22 km/s in the direction of galactic longitude $(l = 264.4, b = 48.4)$ degrees [E6].

2. Hemispherical power asymmetry [E124] means that the amplitude of the fluctuations is not same at the opposite sides of the galactic plane (rather near to ecliptic plane): the difference in the amplitude is about 10 per cent. This does not mean that the mean value of temperature would differ at the opposite sides. The anomaly can be parameterized by a deviation of the amplitude from constant by an additive dipole term of amplitude.114 and in the direction (l, b)= (225, -27) degrees in galactic coordinates. Freeman suggest that the asymmetry can be eliminated for $l \leq 8$ by a slight modification of the CMB dipole [E128]. In the average sense this might hold true since dipole term has odd parity. The temperature fluctuations are also stronger in southern than northern galactic hemisphere and there is a peculiar cold spot at southern hemisphere. Dipole term cannot eliminate this kind of anomalies. One might hope that the elimination of the galactic foreground - when done properly - might eliminate this asymmetry. The subtraction of the contribution from the galactic plane affects in the first approximation only the even harmonics: this would affect the interference pattern between even and odd harmonics.

3. There is also an anomaly christened as axis of evil.

   (a) One can assign to the l: th contribution a unique axis maximizing angular momentum dispersion and these directions turn out to be very near to each other for $l = 2$ and $l = 3$ contributions [E90]. De Oliveiro Costa *et al* noticed that this anomaly could be understood if the Universe has a compact direction in this direction of size of order horizon radius. This explanation is ruled out by other tests, including the absence of matched circles. The modification of the contribution from galactic plane would affect the direction assignable to $l = 2$ harmonic but would not affect considerably $l = 3$ contribution. Hence this effect might be due a wrong subtraction.

   (b) The contribution from the harmonics with angular momentum l can be characterized in terms of l unit vectors: what one does is essentially expression of the contribution as a product of the direction cosines between radial unit vector and l unit vectors [E119]. $l = 2$ harmonics defined two vectors of this kind and their cross product defines what is called an area vector. For $l = 3$ there are three vectors of this kind and one can define three area vectors. It turns out that the planes defined by $l = 2$ area vector and two $l = 3$ area vectors are very near to each other and nearly orthogonal to the plane of ecliptic (and thus also galactic plane). These vectors are in reasonable approximation in galactic plane and aligned with the direction of CMB dipole whereas the direction. The direction of the third $l = 3$ area vector deviates about 10 degrees from the normal of the galactic plane.

   Again the smallness of $l = 2$ contribution raises the question whether the dipole correction and galactic foreground subtraction are done properly. Freeman and collaborators [E128] have proposed that a proper subtraction of CMB dipole might allow to get rid of this anomaly. According to [E120] this is probably not possible. In the case of $l = 3$ harmonics galactic subtraction affecting only even harmonics should not have any appreciable effect. The presence of cold spot near Galactic center and hot spot near Gum Nebula, both in the galactic plane, could also relate to the fact that the area vector is aligned with galactic plane.

Consider next two-point correlation functions.

1. The function $C(\theta)$ is obtained by averaging the fluctuations for all pairs of points at the sphere of last scattering separated by angle θ. $C(\theta)$ with galactic cutoff vanishes for $\theta > 60$ degrees the correlation function vanishes in good approximation [E120]. There is also a strange finding [E133] suggesting a strong correlation between the fluctuation spectrum and 2-point correlation function. Large scale cutoff of $C(\theta)$ in the full-sky maps without galactic cutoff is absent while cut-sky maps with the galactic contribution masked are anomalous. The galactic cut is also almost equivalent with the masking of the cold and hot spot assignable to the galactic plane. Accepting the hot and cold spots in the galactic plane as real would give large scale correlations of 2-point correlation functions and vice versa. Also the subtraction of the anomalous quadrupole and octopole contributions from the 1-point correlation function brings back the large scale power. It is also essential that the multipole vectors of these contributions are nearly parallel. Hence it seems that one can choose between two evils: either the power cutoff at large scales or the axis of evil.

2. For low l harmonics statistical isotropy assumption fails [E120]. This means that the correlation functions $\langle a_{lm}a_{l_1,-m_1}\rangle$ in the expansion of ΔT in terms of spherical harmonics $Y_{l,m}$ taken over temporal ensemble are not of form $C_l\delta_{l,l_1}\delta_{m,m_1}$, where C_l would define coefficients of $C(\theta)$ in terms of $P_l(\theta)$. Quadrupole terms ($l = 2$) are also anomalously small.

There are also other anomalous correlations.

1. Unexpectedly high correlation between temperature and E-mode polarization caused by Thomson scattering of CMB photons can be seen as an evidence for a large optical depth and very early star formation [E108].

2. Gaussianity predicts that three-point correlation functions for density fluctuations vanish. Hence also three-point correlation functions at the sphere of the last scattering should vanish. There is some evidence that this is not the case [E268]: the proposed deviation from Gaussianity is parameterized by writing the perturbation of the gravitational potential in the form $\Phi = \Phi_L + f_{NL}(\Phi_L^2 - \langle\Phi_L^2\rangle)$.

4.2.3 What TGD Could Say About The Anomalies?

TGD cosmology involves several new elements. Super-conformal invariance generalizes in TGD framework and one can wonder whether the fluctuations at the sphere of the last scattering could be described in terms of conformal field theory. It turns out that symplectic QFT based on the analogs of fusion rules is more natural in TGD framework. There are p-adic and dark matter hierarchies realized in terms of book like structure of embedding space with levels labeled by Planck constant with gravitational Planck constant assignable to flux tubes mediating gravitational interactions and having gigantic values so that quantum coherence in cosmological scales is possible. Zero energy ontology implies that time like entanglement in cosmic time scales assignable to gravitational interaction is possible so that the notion of state function reduction in astrophysical and cosmic time scales might make sense. Hence one could (just for fun) wonder whether the strange correlations between local galactic and solar geometry and density fluctuations at surface of large scattering might be real after all.

Implications of p-adic and dark matter hierarchies

Consider next the possible implications of p-adic and dark matter hierarchies.

1. In TGD framework there are two hierarchies: hierarchy of p-adic space-time sheets and hierarchy of Planck constants. p-Adic length scales are defined as $L_p \propto \sqrt{p}$, where $p \simeq 2^k$ is prime and k is positive integer. $L(151)$ corresponds in good approximation to 10 nm, cell membrane thickness. The hierarchy of Planck constants reflect the book like structure of the generalized embedding space consisting of almost copies of $M^4 \times CP_2$ glued together like pages of book along common back. The proposed structure of embedding space can be understood as a geometric correlate for the choice of quantization axes at the embedding space level inducing it also at the level of configuration space (world of classical worlds). There are preferred quantization axes associated with both M^4 and CP_2 degrees of freedom. In the

case of M^4 this means preferred plane M^2 defining a quantization axis of spin and in the case of CP_2 preferred homologically non-trivial geodesic sphere defining quantization axis of color isospin. This means breaking of symmetries at particular sector of the embedding space but since the "world of classical worlds" (WCW) is union over different choices of quantization axes, symmetries remain intact as a whole. It would seem that quantum measurement with new quantization axis means a tunnelling from between this kind of sectors.

2. It is important to notice that in TGD Universe the fluctuations emerge during the quantum criticality at the time of decoupling rather than developing from primordial fluctuations as in the case of inflationary cosmology. This kind of periods would be quite general since the smooth cosmic expansion is in TGD Universe replaced by a sequence of quantum leaps during which Planck constant for some relevant space-time sheet increases and implies the increase of the size L of the appropriate space-time sheet scaling like $\hbar$. The same mechanism explains also the accelerated cosmic expansion taking place much later during cosmic expansion and probably corresponding to expansion for large voids of size of order 10^8 ly.

3. In TGD Universe the vanishing of the curvature scalar of 3-space (flatness) corresponds to quantum criticality associated with phase transitions changing the value of Planck constant. Robertson-Walker form of the metric, criticality constraint, and imbeddability as a vacuum extremal to $M^4 \times S^2 \subset M^4 \times CP_2$ fix the critical cosmology highly uniquely. The critical cosmology has a finite temporal duration due to the failure of the global embedding. During early phases the critical mass density behaves as $1/a^2$ which might be interpreted in terms of dominance of string like objects, which in TGD framework are identified as long magnetic flux tubes.

Can one say anything more quantitative about the situation? In particular, can one predict the scale (variance) of $\Delta T/T$?

1. There are two dimensionless numbers available: the value of the integer k characterizing p-adic length scale $L_p \propto 2^{k/2}$ characterizing the surface of the last scattering and the ratio $\hbar/\hbar_0$ of Planck constants associated with dark and visible sectors of WCW .

2. The value of the integer k characterizing p-adic length scale at the time of the transition can be estimated from the radius for the sphere of last scattering identified as radius $R = a(t)$. The transition to matter dominated Universe began in about 400, 000 years old universe. Coupling took about 120, 000 years and was finished at the age of 500, 000 years. From this one can estimate the p-adic length scale in question as light-cone proper time $a(t)/a_0 = (t/t_0)^{2/3}$ in matter dominated cosmology identifiable as curvature radius R in GRT based RW cosmology. My own estimate $a = 3 \times 10^7$ ly in [K94] gives $k \sim 355$.

3. Identifying $\Delta\rho_i$ for a given particle as the energy density $\rho_{i,d}$ of dark variant of the particle implies adiabaticity if one has $\rho_{i,d}/\rho_i = constant$. This is achieved by assuming that the energy densities scale like ρ_{tot}, that is one has $\rho_{d,i} = (\hbar/\hbar_0)^{-n}\rho_i \propto (\hbar/\hbar_0)^{-n}\ a^{-n}$. $n = 2$ is suggested by the early critical cosmology discussed [K94]. This would give $\Delta\rho_i/\rho_i = (\hbar_0/\hbar)^2$. From $\Delta T/T \simeq 10^{-5}$ one would have $r = \hbar/\hbar_0 \sim 300$. The estimate for r is not too far from $k \sim 355$, which might mean that $r = k$ holds true implying that the r would increase logarithmically with the p-adic length scale of the space-time sheet.

Consider next the anomalies from phenomenological point of view.

1. One cannot exclude the possibility that the vanishing of the two-point correlation functions for $\theta > 60$ degrees reflects the finite size of the space-time sheets. In conformal field theory approach this would mean that conformal field theory applies only inside patches at the sphere of last scattering. Suppose that the size of space-time sheets is typically of order p-adic length scale $L_p \propto \sqrt{p}$, where $p \simeq 2^k$ is prime and k is positive integer. For the surface of last scattering $L_p \equiv L(k)$ could be identified as the radius of the sphere and can be estimated from the value of light-cone proper time a at that time.

   The first guess is that only the points of the sphere for which distance is shorter than $L(k)$ can correlate. Simple elementary geometry shows that this is the case only for $\theta < 60$ degrees!

The reduction of the vanishing correlation to almost kinematics must of course be taken with a big grain of salt: if the diameter of the sphere is taken to be L_p, one would have $\theta < 180$ degrees.

The killer prediction is that the non-averaged correlation function for two fixed points of sphere obtained by averaging the fluctuations over ensemble of observations should vanish for smaller values of angular distances when points belong to different patches so that the boundaries of patches should be identifiable from CMB map.

2. As already noticed, the presence of galactic cold and hot spots and axis of evil seem to be the price to be paid for the presence of large scale power [E133]. The finite size of the space-time sheets forcing the vanishing of 2-point correlation function for large angular separations could thus conform with the non-CMB explanation of galactic cold and hot spots and allow to get rid of axis of evil. The pair of cold and hot spots indeed gives a large negative contribution to $C(\theta)$. The finite size of space-time sheets could also explain the hemispherical asymmetry and why fluctuations are stronger at the southern galactic hemisphere.

3. The particles at different pages of the "Big Book" can tunnel between the pages so that the presence of dark space-time sheets could affect the spectrum of temperature fluctuations. If dark matter is responsible for the fluctuations, the tunnelling of dark photons to visible space-time sheets and vice versa might have something to do with the fluctuations of CMB spectrum. Fractality suggests that dark space-time sheets could induce a modulation of the amplitudes of CMB proposed to explain the hemispherical asymmetries but not why the hemispheres correspond to Nothern and Southern galactic spheres. There would be kind of modulation hierarchy. This might relate to the fluctuations in the amplitude of ΔT, and the related small 10 percent deviation of the fluctuation amplitudes at Northern and Souther hemisphere.

A couple of warnings are in order.

1. The proposed mechanism does not explain the strange correlations of CMB with the local geometry. If one accepts quantum coherence in cosmic length scales predicted by the dark matter hierarchy, the choice of quantization axis in cosmic scale having direct geometric correlate in TGD Universe, could explain the asymmetries as a result of state function reduction in cosmic scale.

2. The decomposition into disjoint space-time sheets is not the only manner to explain the anomalies. It will be found that the approach based on symplectic QFT predicts with very general assumptions about 2-point functions hemispherical asymmetry. Symplectic approach might be also able explain the vanishing of $C(\theta)$ in large scales.

Perturbations of the critical cosmology: the naïve approach

Although the naïve formal application of perturbation theory around critical cosmology does not make sense in quantum TGD framework, one can start by looking what it would give at classical level.

1. Concerning the perturbations of the critical cosmology, a natural condition would be that only vacuum extremals of Kähler action are allowed. This means that only perturbations giving rise to 4-surfaces belonging to $M^4 \times Y^2 \subset M^4 \times CP_2$, Y^2 Lagrangian sub-manifold of CP_2, are allowed. If all small deformations of the critical cosmology are allowed, curvature scalar cannot vanish in general. In this framework the notion of adiabaticity involving statements about various particles does not have any obvious meaning whereas the notion of iso-curvature fluctuations can be formulated. The vanishing of the curvature scalar makes sense for the perturbations of RW metric representing vacuum extremals but would break the symplectic symmetry in CP_2 degrees of freedom. Note also that many-sheeted space-time and the generalization of embedding space induced by hierarchy of Planck constants are quite essential piece of TGD vision and are not taken into account in this naïve approach.

2. One can express the perturbations of the metric in terms of gradients of CP_2 coordinates and since for the unperturbed RW metric CP_2 coordinates depend on light-cone proper time only, the perturbations are gradients of CP_2 coordinates with respect to spatial coordinates so that a reduction to scalar perturbations modifying only g_{aa} and vector perturbations implying non-vanishing g_{ai} indeed takes place in the first order. Since g_{ij} remains invariant in the first order, also 3-space remains flat in this order. In second order also other modes become possible.

3. The absence of other than scalar modes in the first order means that classical gravitons are absent in this order. Does this mean that also quantal gravitons are absent in the first order so that the B mode polarization would be smaller than expected? Probably not: the basic reason for developing the vision about physics as the geometry of WCW was the total failure of the perturbative path integral approach theory in TGD framework. Previous considerations also force to ask whether the phase transitions of dark gravitons to ordinary gravitons could be an an essential element of detection of gravitons and mean that dark graviton with very large energy as compared to the wavelength transforms to a bunch of ordinary gravitons. This might lead to the erratic elimination of the graviton signal as a noise. One can also consider the possibility that dark gravitons with very long wave lengths transform to ordinary gravitons with much shorter wavelengths.

Could super-conformal field theory at sphere of last scattering describe the fluctuations?

I have already earlier [K94] proposed that CMB spectrum might be understood in terms of conformal field theory. If some variant of conformal field theory works, the general prediction is the breaking of conformal invariance meaning the appearance of the counterpart of the spectral index from the breaking of conformal symmetry by the generation of central extension to super-conformal algebra. In this framework $1 - n_s$ corresponds to an anomalous dimension having a discrete spectrum in conformal theories and known once the representation of Super Virasoro algebra is known. It would not be surprising if n_s would depend on the value of $\hbar$, which defines a quantum phase q playing also a key role in conformal field theories. Second important prediction would be that 3-point correlation functions are predictable and non-vanishing unless the conformal field theory in question is not free. This would allow the possibility of non-Gaussian behavior.

It however seems that CQFT need not be quite correct idea. Rather, a symplectic variant of conformal field theory is natural in TGD framework and could be used to characterize the ground state in terms of n-points functions. The basic objection against the use of conformal field theory is that it should apply to the construction of physical states pairs of positive and negative energy states and considering thus non-vacuum fluctuations of space-time surfaces around vacuum extremals. Now one is considering vacuum states with respect to Noether charges expressed as functionals in the space of vacuum extremals. Since symplectic transformations are symmetries of the vacuum extremals, a symplectic analogy of conformal field theory might be a more appropriate approach. In the following this argument is made more precise.

1. One must consider small perturbations of the critical cosmology which are also vacuum extremals. This means that the perturbations correspond to surface $X^4 \subset M^4 \times Y^2$, where Y^2 corresponds to Lagrangian sub-manifold of CP_2 having vanishing induced Kähler form. If one poses no other conditions the vacuum extremals possess symplectic transformations of CP_2 leaving given Y^2 invariant as symmetries. These transformations relate closely to so called super-symplectic symmetries which are basic super-conformal symmetries of quantum TGD besides Kac-Moody type symmetries assignable to light-like 3-surfaces identified as basic dynamical objects. Also symplectic (or rather contact-) transformations of $r_M = constant$ sphere of light-cone boundary act as this kind of symmetries which raises the question whether the analog of conformal field theory based having the symplectic group of light-cone boundary as symmetries might be a proper manner to characterize the vacuum degeneracy in quantum TGD.

2. Could conformal field theory possessing these symmetries defined at the sphere of last scattering (S^2) or - as suggested by basic structure of quantum TGD - at the boundary of 3-D

light-cone connecting S^2 to the observer's position - describe the quantum criticality? The hope raised by the fact that critical cosmology is fixed the by the criticality condition without any reference to matter is that the correlation functions could be deduced from universality without any reference to elementary particle physics.

(a) The naïve guess would be that the deviations of CP_2 complex coordinates ξ^k from their values at S^2 should be taken as primary dynamical variables. Unfortunately, the assumption that ξ^k are holomorphic functions of the complex coordinate of the sphere of last scattering would not be consistent with the vacuum extremal property. The use of CP_2 coordinates as dynamical variables is not consistent with general coordinate invariance unless one chooses some special coordinates. This is possible since selection of preferred quantization axis selects preferred complex coordinates unique modulo $U(2) \subset SU(3)$ rotations represented linearly. The simplest manner to achieve general coordinate invariance is by using the gravitational potential defined as the perturbation $\Delta g_{aa} = \Delta(s_{k\bar{l}}\partial_a\xi^k\partial_a\overline{\xi}^l)$. All perturbations of R-W metric can be arranged to the representation of rotation group corresponding to two scalars, vector, and traceless tensor. Unfortunately, the deviations of metric do not however define conformal fields in S^2. They could however define symplectic fields. It seems that conformal field theory approach requires the expression of Δg_{aa} in terms of primary conformal fields, say various currents, and this looks too complicated.

(b) The radial light-like coordinate r_M for the light-cone boundary plays a role analogous to that of complex coordinate for Kac-Moody representations at like 3-surfaces and for super-symplectic representations at light-cone boundary. In this case all vacuum extremals are allowed and the symplectic transformations of $S^2 \times CP_2$ localized with respect to r_M would act as analogos of conformal symmetries. In quantum TGD proper this could quite well make sense but in the recent situation only a QFT at S^2 is needed and light-like conformal invariance does not seem to say anything about the behavior of the correlation functions of temperature fluctuations at S^2.

Could a symplectic analog of conformal field theory work?

Symplectic symmetries of $\delta M^4_+ \times CP_2$ (light-cone boundary briefly) inspire the question whether a symplectic analog of conformal field theory at S^2 could dictate the correlation functions. Therefore it makes sense to play with the idea what symplectic QFT could look like and what one could conclude about the predictions of "symplectic QFT" in the recent situation.

1. In quantum TGD the symplectic transformation of the light-cone boundary would induce action in the "world of classical worlds" (light-like 3-surfaces). In the recent situation it is convenient to regard perturbations of CP_2 coordinates as fields at the sphere of last scattering (call it S^2) so that symplectic transformations of CP_2 would act in the field space whereas those of S^2 would act in the coordinate space just like conformal transformations. The deformation of the metric would be a symplectic field in S^2. The symplectic dimension would be induced by the tensor properties of R-W metric in R-W coordinates: every S^2 coordinate index would correspond to one unit of symplectic dimension. The symplectic invariance in CP_2 degrees of freedom is guaranteed if the integration measure over the vacuum deformations is symplectic invariant. This symmetry does not play any role in the sequel.

2. For a symplectic scalar field $n \geq 3$-point functions with a vanishing anomalous dimension would be functions of the symplectic invariants defined by the areas of geodesic polygons defined by subsets of the arguments as points of S^2. Since n-polygon can be constructed from 3-polygons these invariants can be expressed as sums of the areas of 3-polygons expressible in terms of symplectic form. n-point functions would be constant if arguments are along geodesic circle since the areas of all sub-polygons would vanish in this case. The decomposition of n-polygon to 3-polygons brings in mind the decomposition of the n-point function of conformal field theory to products of 2-point functions by using the fusion algebra of conformal fields (very symbolically $\Phi_k\Phi_l = c^m_{kl}\Phi_m$). This intuition seems to be correct.

3. Fusion rules stating the associativity of the products of fields at different points should generalize. In the recent case it is natural to assume a non-local form of fusion rules given in the case of symplectic scalars by the equation

$$\Phi_k(s_1)\Phi_l(s_2) = \int c_{kl}^m f(A(s_1,s_2,s_3))\Phi_m(s)d\mu_s \ . \tag{4.2.1}$$

Here the coefficients c_{kl}^m are constants and $A(s_1,s_2,s_3)$ is the area of the geodesic triangle of S^2 defined by the sympletic measure and integration is over S^2 with symplectically invariant measure $d\mu_s$ defined by symplectic form of S^2. Fusion rules pose powerful conditions on n-point functions and one can hope that the coefficients are fixed completely.

4. The application of fusion rules gives at the last step an expectation value of 1-point function of the product of the fields involves unit operator term $\int c_{kl} f(A(s_1,s_2,s))Idd\mu_s$ so that one has

$$\langle\Phi_k(s_1)\Phi_l(s_2)\rangle = \int c_{kl} f(A(s_1,s_2,s))d\mu_s \ . \tag{4.2.2}$$

Hence 2-point function is average of a 3-point function over the third argument. The absence of non-trivial symplectic invariants for 1-point function means that $n=1$- an are constant, most naturally vanishing, unless some kind of spontaneous symmetry breaking occurs. Since the function $f(A(s_1,s_2,s_3))$ is arbitrary, 2-point correlation function can have both signs. 2-point correlation function is invariant under rotations and reflections.

CMB data suggest breaking of rotational and reflection symmetries. A possible mechanism of spontaneous symmetry breaking is based on the observation that in TGD framework the hierarchy of Planck constants assigns to each sector of the generalized embedding space a preferred quantization axes. The selection of the quantization axis is coded also to the geometry of "world of classical worlds", and to the quantum fluctuations of the metric in particular. Clearly, symplectic QFT with spontaneous symmetry breaking would provide the sought-for really deep reason for the quantization of Planck constant in the proposed manner.

1. The coding of angular momentum quantization axis to the generalized embedding space geometry allows to select South and North poles as preferred points of S^2. To the three arguments s_1,s_2,s_3 of the 3-point function one can assign two squares with the added point being either North or South pole. The difference

$$\Delta A(s_1,s_2,s_3) \equiv A(s_1,s_2,s_3,N) - A(s_1,s_2,s_3,S) \tag{4.2.3}$$

of the corresponding areas defines a simple symplectic invariant breaking the reflection symmetry with respect to the equatorial plane. Note that ΔA vanishes if arguments lie along a geodesic line or if any two arguments co-incide. Quite generally, symplectic QFT differs from conformal QFT in that correlation functions do not possess singularities.

2. The reduction to 2-point correlation function gives a consistency conditions on the 3-point functions

$$\langle(\Phi_k(s_1)\Phi_l(s_2))\Phi_m(s_3)\rangle = c_{kl}^r \int f(\Delta A(s_1,s_2,s))\langle\Phi_r(s)\Phi_m(s_3)\rangle d\mu_s$$

$$= \tag{4.2.4}$$

$$c_{kl}^r c_{rm} \int f(\Delta A(s_1,s_2,s))f(\Delta A(s,s_3,t))d\mu_s d\mu_t \ . \tag{4.2.5}$$

Associativity requires that this expression equals to $\langle\Phi_k(s_1)(\Phi_l(s_2)\Phi_m(s_3))\rangle$ and this gives additional conditions. Associativity conditions apply to $f(\Delta A)$ and could fix it highly uniquely.

3. 2-point correlation function would be given by

$$\langle\Phi_k(s_1)\Phi_l(s_2)\rangle = c_{kl}\int f(\Delta A(s_1,s_2,s))d\mu_s \quad (4.2.6)$$

4. There is a clear difference between $n>3$ and $n=3$ cases: for $n>3$ also non-convex polygons are possible: this means that the interior angle associated with some vertices of the polygon is larger than π. $n=4$ theory is certainly well-defined, but one can argue that so are also $n>4$ theories and skeptic would argue that this leads to an inflation of theories. TGD however allows only finite number of preferred points and fusion rules could eliminate the hierarchy of theories.

5. To sum up, the general predictions are following. Quite generally, for $f(0)=0$ n-point correlation functions vanish if any two arguments co-incide which conforms with the spectrum of temperature fluctuations. It also implies that symplectic QFT is free of the usual singularities. For symmetry breaking scenario 3-point functions and thus also 2-point functions vanish also if s_1 and s_2 are at equator. All these are testable predictions using ensemble of CMB spectra.

Since number theoretic braids are the basic objects of quantum TGD, one can hope that the n-point functions assignable to them could code the properties of ground states and that one could separate from n-point functions the parts which correspond to the symplectic degrees of freedom acting as symmetries of vacuum extremals and isometries of WCW

1. This approach indeed seems to generalize also to quantum TGD proper and the n-point functions associated with partonic 2-surfaces can be decomposed in such a way that one obtains coefficients which are symplectic invariants associated with both S^2 and CP_2 Kähler form.

2. Fusion rules imply that the gauge fluxes of respective Kähler forms over geodesic triangles associated with the S^2 and CP_2 projections of the arguments of 3-point function serve basic building blocks of the correlation functions. The North and South poles of S^2 and three poles of CP_2 can be used to construct symmetry breaking n-point functions as symplectic invariants. Non-trivial 1-point functions vanish also now.

3. The important implication is that n-point functions vanish when some of the arguments co-incide. This might play a crucial role in taming of the singularities: the basic general prediction of TGD is that standard singularities should be absent and this mechanism might realize this expectation.

Next some more technical but elementary first guesses about what might be involved.

1. It is natural to introduce the moduli space for n-tuples of points of the symplectic manifold as the space of symplectic equivalence classes of n-tuples. In the case of sphere S^2 convex n-polygon allows $n+1$ 3-sub-polygons and the areas of these provide symplectically invariant coordinates for the moduli space of symplectic equivalence classes of n-polygons (2^n-D space of polygons is reduced to $n+1$-D space). For non-convex polygons the number of 3-sub-polygons is reduced so that they seem to correspond to lower-dimensional sub-space. In the case of CP_2 n-polygon allows besides the areas of 3-polygons also 4-volumes of 5-polygons as fundamental symplectic invariants. The number of independent 5-polygons for n-polygon can be obtained by using induction: once the numbers $N(k,n)$ of independent $k\leq n$-simplices are known for n-simplex, the numbers of $k\leq n+1$-simplices for $n+1$-polygon are obtained by adding one vertex so that by little visual gymnastics the numbers $N(k,n+1)$ are given by $N(k,n+1)=N(k-1,n)+N(k,n)$. In the case of CP_2 the allowance

of 3 analogs $\{N, S, T\}$ of North and South poles of S^2 means that besides the areas of polygons (s_1, s_2, s_3), (s_1, s_2, s_3, X), (s_1, s_2, s_3, X, Y), and (s_1, s_2, s_3, N, S, T) also the 4-volumes of 5-polygons (s_1, s_2, s_3, X, Y), and of 6-polygon (s_1, s_2, s_3, N, S, T), $X, Y \in \{N, S, T\}$ can appear as additional arguments in the definition of 3-point function.

2. What one really means with symplectic tensor is not clear since the naïve first guess for the n-point function of tensor fields is not manifestly general coordinate invariant. For instance, in the model of CMB, the components of the metric deformation involving S^2 indices would be symplectic tensors. Tensorial n-point functions could be reduced to those for scalars obtained as inner products of tensors with Killing vector fields of $SO(3)$ at S^2. Again a preferred choice of quantization axis would be introduced and special points would correspond to the singularities of the Killing vector fields.

   The decomposition of Hamiltonians of WCW expressible in terms of Hamiltonians of $S^2 \times CP_2$ to irreps of $SO(3)$ and $SU(3)$ could define the notion of symplectic tensor as the analog of spherical harmonic at the level of WCW . Spin and gluon color would have natural interpretation as symplectic spin and color. The infinitesimal action of various Hamiltonians on n-point functions defined by Hamiltonians and their super counterparts is well-defined and group theoretical arguments allow to deduce general form of n-point functions in terms of symplectic invariants.

3. The need to unify p-adic and real physics by requiring them to be completions of rational physics, and the notion of finite measurement resolution suggest that discretization of also fusion algebra is necessary. The set of points appearing as arguments of n-point functions could be finite in a given resolution so that the p-adically troublesome integrals in the formulas for the fusion rules would be replaced with sums. Perhaps rational/algebraic variants of $S^2 \times CP_2 = SO(3)/SO(2) \times SU(3)/U(2)$ obtained by replacing these groups with their rational/algebraic variants are involved. Tedrahedra, octahedra, and dodecahedra suggest themselves as simplest candidates for these discretized spaces. Also the symplectic moduli space would be discretized to contain only n-tuples for which the symplectic invariants are numbers in the allowed algebraic extension of rationals. This would provide an abstract looking but actually very concrete operational approach to the discretization involving only areas of n-tuples as internal coordinates of symplectic equivalence classes of n-tuples. The best that one could achieve would be a formulation involving nothing below measurement resolution.

4. This picture based on elementary geometry might make sense also in the case of conformal symmetries. The angles associated with the vertices of the S^2 projection of n-polygon could define conformal invariants appearing in n-point functions and the algebraization of the corresponding phases would be an operational manner to introduce the space-time correlates for the roots of unity introduced at quantum level. In CP_2 degrees of freedom the projections of n-tuples to the homologically trivial geodesic sphere S^2 associated with the particular sector of CH would allow to define similar conformal invariants. This framework gives dimensionless areas (unit sphere is considered). p-Adic length scale hypothesis and hierarchy of Planck constants would bring in the fundamental units of length and time in terms of CP_2 length.

These findings raise the hope that quantum TGD is indeed a solvable theory. Even it one is not willing to swallow any bit of TGD, the classification of the symplectic QFTs remains a fascinating mathematical challenge in itself. A further challenge is the fusion of conformal QFT and symplectic QFT in the construction of n-point functions. One might hope that conformal and symplectic fusion rules can be treated separately.

What symplectic QFT tells about fluctuations?

It is interesting to look what one can say about the CMB assuming symplectic QFT using the proposed poor man's formulation.

The general predictions are that all n-point functions are non-vanishing so that Gaussianity fails to be true. In the symmetric scenario there is no breaking of rotational and reflection symmetries. In symmetric breaking scenario both breakings are present.

Consider first 2-point correlation functions.

1. The averaged 2-point correlation function $C(\theta)$ is obtained as

$$C(\theta) = \langle \Phi(s_1)\Phi(s_2)\rangle = \sum_n f_n \langle \int [\Delta A(s_1,s_2,s)]^n d\mu_s\rangle \ ,$$
$$\Delta A(s_1,s_2,s) = A(s_1,s_2,s,N) - A(s_1,s_2,s,P) \ . \quad (4.2.7)$$

2. If $f(\Delta A)$ is odd function of $\Delta A = A(s_1,s_2,s_3,N) - A(s_1,s_2,s_3,P)$, the first order term of the 3-point function changes sign under reflection of the first two arguments with respect to the equatorial plane and same holds true for all odd powers of ΔA as a simple argument shows. Same holds true for the 2-point correlation function so that its average over all points with same angular distance vanishes giving $C(\theta) = 0$. $C(\theta)$ is completely determined by the even part of f and one can write the averaged correlation function as

$$C(\theta) = \sum_n f_{2n} \langle \int [\Delta A(s_1,s_2,s)]^{2n} d\mu_s\rangle \ . \quad (4.2.8)$$

   Thus the rotational averages of the numerically calculable even "moments" $\int [\Delta A(s_1,s_2,s)]^{2n} d\mu_s$ determine $C(\theta)$.

3. Since $C(\theta)$ has also negative values, some of the coefficients f_{2n} must be negative. The variation of the signs of the coefficients is also necessary to explain the presence of positive maxima and negative minima in $C(\theta)$.

4. An open question is whether the smallness of $C(\theta)$ for angle separation larger than 60 degrees could be understood from symplectic invariance alone.

3-point correlation functions are certainly non-trivial and this means means a non-Gaussian behavior. Non-vanishing 2-point functions are averages of the 3-point functions involving identity operator with respect to third argument multiplied by 4π. Hence the non-Gaussian behavior is significant effect. For 3-point functions not involving identity operator the coefficients c_{klm} could be smaller.

Consider next the fluctuations.

1. It would be nice if temperature fluctuations could be interpreted as 1-point functions rather than particular fluctuations. This is not the case since the only reasonable candidate would be obtained in terms of the area of the degenerate geodesic triangle spanned by s and poles. This means that one must interpret the data as fluctuations rather than averages of fluctuations unless one is ready to break the symmetry by shifting slightly the second preferred point, say South Pole.

2. The intuitive notions about distribution for the fluctuations and amplitude of fluctuations are not readily expressible in terms of n-point correlation functions since the moments $\langle \Phi(s)^k\rangle$ vanish identically. One can however perform smoothing out of these quantities and replace the quantity $\langle \Phi(s)^k\rangle$ with $\int \langle \prod_i \Phi(s_i)\rangle \prod_k d\mu_{s_k}/A^n$, where the integrations are over a small disk of area A around point s. This gives a well defined variance and one can speak about fluctuation amplitude in a given resolution defined by A. The moments define in a given resolution what the probability distribution for the fluctuations means.

3. This definition allows to formulate what the evidence for the hemispherical asymmetry for the probability distribution of fluctuations could mean. Hemispherical asymmetry is obtained in the smooth out sense if the two-point correlation functions with arguments differing by a reflection with respect to equatorial plane are not identical: that is if $f(\Delta A)$ contains both even and odd coefficients f_n. The reason is that the sign of ΔA changes in the reflection. This could be tested by considering the counterpart of $C(\theta)$ defined by taking only average with respect to point pairs in upper/lower hemisphere and comparing the results.

To sum ump, the breaking of the rotational symmetry and parity breaking via a selection of a preferred equatorial plane conform with the general properties of the physical correlation functions and it remains to be seen whether fusion rules force f to have both odd and even parts necessary in obtain to obtain the breaking of reflection symmetry. The challenge is to understand whether the correlation between cosmic and local geometries (equatorial plane of S^2 and galactic plane) is a pure accident or whether there is something much deeper involved.

Could cosmic quantum coherence explain the correlation of the quantum fluctuations at surface of last scattering with galactic geometry?

The idea about hierarchy of Planck constants was inspired by the finding that the orbits of inner and outer planets could be regarded in a reasonable approximation as Bohr orbits but with Planck constant which was gigantic and was for outer planets smaller than for the 4 inner planets by a factor of 1/5 [K93]. For Jupiter with $v_0/5$ principal quantum number would be $n_P = 2$ and Mars could be thought to have $n_P = 1$ for $v_0/5$. The gigantic value of the Planck constant at the flux tubes mediating gravitational interactions implies quantum coherence in cosmic scales and this could allow a radically new interpretation of CMB anomalies. In particular, it could explain why the preferred equatorial plane of the sphere of last scattering predicted by symplectic QFT with spontaneous symmetry breaking is near to the galactic plane.

1. Gravitational Planck constant associated with the flux tubes mediating gravitational interactions has a gigantic value, which quantum coherence in cosmological scales. This forces to ask whether the measurement of CMB background should be considered as a quantum measurement in cosmic scales and whether its outcome could be analogous to the state function reduction at the level of particle physics as far as dark space-time sheets are considered. If dark matter dictates the behavior of visible matter one must consider the possibility that quantum measurement in dark scales could dramatically affect the geometric past in cosmic scales. On the other hand, the CMB measurements as such are only about distribution of ordinary photons and can only tell which quantum fluctuation pattern has been selected in quantum measurement in dark matter scales.

2. The situation at quantum criticality would correspond to a superposition of quantum fluctuations having in accordance with zero energy ontology time-like entanglement with the "observer". This entanglement correlates the states of observer with the quantum fluctuations. Observer could be a dark matter system assignable to galaxy, say the field body of galactic system with gigantic Plank constant connecting observer with the sphere of last scattering which in turn might be entangled with the solar system. The question is whether the time-like entanglement correlates some geometric properties of the observing system (say various directions like normal of the ecliptic or galactic plane) with the geometric properties of the quantum fluctuation spectrum (say the direction of the quantization axis defining equatorial asymmetry)?

3. Could one imagine that "we" as observers are entangled with the possible states of the galactic gravito-magnetic body in turn entangled gravitationally with the quantum fluctuations at the sphere of last scattering and that the measurement of the state of galactic system telling the direction of galactic plane, etc... selects also the dark quantum fluctuation in the geometric past. If so, the selection of quantization axes for fluctuations would be same for the observer and sphere of last scattering. If the choice is dictated by the observer, the breaking of rotational symmetry and parity symmetry and choice of galactic plane as preferred plane would be induced by quantum measurement. Note that this does not lead to any obvious contradictions since the spheres of last scattering are in principle different for observers at different positions of the Universe. If this interpretation is correct, the strange anomalies of CMB would provide a rather dramatic verification for the Wheeler's idea about participatory Universe.

Axis of Evil as a memory from primordial cosmology?

Axis of Evil is very interesting CMB anomaly (thanks for Sky Darmos for mentioning it in FB discussion). It has been even proposed that it forces Earth-centeredness. According to the Wikipedia article (see http://tinyurl.com/yb6nabw4):

The motion of the solar system, and the orientation of the plane of the ecliptic are aligned with features of the microwave sky, which on conventional thinking are caused by structure at the edge of the observable universe. Specifically, with respect to the ecliptic plane the "top half" of the CMB is slightly cooler than the "bottom half"; furthermore, the quadrupole and octupole axes are only a few degrees apart, and these axes are aligned with the top/bottom divide.

Axis of Evil is indeed really strange looking finding. To my view it does not however bring pre-Keplerian world view back but is related to the possibility of quantum coherence even in cosmological scales predicted by TGD. It would also reflect the situation during very early cosmology, which in TGD framework is cosmic string dominated.

1. The hierarchy of Planck constants $h_{eff} = n \times h_0$ ($h = 6 \times h_0$ is a good guess) implies the existence of space-time sheets with arbitrary large size serving as quantum coherent regions. $h_{eff} = h_{gr}$ assignable to flux tubes mediating gravitational interaction the value of h_{eff} can be gigantic. One has $h_{gr} = GMm/v_0$, where M and m are masses such that M can be solar mass or even larger mass and $v_0 < c$ has dimensions of velocity [L50] [K11].

2. Cosmic strings dominated the very early TGD inspired cosmology. They have 2-D projections to M^4 and CP_2 so that GRT is not able to describe them. During the analog of inflationary period the dimension of M^4 projection became D=4 and cosmic strings became magnetic flux tubes. Ordinary GRT space-time emerged and GRT started to be a reasonable approximation as QFT limit of TGD.

3. Quantum coherence make possible long range correlations. One correlation of this kind could be occurrene of cosmic strings which are *nearly parallel* in even cosmic scales or more precisely nearly parallel at the time when the TGD counterpart of inflation occurred and the ordinary space-time emerged and cosmic strings thickened to magnetic flux tubes - a process directly corresponding to cosmic expansion. This time corresponds in standard cosmology the end of inflationary period.

   The volume that we observe via CMB now would correspond to a rather small volume at the end of the period when ordinary GRT space-time emerged and it is not too difficult to imagine that in this volume the cosmic strings would have formed a bundle nearly parallel cosmic strings. This property would have been preserved in good approximation during expansion. For instance, angular momentum conservation would have taken care of this if the galaxies along long cosmic strings had angular momenta in parallel: there is indeed evidence for this. Turning of cosmic string to a different direction would require a lot of angular momentum since also the galaxies should be turned at the same time.

4. Cosmic strings thicknened to flux tubes would contain galaxies - pearls in necklace is good metaphor. Galaxies would be local tangles of flux tubes with topology of dipole type magnetic field in reasonable approximation. Also stars and planets would have formed in the similar manner. This leads to a rather detailed model for galaxy formation [L63].

4.3 Simulating Big Bang In Laboratory

Ultra-high energy collisions of heavy nuclei at Relativistic Heavy Ion Collider (RHIC) can create so high temperatures that there are hopes of simulating Big Bang in laboratory. The experiment with PHOBOS detector [C8] probed the nature of the strong nuclear force by smashing two Gold atoms together at ultrahigh energies. The analysis of the experimental data has been carried out by Prof. Manly and his collaborators at RHIC in Brookhaven, NY [C9]. The surprise was that the hydrodynamical flow for non-head-on collisions did not possess the expected longitudinal boost invariance.

This finding stimulates in TGD framework the idea that something much deeper might be involved.

1. The quantum criticality of the TGD inspired very early cosmology predicts the flatness of 3-space as do also inflationary cosmologies. The TGD inspired cosmology is "silent whisper

amplified to big bang" since the matter gradually topologically condenses from decaying cosmic string to the space-time sheet representing the cosmology. This suggests that one could model also the evolution of the quark-gluon plasma in an analogous manner. Now the matter condensing to the quark-gluon plasma space-time sheet would flow from other space-time sheets. The evolution of the quark-gluon plasma would very literally look like the very early critical cosmology.

2. What is so remarkable is that critical cosmology is not a small perturbation of the empty cosmology represented by the future light cone. By perturbing this cosmology so that the spherical symmetry is broken, it might possible to understand qualitatively the findings of [C9]. Maybe even the breaking of the spherical symmetry in the collision might be understood as a strong gravitational effect on distances transforming the spherical shape of the plasma ball to a non–spherical shape without affecting the spherical shape of its M^4_+ projection.

3. The model seems to work at qualitative level and predicts strong gravitational effects in elementary particle length scales so that TGD based gravitational physics would differ dramatically from that predicted by the competing theories. Standard cosmology cannot produce these effects without a large breaking of the cherished Lorentz and rotational symmetries forming the basis of elementary particle physics. Thus the PHOBOS experiment gives direct support for the view that Poincare symmetry is symmetry of the embedding space rather than that of the space-time.

4. This picture was completed a couple of years later by the progress made in hadronic mass calculations [K74]. It has already earlier been clear that quarks are responsible only for a small part of the mass of baryons (170 GeV in case of nucleons). The assumption that hadronic $k = 107$ space-time sheet carries a many-particle state of super-symplectic particles with vanishing electro-weak quantum numbers (meaning darkness in the strongest sense of the word.)

5. TGD allows a model of hadrons predicting their masses with accuracy better than one per cent. In this framework color glass condensate can be identified as a state formed when the hadronic space-time sheets of colliding hadrons fuse to single long stringy object and collision energy is transformed to super-symplectic hadrons.

What I have written above reflects the situation around 2005 when RHIC was in blogs. After 5 years later (2010) LHC gave its first results suggesting similar phenomena in proton-proton collisions. These results provide support for the idea that the formation of long entangled hadronic strings by a fusion of hadronic strings forming a structure analogous to black hole or initial string dominated phase of the cosmology are responsible for the RHIC findings. In the LHC case the mechanism leading to this kind of strings must be different since initial state contains only two protons. I would not anymore distinguish between hadrons and super-symplectic hadrons since in the recent picture super-symplectic excitations are responsible for most of the mass of the hadron. The view about dark matter as macroscopic quantum phase with large Planck constant has also evolved a lot from what it was at that time and I have polished reference to some short lived ideas for the benefit of the reader and me. I did not speak about zero energy ontology at that time and the understanding of the general mathematical structure of TGD has improved dramatically during these years.

4.3.1 Experimental Arrangement And Findings

Heuristic description of the findings

In the experiments using PHOBOS detector ultrahigh energy Au+Au collisions at center of mass energy for which nucleon-nucleon center of mass energy is $\sqrt{s_{NN}} = 130$ GeV, were studied [C8].

1. In the analyzed collisions the Au nuclei did not collide quite head-on. In classical picture the collision region, where quark gluon plasma is created, can be modelled as the intersection of two colliding balls, and its intersection with plane orthogonal to the colliding beams going through the center of mass of the system is defined by two pieces of circles, whose intersection points are sharp tips. Thus rotational symmetry is broken for the initial state in this picture.

2. The particles in quark-gluon plasma can be compared to a persons in a crowded room trying to get out. The particles collide many times with the particles of the quark gluon plasma before reaching the surface of the plasma. The distance $d(z, \phi)$ from the point $(z, 0)$ at the beam axis to the point $(0, \phi)$ at the plasma surface depends on ϕ. Obviously, the distance is longest to the tips $\phi = \pm\pi/2$ and shortest to the points $\phi = 0, \phi = \phi$ of the surface at the sides of the collision region. The time $\tau(z, \phi)$ spent by a particle to the travel to the plasma surface should be a monotonically increasing function $f(d)$ of d:

$$\tau(z, \phi) = f(d(z, \phi)) \ .$$

   For instance, for diffusion one would have $\tau \propto d^2$ and $\tau \propto d$ for a pure drift.

3. What was observed that for $z = 0$ the difference

$$\Delta\tau = \tau(z = 0, \pi/2) - \tau(z = 0, 0)$$

   was indeed non-vanishing but that for larger values of z the difference tended to zero. Since the variation of z correspond that for the rapidity variable y for a given particle energy, this means that particle distributions depend on rapidity which means a breaking of the longitudinal boost invariance assumed in hydrodynamical models of the plasma. It was also found that the difference vanishes for large values of y: this finding is also important for what follows.

A more detailed description

Consider now the situation in a more quantitative manner.

1. Let z-axis be in the direction of the beam and ϕ the angle coordinate in the plane E^2 orthogonal to the beam. The kinematical variables are the rapidity of the detected particle defined as $y = log[E+p_z)/(E-p_z)]/2$ (E and p_z denote energy and longitudinal momentum), Feynman scaling variable $x_F \simeq 2E/\sqrt{s}$, and transversal momentum p_T.

2. By quantum-classical correspondence, one can translate the components of momentum to space-time coordinates since classically one has $x^\mu = p^\mu a/m$. Here a is proper time for a future light cone, whose tip defines the point where the quark gluon plasma begins to be generated, and $v^\mu = p^\mu/m$ is the four-velocity of the particle. Momentum space is thus mapped to an $a = constant$ hyperboloid of the future light cone for each value of a.

   In this correspondence the rapidity variable y is mapped to $y = log[(t+z)/(t-z)]$, $|z| \leq t$ and non–vanishing values for y correspond to particles which emerge, not from the collision point defining the origin of the plane E^2, but from a point above or below E^2. $|z| \leq t$ tells the coordinate along the beam direction for the vertex, where the particle was created. The limit $y \rightarrow 0$ corresponds to the limit $a \rightarrow \infty$ and the limit $y \rightarrow \pm\infty$ to $a \rightarrow 0$ (light cone boundary).

3. Quark-parton models predict at low energies an exponential cutoff in transverse momentum p_T; Feynman scaling $dN/dx_F = f(x_F)$ independent of s; and longitudinal boost invariance, that is rapidity plateau meaning that the distributions of particles do not depend on y. In the space-time picture this means that the space-time is effectively two-dimensional and that particle distributions are Lorentz invariant: string like space-time sheets provide a possible geometric description of this situation.

4. In the case of an ideal quark-gluon plasma, the system completely forgets that it was created in a collision and particle distributions do not contain any information about the beam direction. In a head-on collision there is a full rotational symmetry and even Lorentz invariance so that transverse momentum cutoff disappears. Rapidity plateau is predicted in all directions.

5. The collisions studied were not quite head-on collisions and were characterized by an impact parameter vector with length b and direction angle ψ_2 in the plane E^2. The particle distribution at the boundary of the plane E^2 was studied as a function of the angle coordinate $\phi-\psi_2$ and rapidity y which corresponds for given energy distance to a definite point of beam axis.

The hydrodynamical view about the situation looks like follows.

1. The particle distributions $N(p^\mu)$ as function of momentum components are mapped to space-time distributions $N(x^\mu, a)$ of particles. This leads to the idea that one could model the situation using Robertson-Walker type cosmology. Co-moving Lorentz invariant particle currents depending on the cosmic time only would correspond in this picture to Lorentz invariant momentum distributions.

2. Hydrodynamical models assign to the particle distribution $d^2N/dyd\phi$ a hydrodynamical flow characterized by four-velocity $v^\mu(y,\phi)$ for each value of the rapidity variable y. Longitudinal boost invariance predicting rapidity plateau states that the hydrodynamical flow does not depend on y at all. Because of the breaking of the rotational symmetry in the plane orthogonal to the beam, the hydrodynamical flow v depends on the angle coordinate $\phi-\psi_2$. It is possible to Fourier analyze this dependence and the second Fourier coefficient v_2 of $cos(2(\phi-\psi_2)$ in the expansion

$$\frac{dN}{d\phi} \simeq 1+\sum_n v_n cos(n(\phi-\psi_2)) \tag{4.3.1}$$

was analyzed in [C9].

3. It was found that the Fourier component v_2 depends on rapidity y, which means a breaking of the longitudinal boost invariance. v_2 also vanishes for large values of y. If this is true for all Fourier coefficients v_n, the situation becomes effectively Lorentz invariant for large values of y since one has $v(y,\phi)\rightarrow 1$.

   Large values of y correspond to small values of a and to the initial moment of big bang in cosmological analogy. Hence the finding could be interpreted as a cosmological Lorentz invariance inside the light cone cosmology emerging from the collision point. Small values of y in turn correspond to large values of a so that the breaking of the spherical symmetry of the cosmology should be manifest only at $a\rightarrow\infty$ limit. These observations suggest a radical re-consideration of what happens in the collision: the breaking of the spherical symmetry would not be a property of the initial state but of the final state.

4.3.2 TGD Based Model For The Quark-Gluon Plasma

Consider now the general assumptions the TGD based model for the quark gluon plasma region in the approximation that spherical symmetry is not broken.

1. Quantum-classical correspondence supports the mapping of the momentum space of a particle to a hyperboloid of future light cone. Thus the symmetries of the particle distributions with respect to momentum variables correspond directly to space-time symmetries.

2. The M^4_+ projection of a Robertson-Walker cosmology imbedded to $H=M^4_+\times CP_2$ is future light cone. Hence it is natural to model the hydrodynamical flow as a mini-cosmology. Even more, one can assume that the collision quite literally creates a space-time sheet which locally obeys Robertson-Walker type cosmology. This assumption is sensible in many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) and conforms with the fractality of TGD inspired cosmology (cosmologies inside cosmologies).

3. If the space-time sheet containing the quark-gluon plasma is gradually filled with matter, one can quite well consider the possibility that the breaking of the spherical symmetry develops gradually, as suggested by the finding $v_2 \rightarrow 1$ for large values of $|y|$ (small values of a). To achieve Lorentz invariance at the limit $a \rightarrow 0$, one must assume that the expanding region corresponds to $r = constant$ "coordinate ball" in Robertson-Walker cosmology, and that the breaking of the spherical symmetry for the induced metric leads for large values of a to a situation described as a "not head-on collision".

4. Critical cosmology is by definition unstable, and one can model the Au+Au collision as a perturbation of the critical cosmology breaking the spherical symmetry. The shape of $r = constant$ sphere defined by the induced metric is changed by strong gravitational interactions such that it corresponds to the shape for the intersection of the colliding nuclei. One can view the collision as a spontaneous symmetry breaking process in which a critical quark-gluon plasma cosmology develops a quantum fluctuation leading to a situation described in terms of impact parameter. This kind of modelling is not natural for a hyperbolic cosmology, which is a small perturbation of the empty M^4_+ cosmology.

The embedding of the critical cosmology

Any Robertson-Walker cosmology can be imbedded as a space-time sheet, whose M^4_+ projection is future light cone. The line element is

$$ds^2 = f(a)da^2 - a^2(K(r)dr^2 + r^2d\Omega^2) \ . \tag{4.3.2}$$

Here a is the scaling factor of the cosmology and for the embedding as surface corresponds to the future light cone proper time.

This light cone has its tip at the point, where the formation of quark gluon plasma starts. (θ, ϕ) are the spherical coordinates and appear in $d\Omega^2$ defining the line element of the unit sphere. a and r are related to the spherical Minkowski coordinates (m^0, r_M, θ, ϕ) by $(a = \sqrt{(m^0)^2 - r_M^2}, r = r_M/a)$. If hyperbolic cosmology is in question, the function $K(r)$ is given by $K(r) = 1/(1 + r^2)$. For the critical cosmology 3-space is flat and one has $K(r) = 1$.

1. The critical cosmologies imbeddable to $H = M^4_+ \times CP_2$ are unique apart from a single parameter defining the duration of this cosmology. Eventually the critical cosmology must transform to a hyperbolic cosmology. Critical cosmology breaks Lorentz symmetry at space-time level since Lorentz group is replaced by the group of rotations and translations acting as symmetries of the flat Euclidian space.

2. Critical cosmology replaces Big Bang with a silent whisper amplified to a big but not infinitely big bang. The silent whisper aspect makes the cosmology ideal for the space-time sheet associated with the quark gluon plasma: the interpretation is that the quark gluon plasma is gradually transferred to the plasma space-time sheet from the other space-time sheets. In the real cosmology the condensing matter corresponds to the decay products of cosmic string in "vapor phase". The density of the quark gluon plasma cannot increase without limit and after some critical period the transition to a hyperbolic cosmology occurs. This transition could, but need not, correspond to the hadronization.

3. The embedding of the critical cosmology to $M^4_+ \times S^2$ is given by

$$\begin{aligned} sin(\Theta) &= \frac{a}{a_m} \ , \\ \Phi &= g(r) \ . \end{aligned} \tag{4.3.3}$$

Here Θ and Φ denote the spherical coordinates of the geodesic sphere S^2 of CP_2. One has

$$\begin{aligned} f(a) &= 1 - \frac{R^2 k^2}{(1-(a/a_m)^2)} \ , \\ (\partial_r \Phi)^2 &= \frac{a_m^2}{R^2} \times \frac{r^2}{1+r^2} \ . \end{aligned} \tag{4.3.4}$$

Here R denotes the radius of S^2. From the expression for the gradient of Φ it is clear that gravitational effects are very strong. The embedding becomes singular for $a = a_m$. The transition to a hyperbolic cosmology must occur before this.

This model for the quark-gluon plasma would predict Lorentz symmetry and $v = 1$ (and $v_n = 0$) corresponding to head-on collision so that it is not yet a realistic model.

TGD based model for the quark-gluon plasma without breaking of spherical symmetry

There is a highly unique deformation of the critical cosmology transforming metric spheres to highly non–spherical structures purely gravitationally. The deformation can be characterized by the following formula

$$sin^2(\Theta) = (\frac{a}{a_m})^2 \times (1 + \Delta(a,\theta,\phi)^2) \ . \tag{4.3.5}$$

1. This induces deformation of the g_{rr} component of the induced metric given by

$$g_{rr} = -a^2 \left[1 + \Delta^2(a,\theta,\phi) \frac{r^2}{1+r^2} \right] \ . \tag{4.3.6}$$

   Remarkably, g_{rr} does not depend at all on CP_2 size and the parameter a_m determining the duration of the critical cosmology. The disappearance of the dimensional parameters can be understood to reflect the criticality. Thus a strong gravitational effect independent of the gravitational constant (proportional to R^2) results. This implies that the expanding plasma space-time sheet having sphere as M^4_+ projection differs radically from sphere in the induced metric for large values of a. Thus one can understand why the parameter v_2 is non-vanishing for small values of the rapidity y.

2. The line element contains also the components g_{ij}, $i,j \in \{a,\theta,\phi\}$. These components are proportional to the factor

$$\frac{1}{1-(a/a_m)^2(1+\Delta^2)} \ , \tag{4.3.7}$$

   which diverges for

$$a_m(\theta,\phi) = \frac{a_m}{\sqrt{1+\Delta^2}} \ . \tag{4.3.8}$$

   Presumably quark-gluon plasma phase begins to hadronize first at the points of the plasma surface for which $\Delta(\theta,\phi)$ is maximum, that is at the tips of the intersection region of the colliding nuclei. A phase transition producing string like objects is one possible space-time description of the process.

4.3.3 Further Experimental Findings And Theoretical Ideas

The interaction between experiment and theory is pure magic. Although experimenter and theorist are often working without any direct interaction (as in case of TGD), I have the strong feeling that this disjointness is only apparent and there is higher organizing intellect behind this coherence. Again and again it has turned out that just few experimental findings allow to organize separate and loosely related physical ideas to a consistent scheme. The physics done in RHIC has played completely unique role in this respect.

Super-symplectic matter as the TGD counterpart of CGC?

The model discussed above explained the strange breaking of longitudinal Lorentz invariance in terms of a hadronic mini bang cosmology. The next twist in the story was the shocking finding, compared to Columbus's discovery of America, was that, rather than behaving as a dilute gas, the plasma behaved like a liquid with strong correlations between partons, and having density 30-50 times higher than predicted by QCD calculations [C6]. When I learned about these findings towards the end of 2004, I proposed how TGD might explain them in terms of what I called conformal confinement [K63]. This idea - although not wrong for any obvious reason - did not however have any obvious implications. After the progress made in p-adic mass calculations of hadrons leading to highly successful model for both hadron and meson masses [K74], the idea was replaced with the hypothesis that the condensate in question is Bose-Einstein condensate like state of super-symplectic particles formed when the hadronic space-time sheets of colliding nucleons fuse together to form a long string like object.

A further refinement of the idea comes from the hypothesis that quark gluon plasma is formed by the topological condensation of quarks to hadronic strings identified as color flux tubes. This would explain the high density of the plasma. The highly entangled hadronic string would be analogous to the initial state of TGD inspired cosmology with the only difference that string tension is extremely small in the hadronic context. This structure would possess also characteristics of blackhole.

Fireballs behaving like black hole like objects

The latest discovery in RHIC is that fireball, which lasts a mere 10^{-23} seconds, can be detected because it absorbs jets of particles produced by the collision [C7]. The association with the notion black hole is unavoidable and there indeed exists a rather esoteric M-theory inspired model "The RHIC fireball as a dual black hole" by Hortiu Nastase [C15] for the strange findings.

The Physics Today article [C16] "What Have We Learned From the Relativistic Heavy Ion Collider?" gives a nice account about experimental findings. Extremely high collision energies are in question: Gold nuclei contain energy of about 100 GeV per nucleon: 100 times proton mass. The expectation was that a large volume of thermalized Quark-Gluon Plasma (QCP) is formed in which partons lose rapidly their transverse momentum. The great surprise was the suppression of high transverse momentum collisions suggesting that in this phase strong collective interactions are present. This has inspired the proposal that quark gluon plasma is preceded by liquid like phase which has been christened as Color Glass Condensate (CGC) thought to contain Bose-Einstein condensate of gluons.

The theoretical ideas relating CGC to gravitational interactions

Color glass condensate relates naturally to several gravitation related theoretical ideas discovered during the last year.

1. Classical gravitation and color confinement

Just some time ago it became clear that strong classical gravitation might play a key role in the understanding of color confinement [K100]. Whether the situation looks confinement or asymptotic freedom would be in the eyes of beholder: this is one example of dualities filling TGD Universe. If one looks the situation at the hadronic space-time sheet or one has asymptotic freedom, particles move essentially like free massless particles. But - and this is absolutely essential- in the induced metric of hadronic space-time sheet. This metric represents classical gravitational field becoming extremely strong near hadronic boundary. From the point of view of outsider, the motion of quarks slows down to rest when they approach hadronic boundary: confinement. The distance to hadron surface is infinite or at least very large since the induced metric becomes singular at the light-like boundary! Also hadronic time ceases to run near the boundary and finite hadronic time corresponds to infinite time of observer. When you look from outside you find that this light-like 3-surface is just static surface like a black hole horizon which is also a light-like 3-surface. This gives confinement.

2. Dark matter in TGD

The evidence for hadronic black hole like structures is especially fascinating. In TGD Universe dark matter can be (not always) ordinary matter at larger space-time sheets in particular magnetic flux tubes. The mere fact that the particles are at larger space-time sheets might make them more or less invisible.

Matter can be however dark in much stronger sense, should I use the word "black" ! The findings suggesting that planetary orbits obey Bohr rules with a gigantic Planck constant [K93] , [E87] would suggest quantum coherence of dark matter even in astrophysical length scales and this raises the fascinating possibility that Planck constant is dynamical so that fine structure constant. Dark matter would correspond to phases with non-standard value of Planck constant. This quantization saves from black hole collapse just as the quantization of hydrogen atom saves from the infrared catastrophe.

The basic criterion for the transition to this phase would be that it occurs when some coupling strength - say fine structure constant multiplied by appropriate charges or gravitational constant multiplied by masses- becomes so large that the perturbation series for scattering amplitudes fails to converge. The phase transition increases Planck constant so that convergence is achieved. The attempts to build a detailed view about what might happen led to a generalization of the embedding space concept by replacing M^4 (or rather the causal diamond) and CP_2 with their singular coverings. During 2010 it turned out that this generalization could be regarded as a conventional manner to describe a situation in which space-time surface becomes analogous to a multi-sheeted Riemann surface. If so, then Planck constant would be replaced by its integer multiple only in effective sense.

The obvious questions are following. Could black hole like objects/magnetic flux tubes/cosmic strings consist of quantum coherent dark matter? Does this dark matter consist dominantly from hadronic space-time sheets which have fused together and contain super-symplectic bosons and their super-partners (with quantum numbers of right handed neutrino) having therefore no electro-weak interactions. Electro-weak charges would be at different space-time sheets.

1. Gravitational interaction cannot force the transition to dark phase in a purely hadronic system at RHIC energies since the product GM_1M_2 characterizing the interaction strength of two masses must be larger than unity ($\hbar = c = 1$) for the phase transition increasing Planck constant to occur. Hence the collision energy should be above Planck mass for the phase transition to occur if gravitational interactions are responsible for the transition.

2. The criterion for the transition to dark phase is however much more general and states that the system does its best to stay perturbative by increasing its Planck constant in discrete steps and applies thus also in the case of color interactions and governs the phase transition to the TGD counterpart of non-perturbative QCD. Criterion would be roughly $\alpha_s Q_s^2 > 1$ for two color charges of opposite sign. Hadronic string picture would suggests that the criterion is equivalent to the generalization of the gravitational criterion to its strong gravity analog $nL_p^2M^2 > 1$, where L_p is the p-adic length scale characterizing color magnetic energy density (hadronic string tension) and M is the mass of the color magnetic flux tube and n is a numerical constant. Presumably L_p, $p = M_{107} = 2^{107} - 1$, is the p-adic length scale since Mersenne prime M_{107} labels the space-time sheet at which partons feed their color gauge fluxes. The temperature during this phase could correspond to Hagedorn temperature (for the history and various interpretations of Hagedorn temperature see the CERN Courier article [B21]) for strings and is determined by string tension and would naturally correspond also to the temperature during the critical phase determined by its duration as well as corresponding black-hole temperature. This temperature is expected to be somewhat higher

than hadronization temperature found to be about $\simeq 176$ MeV. The density of inertial mass would be maximal during this phase as also the density of gravitational mass during the critical phase.

Lepto-hadron physics [K109], one of the predictions of TGD, is one instance of a similar situation. In this case electromagnetic interaction strength defined in an analogous manner becomes larger than unity in heavy ion collisions just above the Coulomb wall and leads to the appearance of mysterious states having a natural interpretation in terms of lepto-pion condensate. Lepto-pions are pairs of color octet excitations of electron and positron.

3. Description of collisions using analogy with black holes

The following view about RHIC events represents my immediate reaction to the latest RHIC news in terms of black-hole physics instead of notions related to big bang. Since black hole collapse is roughly the time reversal of big bang, the description is complementary to the earliest one.

In TGD context one can ask whether the fireballs possibly detected at RHIC are produced when a portion of quark-gluon plasma in the collision region formed by to Gold nuclei separates from hadronic space-time sheets which in turn fuse to form a larger space-time sheet separated from the remaining collision region by a light-like 3-D surface (I have used to speak about light-like causal determinants) mathematically completely analogous to a black hole horizon. This larger space-time sheet would contain color glass condensate of super-symplectic gluons formed from the collision energy. A formation of an analog of black hole would indeed be in question.

The valence quarks forming structures connected by color bonds would in the first step of the collision separate from their hadronic space-time sheets which fuse together to form color glass condensate. Similar process has been observed experimentally in the collisions demonstrating the experimental reality of Pomeron, a color singlet state having no Regge trajectory [C12] and identifiable as a structure formed by valence quarks connected by color bonds. In the collision it temporarily separates from the hadronic space-time sheet. Later the Pomeron and the new mesonic and baryonic Pomerons created in the collision suffer a topological condensation to the color glass condensate: this process would be analogous to a process in which black hole sucks matter from environment.

Of course, the relationship between mass and radius would be completely different with gravitational constant presumably replacement by the the square of appropriate p-adic length scale presumably of order pion Compton length: this is very natural if TGD counterparts of black-holes are formed by color magnetic flux tubes. This gravitational constant expressible in terms of hadronic string tension of.9 GeV^2 predicted correctly by super-symplectic picture would characterize the strong gravitational interaction assignable to super-symplectic $J = 2$ gravitons. I have long time ago in the context of p-adic mass calculations formulated quantitatively the notion of elementary particle black hole analogy making the notion of elementary particle horizon and generalization of Hawking-Bekenstein law [K76].

The size L of the "hadronic black hole" would be relatively large using protonic Compton radius as a unit of length. For instnce, for $\hbar = 26\hbar_0$ the size would be $26 \times L_e(107) = 46$ fm and correspond to a size of a heavy nucleus. This large size would fit nicely with the idea about nuclear sized color glass condensate. The density of partons (possibly gluons) would be very high and large fraction of them would have been materialized from the brehmstrahlung produced by the de-accelerating nuclei. Partons would be gravitationally confined inside this region. The interactions of partons would lead to a generation of a liquid like dense phase and a rapid thermalization would occur. The collisions of partons producing high transverse momentum partons occurring inside this region would yield no detectable high p_T jets since the matter coming out from this region would be somewhat like a thermal radiation from an evaporating black hole identified as a highly entangled hadronic string in Hagedorn temperature. This space-time sheet would expand and cool down to QQP and crystallize into hadrons.

4. Quantitative comparison with experimental data

Consider now a quantitative comparison of the model with experimental data. The estimated freeze-out temperature of quark gluon plasma is $T_f \simeq 175.76$ MeV [C16, C15], not far from the total contribution of quarks to the mass of nucleon, which is 170 MeV [K74]. Hagedorn temperature identified as black-hole temperature should be higher than this temperature. The experimental estimate for the hadronic Hagedorn temperature from the transversal momentum distribution of baryons is $\simeq 160$ MeV. On the other hand, according to the estimates of hep-ph/0006020 the values of Hagedorn temperatures for mesons and baryons are $T_H(M) = 195$ MeV and $T_H(B) = 141$ MeV respectively.

D-dimensional bosonic string model for hadrons gives for the mesonic Hagedorn temperature the expression [B21]

$$T_H = \frac{\sqrt{6}}{2\pi(D-2)\alpha'} , \quad (4.3.9)$$

For a string in $D = 4$-dimensional space-time and for the value $\alpha' \sim 1$ GeV^{-2} of Regge slope, this would give $T_H = 195$ MeV, which is slightly larger than the freezing out temperature as it indeed should be, and in an excellent agreement with the experimental value of [B47]. It deserves to be noticed that in the model for fireball as a dual 10-D black-hole the rough estimate for the temperature of color glass condensate becomes too low by a factor 1/8 [C15]. In light of this I would not yet rush to conclude that the fireball is actually a 10-dimensional black hole.

Note that the baryonic Hagedorn temperature is smaller than mesonic one by a factor of about $\sqrt{2}$. According to [B47] this could be qualitatively understood from the fact that the number of degrees of freedom is larger so that the effective value of D in the mesonic formula is larger. $D_{eff} = 6$ would give $T_H = 138$ MeV to be compared with $T_H(B) = 141$ MeV. On the other hand, TGD based model for hadronic masses [K74] assumes that quarks feed their color fluxes to $k = 107$ space-time sheets. For mesons there are two color flux tubes and for baryons three. Using the same logic as in [B47], one would have $D_{eff}(B)/D_{eff}(M) = 3/2$. This predicts $T_H(B) = 159$ MeV to be compared with 160 MeV deduced from the distribution of transversal momenta in p-p collisions.

4.3.4 Are Ordinary Black-Holes Replaced With Super-Symplectic Black-Holes In TGD Universe?

Some variants of super string model predict the production of small black-holes at LHC. I have never taken this idea seriously but in a well-defined sense TGD predicts black-holes associated with super-symplectic gravitons with strong gravitational constant defined by the hadronic string tension. The proposal is that super-symplectic black-holes have been already seen in Hera, RHIC, and the strange cosmic ray events.

Baryonic super-symplectic black-holes of the ordinary M_{107} hadron physics would have mass 934.2 MeV, very near to proton mass. The mass of their M_{89} counterparts would be 512 times higher, about 478 GeV if quark massses scale also by this factor. This need not be the case: if one has $k = 113 \rightarrow 103$ instead of 105 one has 434 GeV mass. "Ionization energy" for Pomeron, the structure formed by valence quarks connected by color bonds separating from the space-time sheet of super-symplectic black-hole in the production process, corresponds to the total quark mass and is about 170 MeV for ordinary proton and 87 GeV for M_{89} proton. This kind of picture about black-hole formation expected to occur in LHC differs from the stringy picture since a fusion of the hadronic mini black-holes to a larger black-hole is in question.

An interesting question is whether the ultrahigh energy cosmic rays having energies larger than the GZK cut-off of 5×10^{10} GeV are baryons, which have lost their valence quarks in a collision with hadron and therefore have no interactions with the microwave background so that they are able to propagate through long distances.

In neutron stars the hadronic space-time sheets could form a gigantic super-symplectic black-hole and ordinary black-holes would be naturally replaced with super-symplectic black-holes in TGD framework (only a small part of black-hole interior metric is representable as an induced metric). This obviously means a profound difference between TGD and string models.

1. Hawking-Bekenstein black-hole entropy would be replaced with its p-adic counterpart given by

$$S_p = (\frac{M}{m(CP_2)})^2 \times log(p) , \quad (4.3.10)$$

where $m(CP_2)$ is CP_2 mass, which is roughly 10^{-4} times Planck mass. M is the contribution of p-adic thermodynamics to the mass. This contribution is extremely small for gauge bosons but for fermions and super-symplectic particles it gives the entire mass.

2. If p-adic length scale hypothesis $p \simeq 2^k$ holds true, one obtains

$$S_p = klog(2) \times (\frac{M}{m(CP_2)})^2 , \tag{4.3.11}$$

$m(CP_2) = \hbar/R$, R the "radius" of CP_2, corresponds to the standard value of $\hbar_0$ for all values of $\hbar$.

3. Hawking-Bekenstein area law gives in the case of Schwartschild black-hole

$$S = \frac{A}{4G} \times \hbar = \pi G M^2 \times \hbar \ . \tag{4.3.12}$$

For the p-adic variant of the law Planck mass is replaced with CP_2 mass and $klog(2) \simeq log(p)$ appears as an additional factor. Area law is obtained in the case of elementary particles if k is prime and wormhole throats have M^4 radius given by p-adic length scale $L_k = \sqrt{k}R$ which is exponentially smaller than L_p. For macroscopic super-symplectic black-holes modified area law results if the radius of the large wormhole throat equals to Schwartschild radius. Schwartschild radius is indeed natural: in [K111] I have shown that a simple deformation of the Schwartschild exterior metric to a metric representing rotating star transforms Schwartschild horizon to a light-like 3-surface at which the signature of the induced metric is transformed from Minkowskian to Euclidian.

4. The formula for the gravitational Planck constant appearing in the Bohr quantization of planetary orbits and characterizing the gravitational field body mediating gravitational interaction between masses M and m [K93] reads as

$$\hbar_{gr} = \frac{GMm}{v_0} \hbar_0 \ .$$

$v_0 = 2^{-11}$ is the preferred value of v_0. One could argue that the value of gravitational Planck constant is such that the Compton length $\hbar_{gr}/M$ of the black-hole equals to its Schwartshild radius. This would give

$$\hbar_{gr} = \frac{GM^2}{v_0} \hbar_0 \ , \ \ v_0 = 1/2 \ . \tag{4.3.13}$$

The requirement that $\hbar_{gr}$ is a ratio of ruler-and-compass integers expressible as a product of distinct Fermat primes (only four of them are known) and power of 2 would quantize the mass spectrum of black hole [K93]. Even without this constraint M^2 is integer valued using p-adic mass squared unit and if p-adic length scale hypothesis holds true this unit is in an excellent approximation power of two.

5. The gravitational collapse of a star would correspond to a process in which the initial value of v_0 , say $v_0 = 2^{-11}$, increases in a stepwise manner to some value $v_0 \leq 1/2$. For a supernova with solar mass with radius of 9 km the final value of v_0 would be $v_0 = 1/6$. The star could have an onion like structure with largest values of v_0 at the core as suggested by the model of planetary system. Powers of two would be favored values of v_0. If the formula holds true also for Sun one obtains $1/v_0 = 3 \times 17 \times 2^{13}$ with 10 per cent error.

6. Black-hole evaporation could be seen as means for the super-symplectic black-hole to get rid of its electro-weak charges and fermion numbers (except right handed neutrino number) as the antiparticles of the emitted particles annihilate with the particles inside super-symplectic black-hole. This kind of minimally interacting state is a natural final state of star. Ideal super-symplectic black-hole would have only angular momentum and right handed neutrino number.

7. In TGD light-like partonic 3-surfaces are the fundamental objects and space-time interior defines only the classical correlates of quantum physics. The space-time sheet containing the highly entangled cosmic string might be separated from environment by a wormhole contact with size of black-hole horizon.

This looks the most plausible option but one can of course ask whether the large partonic 3-surface defining the horizon of the black-hole actually contains all super-symplectic particles so that super-symplectic black-hole would be single gigantic super-symplectic parton. The interior of super-symplectic black-hole would be a space-like region of space-time, perhaps resulting as a large deformation of CP_2 type vacuum extremal. Black-hole sized wormhole contact would define a gauge boson like variant of the black-hole connecting two space-time sheets and getting its mass through Higgs mechanism. A good guess is that these states are extremely light.

4.3.5 Very Cautious Conclusions

The model for quark-gluon plasma in terms of valence quark space-time sheets separated from hadronic space-time sheets forming a color glass condensate relies on quantum criticality and implies gravitation like effects due to the presence of super-symplectic strong gravitons. At space-time level the change of the distances due to strong gravitation affects the metric so that the breaking of spherical symmetry is caused by gravitational interaction. TGD encourages to think that this mechanism is quite generally at work in the collisions of nuclei. One must take seriously the possibility that strong gravitation is present also in longer length scales (say biological), in particular in processes in which new space-time sheets are generated. Critical cosmology might provide a universal model for the emergence of a new space-time sheet.

The model supports TGD based early cosmology and quantum criticality. In standard physics framework the cosmology in question is not sensible since it would predict a large breaking of the Lorentz invariance, and would mean the breakdown of the entire conceptual framework underlying elementary particle physics. In TGD framework Lorentz invariance is not lost at the level of embedding space, and the experiments provide support for the view about space-time as a surface and for the notion of many-sheeted space-time.

The attempts to understand later strange events reported by RHIC have led to a dramatic increase of understanding of TGD and allow to fuse together separate threads of TGD.

1. The description of RHIC events in terms of the formation of hadronic black hole and its evaporation seems to be also possible and essentially identical with description as a mini bang.

2. It took some time to realize that scaled down TGD inspired cosmology as a model for quark gluon plasma predicts a new phase identifiable as color glass condensate and still a couple of years to realize the proper interpretation of it in terms of super-symplectic bosons having no counterpart in QCD framework.

3. There is also a connection with the dramatic findings suggesting that Planck constant for dark matter has a gigantic value.

4. Black holes and their scaled counterparts would not be merciless information destroyers in TGD Universe. The entanglement of particles having particle like integrity would make black hole like states ideal candidates for quantum computer like systems. One could even imagine that the galactic black hole is a highly tangled cosmic string in Hagedorn temperature performing quantum computations the complexity of which is totally out of reach of human intellect! Indeed, TGD inspired consciousness predicts that evolution leads to the increase of information and intelligence, and the evolution of stars should not form exception to this. Also the interpretation of black hole as consisting of dark matter follows from this picture.

Summarizing, it seems that thanks to some crucial experimental inputs the new physics predicted by TGD is becoming testable in laboratory.

4.3.6 Five Years Later

The emergence of the first interesting findings from LHC by CMS collaboration [C5, C1] provide new insights to the TGD picture about the phase transition from QCD plasma to hadronic phase and inspired also the updating of the model of RHIC events (mainly elimination of some remnants from the time when the ideas about hierarchy of Planck constants had just born).

Anomalous behavior of quark gluon plasma is observed also in proton proton collisions

In some proton-proton collisions more than hundred particles are produced suggesting a single object from which they are produced. Since the density of matter approaches to that observed in heavy ion collisions for five years ago at RHIC, a formation of quark gluon plasma and its subsequent decay is what one would expect. The observations are not however quite what QCD plasma picture would allow to expect. Of course, already the RHIC results disagreed with what QCD expectations. What is so striking is the evolution of long range correlations between particles in events containing more than 90 particles as the transverse momentum of the particles increases in the range 1-3 GeV (see the excellent description of the correlations by Lubos Motl in his blog [C2]).

One studies correlation function for two particles as a function of two variables. The first variable is the difference $\Delta\phi$ for the emission angles and second is essentially the difference for the velocities described relativistically by the difference $\Delta\eta$ for hyperbolic angles. As the transverse momentum p_T increases the correlation function develops structure. Around origin of $\Delta\eta$ axis a widening plateau develops near $\Delta\phi = 0$. Also a wide ridge with almost constant value as function of $\Delta\eta$ develops near $\Delta\phi = \pi$. The interpretation is that particles tend to move collinearly and or in opposite directions. In the latter case their velocity differences are large since they move in opposite directions so that a long ridge develops in $\Delta\eta$ direction in the graph.

Ideal QCD plasma would predict no correlations between particles and therefore no structures like this. The radiation of particles would be like blackbody radiation with no correlations between photons. The description in terms of string like object proposed also by Lubos Motl on basis of analysis of the graph showing the distributions as an explanation of correlations looks attractive. The decay of a string like structure producing particles at its both ends moving nearly parallel to the string to opposite directions could be in question.

Since the densities of particles approach those at RHIC, I would bet that the explanation (whatever it is!) of the hydrodynamical behavior observed at RHIC for some years ago should apply also now. The introduction of string like objects in this model was natural since in TGD framework even ordinary nuclei are string like objects with nucleons connected by color flux tubes [L2] , [L2]: this predicts a lot of new nuclear physics for which there is evidence. The basic idea was that in the high density hadronic color flux tubes associated with the colliding nucleon connect to form long highly entangled hadronic strings containing quark gluon plasma. The decay of these structures would explain the strange correlations. It must be however emphasized that in the recent case the initial state consists of two protons rather than heavy nuclei so that the long hadronic string could form from the QCD like quark gluon plasma at criticality when long range fluctuations emerge.

The main assumptions of the model for the RHIC events and those observed now deserve to be summarized. Consider first the "macroscopic description".

1. A critical system associated with confinement-deconfinement transition of the quark-gluon plasma formed in the collision and inhibiting long range correlations would be in question.

2. The proposed hydrodynamic space-time description was in terms of a scaled variant of what I call critical cosmology defining a universal space-time correlate for criticality: the specific property of this cosmology is that the mass contained by comoving volume approaches to zero at the initial moment so that Big Bang begins as a silent whisper and is not so scaring. Criticality means flat 3-space instead of Lobatchevski space and means breaking of Lorentz invariance to SO(4). Breaking of Lorentz invariance was indeed observed for particle distributions but now I am not so sure whether it has much to do with this.

3. The system behaves like almost perfect fluid in the sense that the viscosity entropy ratio is near to its lower bound whose values is predicted by string theory considerations to be $\eta/s = \hbar/4\pi$.

The microscopic level the description would be like follows.

1. A highly entangled long hadronic string like object (color-magnetic flux tube) would be formed at high density of nucleons via the fusion of ordinary hadronic color-magnetic flux tubes to much longer one and containing quark gluon plasma. In QCD world plasma would not be at flux tube.

2. This geometrically (and perhaps also quantally!) entangled string like object would straighten and split to hadrons in the subsequent "cosmological evolution" and yield large numbers of almost collinear particles. The initial situation should be apart from scaling similar as in cosmology where a highly entangled soup of cosmic strings (magnetic flux tubes) precedes the space-time as we understand it. Maybe ordinary cosmology could provide analogy as galaxies arranged to form linear structures?

3. This structure would have also black hole like aspects but in totally different sense as the 10-D hadronic black-hole proposed by Nastase to describe the findings. Note that M-theorists identify black holes as highly entangled strings: in TGD 1-D strings are replaced by 3-D string like objects.

This picture leaves does not yet make the perfect fluid behavior obvious. The following argument relates it to the properties of the preferred extremals of Kähler action.

Almost perfect fluids seems to be abundant in Nature. For instance, QCD plasma was originally thought to behave like gas and therefore have a rather high viscosity to entropy density ratio $x = \eta/s$. Already RHIC found that it however behaves like almost perfect fluid with x near to the minimum predicted by AdS/CFT. The findings from LHC gave additional conform the discovery [C4]. Also Fermi gas is predicted on basis of experimental observations to have at low temperatures a low viscosity roughly 5-6 times the minimal value [D3] . In the following the argument that the preferred extremals of Kähler action are perfect fluids apart from the symmetry breaking to space-time sheets is developed. The argument requires some basic formulas summarized first.

The detailed definition of the viscous part of the stress energy tensor linear in velocity (oddness in velocity relates directly to second law) can be found in [D2] .

1. The symmetric part of the gradient of velocity gives the viscous part of the stress-energy tensor as a tensor linear in velocity. Velocity gradient decomposes to a term traceless tensor term and a term reducing to scalar.

$$\partial_i v_j + \partial_j v_i = \frac{2}{3}\partial_k v^k g_{ij} + (\partial_i v_j + \partial_j v_i - \frac{2}{3}\partial_k v^k g_{ij}) \ . \quad (4.3.14)$$

The viscous contribution to stress tensor is given in terms of this decomposition as

$$\sigma_{visc;ij} = \zeta \partial_k v^k g_{ij} + \eta(\partial_i v_j + \partial_j v_i - \frac{2}{3}\partial_k v^k g_{ij}) \ . \quad (4.3.15)$$

From $dF^i = T^{ij} S_j$ it is clear that bulk viscosity ζ gives to energy momentum tensor a pressure like contribution having interpretation in terms of friction opposing. Shear viscosity η corresponds to the traceless part of the velocity gradient often called just viscosity. This contribution to the stress tensor is non-diagonal and corresponds to momentum transfer in directions not parallel to momentum and makes the flow rotational. This term is essential for the thermal conduction and thermal conductivity vanishes for ideal fluids.

2. The 3-D total stress tensor can be written as

$$\sigma_{ij} = \rho v_i v_j - p g_{ij} + \sigma_{visc;ij} \ . \tag{4.3.16}$$

The generalization to a 4-D relativistic situation is simple. One just adds terms corresponding to energy density and energy flow to obtain

$$T^{\alpha\beta} = (\rho - p) u^\alpha u^\beta + p g^{\alpha\beta} - \sigma^{\alpha\beta}_{visc} \ . \tag{4.3.17}$$

Here u^α denotes the local four-velocity satisfying $u^\alpha u_\alpha = 1$. The sign factors relate to the concentrations in the definition of Minkowski metric $((1,-1,-1,-1))$.

3. If the flow is such that the flow parameters associated with the flow lines integrate to a global flow parameter one can identify new time coordinate t as this flow parameter. This means a transition to a coordinate system in which fluid is at rest everywhere (comoving coordinates in cosmology) so that energy momentum tensor reduces to a diagonal term plus viscous term.

$$T^{\alpha\beta} = (\rho - p) g^{tt} \delta^\alpha_t \delta^\beta_t + p g^{\alpha\beta} - \sigma^{\alpha\beta}_{visc} \ . \tag{4.3.18}$$

In this case the vanishing of the viscous term means that one has perfect fluid in strong sense.

The existence of a global flow parameter means that one has

$$v_i = \Psi \partial_i \Phi \ . \tag{4.3.19}$$

Ψ and Φ depend on space-time point. The proportionality to a gradient of scalar Φ implies that Φ can be taken as a global time coordinate. If this condition is not satisfied, the perfect fluid property makes sense only locally.

AdS/CFT correspondence allows to deduce a lower limit for the coefficient of shear viscosity as

$$x = \frac{\eta}{s} \geq \frac{\hbar}{4\pi} \ . \tag{4.3.20}$$

This formula holds true in units in which one has $k_B = 1$ so that temperature has unit of energy.

What makes this interesting from TGD view is that in TGD framework perfect fluid property in appropriately generalized sense indeed characterizes locally the preferred extremals of Kähler action defining space-time surface.

1. Kähler action is Maxwell action with U(1) gauge field replaced with the projection of CP_2 Kähler form so that the four CP_2 coordinates become the dynamical variables at QFT limit. This means enormous reduction in the number of degrees of freedom as compared to the ordinary unifications. The field equations for Kähler action define the dynamics of space-time surfaces and this dynamics reduces to conservation laws for the currents assignable to isometries. This means that the system has a hydrodynamic interpretation. This is a considerable difference to ordinary Maxwell equations. Notice however that the "topological" half of Maxwell's equations (Faraday's induction law and the statement that no non-topological magnetic are possible) is satisfied.

2. Even more, the resulting hydrodynamical system allows an interpretation in terms of a perfect fluid. The general ansatz for the preferred extremals of field equations assumes that various conserved currents are proportional to a vector field characterized by so called Beltrami property. The coefficient of proportionality depends on space-time point and the conserved current in question. Beltrami fields by definition is a vector field such that the time parameters assignable to its flow lines integrate to single global coordinate. This is highly non-trivial and one of the implications is almost topological QFT property due to the fact that Kähler action reduces to a boundary term assignable to wormhole throats which are light-like 3-surfaces at the boundaries of regions of space-time with Euclidian and Minkowskian signatures. The Euclidian regions (or wormhole throats, depends on one's tastes) define what I identify as generalized Feynman diagrams.

   Beltrami property means that if the time coordinate for a space-time sheet is chosen to be this global flow parameter, all conserved currents have only time component. In TGD framework energy momentum tensor is replaced with a collection of conserved currents assignable to various isometries and the analog of energy momentum tensor complex constructed in this manner has no counterparts of non-diagonal components. Hence the preferred extremals allow an interpretation in terms of perfect fluid without any viscosity.

This argument justifies the expectation that TGD Universe is characterized by the presence of low-viscosity fluids. Real fluids of course have a non-vanishing albeit small value of x. What causes the failure of the exact perfect fluid property?

1. Many-sheetedness of the space-time is the underlying reason. Space-time surface decomposes into finite-sized space-time sheets containing topologically condensed smaller space-time sheets containing.... Only within given sheet perfect fluid property holds true and fails at wormhole contacts and because the sheet has a finite size. As a consequence, the global flow parameter exists only in given length and time scale. At embedding space level and in zero energy ontology the phrasing of the same would be in terms of hierarchy of causal diamonds (CDs).

2. The so called eddy viscosity is caused by eddies (vortices) of the flow. The space-time sheets glued to a larger one are indeed analogous to eddies so that the reduction of viscosity to eddy viscosity could make sense quite generally. Also the phase slippage phenomenon of super-conductivity meaning that the total phase increment of the super-conducting order parameter is reduced by a multiple of 2π in phase slippage so that the average velocity proportional to the increment of the phase along the channel divided by the length of the channel is reduced by a quantized amount.

   The standard arrangement for measuring viscosity involves a lipid layer flowing along plane. The velocity of flow with respect to the surface increases from $v = 0$ at the lower boundary to v_{upper} at the upper boundary of the layer: this situation can be regarded as outcome of the dissipation process and prevails as long as energy is fed into the system. The reduction of the velocity in direction orthogonal to the layer means that the flow becomes rotational during dissipation leading to this stationary situation.

   This suggests that the elementary building block of dissipation process corresponds to a generation of vortex identifiable as cylindrical space-time sheets parallel to the plane of the flow and orthogonal to the velocity of flow and carrying quantized angular momentum. One expects that vortices have a spectrum labelled by quantum numbers like energy and angular momentum so that dissipation takes in discrete steps by the generation of vortices which transfer the energy and angular momentum to environment and in this manner generate the velocity gradient.

3. The quantization of the parameter x is suggestive in this framework. If entropy density and viscosity are both proportional to the density n of the eddies, the value of x would equal to the ratio of the quanta of entropy and kinematic viscosity η/n for single eddy if all eddies are identical. The quantum would be $\hbar/4\pi$ in the units used and the suggestive interpretation is in terms of the quantization of angular momentum. One of course expects a spectrum of eddies so that this simple prediction should hold true only at temperatures

for which the excitation energies of vortices are above the thermal energy. The increase of the temperature would suggest that gradually more and more vortices come into play and that the ratio increases in a stepwise manner bringing in mind quantum Hall effect. In TGD Universe the value of h_{eff} can be large in some situations so that the quantal character of dissipation could become visible even macroscopically. Whether this a situation with large h_{eff} is encountered even in the case of QCD plasma is an interesting question.

The following poor man's argument tries to make the idea about quantization a little bit more concrete.

1. The vortices transfer momentum parallel to the plane from the flow. Therefore they must have momentum parallel to the flow given by the total cm momentum of the vortex. Before continuing some notations are needed. Let the densities of vortices and absorbed vortices be n and n_{abs} respectively. Denote by $v_{\|}$ *resp.* $v_{\perp}$ the components of cm momenta parallel to the main flow *resp.* perpendicular to the plane boundary plane. Let m be the mass of the vortex. Denote by S are parallel to the boundary plane.

2. The flow of momentum component parallel to the main flow due to the absorbed at S is

$$n_{abs} m v_{\|} v_{\perp} S \quad . \tag{4.3.21}$$

This momentum flow must be equal to the viscous force

$$F_{visc} = \eta \frac{v_{\|}}{d} \times S \quad . \tag{4.3.22}$$

From this one obtains

$$\eta = n_{abs} m v_{\perp} d \quad . \tag{4.3.23}$$

If the entropy density is due to the vortices, it equals apart from possible numerical factors to

$$s = n$$

so that one has

$$\frac{\eta}{s} = m v_{\perp} d \quad . \tag{4.3.24}$$

This quantity should have lower bound $x = \hbar/4\pi$ and perhaps even quantized in multiples of x, Angular momentum quantization suggests strongly itself as origin of the quantization.

3. Local momentum conservation requires that the comoving vortices are created in pairs with opposite momenta and thus propagating with opposite velocities $v_{\perp}$. Only one half of vortices is absorbed so that one has $n_{abs} = n/2$. Vortex has quantized angular momentum associated with its internal rotation. Angular momentum is generated to the flow since the vortices flowing downwards are absorbed at the boundary surface.

Suppose that the distance of their center of mass lines parallel to plane is $D = \epsilon d$, ϵ a numerical constant not too far from unity. The vortices of the pair moving in opposite direction have same angular momentum $mv\ \ D/2$ relative to their center of mass line between them. Angular momentum conservation requires that the sum these relative angular momenta cancels the sum of the angular momenta associated with the vortices themselves. Quantization for the total angular momentum for the pair of vortices gives

$$\frac{\eta}{s} = \frac{n\hbar}{\epsilon} \tag{4.3.25}$$

Quantization condition would give

$$\epsilon = 4\pi \quad . \tag{4.3.26}$$

One should understand why $D = 4\pi d$ - four times the circumference for the largest circle contained by the boundary layer- should define the minimal distance between the vortices of the pair. This distance is larger than the distance d for maximally sized vortices of radius $d/2$ just touching. This distance obviously increases as the thickness of the boundary layer increases suggesting that also the radius of the vortices scales like d.

4. One cannot of course take this detailed model too literally. What is however remarkable that quantization of angular momentum and dissipation mechanism based on vortices identified as space-time sheets indeed could explain why the lower bound for the ratio η/s is so small.

4.4 Some Problems Of Cosmology

In this chapter some problems, most of them common to both standard and TGD inspired cosmology, are discussed.

4.4.1 Antimatter as dark matter in TGD sense?

One possibility is that antimatter corresponds to dark matter in TGD sense: that is a phase with non-standard value of Planck constant. It has been found in CERN (see`http://tinyurl.com/jbvwmrp3`) that matter and antimatter atoms have no differences in the energies of their excited states. This is predicted by CPT symmetry. Notice however that CP and T can be separately broken and that this is indeed the case. Kaon is classical example of this in particle physics. Neutral kaon and anti-kaon behave slightly differently.

This finding forces to repeat an old question. Where does the antimatter reside? Or does it exist at all?

In TGD framework one possibility is that antimatter corresponds to dark matter in TGD sense that is a phase with $h_{eff} = n \times h$, $n = 1, 2, 3, ...$ such that the value of n for antimatter is different from that for visible matter. Matter and antimatter would not have direct interactions and would interact only via classical fields or by emission of say photons by matter (antimatter) suffering a phase transition changing the value of h_{eff} before absorbtion by antimatter (matter). This could be rather rare process. Bio-photons could be produced from dark photons by this process and this is assumed in TGD based model of living matter.

What the value of n for ordinary visible matter is? The naïve guess is that it is $n = 1$, the smallest possible value. Randell Mills [D4] has however claimed the existence of scaled down hydrogen atoms - Mills calls them hydrinos - with ground state binding energy considerably higher than for hydrogen atom. The experimental support for the claim is published in respected journals and the company of Mills is developing a new energy technology based on the energy liberated in the transition to hydrino state (see `http://tinyurl.com/hajyqo6`).

These findings can be understood in TGD framework if one has actually $n = 6$ for visible atoms and $n = 1, 2$, or 3 for hydrinos. Hydrino states would be stabilized in the presence of some catalysts (see `http://tinyurl.com/goruuzm`) [L23]. This also suggests a universal catalyst action. Among other things catalyst action requires that reacting molecule gets energy to overcome the potential barrier making reaction very slow. If an atom - say hydrogen - in catalyst suffers a phase transition to hydrogen like state, it liberates binding energy, and if one of the reactant molecules receives it it can overcome the barrier. After the reaction the energy can be sent back and catalyst hydrino returns to the ordinary hydrogen state.

So: could it be that one has n=6 for stable matter and n is different from this for stable antimatter? Could the small CP breaking cause this?

4.4.2 Why Some Stars Seem To Be Older Than The Universe?

There exists experimental evidence that some stars are older than the Universe [E127], [E154, E127]. A related problem is the problem of the two Hubble constants. These paradoxical results can be understood in TGD inspired cosmology. In TGD light can propagate via several routes. In the topological condensate light ray can propagate along one of the many curved space-time sheet as a small condensed particle and in the vapor phase as a small 3-surface in embedding space $H = M^4_+ \times CP_2$, where M^4_+ is future light cone of M^4. The time needed to travel from point A to point B is shorter in the vapor phase than in any space-time surface since the geodesic length along the space-time surface in the induced metric is obviously longer than in free Minkowski space. This time depends also on the space-time sheet so that entire spectrum of effective light velocities and Hubble constants results. The failure to distinguish between vapor phase photons and photons propagating along various space-time sheets leads to the paradox as following arguments shows and possibly also to the problem of two (or in fact more than two) different Hubble constants. The possibility of the vapor phase photons or photons propagating along almost flat space-time sheets emitted by the objects outside the space-time horizon of "our" space-time sheet explains also objects with anomalously large red shifts.

Basic facts

To understand these results one must study TGD based cosmology in more quantitative level.

1. The most general cosmological embedding of M^4_+ to $M^4_+ \times \mathrm{CP}_2$ $, is of form$

$$
\begin{aligned}
s^k &= s^k(a) \ , \\
g_{aa} &= 1 - s_{kl}\frac{ds^k}{da}\frac{ds^l}{da} \ , \\
ds^2 &= g_{aa}da^2 - a^2(\frac{dr^2}{1+r^2} + r^2 d\Omega^2) \ .
\end{aligned}
\tag{4.4.1}
$$

Here s_{kl} is CP_2 metric tensor and describes always expanding cosmology with subcritical or at most critical mass density.

2. The age of the Universe defined as M^4_+ proper time a of the co-moving observer (the co-moving observer on the space-time surfaces is also co-moving in M^4_+) is larger than the age defined as the proper time $s(a)$ of the co-moving observer on space-time surface. For the matter dominated Universe one has $g_{aa} = Ka$, which gives

$$
\frac{age(cond)}{age(vapor)} = \frac{s(a)}{a} = \frac{2}{3}\sqrt{g_{aa}} \ ,
\tag{4.4.2}
$$

for the ratio of the ages.

3. The recent value of g_{aa} can estimated from the expression for the mass density in the expanding cosmology

$$\begin{aligned} \rho &= \frac{3}{8\pi G}(\frac{1}{g_{aa}}+k) \ , \\ k &= -1 \ . \end{aligned} \tag{4.4.3}$$

$k=0$ mass density corresponds to the critical mass density ρ_c. The mass density is believed to be a fraction of order $\epsilon = 0.1-0.5$ of the critical mass density and this gives estimate for $\sqrt{g_{aa}}$:

$$\begin{aligned} \sqrt{g_{aa}} &= \sqrt{1-\epsilon} \ , \\ \epsilon &= \frac{\rho}{\rho_c} \ . \end{aligned} \tag{4.4.4}$$

$\sqrt{g_{aa}} = 2/3$ suggested by the proposed solution to the Hubble constant discrepancy gives $\epsilon = \frac{9}{4}$. $\epsilon = .1$ gives $\sqrt{g_{aa}} \simeq .95$.

4. The ratio of the condensate travel time to the vapor phase travel time for short distances is given by

$$\frac{\tau(cond)}{\tau(vapor)} = \frac{1}{\sqrt{g_{aa}}} \ . \tag{4.4.5}$$

This effect is in principle observable. The effect provides also a means of measuring the mass density of the Universe.

5. The light travelling in the vapor phase can reach the observer from a region, which is the intersection of the past light cone of the observer with the boundary of M^4_+ and therefore finite region of M^4. The M^4 radius of this region in the rest frame of the observer is equal $r_M = a/2$ by elementary geometry.

6. For a null geodesic of the space-time surface representing cosmology, starting at (a_0, r) and ending at $(a, 0)$, one has

$$\begin{aligned} &r = sinh(X) \ , && \text{(hyperbolic cosmology)} \ , \\ &r = X \ , && \text{(critical cosmology)} \ , \\ &X = \textstyle\int_{a_0}^{a} \frac{\sqrt{g_{aa}}}{a} da \ . \end{aligned} \tag{4.4.6}$$

If g_{aa} approaches zero for $a_0 \to 0$, as it does for the radiation dominated cosmology, the integral defining X is finite. This means that the value of $r_M(a_0)$ (M^4 distance of the object from the observer) approaches zero at this limit. All radiation from the moment of the big bang comes from the tip of the light cone. The very early cosmology with a critical mass density corresponds to $g_{aa} = 1-K$, K a very small number, and also in this case the radiation comes from the origin.

Maximum Minkowski distance from which light can propagate

It is interesting to find the maximum value of M^4_+ distance r_M from which it is possible to receive information in various cosmologies. The radius $r_M(a_0)$ has maximum for some finite value of a_0 and this radius defines the M^4 radius of the Universe observed using the condensate photons. For a_0 corresponding to maximum the condition

$$\begin{aligned} \sqrt{g_{aa}} &= tanh(X) \ , \ \text{(hyperbolic cosmology)} \ , \\ \sqrt{g_{aa}} &= X \ , \ \text{(critical cosmology)} \ . \end{aligned} \tag{4.4.7}$$

The maximum corresponds to a rather large value of a_0. Consider now various cases.

i) In case of matter dominated cosmology one has $g_{aa} = Ka$ and one has the condition

$$u_0 = tanh(2(u-u_0)) \simeq 2(u-u_0) \ , \quad u = \sqrt{Ka} \ , \quad u_0 = \sqrt{Ka_0} \ . \tag{4.4.8}$$

This gives in good approximation

$$u_0 = r = \tfrac{2}{3}u \ , \quad a_0 = \tfrac{4}{9}a \ , \quad r_M^0 = \tfrac{8}{27}ua = \tfrac{16}{81}\sqrt{Ka} \times a \ . \tag{4.4.9}$$

ii) In case of vapor phase and also for asymptotic cosmology in the limit of flatness one obviously has

$$r_M^0 = a \ . \tag{4.4.10}$$

iii) In case of critical cosmology with $g_{aa} = 1$ one has

$$a_0 = \tfrac{a}{e} \ , \quad r_0 = 1 \ , \quad r_M^0 = \tfrac{a}{e} \ . \tag{4.4.11}$$

The value of r_M^0 is clearly smallest in matter dominated cosmology.

Many-sheeted space-time allows several snapshots from the evolution of astrophysical objects

Vapor phase photons and condensate photons propagating along various space-time sheets provide in principle a possibility to obtain simultaneous information about the astrophysical object in various different phases of its development. For an object situated at distance r and observed at $(a, r = 0)$, the emission moments a_0 and $a_1 > a_0$ (in Minkowski proper time) for the condensate photon and vapor phase photon are related by the formula

$$\frac{a}{a_1} = exp(2\sqrt{K_1}(a^{1/2} - a_0^{1/2})) \ . \tag{4.4.12}$$

in the matter dominated cosmology $g_{aa} = K_1 a$ ($K_1 a \sim 1$). Hence a sufficiently nearby Super Nova would provide a test for this effect. The first burst of light corresponds to vapor phase photons and subsequent bursts to the condensate photons. The time lag between the bursts provides a way to measure the value of $\sqrt{g_{aa}}$. Unfortunately, the time lag in case of SN1987A is quite too large since the distance of order $1.5 \cdot 10^5$ ly. The observation of the same spectral line with two different cosmological red-shifts is second effect of this kind and might be erratically interpreted as the existence of two different objects on same line of sight.

Why some stars seem to be older than the Universe?

Red-shifts are determined by the apparent velocity of astrophysical object which is in good approximation given $v = Hr$, where H is Hubble constant which in TGD depends on space-time sheet along which photons propagate. One has $r = sinh(X)$ for hyperbolic cosmology and $r = X$ for critical cosmology, where the function X is defined by Eq. 4.4.6. For matter dominated cosmology with $g_{aa} = Ka$ and for almost flat hyperbolic cosmology with $g_{aa} = 1 - \epsilon$ one has

$$X = 2\left[(Ka)^{1/2} - (Ka_0)^{1/2}\right] < 1 \ , \quad \text{(matter dominance)} \ ,$$
$$X = \sqrt{(1-\epsilon)}log(\frac{a}{a_0}) \ , \quad \text{(almost flat hyperbolic)} \ . \quad (4.4.13)$$

From this it is clear that the approximation $sinh(X) \simeq X$ makes sense in case of matter dominated cosmology and the red-shifts do not differ much from those predicted by critical cosmology.

For almost flat hyperbolic cosmology and for vapor phase situation is dramatically different since red-shifts can be exponentially larger. Therefore, if most of radiation comes along matter dominated or critical space-time sheets, then the radiation coming in vapor phase or along almost flat hyperbolic space-time sheets can give rise to huge red-shifts and stars which seem to be older than the Universe. The presence of several space-time sheets means that using common value of Hubble constant one obtains entire spectrum of ages of the Universe. Same astrophysical can also give rise to several images corresponding to the photons propagating along various space-time sheets. It might be that this mechanism might be involved with the observed multiple images of stars.

The puzzle of several Hubble constants

Each cosmic space-time surface has its own Hubble constant defined as

$$H = \frac{1}{a\sqrt{g_{aa}}} \ , \quad (4.4.14)$$

where the value of the light cone proper time corresponds to the light cone proper time of observer in the sub-light cone defined by the sub-cosmology. The value of Hubble constant is smallest at almost flat space-time sheets. Photons propagating along almost flat space-time sheet or in vapor phase provide a possible solution to the puzzle of two different Hubble constants if the mass density is sufficiently large. The distances derived from type Ia super-novae give $H_0^a = 54 \pm 8 \ kms^{-1}Mpc^{-1}$ to be compared with the Hubble result $H_0^b = 80 \pm 17 \ kms^{-1}Mpc^{-1}$ [E127], [E127].

The discrepancy is resolved if the measurement of the distance is correct and made using photons propagating along almost flat hyperbolic space-time sheets so that H_0^a corresponds in good approximation to the Hubble constant of M^4_+, which is by a factor

$$\frac{H_0^a}{H_0^b} = \frac{H_0(M^4_+)}{H_0(X^4)} = \sqrt{g_{aa}} = \sqrt{1-\epsilon} \sim 2/3 \quad (4.4.15)$$

smaller than the Hubble constant of the space-time surface. The needed mass density $\epsilon = 5/9$ and the ratio of the propagation velocities of light differs considerably from unity. For $\epsilon = .1$ the ratio of two Hubble constants is predicted to be .95 and some other explanation for discrepancy is needed. The model for the stationary cosmology indeed suggests that the density of matter is much below the value needed to explain the Hubble discrepancy in this manner.

For instance, for the space-time outside the Kähler charged cosmic string, discussed in [K31], one has

$$g_{tt} = 1 - \frac{R^2\omega^2}{4}(1-u^2) \ , \quad -1 < u(\rho) < 1).$$

The model for the galaxy formation requires $exp(4\omega R) \sim 10^3$ and this gives $\frac{\omega^2 R^2}{4} \simeq .86$ implying $\sqrt{g_{tt}} \geq .37$ so that the reduction of the local light velocity can be rather large and explain the Hubble controversy.

In fact, there are quite recent results [?], which can be interpreted as a support for the many-sheeted space-time picture with separate Hubble constant associated with each sheet. The preliminary result is that the Hubble constant determined from the nearby supernovas is larger than that determined from the faraway supernovas. The proposed interpretation is that the rate of the expansion of the Universe is increasing in the course of time. The increase could be due to the non-vanishing cosmological constant corresponding to a vacuum energy density about 40 per cent of the critical density: the origin of this vacuum energy density remains a mystery.

TGD suggests suggests that Hubble constant depends on the (p-adic) length scale associated with the space-time sheet and decreases as the length scale increases. [This could also solve the problem of the two different Hubble constants since entire spectrum of Hubble constants is predicted]. Photons from nearby supernovas have suffered a topological condensation on a smaller space-time sheet as those from faraway supernovas. Hence the Hubble constant for nearby supernovas is larger and the rate of the expansion of the Universe is found to apparently increase in the course of time.

The decrease of the Hubble constant as a function of the (p-adic) length scale characterizing a given space-time sheet would follow from the fractality of the TGD Universe implying that the mass density as a function of the p-adic length scale decreases in the long length scales. Fractality could in turn would follow from the basic hypothesis necessary to get a sensible cosmology in TGD, namely that a space-time sheet corresponding to a given p-adic length scale expands until it reaches critical size not too much larger than the p-adic length scale in question. This does not exclude the possibility that the matter topologically condensed on the space-time sheet in question continues expanding and is therefore gradually drifted to the boundaries of the space-time sheet. The presence of the large voids with galaxies on their boundaries, is consistent with this assumption. From the view point of a given space-time sheet, smaller space-time sheets behave like particles of fixed size, whose density is gradually reduced in the cosmic expansion.

1. The problem of two Hubble constants persists

The previous comments about the problem of two Hubble constants was written as one of the first applications of TGD inspired cosmology and the problem might have disappeared with improved measurement technology. After about two decades the problem is however still here.

The rate of cosmic expansion manifesting itself as cosmic redshift is proportional to the distance r of the object: the expansion velocity satisfies in good approximation $v = Hr$. The proportionality coefficients H is known as Hubble constant. Hubble constant has dimensions of 1/s. A more convenient parameter is Hubble length defined as $L_H = c/H$, whose nominal value is 14.4 light years and corresponds to the limit at which the distant object recedes with light velocity from observer.

1. The measurement of Hubble constant requires determination of distance of astrophysical object (see `http://tinyurl.com/qe8rqh6`). For instance, the distance using so called standard candles - type I a supernovae having always same brightness decreasing like inverse square of distance (cosmic redshift also reduces the total intensity by shifting the frequencies). This method works for not too large distances (few hunder million light years, the size scale of the large voids (see `http://tinyurl.com/gug9264`)): therefore this method gives the value of the local Hubble constant.

2. The rate can be also deduced from cosmic redhift for CMB radiation. This method gives the Hubble constant in cosmic scales considerably longer than the size of large voids: one speaks of global determination of Hubble constant.

The problem has been that local and global method give different values for H. One might hope that the discrepancy should disappear as measurements become more precise. The recent determinination of the local value of the Hubble constant however demonstrates that the problem persists [E157] (see `http://tinyurl.com/hlr7gah`). The global value is roughly 9 per cent smaller than the local value. For a popular articles about the finding see `http://tinyurl.com/zrxay8j`).

The explanation of the discrepancy [K94] in terms of many-sheeted space-time was one of the first applications of TGD inspired cosmology. The local value of Hubble constant would correspond to space-time sheets of size at most that of large void. Global value would correspond to space-time sheets with size scales up to ten billion years assignable to the entire observed cosmos. The smaller value of the Hubble constant for space-time sheets of cosmic size would reflect the fact that the metric for them corresponds to a smaller average density for them. Mass density would be fractal in accordance with the fractality of TGD Universe implied by many-sheetedness.

Reader has perhaps noticed that I have been talking about space-time sheets in plural. The space-time of TGD is indeed many-sheeted 4-D surface in 8-D $M^4 \times CP_2$. It corresponds approximately to GRT space-time in the sense that the gauge potentials and gravitational fields (deviation of induced metric from Minkowksi metric) for sheets sum up to the gauge potential and gravitational field for the space-time of GRT characterized by metric and gauge potentials in standard model. Many-sheetedness leads to predictions allowing to distinguish between GRT and TGD. For instance, the propagation velocities of particles along different space-time sheets can differ since the light-velocity along space-time sheets is typically smaller than the maximal signal velocity in empty Minkowski space M^4. Evidence for this effect has been observed [K2]. For the first time for supernova 1987A: neutrinos arrived in two bursts and also gamma ray burst arrived at different time than neutrinos: as if the propagation would have taken place along different space-time sheets. Second time for the neutrinos arriving from galactic blackhole Sagittarius A. Two pulses were detected and the difference for arrival time was few hours.

2. Solution of Hubble constant discrepancy from the length scale dependence of cosmological constant

The discrepancy of the two determinations of Hubble constant has led to a suggestion that new physics might be involved (see `http://tinyurl.com/yabszzeg`).

1. Planck observatory deduces Hubble constant H giving the expansion rate of the Universe from CMB data something like 360,000 y after Big Bang, that is from the properties of the cosmos in long length scales. Riess's team deduces H from data in short length scales by starting from galactic length scale and identifies standard candles (Cepheid variables), and uses these to deduce a distance ladder, and deduces the recent value of $H(t)$ from the redshifts.

2. The result from short length scales is 73.5 km/s/Mpc and from long scales 67.0 km/s/Mpc deduced from CMB data. In short length scales the Universe appears to expand faster. These results differ too much from each other. Note that the ratio of the values is about 1.1. There is only 10 percent discrepancy but this leads to conjecture about new physics: cosmology has become rather precise science!

TGD could provide this new physics. I have already earlier considered this problem but have not found really satisfactory understanding. The following represents a new attempt in this respect.

1. The notions of length scale are fractality are central in TGD inspired cosmology. Many-sheeted space-time forces to consider space-time always in some length scale and p-adic length scale defined the length scale hierarchy closely related to the hierarchy of Planck constants $h_{eff}/h_0 = n$ related to dark matter in TGD sense. The parameters such as Hubble constant depend on length scale and its value differ because the measurements are carried out in different length scales.

2. The new physics should relate to some deep problem of the recent day cosmology. Cosmological constant Λ certainly fits the bill. By theoretical arguments Λ should be huge making even impossible to speak about recent day cosmology. In the recent day cosmology Λ is incredibly small.

3. TGD predicts a hierarchy of space-time sheets characterized by p-adic length scales (Lk) so that cosmological constant Λ depends on p-adic length scale $L(k)$ as $\Lambda \propto 1/GL(k)^2$, where $p \simeq 2^k$ is p-adic prime characterizing the size scale of the space-time sheet defining the sub-cosmology. p-Adic length scale evolution of Universe involve as sequence of phase transitions increasing the value of $L(k)$. Long scales $L(k)$ correspond to much smaller value of Λ.

4. The vacuum energy contribution to mass density proportional to Λ goes like $1/L^2(k)$ being roughly $1/a^2$, where a is the light-cone proper time defining the "radius" $a = R(t)$ of the

Universe in the Robertson-Walker metric $ds^2 = dt^2 - R^2(t)d\Omega^2$. As a consequence, at long length scales the contribution of Λ to the mass density decreases rather rapidly.

Must however compare this contribution to the density ρ of ordinary matter. During radiation dominated phase it goes like $1/a^4$ from $T \propto 1/a$ and form small values of a radiation dominates over vacuum energy. During matter dominated phase one has $\rho \propto 1/a^3$ and also now matter dominates. During predicted cosmic string dominated asymptotic phase one has $\rho \propto 1/a^2$ and vacuum energy density gives a contribution which is due to Kähler magnetic energy and could be comparable and even larger than the dark energy due to the volume term in action.

5. The mass density is sum $\rho_m + \rho_d$ of the densities of matter and dark energy. One has $\rho_m \propto H^2$. $\Lambda \propto 1/L^2(k)$ implies that the contribution of dark energy in long length scales is considerably smaller than in the recent cosmology. In the Planck determination of H it is however assumed that cosmological constant is indeed constant. The value of H in long length scales is under-estimated so that also the standard model extrapolation from long to short length scales gives too low value of H. This is what the discrepancy of determinations of H performed in two different length scales indeed demonstrate.

A couple of remarks are in order.

1. The twistor lift of TGD [K106, L22] [L60] suggests an alternative parameterization of vacuum energy density as $\rho_{vac} = 1/L^4(k_1)$. k_1 is roughly square root of k. This gives rise to a pair of short and long p-adic length scales. The order of magnitude for $1/L(k_1)$ is roughly the same as that of CMB temperature T: $1/L(k_1) \sim T$. Clearly, the parameters $1/T$ and R correspond to a pair of p-adic length scales. The fraction of dark energy density becomes smaller during the cosmic evolution identified as length scale evolution with largest scales corresponding to earliest times. During matter dominated era the mass density going like $1/a^3$ would to dominate over dark energy for small enough values of a. The asymptotic cosmology should be cosmic string dominated predicting $1/GT^2(k)$. This does not lead to contradiction since Kähler magnetic contribution rather than that due to cosmological constant dominates.

2. There are two kinds of cosmic strings: for the other type only volume action is non-vanishing and for the second type both Kähler and volume action are non-vanishing but the contribution of the volume action decreases as function of the length scale.

Cosmic redshift but no expansion of receding objects: one further piece of evidence for TGD cosmology

"Universe is Not Expanding After All, Controversial Study Suggests" was the title of very interesting Science News article (see `http://tinyurl.com/o6vyb9g`) telling about study, which forces to challenge Big Bang cosmology. The title of course involved the typical exaggeration.

The idea behind the study was simple. If Universe expands and also astrophysical objects - such as stars and galaxies - participate the expansion, they should increase in size. The observation was that this does not happen! One however observes the cosmic redshift so that it is too early to start to bury Big Bang cosmology. This finding is however a strong objection against the strongest version of expanding Universe. That objects like stars do not participate the expansion was actually known already when I developed TGD inspired cosmology for quarter century ago, and the question is whether GRT based cosmology can model this fact naturally or not.

The finding supports TGD cosmology based on many-sheeted space-time. Individual space-time sheets do not expand continuously. They can however expand in jerk-wise manner via quantum phase transitions increasing the p-adic prime characterizing space-time sheet of object by say factor two of increasing the value of $h_{eff} = n \times h$ for it. This phase transition could change the properties of the object dramatically. If the object and suddenly expanded variant of it are not regarded as states of the same object, one would conclude that astrophysical objects do not expand but only comove. The sudden expansions should be observable and happen also for Eart. I have proposed a TGD variant of Expanding Earth hypothesis along these lines [L55].

When one approximates the many-sheeted space-time of TGD with GRT space-time, one compresses the sheets to single region of slightly curved piece of M^4 and gauge potentials and the deviation of induced metric from M^4 metric are replaced with their sums over the sheets to get standard model. This operation leads to a loss of information about many-sheetedness. Many-sheetedness demonstrates its presence only through anomalies such as different value of Hubble constant in scales of order large void and cosmological scales, arrival of neutrinos and gamma rays from supernova SN1987A as separate bursts (arrival through different space-time sheets). The above observation represents one such anomaly.

One can of course argue that cosmic redshift is a strong counter argument against TGD. Conservation of energy and momentum implied by Poincare invariance at the level of embedding space $M^4 \times CP_2$ does not seem to allow cosmic redshift. This is not the case. Photons arrive from the source without losing their energy. The point is that the source and observer are different gravitationally. The local gravitational field defined by the induced metric induces Lorentz boost of the M^4 projection of the tangent space of the space-time surface so that the tangent spaces at source and receiver are boosted with respect to other: this causes the gravitational redshift as analog of Doppler effect in special relativity.

The TGD inspired prediction would be that the radii of the observed rings are integer multiples of basic radius. 4 rings are reported implying that the outermost ring should be at distance of 240,000 ly, which is considerably larger than the claimed updated size of 150,000 ly. The simple quantization as integer multiples would not be quite correct. Orders of magnitude are however correct.

This would suggest that visible matter has condensed around dark matter at Bohr quantized orbits or circular flux tubes. This dark matter would contribute to the gravitational potential and imply that the velocity spectrum for distance stars is not quite constant but increases slowly as observed (see `http://tinyurl.com/hqzzpfs`).

4.4.3 Mechanism Of Accelerated Expansion In TGD Universe

In TGD framework the most plausible identification for the accelerated periods of cosmic expansion is in terms of phase transitions increasing gravitational Planck constant. These phase transitions would in average sense provide quantum counterpart for smooth cosmic expansion. These phase transitions might be initiated by the repulsive Coulomb interaction between cosmic strings driven to the boundaries of the large voids. It is interesting to see how this view relates with the assumption of positive cosmological constant.

How accelerated expansion results in standard cosmology?

The accelerated of cosmic expansion means that the deceleration parameter

$$q = -(ad^2a/ds^2)/(da/ds)^2$$

is negative. For Robertson-Walker cosmologies one has

$$\begin{aligned} H^2 &\equiv (\frac{da/ds}{a})^2 = \frac{8\pi G\rho + \Lambda}{3} - K/a^2, \quad K = 0, \pm 1 \ , \\ 3\frac{d^2a/ds^2}{a} &= \Lambda - 4\pi G(\rho + 3p) \equiv -4\pi G(1+3w)\rho \ . \end{aligned} \quad (4.4.16)$$

It is clear that the accelerated expansion requires positive value of Λ.

The deceleration parameter can be expressed as $q = \frac{1}{2}(1+3w)(1+K/(aH)^2)$. $K =, 0, 1, -1$ tells whether the cosmology is flat, hyper-spherical, or hyperbolic. The rate for the change of Hubble constant can be expressed as $(dH/ds)/H^2 = (1+q)$ and the acceleration of cosmic expansion means $q < -1$. All particle models predict $q \geq -1$.

On basis of modified Einstein's equations written for the recent metric convention (+, -, -.-) (note that opposite signature changes the sign of the left hand side)

$$-G^{\alpha\beta} - \Lambda g^{\alpha\beta} = 8\pi G T^{\alpha\beta} \quad (4.4.17)$$

it is clear that the introduction of a positive cosmological constant could be interpreted by saying that for gravitational vacuum carries energy density equal to $\Lambda/8\pi$ and negative pressure. The negative gravitational pressure would induce the acceleration.

Cosmological term at the level of field equations could be also interpreted by saying that Einstein's equations hold true in the original sense but that energy momentum tensor contains besides the density of inertial mass also a positive density of purely gravitational mass: $T \rightarrow T+\Lambda g$ so that Equivalence Principle fails. Since cosmological constant means effectively negative pressure $p = -\Lambda/8\pi$ the introduction of the cosmological constant means the effective replacement $\rho+3p \rightarrow \rho + 3p - 2\Lambda/8\pi)$. In the so called $\Lambda - CDM$ model [E15] the densities of dark energy, ordinary matter, and dark matter are assumed to sum up to critical mass density $\rho_{cr} = 3/(8\pi g_{aa} G a^2)$. The fraction of dark matter density is deduced to be $\Omega_\Lambda = .74$ from mere criticality.

Critical cosmology predicts accelerated expansion

In order to get clue about the mechanism of accelerated cosmic expansion in TGD framework it is useful to study the deceleration parameter for various cosmologies in TGD framework.

In standard Friedmann cosmology with non-vanishing cosmological constant one has

$$3\frac{d^2a/ds^2}{a} = \Lambda - 4\pi G(\rho + 3p) \ . \tag{4.4.18}$$

From this form it is obvious why $\Lambda > 0$ is required in order to obtain accelerating expansion.

Deceleration parameter is a purely geometric property of cosmology and defined as

$$q \equiv -a\frac{d^2a/ds^2}{(da/ds)^2} \ . \tag{4.4.19}$$

During radiation and matter dominated phases the value of q is positive. In TGD framework there are several metrics which are independent of details of dynamics.

1. String dominated cosmology

String dominated cosmology is hyperbolic cosmology and might serve as a model for very early cosmology corresponds to the metric

$$g_{aa} \equiv (ds/da)^2 = 1 - K_0 \ . \tag{4.4.20}$$

In this case one has $q = 0$.

2. Critical cosmology

Critical cosmology with flat 3-space corresponds to

$$\begin{aligned} g_{aa} &= 1 - K \ , \\ K &\equiv \frac{K_0}{1-u^2} \ , \\ u &\equiv \frac{a}{a_1} \ . \end{aligned} \tag{4.4.21}$$

g_{aa} has the same form also for over-critical cosmologies. Both cosmologies have finite duration. In this case q is given by

$$q = -K_0\frac{K_0u^2}{1-u^2-K_0} < 0 \ , \tag{4.4.22}$$

and is negative. The rate of change for Hubble constant is

$$\frac{dH/ds}{H^2} = -(1+q) \ , \tag{4.4.23}$$

so that one must have $q < -1$ in order to have acceleration. This holds true for $a > \sqrt{(1-K_0)/(1+K_0)}a_1$.

Quantum critical cosmology could be seen as a universal characteristic of quantum critical phases associated with phase transition like phenomena. No assumptions about the mechanism behind the transition are made. There is great temptation to assign this cosmology to the phase transitions increasing the size of large voids occurring during late cosmology. The observed jerk assumed to lead from de-accelerated to accelerated expansion for about 13 billion years ago might have interpretation as a transition of this kind.

3. Stationary cosmology

TGD predicts a one-parameter family of stationary cosmologies from the requirement that the density of gravitational 4-momentum is conserved. This is guaranteed if curvature scalar is extremized. These cosmologies are expected to define asymptotic cosmologies or at least characterize the stationary phases between quantum phase transitions. The metric is given by

$$\begin{aligned} g_{aa} &= \frac{1-2x}{1-x} \ , \\ x &= (\frac{a_0}{a})^{2/3} \ . \end{aligned} \tag{4.4.24}$$

The deceleration parameter

$$q = \frac{1}{3}\frac{x}{(1-2x)(1-x)} \ . \tag{4.4.25}$$

is positive so that it seems that TGD does not lead to a continual acceleration which might be regarded as tearing galaxies into pieces.

If quantum critical phases correspond to the expansion of large voids induced by the accelerated radial motion of galactic strings as they reach the boundaries of the voids, one can consider a series of phase transitions between stationary cosmologies in which the value of gravitational Planck constant and the parameter a_0 characterizing the stationary cosmology increase by some even power of two as the ruler-and-compass integer hypothesis [K46, K42] and p-adic length scale hypothesis suggests.

4. Summary

One can safely conclude that TGD predict accelerated cosmic expansion during critical periods and that dark energy is replaced with dark matter in TGD framework. There is also a rather clear view about detailed mechanism leading to the accelerated expansion at "microscopic" level. Some summarizing remarks are in order.

1. Accelerated expansion is predicted only during periods of over-critical and critical cosmologies parameterized essentially by their duration. The microscopic description would be in terms of phase transitions increasing the size scale of large void. This phase transition is basically a quantum jump increasing gravitational Planck constant and thus the size of the large void. p-Adic length scales are favored sizes of the large voids. A large piece of 4-D cosmological history would be replaced by a new one in this transition so that quite a dramatic event would be in question.

2. p-Adic fractality forces to ask whether there is a fractal hierarchy of time scales in which Equivalence Principle (EP) in the formulation provided by General Relativity sense fails locally in TGD framework (no failure in stringy sense and at quantum level). The counterpart for EP would be the vanishing of the energy momentum tensor for Kähler action guaranteed by Einstein's equations but not implying them. This would predict a fractal hierarchy of large voids and phase transitions during which accelerated expansion occurs.

3. Cosmological constant can be said to be vanishing in TGD framework and the description of accelerated expansion in terms of a positive cosmological constant is not equivalent with TGD description since only effective pressure is negative. TGD description has some resemblance to the description in terms of quintessence [E27], a hypothetical form of matter for which equation of state is of form $p = -w\rho$, $w < -1/3$, so that one has $\rho + 3p = 1 - w < 0$ and deceleration parameter can be negative. The energy density of quintessence is however positive. TGD does not predict endlessly accelerated acceleration tearing galaxies into pieces if the total purely gravitational energy of large voids is assumed to vanish so that Equivalence Principle holds above this length scale.

TGD counterpart of Λ as a density of dark matter rather than dark energy

The value of Λ is expressed usually as a fraction of vacuum energy density from the critical mass density. Combining the data about acceleration of cosmic expansion with the data about cosmic microwave background gives $\Omega_\Lambda \simeq .74$.

1. Critical mass density requires also in TGD framework the presence of dark contribution since visible matter contribute only a few percent of the total mass density and $\Omega_\Lambda \simeq .-74$ characterizes this contribution. Since the acceleration mechanism has nothing to do with dark energy, dark energy can be replaced with dark matter in TGD framework.

2. The dark matter hierarchy labeled by the values of Planck constant suggests itself. The $1/a^2$ behavior of dark matter density suggests an interpretation as dark matter topologically condensed on cosmic strings. Besides ordinary particles also super-symplectic bosons and their super partners playing a key role in the model of hadrons and black holes suggest themselves.

3. Stationary cosmology predicts that the density of stringy matter and thus dark matter decreases like $1/a^2$ as a function of M^4_+ proper time. This behavior is very natural in cosmic string dominated cosmology and one expects that the TGD counterpart of cosmological constant should behave as $\Lambda \propto 1/a^2$ in average sense. At primordial period cosmological constant would be gigantic but its recent value would be extremely small and naturally of correct order of magnitude if the fraction of positive gravitational energy is few per cent about negative gravitational energy. Hence the basic problem of the standard cosmology would find an elegant solution.

Piecewise constancy of TGD counterpart of Λ and p-adic length scale hypothesis

There are good reasons to believe that TGD counterpart of Λ is piecewise constant. Classical picture suggests that the sizes of large voids increase in discrete jumps. The transitions increasing the size of the void would occur when the galactic strings end up to the boundary of the large void and large repulsive Coulomb energy forces the phase transition increasing Planck constant.

Also the quantum astrophysics based on the notion of gravitational Planck constant strongly suggests that astrophysical systems are analogous to stationary states of atoms so that the sizes of astrophysical systems remain constant during the cosmological expansion, and can change only in quantum jumps increasing the value of Planck constant and therefore increasing the radius of the large void regarded as dark matter bound state.

Since the set of preferred values of Planck constant is closed under multiplication by powers of 2, p-adic length scales L_p, $p \simeq 2^k$ form a preferred set of sizes scales for the large voids with phase transitions increasing k by even integer. What values of k are realized depends on the time scale of the dynamics driving the galactic strings to the boundaries of expanded large void. Even if all values of k are realized the transitions becomes very rare for large values of a.

p-Adic fractality predicts that the effective cosmological constant Λ scales as $1/L^2(k)$ as a function of the p-adic scale characterizing the space-time sheet implying a series of phase transitions reducing the value of effective cosmological constant Λ. As noticed, the allowed values of k would be of form $k = k_0 + 2n$, where however all integer value need not be realized. By p-adic length scale hypothesis primes are candidates for k. The recent value of the effective cosmological constant can be understood. The gravitational energy density usually assigned to the cosmological constant is identifiable as that associated with topologically condensed cosmic strings and magnetic flux tubes to which they are gradually transformed during cosmological evolution.

p-Adic prediction is consistent with the recent study [E262] according to which cosmological constant has not changed during the last 8 billion years: the conclusion comes from the reshifts of supernovae of type I_a. If p-adic length scales $L(k) = p \simeq 2^k$, k any positive integer, are allowed, the finding gives the lower bound $T_N > \sqrt(2)/(\sqrt{2}-1)) \times 8 = 27.3$ billion years for the recent age of the universe.

Brad Shaefer from Lousiana University has studied the red shifts of gamma ray bursters up to a red shift $z = 6.3$, which corresponds to a distance of 13 billion light years [E67], and claims that the fit to the data is not consistent with the time independence of the cosmological constant. In TGD framework this would mean that a phase transition changing the value of the cosmological constant must have occurred during last 13 billion years. In principle the phase transitions increasing the size of large voids could be observed as sudden changes of sign for the deceleration parameter.

The reported cosmic jerk as an accelerated period of cosmic expansion

There is an objection against the hypothesis that cosmological constant has been gradually decreasing during the cosmic evolution. Type Ia supernovae at red shift $z \sim .45$ are fainter than expected, and the interpretation is in terms of an accelerated cosmic expansion [E61]. If a period of an accelerated expansion has been preceded by a decelerated one, one would naïvely expect that for older supernovae from the period of decelerating expansion, say at redshifts about $z > 1$, the effect should be opposite. The team led by Adam Riess [E156] has identified 16 type Ia supernovae at redshifts $z > 1.25$ and concluded that these supernovae are indeed brighter. The conclusion is that about about 5 billion years ago corresponding to $z \simeq .48$, the expansion of the Universe has suffered a cosmic jerk and transformed from a decelerated to an accelerated expansion.

The apparent dimming/brightening of supernovae at the period of accelerated/decelerated expansion the follows from the luminosity distance relation

$$\mathcal{F} = \frac{\mathcal{L}}{4\pi d_L^2} \ , \tag{4.4.26}$$

where $\mathcal{L}$ is actual luminosity and $\mathcal{F}$ measured luminosity, and from the expression for the distance d_L in flat cosmology in terms of red shift z in a flat Universe

$$\begin{aligned} d_L &= (1+z)\int_0^z \frac{du}{H(u)} \\ &= (1+z)H_0^{-1}\int_0^z exp\left[-\int_0^u du\,[1+q(u)]\,d(ln(1+u))\right] du \ , \end{aligned} \tag{4.4.27}$$

where one has

$$\begin{aligned} H(z) &= \frac{dln(a)}{ds} \ , \\ q &\equiv -\frac{d^2a/ds^2}{aH^2} = \frac{dH^{-1}}{ds} - 1 \ . \end{aligned} \tag{4.4.28}$$

In TGD framework a corresponds to the light-cone proper time and s to the proper time of Robertson-Walker cosmology. Depending on the sign of the deceleration parameter q, the distance d_L is larger or smaller and accordingly the object looks dimmer or brighter.

The natural interpretation for the jerk would be as a period of accelerated cosmic expansion due to a phase transition increasing the value of gravitational Planck constant.

4.4.4 New Anomaly In Cosmic Microwave Background

A new anomaly in CMB has been found. The article by L. Rudnick, S. Brown, L. R. Williams is *Extragalactic Radio Sources and the WMAP Cold Spot* tells that a cold spot in the microwave background has been discovered. The amplitude of the temperature variation is -73 μK at maximum. The authors argue that the variation can be understood if there is a void at redshift $z \leq 1$, which corresponds to $d \leq 1.4 \times 10^{10}$ ly. The void would have radius of 140 Mpc making 5.2×10^8 ly.

Neil Turok's recent talk at PASCOS was entitled *Is the Cold Spot in the CMB a Texture?*. Turok has proposed that the cold spot results from a topological defect associated with a cosmic string of GUT type theories.

Comparison with sizes and distances of large voids

It is interesting to compare the size and distance of the argued CMB void to those for large voids [E42].

The largest known void has size of 163 Mpc making 5.3×10^8 ly which does not differ significantly from the size $8 \times 6.5 \times 10^8$ ly of CMB void. The distance is 201 Mpc making about 6.5×10^8 ly and roughly by a factor 1/22 smaller than CMB void.

Is it only an accident that the size of CMB void is same as that for largest large void? If large voids follow the cosmic expansion in a continuous manner, the size of the CMB void should be roughly 1/22 time smaller. Could it be that large voids might follow cosmic expansion by rather seldomly occurring discrete jumps? TGD inspired quantum astrophysics indeed predicts that expansion occurs in discrete jumps [K79].

The explanation of CMB void

Concerning the explanation of CMB void one can consider two options.

1. p-Adic evolution of cosmological constant as explanation for the constancy of the void size

If the large CMB void is similar to the standard large voids it should have emerged much earlier than these or the durations of constant value of v_0 could be rather long so that also the nearby large voids should have existed for a very long time with same size. Even in the case that all values of k corresponds to possible p-adic length scales characterizing effective Λ it is possible that no transitions reducing effective Λ have occurred during the time interval considered.

The constancy of the size of the large void during the time interval considered is predicted by other experimental findings. As already found, there is empirical evidence that cosmological constant has remained constant during last 8 billion years at least and the observed jerk suggests that this kind of phase transition has occurred for 13 billion years ago. This would predict that large voids have had the same size between 13 and 8 billion years.

2. Are fractally scaled up variants of large voids possible?

One can also consider the possibility that CMB void is a fractally scaled up variant of large void. The p-adic length scale of the CMB void would be $L_p \equiv L(k)$, $p \simeq 2^k$, $k = 263$ (prime). If it has participated cosmic expansion in the average sense its recent p-adic size scale would be about $16 < 22$ times larger and p-adic scale would be $L(k)$, $k = 271$ (prime). This explanation has no obvious connection with the empirical findings about the behavior of cosmological constant and does not therefore look promising.

4.4.5 Could Many-Sheeted Cosmology Explain The Claimed Time Dependence Of The Fine Structure Constant?

There is recent evidence for the time dependence of the fine structure constant in cosmological time scales [E167]. The spectroscopic observations of a number of absorption systems in the spectra of distant quasars indicate a smaller value of α in the past. The comparison of the ratios of the frequencies for relativistic atomic transitions depending non-linearly on α^2 gives the average value $\Delta\alpha/\alpha = -0.72 \pm .18 \times 10^{-5}$ in the red shift range $z = .5 - 3.5$.

On the other hand, the data about the isotopic abundances in Oklo natural reactor which operated at 1.8×10^9 years ago gives the upper bound $\Delta\alpha/\alpha \leq 10^{-7}$ [E73]: this corresponds to the red shift $z = .13$. This suggests an abrupt change of the fine structure constant in the range $.13 < z_0 \leq .5$.

A further important piece of data is about type Ia super-novae in distant galaxies. These data have extended the Hubble diagram to red shifts $z \geq 1$ [E153]. The data imply an accelerated expansion of the universe in the framework of standard cosmology requiring the introduction of cosmological constant and vacuum energy density of unknown origin. More recent measurements have measured no variation [E116]. Despite this it is an interesting exercise to see whether the variation might have some explanation in TGD framework.

The notion of the many-sheeted cosmology might explain the apparent acceleration of the cosmological expansion. The notion of the many-sheeted space-time could also explain the apparent time variation of the fine structure constant as the following arguments tend to demonstrate.

Classical model based on many-sheeted space-time

Assume that new space-time sheets with size determined by the p-adic length scale $L(k)$ emerge at values $t \sim L(k)$ of the time coordinate during the cosmological evolution. It is also assumed that the proper description of atoms involves in an essential manner the concept of classical em field. This is indeed the case in TGD framework but not for the Bether-Salpeter equation relying on correlation functions and the abstraction of the basic features of perturbative QED.

1. The basic idea is that atomic nuclei need not feed their entire electric gauge fluxes to the atomic space-time sheet, which presumably corresponds to $p \simeq 2^k$, $k = 131$ or $k = 137$, but can feed a small fraction of the electric flux also to the larger space-time sheets. The simplest assumption is that each new cosmological space-time sheet receives a constant fraction of the existing nuclear gauge charge. Stability requirement suggests that also each electron feeds a negative fraction of its electric flux to the larger space-time sheet so that an overall charge neutrality is preserved. The fraction must be negative to guarantee that the nuclear and electronic charges effectively increase in magnitude when new larger space-time sheets emerge during the cosmological evolution. Negative fraction is favored also by the fact that the effective nuclear charge would otherwise approach zero in the sufficiently distant geometric future. The effect corresponds to an apparent renormalization of the fine structure constant having nothing to do with the ordinary QED renormalization or the renormalization of the fine structure constant suggested by the p-adic coupling constant evolution.

2. The experimental findings suggest that the distribution of the electric gauge fluxes between different space-time sheets could have changed in some abrupt manner during the period $.16 < z_0 < .5$. The lower bound follows from the fact that Oklo natural reactor data are consistent with the laboratory value of the effective fine structure constant. Assume that this abrupt change corresponds to the emergence of a new space-time sheet at $z = z_0$ taking a negative fraction of order $\epsilon \sim -10^{-5}$ of the nuclear and electronic gauge fluxes so that the effective nuclear and electronic charges increase correspondingly in magnitude. More generally, assume that this occurs for all values of cosmic time $t(k) \sim L(k)$ corresponding to p-adic length scales.

3. If the p-adic length scale L_p appears at $t = a \simeq L_p$ then p-adic length scales appear at $a(k_n) = 2^{(k_n-k_0)/2}a_{k_0}$. The effective fine structure constant is predicted to be constant inside intervals $[a(k_n), a(k_{n-1})]$. The minimum value for the increment of k_n is $\Delta k = k_n - k_{n-1} = 2$ and corresponds to a variation of a by single octave and to a pair of twin primes $k_n = k_{n-1}+2$. This predicts the constancy of the effective fine structure constant after $z = z_0$ in accordance with the experimental facts. If $z_0 = a_{now}/a_0 - 1$ corresponds to the first abrupt change in the range $.13 < z_0 < .5$ then for $\Delta k = 2$ another abrupt change would occur at $z_1 = 2z_0 + 1$, $1.26 < z_1 < 3$. If each space-time sheet receives the same amount of electric flux, one has $\Delta[log(\alpha\ )\ ]\ (\mathrm{z}_1) \simeq 2\Delta[log(\alpha)](z_0)$, which is excluded in the range considered. For $\Delta k = 4$ the next abrupt change would correspond to $z_2 = 4z_0 + 3$: $3.52 < z_2 < 5$. Unfortunately, this value of z is slightly above the range studied in [E168]. For $\Delta k = 6$ one would have $z_3 = 8z_0 + 7$, $8 < z_3 < 11$.

4. The negative em flux which is fraction of order $\epsilon \sim -10^{-5}$ of nuclear electromagnetic charge flowing to single space-time sheet does not lead to any inconsistencies since the number of the primary p-adic length scales between atomic length scale and cosmological length scales is only 45. Therefore the total variation between $a = a_{now} \sim 10^{10}$ years and $a = 10^7$ years (this is the range probed by the cosmic microwave background) would correspond to something like five p-adic length scales for $t = a$ and the predicted net variation in the red shift interval $.13 < z < 10^3$ would not be larger than $\Delta[log(\alpha)] \sim 10^{-4}$ if each p-adic space-time sheet receives the same amount of the electric flux.

Note that this model might be seen as a topological and microscopic version of the Bekenstein's field theory model [E188] based on the assumption that fine structure constant is a slowly varying scalar field Φ having naturally the needed linear coupling to the Maxwell action. In [E73] it was suggested that Φ could correspond to the so called quintessence field believed to give rise to cosmological vacuum energy and that Bekenstein's model could explain the observed variation of the fine structure constant. Note that in many-sheeted cosmology charge conservation is not lost although the effective fine structure constant depends on cosmological time.

Could hierarchy of Planck constants be involved?

The introduction of hierarchy of Planck constants [K42, K81] suggests also mechanisms based on charge fractionization and change of Planck constant from its standard value.

Fine structure constant is proportional to $1/\hbar$. In the lowest order perturbative QED the predictions are more or less same as the predictions of classical theory and do not depend at all on $\hbar$. Radiation corrections appear in higher orders in powers of α, and would allow to deduce the value of $\hbar$ associated with the dark matter system. The possibility that the value of $\hbar/\hbar_0$, which is rational number, has changed a little bit in past for what we regard as visible matter does not however look very plausible.

One can imagine also another effect related to the hierarchy of Planck constants.

1. The pages of the book like structures associated with causal diamond CD and CP_2 are labeled by integers n_a and n_b characterizing the cyclic group associated with the singular covering or factor space defining the page. Both n_a and n_b could make themselves visible physical if the Kähler gauge potential has a pure gauge part ΔA in both CD and CP_2 degrees of freedom (with g_K included as scaling factor so that ΔA has dimension of $\hbar$) [K81]. This would give a fractional shift to both spin and color hyper charge and color isospin.

2. Since the holonomy group of CP_2 identifiable as electro-weak gauge group corresponds in natural manner to the $U(2)$ subgroup of color group, the interpretation of the anomalous color hyper charge and color isospin in terms of anomalous weak isospin and hyper charge can be considered.

3. This contribution to the charge in units of $\hbar_0$ would be of form $(a\Delta A_\psi + b\Delta A_\Phi)/\hbar_0$, where Ψ and Φ denote the phases assignable to the complex coordinates of CP_2 transforming linearly under $U(2)$. For a page of CP_2 book, which corresponds to a singular covering characterized by integer n_b, the physically most plausible scenario would give $\Delta A_\Psi = \Delta A_\Phi = \hbar_0/n_b$ for coverings so that for coverings em charge would be shifted by $1/n_b$ units. For singular factor spaces formal guess would be $\Delta A_\Psi = \Delta A_\Phi = \hbar_0 n_b$. One can argue that ΔA can be eliminated by a global gauge transformation: this transformation however induces a phase into induced spinor field giving rise to anomalous charge. This fractionization means a shift of the charge so that even neutrino would receive a small fractional em charge. Nothing prevents from asking whether this kind of fractionization could actually take place and seeing the trouble of demonstrating that it cannot be involved with the claimed anomaly.

Could cosmos have North-South axis: How?

Wes Johnson told about very interesting observations suggesting that cosmology has North-South (N-S) axis in the sense that fine structure constant has N-S variation with respect to this axis. The popular article is at `http://tinyurl.com/yct36gff`. Here is the abstract of the article of Webb *et al* [E169] (`https://tinyurl.com/ycpo4kcv`).

Observations of the redshift $z = 7.085$ quasar J1120+0641 are used to search for variations of the fine structure constant, a, over the redshift range 5.5 to 7.1. Observations at $z = 7.1$ probe the physics of the universe at only 0.8 billion years old. These are the most distant direct measurements of a to date and the first measurements using a near-IR spectrograph. A new AI analysis method is employed. Four measurements from the X-SHOOTER spectrograph on the Very Large Telescope (VLT) constrain changes in a relative to the terrestrial value (α_0). The weighted mean electromagnetic force in this location in the universe deviates from the terrestrial value by $\Delta\alpha/\alpha = (\alpha_z - \alpha_0)/\alpha_0 = (-2.18 \pm 7.27) \times 10^{-5}$, consistent with no temporal change. Combining these measurements with existing data, we find a spatial variation is preferred over a no-variation model at the 3.9 σ level.

To repeat: the difference from earthly value of α is small and consistent with no temporal change. If the measurements are combined with existing data, one finds that the model assuming spatial variation in north-south direction is preferred over no-variation model at 3.9 sigma level.

The presence of N-S direction looks very strange and counterintuitive and the effect might disappear: there are many uncertainties involved since data from several experiments are combined. If the effect is real, there is challenge to understand it so that one cannot avoid the temptation for intellectual exercise.

In TGD framework many-sheeted space-time serves as a starting point.

1. The notion of space-time sheet requires that the M$^4 projectionofspace - timesurfacesis4 - D : Icallthesespace{-}timesheetsEinsteinian.Thiswasnottrueinprimordialcosmologyduringwhichcosmicst$
DM^4 projection dominated (2-D in good approximation) - space-time was not Einsteinian yet. During the analog of inflationary period cosmic strings thickened to flux tubes and liberated energy giving rise to ordinary particles. Transition to radiation dominated cosmology took place during this period.

2. The fluctuations in the density of matter tell that this transition did not take at exactly the same value of cosmic time T but there are fluctuations of order $/T \simeq 10^{-5}$. This happens to be same order of magnitude as the reported value of $\Delta\alpha/\alpha$ along North-South direction, which puts bells ringing. Could same cosmic parameter determine fluctuation amplitude $/T$ and the relative change $\Delta\alpha/\alpha$ along N-S direction?

   Could it be that the transition to radiation dominated cosmology took place in a wave propagating in North-South (N-S) direction so that there would be a gradient of T along N-S direction: $/T$ - not fluctuation. This does f not require gradient in fluctuations $\Delta T/T$ and $\Delta\rho/\rho$. Could this gradient also explain the gradient in measured α along N-S direction?

How the N-S gradient in α could be understood?

1. At QFT limit particle experiences the sum of induced gauge fields assignable to the space-time sheets which it necessarily touches because it has same size of order CP_2 size as the sheets on top of each other in CP_2 directions. Standard model gauge fields can be indeed defined as sums of these induced gauge fields. Same applies to gravitational field identified in terms of metric of Einsteinian space-time having 4-D M^4 projection.

2. The many-sheeted space-time was not quite the same thing in today and in ancient universe. The number of space-time sheets could have been different. Space-time sheets carried also induced classical fields with different strength.

   Monopole flux tubes created during the analog of inflationary period from cosmic strings indeed evolve during cosmic evolution. Their thickness increases in rapid jerks and in average sense this corresponds to a smooth cosmic expansion. This conforms with the fact that astrophysical objects do not seem to expand themselves in cosmic expansion although they co-move as particles in this expansion.

   The increase of the thickness of monopole magnetic flux tube reduces its magnetic field strength since monopole flux is conserved. This in turn reduces the contribution of this space-time sheet to the classical em field experienced by a charged particle. In particular, this would affect the binding energies of atoms slightly.

3. Could this together with the wave like progression of the transition to radiation dominated cosmology be responsible for the dependence α on N-S direction with the increase $\Delta\alpha/\alpha \simeq 10^{-5}$?

4.4.6 The Problem Of Fermion Families

The generation-genus correspondence implies that the number of the particle families is apparently infinite. The arguments developed in the second part of the book however suggest that $g > 2$ particle families have masses of order $m_0 \sim 10^{-3.5} m_{Pl}$ except possibly at the very early stages of the cosmology in the vapor phase. One should somehow understand how the effective number of particle families manages to be finite and whether very early TGD inspired cosmology allows infinite number of light particle families. In the following I shall consider the possibility that the existence of the vapor phase might provide solutions to this problem.

Without additional constraints TGD predicts infinite number of particles families (both bosonic and fermionic) since each boundary topology characterized by the handle number corresponds to a separate elementary particle. On the other hand, GRT based cosmology poses stringent bounds on the number of the fermion families. The number of the light fermion families is generally believed to be not larger than 3 or 4. In TGD the problem is even more acute if all elementary particles are massless in the vapor phase.

The original proposal for the solution of the problem was based on the following arguments.

1. The masses $M(g)$ of the topologically condensed elementary fermions increase as a function of the genus of the boundary component. In particular, higher genus neutrinos are (very) massive. The properties of the elementary particle vacuum functionals suggest that condensed $g > 2$ particle families have masses of order CP_2 mass.

2. Massive condensed fermions with mass $M(g)$ begin to decay at temperature $T \simeq M(g)$. If $M(g)$ increases sufficiently rapidly the number $N(a)$ of the effectively massless fermions in the topological condensate is always finite due to the decay of the massive fermions. The temperature equals to the critical temperature $T_H \sim 1/R$ before $a = a_F \sim 10^{-11}$ *sec*. If the masses of the higher fermion families are larger than T_H, their contribution to the mass density is exponentially suppressed and they are effectively absent from cosmology. Thus the number of fermion families is effectively finite and equal to three if the argument based on elementary particle vacuum functionals holds true.

3. Massless fermions could be present in vapor phase but their fraction of energy density is presumably negligible since vapor phase is expected to be in zero temperature.

It has turned out [K26] that under very general conditions the number of fermion families is three. The idea is that the property of being fermion has some space-time correlate. There are reasons to believe that this correlate is Z_2 conformal symmetry for the corresponding partonic 2-surfaces. This symmetry implies that fermionic elementary particle vacuum functionals vanish identically for $g > 2$. This holds true also for gauge bosons which can be regarded as fermion anti-fermion pairs associated with the light-like throats of wormhole contact. The argument is represented in detail in [K26].

4.4.7 The Redshift Anomaly Of Quasars

There are strange findings about the time dilation of quasar dynamics challenging the standard cosmology [E203]. One expects that the farther the object is the slower its dynamics looks as seen from Earth. Lorentz invariance implies red shift for frequencies and in time domain this means the stretching of time intervals so that the evolution of distant objects should look the slower the longer their distance from the observer is. In the case of supernovae this seems to be the case. What was studied now were quasars at distances of 6 and 10 billion years and the time span of the study was 28 years [E222]. Their light was red shifted by different amounts as one might expect but their evolution went on exactly the same rhythm. This looks really strange.

One must notice that the frequency assigned to electromagnetic signature is not ordinary light frequency. For instance, is it analogous to a frequency assignable to massive particle or massless particle? Consider ordinary Doppler effect as an analog. If the redshift is effectively that of a massive particle then the redshift is given by $f \rightarrow (1-v^2)^{1/2}f = (1+z)f$ and for small relative velocities the redshift is about $z = \Delta f/f = v^2$ smaller than for massless case $f \rightarrow ((1-v)/(1+v))^{1/2} \times f = zf$ giving $z = \Delta f/f = v$ in the same approximation. In the recent case however redshifts are large. From $z+1 = Hr$, with redshift $z = 7$ associated with $r = .75$ billion years one deduces $z = 56$ for 6 billion ly and $z = 93.3$ for 10 billion ly. Therefore the redshifts for massive and massless case are related by a factor of 2 as one easily finds.

Consider now the situation in TGD framework.

1. Causal diamond defined as the intersection of future and past directed light-cones is the fundamental geometric object in zero energy ontology. In cosmological scales a possible interpretation of CD is as sub-cosmology. In particular, our comology would correspond to this kind of CD having sub-CD s having.... CDs possess moduli space. CD has M^4 position identified as say that of the lower tip. One can perform Lorentz boosts for CD leaving the lower tip invariant. The proper time distance between tips of CD is Lorentz invariant and defines an internal time standard of CD. For instance, for electron, d, and u quarks this time is.1 seconds, 1/1.28 milliseconds, and 6.5 milliseconds corresponding to masses.5 Mev, 5 MeV, and 2 MeV [C11].These time scales define fundamental biorhythms [K87].

2. p-Adic length scale hypothesis follows if the light-cone proper time distance between the tips of the CD is quantized in powers of two. This means that future light-cone is replaced with a union of light-cone proper time constant hyperboloids with size scales coming as powers of two. Cosmic time in quantum cosmology identified as the distance between the tips would be quantized and cosmic time would increase in jumps. As a matter fact, the relative coordinate between the tips should be quantized quite generally so that the light-cone proper time constant hyperbloids would be replaced with discrete lattice like structures. This would predict quantization of cosmic redshifts and explain the claimed strange phenomena like God's fingers containing galaxies along the line of sight with a quantized redshift.

3. Could the quantization of the cosmic time relate to the strange observation? What does the dynamics of objects with a frozen value of cosmic time look like when viewed from Earth? What is clear that the distant object does not recede away during the studied evolution period. The overall redshift for the studied events during its evolution is same. No dilation of the time interval between periodic events would takes place. But isn't this the case in good approximation also in the measurements? And obviously this argument does not say anything about the time dilations associated with the samples at different distances.

4. Let us make a second trial. The above idea that the observed system behaves like a particle would make sense at the level of sub-CD assignable to it. One can perform Lorentz boosts to the CD and from the point of view of observer this induces a dilation of the time scales of internal dynamics expressible as fractions of the proper time distance between its tips. Should one speak about two kinds of redshifts: the cosmic redhift associated with all radiation coming from the CD and the internal redshift associated the dynamics of CD. The observations about supernovae would suggests that cosmic expansion implies CDs of distant objects have systematically suffered a radial Lorentz boost in radial direction in the manner dictated by Hubble's law.

   This means that the time-like direction defined by the vector connecting tips of CD in M^4 is same as the time direction in co-moving system thus a time-like vector pointing from the tip of the very big CD defining what we call our Big Bang cosmology at this moment to the M^4 point at which the CD containing astrophysical object is located. This position characterizes all points of given CD so that the time dilation is same the for internal dynamics inside the CD.

5. Why the Lorentz boosts of quasar CDs in the two samples should be identical? Could the explanation relate to the fact that quasars are extremely distant objects meaning that the corresponding CDs are very large? Could the quasars in the two samples belong to the same CD?! If so then the internal dynamics would obey same rhythm but there would be a purely cosmological redshift! This effect would be basic prediction of zero energy ontology in cosmological scales and would become visible in very long length scales.

4.5 Matter-Antimatter Asymmetry, Baryo-Genesis, Lepto-Genesis, And TGD

The generation of matter-antimatter asymmetry is still poorly understood. There exists a multitude of models but no convincing one. In TGD framework the generation of matter-antimatter asymmetry can be explained in terms of cosmic strings carrying dark energy identified as Kähler magnetic energy. Their decay to ordinary and dark matter would be the analog for the decay of the inflaton field to matter and the asymmetry would be generated in this process. The details of the process have not been considered hitherto.

The stimulus for constructing a general model for this process came from attempt to understand the notion of sphaleron [B7] claimed to allow a non-perturbative description for a separate non-conservation of baryon and lepton numbers in standard model. The separate non-conservation of B and L would make possible models of baryo-genesis and even lepto-genesis assuming that in the primordial situation only right-handed inert neutrinos are present. To my opinion these models however fail mathematically because they equate the non-conservation of axial fermion numbers - which is on a mathematically sound basis - with the non-conservation of fermion numbers. This kind of assumption is unjustified and to my opinion is misuse of the attribute "non-perturbative".

The basic vision about lepto-genesis followed by baryo-genesis is however very attractive. This even more so because right-handed neutrino is in a completely unique role in TGD Universe. The obvious question therefore is whether this vision could make sense also in TGD framework. It would be wonderful if cosmic strings - infinitely thin Kähler magnetic flux tubes carrying magnetic monopole field, which later develop finite sized and expanding M^4 projection - carrying only right-handed neutrinos were the fundamental objects from which matter would have emerged in a way analogous to the decay of vacuum expectations of instanton fields. Even better, Kähler magnetic energy has interpretation as dark energy and magnetic tension gives rise to the negative "pressure" inducing accelerated expansion of the Universe.

The basic question is whether B and L are conserved separately or not. In TGD Universe one can consider two options depending on the answer to this question. For option I - the "official" version of TGD - quarks and leptons correspond to opposite 8-D chiralities of the induced spinor fields and B and L are conserved separately. For option II [K28] only leptonic spinor fields would be fundamental, and the idea is that quarks could be fractionally charged leptons. This option could lead to genuine baryo-genesis, and in the simplest model baryons would be generated from 3-leptons as 3-sheeted structures for which fractionization of color hyper-charge occurs. Leptonic embedding space spinors moving in triality zero color partial waves would be replaced with triality ± 1 partial waves assigned with quarks. Whether this replacement is on a mathematically sound basis, is far from obvious since induced spinor fields at space-time level would couple to induced spinor fields with leptonic couplings.

In any case, one can check whether leptogenesis, baryogenesis, and matter antimatter asymmetry are possible for either of both of these options. It turns out that for both option I and II one can construct simple model in terms for the generation of quarks from leptons via emission of lepto-quarks analogous to gauge bosons but differing from their counterparts in GUTs. Option II allows also genuine baryogenesis from leptons. The conclusion is that the "official" version of TGD predicting separate conservation of B and L allows an elegant vision about the generation of matter from cosmic strings containing only right-handed neutrinos in the initial states.

4.5.1 Background

A brief summary about conditions for the generation of matter-antimatter asymmetry and some of existing theories explaining it is in order.

Basic conditions for the generation of matter-antimatter asymmetry by baryon number generating interaction

The basic conditions for the generation of matter-antimatter asymmetry by baryon number generating interaction (see `http://tinyurl.com/62t6s6k`) [B2] were deduced by Saharov and are following.

1. Baryon number non-conservation.

2. C breaking and CP breaking. Matter-antimatter asymmetry requires these symmetry breakings.

3. Thermal non-equilibrium which naturally corresponds to a phase transition. In a typical cosmological situation the reactions responsible for preserving thermal equilibrium become slower that the rate for the cosmological expansion so that the particles participating the reactions decouple from each other and from thermal equilibrium. Otherwise these reactions destroy matter-antimatter asymmetry.

Also scenarios in which baryon number and lepton number are conserved are possible - TGD in its standard form allows one such option. The basic idea is that the universe decomposes into regions dominated by matter or antimatter. If slight matter-antimatter asymmetries - necessarily of opposite sign - are generated in region and its environment, the annihilation of particles and antiparticles leads to a situation in which there is only matter or antimatter present in both regions. If cosmic strings correspond are carriers of dark energy decaying to dark matter, they correspond naturally to the regions, where the asymmetry is generated. These cosmic strings could correspond "big" cosmic strings (magnetic flux tubes) going through large voids or the strings containing galaxies like pearls in necklace along them [K31] [L3]. Cosmic strings would serve as seats of antimatter whereas the surrounding regions would contain matter. What is lacking is a more detailed view about how cosmic strings burn to ordinary and dark matter and the identification of an exact mechanism for the generation of matter-antimatter asymmetry.

Generation of matter-antimatter asymmetry in GUTs and standard model

Most of models for the generation of matter anti-matter asymmetry rely on GUT philosophy and give up the assumption about separate conservation of B and L so that these these theories are also theories of baryo-genesis (for the theories of baryo-genesis (see `http://tinyurl.com/ycbk6jjw`) see the article by Riotto [B13]). For GUTs the non-conservation is present at the level of action but there is also a proposal that standard model could accommodate the non-conservation non-perturbatively.

1. In a typical model B and L are not conserved separately. Only B-L is conserved (the convention is that proton has B=1, and electron L=1). B and L are defined as vectorial fermion numbers. Axial B and L are not conserved for massive fermions and Higgs mechanism leads to the massivation of a theory which is originally massless.

2. In GUTs one arranges quarks and leptons of given generation into same multiplet. This implies that B and L are not conserved separately whereas B-L is. The exchanges of lepto-quarks (gauge bosons) assumed to have mass of order 10^{-4} Planck masses (of order CP_2 mass) induce proton decay. No proton decays have been observed yet and this has led to a fine-tuning of the parameters of these theories to avoid too fast proton decay.

Some theoreticians believe that even standard model could allow to understand baryo-genesis and generation of matter-antimatter asymmetry. Instanton (see `http://tinyurl.com/3s5dphr`) [B5] and sphaleron (see `http://tinyurl.com/y8atcgwc`) [B7] (see also the introductory article about sphalerons (see `http://tinyurl.com/y8xf6uyr`) [B34] and conference slides (see `http://tinyurl.com/yamdws4a`) [B12] about instantons/sphalerons and possible new physics within standard model)are the key notions of this approach. Perturbative approach to standard model predicts that both vectorial and axial quark and lepton numbers are separately conserved for massless fermions. The non-conservation of B and L is claimed to have a non-perturbative origin. The picture is roughly following.

1. Axial fermion numbers are not conserved for massive fermions even when the mass results from Higgs mechanism. Non-conservation is due to the fact that axial gauge symmetries are not genuine symmetries quantum mechanically because the integration measure for the path integral is not invariant under the axial gauge symmetries for which left and right handed fermions have opposite gauge charges.

2. By using refined topological arguments one can express the divergence $D_\mu A^\mu$ (see http://tinyurl.com/y7ooddnf) for the axial fermion current in terms of so called instanton density for the gauge field [B3]. Each fermion family gives a similar contribution to the divergence. One can calculate the changes of axial fermion numbers for an instanton connecting two states as the integral of instanton density reducing to the difference of so called Chern-Simons charges for final and initial field configurations.

   A numerical study of the situation using lattice gauge theories is possible (see http://tinyurl.com/y7owcxko) [B25] and provides information about rates for the appearance of instantons. Axial B-L is still conserved because the divergence of axial current is same for all fermions. Anomaly argument does not however force the non-conservation vectorial B and L (briefly B and L) and perturbatively they are conserved: here the weakness of the standard model approach obviously lies.

3. As noticed, the notion of instantons is crucial for the approach. Instantons are solutions of pure YM field equations (without Higgs field) in 4-D Euclidian 4-sphere S^4 or Euclidian space E^4: the Wick rotation to M^4 is of course mathematically and physically questionable step. Instantons connected two field configuration characterized by different Chern-Simons charges. The change of the Chern-Simons charge is integer valued. One can say that instantons transform two topologically non-equivalent vacua to each other. The proposed interpretation is that instanton tranforms incoming Dirac sea so that filled vacancy representing fermion with definite handedness becomes superposition of a hole and filled vacancy (fermions of opposite handedness). This would lead to the non-conservation of axial fermion numbers. It is important to stress again that the fermion numbers are axial - not vectorial- and that fermion number non-conservation does not follow from the presence of instantons alone.

4. The notion of sphalerons is a related concept. Sphalerons are static but unstable solutions of YM equations in Euclidian space E^4 in presence of Higgs field and are interpreted as a signature for the phase transition leading to generation of baryons from leptons. Since in Euclidian metric time and space do not differ in any manner, one can interpret one of the spatial directions as time direction so that the situation becomes dynamical. Since there is a change of the sign of the Higgs vacuum expectation between diametrically opposite points of sphere S^3 at infinity, there is also a change of Higgs vacuum expectation in time direction. With a sufficient amount of good will one can say that sphaleron connects to in-equivalent local Higgs vacua. Sphaleron is hoped to give a simplified description of the situation, which might have something to do with reality.

5. The vision about non-perturbative breaking of baryon conservation has inspired models for the generation of matter-antimatter asymmetry and for how originally purely leptonic state generates baryons.

These models can be however criticized for sloppy mathematics.

1. The additional assumption that the change of the axial fermion number equals to the change of the vectorial fermion number is highly questionable and actually forces non-conservation of B and L by hand. To me this assumption looks like a misuse of the attribute "non-perturbative". This assumption can hold true only if one assumes that the fermionic handedness correlates with the sign of ΔQ_{C-S}. The instanton region would contain only left or right handed fermions depending on the sign of the integer characterizing instanton.

2. It is difficult to imagine what the non-conservation of (vectorial) B and L could mean in terms of particle reactions. Why not to be happy with what good mathematics gives: B and L are conserved and only axial fermion numbers fail to do so? This is perfectly natural since axial fermion numbers are opposite for right and left handed fermions. If this is accepted, baryogenesis and related generation of matter-antimatter asymmetry are impossible in standard model framework.

3. Also the allowance of anomalies in path integral measure is questionable. For instance, in super string models the basic condition selecting the various candidates is that anomalies are absent.

The idea that leptons could transform to baryons in or without presence of instantons and at the same time generate matter-antimatter asymmetry is very attractive, and one one can wonder whether one could find a more coherent theoretical framework allowing this. The most ambitious models based on a small modification of it assume the existence of inert right-handed neutrinos (for which there is some cosmological support). They would have been the only particles present during the primordial phase and would have have generated leptons, which in turn have generated baryons by instantons. This idea is especially interesting from TGD point of view since right-handed neutrinos are in completely exceptional role in TGD Universe and the phase consisting of them possesses 4-D generalization of conformal SUSY (much large symmetry algebra than ordinary super-conformal algebra of M^4) so that the generation of matter from right handed neutrinos would have interpretation as breaking of this gigantic super-conformal symmetry.

4.5.2 Could TGD Allow Matter-Antimatter Asymmetry And Baryo-Genesis?

What makes the idea about non-conservation of B attractive is that TGD allows two variants.

1. For Option I quarks and leptons correspond to different chiralities of H spinors. Chirality is now not M^4 chirality (handedness) but 8-D H-chirality. B and L are separately conserved and proton is stable against decays predicted by GUTs.

   A possible but rather weak objection is following. The naïve expectation is that various bosons come in two varieties. Vector bosons in 8-D sense would couple to 8-D vector currents and thus have same coupling to both quarks and leptons. Axial bosons in 8-D sense would couple to 8-D axial currents and have opposite couplings to quarks and leptons. Axial and vectorial bosons can of course mix but one would expect more bosons than observed (W bosons are vectorial in 8-D sense, photon and Z^0 couple are mixtures of axial and vector bosons, and gluons in TGD framework couple vectorially (also leptons are predicted to have colored excitations).

2. For Option II only leptons appear as fundamental fermions. Leptons instead of quarks are favored by the supersymmetry (actually super-conformal symmetry) generated by right-handed neutrinos. In fractional quantum Hall effect (FQHE) charge fractionization takes place and this inspires the question whether quarks inside hadrons could be leptons with fractional charge. I considered this already around 2005 as a side product of work with hyper-finite factors of type II_1 [K28].

   Charge fractionization would result from the replacement $Q_L \rightarrow Q_L - 1/3$ for antileptons. Lepton number would the only conserved quantity and quarks and baryons could result by a phase transition in which leptons would somehow transform to quarks or to baryons.

   This raises several questions. What charge fractionization means? What lepto-quarks could be? What is this phase transition?

Could the option assuming only leptonic spinors make sense?

The stability of proton supports Option I but since only lower bounds for proton lifetime can be deduced experimentally, one must be ready to consider also Option II.

1. One cannot deny the attractiveness of the idea that quarks could be fractionally charged variants of leptons. For this option the process leading to the generation of baryons would not break any conservation laws and the mathematically highly questionable anomalous path integral would not be needed. In fact, path integral over gauge fields is replaced with functional integral over 3-surfaces in TGD framework.

2. Right-handed neutrino behaves like inert neutrino and in TGD ν_R has a unique role. The reason is that the conservation of electric charge forces to assume that all fermions except purely right-handed neutrino are localized at 2-D surfaces, "string world sheets". Pure right-handed neutrino is de-localized at entire space-time sheets - which could be identifiable magnetic flux tubes assignable to elementary particles. ν_R can give rise to a SUSY, which is

however not the $\mathcal{N}=1$ SUSY considered usually - almost excluded at LHC at TeV energy scale. The reason is that 8-D spinors cannot be Majorana spinors (see http://tinyurl.com/y75omzhq) [B8]. Right-handed neutrino obeys also maximal super-conformal symmetry extending 2-D conformal symmetry to $D=4$ [K116] so that the generation of matter could be seen as a symmetry breaking.

3. One can indeed imagine a scenario in which right handed neutrinos mix with left-handed neutrinos localized at string world sheets. The weak interactions of left handed neutrinos (or actually mixtures of right and left handed neutrinos) would generate other leptons. Leptonic phase could in turn generate fractionally charged quarks (or baryons) and hadronization would lead to generation of baryons and other hadrons.

   This vision can be coupled with the earlier proposal for how matter-antimatter asymmetry is generated. Right handed neutrinos could reside at magnetic flux tubes representing cosmic strings and the process leading to generation of leptons and quarks would take place here.

What it could be to be a fractionally charged lepton?

For option I quark-like and leptonic spinors appear at both space-time level and embedding space level.

1. At space-time level one has second quantized induced spinor fields satisfying Kähler-Dirac equation. The condition that modes have well-defined electromagnetic charge together with the fact that classical W fields are present and mix different em charges implies that this condition can be satisfied only if the induced spinor fields are localized at 2-D surfaces - string world sheets. Right-handed neutrino is an exception and de-localized into entire space-time sheet. The functional integral over preferred extremals gives rise to a perturbative expansion in terms of fermionic propagators when one expresses the spinor modes as functionals of space-time sheet of preferred extremal [K116].

2. Embedding space spinors identified as leptonic and quark spinors differ in one aspect only. Their coupling to CP_2 Kähler gauge potentials is $n=-1$ for quarks and $n=3$ for leptons. Embedding space spinors can be assigned to the center of mass degrees of partonic 2-surfaces (or possibly the position of the tip of CD associated with fermion). Spinor modes represent the ground states for the representations of the symplectic algebra of $\Delta M^4_\pm \times CP_2$ and also for the representations of Kac-Moody algebra associated with isometries and deforming on the light-like orbits of partonic 2-surfaces at which the signature of the induced metric changes from Minkowskian to Euclidian.

   For leptons the spinor harmonics correspond to triality zero ($t=0$) color partial waves in CP_2. For quarks the spinor harmonics correspond to $t=\pm 1$ color partial waves. These modes do not correspond directly to the physical quarks and leptons. States with correct correlation between electro-weak and color quantum numbers are obtained by allowing the action of the colored generators of the symplectic algebra on the physical states. The state construction is represented in [K63].

At the space-time level, where the fundamental spinorial dynamics takes place, the coupling of fermions to the Kähler gauge potential must be unique. If only single fermionic chirality is present, it must be either $n=3$ or $n=-1$ and $n=3$ is favored by the possible SUSY generated by right-handed neutrino.

What about embedding space level? How could the above picture of option I change if one assumes that only leptonic spinors are present at the space-time level?

1. For Option I it is natural to assume that the induced space-time spinors correspond to embedding space spinors with the same chirality and same value of n. Could one loosen this correspondence? Could embedding space spinors, which are not second quantized, and are assigned to cm degrees of freedom, be associated with embedding space spinor having both $n=-1$ and $n=3$ for fermions.

(a) Are these two state basis orthogonal? Certainly not as CP_2 spinors. As vacua for WCW spinor fields this could be the case if there is some topological distinction between the 3-surfaces assignable with these state basis. The idea about fractionization of charges (color hyper-charge) suggests that for quark states the space-time surface are 3-valued maps of CP_2 to M^4 analogous to Riemann surface of $z^{1/3}$ so that a color hyper-charge rotation of 2π in CP_2 (say at homologically non-trivial geodesic sphere of CP_2 defining coordinates of the partonic 2-surface) does not lead to the original point and only the rotation by 6π does this. This would be an analog for spin fractionization. This could justify the use of quark spinor harmonics for the embedding space spinors.

(b) Could the two state basis be non-orthogonal and provide alternative state basis? Many-quark states can correspond to many-lepton states only if the differences $N_q - N_{\overline{q}}$ of numbers of quarks and antiquarks is a multiple of 3 so that the many-fermion state has triality $t = 0$. Color confinement is consistent with this condition and implies it. This option does not look attractive and will not be assumed in the sequel.

2. A serious problem is caused by the $n = -1$ coupling of the induced leptonic spinor fields. Internal consistency could quite well force the embedding space spinors to have the same coupling.

How leptons could transform directly to baryons for Option II?

If the direct transformation of leptons to quarks identified as fractionally charged leptons is possible, it must be non-perturbative in the sense that it involves several leptons and quarks simultaneously in order to satisfy the conservation of color and em charge. Since the resulting many quark state must have a vanishing triality, the number of quarks and therefore also leptons must be a multiple of 3. The simplest situation corresponds to a transformation of 3 leptons to 3 quarks forming a color singlet - perhaps identifiable as baryon.

The geometric view about color spin fractionization suggests that three leptonic space-time sheets defining 1-fold coverings of CP_2 fuse to from a 3-fold covering of CP_2 (so that M^4 coordinates are 3-valued as functions of CP_2 coordinates). The proposed explanation for the effective hierarchy of Planck constants $\hbar_{eff} = n\hbar$ is in terms of n-furcations of 3-surface: the recent case might correspond $n = 3$. Each sheet of the covering would carry lepton number 1. These 3-quark states would be only a special case of more general states containing $n = 1, 2$ or 3 quarks at the 3-sheeted structure.

In the process transforming 3 anti-leptons to baryon - say proton - one unit of em charge must be carried away and W^+ boson could do this. In the reverse process proton would decay to 3 leptons and W^- boson. $W^\pm$ boson must be virtual and absorbed by another particle so that weak interactions are also involved. The probability for this process must be very low, probably much lower than beta decay rate (I do not know whether possible decays of baryon to leptons and W boson have been studied). This means that the coupling for the fusion vertex must be very small.

If this picture is correct, the key non-perturbative element would be a phase transition changing the effective value of $\hbar$ to $3\hbar$. These phase transitions for large values of n are essential in the TGD inspired model of living matter. There is also a proposal that gravitons possess a very large value of $\hbar$ and decay to bursts of ordinary gravitons. This could explain the failure to observe gravitational waves [K79]. This mechanism forces to consider a geometric description of proton as a 3-sheeted structure presumably assignable to the magnetic body of proton.

It is too early to say whether this picture is consistent with the existing view about hadrons in which quarks space-time sheets are assumed to be connected by Kähler-magnetically charged color flux tubes. Also the question whether quarks understood as 3-sheeted structures containing only single quark could be allowed remains open. In any case, many-quark states must have triality zero so that quark number must be a multiple of 3.

Generation of matter-antimatter asymmetry without breaking the separate conservation of B and L

Cosmic strings dominate the TGD inspired cosmology [K94] during the primordial period after which a phase transition leading to radiation dominated cosmology takes place. The transformation of neutrinos to leptons inside cosmic strings which in turn decays to quarks and lepto-quarks which partially leak out from the system is an attractive mechanism for the generation of matter-antimatter asymmetry.

The mechanism to be discussed conserves B and L and thus works for option I. It works also for option II, if it makes sense to speak about quarks rather than only color singlet bound states of quarks formed as 3-sheeted structures with quark number 3, and treat quarks as independent objects. Many-quark states must however have quark number coming as a multiple of 3.

What can one say about the transformation of leptons to quarks by lepto-quark emission?

1. The charges of lepton and corresponding quark are different but this not a problem if one assumes the existence of lepto-quarks identified as gauge boson like states with quark (lepton with fractional charge) and lepton at opposite wormhole throats. For option I there is no reason why leptoquarks could not exist.

2. The most general assumption is that all possible combinations of quarks and leptons are allowed. Lepto-quarks qL and $\overline{q}\overline{L}$ have vanishing B-L for option I and vanishing L for option II: this makes them highly analogous to gauge bosons for option II. Lepto-quarks $q\overline{L}$ and $\overline{q}L$ have vanishing B+L for option I and have L=2 for option II. In the following only the option involving only qL and $\overline{q}\overline{L}$ is considered but the arguments generalize to the remaining cases trivially.

3. The transformation of antilepton to quark would take place by emission of lepto-quark $\overline{L}\overline{q}$ taking care of the conservation of various quantum numbers. The exchange of lepto-quarks is B and L conserving process and cannot lead to a decay of proton. It however predicts a new and presumably very slow decay channel for the decay of proton-antiproton pair to leptons.

   In the transformation $e^- \rightarrow \overline{u}$ a lepto-quark e^-u with charge $-1/3$ is emitted. In the transformation $e^- \rightarrow \overline{d}$ lepto-quark e^-d with charge $-4/3$ is emitted. More generally, $L \rightarrow \overline{q}$ proceeds via the emission of Lq type lepto-quark. Note that the lepton number of the lepto-quark vanishes for option II so that it represents an ordinary gauge boson with vanishing fermion number.

4. What happens to the emitted lepto-quarks? The lepto-quark can decay to $L + q$ so that the situation is the original one plus quark antiquark pair unless the lepto-quark has leaked outside the cosmic string. It the decay occurs inside cosmic strong, the process can continue and in principle single lepton or anti-lepton can generate a larger number of $q\overline{q}$ pairs. Kinematically these decays are not possible for ordinary on mass shell leptons but TGD allows the existence of scaled up copies of leptons, say leptons characterized by Mersenne prime M_{89} having mass scale about $2^{(127-89)/2}m_e \simeq 250$ GeV. These leptons could generate ordinary quarks through their decays.

5. This mechanism alone cannot generate matter-antimatter asymmetry. Suppose that the rates for the decays $\overline{L} \rightarrow q + \overline{L}\overline{q}$ are slightly lower than those for $L \rightarrow \overline{q} + qL$. A surplus of lepto-quarks Lq over $\overline{L}\overline{q}$ is generated. If there is a transfer of lepto-quarks Lq and their antiparticles from the interior of cosmic string to the environment and transfer rates are same, more Lq: s are transferred and their decays generate a net density of quark and lepton numbers in the environment. Inside cosmic string net density of opposite sign is generated by B and L conservation.

6. If the decay rate of lepto-quark is of order g^2M with M of order CP_2 mass, leakage is possible if the M^4 projection of the cosmic string is below $1/g^2M_{CP_2}$. Therefore the process could become active after the cosmic string dominated primordial period and could be associated with the phase transition from string dominated phase to radiation dominated phase during which space-time sheets corresponding to preferred extremals with large 4-D M^4 projection in the transversal scale of cosmic string emerge. Since the process conserves B and L separately, it could however take place also in much longer p-adic length scales.

   The masses of the lepto-quark could result from couplings to Higgs like bosons but the mass scale of the vacuum expectation value inside cosmic string corresponds to a rather small p-adic prime instead of M_{89} for weak interactions. Mersenne primes are the first guess for p-adic primes assignable to gauge bosons and $M_7 = 127$ is a reasonable guess for the p-adic prime during the transition to radiation dominated phases.

The conclusion is that lepto-quark mechanism works for both Option I and II and therefore Option II is not needed to understand generation of matter-antimatter asymmetry or even leptogenesis and baryogenesis. This does not of course mean that Option II would be necessarily excluded.

Generation of matter asymmetry accompanied with a genuine baryo-genesis for option II

One can also consider a generation of matter-antimatter asymmetry and baryo-genesis based on fusion of leptons to baryons by the proposed mechanism for the formation of baryons from anti-leptons at cosmic strings. If the rates for the fusion process are different for leptons and anti-leptons, a net density of baryon number is generated in environment.

Suppose that in the interior of cosmic string anti-leptons transform to baryons with a rate slightly higher that leptons to anti-baryons. As a consequence, the number densities of baryons and leptons become higher than those for anti-baryons and anti-leptons inside cosmic string. If the transfer rates for baryons and anti-baryons to environment are same, the outcome would be net density of baryon number in environment. The faster transfer of anti-leptons than leptons from environment to cosmic string induced by the larger density gradient would induce net density of lepton number in environment. As a consequence, opposite net densities of B and L in environment and interior of string would be generated.

Could all matter be generated from right-handed neutrinos at magnetic flux tubes?

The idea about leptogenesis (see `http://tinyurl.com/ychexeak`) [B24] initiated form right-handed neutrinos and followed by baryogenesis (see `http://tinyurl.com/62t6s6`) [B13] is highly attractive. TGD leads to the vision that matter and dark matter has been generated from dark energy identified as Kähler magnetic energy for magnetic flux tubes which have evolved from cosmic strings by the gradual thickening of M^4 projection [L3]. I have not yet considered any detailed model for this process.

Right-handed neutrino has a unique role in TGD framework [K116] and an attractive idea is that during primordial phase - and perhaps even at magnetic flux tubes evolved from them - the physics started from something extremely simple and symmetric: only magnetic flux tubes containing right-handed neutrinos. This situation would correspond to a 4-D extension of super-conformal symmetry [K116], and the emergence of string world sheets would reduce this 4-D to super-conformal symmetry to ordinary 2-D one. Other fermions localized at string world sheets would have emerged only after the mixing of right handed neutrino to mixtures of left and right handed neutrinos localized at string worlds sheets. Neutrinos in turn would decay to charged leptons and W bosons by weak interactions. The decay $L \rightarrow \overline{q} + Lq$ in turn would have generated baryons and matter-antimatter asymmetry for both options. For option II also the direct fusion of leptons to baryons or more general color singlet quark triplets could have occurred.

One should construct a model for the mixing of right- and left-handed neutrinos.

1. Mixing should reduce to fermionic propagation and be dictated by the dynamics of the Kähler-Dirac operator alone. The mixing amplitude would be obtained by calculating a transition amplitude between ν_R and ν_L located at partonic 2-surfaces at opposite ends of CD. This requires integration over CD inducing perturbation theory using fermionic propagator defined by the Kähler-Dirac action with coupling to WCW degrees of freedom via the gauge coupling to induced CP_2 spinor connection. ν_R propagates 4-dimensionally and the other leptonic modes only 2-dimensionally. Also the mixing of lepton generations induced by the mixing of the topologies of fermion number carrying partonic 2-surfaces must be taken into account.

2. The overall parameterization at the QFT limit would be in terms of a generalization of CKM matrix, which is known to be non-trivial and force also neutrino massivation in turn forcing mixing of the right- and left-handed neutrinos.

Conclusions

The cautious conclusion is that option I - that is the "official" version of TGD identifying quarks and leptons and two chiralities of embedding space spinors - leads to an elegant model for leptogenesis, baryogenesis, and generation of matter antimatter asymmetry and at the same time to a more detailed model for how the Kähler magnetic energy of magnetic flux tubes transforms to matter and dark matter. One cannot however exclude option II involving only leptons whose anyonic states would give rise to baryons.

4.6 Cosmic Evolution As Transformation Of Dark Energy To Matter

The proposed bubble option favored by the fact that Newtonian theory works so well inside planetary system favors bound state precessing solutions without nutation. These solutions are expected to be stable against dissipation. Small nutation around the equilibrium solution could explain the slow variation of the precession rate. The variation could be also caused by external perturbations. What is amusing from the mathematical point of view is that the model is analytically solvable and that the solution involves elliptic functions just as the Newtonian two-body problem does.

The model suggests a universal fractal mechanism leading to the formation of astrophysical and even biological structures as a formation of bubbles of ordinary or dark matter inside magnetic flux tubes carrying dark energy identified as magnetic energy of the flux tubes. In primordial cosmology these flux tubes would have been cosmic strings with enormous mass density, which is however below the black hole limit for straight strings. Strongly entangled strings could form black holes if general relativistic criteria hold true in TGD.

One must be very critical concerning the model since in TGD framework the accelerated cosmic expansion has several alternative descriptions, which should be mutually consistent. It seems that these descriptions corresponds to the descriptions of one and same thing in different length scales.

1. The critical and over-critical cosmologies representable as four-surfaces in $M^4 \times CP_2$ are unique apart from their duration [K94]. The critical cosmology corresponds to flat 3-space and would effectively replace inflationary cosmology in TGD framework and criticality would serve as a space-time correlate for quantum criticality in cosmological scales natural if hierarchy of Planck constants is allowed. The expansion is accelerating for the critical cosmology and is caused by a negative "pressure" basically due to the constraint force induced by the imbeddability condition, which is actually responsible for most of the explanatory power of TGD (say geometrization of standard model gauge fields and quantum numbers).

2. A more microscopic manner to understand the accelerated expansion would be in terms of cosmic strings. Cosmic strings [K31] expand during cosmic evolution to flux tubes and serve as the basic building bricks of TGD Universe. The magnetic tension along them generates a negative "pressure", which could explain the accelerated expansion. Dark energy would be magnetic energy.

   The proposed boiling of the flux tubes with bubbles representing galaxies, stars, ..., cells, etc.. would serve as a universal mechanism generating ordinary and dark matter. The model should be consistent with the Bohr orbitology for the planetary systems [K93] in which the flux tubes mediating gravitational interaction between star and planet have a gigantic Planck constant. This is the case if the magnetic flux tubes quite generally correspond to gigantic values of Planck constant of form $\hbar_{gr} = GM_1M_2/v_0$, $v_0/c < 1$, where M_1 and M_2 are the masses of the objects connected by the flux tube.

3. Even more microscopic description of the accelerated expansion would be in terms of elementary particles. In TGD framework space-time decomposes into regions having both Minkowskian and Euclidian signatures of the induced metric [K111]. The Euclidian regions are something totally new as compared to the more conventional theories and have interpretation as space-time regions representing lines of generalized Feynman diagrams.

The simplest GRT limit of TGD relies of Einstein-Maxwell action with a non-vanishing cosmological constant in the Euclidian regions of space-time [K111]: this allows both Reissner-Nordström metric and CP_2 as special solutions of field equations. The cosmological constant is gigantic but associated only with the Euclidian regions representing particles having typical size of order CP_2 radius. The cosmological constant explaining the accelerated expansion at GRT limit could correspond to the space-time average of the cosmological constant and therefore would be of a correct sign and order of magnitude (very small) since most of the space-time volume is Minkowskian.

This picture can be consistent with the idea that magnetic flux tubes which have Minkowskian signature of the induced metric are responsible for the effective cosmological constant if the magnetic energy inside the magnetic flux tubes transforms to elementary particles in a phase transition generating dark and ordinary matter from dark energy and therefore gives rise to various visible astrophysical objects.

4.7 The Origin Of Cosmic Rays

The origin of cosmic rays remains still one of the mysteries of astrophysics and cosmology. The recent finding of a super bubble (see http://tinyurl.com/o5pgkb4) [E199] emitting cosmic rays might cast some light in the problem.

4.7.1 What has been found?

The following is the abstract (see http://tinyurl.com/yb8t3beb) of the article published in Science [E95].

The origin of Galactic cosmic rays is a century-long puzzle. Indirect evidence points to their acceleration by supernova shockwaves, but we know little of their escape from the shock and their evolution through the turbulent medium surrounding massive stars. Gamma rays can probe their spreading through the ambient gas and radiation fields. The Fermi Large Area Telescope (LAT) has observed the star-forming region of Cygnus X. The 1- to 100-gigaelectronvolt images reveal a 50-parsec-wide cocoon of freshly accelerated cosmic rays that flood the cavities carved by the stellar winds and ionization fronts from young stellar clusters. It provides an example to study the youth of cosmic rays in a superbubble environment before they merge into the older Galactic population. The usual thinking is that cosmic rays are not born in states with ultrahigh energies but are boosted to high energies by some mechanism. For instance, super nova explosions could accelerate them. Shock waves could serve as an acceleration mechanism. Cosmic rays could also result from the decays of heavy dark matter particles.

The story began when astronomers detected a mysterious (see http://tinyurl.com/pou4b83)source of cosmic rays (see http://tinyurl.com/pou4b83) in the direction of the constellation Cygnus X [E84]. Supernovae happen often in dense clouds of gas and dust, where stars between 10 to 50 solar masses are born and die. If supernovae are responsible for accelerating of cosmic rays, it seems that these regions could also generate cosmic rays. Cygnus X is therefore a natural candidate to study. It need not however be the source of cosmic rays since magnetic fields could deflect the cosmic rays from their original direction. Therefore Isabelle Grenier and her colleagues decided to study, not cosmic rays as such, but gamma rays created when cosmic rays interact with the matter around them since they are not deflected by magnetic fields. Fermi gamma-ray space telescope was directed toward Cygnus X. This led to a discovery of a superbubble with diameter more than 100 light years. Superbubble contains a bright regions which looks like a duck. The spectrum of these gamma rays implies that the cosmic rays are energetic and freshly accelerated so that they must be close to their sources.

The important conclusions are that cosmic rays are created in regions in which stars are born and gain their energies by some acceleration mechanism. The standard identification for the acceleration mechanism are shock waves created by supernovas but one can imagine also other mechanisms.

4.7.2 Cosmic rays in TGD Universe?

In TGD framework one can imagine several mechanisms producing cosmic rays. According to the vision already discussed, both ordinary and dark matter would be produced from dark energy identified as Kähler magnetic energy and producing as a by product cosmic rays. What causes the transformation of dark energy to matter, was not discussed earlier, but a local phase transition increasing the value of Planck constant of the magnetic flux tube could be the mechanism. A possible acceleration mechanism would be acceleration in an electric field along the magnetic flux tube. Another mechanism is super-nova explosion scaling-up rapidly the size of the closed magnetic flux tubes associated with the star by $\hbar$ increasing phase transition preserving the Kähler magnetic energy of the flux tube, and accelerating the highly energetic dark matter at the flux tubes radially: some of the particles moving along flux tubes would leak out and give rise to cosmic rays and associated gamma rays.

1. The mechanism transforming dark energy to dark matter and cosmic rays

Consider first the mechanism transforming dark energy to dark matter.

1. The recent model for the formation of stars and also galaxies is based on the identification magnetic flux tubes as carriers of mostly dark energy identified as Kähler magnetic energy giving rise to a negative "pressure" as magnetic tension and explaining the accelerated expansion of the Universe. Stars and galaxies would be born as bubbles of ordinary are generated inside magnetic flux tubes. Inside these bubbles dark energy would transform to dark and ordinary matter. Kähler magnetic flux tubes are characterized by the value of Planck constant and for the flux tubes mediating gravitational interactions its value is gigantic. For a start of mass M its value for flux tubes mediating self-gravitation it would be $\hbar_{gr} = GM^2/v_0$, $v_0 < 1$ (v_0 is a parameter having interpretation as a velocity).

2. On possible mechanism liberating Kähler magnetic energy as cosmic rays would be the increase of the Planck constant for the magnetic flux tube occurring locally and scaling up quantal distances. Assume that the radius of the flux tube is this kind of quantum distance. Suppose that the scaling $\hbar \rightarrow r\hbar$ implies that the radius of the flux tube scales up as r^n, $n = 1/2$ or $n = 1$ ($n = 1/2$ turns out to be the sensible option). Kähler magnetic field would scale as $1/r^{2n}$. Magnetic flux would remain invariant as it should and Kähler magnetic energy would be reduced as $1/r^{2n}$. For both options Kähler magnetic energy would be liberated. The liberated Kähler magnetic energy must go somewhere and the natural assumption is that it transforms to particles giving rise to matter responsible for the formation of star.

   Could these particles include also cosmic rays? This would conform with the observation that stellar nurseries could be also the birth places of cosmic rays. One must of course remember that there are many kinds of cosmic rays. For instance, this mechanism could produce ultra high energy cosmic rays having nothing to do with the cosmic rays in 1-100 GeV rays studied in the recent case.

3. The simplest assumption is that the thickening of the magnetic flux tubes during cosmic evolution is based on phase transitions increasing the value of Planck constant in step-wise manner. This is not a new idea and I have proposed that entire cosmic expansion at the level of space-time sheets corresponds to this kind of phase transitions. The increase of Planck constant by a factor of two is a good guess since it would increase the size scale by two. In fact, Expanding Earth hypothesis having no standard physics realization finds a beautiful realization in this framework. Also the periods of accelerating expansion could be identified as these phase transition periods.

4. For the values of gravitational Planck constant assignable to the space-time sheets mediating gravitational interactions, the Planck length scaling like $r^{1/2}$ would scale up to black-hole horizon radius. The proposal would imply for $n = 1/2$ option that magnetic flux tubes having M^4 projection with radius of order Planck length primordially would scale up to blackhole horizon radius if gravitational Planck constant has a value GM^2/v_0, $v_0 < 1$, assignable to a star. Obviously this evolutionary scenario is consistent with with what is known about the relations ship between masses and radii of stars.

2. What is the precise mechanism transforming dark energy to matter?

What is the precise mechanism transforming the dark magnetic energy to ordinary or dark matter? This is not clear but this mechanism could produce very heavy exotic particles not yet observed in laboratory which in turn decay to very energetic ordinary hadrons giving rise to cosmic rays spectrum. I have considered a mechanism for the production of ultrahigh energy cosmic rays based on the decays of hadrons of scaled up copies of ordinary hadron physics [K68]. In this case no acceleration mechanism would be necessary. Cosmic rays lose their energy in interstellar space. If they correspond to a large value of Planck constant, situation would change and the rate of the energy loss could be very slow. The above described experimental finding about Cygnus X however suggests that acceleration takes place for the ordinary cosmic rays with relatively low energies. This of course does not exclude particle decays as the primary production mechanism of very high energy cosmic rays. In any case, dark magnetic energy transforming to matter gives rise to both stars and high energy cosmic rays in TGD based proposal.

3. What is the acceleration mechanism of cosmic rays or is there any such mechanism?

How cosmic rays are created by this general process giving rise to the formation of stars?

1. Cosmic rays could be identified as newly created matter leaking out from the system. Even in the absence of accelerating fields the particles created in the boiling of dark energy to matter, particles moving along magnetic flux tubes would move essentially like free particles whereas in orthogonal directions they would feel $1/\rho$ gravitational force. For large values of $\hbar$ this could explain very high energy cosmic rays. The recent findings about gamma ray spectrum however suggests that there is an acceleration involved for cosmic rays with energies 1-100 GeV.

2. One possible alternative acceleration mechanism relies on the motion along magnetic flux tubes deformed in such a way that there is an electric field orthogonal to the magnetic field in such a way that the field lines of these fields rotate around the direction of the flux tube. The simplest embeddings of constant magnetic fields allow deformations allowing also electric field [K57], and one can expect the existence of preferred extremals with similar structure. Electric field would induce an acceleration along the flux tube. If the flux tube corresponds to large non-standard value of Planck constant, dissipation rate would be low and the acceleration mechanism would be very effective.

   Similar mechanism might even explain the observations about ultrahigh energy electrons associated with lightnings at the surface of Earth: they should not be there because the dissipation in the atmosphere should not allow free acceleration in the radial electric field of Earth.

   Here one must be very cautious: the findings are based on a model in which gamma rays are generated with collisions of cosmic rays with matter. If cosmic rays travel along magnetic flux tubes with a gigantic value of Planck constant, they should dissipate extremely slowly and no gamma rays would be generated. Hence the gamma rays must be produced by the collisions of cosmic rays which have leaked out from the magnetic flux tubes. If the flux tubes are closed (say associated with the star) the leakage must indeed take place if the cosmic rays are to travel to Earth.

3. There could be a connection with supernovae although it would not be based on shock waves. Also supernova expansion could be accompanied by a phase transition increasing the value of Planck constant. Suppose that Kähler magnetic energy is conserved in the process. This is the case if the lengths of the magnetic flow tubes r and radii by $r^{1/2}$. The closed flux tubes associated with supernova would expand and the size scale of flux tubes would increase by factor r. The fast radial scaling of the flux tubes would accelerate the dark matter at the flux tubes radially.

   Cosmic rays having ordinary value of Planck constant could be created when some of the dark matter leaks out from the magnetic flux tubes as their expanding motion in radial direction accelerates or slows down. High energy dark particles moving along flux tube would leak out in the tangential direction. Gamma rays would be generated as the resulting particles interact with the environment. The energies of cosmic rays would be the outcome of acceleration process: only their leakage would be caused by it so that the mechanism differs in a decisive manner from the mechanism involving shock waves.

4. The energy scale of cosmic rays - let us take it to be about E=100 GeV for definiteness- gives an order of magnitude estimate for the Planck constant of dark matter at the Kähler magnetic flux tubes if one assumes that supernovae is producing the cosmic rays. Assume that electro-magnetic field equals to induced Kähler field (the space-time projection of space-time surface to CP_2 belongs homologically non-trivial geodesic sphere). Assume that E equals the cyclotron energy scale given by $E_c = \hbar eB/m_e$ in non-relativistic situation and by $E_c = \sqrt{\hbar eB}$ in relativistic situation. The situation is relativistic for both proton and electron now and at this limit the cyclotron energy scale does not depend on the mass of the charged particle at all. This means that same value of $\hbar$ produces same energy for both electron and proton.

   (a) The magnetic field of pulsar (see `http://tinyurl.com/y9uw4kae`) can be estimated from the knowledge how much the field lines are pulled together and from the conservation of magnetic flux: a rough estimate is $B = 10^8$ Tesla and will be used also now. This field is $2 \times 10^{12} B_E$ where $B_E = .5$ Gauss is the nominal value of Earth's magnetic field.

   (b) The cyclotron frequency of electron in Earth's magnetic field is $f_c(e) = 6 \times 10^5$ Hz in a good approximation and correspond to cyclotron energy $E_c = 10^{-14}(f_c/Hz)$ eV from the approximate correspondence $eV \leftrightarrow 10^{14}\ \ Hz$ true for $E = hf$. For the ordinary value of Planck constant electron's cyclotron energy would be for supernova magnetic field $B_S = 10^8$ Tesla equal to $E_c = 2 \times 10^{-2}(f_c/Hz)$ eV and much below the energy scale $E = 100$ GeV.

   (c) The required scaling $\hbar \rightarrow r\hbar$ of Planck constant is obtained from the condition $E_c = E$ giving in the case of electron one can write

$$r = (\frac{E}{E_c})^2 \times = \frac{B_E}{B_S} \times \frac{\hbar e B_E}{m_e^2} \quad .$$

   The dimensionless parameter $\hbar e B_E/m_e^2 = 1.2 \times 10^{-14}$ follows from $m_e = .5$ MeV. The estimate gives $r \sim 2 \times 10^{12}$. Values of Planck constant of this order of magnitude and even larger ones appear in TGD inspired model of brain but in this case magnetic field is Earth's magnetic field and the large thickness of the flux tube makes possible to satisfy the quantization of magnetic flux in which scaled up $\hbar$ defines the unit.

To sum up, large values of Planck constant would be absolutely essential making possible high energy cosmic rays and just the presence of high energy cosmic rays could be seen as an experimental support for the hierarchy of Planck constants. The acceleration mechanism of cosmic rays are poorly understood and TGD option predicts that there is no acceleration mechanism to search for.

4.8 Quantum Fluctuations In Geometry As A New Kind Of Noise?

The motivation for writing the original variant of this section came from the email of Jack Sarfatti. I learned that gravitational detectors in GEO600 experiment have been plagued by unidentified noise in the frequency range 300-1500 Hz [E209]. Craig J. Hogan has proposed an explanation in terms of holographic Universe [E76]. By reading the paper I learned that assumptions needed might be consistent with those of quantum TGD. Light-like 3-surfaces as basic objects, holography, effective 2-dimensionality, are some of the terms appearing repeatedly in the article. The model contains some unacceptable features such as Planck length as minimal wave length in obvious conflict with Lorentz invariance.

Towards the end of year 2015 I rewrote the article since I realized that the diffraction analog serving as the starting point in Hogan's model cannot be justified in TGD framework. Fortunately, diffraction can be replaced by diffusion emerging very naturally in TGD framework and finally allowing to understand how Planck length emerges from TGD framework, where CP_2 size is the fundamental length parameter.

4.8.1 The Experiment

Consider first the graviton detector used in GEO600 experiment. The detector consists of two long arms (the length is 600 meters)- essentially rulers of equal length. The incoming gravitational wave causes a periodic stretch of the arms: the lengths of the rulers vary. The detection of gravitons means that laser beam is used to keep record about the varying length difference. This is achieved by splitting the laser beam into two pieces using a beam splitter. After this the beams travel through the arms and bounce back to interfere in the detector. Interference pattern tells whether the beam spent slightly different times in the arms due to the stretching of arm caused by the incoming gravitational radiation. The problem of experimenters has been the presence of an unidentified noise in the range 100-1500 Hz.

The prediction of the article *Measurement of quantum fluctuations in geometry* by Craig Hogan [E76] is that holographic geometry of space-time should induce fluctuations of classical geometry with a spectrum which is completely fixed. Hogan's prediction is very general and - if I have understood correctly - the fluctuations depend only on the duration (or length) of the laser beam using Planck length as a unit. Note that there is no dependence on the length of the arms and the fluctuations characterize only the laser beam. Although Planck length appears in the formula, the fluctuations need not have anything to with gravitons but could be due to the failure of the classical description of laser beams. The great surprise was that the prediction of Hogan for the noise is of the same order of magnitude as the unidentified noise bothering experiments in the range 100-700 Hz.

In the following I will discuss Hogan's model and consider two alternative TGD based explanations for the observations (assuming that they are real).

4.8.2 Hogan's Theory

Let us try to understand Hogan's theory in more detail.

1. The basic quantitative prediction of the theory is very simple. The spectral density of the noise for high frequencies is given by $h_H = t_P^{1/2}$, where $t_P = (\hbar G)^{1/2}$ is Planck time. For low frequencies h_H is proportional to 1/f just like 1/f noise. The power density of the noise is given by t_P and a connection with poorly understood 1/f noise appearing in electronic and other systems is suggestive. The prediction depends only Planck scale so that it should very easy to kill the model if one is able to reduce the noise from other sources below the critical level $t_P^{1/2}$. The model predicts also the distribution characterizing the uncertainty in the direction of arrival for photon in terms of the ratio l_P/L. Here L is the length or beam of equivalently its duration. A further prediction is that the minimal uncertainty in the arrival time of photons is given by $\Delta t = (t_P t)^{1/2}$ and increases with the duration of the beam.

2. Both quantum and classical mechanisms are discussed as an explanation of the noise. Gravitational holography is the key assumption behind both models. Gravitational holography states that space-time geometry has two space-time dimensions instead of three at the fundamental level and that third dimension emerges via holography. A further assumption is that light-like (null) 3-surfaces are the fundamental objects.

Heuristic argument

The model starts from an optics inspired heuristic argument.

1. Consider a light ray with length L, which ends to aperture of size D. This gives rise to a diffraction spot of size $R = \lambda L/D$. The resulting uncertainty of the transverse position of source is minimized when the size of diffraction spot is same as aperture size: $R = D$. This

gives for the transverse uncertainty of the position of source $\Delta x = R = D = (\lambda L)^{1/2}$. The orientation of the ray can be determined with a precision $\Delta\theta = (\lambda/L)^{1/2}$. The shorter the wavelength the better the precision. Planck length is believed to pose a fundamental limit to the precision. The conjecture is that the transverse indeterminacy of Planck wave length quantum paths corresponds to the quantum indeterminacy of the metric itself. What this means is not quite clear to me.

2. The basic outcome of the model is that the uncertainty for the arrival times of the photons after reflection is proportional to

$$\Delta t = t_P^{1/2} \times (sin(\theta))^{1/2} \times sin(2\theta) \ ,$$

where θ denotes the angle of incidence on beam splitter. In normal direction Δt vanishes. The proposed interpretation is in terms of Brownian motion for the distance between beam splitter and detector the interpretation being that each reflection from beam splitter adds uncertainty. This is essentially due to the replacement of light-like surface with a new one orthogonal to it inducing a measurement of distance between detector and bean splitter.

This argument has some aspects which I find questionable.

1. The assumption of Planck wave length waves is certainly questionable. The underlying assumption is that it leads to the classical formula involving the aperture size which is eliminated from the basic formula by requiring optimal angular resolution. One might argue that a special status of waves with Planck wave length breaks Lorentz invariance but since the experimental apparatus defines a preferred coordinate system this ned not be a problem.

2. Unless one is ready to forget the argument leading to the formula for $\Delta\theta$, one can argue that the description of the holographic interaction between distant points induced by these Planck wave length waves in terms of aperture with size $D = (l_P L)^{1/2}$ (of order proton Compton length for $L = 10^4$ meters) should have some more abstract physical counterpart.

   Could elementary particles as extended 2-D objects (as in TGD) play the role of ideal apertures to which a radiation with Planck wave length arrives? In this case L would be optimized. If one gives up the assumption about Planck wave radiation the uncertainty increases as λ. To my opinion one should be able to deduce the basic formula without this kind of argument.

   Could Planck length correspond ib TGD framework to the uncertainty for the position of the fermion lines associated with the generalized Feynmann graphs defined by light-like orbits of wormhole throats?

Argument based on Uncertainty Principle for waves with Planck wave length

Second argument can do without diffraction but still uses the highly questionable Planck wave length waves.

1. The interactions of Planck wave length radiation at null surface at two different times corresponding to normal coordinates z_1 and z_2 at these times are considered. From the standard uncertainty relation between momentum and position of the incoming particle one deduces uncertainty relation for transverse position operators $x(z_i)$, i=1, 2. The uncertainty comes from uncertainty of $x(z_2)$ induced by uncertainty of the transverse momentum $p_x(z_i)$. The uncertainty relation is deduced by assuming that $(x(z_2) - x(z_1)/(z_2 - z_1)$ is the ratio of transversal and longitudinal wave vectors. This relates $x(z_2)$ to $p_x(z_i)$ and the uncertainty relation can be deduced. The uncertainty increases linearly with $z_2 - z_1$. Geometric optics is used to describe the propagation between the two points and this should certainly work for a situation in which wavelength is Planck wavelength if the notion of Planck wave length wave makes sense. From this formula the basic predictions follow.

2. Hogan emphasizes that the basic result is obtained also classically by assuming that light-like surfaces describing the propagation of light between ends points of arm describe Brownian like random walk in directions transverse to the direction of propagation. Does this mean that Planck wave length wave is not absolutely necessary for this approach.

I admit that I find it difficult to follow the arguments.

Description in terms of equivalent gravitonic wave packet

Hogan discusses also an effective description of holographic noise in terms of gravitational wave packet passign through the system.

1. The holographic noise at frequency f has equivalent description in terms of a gravitational wave packet of frequency f and duration $T = 1/f$ passing through the system. In this description the variance for the length difference of arms using standard formula for gravitational wave packet is given by

$$\frac{\Delta l^2}{l^2} = h^2 f \ ,$$

where h characterizes the spectral density of the gravitational wave. This is extremely small number requiring l to be macroscopic length so that amplification from Planck lengths takes place.

2. For high frequencies one obtains

$$h = h_P = (t_P)^{1/2} \ .$$

3. For low frequencies the model predicts

$$h = \frac{f_{res}}{f}(t_P)^{1/2}.$$

Here f_{res} characterized the inverse residence time in detector and is estimated to be about 700 Hz in GEO600 experiment.

4. The predictions of the theory are compared to the unidentified noise in the frequency range 100-600 Hz which introduces amplifying factor varying from 7 to 1. The orders of magnitude are same.

4.8.3 TGD Based Model

Planck length as a minimal wavelength is in sharp conflict with Lorentz invariance. This is the fatal failure of the model for the claimed noise relying on diffraction as analog phenomenon. TGD approach suggests that diffusion in degrees of freedom transversal to light-orbits of partonic 2-surfaces representing particle orbits is a more promising analogy to start with.

Some background

Consider first the general picture behind the TGD inspired model.

1. What authors emphasize can be condensed to the following statement: *The transverse indeterminacy of Planck wave length seems likely to be a feature of 3+1 D space-time emerge is as a dual of quantum theory on a 2+1-D null surface.* In TGD light-like 3-surfaces indeed are the fundamental objects and 4-D space-time surface is in a holographic relation to these light-like 3-surfaces. The analog of conformal invariance in light-like radial direction implies that partonic 2-surfaces are actually basic objects in short scales in the sense that one 3-dimensionality only in discretized sense.

2. Both the interpretation as almost topological quantum field theory, the notion of finite measurement resolution, number theoretical universality making possible p-adicization of quantum TGD, and the notion of quantum criticality lead to a fundamental description in terms of discrete points sets. These are defined as intersections of what I call number theoretic braids with partonic 2-surfaces X^2 at the boundaries of causal diamonds identified as intersections of future and paste directed light-cones forming a fractal hierarchy. These 2-surfaces X^2 correspond to the ends of light-like three surfaces. Only the data from this discrete point set is used in the definition of M-matrix: there is however continuum of selections of this

data set corresponding to different directions of light-like ray at the boundary of light-cone, and in detection one of these direction is selected and corresponds to the direction of beam in the recent case.

3. Fermions correspond to CP_2 type vacuum extremal with Euclidian signature of induced metric condensed to space-time sheet with Minkowskian signature and light-like wormhole throat for which 4-metric is degenerate carries the quantum numbers. Bosons correspond to wormhole contacts consisting of a piece of CP_2 vacuum extremal connecting two two space-time sheets with Minkowskian signature of induced metric. The strands of number theoretic braids carry fermionic quantum numbers and discretization is interpreted as a space-time correlate for the finite measurement resolution implying the effective grainy nature of 2-surfaces.

How to end up with TGD inspired model?

TGD does not seem to provide a justification for the models based on diffraction as physical phenomenon behind the noise.

1. Could one assign Planck wave length with the light-like orbit of partonic 2-surface involving periodic variation of CP_2 coordinates characerized by Planck length? Here the problem is that CP_2 length which is 10^4 times longer seems more natural guess for the minimum wavelength in this sense. For shorter wavelengths induced metric changes signature as simple ansatz shows.

2. Planck wave length as minimum wavelength means breaking of Lorentz invariance. Generalized Feynman diagrams correspond to space-time regions with Euclidian signature of induced metric- wormhole contacts typically. Elementary particles correspond to pairs of wormhole contacts. Could one assign the Planck length as wavelength to a periodic variation of angle-like CP_2 coordinate inside wormhole contact? One would could avoid problems with Lorentz invariance and maybe the diffraction picture would make sense inside Euclidian regions. The problem is that wave motion is impossible in Euclidian signature.

3. Could Planck length correspond to the position uncertainty section of so called massless extremals (MEs) assignable to MEs and orthogonal to the direction of propagation. Or could one interpret Planck length as uncertainty for the transverse position of the fermionic lines entering the diffraction slit? This however forces to give up the diffraction picture and formulas become just dimensional arguments.

Could diffusion replace diffraction as starting point?

1. Could one begin directly from the formula $\Delta x = R = D = \sqrt{l_P L}$. This would allow also to avoid problems with Lorentz invariance coming from the idea of minimum wavelength. One would give up the interpretation of l_P as wavelength so that the formula would be just dimension analytic guess and therefore unsatisfactory.

2. Could one assign Δx to the randomness of the light-like orbit of wormhole contact/partonic 2-surface/fermionic line at it. Δx would represent the randomness of the transversal coordinate for light-like parton orbit. This randomness could be also assigned to the light-like curves defining fermion lines at the orbits of partonic 2-surfaces. Diffusion would provide the physical analogy rather than diffraction.

   $T = L/c$ would correspond to time and $\Delta x = R = D$ would be analogous to the mean square distance $\langle r^2 \rangle = DT$. $D = c^2 t_P$, diffused during time T. This would also conform qualitatively with the basic idea of p-adic thermodynamics. One would also find the long sought interpretation of Planck length in TGD framework where CP_2 length scale is the fundamental length scale.

3. Why the noise would appear at certain frequency range? A possible explanation is that large Planck constants are involved. The ratios of the frequency f_h of laser beam to the relatively low frequencies f_l in the frequency range of noise corresponds to the spectrum of Planck

constants $h_{eff} = f_h/f_l$ involved? Maybe low frequencies could correspond to bunches of dark low energy photons with total energy equal to that of laser photon. Dark photons could relate to the long range correlations inside laser beam.

The presence of large values of Planck constants suggests strongly quantum criticality, which should relate to laser beam. Could one assign the long range correlations of laser beam with quantum criticality realized as spectrum of Planck constants?

Large h_{eff} gravitons do not explain the claimed anomaly

In [K79] I have proposed that part of gravitons could arrive as large h_{eff} gravitons having same frequency as ordinary gravitons but by a factor h_{eff}/h higher energy, and thus have much larger effect than ordinary gravitons. They could transfrom with some probability to ordinary very high energy gravitons or decay to a bunch of $h_{eff}/h = n$ ordinary gravitons with the same frequency.

The additional assumption is $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where M is mass of the source of gravitations, m the mass of the receiver particle (elementary particle, most naturally proton), and v_0 is some characteristic velocity parameter associated with the source, characterizes the Kähler magnetic flux tubes along which dark gravitons arrive.

Dark gravitons could be detected in two ways. They could transform to ordinary gravitons but with much larger energy and absorbed by oscillator like system. This detection mechanism would be purely quantal. If the value of h_{gr} is of same order of magnitude as the model for bio-photons as decay products of dark photons suggests, the energy of "bio-graviton" would be in range of visible and UV energies. Bio-.gravitons could be important in living matter.

Second option is that dark graviton decays to a bunch of h_{eff}/h ordinary gravitons, which because of their large number define a semiclassical state (large n limit for a harmonic oscillator corresponds to quasiclassical state). In semiclassical approximation one would have a classical gravitational wave with amplitude defined by oscillator state containing $n = h_{eff}/h = GMm/v_0\hbar$ gravitons. Since n is large, the oscillator state allows an approximation as classical gravitational wave with amplitude scaled up by $\sqrt{n}$ from its value for ordinary value of Planck constant. The amplitude would be by a factor $\sqrt{GMm/v_0\hbar}$ for the oscillation amplitude of distance between the ends of the arm of the detector would scale up by a factor $\sqrt{Gmm/v_0\hbar}$, which is of order 10^{11} for M of order solar mass, m proton mass and $v_0/c \simeq 10^{-3}$. If the amplitude for oscillation of distance between ends of arm is about 10^{-17} meters, it would be amplified to cell scale 10^{-6} meters, perhaps not an accident.

This kind of bunches of ordinary gravitons would be interpreted as noise in GRT framework. The noise in above sense cannot correspond to dark gravitons.

4.8.4 Hogan's Formula Again

My interest to the claimed unidentified noise modelled by Hogan was re-stimulated eight years later as Bee (see `http://tinyurl.com/y8fm8d6f`) told in rather critical tone about an article titled "Search for Space-Time Correlations from the Planck Scale with the Fermilab Holometer" reporting the results of Fermilab experiment (see `http://tinyurl.com/y8btj956`) [E135].

The claim of Craig Hogan, who leads the experimental group, is that the experiment is able to demonstrate the absence of quantum gravity effects. The claim is based on a dimensional estimate for transversal fluctuations of distances between mirrors reflecting light - it seems to be essentially the same as discussed in detail above. The fluctuations of the distances between mirrors would be visible as a variation of interference pattern and the correlations of fluctuations between distant mirrors could be interpreted as correlations forced by gravitational holography. No correlations were detected and the brave conclusion was that predicted quantum gravitational effects are absent.

Although no quantitative theory for the effect exists, the effect is expected to be extremely small and non-detectable by quantum holographists. Hogan has however different opinion based on his view about gravitational holography not shared by workers in the field (such as Lenny Susskind). This of course need not mean that his formulate might not be correct!

One has volume size R and the area of of its surface gives bound on entanglement entropy implying that fluctuations must be correlated. A very naïve dimensional order of magnitude estimate would suggest that the transversal fluctuation of distance between mirrors (due to the fluctuations of space-time metric) would be given by $\langle \Delta x^2 \rangle \sim (R/l_P) \times l_P^2$. For macroscopic R this could be measurable number. In the above application R becomes the length of the laser beam. This estimate is of course ad hoc, involves very special view about holography, and also Planck length scale mysticism is involved. There is no theory behind it as Bee correctly emphasizes. Therefore the correct conclusion of the experiments would have been that the formula used is very probably wrong.

How the view of Hogan about holography is wrong?

Why I saw the trouble of writing comments about this was that I want to try to understand what is involved and maybe make some progress in understanding TGD based holography to the GRT inspired holography. The somewhat polarized comment went as follows.

1. The argument of Hogan involves an assumption, which seems to be made routinely by quantum holographists: the 2-D surface involved with holography is *outer* boundary of macroscopic system and bulk corresponds to its interior. This would make the correlation effect large for large R if one takes seriously the dimensional estimate large for large R. The special role of outer boundaries is natural in AdS/CFT framework. In the actual situation however R is replaced with the length of beam so that the situation need not have much to do with holography.

2. In TGD framework outer boundaries do not have any special role. For strong form of holography (SH) the surfaces involved are string world sheets and partonic 2-surfaces serving as "genes" from which one can construct space-time surfaces as preferred extremals by using infinite number of conditions implying vanishing of classical Noether charges for sub-algebra of super-symplectic algebra.

   For weak form of holography one would have 3-surfaces defined by the light-like orbits or partonic 2-surfaces: at these 3-surfaces the signature of the induced metric changes from Minkowskian to Euclidian and they have partonic 2-surfaces as their ends at the light-like boundaries of causal diamonds (CDs). For SH one has at the boundary of CD fermionic strings and partonic 2-surfaces. Strings serve as geometric correlates for entanglement and SH suggests a map between geometric parameters - say string length - and information theoretic parameters such as entanglement entropy.

3. The typical size of the partonic 2-surfaces is CP_2 scale about 10^4 Planck lengths for the ordinary value of Planck constant. The naïve scaling law for the the area of partonic 2-surfaces would be $A \propto h_{eff}^2$, $h_{eff} = n \times h$. An alternative form of the scaling law would be as $A \propto h_{eff}$. CD size scale T would scale as h_{eff} and p-adic length scale as its square root (diffused distance R satisfies $R \sim L_p \propto T^{1/2}$ in diffusion; p-adic length scale would be analogous to R).

4. The most natural identification of entanglement entropy would be as entanglement entropy assignable with the *union* of partonic 2-surfaces for which the light-like 3-surface representing generalized Feynman diagram is connected. Entanglement would be between ends of strings beginning from different partonic 2-surfaces. There is *no* bound on the entanglement entropy associated with a given Minkowski 3-volume coming from the area of its *outer* boundary since interior can contain very large number of partonic 2-surfaces contributing to the area and thus entropy. As a consequence, the correlations between fluctuations are expected to be weak.

5. Just for fun one can feed numbers into the proposed dimensional estimate, which of course does not make sense now. For R about of order CP_2 size it would predict completely negligible effect for ordinary value of Planck constant: this entropy could be interpreted as entropy assignable to single partonic 2-surface. Same is true if R corresponds to Compton scale of elementary particle.

This argument demonstrates how sensitive the quantitative estimates are for the detailed view about what holography really means. Loose enough definition of holography can produce endless number of non-sense formulas and it is quite possible that AdS/CFT modelled holography in GRT is completely wrong.

The difference between TGD based and GRT inspired holographies is forced by the new view about space-time allowing also Euclidian space-time regions and from new new view about General Coordinate Invariance implying SH. This brings in a natural identification of the 2-surfaces serving as holograms. In GRT framework these surfaces are identified in ad hoc manner as outer surfaces of arbtrarily chosen 3-volume.

Why the formula used by Hogan could be partially correct after all?

After I had went through the earlier model for the claimed noise and modified it in some respects, I had still unpleasant feeling that I have not understood everything. TGD predicts the noise and it could be called quantum gravitational. The earlier experiment provides a support for its existence but the recent experiment does not.

How does the earlier experiment reporting unidentified fluctuations and interpreted in the proposed manner in TGD framework relate to the recent experimental finding reporting no fluctuations? I am not experimentalists but the experimental situations look very much the same.

The simplest explanation emerging from quantum criticality in TGD sense is that the frequency range studied in Fermilab experiment does not correspond to the frequencies made possible by the available spectrum of Planck constants. If I have understood correctly, the range corresponds to considerably higher frequencies than the range 300-1500 Hz for the noise detected in the original experiments.

I do not know whether people have been able to eliminate the noise reported in the motivating article [E209]. I hope not! It is unclear whether how the model relates to the Hogan's later model proposing that the correlations implied by holography as he interprets it, are not found. Certainly the idea that Planck wave length waves would be amplified to observable noise does not make sense in TGD framework. It is diffusion of fermion lines in transversal degrees of freedom of light-like random orbits of partonic 2-surfaces serving as a signature of non-point-likeness of fundamental objects, which would become visible as noise. The effect could also seem as signature for the hierarchy of Planck constants and also to quantum gravitational holography.

4.9 Could Hyperbolic 3-Manifolds And Hyperbolic Lattices Be Relevant In Zero Energy Ontology?

In zero energy ontology (ZEO) lattices in the 3-D hyperbolic manifold defined by H^3 ($t^2 - x^2 - y^2 - z^2 = a^2$) (and known as hyperbolic space to distinguish it from other hyperbolicmanifolds (see `http://tinyurl.com/yct48tv6`) [A7]) emerge naturally. The interpretation of H^3 as a cosmic time=constant slice of space-time of sub-critical Robertson-Walker cosmology (giving future light-cone of M^4 at the limit of vanishing mass density) is relevant now.

4.9.1 Hyperbolic Lattices In H^3 From Zero Energy Ontology

In TGD framework zero energy ontology (ZEO) indeed predicts the hyperbolic lattices if one accepts the following argument.

1. Causal diamond CD is basic element of ZEO. It is defined as the intersection of a pair of future and past directed light-cones and looks like double pyramid Cartesian product with CP_2 makes it 8-D region off $M^4 \times CP_2$ but the presence of CP_2 as Cartesian factor is not relevant. Its opposite light-like boundaries contain positive and negative energy parts of zero energy states with opposite total quantum numbers. In the usual positive energy ontology zero energy states corresponds to physical events consisting of initial and final states. ZEO is consistent with the crossing symmetry of QFTs. ZEO leads to a generalization of S-matrix concept. The time-like entanglement coefficients between positive and negative energy parts of zero energy state define M-matrix identifiable as a "complex square root" of density matrix and expressible as a product of Hermitian square root of density matrix and unitary S-matrix. One can say that quantum theory corresponds to a square root of thermodynamics in ZEO.

2. The "lower" tip of CD can have any position in M^4: one can argue that these degrees of freedom give rise to 4-momentum. The "upper" tip is at M^4 proper time distance a assumed to be integer multiple of CP_2 size. The assumption motivated by number theoretical considerations (the goal is to fuse real and p-adic physics and real continuum must be effectively replaced by rationals or at most their algebraic extension). One can of course consider also the discretization for the position of the lower tip in M^4 and interpret it in terms of finite measurement resolution for four-momentum.

3. One can perform for CD Lorentz boosts preserving the fixed position of "lower" tip but one cannot allow all possible transformations since one would have two separate 3-D continuous degrees of freedom in this case (here is the crux of argument). Therefore I assume that "upper" tip which lies on the hyperbolic space H^3 - hyperboloid - defined by $t^2-x^2-y^2-z^2=a^2$, $a=n$ in proper units defined by the size scale of CP_2, can have only discrete positions corresponding to a discrete subgroup G of $SL(2,C)$ (double covering of Lorentz group). Recall that H^3 has negative constant sectional curvature.

4. The discrete subgroup G defining G-coset as points of H^3/G is in the most general case discrete subgroup of $SL(2,C)$. It could be also modular subgroup $SL(2,Z)$ or its. Quite generally, one obtains a tessellation of H^3 with a lattice characterizing positions of unit cells H^3/G, which are closed hyperbolic manifolds in absence of singular points known as cusp points and giving rise to punctures and effectively holes. Physically unit cell or fundamental domain corresponds to an open set and effective identification of boundary points comes through "G-periodic" boundary conditions for physical fields analogous to periodic boundary conditions in the case of condensed matter physics. H^3/G has constant negative curvature metric.

Some examples of hyperbolic manifolds

In order to make things more concrete it is good to have some examples about hyperbolic manifolds.

1. Examples about hyperbolic manifolds are provided by compactifications of tetrahedron and dodecahedron. It is possible to remove the vertices of tetrahedron and identify the faces of tetrahedron in a pairwise manner to get a compact manifold with boundary having the topology of Klein bottle (non-orientable torus). This manifold is known as Gieseking manifold (see `http://tinyurl.com/y9elobcs`) [A6]. This space has finite volume, is non-orientable, and the boundary corresponds to the cusp. Gieseking manifold is a double cover of the knot complement of figure eight knot which explains why the boundary has genus $g=1$.

2. The so called Seifert-Weber space (see `http://tinyurl.com/ya249rkf`) [?] is a closed hyperbolic manifold obtained by gluing each face of a dodecahedron with its opposite. So called Weeks manifold (see `http://tinyurl.com/yd8e5ysz`) [?] has smallest volume among closed hyperbolic 3-manifolds. If the volume of the hyperbolic manifolds surfaces as the analog of energy in topological thermodynamics, Weeks manifold might be one of the favored 3-manifold topologies.

3. Thurston's geometrization conjecture (see `http://tinyurl.com/yb2jlcca`) [?] (actually a theorem thanks to the work of Grigori Perelman) implies that all knot complements except those of satellite knots (they include composites of prime knots and torus knots!) and torus knots (trefoil is the simplest example) are hyperbolic manifolds.

4. Kleinian groups (see `http://tinyurl.com/melaebe`) [A10] identified as a discrete subgroups G of $PSL(2C)$ acting as isometries of H^3 and conformal symmetries of Riemannian sphere (Möbius transformations) define hyperbolic manifolds as quotients H^3/G. The fundamental group of any hyperbolic manifold is Kleinian group acting also as group of symmetries of a tessellation of H^3.

Questions

Could hyperbolic lattices and crystals and hyperbolic manifolds have some physical role in TGD?

1. The points of hyperbolic lattices could label astrophysical (possibly dark matter) objects. The indications for the existence of astrophysical objects at lines of sight and coming with quantized redshift [E176, E264] supports this picture [K94]. In cosmology redshift for small distances r is from Hubble law given by $v = Hr$ so that the recession velocity - or equivalently cosmic redshift - serves as a natural measure for the distance.

   If dark matter objects corresponds to CDs with upper vertices at the points of H^3/G, both the directions and magnitudes of the recession velocities would be quantized. The quantization for the velocities would follow from the quantization of the hyperbolic angle η defining Lorentz boosts as integer multiples of basic value: $\eta = n\eta_0$ giving $v/\sqrt{1-v^2} = sinh(\eta) = sinh(n\eta_0)$ $(c = 1)$ reducing for non-relativistic velocities to $v \simeq n\eta_0$.

2. 3-surface is a fundamental dynamical object in TGD. Hyperbolic 3-manifolds are central in the theory of 3-manifolds, and very many 3-manifolds are hyperbolic. Note that also 2-D manifolds with $g > 1$ are hyperbolic. For instance, knot complements of prime knots are hyperbolic apart from some exceptions, and also surface bundles over circle (see `http://tinyurl.com/y7mqceqc`) [?] are hyperbolic. Thurston's theorem (see `http://tinyurl.com/y9hv3y9h`) [?] states that the volume of the hyperbolic manifold defines a topological invariant so that continuous deformations of 3-surfaces would correspond to the same hyperbolic volume, which could thus appear as a counterpart of energy in topological thermodynamics telling which hyperbolic 3-manifold topologies contribute significantly to the physical states (in ZEO this thermodynamics is replaced with its "square root").

3. In TGD framework elementary particles correspond to closed flux tube like structures carrying monopole flux. The solutions of the Kähler-Dirac equation [K116] assign to them closed stringy curves, which can get knotted (see `http://tinyurl.com/y7kb7mvl`) [K54] and in general case when several flux tubes are associated with the elementary particle (say in case of boson) even braiding becomes possible. The homological non-triviality of the knot brings in additional quantum numbers.

   It is natural to assign to the flux tube the geometry $X^2 \times S^1$ corresponding to trivial surface bundle over sphere. The two wormhole contacts associated with the ends of the flux tube allow gluing of X^2 from upper space-time sheet with that associated with the lower space-time sheet and this would transform $X^2 \times S^1$ to a non-trivial bundle. Hence the topology of the flux tube could be characterized by hyperbolic volume. The induced metric of course need not be hyperbolic metric.

4. What is interesting that the isometry group of H^3 has $SL(2, C)$ as a double covering and H^2 realized as upper half-plane has $SL(2, C)$ as conformal isometries. Could this mean some kind of duality analogous to AdS-CFT duality? The hyperbolic manifolds H^3/G have 2-D boundary: could there be a duality between 2-D conformal field theory at the boundary and string theory in the interior. This is suggested by the strong form of holography (equivalently strong form of general coordinate invariance) stating that partonic 2-surfaces and their 4-D tangent space data code for quantum physics in TGD Universe.

This raises several questions.

1. What happens to 3-D Euclidian crystallography when E^3 is replaced with H^3? How the negative constant sectional curvature affects the character of lattices obtained?

2. Can one build a rough overview about hyperbolic manifolds? Under what conditions the fundamental domain regarded as an open manifold analogous to lattice cell can be compactified by G-periodic boundary conditions to a closed 3-manifold? To me this is not obvious since the compactified manifold could have singularities known as cusps points and represent punctures.

3. Does one obtain also hyperbolic quasicrystals? One can imagine also 2-D hyperbolic quasicrystals analogous to Penrose tilings (see `http://tinyurl.com/y8cddhz6`) [?] defined by the embedding of 2-D hyperbolic manifold H^2 to H^3 (or higher dimensional hyperbolic space) and by projecting the points of H^3 to H^2 along geodesic lines orthogonal to H^3. One can also

imagine 3-D hyperbolic quasicrystals as analogs of Penrose tilings obtained by embedding H^3 to H^4 or H^5 and performing similar projection.

It turns out that a visit to Wikipedia allows to answer the first two questions.

4.9.2 Comparing Crystallographies in E^3 and H^3

Consider first crystallography in E^3. There exists a large number of lattice like structures depending on detailed definition used and it is good to summarized first the basic notions.

Some definitions

Consider first some basic notions.

1. The difference between crystal and lattice is that crystal structure assigns to a given point of lattice some structure, which can be rather complex. In the simplest case this structure is a Platonic solid - a polyhedron which can be regarded as an orbit of a discrete group generated by reflections and rotations.

2. Lattice (see `http://tinyurl.com/vtkbd`) [A2] in 3-D case can be defined group theoretically in terms of the group leaving the lattice invariant. This group - call it G - is generated by the elements of two groups, the crystallographic point group (see `http://tinyurl.com/l3f9a37`) [?] and space-group (see `http://tinyurl.com/ox9sn66`) [?].

   Point group leaves at least single point of the lattice fixed and defines the symmetries of the structure attached to the lattice point identified as the center point of the structure. There are 32 point groups and they contain reflections across plane, rotations, inversions (3-D reflecting with respect to origin), and improper rotations (rotations followed by inversion).

   Space group contains pure translations, screw transformations rotating around axing and translating along it, and gliding transformation consistent of reflection with respect to plane followed by a translation. There are 230 distinct space groups. The lattice is defined as the set of cosets E^3/G, where G is so called space-group leaving the lattice invariant.

3. The lattice points are in the general case linear combinations of three - in general non-orthogonal - basis vectors (a, b, c) generating the discrete subgroup of translations. The condition that one has crystal consisting of say tetrahedrons as unit cells - poses additional conditions. The duals of the lattice vectors defined by their cross products generate dual lattice.

Tessellations

Tessellation or tiling is second key notion and there are many different variants of this notion. The most stringent definition of tessellations considered in following is in terms of by a $n+1$-dimensional regular polytope in n-dimensional sphere, Euclidian space, or hyperbolic space.

1. Polytopes are constructed of regular p-polygons in turn defining the 2-D faces of 3-D polyhedrons in defining the 4-D polychrones.

2. n-dimensional tessellations can be defined as boundaries of $n + 1$-dimensional polygons. Schläfli symbol (see `http://tinyurl.com/5vbt6tx`) [?] allows to represent n-dimensional tessellations in terms of integer n-tuple of integers. In 3-D case one has triple (p, k, r). p is the number of vertices of 2-polygon defining the face of 3-D polyhedron (p, k) and k is the number of faces associated with a given vertex of the polyhedron. r is the number of 3-D polyhedra associated with a given edge of the tessellation.

3. In the case of 2-sphere tessellation in E^3 contains finite number of identical faces projected to the sphere. tessellations can make sense also if the n-D space is non-compact and the replacement of sphere S^3 of E^4 with hyperbolic space H^3 gives rise to infinite tessellation of H^3. Also tessellations in hyperbolic manifolds H^3/G are possible and in closed case contain a finite number of basic elements.

tessellations by regular polytopes (see http://tinyurl.com/dxmjm7r) [A12] satisfy strong constraints and there are only four tessellations by regular polytopes in H^3 and one in E^3.The list of tessellations is following.

(a) E^2 allows three regular tessellations by squares, triangles and hexagons: the Schäfli symbols for them are (4, 4), (3, 6), (6, 3).

(b) H^2 is exceptional and allows infinite number of tessellations.

(c) E^3 allows single tessellation by cubes: the Schläfli symbol is $(4, 3, 4)$.

(d) H^3 allows four tessellations. The Schläfli symbols are (3, 5, 3), (4, 3, 5), (5, 3, 4), (5, 3, 5). Second and third tessellation are dual tessellations by cubes and dodecahedra. First and fourth tessellation correspond to self-dual tessellations by icosahedra and dodecadedra. For instance, for (5, 3, 5) means each edge has 5 dodecahedrons around it.

The large voids with size of order 10^8 ly give rise to honeycomb like structures. Could they correspond to ordinary matter condensed around dark matter honeycomb consisting of dodecahedra?

(e) For $n > 4$ there are three regular tessellations by convex polyhedra in Euclidian space. There are no regular hyperbolic tessellations by convex polyhedra in dimensions $n > 5$.

4. If an infinite n-D tessellation is induced by $n + 1$-D regular polytope, it seems obvious that the polygon must have infinite number of basic units. There indeed exists this kind of infinite polytopes known as infinite skew polytopes (see http://tinyurl.com/y7q4bxu9) [A9]. 1-D lattice requires 2-D zigzag curve reflected from the real axis at the lattice points. In 1-D cases zigzag curve actually gives two parallel lines carrying lattices and the parallel lines together define a boundary of a stripe. Similar doubling is expected in higher dimensions since it is the boundaries of polytopes, which must give rise to H^n or E^n.

5. The tessellations having E^3/G as a unit cell are obtained by assuming G to be a subgroup of translations. As already noticed this subgroup in question is generated by 3 generators represented by - in general non-orthogonal vectors - and the fundamental domain is parallelpiped generated by these vectors. When the vectors are orthogonal and have same length one obtains the regular tessellation by cubes. The four tessellations by regular polytopes must be distinguished from the infinite number of tessellations defined by the orbit of discrete subgroup $G \subset PSL(2, C)$ in H^3 with fundamental domain H^3/G replacing the polyhedron as a basic unit. The case of E^3 suggests that these tessellations give as a special case the 4-tessellations using regular polytopes. A good first guess is that G is generated by Lorentz boosts with same velocity in 3 orthogonal directions.

Tessellations of H^3

Consider now the case of H^3 more closely.

1. In the case of H^3 a discrete subgroup G of Lorentz group $SL(2, C)$ with infinite number of elements representing Lorentz boots replaces discrete subgroup of translations in E^3. G is known as Kleinian group (see http://tinyurl.com/melaebe) [A10]. G can be also restricted to be a subgroup of the modular group $SL(2, Z)$. Note that $G = SL(2, Z)$ is braid group for 3-braid divided by its center and isomorphic to the knot group of trefoil as one learns from Wikipedia (see http://tinyurl.com/yroeq5e) [?]. Therefore the subgroups of the knot group of trefoil are very interesting concerning lattices in H^3. The complement of trefoil and any torus knot however fails to defined hyperbolic 3-manifold. For larger subgroups of $SL(2, C)$ one obtains smaller fundamental domain and more lattice points.

2. For non-compact discrete subgroups of $SL(2, Z)$ (and also $SL(2, C)$!) the lattice consists in the language of cosmologist of locations of astrophysical objects (possibly consisting of dark matter) with quantized redshifts and direction angles. The counterparts of parallelepipeds

are interiors of hyperbolic 3-manifolds and there are very many of them. For prime knot complements which very often are hyperbolic 3-manifolds, the boundary is torus and allows a constant sectional curvature metric with vanishing sectional curvature. This motivates the question whether $g > 1$ negative constant sectional curvature 2-surfaces could appear as boundaries of hyperbolic 3-manifolds.

3. It is not completely obvious how to define the edges and faces of hyperbolic polygons. Edges are naturally defined as geodesic lines but what about faces. In E^3 they are pieces of plane which are minimal surfaces but also geodesic sub-manifolds with vanishing second fundamental form meaning that all geodesics of these surfaces are also geodesics of E^3. Minimal 2-surfaces are by definition manifolds with a negative curvature and this seems to fit with the negative curvature property of H^3. H^3, E^3, and S^3 are very closely related (they define the 3 constant sectional curvature Robertson Walker cosmologies) In the case of S^3 spheres S^2 are geodesic sub-manifolds. In the similar manner H^2 defines a geodesic sub-manifold of H^3. If so, the faces would be 2-D hyperbolic manifolds with boundary, and having constant negative sectional curvature.

4. One can wonder what is the 4-D space used to define H^3 tessellations. Is it Minkowski space M^4 or is it H^4? The first problem is that tessellation is infinite. Second problem is that H^3 should but cannot play the same role as sphere S^2 in E^3. The problem is that H^3 can be thought of as having boundary at infinity, and therefore is not itself a boundary unlike S^2. It is the boundary property of S^2, which allows to assign Platonic solid with the vertices of tetrahedron at the surface of S^2.

   Infinite tessellation requires infinite polytope as already noticed. For $1-D$ tessellation one has zigzag curve in planar stripe, and one obtains two copies of the tessellation defining a boundary of 2-D stripe. Are the segments of zigzag curve replaced by a 4-D object having as boundary cube, icosahedron, or dodecahedron of H^3? Does the boundary property require that there are two lattices at hyperboloids $a = a_1$ and $a = a_2$ of M^4. These hyperboloids define a boundary and one can speak about the interior and boundary of 4-D polytope.

   An interesting question is how this relates to zero energy ontology, where CD plays a key role. Can one imagine that the pair of H^3: s is replaced with a pairs of hyperboloids with opposite time orientation so that their intersection consists of temporal mirror images of part of H^3 glued together along 2-sphere (this could be seen as a generalization of CD)? The boundaries of CD would correspond to the limiting case $a = 0$ for H^3 giving light-cone boundary for which radial coordinate does not contribute to metric so that metrically one has 2-D sphere (this makes possible huge extension of conformal invariance in TGD Universe). How could one define tessellations of light-cone boundary?

5. For Platonic solids boundary is always topologically a sphere. For prime knot complements the boundary is 2-torus $S^1 \times S^1$. What does this mean geometrically in the gluing of fundamental domains together? Also 2-surface bundles over spheres are hyperbolic manifolds and are obtained by identifying the ends of $X^2 \times D^1$ by a homeomorphism. The homotopy equivalence class of the map $X^2 \to X^2$ characterizes the bundle structure. In this case one should fill the twisted torus like surface by polygon lattice.

4.9.3 About uniform tessellations of hyperbolic, Euclidian, spherical spaces

It has become clear that 3-D hyperbolic tessellations are probably very important in the TGD framework. The 3-D hyperbolic space H^3 is realized as a mass shell or cosmic time constant hyperboloid and an interesting conjecture is that particles with a fixed value of mass squared are associated with the vertices of a hyperbolic tessellation. This would give rise to a quantization of momenta consistent with the number theoretic discretization. Hyperbolic tessellations could also appear in cosmological scales. So called icosa-tetrahedral tessellation seems to provide a model of genetic code and DNA and suggests that genetic code is not restricted in biology but universal and realized in all scales Euclidian.

Uniform tilings/tessellations/honeycombs can be identified by their vertex configuration given given a list $n_1.n_2.n_3...$ for the numbers n of of vertices of regular n-polygons associated with the vertex. Uniform tilings can be regular, meaning that they are both vertex- and edge-transitive. Quasi-regular tessellations are only vertex-transitive and semiregular tessellations are neither vertex- or face-transitive. Non-regular tessellations give for instance Archimedean solids obtained from Platonic solids by operations like truncation. In this case the vertices are obtained by symmetries from each other but not the faces, which need not be identical anymore.

There exists an extremely general construction of tessellation of hyperbolic, Euclidian, and spherical tessellations which works at least in 2- and 3-D cases known as Wyuthoff construction. In the 2-D case, this construction is based on the so-called Schwarz triangles associated with a fundamental region of tessellation in the 2-D case and so-called Goursat tetrahedrons in the 3-D case. A natural generalization is that in n-dimensional one has n-simplexes. One would have what topologists call triangulation, which is very special in the sense that it utilizes the symmetries of the tessellation. These very special simplices are also consistent with the number theoretical constraints in the the angles between n-1-faces corresponds to angles defined by the roots of unity.

In the 2-D case the angles between the edges of the fundamental triangle are rational multiples of π so that the cosines and sines of the angle are algebraic numbers, which are natural for a tessellation whose points in natural coordinates (momenta) have components which are numbers in an algebraic extension of rationals. In the 2-D case, the fundamental triangle is obtained by drawing from center points of the 2-D unit cell, say a regular polygon, connecting it to its vertices. In the 3-D case the same is done for the 3-D unit cells of the fundamental region. Note that the tessellation can have several different types of unit cells and this is indeed true the case for icosa-tetrahedral tessellations.

2-dimensional case

In the 2-D case the angles between the edges of the triangle are given as $(1/p, 1/r, 1/s)$- multiples of π. p, r, and s are the orders of discrete rotation groups assignable to the vertices. They are generated by the reflections s_i with respect to edges of the triangle in one-one-correspondence with opposite vertices. They satisfy the conditions $s_i^2 = 1$ as reflections and the reflections s_i. The reflections s_i and s_{i+j}, $j > 1$ commute and $s_i s_{i+1}$ generates a rotation with respect to the third vertex of the triangles with order determined by one of the numbers p, r, s. The conditions can be summed up to $s_i^2 = 1$ and $(s_i s_j)^{m_{ij}} = 1$ $m_{ij} = 2$ for $j \neq i \pm 1$ and $m_{ij} > 2$ for $j = i \pm 1$. The conditions can be expressed in a concise way by using Coxeter-Dynkin diagrams having 3 vertices connected by edges. For $s_{ij} = 2$ there is no edge and for $s_{ij} > 2$ there is an edge and a number telling the order of the cyclic group in question.

All these 3 spaces are constant curvature spaces with positive, vanishing or negative curvature, which is reflected as properties of the angle sum of the geodesic Scwartz triangle (note that these spaces also occur in cosmology). In the spherical case the sum is larger than π and one has $1/p+1/r+1/s \geq 1$. In the Euclidian case the sum of the angles of the Schwarz triangle is π, which gives the condition $1/p + 1/r + 1/s = 1$. In the hyperbolic case the angle sum is smaller than π andone has $1/p + 1/r + 1/s \leq 1$. Note that in the hyperbolic plane the angles of infinitely sized Scwartz triangle can vanish (ideal triangle). For the 2-sphere these conditions give only Platonic solids as regular (vertex- and face-transitive) tessellation (no overlap between triangles). For the(plane) the non-compactness implies that the conditions are not so restrictive as for the sphere. The most symmetric tessellations are regular tessellations: they involve only one kind of polygon and are vertex-, edge-, and face-transitive. For the Euclidian plane there are regular tessellations by triangles, squares and hexagons. If one weakens the transitivity conditions to say vertex-transitivity, more tessellations are possible and involve different kinds of regular polygons.

The Wikipedia article about the uniform tilings of hyperbolic plane gives a good overall view of the uniform tessellations of hyperbolic plane. For the hyperbolic tessellations the conditions are the least restrictive. Intuitively this is due to the fact that the angle sum can be small and this allows small angles between edges and more degree of freedom at vertices. For a spherical tessellation the situation is just the opposite. Uniform tilings of hyperbolic plane H^2 are by definition vertex transitive and have a constant distance between neighboring vertices. This condition is physically natural and would correspond to mechanical equilibrium in which vertices are connected by springs of the same string tension. Each symmetry (p,r,s) allows 7 uniform tilings characterized by Wythoff symbol or Coxeter diagram. These tiling in general contain several kinds of geodesic polygons. Families with $r=2$ (right triangle) contain hyperbolic regular tilings.

The 3-dimensional case

There is a Wikipedia article about the uniform tessellations/honeycombs, in the 3-D case, obtained by Wyuthoff construction, is a generalization from the 2-D case. Schwarz triangle is replaced with Goursat tetrahedron and reflections are now in tetrahedral faces opposite to the vertices of the tetrahedron so that there are 4 reflections si satisfying $s_i^2=1$ and $s_is_j)^{m_{ij}}=1$, $m_{ij}=2$ for $j\neq i\pm 1$. The cyclic subgroups act as rotations of faces meeting at the edges and the angles defining the cyclic groups are dihedral angles. There are 9 compact Coxeter groups, and they define uniform tessellations with a finite fundamental domain. What is interesting is that the cyclic subgroups involved do not have order larger than 5.

The conditions are expressible in terms of Coxeter-Dynkin diagram with 4 vertices. The 2-D conditions are satisfied for the Schwarz triangles defining the faces of the tetrahedron. Besides the angle parameters defining the triangular phases of the tetrahedron there are angle parameters defining the angles between the faces. All these angles are rational multiples of π and define subgroups of the symmetries of the tessellation. What is so beautiful is that the construction is generalized to higher dimensions and is recursive/hierarchical.

The hyperbolic character of the geometry allows Schwarz triangles and Goursat tetrahedra which in Euclidian case would not be possible due to the condition that the edges have the same length and faces have the same area.

Could hyperbolic, Euclidian, and spherical tessellations be realized in TGD space-time

An interesting question is whether the hyperbolic, Euclidian, and spherical tessellations could be realized in the TGD framework as induced 3-D geometry or rather, as slicing of space-time surface by time parameter such that each slice represents hyperbolic, Euclidian or spherical geometry locally allowing the tessellation.

Hyperbolic tessellations can be realized on the cosmic time constant hyperboloids and Euclidian tessellations on the Minkowski time constant hyperplanes of M^4 and possibly partially on 3-surfaces which have hyperbolic 3-space as M^4 projection.

The question boils down to a construction of a model of Robertson-Walker cosmology for which the induced metric of $a = constant$ 3-surface is that of H^3, E^3 or S^3 corresponding to the cosmologies with subcritical, critical and overcritical mass densities. The metric of H^3 is proportional to a^2 scale factor. The simplest ansatz is a geodesic circle at geodesic sphere $S^2\subset CP_2$ with metric $ds^2=-R^2d\theta^2-sin^2(\theta)d\Phi^2$. The ansatz $(sin(\theta)=a/a_0,\Phi=f(r))$ gives in Robertson-Walker coordintes the induced metric

$$ds^2=[1-R^2(\frac{d\theta}{da})^2]da^2-a^2(\frac{1}{1+r^2}+(\frac{R}{a_0})^2(\frac{df}{dr})^2)dr^2+r^2d\Omega^2) \ .$$

This gives the flat metric of E^3 if the condition

$$(\frac{df}{dr})^2=(\frac{a_0}{R})^2\frac{r^2}{1+r^2} \ .$$

This condition is satisfied for all values of r.

For S^3 metric one obtains the condition

$$(\frac{df}{dr})^2=(\frac{a_0}{R})^2\frac{2r^2}{1-r^4} \ .$$

$r=1$ corresponds to singularity. For $r=1$, one has $r_M=ar=a$, which gives $t=\sqrt{2}a$. One can construct the S^3 by gluing together the hemispheres corresponding to the 2 roots for df/dr so that it seems that one obtains the tessellations. The divergence of df/dr tells that the half-spheres become orthogonal to H^3 at the gluing points.

For both E^3 and S^3 option, the component g_{aa} of the induced metric is equal to

$$g_{aa} = 1 - (\frac{R}{a_0})^2 \frac{1}{1-(\frac{a}{a_0})^2} \quad .$$

g_{aa} diverges at $a = a_0$ so that the cosmic time would run infinitely fast. g_{aa} changes sign for $a = a_0$ so that for $a > a_0$ the signature of the induced metric becomes Euclidian. Unless one allows Euclidian signature in long scales, one must assume $a < a_0$. Note that the action defined as the sum of Kähler action and volume action, If S^2 corresponds to the homologically trivially geodesic sphere of CP_2, the action reduces to volume action for these surfaces. The densities of Noether currents for volume action vanish at $a = a_0$ since they are proportional to the factor $\sqrt{g_{aa}}g^{aa}$ and thus approach to zero like $\sqrt{1-(a/a_0)^2}$. This is true also for the contribution of Kähler action present for homologically non-trivial geodesic sphere of CP_2. Very probably, this surface is not a minimal surface although the volume is finite. This is suggested by the fact that the volume element increases in comparison to hyperbolic volume element giving rise to minimal volume increases as the parameter a increases.

4.9.4 About Congruence Groups

Stephen Crowley made a very interesting observation about Gaussian Mersennes in the comment section of the posting *Pion of $M_{G,79}$ hadron physics at LHC?* (see `http://tinyurl.com/y8hx3fft`). I glue the comment below.

Matti, why Low Gaussian primes? Your list of primes is a subset of the factors of the dimension of the friendly giant group.

The monster group (see `http://tinyurl.com/ydxpekmp`*) was investigated in the 1970s by mathematicians Jean-Pierre Serre, Andrew Ogg and John G. Thompson; they studied the quotient of the hyperbolic plane by subgroups of $SL2(R)$, particularly, the normalizer $\Gamma_0(p)_+$ of $\Gamma_0(p)$ in $SL(2,R)$. They found that the Riemann surface resulting from taking the quotient of the hyperbolic plane by $\Gamma_0(p)_+$ has genus zero if and only if p is 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 41, 47, 59 or 71. When Ogg heard about the monster group later on, and noticed that these were precisely the prime factors of the size of Monster, he published a paper offering a bottle of Jack Daniel's whiskey to anyone who could explain this fact (Ogg (1974)).*

I must first try to clarify to myself some definitions so that I have some idea about what I am talking about.

1. Congruence group $\Gamma_0(p)$ is the kernel of the modulo homomorphism mapping $SL(2,Z)$ to $SL(2,Z/pZ)$ and thus consists of $SL(2,Z)$ matrices which are are unit matrices modulo p. More general congruence subgroups $SL(2,Z/nZ)$ are subgroups of $SL(2,Z/pZ)$ for primes p dividing n. Congruence group can be regarded as subgroup of p-adic variant of $SL(2,Z)$ with elements restricted to be finite as real integers. One can give up the finiteness in real sense by introducing p-adic topology so that one has $SL(2,Z_p)$. The points of hyperbolic plane at the orbits of the normalizer of $\Gamma_0(p)_+$ in $SL(2,C)$ are identified.

2. Normalizer $\Gamma_0(p)_+$ is the subgroup of $SL(2,R)$ commuting with $\Gamma_0(p)$ but not with its individual elements. The quotient of hyperbolic space with the normalizer is sphere for primes k associated with Gaussian Mersennes up to $k = 47$. The normalizer in $SL(2,Z_p)$ would also make sense and an interesting question is whether the result can be translated to p-adic context. Also the possible generalization to $SL(2,C)$ is interesting.

First some comments inspired by the observation about Gaussian Mersennes by Stephen.

1. Gaussian primes are really big but the primes defining them are logarithmically smaller. $k = 379$ defines scale slightly large than that defined by the age of the Universe. Larger ones exist but are not terribly interesting for human physicists for a long time.

   Some primes k define Gaussian Mersenne as $M_{G,k} = (1+i)^k - 1$ and the associated real prime defined by its norm is rather large - rather near to 2^k and for $k = 79$ this is already quite big. $k = 113$ characterises muon and nuclear physics, $k = 151, 157, 163, 167$ define a number theoretical miracle in the range cell membrane thickness- size of cell nucleus. Besides this there are astro-physically and cosmoplogically important Gaussian Mersennes (see the earlier posting (see `http://tinyurl.com/yan2xh3x`)).

2. The Gaussian Mersennes below M_{89} correspond to $k = 2, 3, 5, 7, 11, 19, 29, 47, 73$. Apart from $k = 73$ this list is indeed contained by the list of the lowest monster primes $k = 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 41, 47, 59, 71$. The order d of Monster is product of powers of these primes: $d = 2^{46} \times 3^{20} \times 5^9 \times 7^6 \times 11^2 \times 13^3 \times 17 \times 19 \times 23 \times 29 \times 31 \times 41 \times 47 \times 59 \times 71$ (see `http://tinyurl.com/onl32na`).

   Amusingly, Monster contains subgroup with order, which is product of exactly those primes k associated with Gaussian Mersennes, which are definitely outside the reach of LHC! Should one call this subgroup Particle Physics Monster? Number theory and particle physics would meet each other! Or actually they would not!

   Speaking seriously, could this mean that the high energy physics above $M_{G,79}$ energy is somehow different from that below in TGD Universe? Is $k = 47$ somehow special: it correspond to energy scale 17.6×10^3 TeV=17.6 PeV (P for Peta). Pessimistic would argue that this scale is the Monster energy scale never reached by human particle physicists.

The continuations of congruence groups and their normalizers to the p-adic variants $SL(2, Z_p)$ of $SL(2, Z + iZ)$ $(SL(2, C)$ are very interesting in TGD framework and are expected to appear in the adelization. Now hyperbolic plane is replaced with 3-D hyperbolic space H^3 (mass shell for particle physicist and cosmic time constant section for cosmologist).

1. One can construct hyperbolic manifolds as spaces of the orbits of discrete subgroups in 3-D hyperbolic space H^3 if the discrete subgroup defines tessellation/lattice of H^3. These lattices are of special interest as the discretizations of the H^3 parametrizing the position for the second tip of causal diamond (CD) in zero energy ontology (ZEO), when the second tip is fixed. By number theoretic arguments this moduli space should be indeed discrete.

2. In TGD inspired cosmology the positions of dark astrophysical objects could tend to be localized in hyperbolic lattice and visible matter could condense around dark matter. There are infinite number of different lattices assignable to the discrete subgroups of $SL(2, C)$. Congruence subgroups and/or their normalizers might define p-adically natural tessellations. In ZEO this kind of lattices could be also associated with the light-like boundaries of CDs obtained as the limit of hyperbolic space defined by cosmic time constant hyperboloid as cosmic time approaches zero (moment of big bang). In biology there is evidence for coordinate grid like structures and I have proposed that they might consist of magnetic flux tubes carrying dark matter.

   Only a finite portion of the light-cone boundary would be included and modulo p arithmetics refined by using congruence subgroups $\Gamma_0(p)$ and their normalizers with the size scale of CD identified as secondary p-adic time scale could allow to describe this limitation mathematically. $\Gamma(n)$ would correspond to a situation in which the CD has size scale given by n instead of prime: in this case, one would have multi-p p-padicity.

3. In TGD framework one introduces entire hierarchy of algebraic extensions of rationals. Preferred p-adic primes correspond to so called ramified primes of the extension. p-Adic continuations identifiable as imaginations would be due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K75]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes.

   Also p-adic length scale hypothesis can be understood and generalized if one accepts Negentropy Maximization Principle (NMP) and the notion of negentropic entanglement. Given extension of rationals induces an extension of p-adic numbers for each p, and one obtains extension of of ordinary adeles. Algebraic extension of rationals leads also an extension of $SL(2, Z)$. Z can be replaced with any extension of rationals and has p-adic counterparts associated with p-adic integers of extensions of p-adic numbers. The notion of primeness generalizes and the congruence subgroups $\Gamma_0(p)$ generalize by replacing p with prime of extension.

Above I have talked only about algebraic extensions of rationals. p-Adic numbers have however also finite-dimensional algebraic extensions, which are not induced by those of rational numbers.

1. The basic observation is that e^p exists as power series p-adically as p-adic integer of norm 1 - e^p cannot be regarded as a rational number. One can introduce also roots of e^p and define in these manner algebraic extensions of p-adic numbers. For rational numbers the extension would be algebraically infinite-dimensional.

   In real number based Lie group theory e is in special role more or less by convention. In p-adic context the situation changes. p-adic variant of a given Lie group is obtained by exponentiation of elements of Lie algebra which are proportional to p (one obtains hierarchy of sub-Lie groups in powers of p) so that the Taylor series converges p-adically.

   These subgroups and algebraic groups generate more interesting p-adic variants of Lie groups: they would decompose into unions labelled by the elements of algebraic groups, which are multiplied by the p-adic variant of Lie group. The roots of e are mathematically extremely natural serving as hyperbolic counterparts for the roots of unity assignable to ordinary angles necessary if one wants to talk about the notion of angle and perform Fourier analysis in p-adic context: actually one can speak only about trigonometric functions of angles p-adically but not about angles. Same is true in hyperbolic sector.

2. The extension of p-adics containg roots of e could even have application to cosmology! If the dark astrophysical objects tend to form hyperbolic lattices and visible matter tends to condensed around lattice points, cosmic redshifts tend to have quantized values. This tendency is observed. Also roots of e^p could appear. The recently observed evidence for the oscillation of the cosmic scale parameter could be understood if one assumes this kind of dark matter lattice, which can oscillate. Roots of e^2 appear in the model! (see the posting *Does the rate of cosmic expansion oscillate?* at `http://tinyurl.com/ybudjrul`). Analogous explanation in terms of dark matter oscillations applies to the recently observed anomalous periodic variations of Newton's constant measured at the surface of Earth and of the length of day. (see *Variation of Newton's constant and of length of day at* `http://tinyurl.com/ybywy73w`)) [L16].

3. *Things can get even more complex! e^π converges π-adically for any generalized p-adic number field defined by a prime π of an algebraic extension and one can introduce genuinely p-adic algebraic extensions by introducing roots $e^{\pi/n}$! This raises interesting questions. How many real transcendentals can be represented in this manner? How well the hierarchy of adeles associated with extensions of rationals allowing also genuinely p-adic finite-dimensionals extensions of p-adics is able to approximate real number system? For instance, can one represent π in this manner?*

4.9.5 Quasicrystals

One can also ask whether hyperbolic quasicrystals are possible. In the following some basic facts about quasicrystals are summarized and some questions relating to the dynamics of quasicrystals are considered before brief comments on hyperbolic quasicrystals.

Basic facts about quasicrystals

Quasicrystals are lattices, which do not have translational symmetries. Quasicrystals can be finite or infinite and only in special cases local matching rules give rise to infinite quasicrystal instead of finite local empire (to be defined later). The so called empire problem for Penrose tilings (see `http://tinyurl.com/yc75bvd8`) has been solved by Laura Effinger-Dean [?].

1. Especially interesting example about quasiperiodic 2-D lattices are Penrose tilings (see `http://tinyurl.com/y8cddhz6`) [?] for which basic objects have 5-fold local rotation symmetry: this is not allowed in ordinary crystallography. They are also self-similar. Their number is uncountably infinite. There is a theorem [?] stating that Penrose tilings are obtained as projections of 5-dimensional lattices to 2-D plane imbedded in 5-D Euclidian space. If the

parameters characterizing the plane have irrational values one obtains quasicrystal. This theorem generalizes to Euclidian spaces E^n imbbedded to higher-dimensional Euclidian spaces E^{n+k} carrying lattice structure.

2. In the case of Penrose tiling the plane is characterized by its normal space characterizing the orientation of the plane: for rational values of the "slope" of the plane one obtains periodic lattices with finite number of points projected to same point at E^2. For irrationals slopes just one point is projected to a given point of E^2. One can regard the space of the plane embeddings containing also Penrose tilings as a coset space $SO(5)/SO(2) \times SO(3)$ having dimension $D = 10 - 1 - 3 = 6$. The space for Penrose tilings (with crystals excluded) is rather delicate mathematical notion and represents basic example of a non-commutative geometry [?].

3. An important concept related to Penrose tilings is the notion of already mentioned [?]. One starts from a given "seed" for a quasicrystal, and builds a larger quasicrystal using local matching rules forbidding gaps. Local empire is the largest quasicrystal obtained in this manner and is a connected structure. Empire in turn is the largest set of tiles shared by all tilings containing the "seed" and is in general non-connected and can be even infinite. For ordinary crystals single unit cell fixes the lattice completely as its empire.

About dynamics of quasicrystals

Consider next possible dynamics of quasicrystals.

1. The fact that the local matching rules are not enough to construct infinite quasicrystal uniquely and that there is no guarantee that a given seed leads to infinite quasicrystal led Penrose to ask whether the formation of quasicrystal involves macroscopic quantum phase transition in which quasicrystal is created in single quantum leap rather than being a result of growth process. Experimentalist can of course argue that real quasicrystals are always infinite and this is just because the growth process stops because local matching rules fail at some step.

2. The conditions that quasicrystal property is preserved in the dynamics of quasicrystal is extremely strong. One manner to satisfy it would be the reduction of the dynamics to dynamics in the space of quasicrystals and crystals. The rigid body dynamics associated with the rotation of E^n in E^{n+k} containing the mother crystal would induce the variation of the projection of the crystal to E^n containing also quasicrystal configurations. In the case of embeddings $E^2 \subset E^5$ containing also Penrose tilings, the analog of rigid body motion would take place in $SO(5)/SO(3) \times SO(2)$. This dynamics can be solved both classically and quantum mechanically. The special feature of the dynamics would be correlation between short and long scale aspects of the dynamics since both local consistency rules and global consistency rules are automatically satisfied.

3. Quasicrystal excitations are known as phasons (see `http://tinyurl.com/ycb86kzc`) [D6]. The intriguing observation is that they can be described using hydrodynamics (long length scale description) and microscopically as re-arrangements of nearby atoms. There is a strong correlation between short and long length scales. If quasicrystal property is preserved by the dynamics, this is expected. The reduction to rigid body dynamics with only 6 degrees of freedom might of course be quite too restrictive an assumption and it is quite possible that the excitations have nothing to do with quasicrystallinity. Macroscopic quantum transitions can be also considered. The most mundane explanation would be in terms of thermodynamics: in ZEO square root of thermodynamics could unify quantal and thermodynamical explanations.

What about hyperbolic quasicrystals?

Hyperbolic 2-D quasicrystals are of special interest in TGD since they can be assigned to the spaces H^2 imbedded to H^3. Could one generalize the construction of Penrose tilings to a construction recipe for hyperbolic quasicrystals? For the hyperbolic counterparts of Penrose tilings one could imagine isometric embedding of $H^2 \subset H^n$, $n > 2$. H^3 is the physically preferred option in

TGD. Embedding would represent 2-D hyperboloid $H^2 = SO(1,2)/SO(2)$ of M^3 as constant sectional curvature sub-manifold of n-dimensional hyperboloid in $H^n = SO(1,n)/SO(n)$. There is a continuum of this kind of embeddings. In the compact case one has embeddings of S^2 to S^3 and the space of embeddings is $SO(3)/SO(1) \times SO(2) = S^1$. Same holds true in the hyperbolic case. For $H^n \subset H^{n+k}$ one has $SO(n+k)/SO(n) \times SO(k)$. One can consider also 3-D hyperbolic quasicrystals and the embedding $H^3 \to H^n$, $n > 3$ might gives this kind of quasicrystals. This embedding would not however have a concrete geometric interpretation in TGD framework.

Could hyperbolic 2-planes or finite pieces of them allow a physical interpretation as 2-D physical systems in cosmological scales? Certainly the existence of quasicrystals and even more that of crystals in cosmological scales requires quantum coherence in cosmological scales, and dark matter and dark energy as phases with large and even gigantic value of Planck constant [K42] [L6] could give rise this kind of structures.

4.9.6 Could Quasi-Lattices And Quasi-Crystals Emerge From TheNotion Of P-Adic Manifold?

This section is inspired by the considerations of the new chapter "What p-adic icosahedron could mean? And what about p-adic manifold?" [K117]. The original purpose was to understand what the notion of p-adic icosahedron could mean but soon it turned out that the key challenge is to understand what p-adic manifold means. Also in TGD framework this is one of the basic challenges posed by the condition of number theoretical universality and the idea about algebraic continuation of physics between different number fields.

The basic problem is that p-adic topology is totally disconnected meaning that p-adic balls are either disjoint or nested so that the usual construction of manifold structure fails. The basic criticism against the notion of p-adic icosahedron, and more generally, the notion of p-adic manifold, is the technical complexity of the existing constructions by mathematicians.

TGD however suggests much simpler construction. The construction relies on a simple modification of the notion of manifold inspired by the interpretation of p-adic preferred extremals defining counterparts of real preferred extremals as cognitive representations of the latter. This requires a mapping from p-adic preferred extremals to real ones and vice versa. In manifold theory chart maps are the analogs of these maps and the only difference is that they are between different number fields (see the appendix of the book).

What I have christened as canonical identification $I_{k,l}^Q$ mapping rationals $p^{rk}m/n$ with $|m|_p > p^{-k}$, $|n|_p > p^{-k}$, as $I_{k,l}^Q(p^{rk}(m/n)) = p^{-rk}I_{k,l}(m)/I_{k,l}(n)$, where $I_{k,l}(m = \sum m_n p^{nk}) = \sum_{n<l} m_n p^{-nk}$ defines canonical identification for p-adic numbers m,n satisfying the above conditions in their pinary expansion with two cutoffs k and l. $I_{k,l}^Q$ is ill defined for irrational p-adic numbers since for them the representation as rational is not unique. A generalization to algebraic extensions is straightforward.

$I_{k,l}^Q$ is a compromise between the direct identification along common rationals favored by algebra and symmetries but being totally discontinuous without the cutoff $n < l$. This cutoff breaks symmetries slightly but guarantees continuity in finite measurement resolution defined by the pinary cutoff l. Symmetry breaking can be made arbitrarily small and has interpretation in terms of finite measurement resolution. Due to the pinary cutoff the chart map applied to various p-adic coordinates takes discrete set of rationals to discrete set of rationals and preferred extremal property can be used to make a completion to a real space-time surface. Uniqueness is achieved only in finite measurement resolution and is indeed just what is needed. Also general coordinate invariance is broken in finite measurement resolution. In TGD framework it is however possible to find preferred coordinates in order to minimize this symmetry breaking.

TGD based view about p-adic manifolds

The construction of p-adic manifold topology somehow overcoming the difficulty posed by the fact that p-adic balls are either disjoint or nested is necessary. It should also allow a close relationship between p-adic and real preferred extremals. It will be found that TGD leads naturally to a proposal of p-adic manifold topology [K117] based on canonical identification used to map the predictions of p-adic mass calculations to real numbers. This map would define coordinate charts for p-adic space-time surfaces - not as p-adic chart leafs as in the standard approach - but as real chart leafs. The real topology induced from real map leafs to the p-adic realm would be path-connected as required (see **Fig.** `http://tgdtheory.fi/appfigures/padmanifold.jpg` or **Fig. ??** in the appendix of this book).

In TGD framework one must also require finite measurement resolution meaning that the canonical identification is characterized by pinary cutoff takes a discrete subset of rational points of p-adic preferred extremal to its real counterpart: for a subset of this subset rationals are mapped to themselves. One can complete this point set to a real preferred extremal in finite measurement resolution. This construction allows also to define p-adic integrals and differential forms in terms of their real counterparts by algebraic continuation. Therefore geometric notions like distance and volume make sense and there is a very close correspondence between real space-time geometries and their p-adic counterpart in the situations when they exist.

Can one consider a p-adic generalization of Penrose tiling and quasicrystals?

The mathematically rigorous generalization of Penrose Tilings and quasicrystals to p-adic context might be possible but is bound to be rather technical. The p-adic icosahedron as it is defined in the article does not seem very promising notion. The point is that it is defined in terms of fixed point set for subgroups of icosahedral group acting on Riemann sphere: the action in Euclidian 3-space is now more natural and certainly makes sense and actually simplifies the situation since Q_p^3 sd analog of E^3 is simplest possible 3-D p-adic manifold. It does not however allow Bruhat-Tits tree since the points of Q_p^n are not in 1-1 correspondence with the lattices of Q_p^n. The possibility to construct Bruhat-Tits tree is a special feature of projective spaces.

TGD based view about p-adic E^3 and S^2 as its sub-manifold allows to define also the counterpart of Penrose tiling and QCs in an elegant manner with a close relationship between real and p-adic variants of QC.

1. If one considers lattices in n-dimensional p-adic space Q_p^n replacing E^n, a more natural definition would be in terms of this space than in terms of sphere. For the counterpart of E^3 one can define the action of the subgroup A_5 of rotation group $SO(3)$ by introducing an algebraic extension of the p-adic numbers containing $cos(2\pi/5)$, $sin(2\pi/5)$ and $cos(2\pi/3)$, $sin(2\pi/3)$ and their products. What is interesting is that algebraic extension is forced automatically in p-adic context! In cut and project (see `http://tinyurl.com/ybdbvjoa`) method [?] the QC structure requires also this since the imbedded space has an algebraic dimension over integers equal to the dimension of the embedding space over reals.

   Could it be that p-adic variants of QCs might provide number theoretic insights about QCs? Subspace would define algebraic extension of p-adic numbers and this extension would be such that it allows the representation of the isometry group of the Platonic solid possibly assignable to the QC.

2. One can also now define the icosahedron or any Platonic solid in terms of fixed points also now. Only discrete subgroups of the rotation group can be represented p-adically since algebraic extension is required. This brings in mind the notion of finite measurement resolution leading to a discretization of p-adically representable rotations and more general symmetries. For instance, without algebraic extension only rotations for which the rotation matrices are rational numbers are representable. It seems that finite subgroups of this kind are generated by rotations with rotation angle $\pi/2$ around various coordinate axes. Pythagorean triangles correspond to rationals values of cosine and sine and rotations for which rotation angle corresponds to Pythagorean angle define rational rotation matrices: these groups are discrete but contain infinite number of elements.

   Altogether this suggests a hierarchy of p-adic extensions leading to higher algebraic dimensions and larger discrete symmetries. This conforms with the general number theoretic vision about TGD.

3. Lattices in Q_p^n with integer coefficients make also sense and are characterized by n linearly independent (over p-adic integers) basic vectors $(a_1, ..., a_n)$. Most points of lattice would correspond to values of p-adic integers n_i in $\sum_i n_i a_i$ infinite as real numbers.

Consider first a non-realistic option in which p-adic integers are mapped to p-adic integers as such. Note also that most of p-adic lattice points would map to real infinity. This kind of correspondence makes sense also for rationals but would give a totally discontinuous correspondence between reals and p-adics.

p-Adic manifold topology defined in terms of the canonical identification I_{kl} allows to interpret the p-adic lattice as a cognitive representation of the real one. The presence of pinary cutoffs k and l having interpretation in terms of finite cognitive resolution has two implications. Integers $n_i < p^k$ are mapped to themselves so that this portion of lattice is mapped to itself faitfully. The integers $k \leq n < l$ are not mapped to integers and the length of the image is bounded below. The real image of the p-adic lattice under I_{kl} is necessary compressed to a finite volume of E^3. This kind of compression and cutoff is natural for cognitive representations for which numerics with finite cutoff provides one particular analogy.

4. Could the notion of p-adic QC and Penrose tiling make sense if one considers p-adic counterparts of Euclidian space and a n-D cubic lattice with integer valued coefficients and spanned by unit vectors? Could the cut and project method [?] generalize?

   This is not clear since projection would lead from a lattice in Q_p^n to a QC in lower-dimensional space which is associated with algebraic extension of Q_p but having algebraic dimension equal to n. If this space is K^m, K an algebraic extension of Q_p, one has $n = dim(K) \times m$. For prime values of n this would mean that $m = 1$ and one has n-D algebraic extension.

   Projection should be generalized to a map mapping points of n-D space to m-dimensional subspace K^m associated with algebraic extension of Q_p. Maybe it is better to formally extend Q_p^n to K^n and restrict the lattice to integer lattice in $Q_p^n \subset K^n$. In this manner the projection becomes well-defined as map from $Q_p^n \subset K^n$ to a subspace K^m of K^n. The basic condition could be that the points of the subspace K^m in K^n with algebraic dimension $n \times dim(K)$ define and m-dimensional subspace over K and n-dimensional subspace of Z_p.

   The "irrational angles" associated with the lower-dimensional subspace defining quasilattice defining algebraic extension of Q_p should be such that it allows the representation of the isometry group of the p-adic Platonic solid possibly assignable to the QC in question.

Cut and project construction of quasicrystals from TGD point of view

Cut and project (see `http://tinyurl.com/ybdbvjoa`) [?] method is used to construct quasicrystals (QCs) in sub-spaces of a higher-dimensional linear space containing an ordinary space filling lattice, say cubic lattice. For instance, 2-D Penrose tiling is obtained as a projection of part of 5-D cubic lattice - known as Voronyi cell - around 2-D sub-space imbedded in five-dimensional space. The orientation of the 2-D sub-space must be chosen properly to get Penrose tiling. The nice feature of the construction is that it gives the entire 2-D QC. Using local matching rules the construction typically stops.

1. Sub-manifold gravity and generalization of cut and project method

The representation of space-time surfaces as sub-manifolds of 8-D $H = M^4 \times CP_2$ can be seen as a generalization of cut and project method.

1. The space-time surface is not anymore a linear 4-D sub-space as it would be in cut and project method but becomes curved and can have arbitrary topology. The embedding space ceases to be linear $M^8 = M^4 \times E^4$ since E^4 is compactified to CP_2. Space-time surface is not a lattice but continuum.

2. The induction procedure geometrizing metric and gauge fields is nothing but projection for H metric and spinor connection at the continuum limit. Killing vectors for CP_2 isometries can be identified as classical gluon fields. The projections of the gamma matrices of H define induced gamma matrices at space-time surface. The spinors of H contain additional components allowing interpretation in terms of electroweak spin and hyper-charge.

2. Finite measurement resolution and construction of p-adic counterparts of preferred extremals forces "cut and project" via discretization

In finite measurement resolution realized as discretization by finite pinary cutoff one can expect to obtain the analog of cut and project since 8-D embedding space is replaced with a lattice structure.

1. The p-adic/real manifold structure for space-time is induced from that for H so that the construction of p-adic manifold reduces to that for H.

2. The definition of the manifold structure for H in number theoretically universal manner requires for H discretization in terms of rational points in some finite region of M^4. Pinary cutoffs- two of them - imply that the manifold structures are parametrized by these cutoffs charactering measurement resolution. Second cutoff means that the lattice structure is piece of an infinite lattice. First cutoff means that only part of this piece is a direct imagine of real/p-adic lattice on p-adic/real side obtained by identifying common rationals (now integers) of real and p-adic number fields. The mapping of this kind lattice from real/p-adic side to p-adic/real side defines the discrete coordinate chart and the completion of this discrete structure to a preferred extremal gives a smooth space-time surface also in p-adic side if it is known on real side (and vice versa).

3. Cubic lattice structures with integer points are of course the simplest ones for the purposes of discretization and the most natural choice for M^4. For CP_2 the lattice is completely analogous to the finite lattices at sphere defined by orbits of discrete subgroups of rotation group and the analogs of Platonic solids emerge. Probably some mathematician has listed the Platonic solids in CP_2.

4. The important point is that this lattice like structure is defined at the level of the 8-D embedding space rather than in space-time and the lattice structure at space-time level contains those points of the 8-D lattice like structure, which belong to the space-time surface. Finite measurement resolution suggests that all points of lattice, whose distance from space-time surface is below the measurement resolution for distance are projected to the space-time surface. Since space-time surface is curved, the lattice like structure at space-time level obtained by projection is more general than QC.

The lattice like structure results as a manifestation of finite measurement resolution both at real and p-adic sides and can be formally interpreted in terms of a generalization of cut and project but for a curved space-time surface rather than 4-D linear space, and for H rather than 8-D Minkowski space. It is of course far from clear whether one can obtain anything looking like say 3-D or 4-D version of Penrose tiling.

1. The size scale of CP_2 is so small (10^4 Planck lengths) that space-time surfaces with 4-D M^4 projection look like M^4 in an excellent first approximation and using M^4 coordinates the projected lattice looks like cubic lattice in M^4 except that the distances between points are not quite the M^4 distances but scaled by an amount determined by the difference between induced metric and M^4 metric. The effect is however very small if one believes on the general relativistic intuition.

   In TGD framework one however can have so called warped embeddings of M^4 for which the component of the induced metric in some direction is scaled but curvature tensor and thus gravitational field vanishes. In time direction this scaling would imply anomalous time dilation in absence of gravitational fields. This would however cause only a the compression or expansion of M^4 lattice in some direction.

2. For Euclidian regions of space-time surface having interpretation as lines of generalized Feynman diagrams M^4 projection is 3-dimensional and at elementary particle level the scale associated with M^4 degrees of freedom is roughly the same as CP_2 scale. If CP_2 coordinates are used (very natural) one obtains deformation of a finite lattice-like structure in CP_2 analogous to a deformation of Platonic solid regarded as point set at sphere. Whether this lattice like structure could be seen as a subset of infinite lattice is not clear.

3. One can consider also string like objects $X^2 \times Y^2 \subset M^4 \times CP_2$ with 2-D M^4 projection and their deformations. In this case the projection of M^4 lattice to X^2 - having subset of two

M^4 coordinates as coordinates - can differ considerably from a regular lattice since X^2 can be locally tilted with respect to M^4 lattice. This cannot however give rise to Penrose tiling requiring 5-D flat embedding space. This argument applies also to 2-D string world sheets carrying spinor modes. In the idealized situation that string world sheet is plane in M^4 one might obtain an analog of Penrose tiling but with 4-D embedding space.

The above quasi lattice like structures (QLs) are defined by a gravitational deformation of the cubic lattice of M^4. Is there any hope about the 4-D QLs in M^4 so that gravitation would give rise to the analogs of phason waves deforming them? Could cut and project method be generalized to give QL in M^4 as projection of 8-D cubic lattice in M^8?

3. $M^8 - H$ duality

Before considering an explicit proposal I try to describe what I call $M^8 - H$ duality ($H = M^4 \times CP_2$).

1. What I have christened $M^8 - H$ duality is a conjecture stating that TGD can be equivalently defined in M^8 or $M^4 \times CP_2$. This is the number theoretic counterpart of spontaneous compactification of string models but has nothing to do with dynamics: only two equivalent representations of dynamics would be in question.

2. Space-time surfaces (preferred extremals) in M^8 are postulated to be quaternionic sub-manifolds of M^8 possessing a fixed $M^2 \subset M^4 \subset M^8$ as sub-space of tangent space. "Quaternionic" means that the tangent space of M^4 is quaternionic and thus associative. Associativity conditions would thus determine classical dynamics. More generally, these subspaces $M^2 \subset M^8$ can form integrable distribution and they define tangent spaces of a 2-D sub-manifold of M^4. If this duality really holds true, space-time surfaces would define a lattice like structure projected from a cubic M^8 lattice. This of course does not guarantee anything: M^8-H duality itself suggests that these lattice like structures differ from regular M^4 crystals only by small gravitational effects.

3. The crucial point is that quaternionic sub-spaces are parametrized by CP_2. Quaternionic 4-surfaces of $M^8 = M^4 \times CP_2$ containing the fixed $M^2 \subset M^8$ can be mapped to those of $M^4 \times CP_2$ by defining M^4 coordinates as projections to preferred $M^4 \subset M^8$ and CP_2 coordinates as those specifying the tangent space of 4-surface at given point.

4. A second crucial point is that the preferred subspace $M^4 \subset M^8$ can be chosen in very many ways. This embedding is a complete analog of the embedding of lower-D subspace to higher-D one in cut and project method. M^4 can be identified as any 4-D subspace imbedded in M^4 and the group $SO(1,7)$ of 8-D Lorentz transformations defines different embeddings of M^4 to M^8. The moduli space of different embeddings of M^4 is the Grassmannian $SO(1,7)/SO(1,3) \times SO(4)$ and has dimension $D = 28 - 6 - 6 = 16$.

   When one fixes two coordinate axes as the real and one imaginary direction (physical interpretation is as an identification of rest system and spin quantization axes), one obtains $SO(1,7)/SO(2) \times SO(4)$ with higher dimension $D = 28 - 1 - 6 = 21$. When one requires also quaternionic structure one obtains the space $SO(1,7)/SU(1) \times SU(2)$ with dimension $D = 28 - 4 = 24$. Amusingly, this happens to be the number of physical degrees of freedom in bosonic string model.

5. How to obtain quasilattices and quasi-crystals in M^4?

Can one obtain quasi-lattice like structures (QLs) at space-time level in this framework? Consider first the space-time QLs possibly associated with the standard cubic lattice L^4_{st} of M^4 resulting as projections of the cubic lattice structure L^8_{st} of M^8.

1. Suppose that one fixes a cubic crystal lattice in M^8, call it L^8_{st}. Standard M^4 cubic lattice L^4_{st} is obtained as a projection to some M^4 sub-space of M^8 by simply putting 4 Euclidian coordinates for lattice points o constant. These sub-spaces are analogous to 2-D coordinate planes of E^3 in fixed Cartesian coordinates. There are $7!/3!4! = 35$ choices of this kind.

One can consider also E_8 lattice (see http://tinyurl.com/y9x7vevr) is an interesting identification for the lattice of M^8 since E_8 is self-dual and defines the root lattice of the exceptional group E_8. E_8 is union of Z^8 and $(Z+1/2)^8$ with the condition that the sum of all coordinates is an even integer. Therefore all lattice coordinates are either integers or half-integers. E_8 is a sub-lattice of 8-D cubic lattice with 8 generating vectors $e_i/2$, with e_i unit vector. Integral octonions are obtained from E_8 by scaling with factor 2. For this option one can imbed L^4_{st} as a sub-lattice to Z^8 or $(Z+1/2)^8$.

2. Although $SO(1,3)$ leaves the imbedded 4-plane M^4 invariant, it transforms the 4-D crystal lattice non-trivially so that all 4-D Lorentz transforms are obtained and define different discretizations of M^4. These are however cubic lattices in the Lorentz transformed M^4 coordinates so that this brings nothing new. The QLs at space-time surface should be obtained as gravitational deformations of cubic lattice in M^4.

3. L^4_{st} indeed defines 4-D lattice at space-time surface apart from small gravitational effects in Minkowskian space-time regions. Elementary particles are identified in TGD a Euclidian space-time regions - deformed CP_2 type vacuum extremals. Also black-hole interiors are replaced with Euclidian regions: black-hole is like a line of a generalized Feynman diagram, elementary particle in some sense in the size scale of the black-hole. More generally, all physical objects, even in everyday scales, could possess a space-time sheet with Euclidian metric signature characterizing their size (AdS^5/CFT correspondence could inspire this idea). At these Euclidian space-time sheets gravitational fields are strong since even the signature of the induced metric is changed at their light-like boundary. Could it be that in this kind of situation lattice like structures, even QCs, could be formed purely gravitationally? Probably not: an interpretation as lattice vibrations for these deformations would be more natural.

It seems that QLs are needed *already at the level of* M^4. M^8-H duality indeed provides a natural manner to obtain them.

1. The point is that the projections of L^8_{str} to sub-spaces M^4 defined as the $SO(1,7)$ Lorentz transforms of L^4_{st} define generalized QLs parametrized by 16-D moduli space $SO(1,7)/SO(1,3)\times SO(4)$. These QLs include also QCs. Presumably QC is a QL possessing a non-trivial point group just like Penrose tiling has the isometry group of dodecagon as point group and 3-D analog of Penrose tiling has the isometries of icosahedron as point group.

   This would allow to conclude that the discretization at the level of M^8 required by the definition of p-adic variants of preferred extremals as cognitive representations of their real counterparts would make possible 4-D QCs. M^8 formulation of TGD would explain naturally the QL lattices as discretizations forced by finite measurement resolution and cognitive resolution.

   A strong number theoretical constraint on these discretizations come from the condition that the 4-D lattice like structure corresponds to an algebraic extension of rationals. Even more, if this algebraic extension is 8-D (perhaps un-necessarily strong condition), there are extremely strong constraints on the 22-parameters of the embedding. Note that in p-adic context the algebraic extension dictates the maximal isometry group identified as subgroup of $SO(1,7)$ assignable to the embedding as the discussion of p-adic icosahedron demonstrates.

2. What about the physical interpretation of these QLs/QCs? As such QLs define only natural discretizations rather than physical lattices. It is of course quite possible to have also physical QLs/QCs such that the points - rather time like edge paths - of the discretization contain real particles. What about a "particle" localized to a point of 4-D lattice? In positive energy ontology there is no obvious answer to the question. In zero energy ontology the lattice point could correspond to a small causal diamond containing a zero energy state. In QFT context one would speak of quantum fluctuation. In p-adic context it would correspond to "though bubble" lasting for a finite time.

3. It is also possible to identify physical particles as edge paths of the 4-D QC, and one can consider time= constant snapshots as candidates for 3-D QCs. It is quite conceivable that the non-trivial point group of QCs favors them as physical QLs.

5. Expanding hyperbolic tessellations and quasi tessellations obtained by embedding $H^3 \subset M^4$ to $H^7 \subset M^8$

M^8-$M^4 \times CP_2$ duality and the discretization required by the notion of p-adic manifold relates in an interesting manner to expanding hyperbolic tessellations and quasi tessellations in $H^7 \subset M^8$, and possible expanding quasi-tessellations in obtained by embedding $H^3 \subset M^4$ to $H^7 \subset M^8$

1. Euclidian lattices E_8, E_7, E_6

   I have already considered E_8 lattice in M^8. The background space has however Minkowskian rather than Euclidian metric natural for the carrier space of the E_8 lattice. If one assigns some discrete subgroup of isometries to it, it is naturally subgroup of $SO(8)$ rather than $SO(1,7)$. Both these groups have $SO(7)$ as a subgroup meaning that preferred time direction is chosen as that associated with the real unit and considers a lattice formed from imaginary octonions.

   E_8 lattice scaled up by a factor 2 to integer lattice allows octonionic integer multiplication besides sums of points so that the automorphism group of octions: discreted subgroups of $G_2 \subset SO(7)$ would be the natural candidates for point groups crystals or lattice like structures.

   If one assumes also fixed spatial direction identified as a preferred imaginary unit, G_2 reduces to $SU(3) \subset SO(6) = SU(4)$ identifiable physically as color group in TGD framework. From this one ends up with the idea about $M^8 - M^4 \times CP_2$ duality. Different embeddings of $M^4 \subset M^8$ are quaternionic sub-spaces containing fixed M^2 are labelled by points of CP_2.

   All this suggests that E_7 lattice in time=constant section of even E^6 lattice is a more natural object lattice to consider. Kind of symmetry breaking scenario $E_8 \rightarrow E_7 \rightarrow E_6 \rightarrow G_2 \rightarrow SU(3)$ is suggestive. This Euclidian lattice would be completely analous to a slicing of 4-D space-time by 3-D lattices labelled by the value of time coordinate and is of course just what physical considerations suggest.

2. Hyperbolic tessellations

   Besides crystals defined by a cubic lattice or associated with E_6 or E_7, one obtains an infinite number of hyperbolic tessellations in the case of M^8. These are much more natural in Minkowskian signature and could be also cosmologically very interesting. Quite generally, one can say that hyperbolic space is ideal for space-filling packings defined by hyperbolic manifolds H^n/Γ: they are completely analogous to space-filling packings of E^3 defined by discrete subgroups of translation group producing packings of E^3 by rhombohedra. One only replaces discrete translations with discrete Lorentz transformations. This is what makes these highly interesting from the point of view of quantum gravity.

   (a) In M^{n+1} one has tessellations of n-dimensional hyperboloid H^n defined by $t^2 - x1^2 - ... - x_n^2 = a^2 > 0$, where a defines Lorentz invariant which for $n = 4$ has interpretation as cosmic time in TGD framework. Any discrete subgroup Γ of the Lorentz group $SO(1,n)$ of M^{n+1} with suitable additional conditions (finite number of generators at least) allows a tessellation of H^n by basic unit H^n/Γ. These tessellations come as 1-parameter families labelled by the cosmic time parameter a. These 3-D tessellations participate cosmic expansion. Of course, also ordinary crystals are crystals only in spatial directions. One can of course discretize the values of a or some function of a in integer multiples of basic unit and assign to each copy of H^n/Γ a "center point" to obtain discretization of M^{n+1} needed for p-adicization.

   (b) For $n = 3$ one has M^4 and H^3, and this is very relevant in TGD cosmology. The parameter a defines a Lorentz invariant cosmic time for the embeddings of Robertson-Walker cosmologies to $M^4 \times CP_2$. The tessellations realized as physical lattices would have natural interpretation as expanding 3-D lattice like structures in cosmic scales. What is new is that discrete translations are replaced by discrete Lorentz boosts, which correspond to discrete velocities and observationally to discrete red shifts for distant objecst. Interestingly, it has been found that red shift is quantized along straight lines [E176]: "God's fingers" is the term used. I proposed for roughly two decades ago an explanation based on closed orbits of photons around cosmic strings [K31]. but explanation in terms of tessellations would also give rise to periodicity. A fascinating possibility is that these tessellation have defined macroscopically quantum coherent structures during the very early cosmology the size scale of H^3/Γ was very small. One can also ask whether the macroscopic quantum coherence could still be there.

Hyperbolic manifold property has purely local signatures such as angle surplus: the very fact that there are infinite number of hyperbolic tessellations is in conflict with the fact that we have Euclidian 3-geometry in every day length scales. In fact, for critical cosmologies, which allow a one-parameter family of embeddings to $M^4 \times CP_2$ (parameter characterizes the duration of the cosmology) one obtains flat 3-space in cosmological scales. Also overcritical cosmologies for which $a = constant$ section is 3-sphere are possible but only with a finite duration. Many-sheeted space-time picture also leads to the view that astrophysical objects co-move but do not co-expand so that the geometry of time=constant snapshot is Euclidian in a good approximation.

3. Does the notion of hyperbolic quasi-tessellation make sense?

   Can one construct something deserving to be called quasi tessellations (QTs)? For QCs translational invariance is broken but in some sense very weakly: given lattice point has still an infinite number of translated copies. In the recent case translations are replaced by Lorentz transformations and discrete Lorentz invariance should be broken in similar weak manner.

   If cut and project generalizes, QTs would be obtained using suitably chosen non-standard embedding $M^4 \subset M^8$. Depending on what one wants to assume, M^4 is now image of M^4_{st} by an element of $SO(1,7)$, $SO(7), SO(6)$ or G_2. The projection - call it P - must take place to M^4 sliced by scaled copies of H^3 from M^8_{st} sliced by scaled copies of H^7/Γ tessellation. The natural option is that P is directly from H^7 to $H^3 \subset H^7$ and is defined by a projecting along geodesic lines orthogonal to H^3. One can choose always the coordinates of M^4 and M^8 in such a way that the coordinates of points of M^4 are $(t,x,y,z,0,0,0,0)$ with $t^2 - r^2 = a_4^2$ whereas for a general point of H^7 the coordinates are $(t,x,y,z,x_4,...x_7)$ with $t^2 - r^2 - r_4^2 = a_8^2$ for $H^3 \subset H^7$. The projection is in this case simply $(t,x,y,z,x_4,...,x_7) \rightarrow (t,x,y,z,0,...,0)$. The projection is non-empty only if one has $a_4^2 - a_8^2 \geq 0$ and the 3-sphere S^3 with radius $r_4 = \sqrt{a_4^2 - a_8^2}$ is projected to single point. The images of points from different copies of H^7/Γ are identical if S^3 intersects both copies. For r_4 much larger than the size of the projection $P(H^7/\Gamma)$ of single copy overlaps certainly occurs. This brings strongly in mind the overlaps of the dodecagons of Penrose tiling and icosahedrons of 3-D icosahedral QC. The point group of tessellation would be Γ.

4. Does one obtain ordinary H^3 tessellations as limits of quasi tessellations?

   Could one construct expanding 3-D hyperbolic tessellations H_3/Γ_3 from expanding 7-D hyperbolic tessellations having H^7/Γ_7 as a basic building brick? This seems indeed to be the outcome at at the limit $r_4 \rightarrow 0$. The only projected points are the points of H^3 itself in this case. The counterpart of the group $\Gamma_7 \subset SO(1,7)$ is the group obtained as the intersection $\Gamma_3 = \Gamma_7 \cap SO(1,3)$: this tells that the allowed discrete symmetries do not lead out from H^3. This seems to mean that the 3-D hyperbolic manifold is H^3/Γ_3, and one obtains a space-filling 3-tessellation in complete analogy for what one obtains by projecting cubic lattice of E^7 to E^3 imbedded in standard manner. Note that $\Gamma_3 = \Gamma_7 \cap SO(1,3)$, where $SO(1,3) \subset SO(1,7)$, depends on embedding so that one obtains an infinite family of tessellations also from different embeddings parametrized by the coset space $SO(1,7)/SO(1,3)$. Note that if Γ_3 contains only unit element $H^3 \subset H^7/\Gamma_7$ holds true and tessellation trivializes.

4.10 About syncronization of clocks

This section originated from a debate with some anti-Einsteinians about synchronization of clocks. At modern times physicists regard this kind of ponderings “philosophical” and something negative.

The discussion however led to the question whether it is possible to synchronize clocks in Lorentz invariant manner. The answer to this question is positive quite generally in TGD - put the clocks at hyperboloid of light-cone- and leads to a vision about synchronization in terms of quantum entanglement in a tensor network defined by a tessellation of hyperboloid of M^4.

4.10.1 Einstein did not assume that clock synchorinization is Lorentz invariant

I participated an FB discussion with several anti-Einsteinians. As a referee I have expressed my opinion about numerous articles claiming that Einstein's special or general relativity contains a fatal error not noticed by any-one before. I have tried to tell that colleagues are extremely eager to find a mistake in the work of colleague so that logical errors can be safely excluded. If something goes wrong it is at the level of basic postulates. In vain.

Once I had a long email discussion with a professor of logic who claimed to have found logical mistake in the deduction of time dilation formula. It was easy to find that he thought in terms of Newtonian space-time and this was of course in conflict with relativistic view. The logical error was his, not Einstein's. I tried to tell this. In vain again.

At this time I was demanded to explain why the 2 page article of Stephen Crothers (see `http://tinyurl.com/yc2qqncz`). This article was a good example of own logical error projected to that of Einstein. The author assumed besides the basic formulas for Lorentz transformation also synchronization of clocks so that they show the same time everywhere (about how this is achieved see `http://tinyurl.com/jdccns4n`).

Even more: Crothers assumes that *Einstein assumed* that this synchronization is Lorentz invariant. Lorentz invariant synchronization of clocks is not however possible for the linear time coordinate of Minkowski space as also Crothers demonstrates. Einstein was wrong! Or was he? No!: Einstein of course did not assume Lorentz invariant synchronization!

The assumption that the synchronization of clock network is invariant under Lorentz transformations is of course in conflict with SR. In Lorentz boosted system the clocks are not in synchrony. This expresses just Einstein's basic idea about the relativity of simultaneity. Basic message of Einstein is misunderstood!

The basic predictions of SR - time dilation and Lorentz contraction - do not depend on the model of synchronization of clocks . Time dilation (see `http://tinyurl.com/qdnn5h9`) and Lorentz contraction (see `http://tinyurl.com/nuxr9db`) follow from the basic geometry of Minkowskian space-time extremely easily.

Draw system K and K' moving with constant velocity with respect to K. The t' and x' axis of K' have angle smaller than $\pi/2$ and are the in first quadrant.

1. Assume first that K corresponds to the rest system of particle. You see that the projection of segment $(0,t')$ of t'-axis to t-axis is shorter than the segment $(0,t)$: time dilation.

2. Take K to be the system of stationary observer. Project the segment $L=(0,x')$ to segment on x axis. It is shorter than L: Lorentz contraction.

There is therefore no need to build synchronized networks of clocks to deduce time dilation and Lorentz contraction. They follow from Minkowskian geometry.

4.10.2 Is it possible to have Lorentz invariant synchronization?

The above argument raises a question. Is it possible to find a system in which synchronization is possible in Lorentz invariant manner? The quantity $a^2 = t^2 - x^2$ defines proper time coordinate a along time like geodesics as Lorentz invariant time coordinate of light-one. a = constant hypersurfaces are now hyperboloids. If you have a synchronized network of clocks, its Lorentz boost is also synchronized. General coordinate invariance of course allows this choice of time coordinate.

For Robertson-Walker cosmologies with sub-critical mass time coordinate a is Lorenz invariant so that one can have Lorentz invariant synchronization of clocks. General Coordinate Invariance allows infinitely many choices of time coordinate and the condition of Lorentz invariant synchronization fixes the time coordinate to cosmic time (or its function to be precise). To my opinion this is rather intesting fact.

What about TGD? In TGD space-time is 4-D surface in $H = M^4 \times CP_2$. $a^2 = t^2 - r^2$ defines Lorentz invariant time coordinate a in future light-cone $M^4_+ \subset M^4$ which can be used as time-coordinate also for space-time surfaces.

Robertson-Walker cosmologies can be imbedded as 4-surfaces to $H = M^4 \times CP_2$. The empty cosmology would be just the lightcone M^4_+ imbedded in H by putting CP_2 coordinates constant. If CP_2 coordinates depend onM^4_+ proper time a, one obtains more general expanding RW cosmologies. One can have also sub-critical and critical cosmologies for which Lorentz transformations are not isometries of $a=$ constant section. Also in this case clocks are synchronized in Lorentz invariant manner. The duration of these cosmologies is finite: the mass density diverges after finite time.

4.10.3 What about actual realization of Lorentz invariant synchronization?

What about actual Lorentz invariant synchronization of the clocks? Could TGD say something non-trivial about this problem? I received an interesting link relating to this (see `http://tinyurl.com/gkr62bt`). The proposed theory deals with fundamental uncertainty of clock time due to quantum-gravitational effects. There are of course several uncertainties involved since quantum theory of gravity does not exist (officially) yet!

1. Operationalistic definition of time is adopted in the spirit with the empiristic tradition. Einstein was also empirist and talked about networks of synchronized clocks. Nowadays particle physicists do not talk much about them. Symmetry based thinking dominates and Special Relativity is taken as a postulate about symmetries.

2. In quantum gravity situation becomes even rather complex. If quantization attempt tries to realize quantum states as superpositions of 3-geometries one loses time totally. If GRT space-time is taken to be small deformation of Minkowski space one has path integral and classical solutions of Einstein's equation define the background.

   The difficult problem is the identification of Minkowski coordinates unless one regards GRT as QFT in Minkowski space. In astrophysical scales QFT picture one must consider solutions of Einstein's equations representing astrophysical objects. For the basic solutions of Einstein's equations the identification of Minkowski coordinates is obvious but in general case such as many-particle system this is not anymore so. This is a serious obstacle in the interpretation of the classical limit of GRT and its application to planetary systems.

What about the situation in TGD? Particle physicist inside me trusts symmetry based thinking and has been somewhat reluctant to fill space-time with clocks but I am ready to start the job if necessarily! Since I am lazy I of course hope that Nature might have done this already and the following argument suggests that this might be the case!

1. Quantum states can be regarded as superpositions of space-time surfaces inside causal diamond of embedding space $H = M^4 \times CP_2$ in quantum TGD. This raises the question how one can define universal time coordinate for them. Some kind of absolute time seems to be necessary.

2. In TGD the introduction of zero energy ontology (ZEO) and causal diamonds (CDs) as perceptive fields of conscious entities certainly brings in something new, which might help. CD is the intersection of future and past directed light-cones analogous to a big bang followed by big crunch. This is however only analogy since CD represents only perceptive field not the entire Universe.

   The imbeddability of space-time as to $CD \times CP_2 \subset H = M^4 \times CP_2$ allows the proper time coordinate $a^2 = t^2 - r^2$ near either CD bouneary as a universal time coordinate, "cosmic time". At $a=$ constant hyperboloids Lorentz invariant synchronisation is possible. The coordinate a is kind of absolute time near a given boundary of CD representing the perceptive field of a particular conscious observer and serves as a common time for all space-time surfaces in the superposition. Newton would not have been so wrong after all.

   Also adelic vision involving number theoretic arguments selects a as a unique time coordinate. In p-adic sectors of adele number theoretic universality (NTU) forces discretization since the coordinates of hyperboloid consist of hyperbolic angle and ordinary angles. p-Adicallhy one cannot realize either angles nor their hyperbolic counterparts. This demands discretization in terms of roots of unity (phases) and roots of e (exponents of hyperbolic angles) inducing finite-D extension of p-adic number fields in accordance with finiteness of cognition. a as Lorentz invariant would be genuine p-adic coordinate which can in principle be continuous in p-adic sense. Measurement resolution however discretizes also a.

This discretization leads to tessellations of a=constant hyperboloid having interpretation in terms of cognitive representation in the intersection of real and various p-adic variants of space-time surface with points having coordinates in the extension of rationals involved. There are two choices for a. The correct choice corresponds to the passive boundary of CD unaffected in state function reductions.

3. Clearly, the vision about space-time as 4-surface of H and NTU show their predictive power. Even more, adelic physics itself might solve the problem of Lorentz invariant synchronization in terms of a clock network assignable to the nodes of tessellation!

   Suppose that tessellation defines a clock network. What synchronization could mean? Certainly strong correlations between the nodes of the network Could the correlation be due to maximal quantum entanglement (maximal at least in p-adic sense) so that the network of clocks would behave like a single quantum clock? Bose-Einstein condensate of clocks as one might say? Could quantum entanglement in astrophysical scales predicted by TGD via $h_{gr} = h_{eff} = n \times h$ hypothesis help to establish synchronized clock networks even in astrophysical scales? Could Nature guarantee Lorentz invariant synchronization automatically?

   What would be needed would be not only 3-D lattice but also oscillatory behaviour in time. This is more or less like time crystal (see `http://tinyurl.com/jbj5j68` and `http://tinyurl.com/zy73t6r`)! Time crystal like states have been observed but they require feed of energy in contrast to what Wilzek proposed. In TGD Universe this would be due to the need to generate large $h_{eff}/h = n$ phases since the energy of states with n increases with n [?]. In biological systems this requires metabolic energy feed. Can one imageine even cosmic 4-D lattice for which there would be the analog of metabolic energy feed?

   I have already a model for tensor networks and also here a appears naturally [L21]. Tensor networks would correspond at embedding space level to tessellations of hyperboloid $t^2 - r^2 = a^2$ analogous to 3-D lattices but with recession velocity taking the role of quantized position for the point of lattice. They would induce tessellations of space-time surface: space-time surface would go through the points of the tessellation (having also CP_2 counterpart). The number of these tessellations is huge. Clocks would be at the nodes of these lattice like structures. Maximal entanglement would be key feature of this network. This would make the clocks at the nodes one big cosmic clock.

   If astrophysical objects serving as clocks tend to be at the nodes of tessellation, quantization of cosmic redshifts is predicted! What is fascinating is that there is evidence for this [E176, E264]: for TGD based model for this see [K94, K66]! Maybe dark matter fraction of Universe might have taken care of the Lorentz invariant synchronization so that we need not worry about that!

4.11 Does The Rate Of Cosmic Expansion Oscillate?

H. I. Ringermacher and L. R. Mead have written a very nice article (`http://tinyurl.com/oqcn2hp`) with title "Observation of discrete oscillations in a model-independent plot of cosmological scale factor versus lookback time and scalar field model" [E233]. In the following I summarize the contents of the article as I understand it. After that I consider TGD inspired model for the findings based on the assumption that dark matter corresponds to phase with gigantic values of effective Planck constant. Appendix contains summary about Gaussian Mersennes which predict correctly both cosmological, astrophysical, biological, nuclear physics, length scales and predict new important length scales in particle physics.

The claim of the article is that the time derivative of the cosmic scale parameter da/dt oscillates peroidically. When da/dt has minimum or maximum, the acceleration parameter d^2a/dt^2

of the Universe changes sign acclerating expansions changes to slowing down or vice versa. The authors have used several methods such as smoothing, fast Fourier transform and autocorrelation and they are reported to all give the same results. 3.5 sigma is mentioned as characterization of the reliability of finding: the probability that it finding is fluke would be smaller than .1 per cent if the observable value obey Gaussian distribution (`http://tinyurl.com/zp6tpr3`). For a layman it seems a miracle that the authors can extract from the chaotic looking data for da/dt a nice graph showing at least three minima and maxima.

Authors reports that the acceleration for the rate of cosmic expansion oscillates rather than being approximately constant. Instead of single transition redshift at which acceleration changes sign there are three in the region of redshifts studied. The period of oscillation in cosmic time t is deduced to be approximately .15 ($\simeq 1/7$) Hubbles times $T_H = 1/H_0 \simeq 1.4 \times 10^{10}$ years= 14 aeons from the nominal value of $H_0 = 68kms^{-1}MPc^{-1}$.

The findings are explained in terms of a model of dark energy and matter. Quite generally, these models explain dark energy in terms of vacuum energy of some field. It is assumed that scalar field vacuum expectation value oscillating with frequency $f = .15H_0$ and attenuating exponentially with an attenuation coefficient $\lambda = 2.8/t(now)$, where $t(now)$ is the age of the Universe about $t(now) = 1.38 \times 10^{10}$ years. The mass of the scalar field would be incredibly small - about 3×10^{-32} eV. The corresponding Compton time would be 1.3×10^{10} years and very close the age of the Universe. The model is otherwise like ΛCDM model but adds this tiny effect. Hence the constantly accelerating expansion is modified with oscillating expansion slightly deviating from from during the early cosmology.

In absence of accelerating expansion redshift z would be in good approximation linear in time. Now the situation is however nonlinear and authors deduce the relationship $t = t(z)$ allowing to express a and da/dt as functions of redshift z, which in ideal cosmic expansion is given by $z = a(now)/a(then) - 1$, where $a(now)$ and $a(then)$ are value of scale radius a now and at the moment of emission.

The model thus replaces single transition redshift with average value $z = .77$ with three transition redshifts. In fact, it has been found that Planck date differ in details from the earlier CMB data modelled rather satisfactorily in ΛCDM model.

The relative minima of da/dt were found at times $t/t(now) = 0.78$, 0.63 and 0.47 and relative maxima at times $t/t(now) = 0.87$, 0.71 and 0.56. $\Delta t/t(now) = .15$ is clearly the period. The relative minima correspond to red-shifts of $z = 0.26$, 0.51, and 0.9: note that the first two correspond to approximate periodicity with $\Delta z = .25$ but the third - the earliest minimum at which acceleration begins to corresponds to much larger redshift than one might expect. The relative maxima correspond to $z = 0.14$, 0.3, and 0.66 (in the maximum the acceleration becomes negative). The reported transition phase shifts have a rather wide distribution. The identified transition redshifts are reported to be near to those reported in literature. The wide distribution of transition redshifts shows how large the uncertainties concerning the beginning of the accelerated expanations are.

4.11.1 TGD Based Model For The Findings

TGD based model relies heavily on recent TGD inspired view about cosmology and general ideas of quantum TGD, in particular the possibility of dark matter quantum coherent in astrophysical and even cosmological scales.

1. p-Adic length scale hypothesis allows to make quantitative estimates and so called Gaussian Mersennes discussed in the Appendix allow to identify fundamental length and time scales covering cosmology, astrophysics, biology, nuclear physics, and particle physics. TGD based description of dark matter as a hierarchy of phases with non-standard value of Planck constant is second new element.

   (a) p-Adic length scale hypothesis leads to the vision that cosmic expansion is not smooth at the level of many-sheeted space-time but takes place as rather rapid phase transitions. Either the p-adic length scale or dark length scale characterized by the value of the effective Planck constant $h_{eff} = n \times h$ assignable to the dark matter changes. The identification $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ assignable to a dark energy carrying magnetic flux tube connecting masses M and m is very attractive: v_0 is a velocity parameter characterizing the system and in the model for the planetary system has same value for inner (outer) planets [K93, K79].

(b) For a given dark matter object no expansion would occur during the intermediate periods. For instance, it is known that solar system does not participate cosmic expansion but only comoves. I have proposed that even Earth has suffered a local variant of such a phase transition increasing its size by a factor two: Cambrian explosion in biology would relate to this transition [L55].

(c) Critical cosmology would describe the phase transition. This model is a long length scale description of the situation in single sheeted space-time of GRT obtained by replacing the sheets of many-sheeted space-time with a slightly curved regions of Minkowski space with gravitational and other fields determined as sums of the gravitational fields and gauge potentials for the sheets [K111]. TGD inspired cosmology suggests a one parameter model for these phase transitions [K94]. This model is also behind the TGD counterpart of inflationary cosmology identified as a phase transition from cosmic string dominated phase to that in which GRT type space-time dominates. Phase transitions modellable by critical cosmology could also explain accelerated expansion considered now as occurring in much longer length and time scales.

(d) At the deeper level magnetic flux tubes carrying monopole fluxes are carriers of dark energy as magnetic energy and of dark matter as large h_{eff} phases. No new scalar fields such as inflaton fields are introduced. The hierarchy of Planck constants can be reduced to quantum criticality of TGD Universe allowing quantification in terms of a hierarchy of algebraic extensions of rationals in number theoretic formulation of TGD [K114]. The parameters characterizing string world sheets and partonic 2-surfacs serving as "space-time genes" and continuable to space-time surfaces as preferred extremals of Kähler action in strong holography belong to these algebraic extensions forming a hierarchy and inducing corresponding extensions of p-adic number fields allowing to extend real number based physics to adelic physics.

2. Zero energy ontology brings in further new elements.

(a) The number theoretic vision leads to the discretization of the moduli space for causal diamonds (CDs, basic element of ZEO) with second boundary fixed. Without discretization the moduli space would be hyperbolic space H^3 - cosmic time $a = constant$ section of future directed lightcone. Note that a corresponds to the scale factor $a(t)$ in TGD based cosmology. Discretization of H^3 is necessary and is obtained as a tessellation by identifying the points related by a infinite discrete sub-group H of $SL(2,C)$. The counterpart of lattice cell is H_3 coset defining hyperbolic manifold. The causal diamonds crucial for zero energy ontology have discrete wave function in this space. This suggests a lattice like structures in the sense that position of a physical system defined by the non-fixed top of corresponding CD has discrete position in the lattice defined by the action of the subgroup H. In ordinary 3-D lattices position is quantized. Now the direction of recession velocity and the hyperbolic angle defining the redshiftassociated with the corresponding astrophysical objects is quantized. Note that the redshift characterized the position only if the object is co-moving.

(b) Also the tessellation of second light-like boundary of causal diamond (CD) defines discrete moduli space identifiable as the orbit of discrete subgroup H: this tessellation would be limiting case of that for hyperbolic 3-space. In this case the lattice like structure would be physical and realized at space-time level. The positions of partonic 2-surfaces would form lattice like structure at the light-like boundary. Biology suggests that dark flux tubes form a grid like structure analogous to coordinate grid. For instance, in TGD based model galaxies are like pearls in the necklace formed by a flux tube. The dynamics of this dark lattice like structure would make it visible itself in the behavior of the visibile matter.

There is a strong temptation to think that the dark matter can form lattice like structures at the light-like boundary of CD. And these structures would expand in stepwise manner by rapid quantum phase transitions. This because dark matter could be quantum coherent in cosmological length scales.

(c) Adelic physics [K114] allows to consider a concrete prediction for the unit of quantized cosmic redhifts if astrophysical objects form tessellations of light-cone boundary and even H^3 in cosmic scales. The basic unit appearing in the exponent defining the Lorentz boost would depend on the algebraic extension involved and of p-adic prime defining effective p-adicity and would be $e^{\eta} = e^{k/np}$, $0 \leq k < np$. The hyperbolic "phase" relates by by the standard formula to the redshift: $1 + z = e^{\eta} = e^{k/np}$. The relationship to the cosmic recession velocity $\beta = v/c$ is obtained from $exp(\eta) = \gamma \times (1+\beta) = \sqrt{(1+\beta)/(1-\beta)}$, $\gamma = 1/\sqrt{1-\beta^2}$: $\beta = (exp(2\eta) - 1)/(exp(2\eta) + 1) = (exp(2k/np) + 1)/(exp(2k/np) - 1) \simeq k/np$. The recession velocity v is approximately quantized in multiples of $v_0 = c/np$. This formula for redshifts would hold true if cosmic expansion is the sole reason for the redshift and matter is concentrated at lattice points. The obvious question is whether the transition redshifts correspond to lattice points with constant red-shift difference in the first approximation. There indeed exist support for the quantization of redhifts [E264, E176]. As shown in [K115] [L11] the discretization at the level of moduli space of CDs could have direct connection with quantum groups describing finite measurement resolution at quantum level.

3. One cannot avoid bringing in TGD inspired theory of consciousness when one speaks about quantum phase transitions in ZEO [K112, K8].

   (a) ZEO based theory of quantum measurement defines a theory of consciousness and leads rather straightforwardly to the identification of the quantum physical correlates for the notion of self [K90, K8, K112]. These quantum phase transitions could correspond to state function reductions to the opposite boundary of CD following a sequence of reductions at fixed boundary (analog of repeated quantum measurement giving rise to Zeno effect). The reduction to opposite boundary would mean change of the arrow of time for CD in the scale considered: recall that CDs form a hierarchy and the arrow of time changes for dark matter.

   (b) Could the phase transitions changing the size scale of the lattice be this kind of phase transitions? It seems clear that if state function reductions at opposite boundary occur in cosmic scale, it must be followed rather rapidly by a phase transition bringing back the original arrow of time since otherwise the cosmology would become time reversed. Could the arrow of time associated with a larger CD force define standard arrow of time and force a rapid return to it for sub-CDs?

The following model for cosmic expansion as rapid phase transitions followed by damped oscillations suggests itself.

1. Dark matter lattice would not expand smoothly but by phase transitions in which the scale of the lattice would increase by a power of two (one cannot exclude $\sqrt{2}$ and in principle even powers of p or $\sqrt{p}$ must be considered). This could be interpreted as an increase of p-adic length scale or of effective Planck contant by factor 2. The subgroup H defining the lattice cell might change and the standard wisdom about phase transitions suggests that symmetry breaking to subgroup occurs. Super-symplectic algebra allows infinite hierarchy of sub-algebras isomorphic to with conformal weights coming as multiples of those for the entire algebra so that one has fractality: symmetry breaking without symmetry breaking. Same symmetry appears in larger scale defined by the new value of h_{eff}.

2. During the phase transitions rapid acceleration would occur and z would be larger than predicted by the models with smooth expansion. The authors indeed find that the earliest transition redshift is unexpectedly large. These transitions would be followed by lattice oscillations inducing the oscillations of da/dt too.

3. Visible matter would comove in the background defined by dark matter and would respond to dark matter phase transitions in cosmic scale in induced dynamics with additional anomalous expansion lasting the duration of dark matter phase transition. Comoving property means for visible matter means that in the scale of CD involved visible matter does not expand during the intermediate periods. This is known to be the case for solar system.

4. As found, the claimed transition redshifts correspond to scalings of a by factor smaller 2, which suggests that they three cycles (also fourth could be included in the model of authors) do not correspond to separate phase transitions but to single phase transition followed by an oscillation as in the proposed model. Time value t assigned to the three minima and maxima of da/dt are evenly spaced in good approximation.

   Number theoretical quantization for the exponents of the hyperbolic angles (analogous to phases) gives $z = exp(k/np) - 1$, $k = 1, ..., np - 1$ if no other sources of redshifts are present. If there are four minima within octave of a/a_0, one must have $p = 2$ and $n = 2$: both values are very natural. In this case the linear approximation for z is not good. The kinematical redshifts for the minima would be $z \in \{.28, .65, 1.12)\}$: note that the ratios of $1+z$ factors remain below 2. The reported redshifts for the minima are $z \in \{0.26, 0.51, 0.9\}$ smaller. There seems to be a contribution reducing the redshifts from their kinematical values: this contribution could come from a lattice oscillation partially compensating the comoving accelerated expansion and bringing acceleration to zero and at the same time reducing the expansion rate and thus also z.

A possible criticism of the model is the introduction of dark matter lattice replacing the scalar field of [E233] with oscillating vacuum expectation value. The observed redshift quantization could be used to defend this assumption. Quantum coherence in cosmological scales of course raises the eyebrows of the standard physicist but the recent fashion in which wormholes are assumed to connect blackholes and give rise to quantum coherence is consistent with this picture, which an be seen as a GRT adaptation of TGD vision in which magnetic flux tubes replace wormholes and partonic 2-surfaces replaced blackhole horizons and space-time regions having Euclidian signature of induced metric serving as lines of generalized Feynman diagrams replace blackhole interiors.

4.11.2 Appendix: P-Adic Length Scale Hypothesis And Gaussian Mersennes

The proposed model does not say much about p-adic primes important in cosmology. The following arguments demonstrate as a by-product that Gaussian Mersennes define p-adic length scales having identification as fundamental length scales both in cosmology and astrophysics. The largest Gaussian Mersenne defines slightly longer time scale than the age of the Universe appearing as the parameter in the model for oscillations and this Gaussian Mersenne could explain why just this time scale appears. What is remarkable the age of the Universe would correspond to a length scale analogous to length scales fundamental in TGD inspired quantum biology and one can wonder whether this has a deeper meaning. What is also remarkable, that the p-adic Compton lengths for dark electron define the fundamental scales. Does this mean that dark electrons or their p-adically scaled down variants are important in all these scales?

p-Adic length scale hypothesis states that primes slightly below powers of two are physically preferred ones. Mersenne primes $M_n = 2^n - 1$ obviously satisfy this condition optimally. The proposal generalizes to Gaussian Mersenne primes $M_{G,n} = (1 + i)^n - 1$ (`http://tinyurl.com/pptxe9c`). It is now possible to understand preferred p-adic primes as so called ramified primes of an algebraic extension of rationals to which the parameters characterizing string world sheets and partonic 2-surfaces belong. Strong form of holography is crucial: space-time surfaces are constructible from these 2-surfaces: for p-adic variants the construction should be easy by the presence of pseudo-constants. In real sector very probably continuation is possible only in special cases. The interpretation would be that some space-time surfaces can be imagined but not realized [K75]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survivalandcorresponding ramified primes would be preferred p-adic primes.

In the framework of consciousness theory the interpretation is that in this case imaginations (p-adic space-time surfaces) are realizable. Also p-adic length scale hypothesis can be understood and generalizes: primes near powers of any prime are preferred.

The definition of p-adic length scale is a convention to some degree.

1. One possible definition for L_p is as Compton length for the smallest mass possible in p-adic thermodynamics for a given prime if the first order contribution is non-vanishing.

2. Second definition is the Compton length $L_{p,e}$ for electron if it would correspond to the prime in question: in good approximation one has $L_p = \sqrt{5} \times L_{p,e}$ from p-adic mass calculations. If p-adic length scale hypothesis is assumed ($p \simeq 2^k$) one has $L_{p,e} \equiv L(k,e) = 2^{(k-127)/2} L_e$, where L_e is electron Compton length (electron mass is .5 MeV). If one is interested in Compton time $T(k,e)$, one obtains it easily from electrons Compton time .1 seconds (defining fundamental biorhythm) as $T(k,e) = 2^{(k-2*127)/2} \times .1$ seconds. I will mean with p-adic length scale $T(k,e) \simeq \sqrt{5}T(k)$ in the following.

Mersenne primes $M_n = 2^n - 1$ are as near as possible to power of two and are therefore of special interest.

1. Mersenne primes corresponding to $n \in \{2,3,5,7,13,17,19,31,61\}$ are out of reach of recent accelerators.

2. $n = 89$ characterizes weak bosons and suggests a scaled up version of hadron physics which should be seen at LHC. There are already several indications for its existence.

3. $n = 107$ corresponds to hadron physics and tau lepton.

4. $n = 127$ corresponds to electron. Mersenne primes are clearly very rare and characterize many elementary particle physics as well as hadrons and weak bosons. The largest Mersenne prime which does not define completely super-astrophysical p-adic length scale is M_{127} associated with electron.

Gaussian Mersennes (complex primes for complex integers) are much more abundant and in the following I demonstrate that corresponding p-adic time scales might seem to define fundamental length scales of cosmology, astrophysics, biology, nuclear physics, and elementary physics. I have not previously checked the possible relevance of Gaussian Mersennes for cosmology and for the physics beyond standard model above LHC energies: there are as many as 10 Gaussian Mersennes besides 9 Mersennes above LHC energy scale suggesting a lot of new physics in sharp contrast with the GUT dogma that nothing interesting happens above weak boson scale- perhaps copies of hadron physics or weak interaction physics. The list of Gaussian Mersennes is following.

1. $n \in \{2,3,5,7,11,19,29,47,73\}$ correspond to energies not accessible at LHC. $n = 79$ might define new copy of hadron physics above TeV range -something which I have not considered seriously before. The scaled variants of pion and proton masses (M_{107} hadron physics) are about 2.2 TeV and 16 TeV. Is it visible at LHC is a question mark to me.

2. $n = 113$ corresponds to nuclear physics. Gaussian Mersenne property and the fact that Gaussian Mersennes seem to be highly relevant for life at cell nucleus length scales inspires the question whether $n = 113$ could give rise to something analogous to life and genetic code. I have indeed proposed realization of genetic code and analogs of DNA, RNA, amino-acids and tRNA in terms of dark nucleon states.

3. $n = 151, 157, 163, 167$ define 4 biologically important scales between cell membrane thickness and cell nucleus size of 2.5 μm. This range contains the length scales relevant for DNA and its coiling.

4. $n = 239, 241$ define two scales $L(e,239) = 1.96 \times 10^3$ km and $L(e,241) = 3.93 \times 10^3$ km differing by factor 2. Earth radius is 6.3×10^3 km, outer core has radius 3494 km rather near to L(2,241) and inner core radius 1220 km, which is smaller than 1960 km but has same order of magnitude. What is important that Earth reveals the two-core structure suggested by Gaussian Mersennes.

5. $n = 283$: $L(283) = .8 \times 10^{10}$ km defines the size scale of a typical star system. The diameter of the solar system is about $d = .9 \times 10^{10}$ km.

6. $n = 353$: $L(353, e) = 2.1$ Mly, which is the size scale of galaxies. Milky Way has diameter about .9 Mly.

7. $n = 367$ defines size scale $L(267, e) = 2.8 \times 10^8$ ly, which is the scale of big voids.

8. $n = 379$: The time scale $T(379, e) = 1.79 \times 10^{10}$ years is slightly longer than the recently accepted age of the Universe about $T = 1.38 \times 10^{10}$ years and the nominal value of Hubble time $1/H = 1.4 \times 10^{10}$ years. The age of the Universe measured using cosmological scale parameter $a(t)$ is equal to the light-cone proper time for the light-cone assignable to the causal diamond is shorter than t.

For me these observations are shocking and suggest that number theory is visible in the sructure of entire cosmos. Standard skeptic of course labels all this as numerology. Only understood fact is fact. TGD indeed allows to understand these facts.

4.12 Correlated Triangles and Polygons in Standard Cosmology and in TGD

Peter Woit had an interesting This Week's Hype (see `http://tinyurl.com/hmmj9bp`). The inspiration came from a popular article in Quanta Magazine (see `http://tinyurl.com/jhd5xpe`) telling about the proposal of Maldacena and Nima Arkani-Hamed that the temperature fluctuations of cosmic microwave background (CMB) could exhibit deviation from Gaussianity in the sense that there would be measurable maxima of n-point correlations in CMB spectrum as function of spherical angles. These effects would relate to the large scale structure of CMB. Lubos Motl wrote about the article in different and rather aggressive tone (see `http://tinyurl.com/zzwt6ou`).

The article in Quanta Magazine does not go into technical details but the original article of Maldacena and Arkani-Hamed [B39] (see `http://tinyurl.com/ych26gcm`) contains detailed calculations for various n-point functions of inflaton field and other fields in turn determining the correlation functions for CMB temperature. The article is technically very elegant but the assumptions behind the calculations are questionable. In TGD Universe they would be simply wrong and some habitants of TGD Universe could see the approach as a demonstration for how misleading the refined mathematics can be if the assumptions behind it are wrong.

It must be emphasized that already now it is known and stressed also in [B39] that the deviations of the CMB from Gaussianity are below recent measurement resolution and the testing of the proposed non-Gaussianities requires new experimental technology such as 21 cm tomography [B28] (see `http://tinyurl.com/y7j9p35j`) mapping the redshift distribution of 21 cm hydrogen line to deduce information about fine details of CMB now n-point correlations.

Inflaton vacuum energy is in TGD framework replaced by Kähler magnetic energy and the model of Maldacena and Arkani-Hamed does not apply. The elegant work of Maldacena and Arkani-Hamed however inspired a TGD based consideration of the situation but with very different motivations. In TGD inflaton fields do not play any role since inflaton vacuum energy is replaced with the energy of magnetic flux tubes. The polygons also appear in totally different manner and are associated with symplectic invariants identified as Kähler fluxes, and might relate closely to quantum physical correlates of arithmetic cognition. These considerations lead to a proposal that integers $(3, 4, 5)$ define what one might called *additive primes* for integers $n \geq 3$ allowing geometric representation as non-degenerate polygons - prime polygons. On should dig the enormous mathematical literature to find whether mathematicians have proposed this notion - probably so. Partitions would correspond to splicings of polygons to smaller polygons.

These splicings could be dynamical quantum processes behind arithmetic conscious processes involving addition. I have already earlier considered a possible counterpart for conscious prime factorization in the adelic framework [L27]. This will not be discussed in this section since this topic is definitely too far from primordial cosmology. The purpose of this article is only to give an example how a good work in theoretical physics - even when it need not be relevant for physics - can stimulate new ideas in completely different context [L25].

4.12.1 Could cosmic microwave background exhibit non-local correlations?

It is good to start by summarizing my understanding about the basic ideas in the work of Maldacena and Arkani-Hamed [B39] (see http://tinyurl.com/ych26gcm). Besides inflationary scenario the existence of very massive particles with mass of the order of inverse Hubble radius during inflationary period or even before it are assumed. They would correspond to massive excitations of superstrings. These very massive particles would decay to inflatons and these couplings would make possible non-trivial $n > 2$ point correlation functions for inflaton field. These correlations would in turn be inherited by the cosmic energy density and thus correlation functions of CMB temperature. There would be a tendency for the appearance of triangles and higher polygons for which maximum for the modulus of the n-point correlator and the hope would be that these maxima could be detected some day in CMB spectrum.

The correlation functions are calculated in de-Sitter background - e de-Sitter space is a good model for inflationary period and one can use the symmetries of de-Sitter space to make rather detailed conclusions about the general form of correlation functions.

One has only 3-D translational invariance since time translation is not isometry of de-Sitter space. By this symmetry one can perform Fourier transformation and n-point correlation functions in momentum space vanish only at points in which the sum of momenta vanishes. Momenta therefore define a closed polygon - triangle, square, etc... in momentum space. Besides 3-D translational invariance there is also 3-D conformal invariance. As in the case of 2-D conformal invariance, one can deduce the general form of lowest n-point functions highly uniquely for any spin (string excitations can have arbitrarily high spin) in both momentum space and x-space.

There is analogy analogy to what particle theorists are doing at LHC: in this case four-momentum conservation gives similar constraint and define polygons in four-momentum space. The correlation functions of fields define the scattering amplitudes. In cosmology one is interested on extracting non-trivial n-point correlations from the background. These special configurations would correspond to squeezed triangles. At LHC final state particles with very large transversal momentum would be an analogous source of information.

One could say that inflationary period defines a cosmic particle accelerator and that the scatterings, which have taken near to the end of the inflationary period are visible in CMB: this because the exponential expansion would have destroyed the memories about earlier times. The cosmic particle experiment would end, when inflationary period ends. From the graph of Wikipedia article (see http://tinyurl.com/odlpyg8) one learns that this would correspond to Hubble radius $1/H$ of order $1/H = 10^{-25}$ meters so that the mass of the massive string excitations would be larger than mass of about $H_{min} \sim 10^{10} \times m_p$ or about 10^{-9} Planck masses.

The article in Quanta Magazine suggests that the triangles correspond to triplets of hot spots in CMB: maybe this follows from the assumption that the modulus correlation function is maximum. I do not quite understand this. There is correlation between values of temperature but this does not imply that temperature at the hot spots would be higher and same. It is mentioned that the so called cosmic fluctuations might make it impossible to detect these basically quantal correlations.

4.12.2 Early cosmology in TGD framework

In TGD framework polygons interpreted in terms of enhanced correlations of inflaton field do not appear in cosmology since inflaton field is not needed. Momentum conservation gives rise to polygons also now but they will not be considered in the sequel. In TGD framework the physical picture is very different although inflation has TGD analog and also causal diamonds (CDs) serving as key geometric element of Zero Energy Ontology (ZEO) are bring in mind Big Bang followed by Big Crunch.

1. The starting point is the fact cosmic temperature is constant with variations of order $\Delta T/T \sim 10^{-5}$. Inflationary theory was born to explain this miracle in terms of exponential expansion destroying all details of the primordial temperature distribution.

2. Also in TGD framework the analog for the exponential expansion is predicted but it would not be needed to explain the constancy of the temperature as resulting of smoothing out of

fluctuations. Temperature fluctuations would reduce to fluctuations for the beginning of the transition to the radiation dominated phase.

The primordial state preceding the TGD analog of inflationary period would be gas of cosmic strings having arbitrarily long lengths and form a fractal structure - this is new and makes sense because the size of horizon is infinite in M^4. Cosmic strings could serve as correlates for quantum entanglement and an elegant explanation for the constancy of temperature would be in terms of quantum coherence in cosmic length scales involving negentropic entanglement (NE) and hierarchy of Planck constants $h_{eff} = n \times h$. This together with Zero Energy Ontology (ZEO) leads to a TGD analog of the cyclic cosmology with entire cosmos regarded as conscious entity [K94] [L19]. In the cyclic cosmology the cosmic strings near the boundary of CD would not be any more free cosmic strings but magnetic flux tubes and every period of cycle would make them thicker so that genuine evolution would take place instead of boring repetition.

The analog of the inflationary period corresponds to a creation of space-time in GRT sense. Space-time sheets with 4-D M^4 projection are generated and gas of cosmic strings topologically condensed at them and starts (or continues) transformation to (thicker) magnetic flux tubes. In other words, 2-D M^4 projection (string world sheet) begins to grow in thickness. Ordinary matter emerges from the decay of the magnetic energy of cosmic string to ordinary particles during this period and the analog of inflationary cosmology would describe this matter (it is not quite clear whether also the energy of topologically condensed cosmic strings is included).

3. The magnetic energy density of flux tubes replaces the vacuum energy density of inflaton fields in TGD framework. The massive particles (string excitations) decaying to inflatons correspond to topologically condensing cosmic strings carrying conserved monopole flux. Their magnetic energy decays to particles as their thickness grows and magnetic field strength and therefore also magnetic energy density per unit length is reduced.

   Magnetic flux tubes would be present also in the recent cosmology and form basic building bricks of various astrophysical structures. For instance, galaxies would be string like objects, which are like pearls in a necklace formed by long string like objects at the boundaries of large voids. The sensational news would be that the primordial stringy structures are directly visible in the recent cosmology and seen long time ago! No statistical description is needed and if possible it must take into account the fractality realized in terms of p-adic length scale hierarchy and hierarchy of Planck constants, which is of course one of the predictions.

4. TGD suggests a model for the transition from the gas of cosmic strings to the radiation dominated cosmology as Robertson-Walker cosmology in terms of vacuum extremal having interpretation as critical or over-critical cosmology in GRT framework [K94]. This cosmology is unique apart from its finite duration. Mass density approaches infinite value before a transition to Euclidian signature of induced metric would happen (TGD interpretation could be in terms of TGD analog of blackhole). The condition that the energy density of space-time surface does not exceed that of cosmic strings in M^4 implies that the transition to radiation dominated cosmology takes place already earlier.

   This cosmology would replace the de-Sitter cosmology in the model of Maldacena and Arkani-Hamed if the notion of inflaton field would make sense. The critical cosmology has flat 3-space and in this case one could apply momentum conservation but energy conservation would not apply. The conservation law of 3-momentum applies at space-time level and should not be confused with the fundamental conservation of four-momentum at embedding space level. QFT at space-time level would be at best an approximation. The modes of quantum fields are replaced with spinor harmonics of embedding space defining ground state of the super-symplectic representations and one cannot neglect this algebra in the fundamental description using scattering amplitudes coded by zero energy states representable as modes of spinor fields of WCW.

5. The fractal structure of cosmic string condensate implies the failure of QFT description based on point like particles described by inflaton field. Strong form of holography (SH) states that string world sheets and partonic 2-surfaces serve as “space-time genes”. This would suggests

that string model in many-sheeted space-time could provide a fundamental description for the topological condensation and decay of cosmic strings to ordinary particles. The "space-time half" (or bulk half) of SH conforms with the idea that the cosmic strings are still there as magnetic flux tubes serving as building bricks of directly observed astrophysical and cosmological structures. For instance, galactic dark matter could be identified as magnetic energy of the long string like object defining the cosmic necklace with galaxies as pearls.

4.12.3 How do polygons emerge in TGD framework?

The duality defined by strong form of holography (SH) has 2 sides. Space-time side (bulk) and boundary side (string world sheets and partonic 2-surfaces). 2-D half of SH would suggest a description based on string world sheets and partonic 2-surfaces. This description should be especially simple for the quantum states realized as spinor fields in WCW ("world of classical worlds"). The spinors (as opposed to spinor fields) are now fermionic Fock states assignable to space-time surface defining a point of WCW. TGD extends ordinary 2-D conformal invariance to super-symplectic symmetry applying at the boundary of light-cone: note that given boundary of causal diamond (CD) is contained by light-cone boundary.

1. The correlation functions at embedding space level for fundamental objects, which are fermions at partonic 2-surfaces could be calculated by applying super-symplectic invariance having conformal structure. I have made rather concrete proposals in this respect. For instance, I have suggested that the conformal weights for the generators of supersymplectic algebra are given by poles of fermionic zeta $\zeta_F(s) = \zeta(s)/\zeta(2s)$ and thus include zeros of zeta scaled down by factor 1/2 [L12]. A related proposal is conformal confinement guaranteeing the reality of net conformal weights.

2. The conformally invariant correlation functions are those of super-symplectic CFT at light-cone boundary or its extension to CD. There would be the analog of conformal invariance associated with the light-like radial coordinate r_M and symplectic invariance associated with CP_2 and sphere S^2 localized with respect to r_M analogous to the complex coordinate in ordinary conformal invariance and naturally continued to hypercomplex coordinate at string world sheets carrying the fermionic modes and together with partonic 2-surfaces defining the boundary part of SH.

Symplectic invariants emerge in the following manner. Positive and negative energy parts of zero energy states would also depend on zero modes defined by super-symplectic invariants and this brings in polygons. Polygons emerge also from four-momentum conservation. These of course are also now present and involve the product of Lorentz group and color group assignable to CD near its either boundary. It seems that the extension of Poincare translations to Kac-Moody type symmetry allows to have full Poincare invariance (in its interior CD looks locally like $M^4 \times CP_2$).

1. One can define the symplectic invariants as magnetic fluxes associated with S^2 and CP_2 Kähler forms. For string world sheets one would obtain non-integrable phase factors. The vertices of polygons defined by string world sheets would correspond to the intersections of the string world sheets with partonic 2-surfaces at the boundaries of CD and at partonic 2-surfaces defining generalized vertices at which 3 light-like 3-surfaces meet along their ends.

2. Any polygon at partonic 2-surface would also allow to define such invariants. A physically natural assumption is that the vertices of these polygons are realized physically by adding fermions or antifermions at them. Kähler fluxes can be expressed in terms of non-integrable phase factors associated with the edges. This assumption would give the desired connection with quantum physics and fix highly uniquely but not completely the invariants appearing in physical states.

The correlated polygons would be thus naturally associated with fundamental fermions and a better analogy would be negentropically entangled n-fermion state rather than corresponding to maximum of the modulus of n-point correlation function. Hierarchy of Planck constants makes these states possible even in cosmological scales. The point would be that negentropic entanglement assignable to the p-adic sectors of WCW would be in key role.

4.12.4 Symplectic invariants and Abelian non-integrable phase factors

Consider now the polygons assignable to many-fermion states at partonic 2-surfaces.

1. The polygon associated with a given set of vertices defined by the position of fermions is far from unique and different polygons correspond to different physical situations. Certainly one must require that the geodesic polygon is not self-intersecting and defines a polygon or set of polygons.

2. Geometrically the polygon is not unique unless it is convex. For instance, one can take regular n-gon and add one vertex to its interior. The polygon can be also constructed in several ways. From this one obtains a non-convex $n+1$-gon in $n+1$ ways.

3. Given polygon is analogous with Hamiltonian cycle connecting all points of given graph. Now one does not have graph structure with edges and vertices unless one defines it by nearest neighbor property. Platonic solids provide an example of this kind of situation. Hamiltonian cycles [A8, **?**] are key element in the TGD inspired model for music harmony leading also to a model of genetic code [K87] [L8].

4. One should somehow fix the edges of the polygon. For string world sheets the edges would be boundaries of string world sheet. For partonic 2-surfaces the simplest option is that the edges are geodesic lines and thus have shortest possible length. This would bring in metric so that the idea about TGD as almost topological QFT would be realized.

One can distinguish between two cases: single polygon or several polygons.

1. One has maximal entanglement between fundamental fermions, when the vertices define single polygon. One can however have several polygons for a given set of vertices and in this case the coherence is reduced. Minimal correlations correspond to maximal number of 3-gons and minimal number of 4-gons and 5-gons.

2. For large $h_{eff} = n \times h$ the partonic 2-surfaces can have macroscopic and even astrophysical size and one can consider assigning many-fermion states with them. For instance, anyonic states could be interpreted in this manner. In this case it would be natural to consider various decompositions of the state to polygons representing entangled fermions.

The definition of symplectic invariant depends on whether one has single polygon or several polygons.

1. In the case that there are several polygons not containing polygons inside them (if this the case,then the complement of polygon must satisfy the condition) one can uniquely identify the interior of each polygon and assign a flux with it. Non-integrable phase factor is well-defined now. If there is only single polygon then also the complement of polygon could define the flux. Polygon and its complement define fluxes Φ and $\Phi_{tot} - \Phi$.

2. If partonic 2-surface carries monopole Kähler charge Φ_{tot} is essentially $n\pi$, where n is magnetic monopole flux through the partonic 2-surface. This is half integer - not integer: this is key feature of TGD and forces the coupling of Kähler gauge potential to the spinors leading to the quantum number spectrum of standard model. The exponent can be equal to -1 for half-odd integer.

   This problem disappears if both throats of the wormhole contact connecting the space-time sheets with Minkowski signature give their contribution so that two minus-signs give one plus sign. Elementary particles necessarily consist of wormhole contacts through which monopole flux flows and runs along second space-time sheet to another contact and returns along second space-time sheet so that closed monopole flux tube is obtained. The function of the flux must be single valued. This demands that it must reduce to the cosine of the integer multiple of the flux and identifiable as as the real part of the integer power of magnetic flux through the polygon.

The number theoretically deepest point is geometrically completely trivial.

1. Only $n > 2$-gons are non-degenerate and 3-, 4- and 5-gons are prime polygons in the sense that they cannot be sliced to lower polygons. Already 6-gon decomposes to 2 triangles.

2. One can wonder whether the appearance of 3 prime polygons might relate to family replication phenomenon for which TGD suggests an explanation in terms of genus of the partonic 2-surface [K26]. This does not seem to be the case. There is however other three special integers: namely 0,1, and 2.

   The connection with family replication phenomenon could be following. When the number of handles at the parton surface exceeds 2, the system forms entangled/bound states describable in terms of polygons with handles at vertices. This would be kind of phase transition. Fundamental fermion families with handle number 0,1,2 would be analogous to integers 0,1,2 and the anyonic many-handle states with NE would be analogous to partitions of integers $n > 2$ represented by the prime polygons. They would correspond to the emergence of p-adic cognition. One could not assign NE and cognition with elementary particles but only to more complex objects such as anyonic states associated with large partonic 2-surfaces (perhaps large because they have large Planck constant $h_{eff} = n \times h$) [K81].

The identification of prime polygons as geometric representations of “additive primes” for integers $n > 2$ is a number theoretically fascinating idea and the possible connection with the realization of arithmetic consciousness is equally interesting idea to consider but because this would take too far from primordial cosmology it is better to leave this topic to another article [L25].

4.13 Cosmology in crisis

Standard cosmology is in crisis. There are a lot of anomalies but two of them have received special attention recently. The most recent anomaly is due to the findings that the so called lensing amplitude in CMB is larger than ΛCDM predicts [E91]. This suggest that the density of the Universe is 5 per cent higher than the critical density so that Universe should closed rather than flat and infinite. Second anomaly is old: depending on measurement method one obtains two values for the Hubble constant differing remarkably. The debate about this has continued for decades and continues still.

These anomalies and many other suggest that something is wrong with - not only the assumptions of GRT based cosmology - but with Einsteinian space-time. TGD indeed predicts new view about space-time. Space-time at fundamental level is identified as 4-D surface in 8-D $M^4 \times CP_2$. The resulting many-sheeted space-time is locally extremely simple but has non-trivial topology in all scales. The M^4 projection of space-time regions can have dimension $D \leq 4$. For $D = 4$ one can speak of Einsteinian space-time. Non-Einsteinian configurations such as CP_2 type extremals $D = 1$ representing elementary particles and cosmic strings with$D = 2$ play central role in TGD Universe in all scales. For $D < 4$ the dimension of projection is topologically unstable and cosmic strings thicken to flux tubes. GRT space-time is obtained by taking into account only the Einsteinian spacetime surfaces at QFT-GRT limit but one expects that this is not enough: cosmic strings bring in new effects not present in typical GRT cosmology.

In this section the two above mentioned problems classified as crises are discussed in terms of TGD view about space-time.

4.13.1 Is 3-space closed or flat and infinite?

ΛCMD model (see `http://tinyurl.com/z8z8ulu`) provides the standard model for cosmology model assumes flat 3-space cold dark matter realized in terms of dark matter halos at galactic level. Cosmological constant Λ parameterizes dark energy density. The gives a rather satisfactory description of the CMB data in terms of 6 parameter but there are however some anomalies. There deviations from the predictions from the actual CMB data. The problems related to the notions of dark matter and energy itself are at deeper levels.

Now a new problem - even crisis - has emerged (I have the feeling that it has been always in crisis). There is evidence that 3-space is actually closed rather than flat and infinite! But 3-space cannot be both simultaneously.

Findings

Alessandro Melchiorri of Sapienza University of Rome Eleonora di Valentino of the University of Manchester and Joseph Silk, principally of the University of Oxford, published in Nature Astronomy a paper "*Planck evidence for a closed Universe and a possible crisis for cosmology*" [E91] (see `http://tinyurl.com/y5q55ds3`). Here is the abstract of the article.

The recent Planck Legacy 2018 release has confirmed the presence of an enhanced lensing amplitude in cosmic microwave background power spectra compared with that predicted in the standard Λ *cold dark matter model, where* Λ *is the cosmological constant.*

A closed Universe can provide a physical explanation for this effect, with the Planck cosmic microwave background spectra now preferring a positive curvature at more than the 99 per cent confidence level.

Here, we further investigate the evidence for a closed Universe from Planck, showing that positive curvature naturally explains the anomalous lensing amplitude, and demonstrating that it also removes a well-known tension in the Planck dataset concerning the values of cosmological parameters derived at different angular scales. We show that since the Planck power spectra prefer a closed Universe, discordances higher than generally estimated arise for most of the local cosmological observables, including baryon acoustic oscillations. The assumption of a flat Universe could therefore mask a cosmological crisis where disparate observed properties of the Universe appear to be mutually inconsistent. Future measurements are needed to clarify whether the observed discordances are due to undetected systematics, or to new physics or simply are a statistical fluctuation.

A lensing amplitude 5 per cent larger than expected is observed. Concretely this means following.

1. Gravitational lensing (see `http://tinyurl.com/c3n6b8g)`) is essentially scattering of the incoming light in the gravitational field of matter between the detector an sources so that for a single object between the source the light seems to becoming from a circular object rather than point like object.

2. The light of CMB entering detector has experienced large number of lensings and the images of various features in the data become blurred. The larger the lensing, the more blurred the object image. Lensing amplitude is proportional to the curvature of 3-space and if the curvature vanishes as in flat cosmology, lensing amplitude should be very small and due to fluctuations. There should be for other reasons.

3. ΛCDM predicts flat 3-space so that the observed lensing is anomaly if indeed real effect. The obvious explanation would be that the density of matter is about 5 per cent higher than the model predicts. The density would become overcritical and the infinite flat 3-space would close to sphere. This would be a dramatic change in the topology of 3-space.

As the abstract tells, positive curvature would also remove the well-known tension in the Planck dataset concerning the values of cosmological parameters derived at different angular scales.

There are however objections. For instance, inflation theory favours infinite 3-space. There is also second manner to deduce 3-curvature. Lensing reconstruction measures correlations from sets of four points in the sky to deduce 3-curvature. The results are in accordance with flatness.

Various empirical inputs force flat 3-space so that one cannot just add to ΛCDM the curvature as 7:th parameter. For instance, it would very difficult to understand how this modification could be consistent with inflation theory involving flat expanding Universe. Therefore one can say that cosmology is in crisis.

What says TGD?

Something new is needed. Hyperbolic or flat Universe seems to be a natural assumption in TGD framework assuming that at fundamental level space-times are surfaces in $M^4 \times CP_2$.

1. General Relativity emerges as a long length scale approximation in which space-time surfaces are assumed to be Einsteinian in long scale, that is having 4-D M^4 projection. There are also non-Einsteinian space-time surfaces. CP_2 type extremals with 1-D light geodesic as M^4 projection, and string like objects with 2-D M^4 projection.

2. Cosmic strings are basic entities of the primordial cosmology in TGD Universe and have 2-D M^4 projection as string world sheets: there is no Einsteinian space-time and it emerges during the TGD analog of the inflationary period [K94, K66]. Cosmic strings are unstable against thickening of the $M4$ projection of cosmic strings so that they tend to thicken to flux tubes. Cosmic strings and flux tubes are present also during the Einsteinian era. One can speak of topological condensation of cosmic strings to space-time surface. In GRT based cosmology these objects have no counterpart.

   Cosmic strings appear in two varieties depending on whether the quantizes magnetic flux associated with their closed cross section is monopole flux or not (vanishes). What is important that monopole fluxes require no currents, which solves several problems of cosmology and astrophysics. One example is the presence of magnetic fields in cosmic length scales, stability of the Earth's magnetic field [L13] and the present strange findings about the magnetic field of Mars [L71].

3. The model for the formation of various astrophysical objects [L63, L82, L83] relies on the thickening of cosmic string portions to monopole flux tubes. One must therefore include them. In accordance with the notion of many-sheeted space-time, cosmology must be replaced with a fractal hierarchy of cosmologies with length scale dependent parameters such as cosmological constant [L22].

   Remark: String world sheets appear also as singularities of space-time surfaces as minimal surfaces appearing as extremals of also 4-D Kähler action obtained as a dimensional reduction of the twistor lift of 4-D Kähler action. These strings are like edges of 3-space at which tangent space-time dimension of space-time surface is 2 instead of 4.

4. Cosmic strings carry dark energy and dark matter. Dark energy is sum of magnetic and volume contributions. The latter is proportional to cosmological constant Λ, which depends on the size scale of the space-time sheets and comes in some negative powers of 2 corresponding to preferred p-adic length scales. Λ_{CDM} would correspond to length scale for space-time sheets of order recent size of cosmos.

In this framework the most recent crisis of cosmology would reflect the failure of the Einsteinian space-time concept basically due to the existence of cosmic strings and other objects with lower-D projection.

The observed too large lensing amplitude is intuitively easy to understand in terms of cosmic strings. The incoming CMB photon would express additional scattering from long cosmic strings along its route. Second manner to deduce the curvature is by measuring correlations from sets of 4 points in the sky. The correlations should not change if TGD is correct. I do do not understand enough these correlations to tell whether the presence of cosmic strings and flux tubes affect the correlations or not.

The conceptual and technical challenge is to understand how two treat cosmic strings in the QFT-GRT limit of TGD based fractal cosmology.

1. For space-time surfaces with 4-D M^4 projection the GRT space-time is obtained as 4-D piece of M^4 with gauge potentials and the deviation of metric from flat M^4 metric as a sum of those for space-time sheets. One actually obtains a length scale hierarchy of space-times assignable to causal diamonds (CDs) and standard cosmology should correspond to the limit of CD size, which is about the size of the recent cosmology. CMB data indeed suggest length scale dependence of CMB parameters.

2. At every step in hierarchy 3-space is finite corresponding to the radius of CD at give value of Minkowski time. The actual 3-surfaces are always closed and can be though of as pairs of 3-surfaces with boundary at boundary of CD glued together along their boundaries. Covering of flat 3-space would be in question. Could this somehow relate to why closed Universe seems to work in some respects?

   The hierarchy brings in new elements such as hierarchy of cosmological constants with a concrete interpretation discussed elsewhere.

3. But what should one do with the cosmic strings and flux tubes? The addition of them as singular string world sheets in space-time carrying concentrated a string world sheet is one possibility which comes into mind. GRT based cosmology relies on pointlike objects and infinitely long cosmic strings are not pointlike objects in any scale. A more plausible approach would be in terms of tensor nets with cosmic strings and flux tubes defining the connections between the nodes of the net. The identification of dark matter as $h_{eff} = n \times h_0$ phases of ordinary matter would make possible quantum coherence in arbitrarily long length scales. Fractal tensor net would be genuinely quantal object in all scales, and provide very different view about the role of quantum dynamics in cosmology and astrophysics.

4.13.2 The problem of two Hubble constants

I received a link to a popular article relating to the two values of Hubble constant (see `http://tinyurl.com/yxgvsaam`). The popular article states that the expansion is 9 per cent faster than expected. This problem is old and earlier and has been seen discrepancy: measurement suggest two different values of Hubble constant. The article suggests that the bigger value is now accepted as the correct value. Hype warning is in order. The refusal to accept the possibility of two different values might mean only the continuation of the long lasting fruitless debate. It is better two try to explain why two different values are obtained.

I have considered the problem of two value of cosmological constant already earlier in the framework provided by many-sheeted space-time [K66]. In the sequel the puzzle of two Hubble constants is discussed applying the recent view about cosmological constant. What is new that twistor lift of TGD [L22] predicts that cosmological constant is length scale dependent and that cosmological expansion consists of jerks involving accelerated periods followed by a phase transition changing reducing cosmological constant by a negative power of two and and inducing the transformation of the magnetic energy of monopole flux tubes to ordinary matter.

Monopole flux tubes have become a central element of TGD inspired cosmology and astrophysics and the natural question is whether length scale dependent cosmological constant could solve the Hubble discrepancy? It seems that the higher value of cosmological constant corresponds to a smaller scale for observations: this could explain the discrepancy. The model requires a more detailed consideration of what it it is to be a standard candle. In many-sheeted space-time of TGD also the environment of the standard candle identified as monopole flux tube matters.

For distant standard candles the environment defined by the flux tube is younger than for nearby ones. The thickening associated with the ageing of the flux tubes involving the decay of magnetic energy to ordinary matter. The reduction of magnetic energy density in turn increases the value of the metric component $\sqrt{g_{aa}}$ in the natural space-time coordinates provided by the Robertson-Walker coordinates of the light-cone (a corresponds to the proper time coordinate of the light-cone). This can give rise to the increase of the Hubble constant $H = 1/\sqrt{g_{aa}}a$ explaining why the nearby flux tubes correspond to a larger value Hubble constant. Therefore monopole magnetic flux tubes could explain also the Hubble constant discrepancy.

The many-sheeted space-time suggests a possible solution to the Hubble constant discrepancy.

1. The first TGD based explanation coming into mind is based on many-sheeted space-time that I proposed decades ago. The value of Hubble constant depends on the metric of the space-time sheet the the p-adic size scale assignable to the space-time sheet. Could the measured values of Hubble constant which differ by 9 per cent correspond to different space-time sheets having slightly different Hubble constants. p-Adic length scales come as half octaves and different p-adic lengths scales would suggest a larger difference. For instance, there is evidence that the gamma rays and neutrinos from supernova SN1987A propagated with several velocities [K98] and the explanation could be the same.

2. Could length scale dependent cosmological constant assignable to the space-time surfaces solve the problem? Could it lead to length scale dependent Hubble constant H explaining the 9 per cent discrepancy as reflecting different values of H at long and short distances or equivalently at different values of cosmological time?

In the sequel the latter option - actually a more precise formulation of the first one - is considered. An essential element of the model is the notion of length scale dependent cosmological constant predicted by the twistor lift of TGD and the phase transitions reducing the value of Λ followed by the thickening of the flux tubes induced by the decay of the magnetic energy to ordinary matter. This would lead to the increase of the Hubble constant associated with the flux tube.

The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L22].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = (8\pi)^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as $\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L22]. For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L63].

Consider now some representative examples to see whether this picture can be connected to empirical reality.

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see `http://tinyurl.com/k4bwlzu`). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.

2. If the large scale R is solar radius about 7×10^8 m, the short scale $r \simeq 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to Mersenne prime $M_{127} = 2^{127} - 1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L26, L31]: this requires $h_{eff} \sim 2^{12}$!

   Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

   The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L82] (see `http://tinyurl.com/y38m54ud`) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion". The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.

3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$ defining nuclear size scale of $r \sim 10^{-14}$ m, one has $R \sim 10$ km, the radius of a

typical neutron star (see http://tinyurl.com/y5ukv2wt) having a typical mass of 1.4 solar masses.

A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?

4. Short scale $r \sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see http://tinyurl.com/y3n78tjs)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

Accelerated expansion in standard cosmology

To be contact with basic numbers consider first the accelerated cosmic expansion in standard model.

1. Hubble constant is defined as the parameter

$$H^2 = (\frac{\dot{a}}{a})^2 \quad . \tag{4.13.1}$$

Here the shorthand $\dot{a}I = da/dt$ has been used. TGD inspired cosmology one can use Robertson-Walker coordinates as natural space-time coordinates without assuming the symmetries of Robertson-Walker cosmologies, and a corresponds to the light-cone proper time. Time coordinate t corresponds to proper time coordinate of space-time surface and one has $dt^2 = g_{aa}da^2$ so that one has $dt/da = \sqrt{g_{aa}}$. Therefore one can also write

$$H^2 = \frac{1}{g_{aa}a^2} \quad . \tag{4.13.2}$$

In the simplified model redshift z relates to the scale factor via the formula

$$\frac{a(t)}{a(t_{now})} = \frac{f_{obs}}{f_{emit}} = \frac{1}{1+z} \quad . \tag{4.13.3}$$

Here t corresponds to the value of cosmic proper time when the radiation was emitted. Accelerated expansion means that the objects are farther than they would be if the Hubble constant had had its present value all the time.

2. Friedmann equation states that the square H^2 of Hubble constant (see http://tinyurl.com/o8l9oro) can be written as a sum of 4 contributions.

$$H^2 = \frac{8\pi G}{3}(\rho_m + \rho_r) - \frac{k}{a^2} + \frac{\Lambda}{3}) \quad . \tag{4.13.4}$$

The first term is proportional to mass density ρ_m of matter and second term to the mass density ρ_r of radiation. Second ter is curvature contribution depending on the parameter $k = -1, 0, 1$ characterizing the 3-curvature of 3-space. For hyperbolic cosmology expanding forever one has k=-1. Curvature radius a corresponds in TGD to the light-cone proper time coordinate. The third term corresponds to dark energy and cosmological constant. It is positive since the expansion is accelerated. This observation was fatal for superstring theory.

3. One can write the expression of Hubble constant also in the form (see http://tinyurl.com/ycv2t7w6)

$$H^2 = H_0^2(\Omega_k a^{-2} + \Omega_m a^{-3} + \Omega_r a^{-4} + \Omega_{DE} a^{-3(1+w)}) \ . \tag{4.13.5}$$

   H_0 corresponds to Hubble constant for critical mass density and various terms correspond to curvature, matter, radiation and vacuum energy. Experimentally the parameter w characterizes the dark energy density. For $w = -1$ one has cosmological constant, which in TGD would correspond to 3-surfaces very large in all dimensions. For $w = -1/3$ one has $1/a^2$ behavior and ideal cosmic strings and acceleration parameter vanishes in this case. The real situation in TGD is between these two since cosmic strings are thickened to flux tubes.

4. The acceleration equation reads is counterpart of Newton's equation

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3P) \ . \tag{4.13.6}$$

   The pressure term is negative for the accelerated expansion and it is difficult to assign it to ordinary particles. In TGD framework the tension of cosmic strings thickened to flux tube and containing magnetic and volume contribution to energy momentum tensor would give rise to effective negative pressured term.

5. If one assumes that pressure relates to the density of energy as

$$P = w\rho \ . \tag{4.13.7}$$

   one obtains the parameterization given for Hubble constant in terms of w. I am not sure whether this is the most general parameterization of pressure. For $w = -1$ one has Λ_{CDM} model with constant density of dark energy. This corresponds in TGD to 3-surfaces which are large in all directions. $w = -1/3$ corresponds to cosmic strings and cosmic strings thickened to flux tubes correspond to $-1 < w < -1/3$ giving rise to accelerated expansion during the period when cosmological constant associated with volume actions remains constant. The period ends when a phase transition reducing its value by a negative power of 2 takes place. This gives to jerk-wise cosmological expansion, which occurs in all scales.

6. The technical definition for the accelerate expansion is by the following equation

$$\frac{dH}{dt} = -H^2(1+q) \ . \tag{4.13.8}$$

   q is known as deceleration parameter. For $q > -1$ H increases with time. Observations suggest $q = -.55$ so that one has accelerating expansion with $d^a/dt^2 > 0$ but with decreasing H.

Accelerated expansion in TGD framework

Consider first the TGD based model for the accelerated expansion.

1. TGD predicts length scale dependent cosmological constant at the level of space-time as the coefficient of the volume term of the action obtained by dimensional reduction from the Kähler action for twistor lift.

   The first thing to notice is that this cosmological constant need not directly relate to the cosmological constant of QFT limit expect when the space-time surfaces have large dimensions in all directions. For string like objects only one dimension is large and in this case the volume energy is proportional to the length rather than volume. In the idealization that string like objects are infinitely thin the energy of string phase is proportional to $1/a^2$ as function of cosmic time rather than constant as for cosmological constant in GRT. This formula expresses the fact that the amount of string inside comoving volume is proportional to a.

2. There is however a sequence of phases transition reducing the cosmological constant to which volume energy of space-time surface is proportional to. The phase transitions induce accelerated expansion (due to accelerated thickening of monopole flux tubes) as their magnetic energy transforms to ordinary matter [L22] (see `http://tinyurl.com/y2h9wr3`). Eventually the increase of volume energy stops this accelerated expansion. One can argue that (or at least ask whether) this fastens the expansion rate temporarily. Inflation and the recent accelerated expansion would be examples of this kind jerks replacing smooth cosmological expansion in TGD Universe. These jerks occur in all scale: even in scale of Earth [L55] (see `http://tinyurl.com/yc4rgkco`).

3. Since cosmological constant and thus string tension behaves like $1/a^2$ in average sense, the energy density of strings decreases as $1/a^3$ in average sense and strings correspond to comoving matter in this sense. Hence the occurrence of the phase transitions reducing the value of Λ allow avoid the big rip predicted by the standard model.

4. During a period with given value of space-time cosmological constant the situation is between string dominated cosmology and that involving cosmological constant since flux tubes are between cosmic strings and very thick cosmic strings corresponding to cosmological constant. Therefore one expects that the parameter w characterizing acceleration expansion is between the values $w = -1/3$ corresponding to cosmology dominated by ideal strings with no acceleration and $w = -1$ corresponding to cosmological constant.

   It is not quite clear to me that the decay of magnetic energy of flux tubes to ordinary matter is responsible for accelerated expansion although by the conservation of the monopole flux it associated with the thickening of strings.

Remark: In zero energy ontology (ZEO) the TGD counterpart of "big" (ordinary) state function reduction (BSFR) changes the arrow of time whereas "small" state function reductions (SSFRs) serving as TGD counterparts of weak measurements preserve the arrow. The strange findings of Minev *et al* support the change of the arrow of time in BSFRs in atomic systems [L68]. The causal anomalies associated with earthquakes and volcanic eruptions suggest that even these events can correspond to BSFRs in TGD Universe [L73].

Could the formation of TGD counterparts of blackhole be BSFR and correspond to a transformation of dark energy of the thickening cosmic string to ordinary matter but in reverse direction of time [L63]? Could the formation of galaxies and perhaps even stars and planets have interpretation as a formation of white-hole - blackhole in opposite time direction involving a transformations of the dark energy of cosmic string to ordinary matter [L82]?

Could BSFRs take place even in cosmological scales [L52]? Could the phase transitions reducing the value of length scale dependent Λ be BSFRs? Thermodynamics favours the decrease of Λ, which suggests that the arrow of time does not change and SSFR is in question. If Λ increased, the arrow time would change and the process could be actually BSFR producing a cosmology with opposite arrow of time.

Could one understand the two values of Hubble constant in TGD Universe?

Flux tubes are the new element brought by TGD to cosmology, and it would not be surprising if they were essential for the understanding of the Hubble constant discrepancy. A valuable hint comes from the observation that different values of Hubble constant seem to correspond to measurements carried out in different scales: this is due to different methods to determine H from redshift - and distance data.

1. The value of Λ assignable to space-time sheets is expected to come as negative powers of 2. It is not plausible that this could explain the two different values of H. Dark energy density is estimated to be 68 per cent of the total so that this term is the largest and the reduction of this term in the formula for H^2 by factor of say 1/4 is expected to have much larger effect on H than 9 per cent. The value of Λ for space-time surface must be same for the measurements giving different value of H as already noticed.

2. From the formula $H^2 = 1/g_{aa}a^2$ one finds that the value of g_{aa} at recent time as predicted from that in distant past is larger than predicted. The positive value of $\ddot{a}$ implies that $\dot{a} = 1/\sqrt{g_{aa}}$ has increased and objects are at larger distance than they would be in absence of accelerated expansion. The idealization $H = constant$ making sense at short distances to the source corresponds to $g_{aa} \propto 1/a$ predicting $a \propto exp(t)$. The value of g_{aa} assignable to the distant objects seems to be larger than $g_{aa} \propto 1/a$ would predict. g_{aa} decreases faster than constant H predicts.

3. What does standard candle property mean in TGD framework? Standard candles as astrophysical objects should be identical, in particular they should have same age. In many-sheeted space-time there are however additional factors involved.

   Option I: Standard candle (or rather the emitters of standard candle) has environment. Let us assume that it corresponds to a flux tube. At the moment of emission this flux tube is older for nearby objects than for distant ones.

   Option II: Radiation propagates along flux tubes connecting observer and source region. Suppose that one can model it as massless extremal associated with a flux tube. For nearby sources these flux are younger than for distant sources. If these flux tubes are responsible for the effect, it is opposite to that for Option I.

4. With standard arrow of time for flux tubes, the flux tubes should thicken by the transformation of magnetic energy to ordinary matter. The loss of magnetic energy should decrease g_{aa} faster than $1/a$. The longer the flux tube, the larger the decrease of g_{aa} would be since the decrease of the energy of the flux tube increases g_{aa}. H would be smaller for older flux tubes.

5. Scale dependence means that nearby standard candles correspond to a larger value of H. For Option I, H is indeed larger for nearby sources than distant ones. For Option II H is smaller for nearby sources than distant ones, which is obviously wrong. Option II can work only if the arrow of time is non-standard for the flux tubes along which radiation propagates.

To sum up, in TGD Universe also flux tubes serving as links of the cosmic network are essential besides source and receiver and the length and thus age of the flux tube could be essential for the explanation of Hubble constant discrepancy.

A solution to the Hubble constant discrepancy?

This comment was inspired about year after writing the above proposal by an interesting popular article about a possible explanation of Hubble constant discrepancy (`http://tinyurl.com/yd783ow6`). The article told about a proposal of Lucas Lombriser discussed in the article *Consistency of the local Hubble constant with the cosmic microwave background* [E200] (`http://tinyurl.com/ycd4aenh`) for an explanation of this discrepancy. The proposal is that the local region around our galaxy having size of order few hundred Mly - this is the scale of the large voids forming a honeycomb like structure containing galaxies at their boundaries - has average density of the matter 1/2 of that elsewhere.

Consider first the discrepancy. The determination of Hubble constant characterizing the expansion rate of the Universe can be deduced from cosmic microwave background (CMB). This corresponds to long length scales and gives value $H_{cosmo} = 67.4$ km/s/Mpc. Hubble constant can be also deduced from local measurements using so called standard candles in the scales of large voids. This gives Hubble constant $H_{loc} = 75.7$ km/s/Mpc, which is by about 10 percent higher.

The argument of the article is rather simple.

1. It is a well-known fact that Universe decomposes into giant voids with size scale of 10^8 light years. The postulated local region would have this size and mass density would be reduced by factor 1/2.

   Suppose that standard candles used to determine Hubble constant belong to this void so that density is lower than average density. This would mean that the Hubble constant H_{loc} for local measurements of Hubble constant using standar candles would be higher than H_{cosmo} from measurements of CMB.

2. Consider the geometry side of Einstein's equations. Hubble constant squared is given by

$$H^2 = (\frac{dlog(a)}{dt})^2 = \frac{1}{g_{aa} \times a^2} \quad .$$

   Here one has $dt^2 = g_{aa}da^2$. t is proper time for a comoving observer and a is the scale factor in the spatial part of Robertson-Walker metric. The reduction of H^2 is caused by the increase of g_{aa} as the density decreases. At the limit of empty cosmology (future light-one) $g_{aa} = 1$. Hubble constant is largest at this limit for given a, which in TGD framework corresponds to light-cone proper time coordinate.

3. The matter side of Einstein's equations gives

$$H^2 = \frac{8\pi G}{3}\rho_m + \frac{\Lambda}{3} .$$

   The first contribution corresponds to matter and second dark energy, which dominates.

4. It turns out that be reducing ρ_m by factor 1/2, the value of H_{loc} is reduced by about 10 percent so that H_{loc} agrees with H_{cosmo}.

Could one understand the finding in TGD framework? It seems that Hubble constant depends on scale. This would be natural in TGD Universe since TGD predicts p-adic hierarchy of scales coming as half octaves. One can say that many-sheeted space-time gives rise to fractal cosmology or Russian doll cosmology.

Cosmological parameters would depend on scale. For instance, cosmological constant would come naturally as octave of basic values and approach to zero in long length scales. Usually it is constant and this leads to the well-known problem since its value would be huge by estimates in very short length scales. Also its sign comes out wrong in super string theories whereas twistor lift of TGD predicts its sign correctly.

I have already earlier tried to understand the discrepancy in TGD framework in terms of many-sheeted space-time suggesting that Hubble constant depends on space-time sheet - first attempts were first applications of TGD inspired cosmology for decades ago - but have not found a really satisfactory model. The new finding involving factor 1/2 characteristic for p-adic length scale hierarchy however raises hopes about progress at the level of details.

1. TGD predicts fractal cosmology as a kind of Russian doll cosmology in which the value of Hubble constant depends on the size scale of space-time sheet. p-Adic length scale hypothesis states that the scale comes in octaves. One could therefore argue that the reduction of mass density by factor 1/2 in the local void is natural. One can however find objections.

2. The mass density scales as $1/a^3$ and one could argue that the scaling could be like $2^{-3/2}$ if p-adic length scale increas by factor 2. Here one can argue that in TGD framework matter is at magnetic flux tubes and the density therefore scales down by factor 1/2 meaning reduction of string tension by this factor.

3. One can argue that also the cosmological term in mass density would naturally scale down by 1/2 as p-adic length scales is scaled up by 2. If this happened the Hubble constant would be reduced by factor $1/2^{1/2}$ roughly since dark energy dominates. This does not happen.

   Should one assign dark energy parameter Ω to a space-time sheet having scale considerably larger than that those carrying the galactic matter? Should one regarded large void as a local sub-cosmology topologically condensed on much larger cosmology characterized by Ω? But why not use Ω associated with the sub-cosmology? Could it be that the Ω of sub-cosmology is included in ρ_m?

Could the following explanation work? TGD predicts two kinds of magnetic flux tubes: monopole flux tubes, which ordinary cosmologies and Maxwellian electrodynamics do not allow and ordinary flux tubes representing counterparts of Maxwellian magnetic fields. Monopole flux tubes need not currents to generate their magnetic fields and this solves several mysteries related to magnetism: for instance, one can understand why Earth's magnetic field has not decayed long time ago by the dissipation of the currents creating it. Also the existences of magnetic fields in cosmic scales impossible in standard cosmology finds explanations.

1. First kind of flux tubes carry only volume energy since the induced Kähler form vanishes for them and Kähler action is vanishing. There are however induced electroweak gauge fields present at them. I have tentatively identified the flux tubes mediating gravitational interaction with these as these flux tubes.

   Could Ω correspond to cosmological constant assignable to gravitational flux tubes involving only volume energy and be same also in the local void? This because they mediate very long range and non-screened gravitational interaction and correspond to very long length scales.

2. Second kind of flux tubes carry non-vanishing monopole flux associated with the Kähler form and the energy density is sum of volume term and Kähler term. These flux tubes would be carriers of dark energy generating gravitational field orthogonal to the flux tubes explaining the flat velocity spectrum for distant stars around galaxies. These flux tubes be present in all scales would play central role in TGD based model of galaxies, stars, planets, quantum biology, molecular and atomic physics, nuclear physics and hadron physics.

   These flux tubes suffer phase transitions increasing their thickness by factor 2 and reducing the energy density by factor 1/2. This decreases gradually the value of energy density associated with them.

   Could the density ρ_m of matter correspond to the density of matter containing contributions from monopole flux tubes and their decay products: ρ_m would therefore contain also the contribution from both magnetic and volume energy of flux tubes. Could it have been scaled down in a phase transition reducing locally the value of string tension for these flux tubes. Our local void would be one step further in the cosmic evolution by reductions and have experience one more expansions of flux tube thickness by half octave than matter elsewhere.

To sum up, this model would rely on the prediction that there are two kinds of flux tubes and that the cosmic evolution proceeds by phase transitions increasing p-adic length scale by half octave reducing the energy density by factor 1/2 at flux tubes. The local void would be one step further in cosmic evolution as compared to a typical void. This is natural since the information about the local regions is about the oldest version of the Universe.

Chapter 5

Breaking of CP, P, and T in cosmological scales in TGD Universe

5.1 Introduction

The discovery of so called Axis of Evil (AE) in the spectrum of fluctuations for the cosmic microwave background (CMB) implies that the fluctuation spectrum is not isotropic. A possible explanation of AE could be large scale rotation - even the rotation of the Universe has been considered. Preferred direction of rotation in large scales requires cosmic P violation. Standard model allows only a very slow rotation rate of the Universe and inflation theory does not allow rotation at all in large scales since the exponential expansion destroys the rotation very efficiently.

The idea of rotating Universe is not new. Already Gamow wrote about rotating Universe [E177]. The idea was that the rotation of stellar objects is caused by the rotation of the Universe. If so, then rotation of the Universe could be observed.

Gödel in turn constructed a solution of Einstein's equations representing rotating Universe [E193] as a birthday present to his friend Einstein. The solution allows closed time like geodesics so that the arrows of time are opposite near origin and at large distances. This can be seen as a problem. Also Kerr solution describing rotating black hole has similar problem.

Rotation has been observed long time ago in galactic scales and the angular momentum J as a function of mass M satisfies a correlation of form $J = kM^{5/3}$, $k = .4 \times 10^4$ kg$^{-2/3}$m^{2}s^{-1} [E198]. For string like objects one would have formula of form $J = kM^2$. The resemblance inspires the question whether the galaxies could have originated from string like objects and some of the angular momentum would have been lost in the process. This correlation is also satisfied by many other celestial objects. There is also evidence that the spin directions of galaxies correlate. The relative difference $(N_L - N_R)/(N_L + N_R)$ for numbers of right and left-handed spins (opposite for Northern and Southern Earth hemispheres is found to be about 7 per cent [E220].

What could TGD say about large scale rotation.

1. The twistor lift of TGD forces he analog of Kähler form for M^4. Covariantly constant sef-dual Kähler form $J(CD)$ depends on causal diamond of M^4 and defines rest frame and spin quantization axis. This implies a violation of CP, P, and T. By introducing a moduli space for the Kähler forms one avoids the loss of Poincare invariance. The natural question is whether $J(CD)$ could relate to CP breaking for K and B type mesons, to matter antimatter asymmetry and the large scale parity breaking suggested by CMB data.

2. The simplest guess for the coupling strength of $U(1)$ interaction associated with $J(CD)$ predicts a correct order of magnitude for CP violation for K meson and for the antimatter asymmetry and inspires a more detailed discussion. A general mechanism for the generation of matter asymmetry is proposed, and a model for the formation of disk- and elliptic galaxies is considered. The matter antimatter asymmetry would be apparent in the sense that the

CP asymmetry would force matter-antimatter separation: antimatter would reside as dark matter (in TGD sense) inside magnetic flux tubes and matter outside them. Also the angular momenta of dark matter and matter would compensate each other.

Correlation of rotation direction for celestial objects would be a signature for P violation in long scales and P violation could explain large scale spin directions of galaxies. TGD Universe is fractal and the natural expectation is that the correlations are reduced with length scale so that Universe as such would not be rotating. In TGD framework one can also ask whether antimatter is present in a way not discovered yet and whether the net fermion numbers and angular momenta of matter and antimatter could cancel each other: only fermion number and angular momentum separation would be in question.

This question relates also closely to the origin of galaxies. GRT leads to successful stellar models but in the galactic scales situation is different. The flatness of the spectrum of rotational velocities cannot be understood in terms of baryonic mater, and the halo model of dark matter is in grave difficulties [K93] [L46]. The situation is not much better for MOND (see `http://tinyurl.com/pu36kqg`), which introduces an ad hoc modification of laws of gravitation at low (rather than large!) accelerations. My personal intuition is that galactic dynamics goes beyond the explanatory power of GRT and that the its description should be much simpler than provided by the numerical models based on GRT involving large number of model dependent assumptions. The flat velocity spectrum and long range correlations of galactic spins signaling for cosmic P violation look like a promising starting point for the attempts to go beyond GRT view.

This work was largely inspired by a talk *Is the Universe rotating?* by Chu Ming-chung providing a lot of references and historical view about the evolution of the idea about rotating Universe. The slides can be found at `http://tinyurl.com/mzngctn`. These slides have been of considerable help for myself and are warmly recommended. They also contain numerous illustrations, to which I will link in the sequel.

5.2 Theoretical and empirical background

CMB results suggest large scale rotation and it has been even proposed that the entire Universe is rotating. Gödel Universe would be GRT example of this. This raises several questions. Has the notion of rotating Universe operational meaning? Could the milder milder hypothesis about fractal hierarchy of space-time sheet rotating in the sense that they possess non-vanishing angular momentum. The crucial question concerns the empirical support for the rotation in large length scales and here CMB anomalies are crucial.

In TGD framework one can ask further questions. Could matter and antimatter rotate in opposite directions? What conditions does this pose to the possible mechanism leading to matter antimatter separation? Could antimatter be dark in TGD sense?

5.2.1 Does it make sense to talk about rotating Universe?

Does it make sense to speak of rotating Universe? In other words, can one observe the rotation of the Universe? It is very difficult to look Universe from outside and one might hope that rotation could be detected from inside.

Views of Newton and Mach and TGD vision

This question is encountered also for finite systems. With respect to what do they rotate? Newton assumed absolute time and absolute space and rotation would be with respect to this. For rotating water bucket rotation has a visible consequence as the change of the shape of the water surfaces caused by centrifugal force. Mach was not satisfied with this explanation and proposed that rotation is with respect to the distant stars defining a unique inertial system.

1. In special relativity there is no unique inertial system but one can always distinguish between accelerated and inertial systems so that it is possible to tell whether system rotates in Minkowski space-time or not. The isometries of Minkowski space imply the existence of conserved angular momentum so that can speak about rotation of subsystem if the orbital part

of angular momentum is non-vanishing: usually the spin part of much smaller than orbital part. For single vortex one can say that it rotates as a whole. But if this vortex decomposes to smaller vortices spinning in the same direction, it seems that one cannot anymore speak of a rotation of the entire system anymore. The rotation of the entire system requires coherence. A super-fluid rotated with overcritical velocity indeed loses its macroscopic quantum coherence and vortices develop.

A naïve objection against constant rotation velocity Ω of Universe is that the $v = \omega\rho$ around rotation becomes superluminal at large distances ρ from the rotation axis. This would suggest that the rotation velocity, if non-vanishing, must be scale dependent and approach to zero at last distances like $\Omega \propto 1/\rho$ so that one has flat velocity spectrum. Vanishing vorticity outside the vortex core would require $\Omega \propto 1/\rho^2$.

2. In GRT one does not have unique inertial system either and also Lorentz invariance is lost as symmetries so that in principle one does not have conserved angular momentum. In GRT one has rotating solutions such as Gödel Universe, and one say that in this case one might say that the rotation is with respect to distant stars.

3. In TGD framework there are two senses in which rotation can make sense. Rotation must be absolute that is take place in any system of coordinates. This is guaranteed by general coordinate invariance (GCI). At embedding space level causal diamond (CD) of embedding space $H = M^4 \times CP_2$ - kind of mini-Universe as far as conscious perception is considered - defines the universal reference system. CD is analogous to the absolute inertial system of Newton: Lorentz invariant (absolute) time identified as light-cone proper time assignable to either tip of CD. Conserved angular momentum - not existing in GRT in strict sense - defines a measure for amount of rotation. Noether comes in rescue again!

   At space-time level larger space-time sheet at which the system is topologically condensed could serve as such a system. Also the larger space-time sheet could be rotating and cause effects analogous to Coriolis force caused by the rotation of Earth: the shape of hurricane Katrina and typical spiral galaxy are remarkably similar and might be partly due this force: large space-time sheet rotates with respect to the rest system of galaxy like Earth with respect to the rest system of Katrina.

4. What puts bells ringing is the existence of time like closed geodesics. Maybe they make sense after all at GRT limit of TGD, where zero energy ontology (ZEO) allows both arrows of time. In TGD framework the analog of absolute space is provided by the embedding space $M^4 \times CP_2$ and angular momentum is conserved quantity. Hence one can tell whether space-time sheet rotates and in principle can do this for arbitrarily large space-time sheets. The arrow of time depends on space-time sheet. The violation of T symmetry implied by Kähler form $J(CP)$ allows to distinguish between the two opposite arrows for a given space-time sheet.

Rotation in GRT Universe

In GRT the rotation of the Universe should show itself as the properties of the metric. To get the idea one can write ordinary Minkowski metric in rotating coordinates. One finds that the metric tensor has non-vanishing component $g_{t\phi}$. This serves as a guideline, when on tries to find metrics which would represent rotating systems, which are non-vacua. Kerr metric and Gödel's rotating static Universe [E193, E260] are examples of this kind of metrics.

The line element of Gödel metric [E193, E260]is of form

$$ds^2 = a^2(d\tau^2 - dx^2 + (exp(2x)/2)dy^2 - dz^2 + 2exp(x)d\tau dy \ .$$

The existence of closed light-like geodesics is easily verified by writing the equation $ds^2 = a^2(d\tau^2 + (exp(2x)/2)dy^2 + 2exp(x)d\tau dy = 0$ of light like geodesic in (τ, y) coordinate plane in the form $\tau = f_x(y)$. Same happens in Kerr metric.

Can one have closed time-like geodesics in TGD Universe: is it possible to make U-turn in time? In M^4 coordinates for the space-time sheet conserved energy for the geodesic is proportional to dm^0/ds and must vanish if it turns backwards in time. If there is coupling to the sum of vector potentials of Kähler forms of M^4 and CP_2 conserved energy contains also the analog of Coulomb energy proportional to $(dm^0/ds)A_0$, which also vanishes at the turning point.

The QFT limit of TGD should give GRT or something near to it. At this limit space-time is not many-sheeted surface anymore but a small deformation of flat Minkowski space. This limit is only an approximation and there are several anomalies suggesting that many-sheeted space-time is more realistic view about space-time.

The instanton density must vanish for the QCD limit of TGD: this solves the strong CP problem of QCD [L29]. Perhaps also the analog of instanton density for curvature form could vanish also for the GRT limit of TGD. This constraint profoundly modifies the interpretation of GRT: the sum $T - kG$ would represent non-vanishing energy momentum tensor including contributions assigned to matter and gravitation.

In zero energy ontology (ZEO) both arrows of time are possible in quantum sense and the violation of T is essential for this. Could the predicted violations of P, and T in cosmic scales for many-sheeted space-time correspond at GRT limit to the Kerr type metric with closed light-like and time like geodesics? Or does GRT limit simply fail to describe the situation?

Model for the effect of global rotation on the formation of the galaxies

Li-Xin Li has proposed a model in which the rotation of galaxies is caused by the rotation of space-time [E206]. The basic observation is that typhoons and galaxies resemble each other. The slides at `http://tinyurl.com/mzngctn` show that hurricane Katrina and disk galaxy M_{101} have very similar visual appearance. In case of Katrina one as pressure gradient (thermodynamical force) towards center and in the case of galaxy gravitational force (virtual force in GRT). For Katrina Earth and therefore also the rest system of Katrina rotates. For galaxy the rotating Universe would replace Earth. The proposal is that the analog of Coriolis force is responsible for the shape of galaxy. The empirical relation $J \propto M^{5/3}$ is explained and the model is claimed to predict two kinds of galaxies: elliptic and spiral. The estimated rotation speed of the Univese is deduced from data and would be $\Omega \sim 10^{-13}$ rad/year.

In TGD framework the presence of long flux tube would give rise to gravitational force forcing the rotation and constant velocity spectrum would give differential rotation explaining the spiral shape of the galaxy.

5.2.2 CMB and rotating Universe

CMB provides model dependent constraints on upper limits on the rotation velocity of the Universe and so called axis of Evil (AE) can be interpreted as indication for the preferred rotation direction in cosmic scales.

Constraints on the rotation velocity of Universe from CMB

The CMB contraints on the rotation velocity of Universe come from cosmological models treating rotation as perturbation Robertson-Walker cosmology using CMB data as a constraint.

1. Hawking has deduced a constraint on Ω for closed universe [E249]: $\Omega < 10^{-14} - 7 \times 10^{-17}$ rad/yr.

2. Hawking and Collins have deduced a constraint also for open universe [E243]: $\Omega < 2 \times 10^{-17}$ rad/yr .

3. Barrow has deduced a consraint for flat universe [E104]: $\Omega < 1.5 \times 10^{-15}$ rad/yr.

4. Ellis and Olive have shown that inflationary cosmology does not allow rotation large scales [E189]. Exponential expansion damps any rotation.

In TGD framework the rotation is made possible by the strong gravitational field of long flux tubes along which the galaxies would condense. One has actually fractal hierarchy of flux tubes: local groups of galaxies can take the role of pears attaching to strings and strings could be present also in the scale of stars. Elliptic galaxies have declining velocity spectrum being "free" pearls whereas disk galaxies would be pearls gravitationally bound to the string of the necklace, and circular orbits in $1/\rho$ potential would have constant velocity spectrum. Centrifugal force would would cause the flattening to disk galaxies.

Is there a preferred direction in the Universe?

Cosmic microwave background (CMB) predicted by standard cosmology has temperature $T = .2725$ K. The scale of temperature fluctuations $\Delta T/T \simeq 10^{-5}$ corresponds to that for the density fluctuations. The most successful model is inflationary model predicting Gaussian fluctuations, which are isotropic.

However, CMB contains astonishingly large number of anomalies as one learns from the introduction of the article *Preferred axis in cosmology* by W. Zhao and L. Santos [E261] (see `http://tinyurl.com/lr9qbzv`) giving also references to these anomalies. I am not a specialist in this field so that I can only repeat the list of the anomalies given in the introduction of the article: the low quadrupole problem, the lack of both variance and correlation on the largest angular scales, cold spot problem, power asymmetry, hemisphere asymmetry, large-scale quadrant asymmetry, alignment of low multipoles, parity asymmetry, mirror-parity asymmetry, and so on.

Most of these anomalies are directional anomalies and suggest P violation in cosmic scales. One cannot of course exclude that the presence of unknown sources of microwave radiation as an explanation of the anomalies. The anomalies could also reduce to the local physics. If the anomalies have cosmological origin, the prevailing inflationary scenario must be modified.

1. One can express CMB temperature as function of solid angle in terms of spherical harmonics $Y_{lm}(\Omega)$. For given l, one can also assign to the temperature fluctuations an axis for, which the dispersion of angular momentum quantum number m is largest. The direction of this axes should be random. For dipole, quadrupole, and octupole spins these axes are however nearly parallel and aligned with the direction of galactic North pole. This defines the Axis of Evil (AE).

   The direction of AE can be expressed in galactic spherical coordinates for which polar angle θ (latitude $b = \pi/2 - \theta$) with respect to the normal of galactic plane and azimuthal angle ϕ (longitude l) vanishes along the axis connecting Sun (the origin) to the center of galaxy. From WMAP data AE has coordinates $(b, l) \simeq (50°, -90°)$ [L30] (for illustration see `http://tinyurl.com/mzngctn`).

   In Earth centered coordinates with z-axis is orthogonal to the equitorial plane defining the celestial equator. The counterparts of latitude and longitude are declination and right ascension. The declinations associated with the dipole, quadrupole, and octupole (except for one of two WMAP octopoles) are in the range $[-7°, 16°]$. RAs are near to the axes with $RA = 180°$. AE corresponds roughly to the direction of Virgo constellation (for illustration see `http://tinyurl.com/kr3lma8`). Note that AE is almost in the equatorial plane of Earth, which raises the question about local explanation of AE unless the equatorial plane of Earth is parallel to a plane of some structure in larger length scale.

2. The alignment of lower multiples from $l = 1$ to $l = 5$ provide an example of directional anomaly. $l = 1$ anomaly is thought to be purely kinematical and due to the motion of local galaxy cluster with respect to cosmic background. What is strange that $l = 1$ happens to be aligned with the other multipoles: as if the local cluster would be moving along the preferred direction appearing in much large scale - the axis of evil (AE).

   The parity asymmetry between odd and even partial waves is second anomaly: even partial waves have anomalously low amplitudes and odd partial waves anomalously large values indicating parity violation in cosmic scales.

3. Preferred directions are reported in a number of other cosmological observations: the velocity flows, quasar alignment, anisotropy of the cosmic acceleration, the handedness of spiral galaxies, and angular distribution of the fine-structure constant. Even though there are many debates, it has been also reported that all these preferred directions seem to coincide with the CMB kinematic dipole. Also here references can be found from [E261] (see `http://tinyurl.com/lr9qbzv`).

For ordinary spherically symmetric statistics the directional anomalies cancel in the sense that one obtains same result for any choice of spherical coordinates. Therefore the authors of [E261] study the possible presence of preferred directions by using directional statistics breaking rotational invariance or axial symmetry with respect to fixed axis (one drops the $m = 0$ component from spherical harmonics and finds by statistical methods an axis for which P violation is maximal).

The axis found in this manner has strong correlations with AE and with the CMB kinematic dipole. The kinematic dipole is caused by the motion of local group of galaxies in the direction of the galactic coordinates ($\theta = 42°, \phi = 264°$). If the directions of various directional anomalies correspond to same direction, there is temptation to conclude that the anomaly is local.

4. The data can be also characterized by so called multipole vectors in 3-space [E119] (see `http://tinyurl.com/lxv4zmf`). For $l = 1$ harmonics they are are defined by the 3 coefficients of $l = 1$ partial waves c^{1m} defining a direction vector in 3-space. Higher partial waves are representable as symmetrized tensor products formed from $l = 1$ partial waves and orthogonalized with respect to the lower partial waves so that one can assign to $l \geq 1$ contributions l multipole vectors. For low values of l this vectors tend to aligm.

What about TGD view?

1. Directional anomalies are predicted by the twistor lift of TGD and would be due to the analog of covariantly constant Kähler form assignable to causal diamond (CD) in given scale defining preferred direction as quantization axis of angular momentum and time direction fixing rest system violating both CP, P, and T and perhaps involved also with matter antimatter asymmetry and macroscopic arrow of time. CDs would relate to quantum measurements in even cosmic scales.

2. The lack of both variance and correlation on the largest angular scales and large scale quadrant asymmetry (see `http://tinyurl.com/mzaklg4`) could be seen as a support for many-sheeted space-time: space-time sheets having interpretation as coherence regions have a finite size as do also CDs. Fractal hierarchy of parity violations such that the violation gets weaker in longer scales, is highly suggestive. Instead of anomaly in cosmic scale one could have a hierarchy of local parity violations.

5.2.3 Models for the P violation in long length scales

On the following two models for long length scale P possibly explaining the anomalies of CMB are discussed.

Is the cosmological AE due to a large-scale magnetic field?

M. J. Longo has studied the presence of parity violation in scales below .7 Gly [E220] (see the article *Does the Universe have a handedness?* at `http://tinyurl.com/l2aueq8`). The conclusion is that there is a strong signal for the preference for galaxies to be either left- or right-handed: one has $(N_R - N_L)/(N_L + N_R) \simeq 8$ per cent at northern celestial hemisphere (celestial equator is parallel to the Earth's equator). The probability for the occurrence of this asymmetry b change is estimated to be $\sim 3.0 \times 10^{-4}$. The asymmetry axis has $(\delta, RA) \sim (25°, 202°)$ with uncertainty of $\sim 15°$. The axis is aligned with AE having $(\delta, RA) \sim (4°, 173°)$. Milky Way is along with this axis within 8.4° or this spiral axis.

M. J. Longo considers in the article *Is the Cosmic "Axis of Evil" due to a Large-Scale Magnetic Field?* [E221] (see `http://tinyurl.com/m2f3cm3`) the possibility that the preferred direction could be due to the presence of magnetic field in the direction of AE and proposes inverse Compton scattering from the electron currents rotating around the axis of this magnetic field as a concrete mechanism for the generation of AE. I attach here the abstracti of the article.

I propose a mechanism that would explain the near alignment of the low order multipoles of the cosmic microwave background (CMB). This mechanism supposes a large-scale cosmic magnetic field that tends to align the cyclotron orbit axes of electrons in hot plasmas along the same direction.

Inverse Compton scattering of the CMB photons then imprints this pattern on the CMB, thus causing the low-l multipoles to be generally aligned. The spins of the majority of spiral galaxies and that of our own Galaxy appear to be aligned along the cosmic magnetic field.

The article mentions that Campanelli *et al.* [E114] propose that the power suppression in the low-l multipoles can be explained if the universe is "ellipsoidal" with an axis generally along the direction of the quadrupole. They suggest that the eccentricity is produced by a cosmic magnetic field $B_0 = (4-5) \times 10^{-9}$ Gauss.

In TGD framework magnetic flux tubes are the basic structures and suggest the following vision.

1. Disk galaxies are organized along flux tubes like pearls in necklace and the model correctly predicts the flat rotation curve of disk galaxies forming bound states with flux tubes and the declining rotation curve for elliptic galaxies, which would not form bound states with flux tubes. The magnetic fields associated with M^4 ($J(CD)$) and ordinary magnetic fields associated with CP_2 could be present.

   Magnetic field strength is inversely proportional to the thickness of the M^4 projection, which allows to estimate the thickness from flux quantization. For unit flux quantum the thickness of the flux tube for $B_0 = 4 \times 10^{-9}$ Gauss would be of order 7 cm - a biological scale. One expects large number of these flux tubes. In TGD framework one cannot talk about single global direction but fractal hierarchy of preferred directions defining quantization axis in terms of the flux tube directions of magnetic fields.

2. The origin of magnetic fields in cosmic scale is a mystery in standard model. In TGD framework the non-trivial homology of CP_2 allows magnetic flux tubes having closed 2-surface rather than disk as cross section and possessing integer valued magnetic flux. This kind of monopole fluxes does not need any current to generate them (induction coils in electronics) . Therefore these fluxes are topologically stable and would have been present already in primordial cosmology dominated by a gas of long cosmic strings.

3. The counterpart for inflationary period is a period when ordinary space-time was generated as long cosmic strings topologically condensed at emerging space-time sheets and their M^4 projection began to thicken. Flux tubes suffered topological condensation at thicker flux tubes. The decay of closed cosmic strings to ordinary particles analogous to the decay of inflaton field occurred in the reconnections of flux tubes and led to the formation of galaxies and large structures.

4. If AE is a local phenomenon in galactic scale, the first guess is that the preferred direction defining the axis of the magnetic field is roughly orthogonal to the galactic equatorial plane ($\theta \sim 90°$). The reason would be that the flux tube containing Milky Way as a pearl in necklace defines radial gravitational field in radial direction orthogonal to it and thus defines the galactic plane. The direction is however $\theta \sim 42°$. The first explanation is that the direction of AE is associated with a local cluster of galaxies and need not be the same as the direction of the flux tube assignable to Milky Way.

   Interestingly, there is evidence about so called vast polar structure (VPS) consisting of dwarf galaxies rotating in a plane orthogonal to galactic plane and that Milky Way might have experienced kind of cosmic traffic accident with with a galaxy for which the long flux tube would be orthogonal to that for Milky Way [E53] (see `http://tinyurl.com/k553545`). If two nearly orthogonal magnetic flux tubes are involved, the magnetic field experienced by charged particles in the many-sheeted space-time is sum of these magnetic fields and would be in the direction of AE.

The latest support for the importance of cosmic magnetic fields comes from the finding that long range magnetic fields in microgauss range exists at distance of about 5 billion light years [E145] (see `http://tinyurl.com/y9t9rup6`). The existence of so strong long ranged magnetic fields is impossible in early standard cosmology, where the hope has been that they would be generated by some mechanism later as temperature lowered.

Remark: It is of some interest to notice that in TGD inspired theory of consciousness various important biorhythms correspond to cyclotron time scales. The alpha band at 10 Hz corresponds to the cyclotron frequency of Fe^{++} ion in "endogenous" magnetic field $B_{end} = 2/5 \times B_E = B.2 \times 10^{-4}$ Gauss. By scaling the cyclotron time .1 seconds of Fe^{++} ion in $B_0 = 4 \times 10^{-9} = 2 \times 10^{-8} B_{end}$ would be about 2 months, a biological time scale. One can wonder whether this is mere accident.

Axis of Evil as a memory from primordial cosmology?

Axis of Evil is very interesting CMB anomaly (thanks for Sky Darmos for mentioning it in FB discussion). It has been even proposed that it forces Earth-centeredness. According to the Wikipedia article (see `http://tinyurl.com/yb6nabw4`):

The motion of the solar system, and the orientation of the plane of the ecliptic are aligned with features of the microwave sky, which on conventional thinking are caused by structure at the edge of the observable universe. Specifically, with respect to the ecliptic plane the "top half" of the CMB is slightly cooler than the "bottom half"; furthermore, the quadrupole and octupole axes are only a few degrees apart, and these axes are aligned with the top/bottom divide.

Axis of Evil is indeed really strange looking finding. To my view it does not however bring pre-Keplerian world view back but is related to the possibility of quantum coherence even in cosmological scales predicted by TGD. It would also reflect the situation during very early cosmology, which in TGD framework is cosmic string dominated.

1. The hierarchy of Planck constants $h_{eff} = n \times h_0$ ($h = 6 \times h_0$ is a good guess) implies the existence of space-time sheets with arbitrary large size serving as quantum coherent regions. $h_{eff} = h_{gr}$ assignable to flux tubes mediating gravitational interaction the value of h_{eff} can be gigantic. One has $h_{gr} = GMm/v_0$, where M and m are masses such that M can be solar mass or even larger mass and $v_0 < c$ has dimensions of velocity [L50] [K11].

2. Cosmic strings dominated the very early TGD inspired cosmology. They have 2-D projections to M^4 and CP_2 so that GRT is not able to describe them. During the analog of inflationary period the dimension of M^4 projection became D=4 and cosmic strings became magnetic flux tubes. Ordinary GRT space-time emerged and GRT started to be a reasonable approximation as QFT limit of TGD.

3. Quantum coherence make possible long range correlations. One correlation of this kind could be occurrene of cosmic strings which are *nearly parallel* in even cosmic scales or more precisely nearly parallel at the time when the TGD counterpart of inflation occurred and the ordinary space-time emerged and cosmic strings thickened to magnetic flux tubes - a process directly corresponding to cosmic expansion. This time corresponds in standard cosmology the end of inflationary period.

   The volume that we observe via CMB now would correspond to a rather small volume at the end of the period when ordinary GRT space-time emerged and it is not too difficult to imagine that in this volume the cosmic strings would have formed a bundle nearly parallel cosmic strings. This property would have been preserved in good approximation during expansion. For instance, angular momentum conservation would have taken care of this if the galaxies along long cosmic strings had angular momenta in parallel: there is indeed evidence for this. Turning of cosmic string to a different direction would require a lot of angular momentum since also the galaxies should be turned at the same time.

4. Cosmic strings thicknened to flux tubes would contain galaxies - pearls in necklace is good metaphor. Galaxies would be local tangles of flux tubes with topology of dipole type magnetic field in reasonable approximation. Also stars and planets would have formed in the similar manner. This leads to a rather detailed model for galaxy formation [L63].

Super-fluid Universe of Kerson Huang

The model of superfluid model of cosmology by Kerson Juang is an attempt to build a variant of inflation theory allowing to have rotation in cosmic scales, and perhaps also to explain the CBM anomalies. The article *Fantasia of a Superfluid Universe – In memory of Kerson Huang* by Low and Xiong [E182] (see `http://tinyurl.com/lbzt44o`) gives an idea about what is involved. It is instructive to compare the approach of Huang to that of Witten analogous to TGD approach.

The superfluid Universe of Huang makes the following basic hypothesis:

1. The asymptotically free Halpern-Huang scalar field(s) to drive inflation. This scalar field defines an order parameter for super-fluidity. The scalar field as rather complex non-polynomial potential and this could be criticized. Also the assumption about inflation can be subjected to criticism.

2. Quantum turbulence creates matter. Quantum turbulence would be associated with the string like defect lines of the order parameter analogous to vortex cores in ordinary superfluidity. These defect lines can get knotted and linked and can form a complex tangle. They can also reconnected and in this process the energy of the ground states of the order parameter could decay to ordinary matter.

3. Dark energy is the energy density of the cosmic superfluid and dark matter is the deviation of the superfluid density from its equilibrium value.

4. Quantum vorticity would explain phenomena such as the non-thermal filaments at the galactic center, the large voids in the galactic distribution, and the gravitational collapse of stars to fast-rotating blackholes.

Comparison with TGD reveals obvious differences but also common aspects.

1. Inflation is replaced in TGD by the transition from a phase dominated by cosmic strings to a radiation dominated cosmology and the decay of inflaton field is replaced with the decay of magnetic flux tubes to radiation. The identification of dark energy and matter is also different in TGD framework.

2. Also in TGD quantum turbulence would generate matter. In TGD however the flux tubes carrying super-currents/super-fluid flows would be the basic topological entities rather than the defects emerging in the QFT type description of these entities using complex scalar fields.

3. The vortices of supraflow would be generated by heat, collisions of galaxies, and fast rotating systems such as galaxies and blackholes and would not directly correspond to entities observed in cosmology. In TGD framework the flux tubes carrying dark energy and matter would replace the vortices and make themselves visible via the flatness of the velocity spectrum of galaxies.

4. In TGD the superconducting flux tubes would take the role of vortex lines in the modeling above mentioned phenomena such as non-thermal filaments at the galactic center, the large voids, and the gravitational collapse.

In the article *Relativistic superfluidity and vorticity from the nonlinear Klein-Gordon equation* [E194] (see `http://tinyurl.com/mrhgv2s`) by Huang *et al* consider a model for rotating super-fluid using complex scalar field obeying non-linear Klein Gordon equation and deduce from in rotating coordinates the quantum counterparts of centrifugal and Coriolis force terms in Minkowski space generalized to GRT. Also non-relativistic limit is considered.

The scalar field of Huang is taken as a fundamental field.

1. One can argue that this is only a macroscopic description for the particles forming the Bose-Einstein condensate as it is the ordinary super-conductivity and super-fluidity. The highly non-trivial implication would be that mean that these phases indeed exist in cosmological scales. The deeper challenge would be the identification of the "microscopic" entities described by the order parameter.

2. Witten's cosmic strings is an example of this kind of "microscopic" entities. For Witten's superconducting cosmic strings a spontaneous breaking of electromagnetic symmetry takes place inside cosmic strings as in ordinary super-conductivity (Meissner effect). Currents inside strings create strong magnetic fields around the string. Also radial electric fields are generated. Superconducting cosmic strings would not be vortices but basic current carriers.

In TGD the magnetic flux tubes emerge from cosmic strings as they thicken during cosmic evolution. They would be analogous to Witten's cosmic strings, and could serve as wires of both em and $U(1)$ currents. If one wants to use order parameter, one should assign it with single flux tube or maybe pair of them carrying Cooper pairs which define the basic superconducting structures in the TGD inspired model of high T_c superconductivity. It is these object, which would allow to understand CMB anomalies. It could happen that the net $U(1)$ charge density and current vanish inside flux tubes so that $U(1)$ fields outside flux tubes are not generated as in the case of Witten's superconducting strings.

The TGD inspired model of high T_c super-conductor or super-fluidity analogous to the model of Witten for cosmic string as super-conductor would appear as a fundamental description. It is essential that one has large h_{eff} phase. One canimagine three options.

1. One could have BE condensate of fundamental bosons at single flux tube for both super-conductivity and super-fluidity.

2. One could also have a Bose condensate of Cooper pairs. In the TGD based model of high T_c super-conductivity [K85, K86], the flux tubes would appear as pairs with magnetic fluxes in opposite or parallel directions. The members of Cooper pairs would be charged particles associated with different parallel flux tubes would have total spin 0 or or 1 for the two options.

3. $h_{eff}/h = n$ implies n-sheeted covering structure for the space-time surface. Could one have $m \leq n$ -fermion states with fermions at different sheets? These states would apparently break fermionic statistics since they are analogous to fermionic Bose-Einstein condensates. Or does $1/n$ fractionization of fermion number take place?

The QFT-GRT limit of TGD replaces the many-sheeted space-time with a slightly curved metric deformation of Minkowski space and closed flux tubes carrying super-currents/supraflows are idealized with point like particles described by a complex order parameter. Could the analog of the super-fluid Universe of Huang emerge at this limit? It is obvious that the line singularities for this order parameter have nothing to do with the flux tubes so that the information about CMB anomalies would be lost in this description. To sum up, it seems that the physics behind Huang's model and TGD are very different.

Two remarks are in order.

1. An open question is whether the quantum for angular momentum should be taken $\hbar_{eff}$ in which case the particles would be analogous Bose Einstein condensates with charged particles at different sheets of the covering having the same M^4 projection. TGD Universe is quantum critical system and there is temptation to think that this phenomenon occurs in all scales.

2. If fractality is taken at face value, one is led to ask whether also stars form necklace like structures. The string tension of flux tube in question should be so low that the deviation of the gravitational potential from $1/r$ form is not significant in the scale of planetary system. At large enough distances one should however obtain a flat velocity spectrum for objects rotating around Sun in circular orbits whereas for $1/r^2$ forces the velocities behave like $1/\sqrt{r}$. I it possible that this would have remained undetected?

5.3 Kähler form of M^4 as source of large scale breaking of CP, P and T

The analog of Kähler form for M^4 - or rather - for CD and depending on it - is a central element of the twistor lift of TGD.

5.3.1 The analog of Kähler structure of M^4 is forced by twistor lift of TGD

Twistor lift of TGD forces to assume the analog of self-dual covariantly constant Kähler form $J(M^4)$ for Minkowski space M^4 contributing to the Kähler form (or rather for causal diamond

(CD) of M^4). $J(CD)$ corresponds to the presence of parallel constant $U(1)$ electric and magnetic fields coupling to fermion number. This is the just prerequisite for charge separation in CME [L29]!

1. Does the M^4 Kähler form contribute to the $U(1)$ of em field or does it represent a classical field of its own? $J(CD)$ couples to fermion number. In particular, it has also a coupling to right-handed neutrinos! Since neutrinos are em neutral this allows only the interpretation as an additional $U(1)$ field coupling to fermion number. Right-handed neutrinos should be extremely weakly interacting, which demands that the preferred extremals are such that the electric component of $J(CD)$ is small. Alternatively, α_1 is small.

2. In TGD the induced $J(CD)$ field created by the density of nuclear baryonic number replaces the electromagnetic field created by a constant charge density in HN-HN collisions. For the canonical embedding of M^4 the induced $J(CD)$ would be self-dual and charge separation would be forced by $J(CD)$ in the direction defined by the $M^4 = M^2 \times E^2$ decomposition defined by $J(CD)$. There is strong temptation to think that matter-antimatter asymmetry is basically due to CME along $U(1)$ magnetic flux tubes connecting the regions containing matter and antimatter.

3. $J(CD)$ couples to the difference of fermion numbers defined as $F = B - L$ with electron and proton agreed to have the same fermion number. Since leptons and and baryons have opposite fermion numbers, $U(1)$ flux tubes as counterparts of field lines can connect baryons and leptons. Note that atoms have non-vanishing $U(1)$ charge F given by neutron number.

4. What is important that space-time surfaces themselves satisfy the analogs of field equations for point like particles in $U(1)$ field. They are obtained by replacing point like particles 3-D objects. This is one of the key predictions of twistor lift of TGD predicting that 4-D action contains a volume term besides Kähler action. The volume term alone would give the analog of geodesic motion and Kähler action adds coupling to $U(1)$ force. Asymptotic state are minimal surfaces analogous to geodesics having vanishing $U(1)$ force. $U(1)$ force appears only in transient situations like particle scattering events. The first interpretation of volume term would be in terms of cosmological constant. It however seems that the more plausible interpretation of the entire action is in terms of cosmological constant.

5.3.2 Quantitative picture about CP breaking in TGD

One must specify the value of α_1 and the scaling factor transforming $J(CD)$ having dimension length squared as tensor square root of metric to dimensionless $U(1)$ gauge field $F = J(CD)/S$. This leads to a series of questions.

How to fix the scaling parameter S?

1. The scaling parameter relating $J(CD)$ and F is fixed by flux quantization implying that the flux of $J(CD)$ is the area of sphere S^2 for the twistor space $M^4 \times S^2$. The gauge field is obtained as $F = J/S$, where $S = 4\pi R^2(S^2)$ is the area of S^2.

2. Note that in Minkowski coordinates the length dimension is by convention shifted from the metric to linear Minkowski coordinates so that the magnetic field B_1 has dimension of inverse length squared and corresponds to $J(CD)/SL^2$, where L is naturally be taken to the size scale of CD defining the unit length in Minkowski coordinates. The $U(1)$ magnetic flux would the signed area using L^2 as a unit.

How $R(S^2)$ relates to Planck length l_P? l_P is either the radius $l_P = R$ of the twistor sphere S^2 of the twistor space $T = M^4 \times S^2$ or the circumference $l_P = 2\pi R(S^2)$ of the geodesic of S^2. Circumference is a more natural identification since it can be measured in Riemann geometry whereas the operational definition of the radius requires embedding to Euclidian 3-space.

How can one fix the value of $U(1)$ coupling strength α_1? As a guideline one can use CP breaking in K and B meson systems and the parameter characterizing matter-antimatter symmetry.

1. The recent experimental estimate for so called Jarlskog parameter characterizing the CP breaking in kaon system is $J \simeq 3.0 \times 10^{-5}$. For B mesons CP breading is about 50 times larger than for kaons and it is clear that Jarlskog invariant does not distinguish between different meson so that it is better to talk about orders of magnitude only.

2. Matter-antimatter asymmetry is characterized by the number $r = n_B/n_\gamma \sim 10^{-10}$ telling the ratio of the baryon density after annihilation to the original density. There is about one baryon 10 billion photons of CMB left in the recent Universe.

Consider now the identification of α_1.

1. Since the action is obtained by dimensional reduction from the 6-D Kähler action, one could argue $\alpha_1 = \alpha_K$. This proposal leads to unphysical predictions in atomic physics since neutron-electron $U(1)$ interaction scales up binding energies dramatically.

   $U(1)$ part of action can be however regarded a small perturbation characterized by the parameter $\epsilon = R^2(S^2)/R^2(CP_2)$, the ratio of the areas of twistor spheres of $T(M^4)$ and $T(CP_2)$. One can however argue that since the relative magnitude of $U(1)$ term and ordinary Kähler action is given by ϵ, one has $\alpha_1 = \epsilon \times \alpha_K$ so that the coupling constant evolution for α_1 and α_K would be identical.

2. ϵ indeed serves in the role of coupling constant strength at classical level. α_K disappears from classical field equations at the space-time level and appears only in the conditions for the super-symplectic algebra but ϵ appears in field equations since the Kähler forms of J resp. CP_2 Kähler form is proportional to $R^2(S^2)$ resp. $R^2(CP_2)$ times the corresponding $U(1)$ gauge field. $R(S^2)$ appears in the definition of 2-bein for $R^2(S^2)$ and therefore in the modified gamma matrices and modified Dirac equation. Therefore $\sqrt{\epsilon} = R(S^2)/R(CP_2)$ appears in modified Dirac equation as required by CP breaking manifesting itself in CKM matrix.

   NTU for the field equations in the regions, where the volume term and Kähler action couple to each other demands that ϵ and $\sqrt{\epsilon}$ are rational numbers, hopefully as simple as possible. Otherwise there is no hope about extremals with parameters of the polynomials appearing in the solution in an arbitrary extension of rationals and NTU is lost. Transcendental values of ϵ are definitely excluded. The most stringent condition $\epsilon = 1$ is also unphysical. $\epsilon = 2^{2r}$ is favoured number theoretically.

Concerning the estimate for ϵ it is best to use the constraints coming from p-adic mass calculations.

1. p-Adic mass calculations [K63] predict electron mass as

$$m_e = \frac{\hbar}{R(CP_2)\sqrt{5+Y}} \quad .$$

   Expressing m_e in terms of Planck mass m_P and assuming $Y = 0$ ($Y \in (0,1)$) gives an estimate for $l_P/R(CP_2)$ as

$$\frac{l_P}{R(CP_2)} \simeq 2.0 \times 10^{-4} \quad .$$

2. From $l_P = 2\pi R(S^2)$ one obtains estimate for ϵ, α_1, $g_1 = \sqrt{4\pi\alpha_1}$ assuming $\alpha_K \simeq \alpha \simeq 1/137$ in electron length scale.

$$\begin{aligned} \epsilon &= 2^{-30} \simeq 1.0 \times 10^{-9} \quad , \\ \alpha_1 &= \epsilon\alpha_K \simeq 6.8 \times 10^{-12} \quad , \\ g_1 &= \sqrt{4\pi\alpha_1} \simeq 9.24 \times 10^{-6} \quad . \end{aligned}$$

There are two options corresponding to $l_P = R(S^2)$ and $l_P = 2\pi R(S^2)$. Only the length of the geodesic of S^2 has meaning in the Riemann geometry of S^2 whereas the radius of S^2 has operational meaning only if S^2 is imbedded to E^3. Hence $l_P = 2\pi R(S^2)$ is more plausible option.

For $\epsilon = 2^{-30}$ the value of $l_P^2/R^2(CP_2)$ is $l_P^2/R^2(CP_2) = (2\pi)^2 \times R^2(S^2)/R^2(CP_2) \simeq 3.7 \times 10^{-8}$. $l_P/R(S^2)$ would be a transcendental number but since it would not be a fundamental constant but appear only at the QFT-GRT limit of TGD, this would not be a problem.

One can make order of magnitude estimates for the Jarlskog parameter J and the fraction $r = n(B)/n(\gamma)$. Here it is not however clear whether one should use ϵ or α_1 as the basis of the estimate

1. The estimate based on ϵ gives

$$J \sim \sqrt{\epsilon} \simeq 3.2 \times 10^{-5} \quad , \quad r \sim \epsilon \simeq 1.0 \times 10^{-9} \quad .$$

   The estimate for J happens to be very near to the recent experimental value $J \simeq 3.0 \times 10^{-5}$. The estimate for r is by order of magnitude smaller than the empirical value.

2. The estimate based on α_1 gives

$$J \sim g_1 \simeq 0.92 \times 10^{-5} \quad , \quad r \sim \alpha_1 \simeq .68 \times 10^{-11} \quad .$$

   The estimate for J is excellent but the estimate for r by more than order of magnitude smaller than the empirical value. One explanation is that α_K has discrete coupling constant evolution and increases in short scales and could have been considerably larger in the scale characterizing the situation in which matter-antimatter asymmetry was generated.

There is an intriguing numerical co-incidence involved. $h_{eff} = \hbar_{gr} = GMm/v_0$ in solar system corresponds to $v_0 \simeq 2^{-11}$ and appears as coupling constant parameter in the perturbative theory obtained in this manner [K93]. What is intriguing that one has $\alpha_1 = v_0^2/4\pi^2$ in this case. Where does the troublesome factor $(1/2\pi)^2$ come from? Could the p-adic coupling constant evolutions for v_0 and α_1 correspond to each other and could they actually be one and the same thing? Can one treat gravitational force perturbatively either in terms of gravitational field or $J(CD)$? Is there somekind of duality involved?

Atomic nuclei have baryon number equal the sum $B = Z + N$ of proton and neutron numbers and neutral atoms have $B = N$. Only hydrogen atom would be also $U(1)$ neutral. The dramatic prediction of $U(1)$ force is that neutrinos might not be so weakly interacting particles as has been thought. If the quanta of $U(1)$ force are not massive, a new long range force is in question. $U(1)$ quanta could become massive via $U(1)$ super-conductivity causing Meissner effect. As found, $U(1)$ part of action can be however regarded a small perturbation characterized by the parameter $\epsilon = R^2(S^2)/R^2(CP_2)$. One can however argue that since the relative magnitude of $U(1)$ term and ordinary Kähler action is given by ϵ, one has $\alpha_1 = \epsilon \times \alpha_K$.

Quantal $U(1)$ force must be also consistent with atomic physics. The value of the parameter α_1 consistent with the size of CP breaking of K mesons and with matter antimatter asymmetry is $\alpha_1 = \epsilon\alpha_K = 2^{-30}\alpha_K$.

1. Electrons and baryons would have attractive interaction, which effectively transforms the em charge Z of atom $Z_{eff} = rZ$, $r = 1 + (N/Z)\epsilon_1$, $\epsilon_1 = \alpha_1/\alpha = \epsilon \times \alpha_K/\alpha \simeq \epsilon$ for $\alpha_K \simeq \alpha$ predicted to hold true in electron length scale. The parameter

$$s = (1 + (N/Z)\epsilon)^2 - 1 = 2(N/Z)\epsilon + (N/Z)^2\epsilon^2$$

   would characterize the isotope dependent relative shift of the binding energy scale.

   The comparison of the binding energies of hydrogen isotopes could provide a stringent bounds of the value of α_1. For $l_P = 2\pi R(S^2)$ option one would have $\alpha_1 = 2^{-30}\alpha_K \simeq .68 \times 10^{-11}$ and $s \simeq 1.4 \times 10^{-10}$. s is by order of magnitude smaller than $\alpha^4 \simeq 2.9 \times 10^{-9}$ corrections from QED (see `http://tinyurl.com/kk9u4rh`). The predicted differences between the binding energy scales of isotopes of hydrogen might allow to test the proposal.

2. $B = N$ would be neutralized by the neutrinos of the cosmic background. Could this occur even at the level of single atom or does one have a plasma like state? The ground state binding energy of neutrino atoms would be $\alpha_1^2 m_\nu/2 \sim 10^{-24}$ eV for $m_\nu = .1$ eV! This is many many orders of magnitude below the thermal energy of cosmic neutrino background estimated to be about 1.95×10^{-4} eV (see `http://tinyurl.com/ldu95o9`). The Bohr radius would be $\hbar/(\alpha_1 m_\nu) \sim 10^6$ meters and same order of magnitude as Earth radius. Matter should be $U(1)$ plasma. $U(1)$ superconductor would be second option.

5.3.3 Critical comments

One can represent an objection against the assumption that only covariantly constant $J(CD)$ are allowed: one can imagine also spherically and cylindrically symmetric and Lorentz invariant $J(CD)$s. Consider the $U(1)$ Coulomb field of point charge.

1. Should one assign the $U(1)$ electric flux with radial flux tubes? One would assign to each flux tube M^4 Kähler form $J(CD)$ for which the directions of electric and magnetic fields are in the direction of the flux tube. Every flux tube would be accompanied by its own CD and $J(CD)$! This means a lot of CDs, which also overlap! The overlapping CDs would naturally correspond to different space-time sheets perhaps with different size scales.

   What can one say about the relationship of zero energy states a associated with parallel space-time sheets connected by wormhole contacts. These space-time sheets are within respective CDs with either boundary a passive boundary. Suppose that a state function reduction for opposite boundary of CD occurs at the larger space-time sheet. What happens at spacetime sheets at smaller space-tme sheets condensed at it. The change of zero energy states should be induced at the connecting wormhole contacts. The change should leave the parts of zero energy states at passive boundary un-affected as also classical causality would suggest.

   Is this too complex? Why so much CDs are allowed? The proposed explanation is that CD represents the perceptive field of a conscious entity and the preferred directions of CD fix the rest system and spin quantization axis associated with it [L44]. CDs would represent the analog for the covering by open sets defining topological space or manifold. In TGD the notion of adelic/monadic manifold requires an analogous covering with CDs associated with the discrete set of points of space-time surface with the property that the coordinates belong to an extension of rationals [L40]. Conscious entities assignable to CDs would form an analog for the covering of manifold by charts of an atlas providing conscious map of the space-time surface. This covering would also give cognitive maps in the p-adic sectors of the adelic space-time.

2. The simple minimal surface solutions [L17] serving as models for stellar objects are lost if only covariantly constant $J(CD)$:s are allowed and can appear as approximations only.

   Should one accept also non-covariantly constant self-dual $J(CD)$:s with radial electric and magnetic fields necessarily having electric charge and magnetic monopole at the time-like line connecting the tips of CD? Self-dual $J(CD)$ with $J_{\theta\phi} \propto sin(\theta)$ and $J^{0r} = \epsilon^{0r\theta\phi} J_{\theta\phi}$ (note that $\epsilon^{0r\theta\phi}$ is permutation symbol divided by $1/\sqrt{g_4}$ having em charge and magnetic monopole charge at the line connecting the tips of CD would satisfy the conditions. Genuine monopole singularity is however not an attractive idea. Lorentz invariant solution in Robertson-Walker coordinates (a, r, θ, ϕ) is completely analogous. Cylindrically symmetric variant would have fermion charge density along 2-D surface within CD M^2 and is unphysical.

Clearly, the first option suggesting deep connection between the notions of topological space and manifold, number theory, and consciousness theory is the more plausible one.

5.3.4 Could the violations of CP, P, and T correlate?

If CP, P, and T were symmetries they would transform self-dual $J(CD)$ to antiself-dual form [L43]. If these variants of $J(CD)$ are not allowed in the moduli space of $J(CD)$s, one has simultaneous violation of all these symmetries in all scales. One would expect strong correlations between violations of CP, P, and T. The violation of CP in hadronic systems is discussed in [L43] and [L29], where also P violation is considered and assigned with TGD analogs of chiral magnetic effect (CME) and chiral selection effect (CSE) proposed in QCD framework.

Matter antimatter asymmetry and $J(M^4)$

There are several questions to be answered. Could matter antimatter asymmetry be due to the CP breaking in the scale of given space-time sheets due to $J(M^4)$ projection? Could it be due to the separation of matter and antimatter along flux tubes of $J(M^4)$ and be analogous to the so called chiral magnetic effect (CME) and chiral separation effect (CSE) inspired originally by QCD [L29]? A necessary condition would be the presence of nearly parallel electric and magnetic fields, and $J(CD)$ would provide these fields and fermions and antifermions would be driven to opposite directions along the flux tubes.

A more plausible option is following. The reconnection for flux tubes could lead to the decay of dark energy of flux tubes to elementary particles and by CP breaking anti-fermion number would generated inside flux tubes containing dark matter and fermion number would be generated in their exterior containing ordinary matter. After annihilation this would lead to matter antimatter asymmetry and apparent disappearance of antimatter.

Parity violation and large scale rotation

Could the violation of P in galactic scales and even in cosmic scales - as suggested by CMB anomalies - relate to the breaking of P caused by $J(CD)$ definition quantization axis for macroscopic quantum coherence regions defined by CDs? Could $h_{gr} = h_{eff} = n \times h$ phases with quantum coherence even in cosmic scales relate to the generation of correlations for spin directions of galaxies? Could the many-sheeted space-time implying a hierarchy of CDs assignable to flux tubes with increasingly large cross section allow to understand the generation of net angular momentum of matter at given level of hierarchy?

Ordinary matter would naturally rotate around the flux tubes in its gravitational field and have a flat velocity spectrum asymptotically. If hydrodynamic approximation makes sense, the rotation direction would be same for all subsystems and net angular momentum would be generated but it is not at all clear why the ordinary matter would have net angular momentum. However, the macroscopic quantum phases inside dark matter flux tubes rotating at cyclotron orbits would naturally have non-vanishing angular momentum and conservation of angular momentum would force ordinary matter to have opposite angular momentum. This mechanism is possible in all length scales by fractality.

P violation would manifest itself in the tendency of the spin direction of the spinning dark antimatter inside flux tubes to be preferentially right- or left-handed. Angular momentum conservation would induce similar preference for the spin directions of galaxies.

Parity breaking in living matter manifesting itself as chiral selection could have similar origin. ATPase is a protein central for metabolism and is analogous to the rotating generator of power plant transforming ADP to ATP and feeding to ATP energy serving as a metabolic energy currency. P violation strongly suggests a preferred direction of rotation. For “wrong” direction of rotation the generator would transform to a motor soaking up energy from environment. The anomalous behavior found by Russian researchers Roschin and Godin [H10] in rotating magnetic systems involves also parity violation [K10]. The system is reported to depicts apparent antigravitational effect and spontaneously accelerate above critical rotation frequency about 10 Hz (fundamental bio-rhythm!). This happens only for the second rotation direction. Also cooling of air around the system is reported in conflict with thermodynamical expectations and suggests time reversal at some space-time sheets.

Cosmic T violation and dominant arrow of time

TGD inspired theory of consciousness relies on zero energy ontology (ZEO) and predicts that conscious entities - selves - can have both arrows of time. Zero energy states are pairs of positive and negative energy states associated with opposite boundaries of causal diamond (CD). The passive boundary remains fixed during the state function sequences defining self as also the members of state pairs at it. The opposite (active) boundary shifts farther away and states at it suffer a sequence of unitary evolutions in the sequence fo state function reductions defining self as generalized Zeno effect. In the first reduction to the opposite boundary self dies and reincarnates as self with opposite arrow of clock time. Different arrows of time correspond to the growth of CD to opposite directions.

The usual view is that there is universal arrow of time. In TGD framework the flips for the arrow of time occurs in all possible scales. In living matter there is evidence for both arrows of time and already Fantappie realized this and proposed that syntropy as time-reversal of entropy is needed in order to understand living matter [J3].

There are several questions to be answered.

1. Why it is so difficult to systems have the non-standard arrow of time? What about living system. Could we actually experience it - say during sleep and unconscious states? Could T violation relate to the belief that the arrow of time is universal. For instance, could T violation imply that the life-times of selves with standard arrow of time are much longer than those with non-standard arrow of time sos that the standard arrow of time would dominate?

2. Suppose that one can speak about dominant arrow of time. Could the dominant arrow of time for dark antimatter be opposite to that for matter?

In GRT metrics for rotating systems such as Kerr metric and Göedel metric for rotating Universe have closed time like geodesics so that the arrow of time is not global. GRT is expected to be QFT limit of TGD in long scales. What could be the space-time correlates for the arrow of time be in TGD? Could rotating systems have arrow of time opposite to that for their exterior? Could macroscopic T violation have classical space-time correlates?

1. At the fundamental level one cannot have closed time like geodesics in TGD. This would require that the derivative of M^4 time with respect to the internal time of space-time surface changes and this implies that system has vanishing energy.

2. T breaking however means that the preferred extremals for given CD are not time reversals with respect to the center point of CD and in this sense the arrow of time has space-time correlates.

3. Could parallel space-time sheeets connected by wormhole contacts with Euclidian signature of metric and thus the corresponding CDs have opposite arrows of time?

5.4 Matter antimatter asymmetry and large scale rotation as aspects of $U(1)$ charge separation due to $J(CD)$

The presence of $J(CD)$ implies simultaneous violations of CP, P, and T and suggests that matter antimatter asymmetry and large scale rotation are aspects of the same phenomenon leading to a separation of opposite $U(1)$ charges.

5.4.1 Is dark antimatter at dark magnetic flux tubes?

If $J(M^4)$ (or rather $J(CD)$) leads to charge separation, the obvious idea is that charge separation could be also behind matter antimatter asymmetry.

1. I worked long time ago a model for large scale voids as extremals of Kähler action [K31, K94]. The idea was that Kähler force due to the induced CP_2 Kähler form drives fermions to the boundaries of large voids and antifermions to "big" cosmic strings going through the void. The same could take place in all scales. In particular, cosmic strings containing galaxies as pearls in string would contain dark matter in super-conducting or superfluid state or its analog based on many-sheeted fermion states made possible by the covering structure of the space-time surface.

2. A modification of model would be based on $J(M^4)$ having opposite couplings to fermions and antifermions. Quantum classical correspondence (QCC) demands that $U(1)$ charge F corresponds to the difference $F = B - L$ of baryon and lepton numbers so that its average density can vanish separately for matter and antimatter since proton and electron have opposite $U(1)$ charges. Above it has been assumed that the classical $U(1)$ forces is accompanied by a quantal force. The estimate for the $U(1)$ coupling strength as $\alpha_1 = R^2(S^2)^2/R^2(CP_2) = l_P^2/4\pi^2R^2$ was deduced is consistent with CP breaking in K system and matter antimatter symmetry.

3. Could the dark antimatter at the cosmic string serve as a source of a radial $U(1)$ force as Maxwellian intuition would suggests? It indeed seems natural to assign to a given flux

carrying $U(1)$ flux tube opposite $U(1)$ charges - fermion numbers - at the ends of the flux tube. The average flux for the induced $U(1)$ electric field corresponds to that for $U(1)$ charged string in Maxwellian theory. The density of $F = B - L$ could vanish separately for matter and antimatter so that no radial force is generated.

4. Antimatter could be a macroscopic quantum phase with $h_{eff}/h = n$ at flux tubes or even as Cooper pairs whose members are located at parallel flux tubes. For instance, long flux tubes which look like highly flattened squares could be considered. In this case the magnetic fluxes would be antiparallel and have identical magnitudes. Cooper pairs would have spin zero. They could however rotate around the magnetic axis inside flux tube and also around the closed flux tube and therefore have net angular momentum.

5. The "big" cosmic string proposed to go through the large voids would create a transversal gravitational $1/\rho$ force proportional to string tension and the matter at the boundaries of void rotates with velocity that does not depend on ρ. At the level of many-sheeted space-time gravitational force is mediated by gravitational flux along the radial flux tubes orthogonal to the axis of "big" cosmic string. If there is $U(1)$ force associated with these flux tubes, it means $1/\rho$ repulsive force tending to reduce gravitational force but not changing its form predicting flat velocity spectrum. One can of course $U(1)$ force appearing in the field equations for preferred extremals as generalization of corresponding force for point like particles relates to the accelerated expansion. One could imagine also a tessellation of hyperboloid of M^4_+ by cells having void as unit cell.

5.4.2 What could be the mechanism of matter antimatter separation and B-L separation?

Basic idea is that matter antimatter asymmetry is local so that the amounts of matter and antimatter are identical in all scales and only the locations of matter and antimatter in many-sheeted space-time are different and antimatter is dark in TGD sense. CP violation caused by $J(CD)$ could indeed imply that antimatter is dark and resides inside long flux tubes where as most matter is outside the flux tubes.

B-L separation is an analog of chiral separation effect (CSE) in hadron physics can be considered. M^4-chiralities would be replaced by H-chiralities in the TGD counterpart for magnetic separation effect (MSE) of QCD [L29]. Pollack effect [L9] involving separation of negative and positive charges in water in presence of gel phase and energy feeded by say infrared radiation gives rise electron-proton separation, which is a special case of B-L separation. Protons would become dark and go to the magnetic flux tubes. This mechanism has become basic mechanism of TGD inspired quantum biology and could explain the formation of negatively charged regions such as DNA and cell.

Matter antimatter separation would correspond to $F - \bar{F}$ separation. Some fraction of antimatter would go to magnetic flux tubes as dark matter and the rest would annihilate with ordinary matter.

Reconnections of flux tubes as a basic mechanism for matter antimatter separation?

The decay of flux tube energy to elementary particles in the reconnections of flux tubes create antimatter and matter and part of antimatter goes to flux tubes. Outside the flux tubes annihilation takes place and leaves a small fraction of matter: the fraction is about 10^{-10} and is for $l_P = 2\pi \times R(S^2)$ the same order of magnitude as $\alpha_1 = R(S^2)/R^2(CP_2) = (1/4\pi^2) \times l_P^2 \simeq 3 \times 10^{-11}$. For $g_1 = \sqrt{4\pi \times \alpha_1}$ one would obtain $g_1 \simeq 6.9 \times 10^{-5}$, which is of the order as Jarlskog parameter for K system. These numbers look rather realistic.

Reconnection could take in many ways. One possibility is inspired by the model of elementary particle in which particle is a pair of flux tubes with opposite fluxes at parallel space-time sheets having wormhole contacts at its ends. The projection of the flux tube to either sheet would be an open string. One can imagine that the flux tube shortens as short pieces split from it and decay to particles of matter with slightly larger probability than to antimatter. Could some particles go to flux tubes as dark antimatter and could some particles remain outside as matter. Annihilation would leave some antimatter inside and some matter outside.

Could flux tube networks lead to matter antimatter separation?

The idea about flux tube network [L21] would suggest a network of $U(1)$ flux tubes connecting nodes, which have non-vanishing F. Given flux tube could be of type $B-L$, $\overline{B}-\overline{L}$, $\overline{B}-B$ or $\overline{L}-L$. The annihilation of fermions and antifermions would delete by flux tube contraction links $\overline{B}-B$ and $\overline{L}-L$ and tend to annihilate matter and antimatter but not links $B-L$ because B and L are separately conserved in TGD Universe.

The reconnection of $\overline{B}-B$ and $L-\overline{L}$ bonds is not present in the ordinary kinetics and would transform matter-antimatter bonds $\overline{B}-B$ or $\overline{L}-L$ to $B-L$ and $\overline{B}-\overline{L}$ and vice versa and could reduce the number of bonds between antimatter and matter. Matter antimatter separation would take place if the process leads to disjoint networks having only $B-L$ bonds and $\overline{B}-\overline{L}$ bonds and vanishing total $B-L$ remain from the process. Due to CP breaking these networks could have different space-time realizations.

The network would have layers corresponding to various values of $h_{eff}/h=n$ and the phase transitions changing n would be possible at quantum criticality. Antimatter would correspond to $n>1$ phase.

5.4.3 TGD based model for the generation of galaxies

TGD view assigns dark matter/energy with long flux tubes having galaxies along them like pearls in necklace.

Consider first the view about disk galaxies.

1. After annihilation a fraction of antimatter remains the flux tube as dark matter and a fraction of matter survives outside the flux tube. Antimatter forms Bose-Einstein condensate like state and begins to rotate quantum coherently in the magnetic field in the same direction. Antileptons and antibaryons could have opposite rotation directions but baryonic angular momentum dominates if the rotation velocities are of same orer because the baryonic mass scale is higher. TGD inspired model of high Tc super-conductivity encourages to consider also pairs of flux tube helices analogous to DNA double strands.

2. Angular momentum conservation induces the rotation of ordinary matter. This would generate both matter antimatter asymmetry and opposite net angular momenta of matter and antimatter. This mechanism would in all scales and one can imagine that there are flux tubes having groups of galaxies around them like pearls in string. One would have fractal structure.

   For the particles of galactic matter the scale of angular momentum $m_oR_o^2\omega_o$ would be much larger than for antimatter particles. The length L_D of flux tubes per single galaxy would compensate for the small radius R_D of rotational orbit. The condition that total angular momenta and masses are identical for matter and antimatter gives the condition $v_D/v_o = R_o/R_D > 1$ relating that orbital radii and velocities of dark and ordinary matter. This would give $\omega_D/\omega_o = R_D^2/R_o^2$. Dark matter would rotate rather fast but not faster than light-velocity: this gives $v_D = (R_o/R_D)\times v_o < 1$. The condition that dark mass per single galaxy is same as galaxy mass gives $(dm_D/dL)L_D = m_o$.

Elliptic galaxies consist of old stars. They do not rotate appreciably and their rotation curve is declining.

1. Some fraction of ellipticals could have been formed in the collisions of disk galaxies as centrifugal forces throw out pieces of matter like droplets of water from a rotating umbrella. They would not bind to flux tubes anymore so that would not spin [L46] and the rotation curve would be declining. The old stars in ellipticals would have originated from spiral galaxies.

2. Elliptical might be also formed in the decay of closed cosmic strings to matter and antimatter by the proposed mechanism. Local decay to matter and antimatter could result if there is a helical structure formed by two flux tubes analogous to a closed DNA double strand. The reconnection of the strands could give rise to a local generation of matter. Since the flux

tube is closed, one expects that the net angular momentum of dark matter inside must be orthogonal to the plane of the flux tube. The angular momentum of ordinary matter forming the elliptic galaxy would be opposite so that it would not spin but rotate around the flux tube in direction opposite to that of antimatter.

These elliptic galaxies might be the pearls, which can condense around long flux tubes. The gravitational field of the flux tube is in transverse direction and would force the elliptical galaxy to rotate, flatten to disk (also Earth is a little bit flattened by rotation), and give flat rotation curve asymptotically.

One can imagine variants of this model but the basic ideas remain the same.

5.4.4 Galactic blackholes as a test for TGD view about formation of galaxies?

Galactic blackholes (or blackhole like entities) could serve as a test for the proposal. Galactic blackholes are supermassive having masses measured in billions of solar masses. These blackhole like entities is thought to grow rapidly as matter falls into them. In this process light is emitted and makes the blackhole a quasar (see `http://tinyurl.com/od6sftt`), one of the most luminous objects in the Universe.

TGD based model predicts that the seed of galaxy would be formed in the reconnection of cosmic strings and consist of dark matter. If galaxies are formed in this manner, the blackhole like entity formed in the reconnection point would get its mass from cosmic strings as dark mass and visible galactic mass would result from dark matter "boiling" to ordinary particles (as in the decay of inflaton field to particles). Matter from cosmic strings could flow to the reconnection point and a fraction of antimatter would remain inside cosmic string as dark matter.

During the "boiling" period intense radiation is generated, which leads to ask whether an interpretation as a formation of a quasar makes sense. The flow of matter would be from the blackhole like object rather than into it as in the ordinary model of quasar. Quasar like objects could of course be created also by the standard mechanism as ordinary matter starts to fall into the galactic dark blackhole and transforms to dark matter. This would occur much later than the formation of galactic blackhole like objects and galaxies around them.

Now three odd-ball quasars have been discovered in the early universe (13 billion years in past, less than billion years after Big Bang) by Eilers *et al* [E122] (see `http://tinyurl.com/kvrjyo5`). The authors conclude that the most compelling scenario is that these quasars have been shining only about 10^5 years. This time is not enough to build the mass that they have. This challenges the standard mechanism for the formation of galactic blackholes. What about the situation in TGD Universe? Could the odd-balls quasars be quasars in the usual sense of the word being created as ordinary matter starts to fall to the galactic dark matter blackhole and transforms to dark matter? Quantum phase transition would be involved.

Chapter 6

TGD View about Coupling Constant Evolution

6.1 Introduction

Atyiah has recently proposed besides a proof of Riemann Hypothesis also an argument claiming to derive the value of the structure constant (see `http://tinyurl.com/y8xw8cey`). The mathematically elegant arguments of Atyiah involve a lot of refined mathematics including notions of Todd exponential and hyper-finite factors of type II (HFFs) assignable naturally to quaternions. The idea that $1/\alpha$ could result by coupling constant evolution from π looks however rather weird for a physicist.

What makes this interesting from TGD point of view is that in TGD framework coupling constant evolution can be interpreted in terms of inclusions of HFFs with included factor defining measurement resolution [K115, K43]. An alternative interpretation is in terms of hierarchy of extensions of rationals with coupling parameters determined by quantum criticality as algebraic numbers in the extension [L41, L42].

In the following I will explain what I understood about Atyiah's approach. My critics includes the arguments represented also in the blogs of Lubos Motl (see `http://tinyurl.com/ycq8fhsy`) and Sean Carroll (see `http://tinyurl.com/y87f8psg`). I will also relate Atyiah's approach to TGD view about coupling evolution. The hasty reader can skip this part although for me it served as an inspiration forcing to think more precisely TGD vision.

There are two TGD based formulations of scattering amplitudes.

1. The first formulation is at the level of infinite-D "world of classical worlds" (WCW) [K89] uses tools like functional integral. The huge super-symplectic symmetries generalizing conformal symmetries raise hopes that this formulation exists mathematically and that it might even allow practical calculations some day. TGD would be an analog of integrable QFT.

2. Second - surprisingly simple - formulation [L61] is based on the analog of micro-canonical ensemble in thermodynamics (quantum TGD can be seen as complex square root of thermodynamics). It relates very closely to TGD analogs of twistorialization and twistor amplitudes [K106, L43].

   During writing I realized that this formulation can be regarded as a generalization of cognitive representations of space-time surfaces based on algebraic discretization making sense for all extensions of rationals to the level of scattering amplitudes. In the adelization the key question is whether it is necessary to define the p-adic counterparts of action exponentials. The number theoretical constraints seem hopelessly strong. One solution would be that the action exponentials for allow space-time surfaces equal to one. This option fails. The solution of the problem is however trivial. Kähler function can have only single minimum for given values of zero modes and the action exponentials cancel from scattering amplitudes completely in this case. This formulation allows a continuation to p-adic sectors and adelization [L41, L42]. Note that no conditions on α_K are obtained contrary to the first beliefs.

One can also understand the relationship of the two formulations in terms of M^8-H duality. This view allows also to answer to a longstanding question concerning the interpretation of the surprisingly successful p-adic mass calculations [K72]: as anticipated, p-adic mass calculations are carried out for a cognitive representation rather than for real world particles and the huge simplification explains their success for preferred p-adic prime characterizing particle as so called ramified prime for the extension of rationals defining the adeles.

The understanding of coupling constant evolution has been one of most longstanding problems of TGD and I have made several proposals during years. TGD view about cosmological constant turned out to be the solution of the problem.

1. The formulation of the twistor lift of Kähler action led to a rather detailed view about the interpretation of cosmological constant as an approximate parameterization of the dimensionally reduced 6-D Kähler action (or energy) allowing also to understand how it can decrease so fast as a function of p-adic length scale. In particular, a dynamical mechanism for the dimensional reduction of 6-D Kähler action giving rise to the induction of the twistor structure and predicting this evolution emerges.

   In standard QFT view about coupling constant evolution ultraviolet cutoff length serves as the evolution parameter. TGD is however free of infinities and there is no cutoff parameter. It turned out cosmological constant replaces this parameter and coupling constant evolution is induced by that for cosmological constant from the condition that the twistor lift of the action is not affected by small enough modifications of the moduli of the induced twistor structure. The moduli space for them corresponds to rotation group $SO(3)$. This leads to explicit evolution equations for α_K, which can be studied numerically.

2. I consider also the relationship to a second TGD based formulation of coupling constant evolution in terms of inclusion hierarchies of hyper-finite factors of type II_1 (HFFs) [K115, K43]. I suggest that this hierarchy is generalized so that the finite subgroups of $SU(2)$ are replaced with Galois groups associated with the extensions of rationals. An inclusion of HFFs in which Galois group would act trivially on the elements of the HFFs appearing in the inclusion: kind of Galois confinement would be in question.

Ramified primes are conjecture to correspond to the preferred p-adic primes characterizing particles. Ramified primes are special in the sense that their expression as a product of primes P_i of extension contains higher than first powers and the number P_i is smaller than the maximal number n defined by the dimension of the extension. It is not quite clear why ramified primes appear as preferred p-adic primes and in the following Dedekind zeta functions and what I call ramified zeta functions inspired by the interpretation of zeta function as analog of partition function are used in attempt to understand why ramified primes could be physically special.

The intuitive feeling is that quantum criticality is what makes ramified primes so special. In $O(p) = 0$ approximation the irreducible polynomial defining the extension of rationals indeed reduces to a polynomial in finite field F_p and has multiple roots for ramified prime, and one can deduce a concrete geometric interpretation for ramification as quantum criticality using $M^8 - H$ duality.

6.2 Criticism of Atyiah's approach

The basic idea of Atyiah is that π and the inverse of the fine structure constant $1/\alpha = 137.035999....$ are related by coupling constant evolution - that is renormalization - which is a basic operation in quantum field theory and has physical interpretation. For a physicist it is easy to invent objections.

1. In quantum field theory fine structure constant and all coupling strengths obey a continuous evolution as function of mass scale or length scale and one should predict the entire evolution rather than say its value at electron length scale. In TGD framework the coupling constant evolution becomes discrete and would basically labelled by the hierarchy of extensions of rationals.

2. π is purely geometric constant - kind of Platonic transcendental having very special role in the mathematical world order - whereas fine structure constant is a dynamical coupling

parameter. Atyiah does not have any proposal for why these constants would be related in this manner. Also no explanation for what it would mean that the circumference of unit circle would grow from 2π to $2/\alpha$ is given.

Remark: In TGD actually the coverings labelled by the value $h_{eff}/n_0 = n$ identified as the order of Galois group of extension of rationals defining given level of the hierarchy of evolutionary levels (entanglement coefficients would belong to this extension as also S-matrix elements). The full angle using M^4 rotation angle as coordinate increases effectively to $n \times 2\pi$ for the covering spaces of extensions introducing n:th root of unity. In TGD would however have n instead of $1/(\alpha\pi)$.

3. That $1/\alpha \sim 137$ should have interpretation as renormalized value of angle π looks rather weird to me. The normalization would be very large and it is extremely difficult to see why $1/\pi$ have a role of fine structure constant say at high energy limit if one accepts coupling constant evolution and identifies $1/\alpha$ as the value of $1/\alpha$ at zero momentum transfer.

In fact, Atyiah proposes a discrete evolution of π to $1/\alpha$ defined by approximations of HFF as a finite-D algebra. Forgetting π as the starting point of the evolution, this idea looks beautiful. At first the idea that all numbers suffer a renormalization evolution, looks really cute. Coupling constant evolution is however not a sequence of approximations but represents a genuine dependence of coupling constants on length scale.

Remark: In TGD framework I propose something different.The length scale evolution of coupling constants would correspond to a hierarchy of inclusions of HFFs rather than a sequence of finite-D approximations approaching HFF. The included factor would represent measurement resolution. Roughly, the transformations of states by operations defined in included factor would leave state invariant in the measurement resolution defined by the included factor. Different values of coupling constant would correspond to different measurement resolutions.

1. Atyiah mentions as one of his inspirers the definition of 2π via a limiting procedure identifying it as the length of the boundary of n-polygon inside unit circle. Amusingly, I have proposed similar definition of 2π in p-adic context, where the introduction of π would give rise to infinite extension.

   Atyiah generalizes this definition to the area of quaternionic sphere so that the limiting procedure involves two integers. For sphere tessellations as analogs of lattices allow only Platonic solids. For torus one could have infinite hierarchy of tessellations [L51] allowing to define the area of torus in this manner. The value of n defined by the extension of rationals containing root of unity $exp(i2\pi/n)$ such that n is maximal. The largest n for the roots of unity appearing in the extension of p-adics would determine the approximation of 2π used.

2. Atyiah suggests a concrete realization for the coupling constant evolution of numbers, not only coupling constants. The evolution would correspond to a sequence of approximation to HFF converging to HFF. One can of course define this kind of evolution but to physicist it looks like a formal game only.

3. HFF is interpreted as an infinite tensor product of 2×2 complex Clifford algebras $M_2(C)$, which can be also interpreted as complexified quaternions. One defines the trace by requiring that the trace of infinite tensor product of unit matrices equals to 1. The usual definition of schoolbooks would given infinite power of 2, which diverges. The inner product is the product of the usual inner products for the factors of the tensor product labelled by n but divided by power $2^{-n_{max}}$ to guarantee that the trace of the identity matrix is unity as product of traces for factors otherwise equal to 2^n. In fact, fermionic Fock algebra familiar to physicist is HFF although in hidden manner.

   Remark: The appearance of quaternions is attractive from TGD point of view since in $M^8 - H$ duality the dynamics at the level of M^8 is determined by associativity of either tangent or normal space of 4-surface in M^8 and associativity is equivalent with quaternionicity [L34]. The hierarchy of HFFs is also basic piece of quantum TGD and realizable in terms of quaternions.

4. Atyiah tells there is an algebra isomorphism from complex numbers C to the subset of commuting matrices in HFF. One can define the map to C as either eigenvalue of the matrix and obtains to isomorphisms: t_+ and t_-. One can define the renormalization map $C \to C$ in terms of the inverse of $t_- \circ t_+^{-1}$ or its inverse. This would assign to a complex numbers z its normalized value.

   HFFs allow an excellent approximation by finite number of tensor factors and one can perform an approximation taking only finite number of tensor factors and at the limit of infinite number of factors get the desired normalization map. The approximation would be $t_-(n) \circ t_+(n)$. I must confess that I did not really understand the details of this argument.

   In any case, to me this does not quite correspond to what I understand with renormalization flow. Rather this is analogous to a sequence of approximations defining scattering amplitude as approximation containing only contributions up to power g^n. I would argue than one must consider the infinite sequence of inclusions of HFFs instead of a sequence of approximations defining HFF.

   In this manner one would the renormalization map would be $t_-(n+1) \circ t_+^{-1}(n)$, where n now labels the hierarchy of HFFs in the inclusion hierarchy. $t_\pm n$ is now the exact map from commuting sub-algebra to complex numbers.

   There is however a rather close formal resemblance since simple inclusions correspond to inclusions of the sub-algebra with one M^2_C factor replaced with mere identity matrix.

5. The proposal of Atyiah is that this renormalization of numbers is mediated by so called Todd exponentiation used in the construction of the characteristic classes. This map would be defined in terms of generating function $G(x) = x/(1 - exp{-x})$ applied to $x = \pi$. If I understood anything about the explanation, this map is extended to infinite number of tensor factors defining the HFF and the outcome would be that $x = \pi$ for single tensor factor would be replaced with $1/\alpha$. Why Todd exponentiation? Atyiah also argues that one has $T(\pi)/\pi = T(\gamma)/\gamma$, where γ is Euler's constant. My mathematical education is so limited that I could not follow these arguments.

6. Atyiah also claims that the approximation $1/\alpha = 137$ assumed by Eddington to be exact has actually deeper meaning. There are several formulas in this approximation such as $1/\alpha = 2^0+2^3+2^7 = 1+8+128$. If I understood correctly, Atyiah tells that the numbers 1, 8, and 128 appear in the Bott periodicity theorem as dimensions of subsequent stable homotopy groups. My own favorite formula is in terms of Mersenne primes: $1/\alpha = M_2+M_3+M_7 = 3+7+127$. The next Mersenne prime would be M_{127} and corresponds to the p-adic length scale of electron.

   Remark: A fascinating numerological fact is that $p \simeq 2^k$, $k \simeq 137$, corresponds to the p-adic length scale near to Bohr radius: kind of cosmic joke one might say. Fine structure constant indeed emerged from atomic physics!

It would be of course marvellous if the renormalization would not depend on physics at all but here physicist protests.

1. The coupling constant evolutions for the coupling strengths of various interactions are different and depend also on masses of the particles involved. One might however hope that this kind of evolution might make sense for fundamental coupling constants of the theory. In TGD Kähler coupling strength $1/\alpha_K$ would be such parameter.

2. The quantum criticality of TGD Universe suggests that Atyiah's claim is true in a weaker sense. Quantum criticality is however a dynamical notion. I have actually proposed a model for the evolution of $1/\alpha_K$ based on the complex zeros of Riemann Zeta [L12] and also a generalization to other coupling strengths assuming that the argument of zeta is replaced with its Möbius transform.

   Very strong consistency conditions should be met. Preferred primes would be primes near prime power of 2 and ramified primes of extension, and also the zero of zeta in question should belong to the extension in question. I am of course the first to admit that this model is motivated more by mathematical aesthetics than concrete physical calculations.

3. The idea about renormalization evolution in this manner could - actually should - generalize. One can consider a maximal set of commuting set of observables in terms of tensor product of HFFs and define for them map to diagonal $n \times n$ matrices with complex eigenvalues. One would have infinite sum over the eigenvalues of diagonal matrices over factors: just as one has for many particle state in QFT containing contribution from all tensor factors which are now however ordered by the label n. The length scale evolution of these observables could be defined by the above formula for inclusion. Fine structure constant basically reduces to charge as eigenvalue of charge operator so that this could make sense.

   The beauty of this view would be that renormalization could be completely universal. In TGD framework quantum criticality (QC) indeed strongly suggests this universality in some sense. The hierarchy of extensions of rationals would define the discrete coupling constant evolution.

6.3 About coupling constant evolution in TGD framework

It is often forgotten that fine structure constant depends on length scale. When Eddington was working with the problem, it was not yet known that fine structure constant is running coupling constant. For continuous coupling constant evolution there is not much point to ponder why its value is what it is at say electron length scale. In TGD framework - adelic physics - coupling parameters however obey discrete length scale evolution deriving from the hierarchy of extensions of rationals. In this framework coupling constants are determined by quantum criticality implying that they do not run at all in the phase assignable to given extension of rational. They are analogous to critical temperature and determined in principle by number theory.

Two approaches to quantum TGD

There are two approaches to TGD: geometric and number theoretic. The "world of classical worlds" (WCW) is central notion of TGD as a geometrization of quantum physics rather than only classical physics.

1. WCW consists of 3-surfaces and by holography realized by assigning to these 3-surfaces unique 4-surfaces as preferred extremals. In zero energy ontology (ZEO) these 3-surfaces are pairs of 3-surfaces, whose members reside at opposite boundaries of causal diamond (CD) and are connected by preferred extremal analogous to Bohr orbit. The full quantum TGD would rely on real numbers and scattering amplitudes would correspond to zero energy states having as arguments these pairs of 3-surfaces. WCW integration would be involved with the definition of inner products.

2. The theory could be seen formally as a complex square root of thermodynamics with vacuum functional identified as exponent of Kähler function. Kähler geometry would allow to eliminate ill-defined Gaussian determinants and metric determinant of Kähler metric and they would simply disappear from scattering amplitudes. WCW is infinite-D space and one might argue that this kind of approach is hopeless. The point is however that the huge symmetries of WCW - super-symplectic invariance - give excellent hopes of really construction the scattering amplitudes: TGD would be integrable theory.

3. A natural interpretation would be that Kähler action as the analog of Hamiltonian defines the Kähler function of WCW and functional integral defined by it allows definition of full scattering amplitudes.

The number theoretic approach could be called adelic physics [L40, L42] providing also the physics of cognition.

1. At space-time level p-adicization as description of cognition requires discretization. Cognitive representations at space-time level consist of finite set of space-time points with preferred coordinates M^8 in extension of rationals inducing the extensions of p-adic number fields. These representations would realize the notion of finite measurement resolution. p-Adicization and adelization for given extension of rationals are possible only in this manner since these points can be interpreted as both real and p-adic numbers.

2. What about cognitive representations at the level of WCW? The discrete set of space-time points would replace the space-time surface with a finite discrete set of points serving also as its WCW coordinates and define the analog of discretization of WCW using polynomials in M^8 fixed by their values at these points [L34]. If the space-time surface is represented by a polynomial, this representation is all that is needed to code for the space-time surface since one can deduce the coefficients of a polynomial from its values at finite set of points. Now the coefficients belong to extension of rationals. If polynomials are replaced by analytic functions, polynomials provide approximation defining the cognitive representation.

While writing this I realized that what I have micro-canonical ensemble [L61] as kind of complex square root of its counterpart in thermodynamics can serve as a cognitive representation of scattering amplitudes. Cognitive representations of space-time surfaces would thus give also cognitive representations of WCW and micro-canonical ensemble would realize cognitive representations for the scattering amplitudes. Cognitive representations define only a hierarhcy of approximations. The exact description would involve the full WCW, its Kähler geometry, and vacuum functional as exponent of Kähler function.

The idea of micro-canonical ensemble as a subset of space-time surfaces with the same vanishing action would select a sub-set of surfaces with the same values of coupling parameters so that the fixing the coupling parameters together with preferred extremal property selects the subset with same value of action. There are two options to consider.

1. The real part of the action vanishes and imaginary part is multiple of 2π so that the action exponential is equal to unity. For the twistor lift this actually implies the vanishing of the entire action since volume term and Kähler term have the same phase (that of $1/\alpha_K$). The role of coupling parameters would be analogous to the role of temperature and applied pressure. In principle this condition is mathematically possible. The electric part of Kähler action in Minkowskian regions has sign opposite to magnetic part and volume term (actually magnetic S^2 part of 6-D Kähler action) so that these two contributions could cancel. The problem is that Kähler function would be constant and therefore also the Kähler metric.

2. I have also proposed [L61] that the analog of micro-canonical ensemble makes sense meaning that all space-time surfaces contributing to the scattering amplitude have the same action. As a consequence, the action exponential and the usual normalization factor would cancel each other and one would obtain just a sum over space-time surfaces with same action: otherwise action exponential would not appear in the scattering amplitudes - this is the case also in perturbative QFTs. This is crucial for the p-adicization and adelization since these exponential factors belong to the extension of rationals only under very strong additional conditions.

   This option has analog also at the level of WCW since Kähler function should have for give values of zero modes only single minimum so that localization in zero modes would mean that the action exponential cancels in the normalization of the amplitudes. It seems that this option is the only possible one.

   Note that the cancellation of the metric determinant and Gaussian determinant possible for Kähler metric with the exponent of Kähler function serving as vacuum functional reduces the perturbative integrations around the minima of Kähler action to a sum over exponents, and if only single minimum contributes for given values of the zero modes, the sum contains only single term.

6.3.1 Number theoretic vision about coupling constant evolution

Let us return to the question about the coupling constant evolution.

1. Each extension of rationals corresponds to particular values of coupling parameters determined by the extension so that it indeed makes sense to ponder what the spectrum of values for say fine structure constant is. In standard QFT this does not make sense.

2. Coupling constant evolution as a function of momentum or length scales reduces to p-adic coupling constant evolution in TGD as function of p-adic prime. Particles are characterized

by preferred p-adic primes - for instance, electron corresponds to $M_{127} = 2^{127} - 1$ - the largest Mersenne prime which does not correspond to super-astronomical Compton length - and the natural identification is as so called ramified primes of extension.

Why the interpretation of p-adic primes as ramified primes?

1. As one increases length scale resolution particle decomposes to more elementary particles.

2. Particles correspond in TGD to preferred p-adic primes. This suggests that when a prime (ideal) of given extension is looked at improved precision determined by an extension of the orignal extension it decomposes into a product of primes. This indeed happens.

   The number of primes of the larger extension appearing in the decomposition to product equals to the dimension of extension as extension of the original extension. All these primes appear and only once in the generic case. Ramified primes of ordinary extension are however odd-balls. Some primes of extension are missing and some appear as higher powers than 1 in their decomposition.

3. Ramified primes are analogous to critical systems. Polynomial with a multiple root - now prime of extension appearing as higher power - corresponds to a critical system. TGD is quantum critical so that one expects that ramified primes are preferred physically and indeed correspond to quantum critical systems.

4. Only the momenta belonging to the extension of rationals are considered and one can identify them as real-valued or p-adic valued momenta. Coupling constants do not depend on the values of the momenta for given extension of rationals and are thus analogous to critical temperature.

   This involves interesting not totally resolved technical question inspired by p-adic mass calculations for which the p-adic mass squared value is mapped to its real value by canonical identification $S\sum x_n p^n \rightarrow \sum x_n p^{-n}$. The correspondence is continuous and can be applied to Lorentz invariants appearing in scattering amplitudes [K73].

   Could this correspondence be applied also to momenta rather than only mass squared values and Lorentz invariants? $M^8 - H$ correspondence [L34] selects fixed Poincare frame as moduli space for octonionic structures and at M^8 level this could make sense.

6.3.2 Cosmological constant and twistor lift of Kähler action

Cosmological constant Λ is one of the biggest problems of modern physics. Surprisingly, Λ turned out to provide the first convincing solution to the problem of understanding coupling constant evolution in TGD framework. In QFTs the independence of scattering amplitudes on UV cutoff length scale gives rise to renormalization group (RG) equations. In TGD there is however no natural cutoff length scale since the theory is finite. Cosmological constant should however evolve as a function of p-adic length scales and cosmological constant itself could give rise to the length scale serving in the role of cutoff length scale. Combined with the view about cosmological constant provided by twistor lift of TGD this leads to explicit RG equations for α_K and scattering amplitudes.

Cosmological constant has two meanings.

1. Einstein proposed non-vanishing value of Λ in Einstein action as a volume term at his time in order to get what could be regarded as a static Universe. It turned out that Universe expanded and Einstein concluded that this proposal was the greatest blunder of his life. For two decades ago it was observed that the expansion of the Universe acclerates and the cosmological constant emerged again. Λ must be extremely small and have correct sign in order to give accelerating rather decelerating expansion in Robertson-Walker cooordinate. Here one must however notice that the time slicing used by Einstein was different and fr this slicing the Universe looked static.

2. Λ can be however understood in an alternative sense as characterizing the dynamics in the matter sector. Λ could characterize the vacuum energy density of some scalar field, call it

quintessense, proportional to 3- volume in quintessence scenario. This Λ would have sign opposite to that in the first scenario since it would appear at opposite side of Einstein's equations.

Cosmological constant in string models and in TGD

It has turned out that Λ could be the final nail to the coffin of superstring theory.

1. The most natural prediction of M-theory and superstring models is Λ in Einsteinian sense but with wrong sign and huge value: for instance, in AdS/CFT correspondence this would be the case. There has been however a complex argument suggesting that one could have a cosmological constant with a correct sign and even small enough size.

   This option however predicts landscape and a loss of predictivity, which has led to a total turn of the philosophical coat: the original joy about discovering the unique theory of everything has changed to that for the discovery that there are no laws of physics. Cynic would say that this is a lottery win for theoreticians since theory building reduces to mere artistic activity.

2. Now however Cumrun Vafa - one of the leading superstring theorists - has proposed that the landscape actually does not exist at all [B40] (see `http://tinyurl.com/ycz7wvng`). Λ would have wrong sign in Einsteinian sense but the hope is that quintessence scenario might save the day. Λ should also decrease with time, which as such is not a catastrophe in quintessence scenario.

3. Theorist D. Wrase *et al* has in turn published an article [B18] (see `http://tinyurl.com/ychrhuxk`) claiming that also the Vafa's quintessential scenario fails. It would not be consistent with Higgs Higgs mechanism. The conclusion suggesting itself is that according to the no-laws-of-physics vision something catastrophic has happened: string theory has made a prediction! Even worse, it is wrong.

   Remark: In TGD framework Higgs is present as a particle but p-adic thermodynamics rather than Higgs mechanism describes at least fermion massivation. The couplings of Higgs to fermions are naturally proportional their masses and fermionic part of Higgs mechanism is seen only as a way to reproduce the masses at QFT limit.

4. This has led to a new kind of string war: now inside superstring hegemony and dividing it into two camps. Optimistic outsider dares to hope that this leads to a kind of auto-biopsy and the gloomy period of superstring hegemony in theoretical physics lasted now for 34 years would be finally over.

String era need not be over even now! One could propose that both variants of Λ are present, are large, and compensate each other almost totally! First I took this as a mere nasty joke but I realized that I cannot exclude something analogous to this in TGD. It turned that this is not possible. I had made a delicate error. I thought that the energy of the dimensionally reduced 6-D Kähler action can be deduced from the resulting 4-D action containing volume term giving the negative contribution rather than dimensionally reducing the 6-D expression in which the volume term corresponds to 6-D magnetic energy and is positive! A lesson in non-commutativity!

The picture in which Λ in Einsteinian sense parametrizes the total action as dimensionally reduced 6-D twistor lift of Kähler action could be indeed interpreted formally as sum of genuine cosmological term identified as volume action. This picture has additional bonus: it leads to the understanding of coupling constant evolution giving rise to discrete coupling constant evolution as sub-evolution in adelic physics. This picture is summarized below.

The picture emerging from the twistor lift of TGD

Consider first the picture emerging from the twistor lift of TGD.

1. Twistor lift of TGD leads via the analog of dimensional reduction necessary for the induction of 8-D generalization of twistor structure in $M^4 \times CP_2$ to a 4-D action determining space-time surfaces as its preferred extremals. Space-time surface as a preferred extremal defines

a unique section of the induced twistor bundle. The dimensionally reduced Kähler action is sum of two terms. Kähler action proportional to the inverse of Kähler coupling strength and volume term proportional to the cosmological constant Λ.

Remark: The sign of the volume action is negative as the analog of the magnetic part of Maxwell action and *opposite* to the sign of the area action in string models.

Kähler and volume actions should have opposite signs. At M^4 limit Kähler action is proportional to $E^2 - B^2$ In Minkowskian regions and to $-E^2 - B^2$ in Euclidian regions.

2. Twistor lift forces the introduction of also M^4 Kähler form so that the twistor lift of Kähler action contains M^4 contribution and gives in dimensional reduction rise to M^4 contributions to 4-D Kähler action and volume term.

   It is of crucial importance that the Cartesian decomposition $H = M^4 \times CP_2$ allows the scale of M^4 contribution to 6-D Kähler action to be different from CP_2 contribution. The size of M^4 contribution as compared to CP_2 contribution must be very small from the smallness of CP breaking [L45] [L43].

   For canonically imbedded M^4 the action density vanishes. For string like objects the electric part of this action dominates and corresponding contribution to 4-D Kähler action of flux tube extremals is positive unlike the standard contribution so that an almost cancellation of the action is in principle possible.

3. What about energy? One must consider both Minkowskian and Euclidian space-time regions and be very careful with the signs. Assume that Minkowskian and Eucidian regions have *same time orientation.*

   (a) Since a dimensionally reduced 6-D Kähler action is in question, the sign of energy density is positive Minkowskian space-time regions and of form $(E^2 + B^2)/2$. Volume energy density proportional to Λ is positive.

   (b) In Euclidian regions the sign of g^{00} is negative and energy density is of form $(E^2 - B^2)/2$ and is negative when magnetic field dominates. For string like objects the M^4 contribution to Kähler action however gives a contribution in which the electric part of Kähler action dominates so that M^4 and CP_2 contributions to energy have opposite signs.

   (c) 4-D volume energy corresponds to the magnetic energy for twistor sphere S^2 and is therefore positive. For some time I thought that the sign must be negative. My blunder was that I erratically deduced the volume contribution to the energy from 4-D dimensionally reduced action, which is sum of Kähler action and volume term rather than deducing it for 6-D Kähler action and then dimensionally reducing the outcome. A good example about consequences of non-commutativity!

The identification of the observed value of cosmological constant is not straightforward and I have considered several options without making explicit their differences even to myself. For Einsteinian option cosmological constant could correspond to the coefficient Λ of the volume term in analogy with Einstein's action. For what I call quintessence option cosmological constant Λ_{eff} would approximately parameterize the total action density or energy density.

1. Cosmological constant - irrespective of whether it is identified as Λ or Λ_{eff} - is extremely small in the recent cosmology. The natural looking assumption would be that as a coupling parameter Λ or Λ_{eff} depends on p-adic length scale like $1/L_p^2$ and therefore decreases in average sense as $1/a^2$, where a is cosmic time identified as light-cone proper time assignable to either tip of CD. This suggests the following rough vision.

   The increase of the thickness of magnetic flux tubes carrying monopole flux liberates energy and this energy can make possible increase of the volume so that one obtains cosmic expansion. The expansion of flux tubes stops as the string tension achieves minimum and the further increase of the volume would increase string tension. For the cosmological constant in cosmological scales the maximum radius of flux tube is about 1 mm, which is biological length scale. Further expansion becomes possible if a phase transition increasing the p-adic length scale and reducing the value of cosmological constant is reduced. This phase transition liberates volume energy and leads to an accelerated expansion. The space-time surface would expand by jerks in stepwise manner. This process would replace continuous cosmic expansion of GRT. One application is TGD variant of Expanding Earth model explaining Cambrian Explosion, which is really weird event [L55].

One can however raise a serious objection: since the volume term is part of 6-D Kähler action, the length scale evolution of Λ should be dictated by that for $1/\alpha_K$ and be very slow: therefore cosmological constant identified as Einsteinian Λ seems to be excluded.

2. It however turns that it possible to have a large number of embedding of the twistor sphere into the product of twistor spheres of M^4 and CP_2 defining dimensional reductions. This set is parameterized by rotations sphere. The S^2 part of 6-D Kähler action determining Λ can be arbitrarily small. This mechanism is discussed in detail in [L63, L64] and leads also to the understanding of coupling constant evolution. The cutoff scale in QFT description of coupling constant evolution is replaced with the length scale defined by cosmological constant.

Second manner to increase 3-volume

Besides the increase of 3-volume of M^4 projection, there is also a second manner to increase volume energy: many-sheetedness. The phase transition reducing the value of Λ could in fact force many-sheetedness.

1. In TGD the volume energy associated with Λ is analogous to the surface energy in superconductors of type I. The thin 3-surfaces in superconductors could have similar 3-surface analogs in TGD since their volume is proportional to surface area - note that TGD Universe can be said to be quantum critical.

   This is not the only possibility. The sheets of many-sheeted space-time having overlapping M^4 projections provide second mechanism. The emergence of many-sheetedness could also be caused by the increase of $n = h_{eff}/h_0$ as a number of sheets of Galois covering.

2. Could the 3-volume increase during deterministic classical time evolution? If the minimal surface property assumed for the preferred extremals as a realization of quantum criticality is true everywhere, the conservation of volume energy prevents the increase of the volume. Minimal surface property is however assumed to fail at discrete set of points due to the transfer of conserved charged between Kähler and volume degrees of freedom. Could this make possible the increase of volume during classical time evolution so that volume and Kähler energy could increase?

   Remark: While writing this for the first time, I did not yet realize that if the action contains also parts associated with string world sheets and their light-like boundaries as $M^8 - H$ duality suggests, then the transfer of conserved quantities between space-time interior and string world sheets and string world sheets and their boundaries is possible, and implies the failure of the minimal surface property at these surfaces. One can however formulated precisely the proposed option and it implies that also string world sheets are quantum critical and therefore minimal surfaces: the question whether this occurs everywhere or only for the portions of string world sheets near the boundaries of causal diamonds remains open [L77].

3. ZEO allows the increase of average 3-volume by quantum jumps. There is no reason why each "big" state function reduction changing the roles of the light-like boundaries of CD could not decrease the average volume energy of space-time surface for the time evolutions in the superposition. This can occur in all scales, and could be achieved also by the increase of $h_{eff}/h_0 = n$.

4. The geometry of CD suggests strongly an analogy with Big Bang followed by Big Crunch. The increase of the volume as increase of the volume of M^4 projection does not however seem to be consistent with Big Crunch. One must be very cautious here. The point is that the size of CD itself increases during the sequence of small state function reductions leaving

the members of state pairs at passive boundary of CD unaffected. The size of 3-surface at the active boundary of CD therefore increases as also its 3-volume.

The increase of the volume during the Big Crunch period could be also due to the emergence of the many-sheetedness, in particular due to the increase of the value of n for space-time sheets for sub-CDs. In this case, this period could be seen as a transition to quantum criticality accompanied by an emergence of complexity.

Is the cosmological constant really understood?

The interpretation of the coefficient of the volume term as cosmological constant has been a long-standing interpretational issue and caused many moments of despair during years. The intuitive picture has been that cosmological constant obeys p-adic length scale scale evolution meaning that Λ would behave like $1/L_p^2 = 1/p \simeq 1/2^k$ [L22].

This would solve the problems due to the huge value of Λ predicted in GRT approach: the smoothed out behavior of Λ would be $\Lambda \propto 1/a^2$, a light-cone proper time defining cosmic time, and the recent value of Λ - or rather, its value in length scale corresponding to the size scale of the observed Universe - would be extremely small. In the very early Universe - in very short length scales - Λ would be large.

A simple solution of the problem would be the p-adic length scale evolution of Λ as $\Lambda \propto 1/p$, $p \simeq 2^k$. The flux tubes would thicken until the string tension as energy density would reach stable minimum. After this a phase transition reducing the cosmological constant would allow further thickening of the flux tubes. Cosmological expansion would take place as this kind of phase transitions (for a mundane application of this picture see [L55]).

This would solve the basic problem of cosmology, which is understanding why cosmological constant manages to be so small at early times. Time evolution would be replaced with length scale evolution and cosmological constant would be indeed huge in very short scales but its recent value would be extremely small.

I have however not really understood how this evolution could be realized! Twistor lift seems to allow only a very slow (logarithmic) p-adic length scale evolution of Λ [L62]. Is there any cure to this problem?

1. The magnetic energy decreases with the area S of flux tube as $1/S \propto 1/p \simeq 1/2^k$, where $\sqrt{p}$ defines the transversal length scale of the flux tube. Volume energy (magnetic energy associated with the twistor sphere) is positive and increases like S. The sum of these has minimum for certain radius of flux tube determined by the value of Λ. Flux tubes with quantized flux would have thickness determined by the length scale defined by the density of dark energy: $L \sim \rho_{vac}^{-1/4}$, $\rho_{dark} = \Lambda/8\pi G$. $\rho_{vac} \sim 10^{-47}$ GeV^4 (see `http://tinyurl.com/k4bwlzu`) would give $L \sim 1$ mm, which would could be interpreted as a biological length scale (maybe even neuronal length scale).

2. But can Λ be very small? In the simplest picture based on dimensionally reduced 6-D Kähler action this term is not small in comparison with the Kähler action! If the twistor spheres of M^4 and CP_2 give the same contribution to the induced Kähler form at twistor sphere of X^4, this term has maximal possible value!

   The original discussions in [K106, L22] treated the volume term and Kähler term in the dimensionally reduced action as independent terms and Λ was chosen freely. This is however not the case since the coefficients of both terms are proportional to $(1/\alpha_K^2)S(S^2)$, where $S(S^2)$ is the area of the twistor sphere of 6-D induced twistor bundle having space-time surface as base space. This are is same for the twistor spaces of M^4 and CP_2 if CP_2 size defines the only fundamental length scale. I did not even recognize this mistake.

The proposed fast p-adic length scale evolution of the cosmological constant would have extremely beautiful consequences. Could the original intuitive picture be wrong, or could the desired p-adic length scale evolution for Λ be possible after all? Could non-trivial dynamics for dimensional reduction somehow give it? To see what can happen one must look in more detail the induction of twistor structure.

1. The induction of the twistor structure by dimensional reduction involves the identification of the twistor spheres S^2 of the geometric twistor spaces $T(M^4) = M^4 \times S^2(M^4)$ and of T_{CP_2} having $S^2(CP_2)$ as fiber space. What this means that one can take the coordinates of say $S^2(M^4)$ as coordinates and embedding map maps $S^2(M^4)$ to $S^2(CP_2)$. The twistor spheres $S^2(M^4)$ and $S^2(CP_2)$ have in the minimal scenario same radius $R(CP_2)$ (radius of the geodesic sphere of CP_2. The identification map is unique apart from $SO(3)$ rotation R of either twistor sphere possibly combined with reflection P. Could one consider the possibility that R is not trivial and that the induced Kähler forms could almost cancel each other?

2. The induced Kähler form is sum of the Kähler forms induced from $S^2(M^4)$ and $S^2(CP_2)$ and since Kähler forms are same apart from a rotation in the common S^2 coordinates, one has $J_{ind} = J + RP(J)$, where R denotes a rotation and P denotes reflection. Without reflection one cannot get arbitrary small induced Kähler form as sum of the two contributions. For mere reflection one has $J_{ind} = 0$.

   Remark: It seems that one can do with reflection if the Kähler forms of the twistor spheres are of opposite sign in standard spherical coordinates. This would mean that they have have opposite orientation.

   One can choose the rotation to act on (y, z)-plane as $(y, z) \rightarrow (cy + sz, -sz + cy)$, where s and c denote the cosines of the rotation angle. A small value of cosmological constant is obtained for small value of s. Reflection P can be chosen to correspond to $z \rightarrow -z$. Using coordinates $(u = cos(\Theta), \Phi)$ for $S^2(M^4)$ and (v, Ψ) for $S^2(CP_2)$ and by writing the reflection followed by rotation explicitly in coordinates (x, y, z) one finds $v = -cu - s\sqrt{1-u^2}sin(\Phi)$, $\Psi = arctan[(su/\sqrt{1-u^2}cos(\Phi) + ctan(\Phi)]$. In the lowest order in s one has $v = -u - s\sqrt{1-u^2}sin(\Phi)$, $\Psi = \Phi + scos(\Phi)(u/\sqrt{1-u^2})$.

3. Kähler form J^{ind} is sum of unrotated part $J(M^4) = du \wedge d\Phi$ and $J(CP_2) = dv \wedge d\Psi$. $J(CP_2)$ equals to the determinant $\partial(v, \Psi)/\partial(u, \Phi)$. A suitable spectrum for s could reproduce the proposal $\Lambda \propto 2^{-k}$ for Λ. The S^2 part of 6-D Kähler action equals to $(J^{ind}_{\theta\phi})^2/\sqrt{g_2}$ and in the lowest order proportional to s^2. For small values of s the integral of Kähler action for S^2 over S^2 is proportional to s^2.

   One can write the S^2 part of the dimensionally reduced action as $S(S^2) = s^2F^2(s)$. Very near to the poles the integrand has $1/[sin(\Theta) + O(s)]$ singularity and this gives rise to a logarithmic dependence of F on s and one can write: $F = F(s, log(s))$. In the lowest order one has $s \simeq 2^{-k/2}$, and in improved approximation one obtains a recursion formula $s_n(S^2, k) = 2^{-k/2}/F(s_{n-1}, \log(s_{n-1})$ giving renormalization group evolution with k replaced by anomalous dimension $k_{n,a} = k + 2log[F(s_{n-1}, log(s_{n-1})]$ differing logarithmically from k.

4. The sum $J^{ind} = J + RP(J)$ defining the induced Kähler form in $S^2(X^4)$ is covariantly constant since both terms are covariantly constant by the rotational covariance of J.

5. The embeddings of $S^2(X^4)$ as twistor sphere of space-time surface to both spheres are holomorphic since rotations are represented as holomorphic transformations. Also reflection as $z \rightarrow 1/z$ is holomorphic. This in turn implies that the second fundamental form in complex coordinates is a tensor having only components of type $(1, 1)$ and $(-1, -1)$ whereas metric and energy momentum tensor have only components of type $(1, -1)$ and $(-1, 1)$. Therefore all contractions appearing in field equations vanish identically and $S^2(X^4)$ is minimal surface and Kähler current in $S^2(X^4)$ vanishes since it involves components of the trace of second fundamental form. Field equations are indeed satisfied.

6. The solution of field equations becomes a family of space-time surfaces parameterized by the values of the cosmological constant Λ as function of S^2 coordinates satisfying $\Lambda/8\pi G = \rho_{vac} = J \wedge (*J)(S^2)$. In long length scales the variation range of Λ would become arbitrary small.

7. If the minimal surface equations solve separately field equations for the volume term and Kähler action everywhere apart from a discrete set of singular points, the cosmological constant affects the space-time dynamics only at these points. The physical interpretation of

these points is as seats of fundamental fermions at partonic 2-surface at the ends of light-like 3-surfaces defining their orbits (induced metric changes signature at these 3-surfaces). Fermion orbits would be boundaries of fermionic string world sheets.

One would have family of solutions of field equations but particular value of Λ would make itself visible only at the level of elementary fermions by affecting the values of coupling constants. p-Adic coupling constant evolution would be induced by the p-adic coupling constant evolution for the relative rotations R combined with reflection for the two twistor spheres. Therefore twistor lift would not be mere manner to reproduce cosmological term but determine the dynamics at the level of coupling constant evolution.

8. What is nice that also $\Lambda = 0$ option is possible. This would correspond to the variant of TGD involving only Kähler action regarded as TGD before the emergence of twistor lift. Therefore the nice results about cosmology [K94] obtained at this limit would not be lost.

6.3.3 Does p-adic coupling constant evolution reduce to that for cosmological constant?

One of the chronic problems if TGD has been the understanding of what coupling constant evolution could be defined in TGD.

Basic notions and ideas

Consider first the basic notions and ideas.

1. The notion of quantum criticality is certainly central. The continuous coupling constant evolution having no counterpart in the p-adic sectors of adele would contain as a sub-evolution discrete p-adic coupling constant evolution such that the discrete values of coupling constants allowing interpretation also in p-adic number fields are fixed points of coupling constant evolution.

   Quantum criticality is realized also in terms of zero modes, which by definition do not contribute to WCW metric. Zero modes are like control parameters of a potential function in catastrophe theory. Potential function is extremum with respect to behavior variables replaced now by WCW degrees of freedom. The graph for preferred extremals as surface in the space of zero modes is like the surface describing the catastrophe. For given zero modes there are several preferred extremals and the catastrophe corresponds to the regions of zero mode space, where some branches of co-incide. The degeneration of roots of polynomials is a concrete realization for this.

   Quantum criticality would also mean that coupling parameters effectively disappear from field equations. For minimal surfaces (generalization of massless field equation allowing conformal invariance characterizing criticality) this happens since they are separately extremals of Kähler action and of volume term.

   Quantum criticality is accompanied by conformal invariance in the case of 2-D systems and in TGD this symmetry extends to its 4-D analogas isometries of WCW.

2. In the case of 4-D Kähler action the natural hypothesis was that coupling constant evolution should reduce to that of Kähler coupling strength $1/\alpha_K$ inducing the evolution of other coupling parameters. Also in the case of the twistor lift $1/\alpha_K$ could have similar role. One can however ask whether the value of the 6-D Kähler action for the twistor sphere $S^2(X^4)$ defining cosmological constant could define additional parameter replacing cutoff length scale as the evolution parameter of renormalization group.

3. The hierarchy of adeles should define a hierarchy of values of coupling strengths so that the discrete coupling constant evolution could reduce to the hierarchy of extensions of rationals and be expressible in terms of parameters characterizing them.

4. I have also considered number theoretical existence conditions as a possible manner to fix the values of coupling parameters. The condition that the exponent of Kähler function should

exist also for the p-adic sectors of the adele is what comes in mind as a constraint but it seems that this condition is quite too strong.

If the functional integral is given by perturbations around single maximum of Kähler function, the exponent vanishes from the expression for the scattering amplitudes due to the presence of normalization factor. There indeed should exist only single maximum by the Euclidian signature of the WCW Kähler metric for given values of zero modes (several extrema would mean extrema with non-trivial signature) and the parameters fixing the topology of 3-surfaces at the ends of preferred extremal inside CD. This formulation as counterpart also in terms of the analog of micro-canonical ensemble (allowing only states with the same energy) allowing only discrete sum over extremals with the same Kähler action [L61].

5. I have also considered more or less ad hoc guesses for the evolution of Kähler coupling strength such as reduction of the discrete values of $1/\alpha_K$ to the spectrum of zeros of Riemann zeta or actually of its fermionic counterpart [L12]. These proposals are however highly ad hoc.

Could the area of twistor sphere replace cutoff length?

As I started once again to consider coupling constant evolution I realized that the basic problem has been the lack of explicit formula defining what coupling constant evolution really is.

1. In quantum field theories (QFTs) the presence of infinities forces the introduction of momentum cutoff. The hypothesis that scattering amplitudes do not depend on momentum cutoff forces the evolution of coupling constants. TGD is not plagued by the divergence problems of QFTs. This is fine but implies that there has been no obvious manner to define what coupling constant evolution as a continuous process making sense in the real sector of adelic physics could mean!

2. Cosmological constant is usually experienced as a terrible head ache but it could provide the helping hand now. Could the cutoff length scale be replaced with the value of the length scale defined by the cosmological constant defined by the S^2 part of 6-D Kähler action? This parameter would depend on the details of the induced twistor structure. It was shown above that if the moduli space for induced twistor structures corresponds to rotations of S^2 possibly combined with the reflection, the parameter for coupling constant restricted to that to $SO(2)$ subgroup of $SO(3)$ could be taken to be taken $s = sin(\epsilon)$.

3. RG invariance would state that the 6-D Kähler action is stationary with respect to variations with respect to s. The variation with respect to s would involve several contributions. Besides the variation of $1/\alpha_K(s)$ and the variation of the $S(^2)$ part of 6-D Kähler action defining the cosmological constant, there would be variation coming from the variations of 4-D Kähler action plus 4-D volume term . This variation vanishes by field equations. As matter of fact, the variations of 4-D Kähler action and volume term vanish separately except at discrete set of singular points at which there is energy transfer between these terms. This condition is one manner to state quantum criticality stating that field equations involved no coupling parameters.

One obtains explicit RG equation for α_K and Λ having the standard form involving logarithmic derivatives. The form of the equation would be

$$\frac{dlog(\alpha_K)}{ds} = -\frac{S(S^2)}{(S_K(X^4)/Vol(X^4)) + S(S^2)}\frac{dlog(S(S^2))}{ds} \quad . \tag{6.3.1}$$

It should be noticed that the choices of the parameter s in the evolution equation is arbitrary so that the identification $s = sin(\epsilon)$ is not necessary. Note that one must use Kähler action per volume.

The equation contains the ratio $S(S^2)/(S_K(X^4) + S(S^2))$ of actions as a parameter. This does not conform with idea of micro-locality. One can however argue that this conforms with the generalization of point like particle to 3-D surface. For preferred extremal the action is indeed determined by the 3 surfaces at its ends at the boundaries of CD. This implies that the construction of quantum theory requires the solution of classical theory.

In particular, the 4-D classical theory is necessary for the construction of scattering amplitudes, and one cannot reduce TGD to string theory although strong form of holography states that the data about quantum states can be assigned with 2-D surfaces. Even more: M^8-H correspondence implies that the data determining quantum states can be assigned with discrete set of points defining cognitive representations for given adel This set of points depends on the preferred extremal!

4. How to identify quantum critical values of α_K? At these points one should have $dlog(\alpha_K)/ds = 0$. This implies $dlog(S(S^2)/ds = 0$, which in turn implies $dlog(\alpha_K)/ds = 0$ unless one has $S_K(X^4) + S(S^2) = 0$. This condition would make exponent of 6-D Kähler action trivial and the continuation to the p-adic sectors of adele would be trivial. I have considered also this possibility [L62].

   The critical values of coupling constant evolution would correspond to the critical values of S and therefore of cosmological constant. The basic nuisance of theoretical physics would determine the coupling constant evolution completely! Critical values are in principle possible. Both the numerator $J^2_{u\Phi}$ and the numerator $1/\sqrt{det(g)}$ increase with ϵ. If the rate for the variation of these quantities with s vary it is possible to have a situation in which the one has

$$\frac{dlog(J^2_{u\Phi})}{ds} = -\frac{dlog(\sqrt{det(g)})}{ds} \quad . \tag{6.3.2}$$

5. One can make highly non-trivial conclusions about the evolution at general level. For the extremals with vanishing action and for which α_K is critical (vanishing derivate), also the second derivative of $d^2S(S^2)/ds^2 =$ holds true at the critical point. The QFT analogs of these points are points at which beta function develops higher order zero. The tip of cusp catastrophe is second analogy.

   The points at which that the action has minimum are also interesting. For magnetic flux tubes for which one has $S_K(X^4) \propto 1/S$ and $S_{vol} \propto S$ in good approximation, one has $S_K(X^4) = S_{vol}$ at minimum (say for the flux tubes with radius about 1 mm for the cosmological constant in cosmological scales). One can write

$$\frac{dlog(\alpha_K)}{ds} = -\frac{1}{2}\frac{dlog(S(S^2))}{ds} \quad , \tag{6.3.3}$$

   and solve the equation explicitly:

$$\frac{\alpha_{K,0}}{\alpha_K} = \frac{S(S^2)}{S(S^2)_0})^x \quad , \quad x = 1/2 \quad . \tag{6.3.4}$$

   A more general situation would correspond to a model with $x \neq 1/2$: the deviation from $x = 1/2$ could be interpreted as anomalous dimension. This allows to deduce numerically a formula for the value spectrum of $\alpha_{K,0}/\alpha_K$ apart from the initial values.

6. One can solve the equation also for fixed value of $S(X^4)/Vol(X^4)$ to get

$$\frac{\alpha_{K,0}}{\alpha_K} = \frac{S(S^2)}{S(S^2)_0})^x \quad , \quad x = 1/2 \quad . \tag{6.3.5}$$

$$\frac{\alpha_K}{\alpha_{K,0}} = \frac{S_K(X^4)/Vol(X^4)) + S(S^2)}{S_K(X^4)/Vol(X^4))} \quad . \tag{6.3.6}$$

At the limit $S(S^2) = \rightarrow 0$ one obtains $\alpha_K \rightarrow \alpha_{K,0}$.

7. One should demonstrate that the critical values of s are such that the continuation to p-adic sectors of the adele makes sense. For preferred extremals cosmological constant appears as a parameter in field equations but does not affect the field equations expect at the singular points. Singular points play the same role as the poles of analytic function or point charges in electrodynamics inducing long range correlations. Therefore the extremals depend on parameter s and the dependence should be such that the continuation to the p-adic sectors is possible.

   A naïve guess is that the values of s are rational numbers. Above the proposal $s = 2^{-k/2}$ motivated by p-adic length scale hypothesis was considered but also $s = p^{-k/2}$ can be considered. These guesses might be however wrong, the most important point is that there is that one can indeed calculate $\alpha_K(s)$ and identify its critical values.

8. What about scattering amplitudes and evolution of various coupling parameters? If the exponent of action disappears from scattering amplitudes, the continuation of scattering amplitudes is simple. This seems to be the only reasonable option. In the adelic approach [L40] amplitudes are determined by data at a discrete set of points of space-time surface (defining what I call cognitive representation) for which the points have M^8 coordinates belong to the extension of rationals defining the adele.

   Each point of $S^2(X^4)$ corresponds to a slightly different X^4 so that the singular points depend on the parameter s, which induces dependence of scattering amplitudes on s. Since coupling constants are identified in terms of scattering amplitudes, this induces coupling constant evolution having discrete coupling constant evolution as sub-evolution.

Could the critical values of α_K correspond to the zeros of Riemann Zeta?

Number theoretical intuitions strongly suggests that the critical values of $1/\alpha_K$ could somehow correspond to zeros of Riemann Zeta. Riemann zeta is indeed known to be involved with critical systems.

The naïvest ad hoc hypothesis is that the values of $1/\alpha_K$ are actually proportional to the non-trivial zeros $s = 1/2 + iy$ of zeta [L12]. A hypothesis more in line with QFT thinking is that they correspond to the imaginary parts of the roots of zeta. In TGD framework however complex values of α_K are possible and highly suggestive. In any case, one can test the hypothesis that the values of $1/\alpha_K$ are proportional to the zeros of ζ at critical line. Problems indeed emerge.

1. The complexity of the zeros and the non-constancy of their phase implies that the RG equation can hold only for the imaginary part of $s = 1/2 + it$ and therefore only for the imaginary part of the action. This suggests that $1/\alpha_K$ is proportional to y. If $1/\alpha_K$ is complex, RG equation implies that its phase RG invariant since the real and imaginary parts would obey the same RG equation.

2. The second - and much deeper - problem is that one has no reason for why $dlog(\alpha_K)/ds$ should vanish at zeros: one should have $dy/ds = 0$ at zeros but since one can choose instead of parameter s any coordinate as evolution parameter, one can choose $s = y$ so that one has $dy/ds = 1$ and criticality condition cannot hold true. Hence it seems that this proposal is unrealistic although it worked qualitatively at numerical level.

It seems that it is better to proceed in a playful spirit by asking whether one could realize quantum criticality in terms of of the property of being zero of zeta.

1. The very fact that zero of zeta is in question should somehow guarantee quantum criticality. Zeros of ζ define the critical points of the complex analytic function defined by the integral

$$X(s_0,s) = \int_{C_{s_0\rightarrow s}} \zeta(s)ds \ , \tag{6.3.7}$$

where $C_{s_0\rightarrow s}$ is any curve connecting zeros of ζ, a is complex valued constant. Here s does not refer to $s = sin(\epsilon)$ introduced above but to complex coordinate s of Riemann sphere.

By analyticity the integral does not depend on the curve C connecting the initial and final points and the derivative $dS_c/ds = \zeta(s)$ vanishes at the endpoints if they correspond to zeros of ζ so that would have criticality. The value of the integral for a closed contour containing the pole $s = 1$ of ζ is non-vanishing so that the integral has two values depending on which side of the pole C goes.

2. The first guess is that one can define S_c as complex analytic function $F(X)$ having interpretation as analytic continuation of the S^2 part of action identified as $Re(S_c)$:

$$\begin{array}{ll} S_c(S^2) = F(X(s,s_0)) \ , & X(s,s_0) = \int_{C_{s_0\rightarrow s}} \zeta(s)ds \ , \\ S(S^2) = Re(S_c) = Re(F(X)) \ , & \\ \zeta(s) = 0 \ , & Re(s_0) = 1/2 \ . \end{array} \tag{6.3.8}$$

$S_c(S^2) = F(X)$ would be a complexified version of the Kähler action for S^2. s_0 must be at critical line but it is not quite clear whether one should require $\zeta(s_0) = 0$.

The real valued function $S(S^2)$ would be thus extended to an analytic function $S_c = F(X)$ such that the $S(S^2) = Re(S_c)$ would depend only on the end points of the integration path $C_{s_0\rightarrow s}$. This is geometrically natural. Different integration paths at Riemann sphere would correspond to paths in the moduli space $SO(3)$, whose action defines paths in S^2 and are indeed allowed as most general deformations. Therefore the twistor sphere could be identified Riemann sphere at which Riemann zeta is defined. The critical line and real axis would correspond to particular one parameter sub-groups of $SO(3)$ or to more general one parameter subgroups.

One would have

$$\frac{\alpha_{K,0}}{\alpha_K} = (\frac{S_c}{S_0})^{1/2} \ . \tag{6.3.9}$$

The imaginary part of $1/\alpha_K$ (and in some sense also of the action $S_c(S^2)$) would determined by analyticity somewhat like the real parts of the scattering amplitudes are determined by the discontinuities of their imaginary parts.

3. What constraints can one pose on F? F must be such that the value range for $F(X)$ is in the value range of $S(S^2)$. The lower limit for $S(S^2)$ is $S(S^2) = 0$ corresponding to $J_{u\Phi} \rightarrow 0$.

The upper limit corresponds to the maximum of $S(S^2)$. If the one Kähler forms of M^4 and S^2 have same sign, the maximum is $2\times A$, where $A = 4\pi$ is the area of unit sphere. This is however not the physical case.

If the Kähler forms of M^4 and S^2 have opposite signs or if one has RP option, the maximum, call it S_{max}, is smaller. Symmetry considerations strongly suggest that the upper limit corresponds to a rotation of 2π in say (y,z) plane ($s = sin(\epsilon) = 1$ using the previous notation).

For $s \to s_0$ the value of S_c approaches zero: this limit must correspond to $S(S^2) = 0$ and $J_{u\Phi} \to 0$. For $Im(s) \to \pm\infty$ along the critical line, the behavior of $Re(\zeta)$ (see `http://tinyurl.com/y7b88gvg`) strongly suggests that $|X| \to \infty$. This requires that F is an analytic function, which approaches to a finite value at the limit $|X| \to \infty$. Perhaps the simplest elementary function satisfying the saturation constraints is

$$F(X) = S_{max}tanh(-iX) \ . \qquad (6.3.10)$$

One has $tanh(x+iy) \to \pm 1$ for $y \to \pm\infty$ implying $F(X) \to \pm S_{max}$ at these limits. More explicitly , one has $tanh(-i/2-y) = [-1+exp(-4y)-2exp(-2y)(cos(1)-1)]/[1+exp(-4y)-2exp(-2y)(cos(1)-1)]$. Since one has $tanh(-i/2+0) = 1-1/cos(1) < 0$ and $tanh(-i/2+\infty) = 1$, one must have some finite value $y = y_0 > 0$ for which one has

$$tanh(-\frac{i}{2}+y_0) = 0 \ . \qquad (6.3.11)$$

The smallest possible lower bound s_0 for the integral defining X would naturally to $s_0 = 1/2 - iy_0$ and would be below the real axis.

4. The interpretation of $S(S^2)$ as a positive definite action requires that the sign of $S(S^2) = Re(F)$ for a given choice of $s_0 = 1/2 + iy_0$ and for a propertly sign of $y - y_0$ at critical line should remain positive. One should show that the sign of $S = a\int Re(\zeta)(s = 1/2 + it)dt$ is same for all zeros of ζ. The graph representing the real and imaginary parts of Riemann zeta along critical line $s = 1/2 + it$ (see `http://tinyurl.com/y7b88gvg`) shows that both the real and imaginary part oscillate and increase in amplitude. For the first zeros real part stays in good approximation positive but the amplitude for the negative part increase be gradually. This suggests that S identified as integral of real part oscillates but preserves its sign and gradually increases as required.

A priori there is no reason to exclude the trivial zeros of ζ at $s = -2n$, $n = 1, 2, ...$

1. The natural guess is that the function $F(X)$ is same as for the critical line. The integral defining X would be along real axis and therefore real as also $1/\alpha_K$ provided the sign of S_c is positive: for negative sign for S_c not allowed by the geometric interpretation the square root would give imaginary unit. The graph of the Riemann Zeta at real axis (real) is given in MathWorld Wolfram (see `http://tinyurl.com/55qjmj`).

2. The functional equation

$$\zeta(1-s) = \zeta(s)\frac{\Gamma(s/2)}{\Gamma((1-s)/2)} \qquad (6.3.12)$$

allows to deduce information about the behavior of ζ at negative real axis. $\Gamma((1-s)/2)$ is negative along negative real axis (for $Re(s) \leq 1$ actually) and poles at $n + 1/2$. Its negative maxima approach to zero for large negative values of $Re(s)$ (see `http://tinyurl.com/clxv4pz`) whereas $\zeta(s)$ approaches value one for large positive values of s (see `http://tinyurl.com/y7b88gvg`). A cautious guess is that the sign of $\zeta(s)$ for $s \leq 1$ remains negative. If the integral defining the area is defined as integral contour directed from $s < 0$ to a point s_0 near origin, S_c has positive sign and has a geometric interpretation.

3. The formula for $1/\alpha_K$ would read as $\alpha_{K,0}/\alpha_K(s = -2n) = (S_c/S_0)^{1/2}$ so that α_K would remain real. This integration path could be interpreted as a rotation around z-axis leaving invariant the Kähler form J of $S^2(X^4)$ and therefore also $S = Re(S_c)$. $Im(S_c) = 0$ indeed holds true. For the non-trivial zeros this is not the case and $S = Re(S_c)$ is not invariant.

4. One can wonder whether one could distinguish between Minkowskian and Euclidian and regions in the sense that in Minkowskian regions $1/\alpha_K$ correspond to the non-trivial zeros and in Euclidian regions to trivial zeros along negative real axis. The interpretation as different kind of phases might be appropriate.

What is nice that the hypothesis about equivalence of the geometry based and number theoretic approaches can be killed by just calculating the integral S as function of parameter s. The identification of the parameter s appearing in the RG equations is no unique. The identification of the Riemann sphere and twistor sphere could even allow identify the parameter t as imaginary coordinate in complex coordinates in $SO(3)$ rotations around z-axis act as phase multiplication and in which metric has the standard form.

Some guesses to be shown to be wrong

The following argument suggests a connection between p-adic length scale hypothesis and evolution of cosmological constant but must be taken as an ad hoc guess: the above formula is enough to predict the evolution.

1. p-Adicization is possible only under very special conditions [L40], and suggests that anomalous dimension involving logarithms should vanish for $s = 2^{-k/2}$ corresponding to preferred p-adic length scales associated with $p \simeq 2^k$. Quantum criticality in turn requires that discrete p-adic coupling constant evolution allows the values of coupling parameters, which are fixed points of RG group so that radiative corrections should vanish for them. Also anomalous dimensions Δk should vanish.

2. Could one have $\Delta k_{n,a} = 0$ for $s = 2^{-k/2}$, perhaps for even values $k = 2k_1$? If so, the ratio c/s would satisfy $c/s = 2^{k_1} - 1$ at these points and Mersenne primes as values of c/s would be obtained as a special case. Could the preferred p-adic primes correspond to a prime near to but not larger than $c/s = 2^{k_1} - 1$ as p-adic length scale hypothesis states? This suggest that we are on correct track but the hypothesis could be too strong.

3. The condition $\Delta d = 0$ should correspond to the vanishing of dS/ds. Geometrically this would mean that $S(s)$ curve is above (below) $S(s) = xs^2$ and touches it at points $s = x2^{-k}$, which would be minima (maxima). Intermediate extrema above or below $S = xs^2$ would be maxima (minima).

6.3.4 An alternative view about the coupling constant evolution in terms of cosmological constant

The above view about the evolution of cosmological constant relies crucially on the identification of $M^4 \times S^2$ as twistor space of M^4, and the assumption that the radii of twistor spheres $S^2(M^4$ and $S^2(CP_2)$ assignable to the twistor bundle of CP_2 are same.

One can however argue that the standard twistor space CP_3 of M^4 with Minkowskian signature (3,-3) is a more feasible candidate for the twistor space of M^4. Accepting this, one ends up to a modification of the above vision about coupling constant evolution [L87, L89]. The progress in understanding SUSY in TGD framework led also to a dramatic progress in the understanding of the coupling constant evolution [L85].

Getting critical about geometric twistor space of M^4

Let us first discuss the recent picture and how to modify it so that it is consistent with the hierarchy of CDs. The key idea is that the twistor space and its base space represents CD so that one obtains scale hierarchy of twistor spaces as a realization of broken scale invariance giving rise to the p-adic length scale hierarchy.

1. I have identified the twistor space of M^4 simply as $T(M^4) = M^4 \times S^2$. The interpretation would be at the level of octonions as a product of M^4 and choices of M^2 as preferred complex sub-space of octonions with S^2 parameterizing the directions of spin quantization axes. Real octonion axis would correspond to time coordinate. One could talk about the space of of

light-like directions. Light-like vector indeed defines M^2. This view could be defended by the breaking of both translation and Lorentz invariance in the octonionic approach due to the choice of M^2 and by the fact that it seems to work.

Remark: $M^8 = M^4 \times E^4$ is complexified to M^8_c by adding a commuting imaginary unit i appearing in the extensions of rationals and ordinary M^8 represents its particular sub-space. Also in twistor approach one uses often complexified M^4.

2. The objection is that it is ordinary twistor space identifiable as CP_3 with (3,-3) signature of metric is what works in the construction of twistorial amplitudes. CP_3 has metric as compact space and coset space. Could this choice of twistor space make sense after all as geometric twistor space?

   Here one must pause and recall that the original key idea was that Poincare invariance is symmetry of TGD for $X^4 \subset M^4 \times CP_2$. Now Poincare symmetry has been transformed to a symmetry acting at the level of M^8 in the moduli space of octonion structures defined by the choice of the direction of octonionic real axis reducing Poincare group to $T \times SO(3)$ consisting of time translations and rotations. Fixing of M^2 reducrs the group to $T \times SO(2)$ and twistor space can be seen as the space for selections of quantization axis of energy and spin.

3. But what about the space H? The first guess is $H = M^4_{conf} \times CP_2$. According to [B10] (see `http://tinyurl.com/y35k5wwo`) one has $M^4_{conf} = U(2)$ such that $U(1)$ factor is time- like and $SU(2)$ factor is space-like. One could understand $M^4_{conf} = U(2)$ as resulting by addition and identification of metrically 2-D light-cone boundaries at $t = \pm\infty$. This is topologically like compactifying E^3 to S^3 and gluing the ends of cylinder $S^3 \times D^1$ together to the $S^3 \times S^1$.

   The conformally compactified Minkowski space M^4_{conf} should be analogous to base space of CP_3 regarded as bundle with fiber S^2. The problem is that one cannot imagine an analog of fiber bundle structure in CP_3 having $U(2)$ as base. The identification $H = M^4_{conf} \times CP_2$ does not make sense.

4. In ZEO based breaking of scaling symmetry it is CD that should be mapped to the analog of M^4_{conf} - call it cd_{conf}. The only candidate is $cd_{conf} = CP_2$ with one hypercomplex coordinate. To understand why one can start from the following picture. The light-like boundaries of CD are metrically equivalent to spheres. The light-like boundaries at $t = \pm\infty$ are identified as in the case of M^4_{conf}. In the case of CP_2 one has 3 homologically trivial spheres defining coordinate patches. This suggests that cd_{conf} is simply CP_2 with second complex coordinate made hypercomplex. M^4 and E^4 differ only by the signature and so would do cd_{conf} and CP_2.

   The twistor spheres of CP_3 associated with points of M^4 intersect at point if the points differ by light-like vector so that one has and singular bundle structure. This structure should have analog for the compactification of CD. CP_3 has also bundle structure $CP_3 \rightarrow CP_2$. The S^2 fibers and base are homologically non-trivial and complex analogs of mutually orthogonal line and plane and intersect at single point. This defines the desired singular bundle structure via the assignment of S^2 to each point of CP_2.

   The M^4 points must belong to the interior of cd and this poses constraints on the distance of M^4 points from the tips of cd. One expects similar hierarchy of cds at the level of momentum space.

5. In this picture $M^4_{conf} = U(2)$ could be interpreted as a base space for the space of CDs with fixed direction of time axis identified as direction of octonionic real axis associated with various points of M^4 and therefore of M^4_{conf}. For Euclidian signature one would have base and fiber of the automorphism sub-group $SU(3)$ regarded as $U(2)$ bundle over CP_2: now one would have CP_2 bundle over $U(2)$. This is perhaps not an accident, and one can ask whether these spaces could be interpreted as representing local trivialization of $SU(3)$ as $U(2) \times CP_2$. This would give to metric cross terms between $U(2)$ and CP_2.

6. The proposed identification can be tested by looking whether it generalizes. What the twistor space for entire M^8 would be? $cd = CD_4$ is replaced with CD_8 and the discussion of the

preceding chapter demonstrated that the only possible identification of the twistor space is now is as the 12-D hyperbolic variant of HP_3 whereas $CD_{8,conf}$ would correspond to 8-D hyperbolic variant of HP_2 analogous to hyperbolic variant of CP_2.

The outcome of these considerations is surprising.

1. One would have $T(H) = CP_3 \times F$ and $H = CP_{2,H} \times CP_2$ where $CP_{2,H}$ has hyperbolic metric with metric signature $(1, -3)$ having M^4 as tangent space so that the earlier picture can be understood as an approximation. This would reduce the construction of preferred extremals of 6-D Kähler action in $T(H)$ to a construction of polynomial holomorphic surfaces and also the minimal surfaces with singularities at string world sheets should result as bundle projection. Since $M^8 - H$ duality must respect algebraic dynamics the maximal degree of the polynomials involved must be same as the degree of the octonionic polynomial in M^8.

2. The hyperbolic variant Kähler form and also spinor connection of hyperbolic CP_2 brings in new physics beyond standard model. This Kähler form would serve as the analog of Kähler form assigned to M^4 earlier, and suggested to explain the observed CP breaking effects and matter antimatter asymmetry for which there are two explanations [L85].

Some comments about the Minkowskian signature of the hyperbolic counterparts of CP_3 and CP_2 are in order.

1. Why the metric of CP_3 could not be Euclidian just as the metric of F? The basic objection is that propagation of fields is not possible in Euclidian signature and one completely loses the earlier picture provided by $M^4 \times CP_2$. The algebraic dynamics in M^8 picture can hardly replace it.

2. The map assigning to the point M^4 a point of CP_3 involves Minkowskian sigma matrices but it seems that the Minkowskian metric of CP_3 is not explicitly involved in the construction of scattering amplitudes. Note however that the antisymmetric bi-spinor metric for the spin 1/2 representation of Lorentz group and its conjugate bring in the signature. $U(2,2)$ as representation of conformal symmetries suggests $(2,2)$ signature for 8-D complex twistor space with 2+2 complex coordinates representing twistors.

   The signature of CP_3 metric is not explicitly visible in the construction of twistor amplitudes but analytic continuations are carried out routinely. One has also complexified M^4 and M^8 and one could argue that the problems disappear. In the geometric situation the signatures of the subspaces differ dramatically. As already found, analytic continuation could allow to define the variants of twistor spaces elegantly by replacing a complex coordinate with a hyperbolic one.

   Remark: For E^4 CP_3 is Euclidian and if one has $E^4_{conf} = U(2)$, one could think of replacing the Cartesian product of twistor spaces with $SU(3)$ group having $M^4_{conf} = U(2)$ as fiber and CP_2 as base. The metric of $SU(3)$ appearing as subgroup of quaternionic automorphisms leaving $M^4 \subset M^8$ invariant would decompose to a sum of M^4_{conf} metric and CP_2 metric plus cross terms representing correlations between the metrics of M^4_{conf} and CP_2. This is probably mere accident.

How the vision about coupling constant evolution would be modified?

The above described vision about coupling constant evolution in case of $T(M^4) = M^4 \times S^2$ would be modified since the interference of the Kähler form made possible by the same signature of $S^2(M^4)$ and $S^2(CP_2)$. Now the signatures are opposite and Kähler forms differ by factor i (imaginary unit commuting with octonion units) so that the induced Kähler forms do not interfere anymore. The evolution of cosmological constant must come from the evolution of the ratio of the radii of twistor spaces (twistor spheres).

1. $M^8 - H$ duality has two alternative forms with $H = CP_{2,h} \times CP_2$ or $H = M^4 \times CP_2$ depending on whether one projects the twistor spheres of $CP_{3,h}$ to $CP_{2,h}$ or M^4. Let us denote the twistor space $SU(3)/U(1) \times U(1)$ of CP_2 by F.

2. The key idea is that the p-adic length scale hierarchy for the size of 8-D CDs and their 4-D counterparts is mapped to a corresponding hierarchy for the sizes of twistor spaces $CP_{3,h}$ assignable to M^4 by M^8-H-duality. By scaling invariance broken only by discrete size scales of CDs one can take the size scale of CP_2 as a unit so that $r = R^2(S^2(CP_{3,h})/R(S^2(F))$ becomes an evolution parameter.

   Coupling constant evolution must correspond to a variation for the ratio of $r = R^2(S^2(CP_{3,h})/R(S^2(F))$ and a reduction to p-adic length scale evolution is expected. A simple argument shows that Λ is inversely proportional to constant magnetic energy assignable to $S^2(X^4)$ divided by $1/\sqrt{g_2(S^2)}$ in dimensional reduction needed to induce twistor structure. Thus one has $\Lambda \propto 1/r^2 \propto 1/L_p^2$. Preferred p-adic primes would be identified as ramified primes of extension of rationals defining the adele so that coupling constant evolution would reduce to number theory.

3. The induced metric would vanish for $R(S^2(CP_{3,h}) = R(S^2(F))$. Λ would be infinite at this limit so that one must have $R(S^2(CP_{3,h}) \neq R(S^2(F))$. The most natural assumption is that one $R(S^2(CP_{3,h}) > R(S^2(F))$ but one cannot exclude the alternative option. Λ behaves like $1/L_p^2$. Inversions of CDs with respect to the values of the cosmological time parameter $a = L_p$ would produce hierarchies of length scales, in particular p-adic length scales coming as powers of $\sqrt{p}$. CP_2 scale and the scale assignable to cosmological constant could be seen as inversions of each other with respect to a scale which is of order 10^{-4} meters defined by the density of dark energy in the recent Universe and thus biological length scale.

4. The above model for the length scale evolution of coupling parameters would reduce to that along paths at $S^2(CP_2)$ and would depend on the ends points of the path only, and also now the zeros of Riemann zeta could naturally correspond to the quantum critical points.

TGD vision about SUSY and coupling constant evolution

TGD view about SUSY leads to radical modification and re-interpretation of SUSY [L87, L85], and to a dramatic progress in the understanding of coupling constant evolution.

Quarks would be the only fundamental fermion fields, and leptons would be spartners of quarks identified as local composites of 3 quarks. Embedding space coordinates would have an expansion in terms of local super-monomials of quarks and antiquarks with vanishing baryon number and appearing as sums of monomial and its conjugate to guarantee hermiticity. Super-spinors would have similar expansion involving only odd quark numbers. This picture is forced by the requirement that propagators are consistent with the statistics of the spartner. Theta parameters would be replaced by creation and annihilation operators for quarks so that super-symmetrization would mean also second quantization. Number theoretic vision requires that only a finite number of Wick contractions of oscillator operators can vanish. These conditions have interpretation as conservation for the Noether currents of some symmetries.

This picture leads to a concrete view about S-matrix for the preferred extremals of a SUSY-variant of the basic action principle relying on the notion of super-variant of embedding space and super-variant of the modified Dirac action. Coupling constant evolution discretizes and would reduce to an increase of the finite number of non-vanishing Wick contractions interpreted as radiative corrections as the dimension of the extension of rationals defining the adele increases. This evolution reflects directly the corresponding evolution at the level of M^8 in terms of octonionic polynomials determining the extension of rationals involved. Whether this view is consistent with the above general vision remains to be seen.

6.3.5 Generalized conformal symmetry, quantum criticality, catastrophe theory, and analogies with thermodynamics and gauge theories

The notion of quantum criticality allows two realizations: as stationarity of S^2 part of the twistor lift of Kähler action and in terms of zeros of zeta are key elements in the explicit proposal for discrete coupling constant evolution reducing to that for cosmological constant.

Quantum criticality from different perspectives

Quantum criticality is however much more general notion, and one must ask how this view relates to the earlier picture.

1. At the real number side continuous coupling constant evolution makes sense. What does this mean? Can one say that quantum criticality makes possible only adelic physics together with large $h_{eff}/h_0 = n$ as dimension for extension of rationals. This hierarchy is essential for life and cognition.

   Can one conclude that living systems correspond to quantum critical values of $S(S^2)$ and therefore α_K and in-animate systems correspond to other values of α_K? But wouldn't his mean that one gives up the original vision that α_K is analogous to critical temperature. The whole point was that this would make physics unique?

   From mathematical view point also continuous α_K can make sense. α_K can be continuous if it corresponds to a higher-dimensional critical manifold at which two or more preferred extremals associated with the same parameter values co-incide - roots of polynomial $P(x,a,b)$ depending on parameters a,b serves as the canonical example. The degree of quantum criticality would vary and there would be a hierarchy of critical systems characterized by the dimension of the critical manifold. One would have a full analog of statistical physics. For mathematician this is the only convincing interpretation.

   2-D cusp catastrophe serves as a basic example helping to generalize [**?**]. Cusp corresponds to the roots of $dP_4/dx = 0$ of third order polynomial $P_4(x,a,b)$, where (a,b) are control variables. The projection of region with 3 real roots to (a,b)-plane is bounded by critical lines forming a roughly V-shaped structure. d^2P_4/dx^2 vanishes at the edges of V, where two roots co-incide and d^3P_4/dx^3 vanishes at the tip of V, where 3 roots co-incide.

2. A hierarchy of quantum criticalities has been actually assumed. The hierarchy of representations for super-symplectic algebra realizing 4-D analog of super-conformal symmetries allows an infinite hierarchy of representations for which infinite-D sub-algebra isomorphic to a full algebra and its commutator with the full algebra annihilate physical states. Also classical Noether charges vanish. What is new is that conformal weights are non-negative integers. The effective dimensions of these systems are finite - at least in the sense that one one has finite-D Lie algebra (or its quantum counterpart) or corresponding Kac-Moody algebra as symmetries. This realization of quantum criticality generalize the idea that conformal symmetry accompanies 2-D criticality.

   This picture conforms also with the vision about hierarchy of hyper-finite-factors with included hyper-finite factor defining measurement resolution [K115]. Hyper-finiteness indeed means finite-dimensionality in excellent approximation.

TGD as catastrophe theory and quantum criticality as prerequisite for the Euclidian signature of WCW metric

It is good to look more precisely how the catastrophe theoretic setting generalizes to TGD.

1. The value of the twistor lift of Kähler action defining Kähler function very probably corresponds to a maximum of Kähler function since otherwise metric defined by the second derivatives could have non-Euclidian signature. One cannot however exclude the possibility that in complex WCW coordinates the (1,1) restriction of the matrix defined by the second derivatives of Kähler function could be positive definite also for other than minima.

   It would seem that one cannot accept several roots for given zero modes since one cannot have maximum of Kähler function for all of them. This would allow only the boundary of catastrophe region in which 2 or more roots co-incide. Positive definiteness of WCW metric would force quantum criticality.

   For given values of zero modes there would be single minimum and together with the cancellation of Gaussian and metric determinants this makes perturbation theory extremely simple since exponents of vacuum functional would cancel.

2. There is an infinite number of zero modes playing the role of control variables since the value of the induce Kähler form is symplectic invariant and there are also other symplectic invariants associated with the M^4 degrees of freedom (carrying also the analog of Kähler form for the twistor lift of TGD and giving rise to CP breaking). One would have catastrophe theory with infinite number of control variables so that the number of catastrophes would be infinite so that standard catastrophe theory does not as such apply.

3. Therefore TGD would not be only a personal professional catastrophe but a catastrophe in much deeper sense. WCW would be a catastrophe surface for the functional gradient of the action defining Kähler function. WCW would consists of regions in which given zero modes would correspond to several minima. The region of zero mode space at which some roots identifiable as space-time surfaces co-incide would be analogous to the V-shaped cusp catastrophe and its higher-D generalizations. The question is whether one allows the entire catastrophe surface or whether one demands quantum criticality in the sense that only the union of singular sets at which roots co-incide is included.

4. For WCW as catastrophe surface the analog of V in the space of zero modes would correspond to a hierarchy of sub-WCWs consisting of preferred extremals satisfying the gauge conditions associated with a sub-algebra of supersymplectic algebra isomorphic to the full algebra. The sub-WCWs in the hierarchy of sub-WCWs within sub-WCWs would satisfy increasingly stronger gauge conditions and having decreasing dimension just like in the case of ordinary catastrophe. The lower the effective dimension, the higher the quantum criticality.

5. In ordinary catastrophe theory the effective number of behavior variables for given catastrophe can be reduced to some minimum number. In TGD framework this would correspond to the reduction of super-symplectic algebra to a finite-D Lie algebra or corresponding Kac-Moody (half-)algebra as modes of supersymplectic algebra with generators labelled by non-negative integer n modulo given integer m are eliminated as dynamical degrees of freedom by the gauge conditions: this would effectively leave only the modes smaller than m. The fractal hierarchy of these supersymplectic algebras would correspond to the decomposition of WCW as a catastrophe surface to pieces with varying dimension. The reduction of the effective dimension as two sheets of the catastrophe surface co-incide would mean transformation of some modes contributing to metric to zero modes.

RG invariance implies physical analogy with thermodynamics and gauge theories

One can consider coupling constant evolution and RG invariance from a new perspective based on the minimal surface property.

1. The critical values of Kähler coupling strength would correspond to quantum criticality of the S^2 part $S(S^2)$ of 6-D dimensionally reduced Kähler action for fixed values of zero modes. The relative S^2 rotation would serve as behavior variable. For its critical values the dimension of the critical manifold would be reduced, and keeping zero modes fixed a critical value of α_K would be selected from 1-D continuum.

   Quantum criticality condition might be fundamental since it implies the constancy of the value of the twistor lift of Kähler action for the space-time surfaces contributing to the scattering amplitudes. This would be crucial for number theoretical vision since the continuation of exponential to p-adic sectors is not possible in the generic case. One should however develop stronger arguments to exclude the continuous evolution of Kähler coupling strength in S^2 degrees of freedom for the real sector of the theory.

2. The extremals of twistor lift contain dependence on the rotation parameter for S^2 and this must be taken into account in coupling constant evolution along curve of S^2 connecting zeros of zeta. This gives additional non-local term to the evolution equations coming from the dependence of the embedding space coordinates of the preferred extremal on the evolution parameter. The derivative of Kähler action with respect to the evolution parameter is by chain rule proportional to the functional derivatives of action with respect to embedding space coordinates, and vanish if 4-D Kähler action and volume term are *separately* stationary

with respect to variations. Therefore minimal surface property as implied by holomorphy guaranteeing quantum criticality as universality of the dynamics would be crucial in simplifying the equations! It does not matter whether there is coupling between Kähler action and volume term.

Could one find interpretation for the miminal surface property which implies that field equations are separately satisfied for Kähler action and volume term?

1. Quantum TGD can be seen as a "complex" square root of thermodynamics. In thermodynamics one can define several thermodynamical functions. In particular, one can add to energy E as term pV to get enthalpy $H = E + pV$, which remains constant when entropy and pressures are kept constant. Could one do the same now?

   In TGD V replaced with volume action and p would be a coupling parameter analogous to pressure. The simplest replacement would give Kähler action as outcome. The replacement would allow RG invariance of the modified action only at critical points so that replacement would be possible only there. Furthermore, field equations must hold true separately for Kähler action and volume term everywhere.

2. It seems however that one must allow singular sets in which there is interaction between these terms. The coupling between Kähler action and volume term could be non-trivial at singular sub-manifolds, where a transfer of conserved quantities between the two degrees of freedom would take place. The transfer would be proportional to the divergence of the canonical momentum current $D_\alpha(g^{\alpha\beta}\partial_\beta h^k)$ assignable to the minimal surface and is conserved outside the singular sub-manifolds.

   Minimal surfaces provide a non-linear generalization of massless wave-equation for which the gradient of the field equals to conserved current. Therefore the interpretation could be that these singular manifolds are sources of the analogs of fields defined by M^4 and CP_2 coordinates.

   In electrodynamics these singular manifolds would represented by charged particles. The simplest interpretation would be in terms of point like charges so that one would have line singularity. The natural identification of world line singularities would be as boundaries of string world sheets at the 3-D light-like partonic orbits between Minkowskian and Euclidian regions having induced 4-metric degenerating to 3-D metric would be a natural identification. These world lines indeed appear in twistor diagrams. Also string world sheets must be assumed and they are are natural candidates for the singular manifolds serving as sources of charges in 4-D context. Induced spinor fields would serve as a representation for these sources. These strings would generalize the notion of point like particle. Particles as 3-surfaces would be connected by flux tubes to a tensor network and string world sheets would connected fermion lines at the partonic 2-surfaces to an analogous network. This would be new from the standard model perspective.

   Singularities could also correspond to a discrete set of points having an interpretation as cognitive representation for the loci of initial and final states fermions at opposite boundaries of CD and at vertices represented topologically by partonic 2-surfaces at which partonic orbits meet. This interpretation makes sense if one interprets the embedding space coordinates as analogs of propagators having delta singularities at these points. It is quite possible that also these contributions are present: one would have a hierarchy of delta function singularities associated with string worlds sheets, their boundaries and the ends of the boundaries at boundaries of CD, where string world sheet has edges.

3. There is also an interpretation of singularities suggested by the generalization of conformal invariance. String world sheets would be co-dimension 2 singularites analogous to poles of analytic function of two complex coordinates in 4-D complex space. String world sheets would be co-dimension 2 singularities analogous to poles at light-like 3-surfaces. The ends of the world lines could be analogous of poles of analytic function at partonic 2-surfaces.

   These singularities could provide to evolution equations what might be called matter contribution. This brings in mind evolution equations for n-point functions in QFT. The resolution of the overall singularity would decompose to 2-D, 1-D and 0-D parts just like cusp catastrophe. One can ask whether the singularities might allow interpretation as catastrophes.

4. The proposal for analogs of thermodynamical functions suggests the following physical picture. More general thermodynamical functions are possible only at critical points and only if the extremals are miminal surfaces. The singularities should correspond to physical particles, fermions. Suppose that one considers entire scattering amplitude involving action exponential plus possible analog of pV term plus the terms associated with the fermions assigned with the singularities. Suppose that the coupling constant evolution from 6-D Kähler action is calculated *without* including the contribution of the singularities.

   The derivative of n-particle amplitude with respect to the evolution parameter contains a term coming from the action exponential receiving contributions only from the singularities and a term coming from the operators at singularities. RG invariance of the scattering amplitude would require that the two terms sum up to zero. In the thermodynamical picture the presence of particles in many particle scattering amplitude would force to add the analog of pressure term to the Kähler function: it would be determined by the zero energy state.

   One can of course ask how general terms can be added by requiring minimal surface property. Minimal surface property reduces to holomorphy, and can be true also for other kinds of actions such as the TGD analogs of electroweak and color actions that I considered originally as possible action candidates.

   This would have interpretation as an analog for YM equations in gauge theories. Space-time singularities as local failure of minimal surface property would correspond to sources for H coordinates as analogs of Maxwell's fields and sources currents would correspond to fermions currents.

6.3.6 TGD view about inclusions of HFFs as a way to understand coupling constant evolution

The hierarchy of inclusions of HFFs is an alternative TGD inspired proposal for understanding coupling constant evolution and the intuitive expectation is that the inclusion hierarchies of extensions and their Galois groups contain the inclusion hierarchies of HFFs as special case. The included factor would define measurement resolution in well-defined sense. This notion can be formulated more precisely using Connes tensor product [**?**, **?**].

How Galois groups and finite subgroups of could $SU(2)$ relate

The hierarchy of finite groups associated with the inclusions of HFF corresponds to the finite subgroups of $SU(2)$. The set of these groups is very small as compared to the set of Galois groups - if I have understood correctly, any finite group can appear as Galois group. Should the hierarchy of inclusions of HFFs be replaced by much more general inclusion hierarchy? Is there a map projecting Galois groups to discrete subgroup of $SU(2)$?

By M^8-H duality quaternions appear at M^8 level and since $SO(3)$ is the automorphism group of quaternions, the discrete subgroups of $SU(2)$ could appear naturally in TGD. In fact, the appearance of quaternions as a basic building brick of HFFs in the simplest construction would fit with this picture.

It would seem that the elements of the discrete subgroups of $SU(2)$ must be in the extension of rationals considered. The elements of finite discrete subgroups G of $SU(2)$ are expressible in terms of rather small subset of extensions of rationals. Could the proper interpretation be that the hierarchy of extensions defines a hierarchy of discrete groups with elements in extension and the finite discrete subgroups in question are finite discrete subgroups of these groups. There would be correlation with the inclusion and extension. For instance, the fractal dimension of extension is an algebraic number defined in terms of root of unity so that the extension must contain this root of unity.

For icosahedron and dodecahedron the group action can be expressed using extension of rationals by $cos(\pi/n)$ and $sin(\pi/n)$ for $n=3,5$. For tetrahedron and cube one would have $n=2,3$. For tetrahedon, cube/octahedron and icosahedron basic geometric parameters are also expressible in terms of algebraic numbers in extension but in case of dodecahedron it is not clear for me whether the surface area proportional to $\sqrt{25+20\sqrt{5}}$ allows this (see http://tinyurl.com/p4rwc7).

It is very feasible that the finite sub-groups of also other Lie groups than $SU(2)$ are associated with the inclusions of HFFs or possibly more general algebras. In particular, finite discrete subgroups of color group $SU(3)$ should be important and extension of rationals should allow to represent these subgroups.

Once again about ADE correspondence

For a non-mathematician like me Mc-Kay correspondence is an inspiring and frustrating mystery (see http://tinyurl.com/y8jzvogn). What could be its physical interpretation?

Mac-Kay correspondence assigns to the extended Dynkin diagrams of ADE type characterizing Kac-Moody algebras finite subgroups of $SU(2)$, more precisely the McKay diagrams describing the tensor product decomposition rules for the fundamental representation of the finite subgroup of $SU(2)$. In the diagram irreps χ_i and χ_j are connected by n_{ij} arrows if χ_j appears n_{ij} times in the tensor product $V \otimes \chi_i$, where V is but need not be fundamental representation.

One can assign also to inclusions of HFFs of index $d \geq 4$ with ADE type Dynkin diagrams. To inclusions with index $d < 4$ one can assign subset of ADE type diagrams for Lie groups (rather than Kac-Moody groups) and they correspond to sub-groups of $SU(2)$. The correspondence generalizes to subgroups of other Lie groups.

1. As explained in [B35] , for $\mathcal{M} : \mathcal{N} < 4$ one can assign to the inclusion Dynkin graph of ADE type Lie-algebra g with h equal to the Coxeter number h of the Lie algebra given in terms of its dimension and dimension r of Cartan algebra r as $h = (dim(g) - r)/r$. For $\mathcal{M} : \mathcal{N} < 4$ ordinary Dynkin graphs of D_{2n} and E_6, E_8 are allowed. The Dynkin graphs of Lie algebras of $SU(n)$, E_7 and D_{2n+1} are however not allowed. E_6, E_7, and E_8 correspond to symmetry groups of tetrahedron, octahedron/cube, and icosahedron/dodecahedron. The group for octahedron/cube is missing: what could this mean?

   For $\mathcal{M} : \mathcal{N} = 4$ one can assign to the inclusion an extended Dynkin graph of type ADE characterizing Kac Moody algebra. Extended ADE diagrams characterize also the subgroups of $SU(2)$ and the interpretation proposed in [**?**] is following.

   The ADE diagrams are associated with the $n = \infty$ case having $\mathcal{M} : \mathcal{N} \geq 4$. There are diagrams corresponding to infinite subgroups: A_∞ corresponding to $SU(2)$ itself, $A_{-\infty,\infty}$ corresponding to circle group $U(1)$, and infinite dihedral groups (generated by a rotation by a non-rational angle and reflection.

   One can construct also inclusions for which the diagrams corresponding to finite subgroups $G \subset SU(2)$ are extension of A_n for cyclic groups, of D_n dihedral groups, and of E_n with $n = 6, 7, 8$ for tetrahedron, cube, dodecahedron. These extensions correspond to ADE type Kac-Moody algebras.

   The extension is constructed by constructing first factor R as infinite tensor power of $M_2(C)$ (complexified quaternions). Sub-factor R_0 consists elements of of R of form $Id \otimes x$. $SU(2)$ preserves R_0 and for any subgroup G of $SU(2)$ one can identify the inclusion $N \subset M$ in terms of $N = R_0^G$ and $M = R^G$, where $N = R_0^G$ and $M = R^G$ consists of fixed points of R_0 and R under the action of G. The principal graph for $N \subset M$ is the extended Coxeter-Dynk graph for the subgroup G.

   Physicist might try to interpret this by saying that one considers only sub-algebras R_0^G and R^G of observables invariant under G and obtains extended Dynkin diagram of G defining an ADE type Kac-Moody algebra. Could the condition that Kac-Moody algebra elements with non-vanishing conformal weight annihilate the physical states state that the state is invariant under R_0 defining measurement resolution. Besides this the states are also invariant under finite group G? Could R_0^G and R^G correspond just to states which are also invariant under finite group G.

   Could this kind of inclusions generalize so that Galois groups would replace G. If this is possible it would assign to each Galois group an inclusion of HFFs and give a precise number theoretic formulation for the notion of measurement accuracy.

2. At M^8-side of $M^8 - H$ duality the construction of space-time surfaces reduces to data at finite set of points of space-time surface since they are defined by an octonionic extension of a polynomial of real variable with coefficients in extension of rationals. Space-time surfaces would have quaternionic tangent space or normal space. The coordinates of quaternions are restricted to extension of rationals and the subgroup of automorphisms reduce to a subgroup for which matrix elements belong to an extension of rationals.

   If the subgroup is finite, only the subgroups appearing in ADE correspondence are possible and the extension must be such that it allows the representation of this group. Does this mean that the extension can is obtained from an extension allowing this representation? For $\mathcal{M} : \mathcal{N} = 4$ case this sub-group would leave the states invariant.

6.3.7 Entanglement and adelic physics

In the discussion about fine structure constant I asked about the role entanglement in coupling constant evolution. Although entanglement does not have direct relationship to coupling constant evolution, I will discuss entanglement from number theoretic point of view since it enlightens the motivations of adelic physics.

1. For given extension of rationals determining the values of coupling parameters by quantum criticality, the entanglement coefficients between positive and negative energy parts of zero energy states are in the extension of rationals. All entanglement coefficients satisfy this condition.

2. Self the counterpart of observer in the generalization of quantum measurement theory - as conscious entity [L44] corresponds to sequence of unitary evolutions followed by weak measurements. The rule for weak measurements is that only state function for which the eigenvalues of the density matrix is in the extension of rationals can occur. In general they are in a higher-D extension as roots of N:th order polynomials, N the dimension of density matrix. Therefore state function reduction cannot occur in the generic case. State cannot decohere and entanglement is stable under weak measurements except in special situations when the eigenvalues of density matrix are in original extension.

3. The extension can change only in big state function reductions in which the arrow of clock time changes: this can be seen as an evolutionary step. From the point of view of consciousness theory big state function reduction means what might be called death and reincarnation of system in opposite time direction.

4. The number theoretical stabilization of entanglement at the passive boundary of CD makes possibility quantum computation in longer time scales than possible in standard quantum theory. $h_{eff}/h_0 = n$ equals to the dimension of extension of rationals and is therefore directly related to this.

   This could have profound technological implications.

1. Ordinary quantum computation as single unitary step is replaced by a sequence of them followed by the analog of weak measurement.

2. ZEO allows also quantum computations in opposite time direction. This might allow shorten dramatically the duration of quantum computations from the perspective of the observed since most of the computation could be done with opposite arrow of clock time.

   The philosophy of adelic physics is discussed in article in book published by Springer [L42, L41] (see `http://tinyurl.com/ybzkfevz` and `http://tinyurl.com/ybqpkwg9`).

6.4 Trying to understand why ramified primes are so special physically

Ramified primes (see `http://tinyurl.com/m32nvcz` and `http://tinyurl.com/y6yskkas`) are special in the sense that their expression as a product of primes of extension contains higher than first powers and the number of primes of extension is smaller than the maximal number n defined by the dimension of the extension. The proposed interpretation of ramified primes is as p-adic primes characterizing space-time sheets assignable to elementary particles and even more general systems.

In the following Dedekind zeta functions (see http://tinyurl.com/y5grktvp) as generalization of Riemann zeta [L62, L72] are studied to understand what makes them so special. Dedekind zeta function characterizes given extension of rationals and is defined by reducing the contribution from ramified reduced so that effectively powers of primes of extension are replaced with first powers.

If one uses the naïve definition of zeta as analog of partition function and includes full powers $P_i^{e_i}$, the zeta function becomes a product of Dedekind zeta and a term consisting of a finite number of factors having poles at imaginary axis. This happens for zeta function and its fermionic analog having zeros along imaginary axis. The poles would naturally relate to Ramond and N-S boundary conditions of radial partial waves at light-like boundary of causal diamond CD. The additional factor could code for the physics associated with the ramified primes.

The intuitive feeling is that quantum criticality is what makes ramified primes so special. In $O(p) = 0$ approximation the irreducible polynomial defining the extension of rationals indeed reduces to a polynomial in finite field F_p and has multiple roots for ramified prime, and one can deduce a concrete geometric interpretation for ramification as quantum criticality using $M^8 - H$ duality.

$M^8 - H$ duality central concept in following and discussed in [L34, L78, L75, L76] [L87]. Also the notion of cognitive representation as a set of points of space-time surface with preferred embedding space coordinates belonging to the extension of rationals defining the adele [L41] is important and discussed in [L81, L80, L86].

6.4.1 Dedekind zeta function and ramified primes

One can take mathematics and physical intuition guided by each other as a guideline in the attempts to understand ramified primes.

1. Riemann zeta can be generalized to Dedekind zeta function ζ_K for any extension K of rationals (see http://tinyurl.com/y5grktvp). ζ_K characterizes the extension - maybe also physically in TGD framework since zeta functions have formal interpretation as partition function. In the recent case the complexity is not a problem since complex square roots of partition functions would define the vacuum part of quantum state: one can say that quantum TGD is complex square root of thermodynamics.

   ζ_K satisfies the same formula as ordinary zeta expect that one considers algebraic integers in the extensions K and sums over non-zero ideals a - identifiable as integers in the case of rationals - with n^{-s} replaced with $N(a)^{-s}$, where $N(a)$ denotes the norm of the non-zero ideal. The construction of ζ_K in the extension of rationals obtained by adding i serves as an illustrative example (see http://tinyurl.com/y563wcwv). I am not a number theorists but the construction suggests a poor man's generalization strongly based on physical intuition.

2. The rules would be analogous to those used in the construction of partition function. $log(N(a))$ is analogous to energy and s is analogous to inverse temperature so that one has Boltzmann weight $exp(-log(N(a)s)$ for each ideal. Since the formation of ideals defined by integers of extension is analogous to that for forming many particle states labelled by ordinary primes and decomposing to primes of extension, the partition function decomposes to a product over partition functions assignable to ordinary primes just like in the case of Riemann zeta. Let K be an extension of rationals Q.

3. Each rational prime p decomposes in the extension as $p = \prod_{i=1,...g} P_i^{e_i}$, where n is the dimension of extension and e_i is the ramification degree. Let f_i be so called residue degree of P_i defined as the dimension of K mod P_i interpreted as extension of rational integers $Z\ mod\ p$. Then one has $\sum_1^g e_i f_i = n$.

   Remark: For Galois extensions for which the order of Galois group equals to the dimension n of the extension so that for given prime p one has $e_i = e$ and $f_i = f$ and $efg = n$.

4. Rational (and also more general) primes can be divided into 3 classes with respect to this decomposition.

   For ramified primes dividing the discriminant D associated with the polynomial ($D = b^2-4c$ for $P(x) = x^2 + bx + c$) one has $e_i > 1$ at least for one i so that $f_i = 0$ is true at least for one index. A simple example is provided by rational primes (determined by roots of $P(x) = x^2 + 1$ with discriminant -4): in this case $p = 2$ corresponds to ramified prime since on has $(1 + i)(1 - i) = 2$ and $1 + i$ and $1 - i$ differ only by multiplication by unit $-i$.

5. Split primes have n factors P_i and thus have $(e_i = 1, f_i = 1, g = n)$. They give a factor $(1 - p^{-s})^{-n}$. The physical analogy is n-fold degenerate state with original energy energy $nlog(p)$ split to states with energy $log(p)$.

   Inert primes are also primes of extension and there is no splitting and one has ($e_1 = e = 1, g = 1, f_1 = f = n$). In this case one obtains factor $1/(1 - p^{-ns})$. The physical analogy is n-particle bound state with energy $nlog(p)$.

6. For ramified primes the situation is more delicate. Generalizing from the case of Gaussian primes $Q[i]$ (see `http://tinyurl.com/y563wcwv`) ramified primes p_R would give rise to a factor

$$\prod_{i=1}^{g} \frac{1}{1 - p_R^{-f_i s}} \quad .$$

   g is the number of *distinct* ideals P_i in the decomposition of p to the primes of extension.

   For Gaussian primes $p = 2$ has $g = 1$ since one can write $(2) = (1+i)(1-i) \equiv (1+i)^2$. This because $1+i$ and $1-i$ differ only by multiplication with unit $-i$ and thus define same ideal in $Q[i]$. Only the number g of distinct factors P_i in the decomposition of p matters.

   One could understand this as follows. For the roots of polynomials ramification means that several roots co-incide so that the number of distinct roots is reduced. $e_i > 1$ is analogous to the number co-inciding roots so that number if distinct roots would be 1 instead of e_i. This would suggests $k_i = 1$ always. For ramified primes the number of factors Z_p the number $\sum_{i=1}^{g} f_i k_i = n$ for un-ramified case would reduce from to $\sum_{i=1}^{g} f_i k_i = n_d$, which is the number of distinct roots.

7. Could the physical interpretation be that there are g types of bound states with energies $f_i log(p)$ appearing with degeneracy $e_i = 1$ both in ramified and split case. This should relate to the fact that for ramified primes p L/p contains non-vanishing nilpotent element and is not counted. One can also say that the decomposition to primes of extension conserves energy: $\sum_{i=1,...,g} e_i f_i log(p) = n_d log(p)$.

   For instance, for Galois extensions ($e_i = e, f_i = f, g = n_d/ef$) for given p the factor is $1/(1 - p^{-es})^{fg}$: $efg = n_d$. If there is a ramification then all P_i are ramified. Note that e, f an g are factors of n_d.

8. One can can extract the factor $1/(1 - p^{-s})$ from each of the 3 contributions and organize these factors to give the ordinary Riemann zeta. The number of ramified primes is finite whereas the numbers of split primes and inert primes are infinite. One can therefore extract from ramified primes the finite product

$$\zeta^1_{R,K} = \prod_{p_R}(1 - p_R^{-s}) \times \zeta^2_{R,K} \quad , \quad \zeta^2_{R,K} = \prod_{p_R}[\prod_{i=1}^{g} \frac{1}{1-p^{-f_i s}}] \quad .$$

   One can organize the remaining part involving infinite number of factors to a product of ζ and factors $(1 - p^{-s})/(1 - \prod p^{-s}))^n$ and $(1 - p^{-s})/(1 - p^{-ns})$ giving rise to zeta function -call it $\zeta_{si,K}$ - characterizing the extension. Note that $\zeta^2_{R,K}$ has interpretation as partition function and has pole of order n_d at origin.

   One therefore can write the ζ_L as

$$\zeta_K = \zeta^1_{R,K} \times \zeta_{si,K} \times \zeta \quad .$$

where $\zeta_{si,K}$ is the contribution of split and inert primes multiplied by $(1-p^{-s})$

ζ_L has pole only at $s=1$ and it carries in no obvious manner information about ramified primes. The naïve guess for ζ_L would be that also ramified primes p_R would give rise to a factor

$$\prod_{i=1}^{g} \frac{1}{(1-p_R^{-f_i s})^{e_i}} \quad .$$

One could indeed argue that at the limit when e_i prime ideals P_i of extension co-incide, one should obtain this expression. The resulting ζ function would be product

$$\zeta_{naive,K} = \zeta_{R,K}\zeta_K \quad , \qquad \zeta_{R,K} = \prod_{p_R} X(p_R)$$

$$X(p_R) = \prod_{i=1}^{g} \frac{1}{(1-p_R^{-f_i s})^{e_i-1}} \quad .$$

Note that the parameters e_i, f_i, g depend on p_R and that for Galois extensions one has $e_i = d, f_i = f$ for given p_R. $\zeta_{R,L}$ would have poles at along imaginary axis at points $s = -n2\pi/log(p)$. Ramified primes would give rise to poles along imaginary axis. As far as the proposed physical interpretation of ramified primes is considered, this form looks more natural.

Fermionic counterparts of Dedekind zeta and ramified ζ

One can look the situation also for the generalization of fermionic zeta as analog of fermionic partition function, which for rationals has the expression

$$\zeta^F(s) = \prod_p (1+p^{-s}) = \frac{\zeta(s)}{\zeta(2s)} \quad .$$

Supersymmetry of supersymmetric arithmetic QFT suggest the product of fermionic and bosonic zetas. Also the supersymmetry of infinite primes for which first level of hierarchy corresponds to irreducible polynomials suggests this. On the other hand, the appearance of only fermions as fundamental particles in TGD forces to ask whether the ramified part of fermionic zeta might be fundamental.

1. By an argument similar to used for ordinary zeta based on interpretation as partition function, one obtains the decomposition of the fermionic counterpart of ζ_K^F Dirichlet zeta to a product $\zeta_K^F = \zeta_{R,K}^F \zeta_{si,K}^F \zeta^F$ of ramified fermionic zeta $\zeta_{R,K}^F$, $\zeta_{si,K}^F$, and ordinary fermionic zeta ζ^F. The basic rule is simple: replace factors $1/(1-p^{-ks}$ appearing in ζ_K with $(1+p^{-ks})$ in ζ_K^F and extract ζ^F from the resulting expression. This gives

$$\zeta_{R,K}^{F,1} = \prod_{p_R}(1-p_R^{-s})\zeta_{R,K}^F \quad , \quad \zeta_{R,K}^F = \prod_{p_R}[\prod_{i=1}^{g}(1+p_R^{-f_i s})] \quad .$$

where p_R is ramified prime dividing the discriminant. $\zeta_{R,K}^F$ is analogous to a fermionic partition function for a finite number of modes defined by ramified primes p_R of extension.

2. Also now one can wonder whether one should define ζ_K^F as a product in which ramified primes give factor

$$\prod_{p_R}[\prod_{i=1}^{g}(1+p_R^{-f_i s})^{e_i}]$$

so that one would have

$$\zeta_{naive,K}^F = \zeta_{R,K}^F \zeta_K^F \quad , \qquad \zeta_R^F = \prod_{p_R} Y(p_R) \quad ,$$

$$Y(p_R) = \prod_{i=1}^{g}(1+p_R^{-f_i s})^{e_i-1}$$

$\zeta_F(na\ddot{\imath}ve, K)$ would have zeros along imaginary axis serving as signature of the ramified primes.

About physical interpretation of $\zeta_{R,K}$ and $\zeta^F_{R,K}$

$\zeta_{R,K}$ and $\zeta^F_{R,K}$ are attractive from the view point of number theoretic vision and the idea that ramified primes are physically special. TGD Universe is quantum critical and in catastrophe theory the ramification for roots of polynomials is analogous to criticality. Maybe the ramification for p-adic primes makes them critical. $K/(p_R)$ has nilpotent elements, which brings in mind on mass shell massless particles.

1. $\zeta_{R,K}$ has poles at

$$s = i\frac{2n\pi}{log(p)f_i}$$

and $p_R^s = exp(in2\pi/f_i)$ is a root of unity, which conforms with the number theoretical vision. Only P_i with $e_i > 1$ contribute.

2. $Z^F_{R,K}$ has zeros

$$s = i\frac{(2n+1)\pi}{log(p)f_i}$$

and $p_R^s = exp(i(2n+1)\pi/f_i)$ is a root of unity. Zeros are distinct from the poles of $Z_{R,K}$.

3. The product $\zeta_{R,tot,K} = \zeta_{R,K}\zeta^F_{R,K}$ has the poles and zeros of $\zeta_{R,K}$ and $\zeta^F_{R,K}$. In particular, there is n:th order pole of $Z_{R,K}$ at $s = 0$. The zeros of $z_{F,K}$ along imaginary axis at $p^{iy} = -1$ also survive in $\zeta_{R,tot,K}$.

   $\zeta^F_{R,K}$ has only zeros and since fundamental fermions are primary fields in TGD framework, one could argue that only it carries physical information. On the other hand, supersymmetric arithmetic QFT [K99] and the fact that TGD allows SUSY [L85] suggests that the product $\zeta_{R,K} \times Z^F_{R,K}$ is more interesting.

From TGD point of view the ramified zeta functions $\zeta_{R,K}$, $\zeta^F_{R,K}$ and their product $\zeta_{R,K}\times\zeta^F_{R,K}$ look interesting.

1. $\zeta_{R,K}$ behaves like s^{-n_d}, $n_d = \sum_1^g(e_i - 1)$ near the origin. Could n_d-fold pole at $s = 0$ be interpreted in terms of a massless state propagating along light-cone boundary of CD in radial direction? This would conform with the proposal that zeros of zeta correspond to complex radial conformal weights for super-symplecti algebra. That ramified primes correspond to massless particles would conform with the identification of ramified prime as p-adic primes labelling elementary particles since in ZEO their mass would result from p-adic thermodynamics from a mixing with very massive states [L76].

   Besides this there would be stringy spectrum of real conformal weights along negative real axis and those coming as non-trivial zeros and these could correspond to ordinary conformal weights.

2. The zeros of $\zeta^F_{R,K}$ along imaginary axis might have interpretation as eigenvalues of Hamiltonian in analogy with Hilbert-Polya hypothesis. Maybe also the poles of $\zeta_{R,K}$ could have similar interpretation. The real part of zero/pole would not produce troubles (on the other hand, for waves along light-cone boundary it can be however absorbed to the integration measure.

3. A possible physical interpretation of the imaginary conformal weights could be as conformal weights associated with radial waves assignable to the radial light-like coordinate r of the light-cone boundary: r indeed plays the role of complex coordinate in conformal symmetry in the case of super-symplectic algebra suggested to define the isometries of WCW. Poles and zero could correspond to radial modes satisfying periodic/anti-periodic boundary conditions.

   The radial conformal weights s defined by the zeros of $\zeta^F_{R,K}$ would be number theoretically natural since one could pose boundary condition $p^{is(r/r_0)} = -1$ at $r = r_0$ requiring $p^{is} = -1$ at the corner of cd (maximum value of r in $CD = cd \times CP_2$.

For the poles of $\zeta_{R,K}$ the periodic boundary condition $p^{is(r/r_0)} = 1$ is natural. The two boundary conditions could relate to Ramond an N-S representations of super-conformal algebras (see `http://tinyurl.com/y49y2ouj`). With this interpretation $s = 0$ would correspond to a radial plane-wave constant along light-like radial direction and therefore light-like momentum propagating along the boundary of CD. Other modes would correspond to other massless modes propagating to the interior of CD.

4. I have earlier considered an analogous interpretation for a subset zeros of zeta satisfying similar condition. The idea was that for given prime p as subset of $s = 1/2 + iy_i$ of non-trivial zeros ζ $p^s = p^{1/2+iy_i}$ is an algebraic number so that p^{iy_i} would be a root of unity. Zeros would decompose to subsets labelled by primes p. Also for trivial zeros of ζ (and also poles) the same holds true as for the zeros and poles ζ_R. This encourages the conjecture that the property is true also for L-functions.

The proposed picture suggests an assignment of "energy" $E = nlog(p)$ to each prime and separation of "ramified" energy $E_d = n_d log(p)$, $n_d = \sum_1^g f_i(e_i - 1)$, to each ramified prime. The interpretation as partition function suggests that that one has g types of states of f_i identical particles and energy $E_i = f_i log(p)$ and that this state is e_i-fold degenerate with energies $E_i = f_i log(p)$. For inert primes one would have $f_i = f = n$. For split primes one would have $e_i = 1, f_i = 1$. In case of ramified primes one can separate one of these states and include it to the Dedekind zeta.

Can one find a geometric correlate for the picture based on prime ideals?

If one could find a geometric space-time correlate for the decomposition of rational prime ideals to prime ideals of extensions, it might be also possible to understand why quantum criticality makes ramified primes so special physically and wha this means.

What could be correlate for f_i fundamental fermions behaving like single unit and what degeneracy for $e_i > 1$ does mean? One can look the situation first at the level of number fields Q and K and corresponding Galois group $Gal(K/Q)$, finite fields $F = Q/p$ and $F_i = K/P_i$, and corresponding Galois group $Gal(F_i/F)$. Appendix summarizes the basic terminology.

1. Inertia degree f_i is the number of elements of F_i/F_p ($F_i = K/P_i$ is extension of finite field $F_p = Q/p$). The Galois group $Gal(F_i/F_p)$ is identifiable as factor group D_i/I_i, where the *decomposition group* D_i is the subgroup of Galois group taking P_i to itself and the *inertia group* I_i leaving P_i point-wise invariant. The orbit under $Gal(F_i/F_p)$ in F_i/F_p would behave like single particle with energy $E_i = f_i log(p)$.

   For inert primes with $f_i = n$ inertia group would be maximal. For split primes the orbits of ideals would consist of $f_i = 1$ points only and isotropy group would be trivial.

2. Ramification for primes corresponds intuitively to that for polynomials meaning multiple roots as is clear also from the expression $p = \prod P_i^{e_i}$. In accordance with the intuition about quantum criticality, ramification means that the irreducible polynomial reduced to a reducible polynomial in finite field Q/p has therefore a multiple roots with multiplicities e_i (see Appendix). For Galois extensions one has ($e_i = e, f_i = f$) Criticality would be seen at the level of finite field $F_p = Q/p$ associated with ramified prime p.

The interpretation of roots of corresponding octonionic polynomials as n-sheeted covering space like structures encourages to ask whether the independent tensor factors labelled by i suggested by the interpretation as a partition function could be assigned with the sheets of covering so that ramification with $e_i > 1$ would correspond to singular points of cognitive representation for which e_i sheets co-incide in some sense, maybe in finite field approximation ($O(p) = 0$). Galois groups indeed act on the coordinates of point of cognitive representation belonging to the extension K. In general the action does not take the point to a point belonging to a cognitive representation but one can consider quantum superpositions of cognitive representations.

This suggests an interpretation in terms of space-time surfaces accompanied by cognitive representation under Galois group. Quantum states would be superpositions of preferred extremals at orbits of Galois group and for cognitive representations the situation would be discrete.

1. To build a concrete connection between geometric space-time picture and number theoretic picture, one should find geometric counterparts of integers, ideals, and prime ideals. The analogs of prime ideals should be associated with the discretizations of space-time surfaces/cognitive representations in $O(p) = 0$ or $O(P_i) = 0$ approximation. Could one include only points of cognitive representations differing from zero in $O(p) = 0$ approximation and form quantum states as quantum superpositions of these points of cognitive representation?

   in $O(p) = 0$ approximation and for ramified primes irreducible polynomials would have multiple roots so that e_i sheets would co-incide at these points in $O(p) = 0$ approximation. Th conjecture that elementary particles correspond to this kind of singularities has been speculated already earlier with inspiration coming from quantum criticality.

2. In M^8 picture the octonionic polynomials obtained as continuation of polynomials with rational coefficients would be reduced to polynomials in finite field F_p. One can study corresponding discrete algebraic surfaces as discrete approximations of space-time surfaces.

3. One would like to have only single embedding space coordinate since the probability that all embedding space coordinates correspond to the same P_i is small. $M^8 - H$ duality reduces the number of embedding space coordinates characterizing partonic 2-surfaces containing vertices for fundamental fermions to single one identifiable as time coordinate.

   At the light-like boundary of 8-D CD in M^8 the vanishing condition for the real or imaginary part (quaternion) of octonionic polynomial $P(o)$ reduces to that for ordinary polynomial, and one obtains n roots r_n, which correspond to the values of M^4 time $t = r_n$ defining 6-spheres as analogs of branes. Partonic 2-surfaces corresponde to intersections of 4-D roots of $P(o)$ at partonic 2-surfaces. Galois group of the polynomial naturally acts on r_n labelling these partonic 2-surfaces by permuting them. One could form representations of Galois group using states identified as quantum superpositions of these partonic 2-surfaces corresponding to different values of $t = r_n$. Galois group leaves invariant the degenerate roots $t = r_n$.

4. The roots can be reduced to finite field F_p or K/P_i. Ramification would take place in this approximation and mean that e_i roots $t = r_n$ are identical in $O(p) = 0$ approximation. e_i time values $t = r_n$ would nearly co-incide. This gives more concrete contents to the statement of TGD inspired theory of consciousness that these time values correspond to very special moments in the life of self. Since this is the situation only approximately, one can argue that one must indeed count each root separately so that partition function must be defined as product of the contribution form ramified primes an Dedekind zeta.

   The assignment of fundamental fermions to the points of cognitive representations at partonic 2-surfaces assignable to the intersections of 4-D roots and universal 6-D roots of octonionic polynomials (brane like entities) conforms with this picture.

5. The analogs of 6-branes would give rise to additional degrees of freedom meaning effectively discrete non-determinism. I have speculated with this determinism with inspiration coming from the original identification of bosonic action as Kähler action having huge 4-D spin glass degeneracy. Also the number theoretic vision suggest the possibility of interpreting preferred extremals as analogs of algebraic computations such that one can have several computations connecting given states [L32]. The degree n of polynomial would determine the number of steps and the degeneracy would correspond to n-fold degeneracy due to the discrete analogs of plane waves in this set.

What extensions of rationals could be winners in the fight for survival?

It would seem that the fight for survival is between extensions of rationals rather than individual primes p. Intuition suggests that survivors tend to have maximal number of ramified primes. These number theoretical speciei can live in the same extension - to "co-operate".

Before starting one must clarify some basic facts about extensions of rationals.

1. Extension of rationals are defined by an irreducible polynomial with rational coefficients. The roots give n algebraic numbers which can be used as a basis to generate the numbers of extension ast their rational linear combinations. Any number of extension can be expressed

as a root of an irreducible polynomial. Physically it is is of interest, that in octonionic picture infinite number of octonionic polynomials gives rise to space-time surface corresponding to the same extension of rationals.

2. One can define the notion of integer for extension. A precise definition identifies the integers as ideals. Any integer of extension are defined as a root of a monic polynomials $P(x) = x^n + p_{n-1}x^{n-1}x^{n-1} + ... + p_0$ with integer coefficients. In octonionic monic polynomials are subset of octonionic polynomials and it is not clear whether these polynomials could be all that is needed.

3. By definition ramified primes divide the discriminant D of the extension defined as the product $D = \prod_{i\neq j}(r_i - r_j)$ of differences of the roots of (irreducible) monic polynomial with integer coefficients defining the basis for the integers of extension. Discriminant has a geometric interpretation as volume squared for the fundamental domain of the lattice of integers of the extension so that at criticality this volume interpreted as p-adic number would become small for ramified primes an vanish in $O(p)$ approximation. The extension is defined by a polynomial with rational coefficients and integers of extension are defined by monic polynomials with roots in the extension: this is not of course true for all monic polynomials polynomial (see `http://tinyurl.com/k3ujjz7`).

4. The scaling of the $n-1$-tuple of coefficients $(p_{n-1}, ..., p_1)$ to $(ap_{n-1}, a^2p_{n-1}....., a^np_0)$ scales the roots by a: $x_n \rightarrow ax_n$. If a is rational, the extension of rationals is not affected. In the case of monic polynomials this is true for integers k. This gives rational multiples of given root.

   One can decompose the parameter space for monic polynomials to subsets invariant under scalings by rational $k \neq 0$. Given subset can be labelled by a subset with vanishing coefficients $\{p_{i_k}\}$. One can get rid of this degeneracy by fixing the first non-vanishing p_{n-k} to a non-vanishing value, say 1. When the first non-vanishing p_k differs from p_0, integers label the polynomials giving rise to roots in the same extension. If only p_0 is non-vanishing, only the scaling by powers k^n give rise to new polynomials and the number of polynomials giving rise to same extension is smaller than in other cases.

   Remark: For octonionic polynomials the scaling symmetry changes the space-time surface so that for generic polynomials the number of space-time surfaces giving rise to fixed extension is larger than for the special kind polynomials.

Could one gain some understanding about ramified primes by starting from quantum criticality? The following argument is poor man's argument and I can only hope that my modest technical understanding of number theory does not spoil it.

1. The basic idea is that for ramified primes the minimal monic polynomial with integer coefficients defining the basis for the integers of extension has multiple roots in $O(p) = 0$ approximation, when p is ramified prime dividing the discriminant of the monic polynomial. Multiple roots in $O(p) = 0$ approximation occur also for the irreducible polynomial defining the extension of rationals. This would correspond approximate quantum criticality in some p-adic sectors of adelic physics.

2. When 2 roots for an irreducible rational polynomial co-incide, the criticality is exact: this is true for polynomials of rationals, reals, and all p-adic number fields. One could use this property to construct polynomials with given primes as ramified primes. Assume that the extension allows an irreducible olynomial having decomposition into a product of monomials $= x - r_i$ associated with roots and two roots r_1 and r_2 are identical: $r_1 = r_2$ so that irreducibility is lost.

   The deformation of the degenerate roots of an irreducible polynomial giving rise to the extension of rationals in an analogous manner gives rise to a degeneracy in $O(p) = 0$ approximation. The degenerate root $r_1 = r_2$ can be scaled in such a way that the deformation $r_2 = r_1(1+q))$, $q = m/n = O(p)$ is small also in real sense by selecting $n >> m$.

   If the polynomial with rational coefficients gives rise to degenerate roots, same must happen also for monic polynomials. Deform the monic polynomial by changing $(r_1, r_2 = r_1)$ to

$(r_1, r_1(1+r))$, where integer r has decomposition $r = \prod_i p_i^{k_i}$ to powers of prime. In $O(p) = 0$ approximation the roots r_1 and r_2 of the monic polynomial are still degenerate so that p_i represent ramified primes.

If the number of p_i is large, one has high degree of ramification perhaps favored by p-adic evolution as increase of number theoretic co-operation. On the other hand, large p-adic primes are expected to correspond to high evolutionary level. Is there a competition between large ramified primes and number of ramified primes? Large $h_{eff}/h_0 = n$ in turn favors large dimension n for extension.

3. The condition that two roots of a polynomial co-incide means that both polynomial $P(x)$ and its derivative dP/dx vanish at the roots. Polynomial $P(x) = x^n + p_{n-1}x^{n-1} + ..p_0$ is parameterized by the coefficients which are rationals (integers) for irreducible (monic) polynomials. $n-1$-tuple of coefficients $(p_{n-1}, ..., p_0)$ defines parameter space for the polynomials. The criticality condition holds true at integer points $n-1-D$ surface of this parameter space analogous to cognitive representation.

   The condition that critical points correspond to rational (integer) values of parameters gives an additional condition selecting from the boundary a discrete set of points allowing ramification. Therefore there are strong conditions on the occurrence of ramification and only very special monic polynomials are selected.

   This suggests octonionic polynomials with rational or even integer coefficients, define strongly critical surfaces, whose p-adic deformations define p-adically critical surfaces defining an extension with ramified primes p. The condition that the number of rational critical points is non-vanishing or even large could be one prerequisite for number theoretical fitness.

4. There is a connection to catastrophe theory, where criticality defines the boundary of the region of the parameter space in which discontinuous catastrophic change can take place as replacement of roots of $P(x)$ with different root. Catastrophe theory involves polynomials $P(x)$ and their roots as well as criticality. Cusp catastrophe is the simplest non-trivial example of catastrophe surface with $P(x) = x^4/4 - ax - bx^2/2$: in the interior of V-shaped curve in (a, b)-plane there are 3 roots to $dP(x) = 0$, at the curve 2 solutions, and outside it 1 solution. Note that now the parameterization is different from that proposed above. The reason is that in catastrophe theory diffeo-invariance is the basic motivation whereas in M^8 there are highly unique octonionic preferred coordinates.

If p-adic length scale hypothesis holds true, primes near powers of 2, prime powers, in particular Mersenne primes should be ramified primes. Unfortunately, this picture does not allow to say anything about why ramified primes near power of 2 could be interesting. Could the appearance of ramified primes somehow relate to a mechanism in which $p = 2$ as a ramified prime would precede other primes in the evolution. $p = 2$ is indeed exceptional prime and also defines the smallest p-adic length scale.

For instance, could one have two roots a and $a + 2^k$ near to each other 2-adically and could the deformation be small in the sense that it replaces 2^k with a product of primes near powers of 2: $2^k = \prod_i 2^{k_i} \to \prod_i p_i$, p_i near 2^{k_i}? For the irreducible polynomial defining the extension of rationals, the deforming could be defined by $a \to a + 2^k$ could be replaced by $a \to a + 2^k/N$ such that $2^k/N$ is small also in real sense.

6.4.2 Appendix: About the decomposition of primes of number field K to primes of its extension L/K

The followings brief summary lists some of the basic terminology related to the decomposition of primes of number field K in its extension.

1. A typical problem is the splitting of primes of K to primes of the extension L/K which has been already described. One would like to understand what happens for a given prime in terms of information about K. The splitting problem can be formulated also for the extensions of the local fields associated with K induced by L/K.

2. Consider what happens to a prime ideal p of K in L/K. In general p decomposes to product $p = \prod_{i=1}^{g} P_i^{e_i}$ of powers of prime ideals P_i of L. For $e_i > 1$ ramification is said to occur. The finite field K/p is naturally imbeddable to the finite field L/P_j defining its extension. The degree of the residue field extension $(L/P_i)/(K/p)$ is denoted by f_i and called inertia degree of P_i over p. The degree of L/K equals to $[L:K] = \sum e_i f_i$.

   If the extension is Galois extension (see `http://tinyurl.com/zu5ey96`), one has $e_i = e$ and $f_i = f$ giving $[L:K] = efg$. The subgroups of Galois group $Gal(L/K)$ known as decomposition group D_i and inertia group I_i are important. The Galois group of F_i/F equals to D_i/I_i.

   For Galois extension the Galois group $Gal(L/K)$ leaving p invariant acts transitively on the factors P_i permuting them with each other. Decomposition group D_i is defined as the subgroup of $Gal(L/K)$ taking P_i to itself.

   The subgroup of $Gal(L/K)$ inducing identity isomorphism of P_i is called inertia group I_i and is independent of i. I_i induces automorphism of $F_i = L/P_i$. $Gal(F_i/F)$ is isomorphic to D_i/I_i. The orders of I_i and D_i are e and ef respectively. The theory of Frobenius elements identifies the element of $Gal(F_i/F) = D_i/I_i$ as generator of cyclic group $Gal(F_i/F)$ for the finite field extension F_i/F. Frobenius element can be represented and defines a character.

3. Quadratic extensions $Q(\sqrt{n})$ are simplest Abelian extensions and serve as a good starting point (see `http://tinyurl.com/zofhmb8`) the discriminant $D = n$ for $p\ mod\ 4 = 1$ and $D = 4n$ otherwise characterizes splitting and ramification. Odd prime p of the extension not dividing D splits if and only if D quadratic residue modulo p. p ramifies if D is divisible by p. Also the theorem by Kronecker and Weber stating that every Abelian extension is contained in cyclotomic extension of Q is a helpful result (cyclotonic polynomials has as it roots all n roots of unity for given n)

Even in quadratic extensions L of K the decomposition of ideal of K to a product of those of extension need not be unique so that the notion of prime generalized to that of prime ideal becomes problematic. This requires a further generalization. One ends up with the notion of ideal class group (see `http://tinyurl.com/hasyllh`): two fractional ideals I_1 and I_2 of L are equivalent if the are elements a and b such that $aI_1 = bI_2$. For instance, if given prime of K has two non-equivalent decompositions $p = \pi_1\pi_2$ and $p = \pi_3\pi_4$ of prime ideal p associated with K to prime ideals associated with L, then π_2 and π_3 are equivalent in this sense with $a = \pi_1$ and $b = \pi_4$. The classes form a group J_K with principal ideals defining the unit element with product defined in terms of the union of product of ideals in classes (some products can be identical). Factorization is non-unique if the factor J_K/P_K - ideal class group - is non-trivial group. $Q(\sqrt{-5})$ gived a representative example about non-unique factorization: $2 \times 3 = (1+\sqrt{-5})(1-\sqrt{-5})$ (the norms are 4×9 and 6×6 for the two factorizations so that they cannot be equivalent.

This leads to class field theory (see `http://tinyurl.com/zdnw7j3` and `http://tinyurl.com/z3s4kjn`).

1. In class field theory one considers Abelian extensions with Abelian Galois group. The theory provides a one-to-one correspondence between finite abelian extensions of a fixed global field K and appropriate classes of ideals of K or open sub-groups of the idele class group of K. For example, the Hilbert class field, which is the maximal unramified abelian extension of K, corresponds to a very special class of ideals for K.

2. Class field theory introduces the adele formed by reals and p-adic number fields Q_p or their extensions induced by algebraic extension of rationals. The motivation is that the very tough problem for global field K (algebraic extension of rationals) defines much simpler problems for the local fields Q_p and the information given by them allows to deduce information about K. This because the polynomials of order n in K reduce effectively to polynomials of order $n\ mod\ p^k$ in Q_p if the coefficients of the polynomial are smaller than p^k. One reduces monic irreducible polynomial f characterizing extension of Q to a polynomial in finite field F_p. This allows to find the extension Q_p induced by f.

   An irreducible polynomial in global field need not be irreducible in finite field and therefore can have multiple roots: this corresponds to a ramification. One identifies the primes p for which complete splitting (splitting to first ordinary monomials) occurs as unramified primes.

3. Class field theory also includes a reciprocity homomorphism, which acts from the idele class group of a global field K, i.e. the quotient of the ideles by the multiplicative group of K, to the Galois group of the maximal abelian extension of K. Wikipedia article makes the statement "*Each open subgroup of the idele class group of K is the image with respect to the norm map from the corresponding class field extension down to K*". Unfortunately, the content of this statement is difficult to comprehend with physicist's background in number theory.

6.5 Appendix: Explicit formulas for the evolution of cosmological constant

What is needed is induced Kähler form $J(S^2(X^4)) \equiv J$ at the twistor sphere $S^2(X^4) \equiv S^2$ associated with space-time surface. $J(S^2(X^4))$ is sum of Kähler forms induced from the twistor spheres $S^2(M^4)$ and $S^2(CP_2)$.

$$J(S^2(X^4) \equiv J = P[J(S^2(M^4)) + J(S^2(CP_2))] \ , \tag{6.5.1}$$

where P is projection taking tensor quantity T_{kl} in $S^2(M^4) \times S^2(CP_2)$ to its projection in $S^2(X^4)$. Using coordinates y^k for $S^2(M^4)$ or $S^(CP_2)$ and x^μ forS^2, P is defined as

$$P : T_{kl} \rightarrow T_{\mu\nu} = T_{kl}\frac{\partial y^k}{\partial x^\mu}\frac{\partial y^l}{\partial x^\nu} \ . \tag{6.5.2}$$

For the induced metric $g(S^2(X^4)) \equiv g$ one has completely analogous formula

$$g = P[g(J(S^2(M^4)) + g(S^2(CP_2))] \ . \tag{6.5.3}$$

The expression for the coefficient K of the volume part of the dimensionally reduced 6-D Kähler action density is proportional to

$$L(S^2) = J^{\mu\nu}J_{\mu\nu}\sqrt{det(g)} \ . \tag{6.5.4}$$

(Note that $J_{\mu\nu}$ refers to S^2 part 6-D Kähler action). This quantity reduces to

$$L(S^2) = (\epsilon^{\mu\nu}J_{\mu\nu})^2\frac{1}{\sqrt{det(g)}} \ . \tag{6.5.5}$$

where $\epsilon^{\mu\nu}$ is antisymmetric tensor density with numerical values +,-1. The volume part of the action is obtained as an integral of K over S^2:

$$S(S^2) = \int_{S^2} L(S^2) = \int_{-1}^{1} du \int_0^{2\pi} d\Phi \frac{J_{u\Phi}^2}{\sqrt{det(g)}} \ . \tag{6.5.6}$$

$(u, \Phi) \equiv (cos(\Theta, \Phi)$ are standard spherical coordinates of $S^2)$ varying in the ranges $[-1, 1]$ and $[0, 2\pi]$.

This the quantity that one must estimate.

6.5.1 General form for the embedding of twistor sphere

The embedding of $S^2(X^4) \equiv S^2$ to $S^2(M^4) \times S^2(CP_2)$ must be known. Dimensional reduction requires that the embeddings to $S^2(M^4)$ and $S^2(CP_2)$ are isometries. They can differ by a rotation possibly accompanied by reflection

One has

$$(u(S^2(M^4)), \Phi(S^2(M^4)) = (u(S^2(X^4), \Phi(S^2(X^4)) \equiv (u, \Phi) \ ,$$

$$\left[u(S^2(CP_2)), \Phi(S^2(CP_2))\right] \equiv (v, \Psi) = RP(u, \Phi)$$

where RP denotes reflection P following by rotation R acting linearly on linear coordinates (x,y,z) of unit sphere S^2). Note that one uses same coordinates for $S^2(M^4)$ and $S^2(X^4)$. From this action one can calculate the action on coordinates u and Φ by using the definite of spherical coordinates.

The Kähler forms of $S^2(M^4)$ resp. $S^2(CP_2)$ in the coordinates $(u = cos(\Theta), \Phi)$ resp.(v, Ψ) are given by $J_{u\Phi} = \epsilon = \pm 1$ resp. $J_{v\Psi} = \epsilon = \pm 1$. The signs for $S^2(M^4)$ and $S^2(CP_2)$ are same or opposite. In order to obtain small cosmological constant one must assume either

1. $\epsilon = -1$ in which case the reflection P is absent from the above formula (RP $\rightarrow$ R).
2. $\epsilon = 1$ in which case P is present. P can be represented as reflection $(x, y, z) \rightarrow (x, y, -z)$ or equivalently $(u, \Phi) \rightarrow (-u, \Phi)$.

Rotation R can represented as a rotation in (y,z)-plane by angle ϕ which must be small to get small value of cosmological constant. When the rotation R is trivial, the sum of induced Kähler forms vanishes and cosmological constant is vanishing.

6.5.2 Induced Kähler form

One must calculate the component $J_{u\Phi}(S^2(X^4)) \equiv J_{u\Phi}$ of the induced Kähler form and the metric determinant $det(g)$) using the induction formula expressing them as sums of projections of M^4 and CP_2 contributions and the expressions of the components of $S^2(CP_2)$ contributions in the coordinates for $S^2(M^4)$. This amounts to the calculation of partial derivatives of the transformation R (or RP) relating the coordinates (u, Φ) of $S^2(M^4)$ and to the coordinates (v, Ψ) of $S^2(CP_2)$.

In coordinates (u, Φ) one has $J_{u\Phi}(M^4) = \pm 1$ and similar expression holds for $J(v\Psi)S^2(CP_2)$. One has

$$J_{u\Phi} = 1 + \frac{\partial(v, \Psi)}{\partial(u, \Phi)} \ . \tag{6.5.7}$$

where right-hand side contains the Jacobian determinant defined by the partial derivatives given by

$$\tfrac{\partial(v,\Psi)}{\partial(u,\Phi)} = \tfrac{\partial v}{\partial u}\tfrac{\partial \Psi}{\partial \Phi} - \tfrac{\partial v}{\partial \Phi}\tfrac{\partial \Psi}{\partial u} \ . \tag{6.5.8}$$

6.5.3 Induced metric

The components of the induced metric can be deduced from the line element

$$ds^2(S^2(X^4) \equiv ds^2 = P[ds^2(S^2(M^4)) + ds^2(S^2(CP_2))] \ .$$

where P denotes projection. One has

$$P(ds^2(S^2(M^4))) = ds^2(S^2(M^4)) = \frac{du^2}{1-u^2} + (1-u^2)d\Phi^2 \ .$$

and

$$P[ds^2(S^2(CP_2))] = P[\frac{(dv)^2}{1-v^2} + (1-v^2)d\Psi^2] \ ,$$

One can express the differentials $(dv, d\Psi)$ in terms of $(du, d\Phi)$ once the relative rotation is known and one obtains

$$P[ds^2(S^2(CP_2))] = \frac{1}{1-v^2}[\frac{\partial v}{\partial u}du + \frac{\partial v}{\partial \Phi}d\Phi]^2 + (1-v^2)[\frac{\partial \Psi}{\partial u}du + \frac{\partial \Psi}{\partial \Phi}d\Phi]^2 \ .$$

This gives

$$\begin{aligned} & P[ds^2(S^2(CP_2))] \\ & = [(\tfrac{\partial v}{\partial u})^2 \tfrac{1}{1-v^2} + (1-v^2)(\tfrac{\partial \Psi}{\partial u})^2]du^2 \\ & +[(\tfrac{\partial v}{\partial \Phi})^2 \tfrac{1}{1-v^2} + (\tfrac{\partial \Psi}{\partial \Phi})^2 1-v^2]d\Phi^2 \\ & +2[\tfrac{\partial v}{\partial u}\tfrac{\partial v}{\partial \Phi}\tfrac{1}{(1-v^2)} + \tfrac{\partial \Psi}{\partial u}\tfrac{\partial \Psi}{\partial \Phi}(1-v^2)]dud\Phi \ . \end{aligned}$$

From these formulas one can pick up the components of the induced metric $g(S^2(X^4)) \equiv g$ as

$$\begin{aligned} g_{uu} &= \tfrac{1}{1-u^2} + (\tfrac{\partial v}{\partial u})^2 \tfrac{1}{1-v^2} + (1-v^2)(\tfrac{\partial \Psi}{\partial u})^2] \ , \\ g_{\Phi\Phi} &= 1-u^2 + (\tfrac{\partial v}{\partial \Phi})^2 \tfrac{1}{1-v^2} + (\tfrac{\partial \Psi}{\partial \Phi})^2(1-v^2) \\ g_{u\Phi} &= g_{\Phi u} = \tfrac{\partial v}{\partial u}\tfrac{\partial v}{\partial \Phi}\tfrac{1}{(1-v^2)} + \tfrac{\partial \Psi}{\partial u}\tfrac{\partial \Psi}{\partial \Phi}(1-v^2) \ . \end{aligned} \tag{6.5.9}$$

The metric determinant $det(g)$ appearing in the integral defining cosmological constant is given by

$$det(g) = g_{uu}g_{\Phi\Phi} - g_{u\Phi}^2 \ . \tag{6.5.10}$$

6.5.4 Coordinates (v, Ψ) in terms of (u, Φ)

To obtain the expression determining the value of cosmological constant one must calculate explicit formulas for (v, Ψ) as functions of (u, Φ) and for partial derivations of (v, Ψ) with respect to (u, Φ).

Let us restrict the consideration to the RP option.

1. P corresponds to $z \rightarrow -z$ and to

$$u \rightarrow -u \ . \tag{6.5.11}$$

2. The rotation R $(x, y, z) \rightarrow (x', y', z')$ corresponds to

$$x' = x, \quad y' = sz + cy = su + c\sqrt{1-u^2}sin(\Phi) \ , \quad z' = v = cu - s\sqrt{1-u^2}sin(\Phi) \tag{6.5.12}$$

Here one has $(s, c) \equiv (sin(\epsilon), cos(\epsilon))$, where ϵ is rotation angle, which is extremely small for the value of cosmological constant in cosmological scales.

From these formulas one can pick v and $\Psi = arctan(y'/x)$ as

$$v = cu - s\sqrt{1-u^2}sin(\Phi) \quad \Psi = arctan[\tfrac{su}{\sqrt{1-u^2}}cos(\Phi) + tan(\Phi)] \ . \tag{6.5.13}$$

3. RP corresponds to

$$v = -cu - s\sqrt{1-u^2}sin(\Phi) \quad \Psi = arctan[-\tfrac{su}{\sqrt{1-u^2}}cos(\Phi) + tan(\Phi)] \ . \tag{6.5.14}$$

6.5.5 Various partial derivatives

Various partial derivates are given by

$$\begin{aligned}
\frac{\partial v}{\partial u} &= -1 + s\frac{u}{\sqrt{1-u^2}}sin(\Phi) \ , \\
\frac{\partial v}{\partial \Phi} &= -s\frac{u}{\sqrt{1-u^2}}cos(\Phi) \ , \\
\frac{\partial \Psi}{\partial \Phi} &= (-s\frac{u}{\sqrt{1-u^2}}sin(\Phi) + c)\frac{1}{X} \ , \\
\frac{\partial \Psi}{\partial u} &= \frac{scos(\Phi)(1+u-u^2)}{(1-u^2)^{3/2}}\frac{1}{X} \ , \\
X &= cos^2(\Phi) + [-s\frac{u}{\sqrt{1-u^2}} + csin(\Phi)]^2 \ .
\end{aligned} \tag{6.5.15}$$

Using these expressions one can calculate the Kähler and metric and the expression for the integral giving average value of cosmological constant. Note that the field equations contain S^2 coordinates as external parameters so that each point of S^2 corresponds to a slightly different space-time surface.

6.5.6 Calculation of the evolution of cosmological constant

One must calculate numerically the dependence of the action integral S over S^2 as function of the parameter $s = sin(\epsilon)$). One should also find the extrema of S as function of s.

Especially interesting values are very small values of s since for the cosmological constant becomes small. For small values of s the integrand (see Eq. 13.4.6) becomes very large near poles having the behaviour $1/\sqrt{g} = 1/(sin(\Theta) + O(s))$ coming from $\sqrt{g}$ approaching that for the standard metric of S^2. The integrand remains finite for $s \neq 0$ but this behavior spoils the analytic dependence of integral on s so that one cannot do perturbation theory around $s = 0$. The expected outcome is a logarithmic dependence on s.

In the numerical calculation one must decompose the integral over S^2 to three parts.

1. There are parts coming from the small disks D^2 surrounding the poles: these give identical contributions by symmetry. One must have criterion for the radius of the disk and the natural assumption is that the disk radius is of order s.

2. Besides this one has a contribution from S^2 with disks removed and this is the regular part to which standard numerical procedures apply.

One must be careful with the expressions involving trigonometric functions which give rise to infinite if one applies the formulas in straightforward manner. These infinities are not real and cancel, when one casts the formulas in appropriate form inside the disks.

1. The limit $u \to \pm 1$ at poles involves this kind of dangerous quantities. The expression for the determinant appearing in $J_{u\Phi}$ remains however finite and $J^2_{u\phi}$ vanishes like s^2 at this limit. Also the metric determinant $1/\sqrt{g}$ remains finite expect at $s = 0$.

2. Also the expression for the quantity X in $\Psi = arctan(X)$ contains a term proportional to $1/cos(\Phi)$ approaching infinity for $\Phi \to \pi/2, 3\pi/2$. The value of $\Psi = arc(tan(X)$ remains however finite and equal to $\pm\Phi$ at this limit depending on on the sign of us.

Concerning practical calculation, the relevant formulas are given in Eqs. 13.4.5, 13.4.6, 13.4.7, 13.4.8, 13.4.9, 13.4.10, and 13.4.15.

The calculation would allow to test/kill the key conjectures already discussed.

1. There indeed exist extrema satisfying $dS(S^2)/ds = 0$.

2. These extrema are in one-one correspondence with the zeros of zeta.

There are also much more specific conjctures to be killed.

1. These extrema correspond to $s = sin(\epsilon) = 2{-}k$ or more generally $s = p^{-k}$. This conjecture is inspired by p-adic length scale hypothesis but since the choice of evolution parameter is to high extent free, the conjecture is perhaps too spesific.

2. For certain integer values of integer k the integral $S(S^2)$ of Eq. 13.4.6 is of form $S(S^2) = xs^2$ for $s = 2^{-k}$, where x is a universal numerical constant.

   This would realize the idea that p-adic length scales realized as scales associated with cosmological constant correspond to fixed points of renormalization group evolution implying that radiative corrections otherwise present cancel. In particular, the deviation from $s = 2^{-d/2}$ would mean anomalous dimension replacing $s = 2^{-d/2}$ with $s^{-(d+\Delta d)/2}$ for $d = k$ the anomalies dimension Δd would vanish.

   The condition $\Delta d = 0$ should be equivalent with the vanishing of the dS/ds. Geometrically this means that $S(s)$ curve is above (below) $S(s) = xs^2$ and touches it at points $s = x2^{-k}$, which would be minima (maxima). Intermediate extrema above or below $S = xs^2$ would be maxima (minima).

Chapter 7

Some questions about coupling constant evolution

7.1 Introduction

In this article questions related to the notions of the p-adic CCE and hierarchy of Planck constants will be considered.

7.1.1 How p-adic primes are determined?

p-Adic length scale (PLS) hypothesis plays a central role in TGD in all length scales. For instance, it makes it possible to use simple scaling arguments to deduce quantitative predictions for the masses of new particles predicted by TGD.

PLS hypothesis states that the size scales of space-time surfaces correspond to PLSs $L_p = \sqrt{p}R(CP_2)$. The additional hypothesis is $p \simeq m^k$, $m = 2, 3, ...$ a small prime. The success of p-adic mass calculations [K63] supports $p \simeq 2^k$ hypothesis [K76] seriously. There also exists empirical evidence for a possible generalization to small primes, in particular $m = 3$, in biology [I15, I16].

The physical and mathematical identification of the origin of the p-adic prime p defining the PLS is however a problem.

The proposal has been that the p-adic prime p defining the PLS corresponds to a ramified prime of the extension of rationals (EQ) associated with the polynomial defining space-time region in M^8 picture. Ramified primes appear as factors of the discriminant of the polynomial defining EQ. I have not been able to find any really convincing explanation for why p should correspond to a ramified prime so that p-dic prime might emerge in some other way.

In p-adic thermodynamics Boltzmann weights $exp(-E/T)$ must be replaced with $p^{L_0/T}$, where L_0 is scaling generator. The exponent $\Omega = exp(K)$ of the Kähler function K of WCW defines vacuum functional. Could Ω be number-theoretically universal and thus exist as a p-adic number for some prime p determining naturally the PLS. This is the case if one has $\Omega = p^n$, n integer.

As such, this idea does not make sense but one consider a subsystem defined by sub-CD defining self in zero energy ontology (ZEO) based theory of consciousness [L84, L108] [K119]?

p-Adic prime defines naturally the scale of CD for trivial extension of rationals and this scale is scaled up by factor n for an extension of dimension n. This also conforms with the assumption that p-adic CCE and "dark" CCE are independent.

7.1.2 Trying to understand p-adic CCE

TGD leads to a number theoretic vision about CCE [L62]. Number theoretic universality plays a key role in this picture. CCE certainly involves the hierarchy of extensions of rationals (EQs) possibly involving non-rational extensions by roots of e, which induce finite extensions of p-adics. It would be nice if the EQ alone would determine the values of the coupling constants.

1. The starting point is that the continuous CCE with respect to length scale reduces to a discrete PLS evolution with respect to L_p, $p \simeq 2^k$. There is also dark evolution with respect to $n = h_{eff}/h_0$. These evolutions are separate since the scaling of the roots of the polynomial do not affect the purely algebraic properties of the extension. The natural assumption is that these evolutions factorize so that one has $\alpha_K = g_K^2(p)/2h_{eff}$.

2. p-Adic CCE would be roughly logarithmic with respect to L_p. The observation that α is near $\alpha = 1/137$ for p-adic length scale $L(137)$ suggests that for α_K defining the fundamental coupling strength one has

$$\alpha_K = \frac{g_K^2(max)}{2kh_{eff}} \quad .$$

Since $1/\alpha_K(137) = 137$ is prime for ordinary matter with $h_{eff} = h$, one must have

$$\frac{g_K^2(max)}{2h} = 1 \quad .$$

giving $h = g_K^2(max)/2$. The value h need not however be the minimal value h_0 of h_{eff} since one can have $h = n_0 h_0$ $\alpha_K(max) = 2n_0$ so that one can write

$$\alpha_K = \frac{1}{knn_0} \quad . \tag{7.1.1}$$

$n_0 > 1$ would mean that the ordinary matter would be actually dark in the sense that the order of the extension of rationals associated with the ground state would be n_0.

For h_0 that value of α_K could be so large that the perturbation series does not converge except in very long length scales for which k is expected to be large. Exotic phases with $h_{eff} < h$ could become possible in these scales.

7.1.3 How p-adic prime is defined at the level of WCW geometry?

The p-adic prime p should emerge from the dynamics defined by Kähler function.

1. The Kähler function K of the "world of classical worlds" (WCW), or more generally the generalization of $exp(K)$ to a vacuum functional possibly involving also a genuine state dependent part is a central quantity concerning scattering amplitudes. Suppose that one can consider a subsystem defined by CD and the contribution ΔK from CD to K.

   Number theoretical universality suggests that the exponential $exp(\Delta K)$ or its appropriate generalization exists in all p-adic number fields or at least in an extension of the p-adic number field corresponding to the p-adic prime p. Could this condition fix p dynamically?

2. Suppose that for some prime p one can write

$$e^{\Delta K} = p^{\frac{\Delta K}{log(p)}}$$

   such that $\Delta K/log(p)$ is integer. The exponential would be a power of p just as the p-adic analog of Boltzmann weight in p-adic thermodynamics [K63]. This would select a unique p-adic prime p defining the PLS and this prime need not be a ramified prime. In p-adic thermodynamics [K63] $X = \Delta K/log(p)$ has interpretation as an eigenvalue of the scaling generator L_0 of conformal algebra and one can even consider the possibility that there is a connection.

7.1.4 What about the evolution of the gravitational fine structure constant?

Nottale hypothesis [E87] predicts gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ ($\beta_0 = v_0/c$ is velocity parameter), which has gigantic values so that the above picture fails. Gravitational fine structure constant is given by $\alpha_{gr} = \beta_0/4\pi$.

Kepler's law $\beta^2 = GM/r = r_S/2r$ suggests length scale evolution $\beta^2 = xr_S/2L_N = \beta_{0,max}^2/N^2$, where x is proportionality constant, which can be fixed. Phase transitions changing β_0 are possible at $L_N/a_{gr} = N^2$ and these scales correspond to radii for the gravitational analogs of the Bohr orbits of gravitational Bohr atom. PLS hierarchy is replaced by that for the radii of Bohr orbits.

What could be the interpretation of N? The safest assumption is that the CCE of β_0 is analogous to that of the other coupling constants and induced from that of α_K.

7.1.5 What is the minimal value of h_{eff}?

The formula $h_{eff} = nh_0$ involves the minimal value h_0 of h_{eff}. The simplest explanation for the findings of Randell Mills [D4] is that one has $h = 6h_0$. h_0 could be also smaller [L23].

What is the value of h_0? A possible answer to this question came from the observation made already during the first 10 years of TGD. The observation was that the imbeddings of spherically symmetric stationary metrics (see the Appendix) suggest that CP_2 radius R is of order Planck length l_P rather than by factor about $10^{7.5}$ longer. Could one have $h = n_0h_0$, $n_0 \sim 10^{7.5}$ so that the ordinary matter would be actually dark?

CP_2 radius would be Planck length apart from numerical constant not far from unity. The p-adic mass calculations would give correct results for $h_{eff} = h_0$. R could be interpreted as $R^2 = n_0 l_P^2$. The perturbative expansion for $h_{eff} < h$ would not converge except in long p-adic length scales, where the p-adic evolution reduces the value of α_K.

Gauge coupling strengths are predicted to be practically zero at gravitational flux tubes with very large h_{eff} so that only gravitational interaction is effectively present. This conforms with the view about dark matter.

7.2 Number theoretical universality of vacuum functional and p-adic CCE

The Kähler geometry of WCW is defined by a Kähler function $K(X^4(X^3))$ identified as the action of preferred extremal consisting of volume term and Kähler action. The vacuum functional is of form $\Omega = exp(K + iS)$. Here K is the real Kähler function and S is the counterpart of real action in the path integral of QFTs.

$exp(iS)$ could be interpreted as a dynamical part of vacuum functional, which depends on state rather than being "God-given". The reason why this would be the case would be that it is possible. For $exp(K)$ there is no choice since the Kähler geometry of WCW is expected to be unique merely from its existence as already in the case of loop spaces [?].

Number theoretical universality is a challenge for this general picture.

1. In the p-adic context the notion of WCW geometry is highly questionable. The integration associated with definition of volume term and Kähler action is the tough problem.

   This has inspired the proposal that the exponent of the action completely disappears from the scattering amplitudes. This indeed happens in quantum field theory based on path integral around stationary point.

2. The classical nondeterminism suggests a weaker formulation. The sum over the contributions of stationary points would be replaced by integral over preferred extremals consisting of 3-surfaces at PB plus sum over the paths of the tree resulting from classical non-determinism.

   The sum over the paths of the tree-like structure remains in the superposition of amplitudes for sub-CD and it might be possible to define the deviation $\Delta K + i\Delta S$ of the action for each of them and separate $exp(\Delta K + i\Delta S)$ from the entire exponent of action, which would therefore disappear from the expression of the scattering amplitudes for given X^3 and given CD. Otherwise, the knowledge of the entire WCW Kähler function would be needed.

A possible interpretation is in terms of a decomposition to an unentangled tensor product corresponding to sub-CD and its environment so that one can separate the physics inside sub-CD from that of environment and code it by $exp(\Delta K + i\Delta S)$.

3. The simplest option, very probably too simple, would be that one has $\Delta K = 0$. Kähler function would be same for all paths of the tree and one would obtain a discretized analog of path integral. This would require that all the branches of the tree have same value of action. This does not however require the same value of volume and Kähler action separately.

   It will be foud that $\Delta K \neq 0$ assuming that $exp(\Delta K)$ reduces to an integer power of p for some prime identifiable as p-adic prime defining the PLS, is more interesting option since it would reduce p-adic thermodynamics to the level of WCW and also allow to the understand of PLS evolution of couping constants.

   The number theoretical existence of the phases $exp(i\Delta S)$ would require that they belong to the EQ defining the space-time region inside CD.

4. This picture suggests that the number theoretically universal part is associated with the sub-CDs and with the discrete physics of the tree-like structure whereas the Kähler function for 3-surfaces would be defined only in real framework. This would neatly separate the physics of sensory and Boolean cognition as something number theoretically universal from the physics proper, so to say.

   Since conscious experience gives all information about physics, one can ask whether the adelic physics associated with various sub-selves could together be enough to represent all that is representable from the physics proper. This could result as somekind of limiting case (EQ approaches algebraic numbers).

If this view is correct, then one expects that various notions shared by QFTs and TGD, in particular CCE, could have number theoretic descriptions as indeed suggested [L62]. In the sequel I will discuss some speculations in this framework.

7.2.1 The recent view about zero energy ontology

Zero energy ontology (ZEO) [K119] [L84, L108] plays a key role in the formulation of TGD based quantum measurement theory.

1. The concept of causal diamond (CD) is central. CD serves as a correlate for the perceptive field of conscious entity: this in the case that one has sub-CD so that the space-time surfaces inside CD continue outside it.

   The scale size scale of the CD identifiable as the temporal distance T between its tips could be proportional the p-adic prime p at the lowest level of dark matter hierarchy and to np at dark sectors. p-Adic length scales L_p characterizing the sizes scale of 3-surfaces are proportional to $\sqrt{p}$ and the proposal is that the relation between T and L_p is same as the relationship between diffusion time T and the root mean square distance R travelled by diffusion.

2. The twistor lift of TGD predicts that the action principle defining space-time surfaces is the sum of a volume term characterized by length scale dependent cosmological constant Λ and Kähler action and induced from 6-D Kähler action whose existence fixes the embedding space uniquely to $M^4 \times CP_2$. The reason is that the required Kähler structure exists only for the twistor spaces of M^4, E^4, and CP_2 [?].

3. The recent progress in the understanding of zero energy ontology (ZEO) [L108] leads to rather detailed view about the dynamics of the space-time surfaces inside sub-CD.

   Space-time surfaces are analogs of soap films spanned by a frame having the 3-surfaces at its ends located at the boundary of CD as fixed part of frame and the dynamically generated parts of frame in the interior of CD. Outside the frame preferred extremal is an analog of a complex surface and a simultaneous extremal of both volume term and Kähler action since the field equations reduce to conditions expressing the analogy of holomorphy [L43, L64]. The field equations reduce to contractions of tensors of type (1,1) with tensors of type (2,0)+(0,2) and are therefore trivially true.

The minimal surface property fails at the frame, and only the full field equations are true. The divergences of isometry currents associated with volume term have delta function singularities which however cancel each other to guarantee field equations and conservation laws. This is expected to give rise to a failure of determinism, which is however finite in the sense that the space-time surfaces associated with given 3-surface X^3 at the passive boundary of CD (PB) form a finite set which is a tree-like structure (for a full determinism only single space-time surface as analog of Bohr orbit would be realized). Therefore the non-determinism of classical dynamics for a fixed X^3 is extremely simple and quantum dynamics and classical dynamics are very closely related since quantum states are superpositions of the paths of the tree.

4. One also ends up to quite precise identification sub-CD or space-time surface inside sub-CD as a correlate of perceptive field of a conscious entity. The essential element of the picture that for sub-CD the 3-surface X^3 at PB is fixed but due to the non-determinism the end at active boundary (AB) is not completely fixed and there is finite non-determinism in the state space defined by superpositions of the paths of the tree.

   For the highest level in the hierarchy of CDs associated with self, the space-time surfaces inside CD do not continue outside it and this CD God-like entity, whose dynamics is not restricted by the boundary conditions.

This view provides additional perspectives on discreteness of adelic physics unifying the physics of sensory experience and cognition [L42, L41].

1. Discreteness is essential in the number theoretic universality since in these case real structures and their p-adic counterparts correspond naturally to each other. This has led to the notion of cognitive representation as a set of points of space-time surface with preferred embedding space coordinates having values in the EQ defined by the polynomial defining the space-time surface in complexified M^8 and mapped to H by $M^8 - H$ duality [L91, L92]. The finite-dimensionality of the state space associated with the tree structure conforms with this vision.

2. Discreteness is natural for the dynamics of concious experience and cognition. Mental images as sub-selves correspond to the sub-CDs inside CD. Sub-CDs are naturally located at the loci of non-determinism defined by the fixed part of the frame dynamically and generated frames in the interior and at AB.

   Attention would fix the 3-surfaces at the PB of a sub-CD as a perceptive sub-field and all CDs in the hierarchy would be fixed in this manner. The loci of non-determinism would serve as targets of attention. Sensory perception, memory recall, and other functions would reduce to directed attention inside CD.

   Fermionic degrees of freedom at boundaries of CD are are additional discrete degrees of freedom and responsible for Boolean cognition whereas the discrete dynamics of frame would correspond to sensory experience and sensory aspects of cognition.

3. This picture inspires the question whether the number theoretically universal parts of adelic physics might relate to the physics due to the non-determinism in the interior of sub-CD. This physics would be basically the physics that can be observed. This would mean enormous simplification.

   This idea is not new. The amazing success of p-adic thermodynamics based mass calculations [K63] could be understood if p-adic physics is seen as a physics of cognitive representation of real number based physics.

In the sequel some speculations are discussed by taking the above picture as a basis.

7.2.2 Number theoretical constraints on $exp(\Delta K)$

Number theoretical universality suggests that the exponents $exp(\Delta K + i\Delta S)$ for X^4 inside sub-CD is well-defined at least for some p-adic number fields or their extensions.

It has been already found that number theoretical universality requires that the phases $exp(i\Delta S)$ belong to the EQ associated with the space-time surfaces considered.

The condition that the phase is a root of unity is more general than the condition of semi-classical approximation of wave mechanics stating that the action is quantized as a multiple of Planck constant h. The analog of this condition would imply $exp(i\Delta S) = 1$. This quantization condition would make S obsolete.

What about the number theoretical universality of $exp(\Delta K)$? One can consider three options.

1. p-Adic exponent function $exp(x)$ exists if the p-adic norm of x is smaller than 1. The problem is that the p-adic exponent function and its real counterpart behave very differently [K73]. In particular, $exp(x)$ is not periodic. Integer powers of e^p are however ordinary p-adic number by its Taylor series and roots of e define finite-D extensions of p-adic number fields. Therefore $exp(\Delta K)$ could make sense as an integer power for a root of e.

   If ΔK is integer, $exp(\Delta K)$ exists p-adically for primes p dividing ΔK.

2. Also $p^{\Delta K/log(p)}$ could exist p-adically if $\Delta K/log(p)$ is integer. This implies strong conditions. ΔK must be of form $\Delta K = log(p)m$, m integer. If ΔK corresponds to Kähler function of WCW, p is fixed and would define the sought-for preferred p-adic prime p defining the PLS.

3. Since the powers p^n converge to zero for $n \rightarrow \infty$, one can formally replace $exp(\Delta K)$ with $exp(\Delta K) = p^{\Delta K)/log(p)}$ and require that the exponent is an integer. The replacement of the ordinary Boltzman weights with powers of p is indeed carried out in p-adic thermodynamics [K63]. This suggests that the Boltzman factors of p-adic thermodynamics reduce to exponents $p^{\Delta K}$ at the level of WCW.

7.3 Hierarchy of Planck constants, Nottale's hypothesis, and TGD

7.3.1 Nottale's hypothesis

Nottale's hypothesis [E87] and its generalization to TGD [K93, K11] has non-relativistic and relativistic forms.

1. The non-relativistic formula for $\hbar_{gr}$ as given by the Nottale's formula

$$\begin{aligned} \hbar_{gr} &= \frac{GMm}{\beta_0} \ , \\ \alpha_{gr} &= \frac{GMm}{4\pi\hbar_{gr}} = \frac{\beta_0}{4\pi} \ . \end{aligned} \tag{7.3.1}$$

   The formula makes sense only $\hbar_{gr}/\hbar > 1$.

2. The relativistically invariant formula for $\hbar_{gr}$ reads for four momenta $P = (M, 0)$ $p = (E, p_3)$ as:

$$\hbar_{gr} = \frac{GP \cdot p}{\beta_0} = \frac{GME}{\beta_0} = \frac{r_s E}{2\beta_0} \ , \tag{7.3.2}$$

   where r_s is Schwartschild radius. Adelic physics implies that momentum components belong to an extension of rationals defining the adele so that the spectrum of E and of $\hbar_{gr}$ are discretized.

Nottale's hypothesis and biology

Nottale's hypothesis involves a lot of uncertainties also at the conceptual level. Hence it is important to see whether basic facts from TGD inspired biology support the Nottale's hypothesis.

1. The cyclotron frequencies in an "endogenous" magnetic field $B_{end} = 2B_E/5$, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic emerge in the explanation of the findings of Blackman and other [J2] showing that ELF photons have effects on vertebrate brain. B_{end} is assigned with the monopole flux tubes of B_E. Also lower and higher values of B_{end} can be considered and the models of hearing [K87] and genetic code [L8] suggests that the values of B_{end} correspond to the notes of 12-note scale. This suggests that also the Z^0 magnetic field might be involved.

2. Biophoton energies are in visible and UV range and in the TGD based model they are assumed to result in the transformations of dark photons with much smaller frequency but same energy to ordinary photons. For instance, photons with 10 Hz frequency can transform to biophotons. By $E = h_{eff}f$, requires $h_{eff} = h_{gr}$. The implication is that cyclotron energies do not depend on particle mass. Furthermore, Schwartschild radius $r_S = .9$ cm of Earth defines universal gravitational Compton length for $\beta_0 = 1/2$.

Assume that $\hbar_{gr}$ corresponds to Earth mass and $\beta_0 = 1/2$ and consider cyclotron states in $B_{end} = .2$ Gauss.

1. The value of $r = \hbar_{gr}/\hbar$ for proton is given as the ratio r_s/L_p, where L_p is the Compton radius of proton. This gives $r = .833 \times 10^{13}$. For ions with mass number A the value of r is scaled to Ar.

2. What is the cyclotron energy associated with the 10 Hz frequency in this case? The energy of a photon with frequency f is for $\hbar_{gr}(m_p)$ given by $E_c/eV = r \times 1.24 \times (f/(3 \times 10^{14} Hz)$. Proton's cyclotron frequency is $f_c = 300$ Hz in B_{end} and corresponds to 10 eV, which is in the UV region and rather large.

3. All cyclotron frequencies of charged particles correspond to $E_c = 10$ eV cyclotron energy, which seems rather large. If $\hbar_{gr}$ is reduced by factor 1/4 as required to explain the findings of Mills at least partially, the cyclotron energy becomes 2.5 eV, which is in the visible range. Scaling by factor 1/2 gives cyclotron energy 5 eV in UV.

4. Smaller values of E_c would require smaller fields. The Z_0 charge of proton is roughly a fraction 1/50 of its em charge and since Kähler field contributes also to Z^0 field one would obtain energy about .2 eV in the IR region.

10 Hz alpha frequency which is of special interest concerning understanding of conscious experience and it is interesting to look for concrete numbers.

1. $f = 10$ Hz is alpha frequency and the cyclotron frequency $f_c = 10$ eV Fe^{2+} ion with mass number $A = 56$. Fe^{2+} ions play a central role in biology.

2. For $f = 10$ Hz the energy $\hbar_{gr}(m_p)$ (proton) is .333 eV to be compared with the metabolic energy currency $\sim .5$ eV and is below the visible range.

3. In the TGD inspired biology, 3 proton units represent dark genetic codons and for $\hbar_{gr}(3m_p)$ the energy corresponds to $E \times 1$ eV, which is still slightly below the visible range [L148, L95, L103]. In the dark variant of double DNA strand parallel to the ordinary double strand, the 2 dark codons form a pair by the dark variant of the base pairing so that one has effective $A06$ and $E = 2$ eV, which corresponds to red light.

4. The energy $E = 2$ eV of the codon pair for $f = 10$ Hz corresponds formally to $A = 6$ and would characterize ^6Li. Litium's cyclotron frequency is around $f_c = 50$ Hz is known to have biological significance. Li is used in the treatment of depression [L53]. One might imagine that the coupling of Lithium to dark codon pairs might be involved.

5. For higher mass numbers, the energies for 10 Hz and $\hbar_{gr}(Am_p)$ belong to the UV region. For oxygen one with $A = 16$ has $E = 5.3$ eV, which could correspond to some important molecular transition energy. Molecular bond dissociation energies (`https://cutt.ly/3QoZxY9`) vary in the range .03 -10 eV. O-H, O=O ad O=CO bond energies are somewhat above 5 eV. The idea indeed is that the transformation of dark photons to ordinary bio-photons allows a control of molecular biochemistry.

6. DNA codons have charge proportional to mass and in a good approximation one has $f_c(DNA) = 1$ Hz independently of the length of the DNA strand. For $\hbar_{gr}(Fe^{++})$ $f_c(DNA)$ would correspond to $E = 1.86$ eV in the range of visible energies.

7.3.2 Trying to understand $\hbar_{eff}$ and $\hbar_{gr}$

Although $\hbar_{eff}$and $\hbar_{gr}$ have become an essential part of quantum TGD, there are still many poorly understood aspects related to them.

Should one introduce a hierarchy of poly-local Planck constants?

The ordinary Planck constant is a universal constant and single-particle entity and serves as a quantization unit for local charges. $\hbar_{gr}$ depends on the masses of the members of the interacting systems and a bi-local character. This suggests that one should not mix these notions.

Both $\hbar_{gr}$ and its possible generalization to gauge interactions such as $\hbar_{em}$, would depend on the charges of the interacting particles. If they serve as charge units, the charges must be bilocal.

Should one introduce a hierarchy of poly-local Planck constants? Later a possible interpretation in terms of Yangian symmetries [?] [B30, B19], which involve poly-local charges, will be considered. Each multi-local contribution to charge would involve its own Planck constant determined number theoretically.

Standard quantization rules for observables use $\hbar$ as a basic unit. Should one modify these rules by replacing $\hbar$ with (say) $\hbar_{em} = q_1q_2e^2/\alpha$ for $q_1q_2\alpha \geq 1$? Could these rules hold true at magnetic flux tubes characterized by $\hbar_{em}$? Could the charge units for the matter in the non-perturbative phase be q_1q_2-multiples of the ordinary basic units? Could one find empirical evidence for the scaling up of the quantization unit in non-perturbative phases?

In order to avoid total confusion, one must distinguish clearly between the single particle Planck constant and its 2-particle and n-particle variants as Yangian picture suggests. One must also distinguish between p-adic CCE as a discrete counterpart of ordinary CCE and dark coupling constant evolution.

The counterpart of $\hbar_{gr}$ for gauge interactions

The gauge couplings g_i for various interactions disappear completely from the basic formulation of TGD since they are automatically absorbed into the definition of the induced gauge potentials. Hence $\beta_0/4\pi \equiv \alpha_K$ appears as a coupling parameter in the perturbative expansion based on the exponent of Kähler function. $\hbar$ or $\hbar_{eff}$ appear as charge unit only in the definition of conserved charges as Noether charges but not in the action exponential.

The generalization of the Nottale formula to other interactions is not quite obvious. Two-particle Planck constant $h_{eff}(2)$ is in question and GMm would be replaced with the product $q_1q_2g_i^2$. Since α_K determines all other coupling strengths so that it is enough to consider it.

The parameter $\beta_0/4\pi$ is analogous to fine structure constant since gravitational perturbative expansion is in powers of it [K93] [L106].

β_0 is the gravitatoinal counterpart of the dimensionless coupling strength α_K defined in the QFT framework as a derived quantity $\alpha_K = g_K^2/4\pi$ but identified in the TGD context as the fundamental parameter appearing in Kähler action.

In TGD e does not appear as gauge coupling at the fundamental level (as opposed to QFT limit) but one can *define* e^2 as $e^2 = 4\pi\alpha\hbar$. α would obey p-adic CCE and $\hbar$ would be universal constant at single particle level. For dark phases, for which one has $h_{eff} > h$, $\alpha(1) \propto 2/n$, n dimension of the extension would hold true.

Consider the analog of the Nottale formula for em interactions. The coupling strength would be $q_1q_2e^2$ and for $q_1q_2e^2\alpha > 1$, one would have

$$\hbar_{em}(2) = \frac{q_1 q_2 e^2}{\beta_0} \quad . \tag{7.3.3}$$

This would give $\alpha_{em}(2) = \beta_0$. For $\beta_0 = \alpha$, one would obtain a coupling parameter α instead of $q_1 q_2 \alpha$ and the interpretation would be in terms of a transition to non-perturbative phase.

Does this phase transition correspond to a transition to dark phase? Could one interpret the phase transition by saying the dimension of extension is scaled by $n = \hbar_{em}(2)/\hbar$ identified as scaling of the dimension of extension of rationals?

Number theoretic vision predicts that in the dark evolution h_{eff} scales as n, the dimension of extension of rationals for all values of particle number in the definition of $h_{eff}(h)$ so that the single particle coupling constant strength would behave like $1/n$.

Charge fractionalization and the value of $\hbar_{eff}$

$\hbar_{eff} < \hbar$ implies charge fractionalization at the level of embedding space. This inspires the question whether an analog of fractional quantum Hall effect could be in question. This is not the case.

1. The TGD based model for anyons [K81] relies on the observation that the unit for the fractional quantization of transverse conductance in fractional quantum Hall effect (FQHE) as

$$\begin{aligned} \sigma &= \nu \times \frac{e^2}{h} \quad , \\ \nu &= \frac{n}{m} \quad . \end{aligned} \tag{7.3.4}$$

   The proposal is that FQHE could be understood as integer quantum Hall effect corresponding to $n \to kn$ for $h_{eff} = km\hbar$. $k = 1$ is the simplest possibility. Interestingly, the observed values of m are primes [D1]: they would correspond to simple Galois groups Z_p in the TGD framework.

2. The fractionalization of charges could be understood at space-time level by noticing that n-sheetedness can be realized as analog of analytic function $z^{1/n}$. n full 2π turns are needed to return to the original point at space-time level so that it is possible to have fractional spin as multiples of $\hbar/n$. The many-particle states however have half-integer spin always since they correspond to representations of the Lorenz group as a symmetry group of $M^4 \times CP_2$. The action of rotations by multiples of 2π would correspond to the action of the Galois group.

   These two apparently conflicting mechanisms of charge fractionization correspond to two views about symmetries: either their act at the level of the embedding space or of space-time.

3. For $GMm/v_0 < \hbar$ one would have formally $\hbar_{eff} < \hbar$. Could this option make sense and give rise to a charge fractionalization? One can argue that for $\hbar_{gr} < \hbar_0$, $\hbar_0$ serves as the quantization unit and holds at the level of ordinary matter. This would give a condition $GMm \leq \beta_0$ to the product Mm of the masses involved.

   A stronger condition would hold true at single particle level and state $M/M_{Pl} \geq \sqrt{\beta_0}$ (or $M/M(CP_2) \geq \sqrt{\beta_0}$) for both masses involved. Dark quantum gravity would hold true only above Planck masses. In applications to elementary particle level this would require quantum coherent states of particles with total mass not smaller than Planck mass. Interestingly, a water blob with the size of a large cell has this size for $\beta_0 = 1/2$ [L90].

What does the dependence of $\hbar_{gr}$ on particle masses mean?

$\hbar_{gr}$ depends on two masses. How could one interpret this geometrically?

1. The interpretation has been that a particle with energy E (and mass m) experiences the gravitational field of mass M via gravitational flux tubes characterized by $h_{gr} = GME/v_0$ so that every particle has its specific gravitational flux tubes.

2. Could the thickness of the gravitational flux tubes correspond to the ordinary Compton length λ_c or gravitational Compton length $\lambda_{gr} = GM/v_0$? λ_c decreases with mass and λ_{gr} looks a more reasonable option concerning gravitational interaction.

3. At least static gravitational fields are analogous to static electric fields and in many-sheeted space-time the voltages as analogs of gravitational potential difference are the same along different space-time sheets. The same should hold for gravitational potential.

   Could one assume that gravitational potential has almost copies at all parallel sheets of the many-sheeted space-time (parallel with respect to M^4). Could these sheets correspond to different particle masses so that a particle with a given mass would have its own space-time sheet to represent its interactions with the central mass M.

4. These classical fields would be somehow represented by Kähler magnetic flux tubes carrying generalized Beltrami fields [B11, B41, B29, B32] having also an electric part.

   Could these flux tubes somehow also represent the classical gravitational field? Could the electric part for the induced M^4 Kähler form predicted by the twistor lift of TGD [L43, L64] giving rise to CP breaking, give a representation for the gravitational potential? Could this concretely realize the analogy between gravitation and electromagnetism?

5. A possible realization of this picture would be a fractal structure consisting of flux tubes within flux tubes emanating from the central mass. The radii of the flux tubes would decrease with m as long as $GMm/\beta > \hbar$ holds true. For smaller masses, the flux tube radius would correspond to Compton length.

   Fractal structures known as fractons (`https://cutt.ly/WRuXnrC`) are the recent hot topic of condensed matter physics (`https://cutt.ly/YQjqyjJ`. The explanation requires the replacement of the time evolution as a time translation with a scaling and condensed matter lattice would be replaced with fractal. These phases have exotic properties: in particular, thermal equilibrium need not be possible. There are also long range correlations due to fractality, which makes these phases ideal for quantum computation.

   In the TGD framework, the time evolutions between SSFRs are indeed generated by the scaling operator L_0 of super-conformal algebra and many-sheeted space-time is both p-adic and dark fractal. The hierarchy of Planck constants makes possible quantum coherence in all scales.

Yangian symmetry and poly-local Planck constants

The product structure of $\hbar_{gr}$ and $\hbar_{em}$ has remained a mystery since it suggests that it characterizes the interaction of 2 space-time sheets whereas the ordinary Planck constant serves as a quantization unit for single particle states. Instead of a Galois group for a single space-time sheet, one would have a product of Galois groups for the two space-time sheets determined as roots for the polynomials in the product. Therefore one should write $\hbar_{gr} = \hbar_{eff,2}$ to distinguish it from a single particle Planck constant $\hbar_{eff}(1) \equiv \hbar_{eff}$.

1. In the TGD framework, wormhole contacts connecting two space-time sheets with Minkowskian signature are indeed building bricks of elementary particles and fundamental fermions appearing as building bricks of elementary particles would be associated with the throats of the wormhole contact.

   Could the two Minkowskian sheets be microscopically k-sheeted entities with sheets parallel to M^4 and perhaps determined as roots of a polynomial of degree k and having Galois group with order m? The maximal Galois group would be S_k with $m = k!$.

The scaling of $\hbar_0 \rightarrow \hbar(2)$ would mean that the pairs of these space-time surface sheets decompose to $\hbar(2)/\hbar_0$ pairs as orbit of $Gal \times Gal$ contributing to various quantum numbers a contribution proportional $\hbar_{gr}(2)/\hbar_0 = n_1 n_2 = k_1 k_2 m^2$.

The quantization unit would be $\hbar_0(2)$ for 2-particle quantities such as relative angular momentum. Spin is however thought to be single particle observable. The ordinary phase has a single-particle Planck constant as $\hbar(1)/\hbar_0 = m$.

2. There is no obvious reason for excluding the values of single particle $h_{eff}(1)/h_0$, which are considerably smaller than m or even equal to the minimal value $h_{eff}(1) = h_0$: they would correspond to Galois groups with smaller orders than $m = k!$ of say S_k.

   These exotic particles would have charge and spin units considerably smaller than $\hbar = mh_0$. Why have they not been observed (the findings of Mills are a possible exception and anyonic charge fractionization seems to be a different phenomenon)? Are these space-time sheets somehow unstable? Does gravitation somehow select the Galois group of stable ground state space-time surface so that R as a fundamental length scale is replaced with l_P as effective fundamental length?

3. Yangian algebras [?] [B30, B19] involve besides single particle observables also $n > 1$-particle observables. Conserved charges have poly-local components which depend on n particles. Note that interaction energy represented as a potential energy is the simplest example about non-local 2-particle contribution to conserved energy.

   Yangian algebras are proposed to be central for TGD [L32] and would reflect the replacement of the space-time locality with locality at the level of "world of classical worlds" (WCW) due to the replacement of a point like with a 3-surface, which can also consist of disjoint parts. Yangian picture suggests that single-particle $\hbar$ has n-particle generalization. The possible number theoretical rule could be

$$\frac{\hbar_{gr,n}}{\hbar_0} = \prod_k n_k \quad , \tag{7.3.5}$$

   where n_k correspond to the orders of Galois groups associated with the space-time sheets involved.

7.3.3 Do Yangians and Galois confinement provide $M^8 - H$ dual approaches to the construction of the many-particle states?

The construction of many-particle states as zero energy states defining scattering amplitudes and S-matrix is one of the basic challenges of TGD. TGD suggests two approaches implied by physics as geometry and physics as number theory views to TGD. Geometric vision suggests Yangians of the symmetry algebras of the "world of classical worlds" (WCW) at the level of $H = M^4 \times CP_2$. Number theoretic vision suggests Galois confinement at the level of complexified M^8. Could these approaches be $M^8 - H$ duals of each other?

Yangian approach

The states would be constructed from fermions and antifermions as modes of WCW spinor field. An idea taking the notion of symmetry to extreme is that this could be done purely algebraically using generators of symmetries.

Consider first the construction of TGD analogs of single particle states as representations of symmetries.

1. For a given vacuum state assignable to a partonic 2-surface and identifiable as a ground state of Kac-Moody type representation, the states would be generated by Kac-Moody algebra. Also super-Kac-Moody algebra could be used to construct states with nonvanishing fermion and antifermion numbers. In the case of super symplectic algebra the generators would correspond to super Noether charges form the isometries of WCW and would have both fermionic and might also have bosonic parts.

2. The spaces of states assignable to partonic 2-surfaces or to a connected 3-surface is however still rather restricted since it assumes in the spirit of reductionism that the symmetries are local single particle symmetries. The first guess for many-particle states in this approach is as free states and one must introduce interactions in an ad hoc manner and the problems of quantum field theories are well-known.

3. In the TGD framework there is a classical description of interactions in terms of Bohr-orbit like preferred extremals and one should generalize this to the quantum context using zero energy ontology (ZEO). Classical interactions have as space-time correlates flux tubes and "massless extremals" connecting 3-surfaces as particle and topological vertices for the partonic 2-surfaces.

4. The construction recipe of many-particle states should code automatically for the interactions and they should follow from the symmetries as a polylocal extension of single particle symmetries. They should be coded by the modification of the usual tensor product giving only free many-particle states. One would like to have interacting many-particle states assignable to disjoint connected 3-surfaces or many-parton states assignable to single connected space-time surfaces inside causal diamond (CD).

Yangian algebras are especially interesting in this respect.

1. Yangian algebras have a co-algebra structure allowing to construct multi fermion representations for the generators using comultiplication operation, which is analogous to the time reversal of a Lie-algebra commutator (super algebra anticommutator) regarded as interaction vertex with two incoming and one outgoing particle. The co-product is analogous to tensor product and assignable to a decay of a particle to two outgoing particles.

2. What is new is that the generators of Yangian are poly-local. The infinitesimal symmetry acts on several points simultaneously. For instance, they could allow a more advanced mathematical formulation for n-local interaction energy lacking from quantum field theories, in particular potential energy. The interacting state could be created by a bi-local generator of Yangian. The generators of Yangian can be generated by applying coproducts and starting from the basic algebra. There is a general formula expressing the relations of the Yangian.

3. Yangian algebras have a grading by a non-negative integer, which could count the number of 3-surfaces (say all connected 3-surfaces appearing at the ends of the space-time surface at the boundaries of causal diamond (CD)), or the number of partonic 2-surfaces for a given 3-surface. There would also be gradings with respect to fermion and antifermion numbers.

There are indications that Yangians could be important in TGD.

1. In TGD, the notion of Yangian generalizes since point-like particles correspond to disjoint 3-surfaces, for a given 3-surface to partonic 2-surfaces, and for a partonic 2-surface to point-like fermions and antifermions. In the TGD inspired biology, the notion of dark genes involves communications by n-resonance. Two dark genes with N identical codons can exchange cyclotron 3N-photon in 3N-resonance. Could genes as dark N-codons allow a description in terms of Yangian algebra with N-local vertex? Could one speak of 3N-propagators for 3N cyclotron-photons emitted by dark codons.

2. In quantum theory, Planck constant plays a central role in the representations of the Lie algebras of symmetries. Its generalization assignable to n-local Lie algebra generators could make sense for Yangians. The key physical idea is that Nature is theoretician friendly. When the coupling strength proportional to a product of total charges or masses becomes so large that perturbation series fails to converge, a phase transition increasing the value of h_{eff} takes place. Could this transition mean a formation of bound states describable in terms of poly-local generators of Yangian and corresponding poly-Planck constant?

   For instance, the gravitational Planck constant $\hbar_{gr}$, which is bilocal and proportional to two masses to which monopole flux tube is associated, could allow an interpretation in terms of Yangian symmetries and be assignable to a bi-local gravitational contribution to energy momentum. Also other interaction momenta could have similar Yangian contributions and characterized by corresponding Planck constants.

It is not clear whether $\hbar_{gr}$ and its generalization can be seen as a special case of the proposal $h_{eff} = nh_0$ generalizing the ordinary single particle Planck constant or whether it is something different. If so, the hierarchy of Planck constant would correspond to a hierarchy of polylocal generators of Yangian.

Galois confinement

The above discussion was at the level of $H = M^4 \times CP_2$ and "world of classical worlds" (WCW). $M^8 - H$ duality predicts that this description has a counterpart at the level of M^8. The number theoretic vision predicting the hierarchy of Planck constants strongly suggests Galois confinement as a universal mechanism for the formation of bound states of particles as Galois singlets.

1. The simplest formulation of Galois confinement states that the four-momenta of particles have components which are algebraic integers in the extension of rationals characterizing a polynomial defining a 4-surface in complexified M^8, which in turn is mapped to a space-time surface in $H = M^4 \times CP_2$, when the momentum unit is determined by the size of causal diamond (CD).

   The total momentum for the bound state would be Galois singlet so that its components would be ordinary integers: this would be analogous to the particle in box quantization. Each momentum component "lives" in n-dimensional discrete extension of rationals with coefficient group, which consists of integers.

   In principle one has a wave function in this discrete space for all momentum components as a superposition of Galois singlet states. The condition that total momentum is Galois singlet forces an entanglement between these states so that one does not have a mere product state.

2. Galois confinement poses strong conditions on many-particle states and forces entanglement. Could Galois confinement be $M^8 - H$ dual of the Yangian approach?

7.3.4 h/h_0 as the ratio of Planck mass and CP_2 mass?

Could one understand and perhaps even predict the value of h_0? Here number theory and the notion of n-particle Planck constant $h_{eff}(n)$ suggested by Yangian symmetry could serve as a guidelines.

1. Hitherto I have found no convincing empirical argument fixing the value of $r = \hbar/\hbar_0$: this is true for both single particle and 2-particle case.

   The value $h_0 = \hbar/6$ [L23] as a maximal value of $\hbar_0$ is suggested by the findings of Randell Mills [D4] and by the idea that spin and color must be representable as Galois symmetries so that the Galois group must contain $Z_6 = Z_2 \times Z_3$. Smaller values of h_0 cannot be however excluded.

2. A possible manner to understand the value r geometrically would be following. It has been assumed that CP_2 radius R defines a fundamental length scale in TGD and Planck length squared $l_P^2 = \hbar G = x^{-2} \times 10^{-6} R^2$ defines a secondary length scale. For Planck mass squared one has $m_{Pl}^2 = m(CP_2, \hbar)^2 \times 10^6 x^2$, $m(CP_2, \hbar)^2 = \hbar/R^2$. The estimate for x from p-adic mass calculations gives $x \simeq 4.2$. It is assumed that CP_2 length is fundamental and Planck length is a derived quantity.

   But what if one assumes that Planck length identifiable as CP_2 radius is fundamental and CP_2 mass corresponds the minimal value h_0 of $h_{eff}(2)$? That the mass formula is quadratic and mass is assignable to wormhole contact connecting two space-time sheets suggests in the Yangian framework that $h_{eff}(2)$ is the correct Planck constant to consider.

One can indeed imagine an alternative interpretation. CP_2 length scale is deduced indirectly from p-adic mass calculation for electron mass assuming $h_{eff} = h$ and using Uncertainty Principle. This obviously leaves the possibility that $R = l_P$ apart from a numerical constant near unity, if the value of h_{eff} to be used in the mass calculations is actually $h_0 = (l_P/R)^2\hbar$. This would fix the value of $\hbar_0$ uniquely.

The earlier interpretation makes sense if $R(CP_2)$ is interpreted as a dark length scale obtained scaling up l_P by $\hbar/\hbar_0$. Also the ordinary particles would be dark.

h_0 would be very small and $\alpha_K(\hbar_0) = (\hbar/\hbar_0)\alpha_K$ would be very large so that the perturbation theory for it would not converge. This would be the reason for why $\hbar$ and in some cases some smaller values of h_{eff} such as $\hbar/2$ and $\hbar/4$ [D4] [L23] seem to be realized.

For $R = l_P$ Nottale formula remains unchanged for the identification $M_P = \hbar/R$.

For $R = l_P$ Nottale formula remains unchanged for the identification $M_P = \hbar/R$ (note that one could consider also $\hbar_0/R^2$ as natural unit of mass squared in the p-adic mass calculations).

Various options

Number theoretical arguments allow to deduce precise value for the ratio $\hbar/\hbar_0$. Accepting the Yangian inspired picture, one can consider two options for what one means with $\hbar$.

1. $\hbar$ refers to the single particle Planck constant $\hbar_{eff}(1)$ natural for point-like particles.

2. $\hbar$ refers to $h_{eff}(2)$. This option is suggested by the proportionality $M^2 \propto \hbar$ in string models due to the proportionality $M^2 \propto \hbar/G$ in string models. At a deeper level, one has $M^2 \propto L_0$, where L_0 is a scaling generator and its spectrum has scale given by $\hbar$.

   Since M^2 is a p-adic thermal expectation of L_0 in the TGD framework, the situation is the same. This also due the fact that one has In TGD framework, the basic building bricks of particles are indeed pairs of wormhole throats.

One can consider two options for what happens in the scaling $h_{eff} \rightarrow kh_{eff}$.

Option 1: Masses are scaled by k and Compton lengths are unaffected.

Option 2: Compton lengths are scaled by k and masses are unaffected.

The interpretation of $M_P^2 = (\hbar/\hbar_0)M^2(CP_2)$ assumes Option 1 whereas the new proposal would correspond to Option 2 actually assumed in various applications.

The interpretation of $M_P^2 = (\hbar/\hbar_0)M^2(CP_2)$ assumes Option 1 whereas the new proposal would correspond to Option 2 actually assumed in various applications.

For Option 1 $m_{Pl}^2 = (\hbar_{eff}/\hbar)M^2(CP_2)$. The value of $M^2(CP_2) = \hbar/R^2$ is deduced from the p-adic mass calculation for electron mass. One would have $R^2 \simeq (\hbar_{eff}/\hbar)l_P^2$ with $\hbar_{eff}/\hbar = 2.54 \times 10^7$. One could say that the real Planck length corresponds to R.

Quantum-classical correspondence favours Option 2)

In an attempt to select between these two options, one can take space-time picture as a guideline. The study of the embeddings of the space-time surfaces with spherically symmetric metric carried out for almost 4 decades ago suggested that CP_2 radius R could naturally correspond to Planck length l_P. The argument is described in detail in Appendix and shows that the $l_P = R$ option with $h_{eff} = h$ used in the classical theory to determine α_K appearing in the mass formula is the most natural.

Deduction of the value of $\hbar/\hbar_0$

Assuming Option 2), the questions are following.

1. Could $l_P = R$ be true apart from some numerical constant so that CP_2 mass $M(CP_2)$ would be given by $M(CP_2)^2 = \hbar_0/l_P^2$, where $\hbar_0 \simeq 2.4 \times 10^{-7}\hbar$ ($\hbar$ corresponds to $\hbar_{eff}(2)$) is the minimal value of $\hbar_{eff}(2)$. The value of h_0 would be fixed by the requirement that classical theory is consistent with quantum theory! It will be assumed that $\hbar_0$ is also the minimal value of $\hbar_{eff}(1)$ both $\hbar_{eff}(2)$.

2. Could $\hbar(2)/\hbar_0(2) = n_0$ correspond to the order of the product of identical Galois groups for two Minkowskian space-time sheets connected by the wormhole contact serving as a building brick of elementary particles and be therefore be given as $n_0 = m^2$?

Assume that one has $n_0 = m^2$.

1. The natural assumption is that Galois symmetry of the ground state is maximal so that m corresponds to the order a maximal Galois group - that is permutation group S_k, where k is the degree of polynomial.

   This condition fixes the value k to $k = 7$ and gives $m = k! = 7! = 5040$ and gives $n_0 = (k!)^2 = 25401600 = 2.5401600 \times 10^7$. The value of $\hbar_0(2)/\hbar(2) = m^{-2}$ would be rather small as also the value of $\hbar_0(1)\hbar(1)$. p-Adic mass calculations lead to the estimate $m_{Pl}/m(CP_2) = \sqrt{m}m(CP_2) = 4.2 \times 10^3$, which is not far from $m = 5040$.

2. The interpretation of the product structure $S_7 \times S_7$ would be as a failure of irreducibility so that the polynomial decomposes into a product of polynomials - most naturally defined for causally isolated Minkowskian space-time sheets connected by a wormhole contact with Euclidian signature of metric representing a basic building brick of elementary particles.

   Each sheet would decompose to 7 sheets. $\hbar_{gr}$ would be 2-particle Planck constant $h_{eff}(2)$ to be distinguished from the ordinary Planck constant, which is single particle Planck constant and could be denoted by $h_{eff}(1)$.

   The normal subgroups of $S_7 \times S_7$ $S_7 \times A_7$ and $A_7 \times A_7$, S_7, A_7 and trivial group. A_7 is simple group and therefore does not have any normal subgroups expect the trivial one. S_7 and A_7 could be regarded as the Galois group of a single space-time sheet assignable to elementary particles. One can consider the possibility that in the gravitational sector all EQs are extensions of this extension so that $\hbar$ becomes effectively the unit of quantization and m_{Pl} the fundamental mass unit. Note however that for very small values of α_K in long p-adic length scales also the values of $h_{eff} < h$, even h_0, are in principle possible.

   The large value of $\alpha_K \propto 1/\hbar_{eff}$ for Galois groups with order not considerably smaller than $m = (7!)^2$ suggests that very few values of $h_{eff}(2) < h$ are realized. Perhaps only $S_7 \times S_7$ $S_7 \times A_7$ and $A_7 \times A_7$ are allow by perturbation theory. Now however that in the "stringy phase" for which super-conformal invariance holds true, h_0 might be realized as required by p-adic mass calculations. The alternative interpretation is that ordinary particles correspond to dark phase with R identified dark scale.

3. A_7 is the only normal subgroup of S_7 and also a simple group and one has $S_7/A_7 = Z_2$. $S_7 \times S^7$ has $S_7 \times S^7/A_7 \times A_7 = Z_2 \times Z_2$ with $n = n_0/4$ and $S_7 \times S^7/A_7 \times S_7 = Z_2$ with $n = n_0/2$. This would allow the values $\hbar/2$ and $\hbar/4$ as exotic values of Planck constant.

   The atomic energy levels scale like $1/\hbar^2$ and would be scaled up by factor 4 or 16 for these two options. It is not clear whether $\hbar \rightarrow \hbar/2$ option can explain all findings of Randel Mills [D4] in TGD framework [L23], which effectively scale down the principal quantum number n from n to $n/2$.

4. The product structure of the Nottale formula suggests

$$n = n_1 \times n_2 = k_1 k_2 m^2 \quad . \tag{7.3.6}$$

   Equivalently, n_i would be a multiple of m. One could say that $M_{Pl} = \sqrt{\hbar/\hbar_0}M(CP_2)$ effectively replaces $M(CP_2)$ as a mass unit. At the level of polynomials this would mean that polynomials are composites $P \circ P_0$ where P_0 is ground state polynomial and has a Galois group with degree n_0. Perhaps S_7 could be called the gravitational or ground state Galois group.

7.3.5 Connection with adelic physics and infinite primes

The structure of $\hbar_{gr}$ and its electromagnetic counterpart $\hbar_{em}$ characterize 2-particle states whereas $\hbar$ characterizes single particle state. Yangian picture suggests that the notion of $\hbar_{eff}(n)$, $n = 1, 2, ..$ makes sense.

One can decompose a state consisting of N particles in several ways to partitions consisting of m subsets with n_i, $i = 1, ..., n$ in a given subset of particles. Could these subsets correspond to gravitationally bound states so that one can take these sets as basic entities characterized by masses and assume that gravitational interactions reduce to gravitational interactions between them and are quantal for $GM_iM_j/v_0 \geq \hbar$. Same question applied to electromagnetic, weak and color interactions.

Connection with adelic physics

This picture would have analog at the level of adelic physics [L91, L92, L104].

1. In the M^8 picture space-time surfaces correspond to "roots" of complexified octonionic polynomials obtained from irreducible real polynomials with rational (or perhaps even algebraic) coefficients. The dynamics realizes associativity of the normal space of the complexified space-time surface having 4-D space-time surface as real part mapped from M^8 to $H = M^4 \times CP_2$ by $M^8 - H$ correspondence.

2. One can consider irreducible polynomials of several variables such that the additional variables are interpreted as parameters [L97]. The parametrized set of polynomials defines a parametrized set of space-time surfaces and one can have a superposition of quantum states corresponding to irreducible polynomial of degree n and products of irreducible polynomials with sum of degrees n_i equal to n. This kind of parametrized set could define sub-spaces of the "world of classical worlds" (WCW).

3. Irreducibility fails for some parameter values forming lower-dimensional manifolds of the parameter space. The failure of the irreducibility means decomposition to a product of polynomials in which the set of roots decomposes to subsets R_i, which are roots of a rational polynomial with a lower degree n_i. Spacetime surface as a coherent structure decomposes to uncorrelated space-time surfaces with a discrete set of points as intersections. In this manner one obtains a decomposition of the parameter space to subsets of decreasing dimension. The generic situation has maximal dimension and dimension equal to that of the parameter space.

4. The catastrophe theory [?] founded by Rene Thom studies these situations. In catastrophe theory, the failure of the irreducibility is of very special nature and means that some roots of the polynomial co-incide and become multiple roots. For polynomials with rational coefficients, they would become multiple rational roots so that the degree of the polynomial determining the extension would be reduced by two units. This is discussed in detail from TGD point of view in [L97]. For polynomials with rational coefficients, typically complex conjugate roots become rational and the dimension of the algebraic extension is reduced.

5. The quantum state defined by the polynomial of several variables would be a superposition of space-time surfaces labelled by the points of the parameter space. It would decompose to subsets defining what is known as a stratification. The subsets for which the polynomial fails to be irreducible would have lower dimension. For polynomials with rational coefficients these sets would be discrete and it is not clear whether the lower-dimensional sets are non-empty in the generic case.

6. The decomposition to k irreducible polynomials with degrees n_i, $i = 1, ..., k$ would correspond to a decomposition of the space-time surface to separate space-time surfaces with $h_{gr,i} = n_i h_0 = GM_i m/v_0$ (same applies to h_{em}) satisfying $\sum n_i = n$. These would correspond to different decompositions of the total energy to a sum of energies E_i: $E = \sum E_i$. The irreducible polynomials with degree n_i could be interpreted as bound states for a subset of basic units. Maximal decomposition would correspond to $n_i = 1$ and have interpretation as a set of elementary particles with $h_{eff} = h_0$ (note that $h = 6h_0$ in the proposal inspired by the findings of Randel Mills [L23]).

Connection with infinite primes

The notion of infinite prime [K99] resonates with this picture.

1. The hierarchy of infinite primes has an interpretation as a repeated second quantization of supersymmetric arithmetic QFT. Polynomial primes of variable polynomials of single variable with rational coefficients follow ordinary primes in the hierarchy. Higher levels correspond to polynomial primes for polynomials of several variables and second quantization corresponds to the formation of polynomials of single variable with coefficients as polynomials of $n-1$ variables.

   Irreducible polynomials of higher than first order have interpretation as bound states whereas polynomials reducing to products of monomials correspond to Fock states of free particles.

2. The beatiful feature would be a number theoretic description of also bound states. The description of the particle decays as a failure of the irreducibility of the polynomials corresponding to infinite primes would extend this picture to the dynamics.

3. Second beautiful feature is the number theoretic description of particle reactions. Particle reactions with unentagled final states would naturally correspond to a situation in which the initial (prepared) and final (state function reduced) states are products of polynomials. Interaction period would correspond to an irreducible polynomial.

   This picture conforms with the proposal inspired originally by a model of "cold fusion". unnelling phenomenon crucial for nuclear reactions would correspond to a formation of dark phase in which the value of h_{eff} increases [L82, L31, L94]. This picture generalizes to all particle reactions.

7.4 How to understand coupling constant evolution?

In this section, the evolutions of Kähler coupling strength α_K and gravitational fine structure constant α_{gr} are discussed. The reason for restricting to α_K is that it is expected to induce the evolution of various gauge couplings, and could also induce the evolution of α_{gr}.

7.4.1 Evolution of Kähler coupling strength

The evolution of Kähler coupling strength $\alpha_K = g_K^2/2h_{eff}$ gives the evolution of α_K as a function of dimension n of EQ: $\alpha_K = g_K^2/2nh_0$. If g_K^2 corresponds to electroweak U(1) coupling, it is expected to evolve also with respect to PLS so that the evolutions would factorize.

Note that the original proposal that g_K^2 is renormalization group invariant was later replaced with a piecewise constancy: α_K has indeed interpretation as piecewise constant critical temperature

1. In the TGD framework, coupling constant as a continuous function of the continuous length scale is replaced with a function of PLS so that coupling constant is a piecewise constant function of the continuous length scale.

   PLSs correspond to p-adic primes p, and a hitherto unanswered question is whether the extension determines p and whether p-adic primes possible for a given extension could correspond to ramified primes of the extension appearing as factors of the moduli square for the differences of the roots defining the space-time surface.

   In the M^8 picture the moduli squared for differences $r_i - r_j$ of the roots of the real polynomial with rational coefficients associated with the space-time surfaces correspond to energy squared and mass squared. This is the case of p-adic prime corresponds to the size scale of the CD.

   The scaling of the roots by constant factor however leaves the number theoretic properties of the extension unaffected, which suggests that PLS evolution and dark evolution factorize in the sense that PLS reduces to the evolution of a power of a scaling factor multiplying all roots.

2. If the exponent $\Delta K/log(p)$ appearing in $p^{\Delta K/log(p))} = exp(\Delta K)$ is an integer, $exp(\Delta K)$ reduces to an integer power of p and exists p-adically. If ΔK corresponds to a deviation from the Kähler function of WCW for a particular path in the tree inside CD, p is fixed and $exp(\Delta K)$ is integer. This would provide the long-sought-for identification of the preferred

p-adic prime. Note that p must be same for all paths of the tree. p need not be a ramified prime so that the trouble-some correlation between n and ramified prime defining padic prime p is not required.

3. This picture makes it possible to understand also PLS evolution if ΔK is identified as a deviation from the Kähler function. $p^{\Delta K/log(p))} = exp(\Delta K)$ implies that ΔK is proportional to $log(p)$. Since ΔK as 6-D Kähler action is proportional to $1/\alpha_K$, $log(p)$-proportionality of ΔK could be interpreted as a logarithmic renormalization factor of $\alpha_K \propto 1/log(p)$.

4. The universal CCE for α_K inside CDs would induce other CCEs, perhaps according to the scenario based on Möbius transformations [L62].

Dark and p-adic length scale evolutions of Kähler coupling strength

The original hypothesis for dark CCE was that $h_{eff} = nh$ is satisfied. Here n would be the dimension of EQ defined by the polynomial defining the space-time surface $X^4 \subset M^8_c$ mapped to H by $M^8 - H$ correspondence. n would also define the order of the Galois group and in general larger than the degree of the irreducible polynomial.

Remark: The number of roots of the extension is in general smaller and equal to n for cyclic extensions only. Therefore the number of sheets of the complexified space-time surface in M^8_c as the number of roots identifiable as the degree d of the irreducible polynomial would in general be smaller than n. n would be equal to the number of roots only for cyclic extensions (unfortunately, some former articles contain the obviously wrong statement $d = n$).

Later the findings of Randell Mills [D4], suggesting that h is not a minimal value of h_{eff}, forced to consider the formula $h_{eff} = nh_0$, $h_0 = h/6$, as the simplest formula consistent with the findings of Mills [L23]. h_0 could however be a multiple of even smaller value of h_{eff}, call if h_0 and the formula $h_0 = h/6$ could be replaced by an approximate formula.

The value of $h_{eff} = nh_0$ can be understood by noticing that Galois symmetry permutes "fundamental regions" of the space-time surface so that action is n times the action for this kind of region. Effectively this means the replacement of α_K with α_K/n and implies the convergence of the perturbation theory. This was actually one of the basic physical motivations for the hierarchy of Planck constants. In the previous section, it was argued that $\hbar/h_0$ is given by the ratio R^2/l_P^2 with R identified as dark scale equals to $n_0 = (7!)^2$.

The basic challenge is to understand p-adic length scale evolutions of the basic gauge couplings. The coupling strengths should have a roughly logarithmic dependence on the p-adic length scale $p \simeq 2^{k/2}$ and this provides a strong number theoretic constraint in the adelic physics framework.

Since Kähler coupling strength α_K induces the other CCEs it is enough to consider the evolution of α_K.

p-Adic CCE of α from its value at atomic length scale?

If one combines the observation that fine structure constant is rather near to the inverse of the prime $p = 137$ with PLS, one ends up with a number theoretic idea leading to a formula for α_K as a function of p-adic length scale.

1. The fine structure constant in atomic length scale $L(k = 137)$ is given $\alpha(k) = e^2/2h \simeq 1/137$. This finding has created a lot of speculative numerology.

2. The PLS $L(k) = 2^{k/2}R(CP_2)$ assignable to atomic length scale $p \simeq 2^k$ corresponds to $k = 137$ and in this scale α is rather near to $1/137$. The notion of fine structure constant emerged in atomic physics. Is this just an accident, cosmic joke, or does this tell something very deep about CCE?

   Could the formula

$$\alpha(k) = \frac{e^2(k)}{2h} = \frac{1}{k}$$

   hold true?

There are obvious objections against the proposal.

1. α is length scale dependent and the formula in the electron length scale is only approximate. In the weak boson scale one has $\alpha \simeq 1/127$ rather than $\alpha = 1/89$.

2. There are also other interactions and one can assign to them coupling constant strengths. Why electromagnetic interactions in electron Compton scale or atomic length scales would be so special?

The idea is however plausible since beta functions satisfy first order differential equation with respect to the scale parameter so that single value of coupling strength determines the entire evolution.

p-Adic CCE from the condition $\alpha_K(k = 137) = 1/137$

In the TGD framework, Kähler coupling strength α_K serves as the fundamental coupling strength. All other coupling strengths are expressible in terms of α_K, and in [L62] it is proposed that Möbius transformations relate other coupling strengths to α_K. If α_K is identified as electroweak $U(1)$ coupling strength, its value in atomic scale $L(k = 137)$ cannot be far from $1/137$.

The factorization of dark and p-adic CCEs means that the effective Planck constant $h_{eff}(n, h, p)$ satisfies

$$h_{eff}(n, h, p) = h_{eff}(n, h) = nh \ . \tag{7.4.1}$$

and is independent of the p-adic length scale. Here n would be the dimension of the extension of rationals involved. $h_{eff}(1, h, p)$ corresponding to trivial extension would correspond to the p-adic CCE as the TGD counterpart of the ordinary evolution.

The value of h need not be the minimal one as already the findings of Randel Mills [D4] suggest so that one would have $h = n_0h_0$.

$$h_{eff} = nn_0h \ , \quad \alpha_{K,0} = \frac{g^2_{K,max}}{2h_0} = n_0 \ . \tag{7.4.2}$$

This would mean that the ordinary coupling constant would be associated with the non-trivial extension of rationals.

Consider now this picture in more detail.

1. Since dark and p-adic length scale evolutions factorize, one has

$$\alpha_K(n) = \frac{g^2_K(k)}{2h_{eff}} \ , \quad h_{eff} = nh_0 \ . \tag{7.4.3}$$

$U(1)$ coupling indeed evolves with the p-adic length scale, and if one assumes that $g^2_K(k, n_0)$ $(h = n_0h_0)$ is inversely proportional to the logarithm of p-adic length scale, one obtains

$$\begin{aligned} g^2_K(k, n_0) &= \frac{g^2_K(max)}{k} \ , \\ \alpha_K &= \frac{g^2_K(max)}{2kh_{eff}} \ . \end{aligned} \tag{7.4.4}$$

2. Since $k = 137$ is prime (here number theoretical physics shows its power!), the condition $\alpha_K(k = 137, h_0) = 1/137$ gives

$$\frac{g^2_K(max)}{2h_0} = \alpha_K(max) = (7!)^2 \ . \tag{7.4.5}$$

The number theoretical miracle would fix the value of $\alpha_K(max)$ to the ratio of Planck mass and CP_2 mass $n_0 = M_P^2/M^2(CP_2) = (7!)^2$ if one takes the argument of the previous section seriously.

The convergence of perturbation theory could be possible also for $h_{eff} = h_0$ if the p-adic length scale $L(k)$ is long enough to make $\alpha_K = n_0/k$ small enough.

3. The outcome is a very simple formula for α_K

$$\alpha_K(n,k) = \frac{n_0}{kn} \ , \tag{7.4.6}$$

(7.4.7)

which is a testable prediction if one assumes that it corresponds to electroweak $U(1)$ coupling strength at QFT limit of TGD. This formula would give a practically vanishing value of α_K for very large values of n associated with h_{gr}. Here one must have $n > n_0$.

For $h_{eff} = nn_0h$ characterizing extensions of extension with $h_{eff} = h$ one can write

$$\alpha_K(nn_0,k) = \frac{1}{kn} \ . \tag{7.4.8}$$

4. The almost vanishing of α_K for the very large values of n associated with $\hbar_{gr}$ would practically eliminate the gauge interactions of the dark matter at gravitational flux tubes but leave gravitational interactions, whose coupling strength would be $\beta_0/4\pi$. The dark matter at gravitational flux tubes would be highly analogous to ordinary dark matter.

7.4.2 The evolution of the gravitational fine structure constant

Nottale [E87] introduced the notion of gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ ($\beta_0 = v_0/c$ is velocity parameter), which has gigantic values so that the original proposal $h_{gr} = nh_0$ would predict very large values for n. If p-adic and dark evolutions are independent this is not a problem since p-adic length scales need not be gigantic.

Evolution of the parameter β_0

Gravitational fine structure constant is given by $\alpha_{gr} = GMm/4\pi\hbar_{gr} = \beta_0/4\pi$. The basic challenge is to understand the value spectrum of β_0.

1. Kepler's law $\beta^2 = GM/r = r_S/2r$ suggests length scale evolution of form

$$\beta_N = \sqrt{\frac{r_S}{2L(N)x}} = \frac{\beta_{0,max}}{N} \ . \tag{7.4.9}$$

The coefficient x has been included in the formula because otherwise a conflict with Bohr model for planetary orbits results.

2. How to identify N?

   (a) $N = n = h_{gr}/h_0$ would give a gigantic value of N and this would give extremely small value for β_0. Actually $N = n$ for n in $h_{gr} = nh_0$ is impossible as is clear from the defining equation.

   (b) It is not clear whether N be identified as a dimension for some factor in the composition of extension to simple factors rather than as n. This would conform with the vision that there are evolutionary hierarchies of extensions of extensions of... for which the dimension is product of dimensions of the extensions involved.

(c) The simplest option is that p-adic length scale evolution determines N as in case of the gauge interactions, and it corresponds to k in $p \simeq 2^k$. $log_2(p)$ exists also for a general prime p in real sense. In p-adic sense it exists for all primes except $p = 2$ as integer valued function. $p = 2$ could be chosen to be the exceptional prime.

This would conform with the idea that gravitational sector and gauge interaction sector correspond to different factors in the decomposition of extension of rationals. Perhaps the gravitational part of EQ extends its gauge part. This would conform with the idea that gravitation does not differentiate between states with different gauge quantum numbers.

What can one say about the value of $\beta_{0,max}$ and its length scale evolution?

1. The value of $\beta_{0,max} = 1/2$ would give for the length scale $L = GM/\beta_{0,max} = r_S$. If one requires that the scale L is not smaller than Scwartschild radius, $\beta_{0,max} \leq 1/2$ follows. $\beta_{0,max} = 1/2$ is the first guess but it turns that number theoretical constraintss exclude it and suggest $\beta_{0,max} = \pi/6$ as the simplest guess.

2. Gravitational Bohr radius a_{gr} given by

$$a_{gr} = \frac{\hbar_{gr}}{\alpha_{gr} m} per. \quad (7.4.10)$$

defines a good candidate for the minimal value of L_n as $L_1 = a_{gr}$.

3. The analogs of p-adic length scales would be equal to the radii of gravitational Bohr atom as n^2- multiples of the gravitational Bohr radius a_{gr}:

$$L_n = n^2 a_{gr} \ , \quad a_{gr} = \frac{4\pi GM}{\beta_0^2} \ . \quad (7.4.11)$$

This expression realizes the condition $\beta_0^2 = xGM/r$ inspired by the Kepler's law with $x = 4\pi$.

4. One must fix a_{gr} as a multiple $a_{gr} = kr_S$ of r_S. Substitution to the above equation gives

$$\beta_{0,max} = \sqrt{\frac{2\pi}{k}} \ .$$

The condition $\beta_{0,max} = 1/2$ would give $k = 8\pi$ and $a_{gr} = 8\pi r_S$ as a minimal radius for a Bohr orbit. The condition $\beta_{0,max} < 1$ gives $k \geq 2\pi$ and $a_{gr} \geq 2\pi r_S$.

Just as in the case of hydrogen atom, the falling of the orbiting system to the blackhole like entity (in TGD frameworkd blackholes are replaced with what might be called flux tube spaghettis [L69, L63]) is prevented. This should have obviously consequences for the view about the dynamics around blackhole like objects. The circular orbits have as analogs s-waves and of these are realized, the falling to blackhole like entity is possible.

5. The proposed formula does not force the condition $\beta_0 < 1$ and it is not clear whether it holds true at the relativistic limit. The replacement $\beta_0 \rightarrow sinh(\eta) = \beta_0/\sqrt{1-\beta_0^2}$, where η is the hyperbolic angle, forces the condition $\beta_0 < 1$, and would give

$$\beta_0 \rightarrow \frac{\beta_0}{\sqrt{1-\beta_0^2}} = \sqrt{\frac{2\pi}{k}} \ .$$

The condition $\beta_{0,max} = 1/2$ gives $k/2\pi = 3$. This would correspond to the minimal Bohr radius $a_{gr} = 6\pi r_S \simeq 18.84 r_S$.

Number theoretical universality as a constraint

Also number theoretical universality could be also used as a constraint. The condition would be that only finite-dimensional extensions are allowed. π defines an infinite-D transcendental extension so that it should disappear in central formulas.

1. The appearance of 4π in the formula $a_{gr} = 4\pi G/\beta_{0,max}^2$ creates number-theoretical worries. Suppose that a_{gr} is a rational number.

2. I have proposed that G is dynamically determined and relates to the CP_2 radius via the formula $G = R^2/\hbar_{grav} = 2\pi R^2/h_{grav}$, where $h_{grav}/h_0 \sim 10^7$ holds true [K11].

   This gives

$$a_{gr} = \frac{4\pi G}{\beta_{0,max}^2} = \frac{8\pi^2 R^2}{h_{grav}\beta_{0,max}^2} \tag{7.4.12}$$

   .

3. Since $\beta_0/4\pi$ appears as coupling strength in the perturbation theory, it should also be rational. $\beta_{0,max} = \pi/6$ would realize the condition $\beta_{0,max} = 1/2$ approximately.

4. With this assumption the rationality of a_{gr} requires that h_{gr} is proportional to π so that also G would be rational. This implies that $\hbar_{eff} = h_{eff}/2\pi$ is rational. Also α_K would be rational if g_K^2 is rational. This would be true also for the other coupling constants.

5. $\beta_0 = \pi/6$ would realize the condition $\beta_0 = 1/2$ approximately. This also implies that α_{gr} is rational. The condition $k/2\pi = 1/\beta_{0,max}^2$ implies $k \propto 1/\pi$. $a_{gr} = kr_s = kGM$ is rational, and this requires $M \propto \pi$. This guarantees the rationality of GM/β_0. Gravitational fine structure constant α_{gr} would be an inverse integer multiple of $\alpha_{gr}(max) = 1/24$. It would seem that the system is consistent.

   The alternative condition $\beta_0^2/(1-\beta_0^2) = 2\pi/k$ is excluded because it implies that k is a rather complex transcendental.

What makes this interesting is that 24 is one of the magic numbers of mathematics (`https://cutt.ly/Rn0x0Tr`) and it appears in the bosonic string model as the number of space-like dimensions.

1. Euclidian string world sheet with torus topology has a conformal equivalence class defined by the ratio ω_2/ω_1 of the complex vectors spanning the parallelogram defining torus as an analog of a unit cell. String theory must be invariant under modular group $SL(2,Z)$ leaving the periods and thus the conformal equivalence class of torus invariant. Same applies to higher genera. In TGD these surfaces correspond to partonic 2-surfaces.

2. Modular invariance raises elliptic functions (doubly periodic analytic functions in complex plane) in a special role. In particular, Weierstrass function, which satisfies the differential equation $(d\mathcal{P}/dz)^2 = 4\mathcal{P}^3 - g_2\mathcal{P} - g_3$ has a key role in the theory of elliptic functions (`https://cutt.ly/Bn0xrMS`).

   The discriminant $\Delta = g_2^3 - 3g_2^3$ of the polynomial at the r.h.s can be locally regarded as a function of the ratio of $\tau = \omega_2/\omega_1$ of the periods of $\mathcal{P}$ defining the conformal equivalence class of torus.

   $\Delta(\tau)$ is not a genuine modular invariant function of τ. Rather, Δ defines a modular form of weight 12 transforming as $\Delta(a\tau + b/(c\tau+d)) \rightarrow (c\tau+d)^{12}\Delta(\tau)$ under $SL(2,Z)$. The number 24 comes from the fact that one can express Δ as 24^{th} power of the Dedekind η function: $\Delta = (2\pi)^{12}\eta^{24}$.

3. In dimension $D = 24$ there are 24 even positive definite unimodular lattices, called the Niemeier lattices, and the so-called Leech lattice is one of them. Interestingly, in dimension 4 there exists a 24-cell analogous to Platonic solid having 24 octahedrons as its 3-D "faces".

This encourages the question whether there might be a connection between TGD and string theory based views of quantum gravitation.

Test cases for the proposal

Phase transitions changing β_0 are possible at $r_n/a_{gr} = n^2$ at the Bohr orbits. For instance, in the Bohr orbit model the orbit of Earth is such an orbit. It can be regarded as $n = 5$ orbital with $\beta_0 \simeq 2^{-11}$ and is nearly circular so that the phase transition with $n = 1$ orbital with $\beta_0 \rightarrow \beta_0/5$ is possible. The outer planets indeed have $\beta_0/5$.

p-Adic length scale hierarchy is replaced union of hierarchies with $\beta_0 = \beta_{0,max}/n = 1/2n$, each of which is a subset of the set of Bohr orbits for $\beta_0 = \beta_{0,max}$. One can test this hypothesis for the proposed applications [L112].

1. In the Bohr orbit model the 4 inner planets Mercury, Venus, and Earth, and Mars identifiable correspond to $n = 3, 4, 5, 6$ orbitals for $\beta_0 \simeq 2^{-11}$. Solar radius is $R_{Sun} \simeq .7$ Gm. The orbital radius of Mercury is $R_M \simeq 58$ Gm $= 82.9 \times R_{Sun}$. This gives $a_{gr} = R_M/9 \simeq 9.2R_{sun}$. This gives $\beta_0 = \sqrt{2\pi R_S/a_{gr}} \simeq 17.1 * 10^{-4}$.

   The approximation used hitherto has been $\beta_0 = 2^{-11)} \simeq 5 \times 10^{-4}$ and is by a factor about 1/3 smaller. Using $a_{gr} = R_M$ instead of $a_{gr} = R_M/9$ would give roughly correct value.

   One could indeed regard Mercury as $n = 1$ orbit for $v_0 = v_0/3$ in which case one would have $a_{gr} = R_M$ and one would obtain $\beta_0 = .57$ which is not far from the valued used. Mercury would therefore correspond to $n = 3$ dark matter gravitationally whereas Venus must correspond to $n = 1, 2$ or $n = 4$.

2. The transition $\beta_0 \rightarrow \beta_0/5$ possible for Earth and required for outer planets could be interpreted as the increase of n having interpretation as increase of dimension of extension of rationals $n \rightarrow 5n$.

For the Earth one has $R_E = 6.371 \times 10^6$ m and $r_S = 10^{-2}$ m. The model of the superfluid fountain effect [K33] [L112] suggests $\beta_0 = 1/2$ for which one would have $GM/v_0 = 1/2$. The value of $a_{gr} = 6\pi r_S$ for the relativistic form of the Nottale condition. The principal quantum number n for the Bohr orbit of the super-fluid would be $n \simeq R_E/a_{gr} = R_E/6\pi r_S \simeq 3.4 \times 10^7$. This would correspond to the large quantum number limit. The difference of radii between nearby Bohr orbits would be $\Delta r = 2R_E/n \simeq 19$ cm, which makes sense.

The levels in the hierarchy of gravitationally dark matters are labelled by $h_{gr} = GMm/\beta_0$ with $\beta_0 = \beta_{0,max}/n$, where n is the dimension of EQ, and each level defines a hierarchy of atomic orbitals. The sets of orbital radii at various levels form a nested hierarchy and phase transitions can occur at least between the states with the same angular momentum and orbital radius.

The quantum variant of the similar picture is expected to apply in the case of the hydrogen atom and the fact that there is evidence for dark valence electrons suggests that these phase transitions indeed take place.

What about long cosmic strings thickened to flux tubes explaining galactic dark matter in the TGD framework? In this case the Kepler law gives $\beta^2 = TG$ so that the all orbiting stars would correspond to the same value of β_0 and n.

7.5 Appendix: Embedding of spherically symmetric stationary symmetric metric as a guideline

There are two basic questions to be answered.

1. Is $R = l_P$ or $R = m^2 l_P$, $m = 7!$ realized?

2. Should one assume that $g_K^2 \propto \hbar_{eff}$ or $\alpha_K \propto 1/\hbar_{eff}$?

For the first option α_K is the same for dark phases but would be subject to p-adic CCE. This would conform with the notion of gravitational Planck constant predicting that the parameter. The *effective* value of α_K would be however given by α_K/n for dark phases since the Galois symmetry is n-fold multiple of the action for a "fundamental region" for the Galois group.

Second option would predict that α_K behaves like $1/n$ so that effective α_K would behave like $1/n^2$. It seems that this option is excluded and one can concentrate on the first question. The increase of g_K^2 with n is not a problem since it does not appear as a parameter of perturbative expansion since g_K is automatically absorbed to a scaling of the induced gauge potentials.

Quantum-classical correspondence suggests that classical theory theory, in particular spherically symmetric stationary embeddings, could help to answer the first question. Even the extremal property is not absolutely necessary.

The action is a sum of Kähler action and volume term proportional to length scale dependent cosmological constant approaching zero in long length scale and in equilibrium both give contributions of the same order of magnitude. This suggests that Kähler action corresponding to $\Lambda = 0$ could serve as a guideline.

I studied the embedding of a stationary spherically symmetric metric as a space-time surface during the first 10 years of TGD and the results suggested that the $R = l_P$ option looks more realistic. p-Adic mass calculations based on the definition of the Compton length as $\hbar/M$ however led to the conclusion that the one must have $r \sim 10^{7.6} l_P$. If one replaces $\hbar$ with $\hbar_0$, $R = l_P$ is natural.

The spherically symmetric ansatz assumes that space-time surfaces has a projection to a geodesic sphere S^2 of CP_2 which can be either homologically trivial or non-trivial. Using spherical coordinates (Θ, Φ) for S^2 and spherical Minkowski (t, r, θ, ϕ) coordinates for M^4, the ansatz reads

$$\begin{aligned} s \equiv sin(\Theta) = f(r) \quad , \quad \Phi = \omega t \quad , \\ g_{tt} = 1 - k^2 s^2 \quad , \qquad k^2 = R^2 \omega^2 \quad . \end{aligned} \tag{7.5.1}$$

In far-away region one can approximate s as

$$s = s_0 + \tfrac{r_1}{r}, \quad s_0 = sin(\Theta_0) \quad . \tag{7.5.2}$$

The induced metric has component g_{tt} given by

$$g_{tt} = 1 - k^2 s_0^2 - 2k^2 s_0 \frac{r_1}{r} \quad , \tag{7.5.3}$$

by taking $u = t\sqrt{2 - k^2 s_0^2}$ as a new time coordinate can expresses g_{tt} in terms of the parameters of Scwartshild metric

$$\begin{aligned} g_{uu} &= 1 - 2k^2 s_0 \tfrac{r_1}{r} \equiv 1 - \tfrac{r_s}{r} \quad , \\ r_s &= 2GM = \tfrac{2k^2 s_0 r_1}{1 - k^2 s_0^2} \quad , \\ r_1 &= \tfrac{1 - k^2 s_0^2}{2k^2 s_0} r_s \equiv k_1 r_s \quad . \end{aligned} \tag{7.5.4}$$

The approximation makes sense for $s \leq 1$, which gives the condition

$$r \geq r_{min} = (1 - s_0) r_1 = (1 - s_0) k_1 r_s = (1 - s_0) \frac{1 - k^2 s_0^2}{2k^2 s_0} r_s \equiv y_1 r_s \quad . \tag{7.5.5}$$

Remark: The radial component of the metric goes to zero much faster than for Schwartschild metric. The shift of time coordinates depending on the radial coordinate allows to correct this problem. This is however not essential for the recent argument. Schwartchild metric however implies that $\sqrt{g}$ in the calculation of mass gives just the volume element of the flat metric since $g_{tt} g_{rr} = 1$ is true. This is assumed in the following.

One can estimate the mass of the system as Kähler electric energy. Assume that the contribution to the mass comes only from the region $r > y_1 r_s$. The Kähler electric mass $M = r_s/2G$ is given by the expression

$$\begin{aligned} M &= \frac{r_s}{2G} \\ &= \frac{\hbar_{eff}}{2\alpha_K}\frac{s_0^2}{1-s_0^2}r_1^2\omega^2\int_{r_{min}}^{\infty}\frac{dr}{r^2} = \frac{\hbar_{eff}}{2\alpha_K}\frac{(1-k^2s_0^2)s_0}{2(1-s_0)}r_s\frac{1}{R^2} \quad . \end{aligned} \tag{7.5.6}$$

This gives a consistency condition relating R and l_P

$$\begin{aligned} R^2 &= \frac{\hbar_{eff}}{\hbar}Xl_P^2 \quad , \\ X &= \frac{(1-k^2s_0^2)s_0}{\alpha_K(1-s_0)} \quad . \end{aligned} \tag{7.5.7}$$

One can consider two cases.

1. For $\hbar_{eff} = \hbar$ the condition reduces to

$$R^2 = Xl_P^2 \quad . \tag{7.5.8}$$

   $l_P = R$ gives $X = (1-k^2s_0^2)s_0/\alpha_K(1-s_0) = 1$. One should have $s_0 \simeq \alpha_K$ so that the value of $1/\alpha_K$ as an analog of critical temperature would be coded to the geometry of the space-time surface.

   $R = (7!)^2)l_P$ would require $X = \hbar/\hbar_0$, one should have $1-s_0 \sim 10^{-5}$ for $\alpha_K \sim 10^{-2}$.

2. For $\hbar_{eff} = \hbar_0$ the condition reduces to

$$R^2 = X\frac{\hbar_0}{\hbar} \times l_P^2 \quad . \tag{7.5.9}$$

   $l_P = R$ gives $X = \hbar/\hbar_0$. One might of course argue that α_K decreases in long scales in the discrete p-adic length scale evolution but this option does not look plausible.

To sum up, intuitively $\hbar$ option with $R = l_P$ looks the most reasonable option.

Part II

MANY-SHEETED ASTROPHYSICS

Chapter 8

TGD and Astrophysics

8.1 Introduction

The concept of 3-space in TGD is considerably more general than in the conventional theories. According to the original picture 3-space is not any more connected but can have arbitrary many disjoint components. Even macroscopic boundaries would be allowed: macroscopic bodies are interpreted as 3-surfaces having outer boundary. This picture has been modified. Space-time is a surface inside causal diamond (CD) and decomposes to Minkowskian and Euclidian regions. The boundaries of Minkowskian/Euclidian regions (to be called parton orbits in the sequel) are light-like 3-surfaces and replace the genuine boundaries. Hence closed 3-surfaces at the ends of CD can be seen as double coverings of with sheets glued together along boundaries of sheets.

There are strong indications that 3-space has a hierarchical fractal structure: 3-surfaces topologically condensed on 3-surfaces condensed on..., where topological condensation means that “small” 3-surface is “glued” to a larger 3-surface by connected sum operation.

The original hypothesis was that preferred extremals of Kähler action are absolute minima of Kähler action. This hypothesis is natural only in Euclidian regions of the space-time surface. Furthermore, zero energy ontology (ZEO) means that pairs of space-like 3 surface located at the opposite boundaries of CD or the unions of these with parton orbits become basic objects. In this case the attribute “preferred” might be possessed by any extremal and space-time surface could be unique apart from gauge symmetries defined by Kac-Moody type algebras respecting the light-likeness of parton orbits. The non-determinism of Kähler action suggests tht this is true in given measurement resolution only. The recent view about preferred extremals is as critical extremals for which a large number of deformations exist with a vanishing second variation of Kähler action: critical deformations correspond to Kac-Moody type conformal algebra. The number n of conformal equivalence classes of 4-surfaces corresponds to the integer defining the effective value of Planck constant $h_{eff} = n \times h$ and also characterizes the breaking of conformal symmetry: only the sub-algebras of conformal algebra with conformal weights divisible by n acts as gauge symmetries. These algebras form fractal inclusion hierarchies bringing strongly in mind those for the hyperfinite factors.

Gravitational fields are always accompanied by long range electro-weak gauge fields with Kähler charge, which in the astrophysical scales is apart from a small but non-vanishing numerical factor equal the mass of particle using Planck mass as unit. In shorter length scales the Kähler charge can be larger and reflects the development of long range classical Z^0 fields. Also long ranged classical color fields with U(1) holonomy are present.

The long ranged W fields are not experienced by induced spinor fields if one requires that em charge for the modes of induced spinor field is well-defined. This forces the localization of the modes to 2-D surfaces - string world sheet and possibly partonic 2-surfaces at which induce W field vanish. One can require also the vanishing of induced Z^0 field - at least above weak scale proportional to h_{eff}. Under this assumption no large parity breaking effects are predicted for ordinary value of Planck constant associated with ordinary matter. For dark matter with large h_{eff} the situation is different.

Topological field quantization is a central concept: the presence of Kähler charge implies that 3-surface has outer boundary unless one replaced it with double covering: the larger the charge the smaller the size of the 3-surface. This makes it possible to relate the size of the 3-surface (topological field quantum) to the Kähler charge of a typical particle in the condensate. The formation of macroscopic quantum systems, such as super conductors, corresponds to the formation of bonds between the boundaries of the neighboring topological field quanta. They could correspond in either flux tubes connecting partonic 2-surfaces and having Euclidian signature or to flux tubes connecting double coverings. A possible astrophysical example is neutron star: join along boundaries bonds are formed between neutrons so that single giant nucleus results.

8.1.1 P-Adic Length Scale Hypothesis And Astrophysics

Various levels of the topological condensate obey effective p-adic topology and form p-adic hierarchy ($p_1 < p_2$ can condense on p_2). Physically interesting length scales should come as square roots of powers of 2: $L_e(k) \simeq 2^{\frac{k}{2}} l$, $l = 1.288 \cdot 10^4 \sqrt{G}$ and various considerations suggest that prime powers are especially interesting values of k. For astrophysical applications interesting prime values of n are: $n = 229, 233, 239, 241, 251, 257, 263...$ and it is of considerable interest to find whether these length scales correspond to astro-physically interesting length scales.

The combination of p-adic length scale hierarchy idea with the concepts of topological evaporation and condensation, join along boundaries bond and long ranged weak and color forces, is an exciting challenge. In this chapter these concepts are applied in astrophysical length scales. The identification of the prime power length scales as fundamental astrophysical length scales is proposed and the identification of the fundamental cosmological length scale identified by Einasto *et al* [E123] as a p-adic length scale is proposed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

8.1.2 Quantum Criticality, Hierarchy Of Dark Matters, And Dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

Quantization of Planck constants and the generalization of the notion of embedding space

The recent geometric interpretation for the quantization of Planck constants is based on Jones inclusions of hyper-finite factors of type II_1 [K42]. The following generalization is only one possibility and might involve too strong assumptions such as the decomposition of the integer n in $h_{eff} = n \times h$ to a product of integers associated with M^4 and CP_2.

1. One can argue that different values of Planck constant correspond to embedding space metrics involving scalings of M^4 *resp.* CP_2 parts of the metric deduced from the requirement that distances scale as $\hbar(CP_2)$ *resp.* $\hbar(M^4)$. Denoting the Planck constants by $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$, one has that covariant metric of M^4 is proportional to n_b^2 and covariant metric of CP_2 to n_a^2.

   This however leads to difficulties with the isometric gluing of CP_2 factors of different copies of H together. Kähler action is however invariant under over-all scaling of H metric so that one can scale it down by $1/n_a^2$ meaning that M^4 covariant metric is scaled by $(n_b/n_a)^2$ and CP_2 metric remains invariant and the difficulties in isometric gluing are avoided. This means that if one regards Planck constant as a mere conversion factor, the effective Planck constant scales as n_a/n_b.

   In Kähler action only the effective Planck constant $\hbar_{eff}/\hbar_0 = \hbar(M^4)/\hbar(CP_2)$ appears and by quantum classical correspondence same is true for Schödinger equation. Elementary particle mass spectrum is also invariant. Same applies to gravitational constant. The alternative assumption that M^4 Planck constant is proportional to n_b would imply invariance of

Schrödinger equation but would not allow to explain Bohr quantization of planetary orbits and would to certain degree trivialize the theory.

2. M^4 and CP_2 Planck constants do not fully characterize a given sector $M^4_\pm \times CP_2$. Rather, the scaling factors of Planck constant given by the integer n characterizing the quantum phase $q = exp(i\pi/n)$ corresponds to the order of the maximal cyclic subgroup for the group $G \subset SU(2)$ characterizing the Jones inclusion $\mathcal{N} \subset \mathcal{M}$ of hyper-finite factors realized as subalgebras of the Clifford algebra of the "world of the classical worlds". This means that subfactor $\mathcal{N}$ gives rise to G-invariant configuration space spinors having interpretation as G-invariant fermionic states.

3. $G_b \subset SU(2) \subset SU(3)$ defines a covering of M^4_+ by CP_2 points and $G_a \subset SU(2) \subset SL_e(2, C)$ covering of CP_2 by M^4_+ points with fixed points defining orbifold singularities. Different sectors are glued together along CP_2 if G_b is same for them and along M^4_+ if G_a is same for them. The degrees of freedom lost by G-invariance in fermionic degrees of freedom are gained back since the discrete degrees of freedom provided by covering allow many-particle states formed from single particle states realized in G group algebra.

4. Phases with different values of scalings of M^4 and CP_2 Planck constants behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of embedding space glued together along M^4 or CP_2 factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence. In particular, quantum energies associated with classical frequencies are scaled up by a factor n_a/n_b which is of special relevance for cyclotron energies and phonon energies (superconductivity). For large $\hbar(CP_2)$ the value of $\hbar_{eff}$ is small: this leads to interesting physics: in particular the binding energy scale of hydrogen atom increases by the factor $(n_b/n_a)^2$.

Preferred values of Planck constants

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and the powers of 2^{11} seem to be especially favored as values of n_a in living matter [K38].

How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anti-commutation relations of various super-conformal algebras. Only the ratio of scalings of M^4 and CP_2 metrics appears in Kähler action. The most natural assumption at the level of hyper-octonion space $HO = M^8$ is that M^4 metric is proportional to n_b^2 and E^4 metric to n_a^2. For $H = M^4 \times CP_2$ the assumption that CP_2 metric is proportional to n_a^2 however leads to mathematical difficulties and to a rather weird looking prediction that CP_2 can have arbitrarily large size. Hence the most natural conclusion is that the scaling of CP_2 metric is universal [K42]. This is achieved elegantly by performing over-all scaling of scaled up H metric allowed by the invariance of Kähler action in this scaling so that a scaling of M^4 covariant metric by $(n_b/n_a)^2$ results and effective Planck constant as a mere conversion factor is scaled by n_a/n_b.

This implies that Kähler function through its dependence on n_a/n_b codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

Phase transitions changing the level in dark matter hierarchy

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

1. If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constant and more precisely, definite groups G_a and G_b characterizing dark matter hierarchy. Particles of different phases could not appear in the same vertex and a phase transition changing the particles to each other analogous to a de-coherence would be necessary.

2. If transition amplitudes involve only a discrete set of common orbifold points of 2-surface belonging to different sectors then the phase transition between relatively dark matters can be described in terms of S-matrix. It seems that this option is the correct one. In fact, also propagators are essential for the interactions of visible and dark matter and since virtual elementary particles correspond at space-time level CP_2 type extremals with 4-dimensional CP_2 projection, they cannot leak between different sectors of imbedding space and therefore cannot mediate interactions between different levels of the dark matter hierarchy. This would suggest that the direct interactions between dark and ordinary matter are very weak.

   If the matrix elements for real-real partonic transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [K27]. then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Of course, the fact that the points which correspond to zero of Riemann Zeta form only a small subset of points common to real partonic 2-surface and corresponding p-adic 2-surface, implies that the rate for phase transition is in general small. On the other hand, for the non-diagonal S-matrix elements for ordinary transitions would become very small by almost randomness caused by strong fluctuations and the rate for phase transition could begin to dominate.

Transition to large $\hbar$ phase and failure of perturbation theory

A further idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

A justification for this picture would be that in non-perturbative phase large quantum fluctuations are present (as functional integral formalism suggests). At space-time level this would mean that space-time sheet is near to a non-deterministic vacuum extremal. At parton level this would mean that partonic surface contains large number of CP_2 orbifold points so that S-matrix elements for the phase transition becomes large. At certain critical value of coupling constant strength one expects that the transition amplitude for phase transition becomes very large.

Dark matter as large $\hbar_{gr}$ phase

D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale. Schrödinger equation need not be involved. Rather, Bohr orbitology could reflect the fact that dark matter is in anyonic phase and confined by charge fractionization at large partonic 2-surfaces with a gigantic value of Planck constant. These surfaces could have complex topologies involving flux tubes around planetary orbits connected by radial spokes to a spherical surface associated with Sun.

Prediction for the parameter v_0

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. v_0 has dimensions of velocity and the identification as typical rotation or orbital velocity is natural first guess. In next chapter it will be found that this identification rather non-trivial but correct prediction and leads to the identification $h_{gr} = h_{eff}$ in elementary particle, and atomic length scales at least. This leads to a rather strong predictions in TGD inspired quantum biology where quantum gravitation in TGD sense becomes a key player.

The planetary mass ratios can be produced with an accuracy better than 10 per cent assuming ruler and compass phases, and the dependence of v_0 on p-adic length scale characterizing the space-time sheets carrying the planet-Sun gravitational force might relate to the discrepancies.

Further predictions

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Shrödinger equation holds true only inside flux quanta for the dark matter.

1. During pre-planetary period dark matter formed a quantum coherent state on the (Z^0) magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full SO(3) or SO(2) symmetry).

2. In the case of spherical shells associated with inner planets the $SO(3) \rightarrow SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

3. The $v_0 \rightarrow v_0/5$ transition allowing to understand the radii of the outer planets in the model of Da Rocha and Nottale can be understood as resulting from the splitting of (Z^0) magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

It is important to notice that effectively a multiplication $n \to 5n$ of the principal quantum number is in question. This allows to consider also alternative explanations. Perhaps external gravitational perturbations have kicked dark matter from the orbit or Earth to $n = 5k$, $k = 2, 3, ..., 7$ orbits: the fact that the tilt angles for Earth and all outer planets except Pluto are nearly the same, supports this explanation. Or perhaps there exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n \ mod \ 5 = 0$ for some reason.

4. A remnant of the dark matter is still in a macroscopic quantum state at the flux quanta. It couples to photons as a quantum coherent state but the coupling is extremely small due to the gigantic value of $\hbar_{gr}$ scaling alpha by $\hbar/\hbar_{gr}$: hence the darkness.

   The rather amazing coincidences between basic bio-rhythms and the periods associated with the states of orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for v_0.

8.1.3 Dark Matter As A Source Of Long Ranged Weak And Color Fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

8.1.4 The Topics Of The Chapter

The following topics discussed in the chapter are following.

1. p-Adic length scale hypothesis can be applied in astrophysical length scales, too and some examples of possible applications are discussed. One of the most interesting implications of p-adicity is the possibility of series of phase transitions changing the value of cosmological constant behaving as $\Lambda \propto 1/L^2(k)$ as a function of p-adic length scale characterizing the size of the space-time sheet.

2. A model for the solar magnetic field as a bundle of topological magnetic flux tubes is constructed and a model of Sunspot cycle is proposed. This model is also shown to explain the mysteriously high temperature of solar corona and also some other mysterious phenomena related to the solar atmosphere. A direct connection with the TGD based explanation of the dark energy as magnetic and Z^0 magnetic energy of the magnetic flux tubes containing dark matter as ordinary matter, emerges. The matter in the solar corona is simply dark matter leaked from the highly curved portions of the magnetic flux tubes to the space-time sheets where it becomes visible. The generation of anomalous Z^0 charge caused by the runoff of dark neutrinos in Super Nova could provide a first principle explanation for the avoidance of collapse to black-hole in Super Nova explosion.

   The recent view about fermions is based on the condition that spinor modes have well-define em charge predicts that induced spinor fields are in the generic case localized to 2-D surfaces at which the classical W field vanishes as does also Z^0 field above weak scale (proportional to effective Planck constant h_{eff}). Hence fermions could feel weak Z^0 field below weak scale corresponding to h_{eff}. No large parity breaking effects for ordinary matter are predicted.

3. One section is devoted to some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly and Flyby anomaly.

k	227	229	233	239	241
$L_e(k)$	$2.3E+3$	$4.6E+3$	$1.9E+4$	$1.5E+5$	$3.0E+5$
k	251	257	263	269	271
$L_e(k)/m$	$.96E+7$	$7.7E+7$	$6.0E+8$	$4.8E+9$	$.9E+10$
k	277	289	293	307	311
$L_e(k)$	$7.7E+10$	$5.0E+12$	$2.0E+13$	$2.5E+15$	$1.0E+16$
k	313	317	329	331	337
$L_e(k)/ly$	2.2	$5.4E+2$	$1.0E+3$	2.2E+3	$8.4E+3$
k	347	349	353	359	367
$L_e(k)ly$	$2.8E+5$	$5.6E+5$	$2.2E+6$	$1.8E+7$	$2.9E+8$
k	373	379			
$L_e(k)/ly$	$2.2E+9$	$1.9E+10$			

Table 8.1: p-Adic length scales $L_e(k) = 2^{(k-127)/2}L_e127$, $p \simeq 2^k$, k prime, $L_{127} \equiv \sqrt{5+Y}\pi/m_e$, $Y \simeq .0317$ possibly relevant to astrophysics. The definition of the length scale involves an unknown factor r of order one and the requirement $L_e(151) \simeq 10^{-8}$ meters, the thickness of the cell membrane, implies that this factor is $r \simeq 1.1$.

4. The astrophysics of solar system involves also an anomaly related to the precession of equinoxes suggesting that Sun might have a companion. TGD suggests a model for anomalies as being due to interaction magnetic flux tube connecting Sun to its companion.

5. The TGD variant of the model of Nottale involved gravitational Planck constant h_{gr} is discussed in detail. Also further indications for large values of Planck constant are discussed. A rather recent result (2014) is that $h_{gr} = GMm/v_0$ hypothesis might be needed only for microscopic objects with small mass m since gravitational acceleration and gravitational Compton length do not depend on particle mass. This allows also the identification $h_{eff} = h_{gr}$ leading to powerful predictions in the TGD based model of living matter.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L7].

8.2 P-Adic Length Scale Hypothesis At Astrophysical And Cosmological Length Scales

p-Adic length scale hierarchy gives quantitative contents for the idea about fractal many-sheeted cosmology and therefore deserves a brief discussion.

8.2.1 List Of Long P-Adic Length Scales

There are not very many p-adic lengths scales $L(k)$ ($p \simeq 2^k$, k power of prime) between 1 meter and 10^{11} light years as the approximate density $\Psi(n) \simeq \frac{1}{ln(n)}$ of prime numbers as function of n shows. Therefore the length scale hypothesis is nontrivial and the attempt to identify physically the length scales is perhaps worth of the trouble although detailed identifications are not attempted in the following. If physics is indeed p-adic below length scale L_p at level p, one expects p-adic fractality, when length scale resolution is smaller than L_p. Length scales $L(k)$ coming as twin pairs corresponding to primes k and $k+2$ seem to define particularly interesting biological length scales. Therefore it is of interest look whether something similar might happen in astrophysical context. L_p is the infrared cutoff scale for p-adic field theory limit of TGD but the idea that quantum effects might be important in astrophysical length scales looks admittedly rather wild.

The length scales can contain some overall factor r of order order one. If this factor is chosen so that the length scale $L_e(151)$ is the thickness of the cell membrane, one must multiply p-adic length scales of the table by a factor $r \simeq 1.1$ to obtain $\hat{L}_e(k) = r * L_e(k)$.

1. $L_e(227) \sim 2.3$ kilometers, $L_e(229) \sim 4.6$ kilometers (twin pair) and $L_e(233) = 19.0$ kilometers. It would be interesting to find whether these length scales could be identified as geo-physically important length scales or/and length scales relevant to the internal structure of stars or planets. $L_e(233)$ is the order of magnitude for the size of neutron star.

2. $L_e(239) \simeq 1.5E+5\ m$ and $L_e(241) \simeq 3.0E+5\ m$ form a twin pair and could represent geophysically/astrophysically interesting length scales.

3. $L_e(251) = .96E+7\ m$ and $L_e(257) = 7.7E+7\ m$. The radii of the planets are of this order of magnitude.

4. $L_e(263) = 6.0E+8\ m$ is of same order of magnitude as solar radius ($\sim 6.96E+8\ m$). Note that $\hat{L}(263) \simeq 6.6E+8$ m is considerably nearer to the solar radius. $L_e(269) \simeq 4.8E+9$ meters and $L_e(271) \simeq .9E+10$ meters form a twin pair. Titius-Bode law for planetary distances reads as $r = r_0 + r_1 2^n\ AU$, $r_0 = .4$ and $r_1 = .3$. A(stronomical) U(nit) corresponds to distance between Earth and Sun: $r_1 \simeq .3AU \simeq 4.5E+10m \sim 2^2 L_e(271)$ holds in a reasonable approximation. $2^2\hat{L}_e(271) \simeq 4.4E+10$ m is quite near to r_1! $L_e(271)$ is a member of twin pair and it might be that length scales corresponding to twin primes lead to approximate 2-adicity of the mass distribution. If primordial mass distribution is 2-adic and of form $((r-r_0)/r_1)^n$ it has peaks at $r - r_0 = r_1 2^k$ and Titius-Bode law is natural consequence. If this is the case then the planetary distance ratios might be universal!

5. For $k = 277, 289 = 17^2, 293, 307$, $L_e(k)$ varies between $7.7E+10\ m$ and about $2.5E+15\ m$. $L_e(277)$ is of same order as the distance from Earth to Sun. The size of the solar system is about $L_e(289)$. $L_e(311) \simeq 1.0\ ly$ and $L_e(313) \simeq 2.0\ ly$ form a twin pair. Could these distances have a tendency to appear as distances between binaries? Or could the distances have a tendency to come as powers $2^n L_e(313)$?

6. $L_e(329) \simeq 1.0E+3$ and $L_e(331) \simeq 2.0E+3$ light years form a twin pair. Sizes for the galactic nuclei are of this order of magnitude. The very powerful energy sources in the nuclei of the galaxies are associated with regions of this distance. A suggested explanation is black hole in the region between the object and also TGD allows galactic black holes. $L_e(337) \simeq 8.4 \cdot 10^3$ light years corresponds to the size of the central region of the galaxy. $L_e(353) \simeq 2.2 \cdot 10^6$ light years corresponds to a typical size scale of the galaxy [E93].

7. $L_e(367) \simeq 2.2 \cdot 10^8$ light years is same order of magnitude as the size of the large voids and perhaps corresponds to the length scale identified by Einasto.

8.2.2 P-Adic Evolution Of Cosmological Constant

One of the most fascinating outcomes of the new view about gravitational energy is the resolution of the most gigantic failure in the art of order magnitude estimates. The naïve estimate for the cosmological constant predicted also by TGD is by a factor 10^{120} larger than its value deduced from the accelerated expansion of the Universe. The resolution comes naturally from the p-adic fractality predicting that cosmological constant is reduced by a factor of 2 in a step wise manner in phase transitions occurring at times $T(k) \propto 2^{k/2}$, which correspond to p-adic time scales. On the average $\Lambda(k)$ behaves as $1/a^2$, where a is the light-cone proper time. This predicts correctly the observed value of Λ.

p-Adic length scale hypothesis plus the detailed study of membrane like vacuum extremals lead to the hypothesis that cosmological constant depends on p-adic length scale $\Lambda/R^2 \propto 1/R^2L^2(k) \propto 2^{-k}$. Amazingly, the recent value of the cosmological constant suggested by the accelerated expansion of the Universe comes out as a correct prediction!

Cosmological expansion at a particular space-time sheet becomes a TGD counterpart for a sequence of periods of increasingly slow inflation which a reduction of Λ by a factor of 2 at each time when the size of space-time sheet exceeds a p-adic length scale. It must be however emphasized that Kähler action determines the classical dynamics and it is by no means clear that exponential expansion is involved. What certainly occurs is liberation of gravitational energy, which means that the difference of inertial energy densities for matter and antimatter is reduced in a phase transition like manner. Maybe the interpretation in terms of annihilation of matter and antimatter is appropriate. Perhaps particles with masses of order p-adic length scale become non-relativistic and annihilate to lighter particles, most naturally those corresponding to the next p-adic length scale.

8.2.3 Evidence For A New Length Scale In Cosmology

There is evidence [E123] for a cubic lattice structure in the length scale of the large cosmic voids containing matter near their boundaries. Single void having galaxies on its boundaries would be the basic unit of this structure. This means a characteristic length scale of order 1.2 Megaparsecs, which in light years makes $7.8E+8$ light years. As noticed in the paper, these observations do not fit with the prediction of the cold dark matter scenarios predicting random distribution of galaxies and galaxy clusters at long length scales.

The first task is to find whether one could understand the length scale of order 1.2 Megaparsecs p-adically. In TGD, the cosmological evolution means the gradual emergence of longer and longer p-adic length scales, that is space-time sheets with size of order not too many p-adic length scales $L(p)$, where p is assumed to be near prime power of two by experience with the p-adic mass calculations: $p \simeq 2^k$, k power of prime. These regions (3-surfaces with outer boundaries!) do not expand any more but move like comoving particles in the expanding background (surface of larger p-adic prime).

There are not too many physically interesting p-adic primes near prime powers of two and the p-adic length scale associated with the prime $p \simeq 2^k$, $k = 367$ is $\hat{L}(367) \simeq 3.2E+8$ light years, whereas the length scale $L(Einasto) = 7.8E+8$ light years, deduced by Einasto *et al* is roughly *two times* this length scale. The two nearest length scales correspond to $p \simeq 2^k$, $k = 359$ with 16 times smaller length scale and $k = 373$ with 8 times larger length scale so that identification is unique. Therefore, it seems that p-adic length scale hypothesis might work even in the cosmological length scales.

The problem is to understand the origin of the lattice like structure. The least radical suggestion mentioned in [E123] is that some kind of acoustic waves during the early cosmology have left their trace in the background and caused the periodicity. Also a new physics in the inflation period has been speculated.

A priori, one can consider in TGD framework two alternative scenarios for the origin of the lattice structure. Either the structure is created during the very early cosmology and during cosmic expansion its size has gradually increased to its recently measured value. Or the structure is created later. TGD inspired cosmology is based on the hypothesis that new p-adic length scales emerge in the topological condensate during the cosmic evolution. Therefore one can consider the possibility that the large voids are structures, which have appeared later rather than having been present all the time. Of course, nothing excludes the possibility that the voids have expanded until they have reached the critical p-adic size for which the expansion has ceased.

The mechanism creating lattice structure could be based on so called p-adic fractals and be a consequence of the effective p-adic topology rather than result from some delicate dynamical mechanism. Already the existence of the p-adic length scales implies one kind of fractality. There is however also a second kind of fractality associated with a given value of the p-adic prime p. This latter kind of fractality, p-adic fractality for short, might provide an explanation for the lattice like structures as the following argument suggests.

p-Adic fractality for the real mass density ρ_R means that the density can be regarded as a map

$$\rho_R = I^{-1} \circ \rho \circ I \ ,$$

where ρ is the p-adic valued mass density in p-adic space-time and I denotes the so called *canonical identification*,

$$I : \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n} \ ,$$

mapping p-adics to reals and inducing a map from real space-time region to p-adic space-time region. Thus, given a p-adically analytic mass density function ρ, the map $\rho_R = I \circ \rho \circ I^{-1}$ induces real density function ρ_R, which turns out to be a fractal as the numerical study of simple examples for small values of p shows.

This lattice structure of the p-adic fractals follows directly from the basic properties of the canonical identification mapping p-adics to reals. The point is that canonical identification in range $[0, p)$ for the real numbers induces discontinuities of the real density $\rho_R = I \circ \rho \circ I^{-1}$ at the points $x = k = 0, 1, ...p - 1$. Same occurs in each interval $[n, n+1)$ at $x = n + kp$, k integer, which are mapped to the reals in the interval $[n, n+1)$ and so on ad infinitum. Therefore the powers $p^{k/2}$ of the basic length scale are preferred scales for this structure. In higher-dimensional case one clearly obtains lattice like structure for the discontinuities. The lattice structure is not quite obvious in the illustrations of the 2-dimensional p-adic fractals represented in the first part of the book. If one plots p-adic fractal of the planar coordinates using different colors for different value ranges of the function, the cubic structure becomes manifest and one obtains extremely beautiful pictures.

8.2.4 Sunspot Cycle

To begin with, consider the general properties of the solar magnetic fields and Sunspots [E181].

1. The average magnetic field of the Sun is dipole field and reverses its polarity with a period of eleven years. The actual solar magnetic field consists of the discrete elements (flux tubes) and all element sizes and magnetic field strengths seem to be possible. The appearance of the discrete structures is not in accordance with the naïve magnetohydrodynamics expectations [E181]: the stability argument (magnetic pressure plus the plasma pressure inside the flux tube equals to the plasma pressure outside the flux tube) gives a lower bound of about 0.1 T for the magnetic field of a stable flux tube and smaller field strengths have been observed.

2. The short time scales associated with the dynamics of the magnetic structures are not in accordance with the magnetohydrodynamics expectations [E181]: in magnetohydrodynamics diffusion determines the time scale for the change of the magnetic fields and the time scale for changes in length scale L is of the order of $T \simeq L^2/\sigma$, where σ is the conductivity of the plasma. For the changes taking place in the length scale of Sun the time is of the order of $T \simeq 10^{10}$ years: dipole field changes its direction during a year! For Sunspots having typically the size of the order of $L \simeq 10^7$ m, the corresponding time is of the order of $T \simeq 10^6$ years.

3. The appearance of the Sunspots is related to the change of the polarity of the Solar magnetic field. Sunspots appear first at latitudes ± 40 *degrees* and gradually the region, where new Sunspots appear, drifts to the direction of the equator. Sunspot magnetic field is bipolar and the field strength is typically about 0.1 T. The magnetic pole is referred to as p or f pole depending on whether the pole in question precedes or follows in the solar rotation (the western pole is by definition the leading pole). The polarity of the leading spots is same (Hale-Nicholson law) for all Sunspots in a given hemisphere and for a given solar cycle. The polarity of the p spot is opposite for the two hemispheres and for two successive cycles. The opposite polarity of the southern and northern p spots guarantees the dipole field nature of the average magnetic field. The change of the polarity in the beginning of the solar cycle (implying the change of the polarity of the dipole field) is however not well understood in the present models.

4. Sunspots seem to be related to the convective motion of the matter. There is a net outward and inward flow of the matter with a velocity of order $\beta \simeq 10^{-5}$ at p and f poles of the Sunspot respectively so that Sunspots take part in the convection. There are also indications that the fibril like structures on the penumbra of p pole are convective rolls [E181]. These features suggest that Sunspots are magnetized helical vortices.

5. The appearance of the Sunspots is accompanied by a reduction of the solar constant: a possible explanation is that part of the solar energy is stored as a kinetic energy of the fluid motion associated with the Sunspots and as a magnetic field energy [E181].

8.2.5 Sunspots As Helical Vortices

TGD suggests an explanation of the discrete magnetic structures as a direct manifestation of the CP_2 geometry. The TGD inspired model for the Sunspot is motivated by the general ideas described earlier and by the basic features of Sunspots. For the reader's convenience only the general ideas are described and calculational details are left later.

1. In accordance with the ideas about the generation of hydrodynamical turbulence as spontaneous Z^0 magnetization, it is assumed that the structures of the solar magnetic field correspond to Z^0 magnetized domains, i.e. vortices of some kind.

2. The TGD based concept of the 3-space suggests strongly that vortices correspond to topological field quanta, that is 3-surfaces of a finite size and with outer boundary, glued to a background 3-space. The outer boundary corresponds to the critical radius for the embedding of the Z^0 magnetic field created by the moving matter. The requirement that the critical radius of the magnetic flux tube is of the order of Sunspot size or smaller, implies that the values of the vacuum quantum numbers associated with the Sunspots must be considerably smaller than those associated with the background 3-space.

3. Also the background space is a carrier of a Z^0 magnetic field (which can be weak) and helical vortex interacts with this field by Z^0 magnetic dipole interaction, which explains the motion of the ends of the helical vortex in the Sunspot cycle.

4. The simplest (Z^0) magnetized domains are vortex like structures and Sunspots are identified as helical vortices, one of whose functions, besides maximizing Kähler function, is the convective transport of heat. This function explains why the ends of the Sunspot are at the surface of the Sun and why the main part of the structure is beneath the surface of the Sun, possibly at the bottom of the convective zone. It should be emphasized that Sunspots are not the only structures of this type: also smaller structures are possible and the radius of the vortex is determined by the value of the fractal quantum number m and magnetic quantum numbers. The small size of these structures however makes them invisible.

5. The velocity field of the vortex serves as a source of Z^0 magnetic field:

$$\nabla \times \bar{B}_Z = NK_Z\bar{v} \ , \tag{8.2.1}$$

   where $N \equiv \rho_m/m_p$ denotes nucleon density and $K_Z = \epsilon_1 10^{-19} = g_Z/\sqrt{\epsilon_Z}$ describes the strength of the Z^0 force. By neutrino screening, the average Z^0 charge density is expected to be much smaller than the density of the nuclei. It has been assumed that neutrinos do not participate in the rotational motion so that nucleons serve effectively as the source of the Z^0 magnetic field. This means that ϵ_Z appearing in the formula refers to the Z^0 gauge flux coming from the "previous" condensate level. For the condensate level at which the elementary particles feed their Z^0 charges, one has therefore $\epsilon_Z = 1$. At the astrophysical scales ϵ_1 is smaller than one.

6. The magnetic field of the Sunspot is generated, when the integers n_i change so that their ratio differs from the value $n_1/n_2 = \omega_1/\omega_2$ guaranteeing the vanishing of the electromagnetic fields. This process implies that Z^0 magnetic line dipole becomes also an ordinary magnetic line dipole and therefore visible, when the ends of the vortex are at the surface of the Sun. This mechanism implies also that magnetic and Z^0 magnetic fields are parallel to each other.

7. Magnetohydrodynamic stability conditions are satisfied if the magnetic field of the Sunspot is parallel with the electric current so that the Lorentz force vanishes: $\nabla \times \bar{B} = \bar{v} \propto \bar{B}_{em}$ [E181]. This condition holds true also for the Z^0 magnetic field. If the magnetic field is generated by changing the values of the magnetic quantum numbers n_1 and n_2, then Z^0 magnetic and magnetic fields are parallel so that also Z^0 magnetic and velocity fields are parallel:

$$\bar{B}^Z \propto \bar{v} \ . \tag{8.2.2}$$

   Helical vortices are the simplest objects allowing this kind of structure. A more detailed model for the helical vortices is postponed to the last subsection.

8.2.6 A Model For The Sunspot Cycle

Consider now a simplified model of the Sunspot cycle in terms of the helical vortices.

1. Sunspots correspond to helical vortices, whose main part is parallel to the surface of the Sun and whose ends are vertical vortices. In accordance with the idea that 3-space is a hierarchical condensate of 3-surfaces of various sizes, it is assumed that helical vortices correspond to topological field quanta condensed to the background 3-space. Also the background 3-space is a carrier of Z^0 magnetic field B_Z, which might be identified as the "average" or "self consistent" magnetic field created by the other topological field quanta.

   Helical vortices possess a definite Z^0 magnetic moment $d\bar{\mu}_Z/dl$ per unit length in the direction of the vortex: magnetic moment is due to the rotational motion of the matter inside the helical vortices. Therefore the vortices interact with the average Z^0 magnetic field of the Sun by the usual dipole interaction. Observations suggests that the poles of the Sunspot behave like independent dynamical objects so that in the first approximation the constraint forces can be neglected the ends of the vortex and vortices suffer a force per unit length given as the gradient of the dipole interaction energy per unit length

$$\frac{d\bar{F}}{dl} = \nabla(\frac{d\bar{\mu}_Z}{dl}\cdot\bar{B_Z}) \ . \tag{8.2.3}$$

   At the beginning of the Sun spot cycle only the radial component of the magnetic field contributes to the force since p and f poles of the Sunspot are to a good approximation at the same latitude. The force is in the direction of the meridian. Since the sign of $d\bar{\mu}/dl$ is opposite for p and f poles they begin to move in opposite directions. The contribution of B_r to the force changes its sign at equator and this motivates the assumption that the p end of the Sunspots oscillates between the latitudes $+40$ and -40 degrees.

   The nice feature of the proposal is that the force is indeed in the right direction at the beginning of the solar cycle and the forces on p and f have opposite directions. The details of the force are not important for the estimate of the duration of solar cycle. It is the latitude at which the Sunspot formation begins, which depends on the detailed properties of the force.

2. The motion of poles and in particular, differential rotation of the Sun implies the stretching of the vortex. If the flow is incompressible the volume of the vortex remains constant (V_0) so that the area (S) of the vortex decreases as $1/L$ as function of the vortex length L:

$$L = L_0\frac{S_0}{S} \ . \tag{8.2.4}$$

   Typical initial values of S and L are $S_0 \simeq \pi\cdot 10^{12}\ m^2$ and $L_0 \simeq 10^7\ m$. The decrease of the cross sectional area implies that the Sunspot becomes invisible after having reached some critical radius.

3. After having reached a certain critical radius of the order of the radiation length $L_{rad} \simeq 3\cdot 10^4\ m$, vortex becomes unstable against pinch and splits to two pieces. The reason is that vortex must be cooler than its surroundings by the magnetic equilibrium conditions ($B^2/2 + nkT_{in} = nT_{out}$) and this is not possible if the radius of the vortex is too small since the radiation flux of the Sun destroys all temperature gradients in the length scales smaller than $L_{rad} \simeq 3\cdot 10^4\ m$. The critical length of the vortex is therefore given by $L_f \sim L_0S_0/S_f \simeq 4\cdot 10^{11}\ m$.

4. Since the stretching of the vortex results mainly from the differential rotation of the Sun (rotation period is $T_{rot} = 25\ d(ays)$ and $T_{rot} = 30\ d$ on poles and equator respectively). This means that the upper bound for the time required to achieve instability is of the order of $T_{cycle} \leq (L_f/R_{Sun})T_{rot} \simeq 4\cdot 11$ years ($R_{Sun} \simeq 8\cdot 10^8\ m$) and of the same order of magnitude

as the period of the Sunspot cycle (recall that the naïve magnetohydrodynamic estimate is about 10^{10} years!). The actual value is smaller since in the beginning of the cycle the effect of the differential rotation is considerably smaller than at the end of the cycle.

5. The stretched magnetized vortices give the dominant contribution to the average dipole field of the Sun and the entanglement of the dipole field lines resulting from the freezing of the magnetic field lines to differentially rotating matter corresponds to the stretching of the co-rotating vortices. The dipole nature of the average solar magnetic field requires that p type poles must have same polarity on the given hemisphere and that the polarities of p type poles are opposite for Southern and Northern hemispheres.

6. The vortices started from the latitude of 40 (-40) degrees achieve critical length at the latitude -40 (40) degrees begin to split to pieces. The resulting pieces achieve their equilibrium volume V_0 by increasing their transverse size from the critical size S_f to S_0 implying the increase of the radius by a factor of order $10^{3/2}$. The pieces are observed as new Sunspots and the gradual splitting starting from the end explains why the Sunspot active region proceeds gradually to the direction of equator. The mysterious reversal of p type polarity results from the opposite polarities of p poles at Northern and Southern hemispheres. This in turn implies the change of polarity of the solar magnetic field at each Sunspot cycle.

7. The energy needed to generate the magnetic field of the thickened vortex and the kinetic energy of the vortex motion is provided by the energy production in the interior of the Sun and the process explains the decrease of the Solar constant.

8.2.7 Helical Vortex As A Model For A Magnetic Flux Tube

The detailed model of the magnetic flux tube as a helical vortex is based on the following physical picture.

1. The velocity field of the vortex serves as source of Z^0 magnetic field

$$\begin{aligned} \nabla \times \bar{B}^Z &= K_Z N \bar{v} \ , \\ K_Z &= -\frac{g_Z^2}{4\sqrt{\epsilon_Z}}\frac{A-Z}{A} \ . \end{aligned} \tag{8.2.5}$$

where $N \equiv \rho_m/m_p$ denotes nucleon density and K_Z describes the strength of Z^0 force. $\epsilon_1 \leq 1$ measures the relative strength of Z^0 and gravitational forces. For the gravitational interaction to dominate over Z^0 force the condition $\epsilon_Z > 10^{36}$ must hold true.

2. The magnetic field is generated, when the integers n_i change so that their ratio differs from the value $n_1/n_2 = \omega_1/\omega_2$ guaranteeing electrovac property. This mechanism implies that magnetic and Z^0 magnetic fields are parallel to each other.

3. Magnetohydrodynamic stability conditions are satisfied if the magnetic field of the Sunspot is parallel with the electric current so that the Lorentz force vanishes: $\nabla \times \bar{B} = \bar{v} \propto \bar{B}_{em}$ [E181]. If the magnetic field is generated by changing the values of the magnetic quantum numbers n_1 and n_2 then Z^0 magnetic and magnetic fields are parallel so that also Z^0 magnetic and velocity fields are parallel:

$$\bar{B}^Z \propto \bar{v} \ . \tag{8.2.6}$$

Helical vortices are the simplest objects allowing this kind of structure and cylindrical symmetry fixes the structure of the helical vortex almost completely.

The helical vortex possesses cylindrical symmetry in the sense that Z^0 magnetic field and velocity field have only z and ϕ components, which depend on the cylindrical coordinate ρ only, so that one has

$$\begin{aligned}
\Phi &= \omega_1 t + k_1 z + n_1\phi \ , \\
\Psi &= k\Phi = \omega_2 t + k_2 z + n_2\phi \ , \\
r &= tan(X(u)) \ , \\
X(u) &= ln((k+u)/C)\epsilon/2 \qquad u = u(\rho) \ , \\
\frac{\omega_2}{\omega_1} &= \frac{k_2}{k_1} = \frac{n_2}{n_1} \ .
\end{aligned} \tag{8.2.7}$$

The relationship between the velocity field and Z^0 magnetic field is dictated by the condition that matter flow serves as source of the Z^0 magnetic field.

The expressions for the non-vanishing components of the induced Z^0 magnetic field are given by

$$\begin{aligned}
B_z^Z &= -\frac{3}{(3+p)} n_1 sin^2 X \frac{\partial_\rho u}{\rho} \ , \\
B_\phi^Z &= -\frac{3}{(3+p)} k_z sin^2 X \frac{\partial_\rho u}{\rho} \ .
\end{aligned} \tag{8.2.8}$$

The requirement $\nabla \times \bar{B^Z} \propto \bar{B^Z}$ implies the condition

$$\frac{\partial_\rho B_z^Z}{\partial_\rho B_\phi^Z} = -\frac{B_\phi^Z}{\rho^2 B_z^Z} \ . \tag{8.2.9}$$

Using the explicit representation as an induced gauge field one obtains the differential equation

$$\begin{aligned}
\partial_\rho Y &= \frac{(1-(\rho/\rho_1)^2)}{(1+(\rho/\rho_1)^2)\rho} Y \\
Y &= sin^2 X \partial_\rho u \ , \\
\rho_1 &= \frac{n_1}{k_z^1} \ ,
\end{aligned} \tag{8.2.10}$$

which gives

$$\begin{aligned}
\partial_\rho Y &= \frac{(1-(\rho/\rho_1)^2)}{\rho(1+(\rho/\rho_1)^2)} Y \ , \\
Y &= sin^2 X \partial_\rho u \ .
\end{aligned} \tag{8.2.11}$$

By integrating this equation, one obtains

$$\begin{aligned}
B_z^Z &= -\frac{3}{(3+p)} \frac{n_1}{[(1+(\rho/\rho_1)^2)\rho_0^2]} \ , \\
B_\phi^Z &= \frac{k_z^1}{n_1} \rho^2 B_z^Z \ ,
\end{aligned} \tag{8.2.12}$$

where ρ_0 is an integration constant possessing the dimension of length.

The magnitudes of the velocity components β_z and β_ϕ are

$$\beta_z = \frac{2k_z^1}{NK_Z\rho_0^2}\frac{p}{2(3+p)}\frac{1}{(1+(\frac{\rho}{\rho_1})^2)} ,$$
$$\beta_\phi = \frac{\rho}{\rho_1}\beta_z . \tag{8.2.13}$$

Stability requirements for helical vortices [E237] suggest that the value of n_1/k_z^1 is of the same order as critical radius. Notice that the vortex rotates like a rigid body near the z-axis and that the longitudinal velocity is also approximately constant near the z-axis.

The above described embedding of the helical Z^0 magnetic field fails at the critical radius $\rho = \rho_{cr}$, which corresponds to the value of $r = \infty$. The expression for the critical radius in present case is obtained from the condition $r = \infty$ and reads as

$$\rho_{cr} = \rho_1\{exp[4(\frac{\rho_0}{\rho_1})^2(u_0+k)exp(-\frac{2\pi m}{\epsilon})X_0]-1\}^{1/2} ,$$
$$\simeq 2\rho_0 exp(-\frac{m\pi}{\epsilon})[(u_0+k)X_0]^{1/2} ,$$
$$X_0 = \frac{(2+\epsilon^2)exp(\frac{\pi}{\epsilon})+\epsilon^2}{1+\epsilon^2} , \tag{8.2.14}$$

where it has been assumed that the value of the exponent is small. It will shortly found that the assumption is physically well founded. Notice that the critical radius depends extremely sensitively on the value of the "fractal" quantum number m and that the critical radii are related by a power of a discrete scaling transformation in the approximation used.

If one requires that Z^0 magnetic flux is quantized with n_1 multiple of some integer n, one has simpler condition

$$\frac{3}{3+p}2(u_0+k)exp(-2\pi m/\epsilon)X_0 = \frac{1}{n} ,$$
$$\rho_{cr} = \rho_1\{exp[2\frac{\rho_0^2}{n\rho_1^2}]-1\}^{1/2} . \tag{8.2.15}$$

If one requires flux quantization without any conditions on n_1, one must assume $n = 1$.

Vortex carries also radial Z^0 electric field: the magnitude of this field is given by

$$|E^Z| = |B_\phi^Z|(\omega_1\rho/n_1) . \tag{8.2.16}$$

The parameterization $\omega_1 = \sqrt{\epsilon_Z}x$, $x \sim 1$ is expected to hold true for ω_1.

8.2.8 Estimates For The Vacuum Parameters Of Magnetic Flux Tube

Consider next the values of the various vacuum parameters appearing in the embedding of the helical vortex.

An estimate for the quantum number ω_1

From the requirement that gravitational interaction is stronger than Z^0 force in long length scales one obtains $\omega_1 \leq 1/R \sim 10^{-4}m_{Planck}$ and $\epsilon_Z > 10^{38}$. The other extreme correspond to the condensate level $n = n_Z$ with $\epsilon_Z(n_Z) \sim 10^{20}$. One must however remember that neutrinos are not expected to serve as the source of Z^0 magnetic field and therefore $\epsilon_Z(n-1)$ appears in the expression of the magnetic field at level n and at level n_Z the total unscreened nuclear charge serves therefore as the source of B_Z. Lorentz invariance implies that the value of k_z^1 is given by

$$k_z^1 \simeq \omega_1\beta_z . \tag{8.2.17}$$

An estimate for the quantum number n_1

The requirement that angular momentum density is of correct order of magnitude gives an estimate for the value of the parameter n_1. The expression of the conserved angular momentum current in the z-direction is given by

$$J^\alpha = T^{\alpha\beta}\partial_\beta m^k m_{kl} j^l \quad , \tag{8.2.18}$$

where j^k denotes the vector field associated with an infinitesimal rotation and $T^{\alpha\beta}$ denotes energy momentum tensor. For the angular momentum density one obtains in the cylindrical M^4 coordinates for X^4 the expression

$$\begin{aligned} J^t &= T^{t\phi}\rho^2 \quad , \\ T^{\alpha\beta} &= \frac{1}{16\pi G}G^{\alpha\beta} \quad , \end{aligned} \tag{8.2.19}$$

where the second equation is Einstein's equation.

Case a:

If the contribution of CP_2 curvature to the curvature tensor is not dominating the leading order contribution to $G^{t\phi} = R^{t\phi} - g^{t\phi}R/2$ comes from the non-vanishing of the metric component $g_{t\phi}$:

$$g_{t\phi} = s^{eff}_{\Phi\Phi}\omega_1 n_1 = -\frac{R^2}{4}(cos^2(X)(k+u)^2 + 1 - u^2)sin^2(X)\omega_1 n_1 \quad , \tag{8.2.20}$$

and one obtains the order of magnitude estimate

$$J^t \simeq -T^{tt}g_{t\phi} \simeq \rho_m \frac{R^2}{4}\omega_1 n_1 \quad . \tag{8.2.21}$$

In order to obtain a correct order of magnitude for the angular momentum density associated with rotational flow one must have

$$\frac{R^2}{4}\omega_1 n_1 \sim \rho\beta(\rho) \quad , \tag{8.2.22}$$

which implies

$$\begin{aligned} n_1 &\simeq \frac{L}{R^2\omega_1}\beta \sim \frac{10^{19}}{\sqrt{\epsilon_Z}x}\frac{L}{R}\beta \quad , \\ \omega_1 &\equiv x\sqrt{\epsilon_Z}m(proton) \quad , \end{aligned} \tag{8.2.23}$$

where L and β are typical scale and velocity associated with the flow and $x \sim 1$ is expected to hold true. If L is taken to be the radius of the vortex ($L \sim 10^7\ m$) and $\beta_\phi \sim 10^{-5}$ the rotation velocity of the vortex, one obtains: $n_1 \sim \frac{10^{55}}{x\sqrt{\epsilon_Z}}$. If L is taken to be the radius of the Sun and β, the rotation velocity of the Sun the value of n_1 is about hundred times larger. The order of magnitude for E^Z is

$$E^Z \sim a\frac{B^Z}{\beta_{rot}} \quad ,$$

with

$$a = x\sqrt{\epsilon_Z}Gm_p\omega_1 << 1 \quad ,$$

and is consistent with the assumption that the density of Z^0 charge is much smaller than the density of the nucleons.

Case b:

If Z^0 field is strong as compared to the gravitational field, the dominating contribution to $G^{t\phi}$ comes from the contribution of the CP_2 curvature to $R^{t\phi}$ and is proportional to the quantity $J^t{}_\rho J^{\rho\phi}$: in this case the previous estimate doesn't hold anymore and one obtains the estimate

$$\frac{n_1}{\omega_1} \simeq \beta L \ . \tag{8.2.24}$$

Since Z^0 field is strong inside the Sunspots one must use this estimate for n_1/ω_1 and one obtains the estimate

$$E^Z \sim \frac{B^Z}{\beta_{rot}} \ .$$

The result would mean that the density of Z^0 charge is of same order of magnitude as the density of the nucleons and by the presence neutrino screening this is not possible. Therefore case 1) is closer to the actual physical situation.

An estimate for the radius ρ_0

An estimate for the radius ρ_0 is obtained by substituting the estimate of k_z to the general expression of β_z at z-axis and one obtains the condition

$$\begin{aligned} \rho_0 &\sim [10^{19}\frac{p}{(3+p)}\frac{1}{\sqrt{G}N\epsilon_1}]^{1/2} \\ &\sim (\frac{1}{\epsilon_1})^{1/2}10^{11}\ m \ , \\ \epsilon_1 &\equiv K_Z 10^{19} \ , \end{aligned} \tag{8.2.25}$$

where the estimate $N \sim 10^{30}/m^3$ for the nucleon density has been used.

An estimate for the fractal quantum number m

En estimate for the value of the fractal quantum number m is obtained from the condition that the exponent appearing in the expression of the critical radius is small:

$$4(\frac{\rho_0}{\rho_1})^2 exp(-2m\pi\epsilon)[(u_0+k)X_0] \ll 1 \ . \tag{8.2.26}$$

Since one has $\rho_0 \simeq \sqrt{1/\epsilon_1}10^{11}\ m$ and $\rho_1 \sim \rho_{cr} \sim 10^6\ m$, one obtains an order of magnitude estimate $exp(-2m\pi/\epsilon) \ll 10^{-10}\epsilon_1/(u_0+k)$ so that the value of m must be rather large unless the value of the parameter $u_0+k = u_0+n_2/n_1$ is very small or the value of ϵ_1 is sufficiently large: the value $\epsilon_1 \geq 10^5$ implies that m is of order 2: a rather natural looking value unlike the large values implied by $\epsilon - 1 \sim 1$.

Estimate for the magnetic field

If the magnetic field is generated by the change of n_1 so that the condition $\omega_1/\omega_2 = n_1/n_2$ ceases to hold true one obtains the following approximate expression for the magnetic field at the z-axis

$$B_z^{em} \simeq \frac{\Delta n_1(3+p)}{\rho_0^2} \ . \tag{8.2.27}$$

The requirement that the magnetic field is of the order of $B_{em} = 10^3\ Gauss$ gives the estimate $\delta n_1 \simeq 10^{36}/\epsilon_1$ so that the relative change of n_1 is given by $\Delta n_1/n_1 = 10^{-19}x\sqrt{\epsilon_Z}/\epsilon_1 << 1$ for alternative 1) in which n_1 is very large. The argument related to the destruction of the super fluidity by the generation of Z^0 magnetic fields suggests the range $\epsilon_Z \in (10^{20} - 10^{22})$ at the condensation level level n_Z, at which elementary particles feed their Z^0 gauge fluxes for ϵ_Z (recall that $1/\sqrt{\epsilon_Z(n)}$ tells which fraction of total nuclear Z^0 charge the unscreened Z^0 charge is at the condensate level n and therefore flows to level $n+1$ via the # throats located near the boundaries of level n surface). This number corresponds to $\epsilon_1(n_Z) = 10^{19} g_Z/\sqrt{\epsilon_Z} \in (10^8 - 10^9)$. Quite strong Z^0 magnetic fields are possible: the strength of the Z^0 magnetic field at the level $n = n_Z + 1$ is below 10^4 $Tesla$ for $\epsilon_Z(n_Z) = 10^{22}$ and $\rho_{cr} \sim 10^6$ m!

8.3 TGD based model for the solar magnetic field, solar cycle, and gamma ray emission

Sabine Hossenfelder gave a link to a popular article (see `http://tinyurl.com/y6mpuggu`) telling about rather shocking new findings about Sun.

8.3.1 Solar surprise: looking sunspots again after decades

There are 5 times more gamma rays than expected and the spectrum has a deep and narrow dip in 30-50 GeV range. Spectrum continues to much higher energies than expected, at least up to 100 GeV. One proposal is that there could be dark matter in the interior of Sun yielding the gamma rays but is unclear how they could get to the surface without experiencing the same fate as the ordinary gammas from nuclear reactions. There is also a correlation with sunspot cycle (see `http://tinyurl.com/aqw2hmz`). Basic data and observations related to correlations with the solar cycle are described in the article [E150] (see `http://tinyurl.com/yxajyzp8` and [E143] (see `http://tinyurl.com/y2qlaaa2`).

1. Power law spectrum is harder than for cosmic rays: spectral indices are $n = -2.2$ and $n = -2.7$ respectively (one has power law behavior E^n for the flux). The spectral intensity at 100 GeV is very nearly the maximum flux predicted by the model assuming that reflection of cosmic gamma rays explains the gammas.

2. The spectrum has two components: poloidal component farther from equator and equatorial component largest during sunspot minimum. The equatorial contribution is maximal at solar minimum. The spectral index of the equatorial contribution is harder and higher energies are present. The energy range is maximal during spot minima. Gamma flux is reduced during sun spot maxima.

How the observed gamma rays could be produced in TGD Universe?

1. Gamma rays cannot cannot be produced by nuclear reactions as ordinary gammas since nuclear energy scale is much below the scale of gamma rays extending to 100 GeV at least. Even the hadronic energy scale is too low. The gamma rays could be cosmic rays having already high energies: the spectral indices are however different. This leaves acceleration of charged particles producing gamma rays as the most plausible mechanism irrespective of whether the charged particles come from solar core or are cosmic rays.

2. Dark magnetic flux tubes are basic notion of TGD and could serve as the channels along which charged particles could propagate to the surface without losing their energies in collisions. An interesting hypothesis considered already earlier is that solar magnetic field are what I call wormhole magnetic fields [K118] consisting of closed monopole flux tubes with flux and return flux at different space-time sheets connected by tiny wormhole contacts. This would predict that the flow is not evenly distributed but reflects the structure of the flux tube distribution. If the flux tubes have same M^4 projection they cause no effects on test particle and behave like dark energy creating only long range gravitational fields.

   Charged particles could accelerate in the electric field of flux tube as they travel along flux tubes and generate gamma rays by some mechanism. The energy would be the increment of Coulomb energy if dissipation is neglected. A simple modification of flux tube type extremals allows the presence of helical magnetic and electric fields along flux tube orthogonal to each other. I have proposed the same mechanism to explain the gamma rays and high energy electrons at MeV energies associated with lightnings [K20]: in standard physics framework dissipative losses do not allow them.

3. What could be the production mechanism of gamma rays? If flux tubes have sharp kinks, charged particles should experience large deceleration in the kinks and could emit high energy gamma ray in the process. The highly relativistic charge particle itself could leak out (one cannot exclude nuclei from solar core). Large deflection angles however requires transfer of momentum also to flux tube degrees of freedom.

4. What could be the origin of the tip around 30-50 GeV? If the acceleration takes place in the electric fields assignable to the closed flux tubes assignable to solar dipolar magnetic field, the charged particle could travel several times around the loop giving rise to several energy bands explaining the gap and suggesting several of them. The flux loop would act as a particle accelerator.

5. The charged particles could be provided by the solar core or they could be cosmic rays. The order of magnitude for gamma ray intensity is 5 times larger than in cosmic ray model, which encourages the identification as cosmic rays (see `http://tinyurl.com/psdp99h`). The origin of cosmic rays is however also a mystery and neutron stars, supernovae, active galactic nuclei, quasars, and gamma-ray bursts have been proposed as sources of cosmic rays.

   A possible mechanism producing cosmic rays could be pair-annihilation of pairs of M_{89} pions with mass about 70 GeV [K68] to gamma ray pairs or charged particles with energies 35 GeV. Could the dip observed in the energy range around 30-50 GeV somehow relate to the charged decay products of M_{89} pions accelerating in the electric fields of flux tubes? Could the dip be gap without the decays of M_{89} pions?

   In TGD the model for the formation of galaxies, quasars, and active galactic nuclei, and even stars, and planets relies on the formation of looped tangles along long thickening cosmic strings with topology resembling that of dipole magnetic field. Galactic matter would be produced by the decay of the flux tube energy to particles as analog of the decay of inflaton field. This could generate both charged particles and gamma radiation in the solar core and in neutron stars. The acceleration could be much more effective due to the strong magnetic and electric fields involved. Also charged particles can leak out from the flux tubes and cosmic rays could be produced by this mechanism. Cosmic rays could move along the highways defined by the long magnetic flux tubes connecting galaxies.

The understanding of the correlations with the solar cycle requires a model for the polarization flip. One can consider several options but the model based on reconnection splitting dipole loops from the flux tube tangle representing the analog dipole field is the simplest one. The simplest variant of the model requires zero energy ontology (ZEO) and quantum coherence at dark flux tubes in solar length scales and that long galactic string defines wormhole magnetic field with two sheets (type I and II) connected by wormhole contacts separated from each other in the sense that M^4 projections are disjoint.

1. Let us denote the numbers of dipole loops of type $i = I, II$ by n_i. Assume that in the initial situation one has $(n_I = n_{max}, n_{II} = 0)$. B as maximum value B_{max}. The arrows of time at the two sheets are assumed to be opposite during cycles.

2. The transition leading $B = B_{max}$ to $B = 0$ would be "big" state function reduction (BSR) changing the arrow of time at sheets of both type I and II. BSR would generate maximum number of new dipole flux loops of type II: $n_{II} \rightarrow n_{max}$ so that one has $n_I = n_{II} = n_{max}$ and $B = 0$.

3. After that dipole loops of type I begin to split away by reconnections in "small" state function reductions (SSRs) so that n_I decreases. They split further in pieces and leak out from Sun whereas n_{II} remains unchanged since it corresponds to the passive boundary of CD - this is essential. Net B increases until one has $B = -B_{max}$.

4. Next occurs BSR generating maximum number of new flux loop portions of type I leading $n_I = n_{II} = n_{max}$ and $B = 0$ and same is repeated except that now n_{II} decreases.

5. One can understand the sunspot cycle in terms of split dipole loops leaving the Sun: their intersection with the solar surface would define sunspot pair and the distance of members of the pair would decrease to zero during the cycle.

   The model leads to rather dramatic predictions.

1. Various magnetic structures are predicted to appear in pairs with members related by an approximate Z_2 symmetry. For the magnetic field of the Sun this symmetry would be naturally inversion symmetry with respect to the surface of Sun. Also reflection symmetry can correspond to Z_2. This symmetry should be universal and the predictions are in sharp contrast with the locality principle of classical physics. One could even understand the mysterious "Axis of Evil" associated as anomaly of CMB and apparently giving special role for solar system (see `http://tinyurl.com/yb6nabw4`).

2. Also unexpected connections with TGD inspired views about biology and consciousness emerge. Magnetic body (MB) is the intentional agent in living system Z_2 realized as inversion could related the parts of MB in the interior and exterior of Earth: could the idea about intra-terrestrial life introduced originally half-jokingly [K60, K62, K35, K35] make sense - at the level of MBs at least? ZEO based theory of consciousness predicts that conscious entities can have both arrows of time and death means reincarnation with opposite arrow of time. But where do these ghostly selves with opposite arrow of time reside? Could Z_2 - possibly realized as inversion - relate these selves to each other.

8.3.2 How the magnetic fields of galaxies and stars are generated?

To get a general enough perspective about the generation of time dependent B, one must consider the general model for how the magnetic fields of galaxies, stars, and planets are generated.

1. The magnetic fields of galaxies, stars, and planets would have formed as tangles along cosmic strings thickened to magnetic flux tubes carrying monopole flux. . Tangles would be formed by the flux tubes forming knotty structures with flux tubes defining analog for subset of flux lines of dipole field. The flux tubes can organize in several ways.

   Cosmic strings would be wormhole magnetic fields carrying opposite monopole fluxes at space-time sheets connected by wormhole contacts (in principle it is possible to consider also single-sheeted monopole fluxes). I will talk about sheets of type I and II. If the flux tubes are on top of each other in the sense that M^4 projections are identical, the magnetic field experienced by test particle touching both flux tubes would vanish. The fact that the energy of the flux tubes gives rise to gravitational field can be used to argue that one can talk about dark energy in this case. The flux tubes can be connected by extremely short wormhole contacts at places, where they are on top of each other. If the Euclidian wormhole contacts can have tube-like M^4 projection, they would be also flux tube like.

2. It is not clear whether the flux tubes of both type I and II are inside the volume bounded by Earth's B or whether second type of flux tubes are outside Earth. This gives rise to several options for how B can be realized as flux tube field and how the time dependence of B is obtained.

3. One can imagine two options, which apply to both types of fluxes separately. For the most general option (Option I) the incoming flux tube can divide to smaller flux tubes going both to the interior and exterior of the dipole core. The extreme options (Option II and II) are that it flows entirely to the dipole core or divides to flux tubes travelling outside the dipole core (this situation is analogous to hydrodynamical flow past obstacle). It will be found that option II is most attractive one.

4. Incoming flux long tube at given sheet forms a tangle. Consider first the tangle formed by the incoming long flux tube of given type at fixed space-time sheet, for definiteness restriction the consideration to flux of type I..

(a) For Option I the neighbouring flux portions of the flux tube portions inside and outside dipole core can have random orientations: this would be like random spin system without any magnetization. The average observed field would be random. For Options II and III this kind of situation is not possible.

(b) The flux tube in the tangle can also arrange like spins in spontaneous magnetization so that neighboring portions of the flux tube are parallel both inside the core and outside it. The flux and return flux would be at different sides of the dipole core. This could give rise to an analog of say dipole field. For instance, dipole core could correspond to a spherical volume bounded by the Earth's surface. The extreme situation would correspond to Option II or III.

5. For Option I the polarity of observed B could be due to a process analogous to spontaneous magnetization, whose degree can vary. The degree of magnetization would be determined by the ratio of the incoming fluxes going to the interior and exterior of the dipole core. The total flux Φ flowing inside dipole core is $\Phi = (p_1 - p_2)\Phi_{in}$, where p_i are the fractions of incoming fluxes going inside the dipole core and outside it. If the ratio equals to unity the net B vanishes in long enough scales. For Options II and II one cannot have time varying B unless the number n_i, $i \in \{I, II\}$ of dipole loops can vary.

   Polarization reversal could be a dynamical process. For the analog of hydrodynamical flow the portions of the flow going through the dipole core and its exterior could change, and the fraction of these portions is the parameter determining the strength B. Oscillating B would mean oscillation of this fraction. Also the numbers n_i change and induce change of B.

6. If the flux tubes of both types are in the volume carrying B, more possibilities arise for Option I since the flux tube portions of type I and II can have magnetizations of varying degree and these can be parallel or opposite inside (outside) dipole core.

7. For Options II and III the magnetization direction cannot vary unless n_i can change and the total average magnetic field would vanish for $n_I = n_{II}$. n_i can however change if dipole loops split away by reconnection. It turns out that option II is the most promising one.

8.3.3 A model of solar magnetic field in terms of monopole flux tubes

The model relies on the notion wormhole magnetic field with flux tubes carrying electric fields, the notion of reconnection, and the theory of quantum measurement based on zero energy ontology (ZEO) [K71] and extending to a theory of consciousness [L44].

Also hydrodynamic analogy, the analogies with ferromagnetic hysteresis cycle, spontaneous magnetization, and de-magnetization, the analogy with the Meissner effect explaining solar spots as magnetic flux branching from the dipole axis of solar magnetic field, and Lenz principle (induction law) stating that magnetic field generates ohmic current in turn generating magnetic field opposing the change of the magnetic field , are used as guidelines.

1. One can argue that the magnetic fields in question correspond to flux tube portions carrying monopole flux. The empirical support for the hypothesis comes from the fact that monopole fluxes need no currents to generate them. Cosmology is indeed full of long range magnetic fields whose presence is mystery in Maxwellian electrodynamics.

2. Interaction of two kinds of magnetic fields would be involved. The first magnetic field identified as solar magnetic field, call it B, is assumed to have flux tubes wormhole magnetic field carrying monopole fluxes. No current is needed to create the magnetic flux: something impossible for ordinary Maxwellian fields. Note also that the cross section of flux tube is closed 2-D surface. One could call B topological magnetic field. Mathematically B could be seen as an analog of the external magnetic field H generating as a response total magnetic field as a sum of H and magnetization M.

   Second magnetic field, call it B_1 would be Maxwellian and generated by Faraday induction. By Lenz principle it opposes the change of the magnetic flux associated with B and has roughly the same direction. B_1 would correspond to M. In the proposed framework the induced currents j would generate B_1 and it would be regarded as secondary rather than primary field.

Remark: The flux tubes of B_1 would be obtained from closed string like objects with CP_2 projection which geodesic sphere S^2 by replacing S^2 with disk D^2, by deforming to get flux tube, and gluing it to a large background space-time sheet along D^2. The current creating B_1 would be associated with the boundary of D^2.

One cannot of course exclude the Maxwellian option for B.

1. The portion of flux tubes of B identifiable as analog of the dipole core of Maxwellian dipole field would consist of particles with magnetic moment whereas for monopole flux no magnetic moment is needed. Magnetic moment could be due to spin or orbitals motion.

   Remark: One could wonder whether quantum-classical correspondence (QCC) requires that the monopole flux has as quantum counterpart magnetization representable in terms of fermions.

2. The contribution of the spin to magnetic field is rather small so that the idea about spontaneous magnetization at flux tubes defining dipole does not look promising. Note however that the large value of h_{eff} together with proportionality of $\mu \propto \hbar_{eff}/m$ could change the situation. Macroscopic quantum coherence making possible quantum states with macroscopic radius for the orbits could be considered and would conform with the idea that the flow of currents generates B. B could be of course generated also classically.

8.3.4 Are wormhole magnetic fields really needed?

The additional assumption is that wormhole magnetic fields involving two space-time sheets connected by wormhole contacts appear in the volume containing B. More generally, fundamental magnetic fields would be wormhole magnetic fields. This additional hypothesis is necessary in the recent model of elementary particles and p-adic fractality suggests that the property holds true also astrophysical scales.

1. In elementary particle scales monopole flux tubes associated with wormhole magnetic fields must be closed and involve return flux along second space-time sheet. If the two space-time sheets have same M^4 projection, the test particle touches both sheets and experiences essentially no gauge fields. At QFT limit one would have no fields. Therefore the M^4 projections of the flux tubes at the two sheets must be disjoint in order that one has normal magnetic field in operational sense.

   The energies of both flux tubes however sum up and the wormhole flux tube pair has long range gravitational interactions. The attractive interpretation is that if the volumes in which the sheets have same M^4 projection, the energy of flux tube pair corresponds to dark energy. The portions giving rise to tangles in which the flux sheets have separate projections give rise to ordinary matter. This would give rise to galaxies, stars, and planets and even smaller objects in various scales. Flux tubes would thicken and their energy would decay to ordinary and dark matter.

2. Wormhole magnetic fields could define pairs of systems. The understanding of the geometric correlates for the hierarchy of Planck constants have already led to the realization that many-sheeted space-time means that one space-time surface can be regarded as n_1-fold covering of CP_2 and n_2-fold covering of M^4 such that one has $h_{eff}/h_0 = n = n_1 n_2$ holds true. For n_1-fold covering of CP_2 the sheets can be disjoint regions of M^4. Although the regions are disjoint, they are physically closely correlated. This is classical correlate for macroscopic quantum coherence coded also by the large value of n.

   For $n_1 = 2$ one obtains the simplest pairs. Also even values of $n_1 = 2m_1$ are of course and would describe a pair of structures with m_1 components. The components would be most naturally flux tubes fusing to larger flux tube fractally.

3. This view becomes understandable if one takes CP_2 coordinates or $M^2\times CP_2$ coordinates as a coordinate system so that the roles of space-time and fields are changed or partially changed. At the level of wormhole contacts the change of the roles of M^4 and CP_2 is necessary. For string like objects $M^2 \times S^2$ replaces M^4. This corresponds to that part of TGD, which does not allow description in terms of GRT.

Playing with the ideas generates questions and new ideas, not always realistic. At this time the question is following.

1. Could the Euclidian region associated with wormhole contact and connecting wormhole throats at the two sheets connect two disjoint, even distant regions of M^4? If so, the wormhole contact would be analogous to Einstein-Rosen bridge except that it has Euclidian signature of the induced metric.

   Could one identify the wormhole contact as a space-time correlate for entanglement or pre-requisite for it? There would be no signal involved since in Euclidian space-time regions one cannot talk about propagation. Euclidian flux tubes are in central role in p-adic mass calculations [K63] but they are extremely short.

   I have assumed that time-like flux tubes can serve as correlates of entanglement. Could one can think that Minkowskian flux tubes would allow classical signalling and Euclidian flux tubes would serve as classical correlates for entanglement. Could both aspects be involved with quantum communications?

   Remark: One can obtain Euclidian space-time region from piece of M^4 by performing a large enough deformation in CP_2 directions and also this could give rise to Euclidian induced metric. One can also have cosmic string with piece of M^2 as string world sheet and deformed such that one has flat E^2. The deformation of this string world sheet would represent Euclidian flux tube.

2. Here one must be however extremely cautious. Hitherto I have regarded shortness of flux tubes as obvious, and might have been right. One cannot however exclude the possibility that also Euclidian wormhole contacts are involved but they do not seem to be necessary: one could have wormhole magnetic fields with wormhole contacts only in the regions where M^4 projections overlap. All depends on the properties of preferred extremals.

8.3.5 How to understand the solar cycle?

Sunspot cycle (see `http://tinyurl.com/y2qlaaa2`) has period of 22 years and consists of two 11 year half-periods during which opposite polarity of B. The understanding of the mechanism causing the flip of the polarity looks the most difficult part of the problem - at least from TGD point of view. Each half cycle starts from a situation in which the dipole part of B vanishes and sunspots appear at opposite sides of equator at symmetrically related positions at mid-latitudes (about 30 degrees from equator).

Sunspots (see `http://tinyurl.com/y2qlaaa2`) carry intense magnetic fields (fields strength is about 2 Tesla in the vicinity of Sunspot according to Wikipedia) and they have lower temperature than surroundings due to the magnetic pressure. During the half-cycle Sunspots drift towards equator and maintain their polarity. The diagrammatic description of the time evolution at the solar surfaces is known as butterfly diagram. The natural interpretation is that the sunspots at opposite sides are connected by flux loops.

During the cycle the dipole field with opposite polarity as compared to previous cycle is generated and towards the end of the cycle there is a period in which no sun-spots are observed: they would be near equator if present. The spots could be present but the density of elementary flux tubes could be too low to give rise to average field strength enough to cause an observable reduction of temperature.

Polarity reversal of B

What could be behind polarity reversal. First some guiding ideas.

1. An analogy with ferromagnetic hysteresis circuit suggests itself. B generates B_1 having opposite direction. When the value of B_1 is critical it induces a phase transition in which the direction of Kähler flux is changed at flux tubes. Second half of the 22 year sunspot cycle would start. The ohmic current j generated by B would change and this would induce the magnetic turbulence accompanying solar spots.

   This analogy is not quite complete since the generation of B with opposite sign occurs slowly whereas the vanishing of magnetic field isa fast process. De-magnetizing phase transitions seems therefore a natural analog for the dis-appearance of B.

2. What the analog of spin flip means is highly non-trivial question when the size of the analog of spinning particle is of the size scale of Sun. Quantal and topological effect in solar scales could be in question and involve both TGD view about space-time and fields as well as hierarchy of Planck constants as description of dark matter. The model to be described in the sequel applies universally in TGD Universe and leads to quite dramatic and testable implications.

Consider next general TGD inspired ideas relating to the change of the polarity of B in TGD framework. A general model based on the formation of flux tube tangle as a representation of the say dipole field looks like a safe starting point and provides also a general model for the change of the polarity. An essential element is the distribution of incoming flux of long cosmic string like object to fluxes going through the interior and exterior of the dipole core and return back through exterior and interior. The fractions going through interior and exterior determine the strength of observed B. Whether both kinds of flux tubes are present or not, depends on model.

The first model, call it Model I, is classical. Now one could do using only single flux tube type, say type I, which however must divide to flux tubes travelling both inside and outside the dipole core.

1. The decay of B would correspond to option I involving the change of fractions p_1 and $p_2 = 1-p_2$ of the flux tube portions going through the dipole core reducing the parameter p_1-p_2 to zero. The permutations of flux tube portions inside and outside core must lead to $p_1-p_2=0$ and one expects that this process continues and changes the sign of p_1-p_2 and therefore induce polarization reversal. The duration of the process taking p_1-p_2 to zero is rather short as compared to the duration of the half-cycle. The duration of the sunspot minimum is about 10 per cent of that for the entire half cycle. In the hydrodynamical analogy the process would be redistribution of the incoming flow and could be modelled phenomenologically as a change of flow resistances associated with the two channels involved.

2. This model does not involve reconnection process and does not provide any obvious explanation for the appearance of sunspots nor for the reconnection process associated with the reversal of the polarization of B. Therefore Model I is not promising.

Second model, call it Model II, is quantum mechanical and involves ZEO in an essential manner and one could assume that incoming flux tube enters to the dipole core entirely (option II).

1. Dipole winding number n_i characterizes the situation for a given type of flux tube. The larger the value of n_i, the larger the dipole strength. n_i could change by reconnection process in which entire dipole loop reconnects and snips away. This followed by further splitting to flux loops would correspond to the emission of magnetic loops from the Sun.

   The opposite process would correspond to a fusion of flux loop with a long flux loop but looks thermodynamically implausible. Also a fusion of a short flux loop with long flux loop and the growth of the reconnected part to large dipole loop looks implausible.

2. Could ZEO based quantum TGD allowing temporary time reversals come in rescue? At dark space-time sheets one can indeed imagine the possibility of time reversals. Ordinary matter would be controlled by dark matter with larger value of $h_{eff}/h_0 = n$ serving as an IQ in TGD inspired theory of consciousness, and would be forced to follow the leader in conflict with its thermodynamical instincts. Could the process involve "big" state function reduction

(BSR) and could the dominance of flux tubes of type I and II correspond to different arrows of time at the level of dark flyx tubes? Reconnections for flux loops of say type II would occur in time direction opposite to the standard direction of time but second law would hold true in generalized sense.

3. The simplest option is that all incoming flux enters to the interior of the dipole core ($p_{2,I} = 0$ identically) or to its exterior ($p_{1,I} = 0$) identically. The first looks more plausible. The integers n_i, $i = \{I, II\}$ characterize the numbers of dipole flux loops carrying magnetic fields with opposite polarizations. Dipole strength is proportional to $n_I - n_{II}$. The arrows of time at the two sheets are assumed to be opposite for flux tube of type I and II.

4. Consider now a model for the first half-cycle.

   (a) Assume for definiteness that in the initial situation one has $(n_I = n_{max}, n_{II} = 0)$. B as maximum value B_{max}.

   (b) The transition leading $B = B_{max}$ to $B = 0$ would be "big" state function reduction (BSR) changing the arrow of time at sheets of both type I and II. BSR would generate maximum number of new dipole flux loops of type II: $n_{II} \rightarrow n_{max}$ so that one has $n_I = n_{II} = n_{max}$ and $B = 0$.

   This transition is clearly a quantum analog of spontaneous magnetization in sector II. Could one say that a spontaneous magnetization already present in sector I induces opposite spontaneous magnetization in sector II?

   Quantum classical correspondence (QCC) inspires the question about there is in the fermionic sector genuine spontaneous magnetization involving fermion spins. Could a formation cyclotron condensate of spin zero Cooper pairs with members at flux tubes of type I and II and having opposite spins accompany this process?

   (c) After that dipole loops of type I begin to split away by reconnections in "small" state function reductions (SSRs) so that n_I decreases. They split further in pieces and leak out from Sun. Net B increases until one has $B = -B_{max}$. This process is analogous to gradual decay of magnetization.

   (d) What looks strange that n_{II} would remains unchanged during this process. In ZEO this makes sense: it would corresponds to the passive boundary of causal diamond (CD). One would have two CDs having common portion of boundary, call it δCD. Since the arrows of time are opposite, $\delta CD \subset \delta CD_{II}$ would be passive and experience generalized Zeno effect whereas $\delta CD \subset \delta CD_I$ for CD$_I$ would be active experiencing gradual decay of magnetization in the sequence of "small" state function reductions (SSRs).

   (e) Topologically one can understand the sunspot cycle in terms of split dipole loops leaving the Sun: their intersection with the solar surface would define sunspot pair and the distance of members of the pair would decrease to zero during the cycle.

5. The model for the second half-cycle is identical. First occurs BSR generating maximum number of new flux loop portions of type I leading $n_I = n_{II} = n_{max}$ and $B = 0$ and same is repeated except that now n_{II} decreases.

The classically highly counter-intuitive aspect of this picture is that dipole loops would appear in BSR as quantum leap in astrophysical scales. There would be no continuous time evolution generating additional dipole loops. Their dis-appearance by reconnections would correspond to classical time evolution. If one performs time reversal for thermodynamic intuition, there is nothing mystical involved.

Model II looks to me more promising -if not even the only possibility - although conservative colleague can criticize it for the speculative new physics features: these features are however basic elements of new physics predicted by TGD.

Sunpots as intersections of split dipole flux loops with the Earth's surface?

How could sunspots be understood in the picture suggested by Model II?

1. BSR would induce the cancellation of B. Sunspots should emerge after the cancellation and serve as a signature of BSR inducing change of the arrow of time at flux tube space-time sheets. The usual statement is that the density of the elementary flux tubes composing the the split flux loop is high enough the average magnetic pressure lowers the temperature so much that the solar spot becomes visible.

   Could the local reduction of temperature inside sunspots, something not expected in the naïve thermodynamical thinking be forced by the change of the arrow of time at dark flux tubes? One would have leveling of temperature differences but in opposite time direction induced by dark flux tubes having arrow of time opposite to the standard one: by dark flux tubes of type I during first half-cycle and flux tubes of type II during second half-cycle.

2. The appearance of sunspots would relate naturally to the reconnection process leading to the disappearance of the dipole loops Do the snipped flux loops, which can split further to pieces eventually leaving Sun, intersect its surface at the sunspots so that the formation of sunspot and its disappearance would correspond to a splitting of closed dipole loop by reconnection and further splitting to smaller loops.

   The motion of sunspots towards equator would correspond to the outwards motion of the split flux dipole loop and solar spots would represent its intersection with solar surface. This also explains why the number of sunpots is gradually reduced during the half-cycle.

3. The fact that sunspots emerge first at latitudes $\pm\pi/6$ means that the split dipole flux loop intersects Earth's surface at positions with distance $h = R_E/2$ from equator. Since the distance is reduced after that, the outward motion of the loop requires that dipole core has height smaller than R_E.

Also in the case of Earth's magnetic field an analogous quantum picture might apply [L13] and solar spots might have "Earth spots" as magnetic anomalies. What is fascinating that the reversals of the Earth's magnetic field would be quantum processes in the scale of entire Earth and the magnetic field would go to zero instantaneously. What this means for living systems is an interesting question to ponder.

Does the polarity inversion involve spatial inversion?

Assume that the flux tubes correspond to monopole flux tube, which defines two-sheeted wormhole magnetic field. There is a strong temptation to assume that the members of the pairs defined by portions of flux tubes of given type (I or II) in the interior and exterior of dipole core are related by an approximate symmetry. If so, one would have doubles or mirror pairs of systems. What kind of symmetry polarity inversion for the solar B could correspond?

1. Assume that the two flux tube sheets of wormhole magnetic field have M^4 projections with empty intersection. Polarization reversal could permute the positions M^4 projections of the two sheets of flux tubes turning the direction of the magnetic flux. If the space-time surface representable as a map from CP_2 to M^4, the flip could be understood as a reflection in CP_2 degrees of freedom permuting the M^4 images and represented also as a reflection or inversion in M^4. In adelic physics [L42, L41] Z_2 has interpretation as subgroup of Galois group.

2. Could the solar magnetic field be doublet structure mapped to itself under Z_2? The identification of the pair as being formed by symmetry related parts of the flux dipole tubes in the interior of Sun and outside it is what comes naturally in mind. The symmetry could be realized as inversion with respect to the surface of Sun mapping inside and outside to each other. Inversions are indeed symmetries of Maxwell's theory, gauge theories, and of twistor Grassmannian approach. Also for $n_1 = 2m_1$ m_1 could correspond to a subgroup of CP_2. One would have double of bundles formed from m_1 flux tubes: dipole flux tuve consisting of m_1 elementary flux tubes.

3. The symmetry involved need not always be inversion. It could be also spatial reflection. The possibility of higher values of $n = n_1 n_2$, $n_1 = 2m_1$ suggests the possibility of long range correlations between m_1 pairs in astrophysical scales manifesting themselves quite concretely.

4. The representability of the group permuting flux tubes as finite discrete subgroups of $SO(3)$ acting as symmetries of Platonic solids would be very natural, and one can ask whether the appearance of Platonic solids in biology reflects this. This might allow to get some idea about why icosahedral model of harmony in terms of Hamiltonian cycles leading to the notion of bio-harmony predicts correctly genetic code [L8].

8.3.6 Trying to understand solar gamma ray spectrum in TGD Universe

One can try to understand the observations about gamma rays [E150, E143] (see `http://tinyurl.com/yxajyzp8` and `http://tinyurl.com/y2qlaaa2`) in the proposed picture. Some kind of acceleration mechanism suggests itself strongly.

1. An electric field associated with flux tubes with helical magnetic field is the simplest option. TGD allows simple deformations of flux tube like solutions [K57] in which Kähler magnetic and electric fields are orthogonal and helical and one can hope that they define preferred extremals.

   What about the electric force experienced by a test particle when the flux tubes of type I and II having same M^4 projection? The identification these objects in terms of dark energy would suggests that also the net electric force cancels and this kind of flux tube pair serves as a kind of superconducting wire.

2. If the flux tubes and gamma rays are dark with large $h_{eff}/h_0 = n = n_1 n_2$, they can propagate without interactions with ordinary matter. The dissipation would be solely due to curvature, in particular the kinks of the flux tube but would not be present at rectilinear portions of the flux tube. Therefore the amount of dissipation would be small.

   Forgetting the losses caused by the curvature of the flux tube, there would be maximum energy $E = ZeV$, V the voltage along flux tube section to which the particles such as protons can be accelerated, and this would define cutoff energy for the emitted gamma rays. I have proposed that this kind of model explains also the gamma rays associated with lightnings [K20].

3. The dip in the spectrum suggests at least two energy scales for accelerated particles emitting gammas as brehmstrahlung and defining the endpoint of the brehmstrahlung spectrum. The explanation that comes in mind is that particles can go through several cycles of acceleration along closed dipole flux tubes and emit gamma rays at kinks. This would give rise to energy bands labelled by the number of acceleration cycle. The possibility of saturation looks plausible. One would have particle accelerator analogous to storage ring. What would be new as compared to LHC would be quantum coherence in the scale of accelerator. For the values of h_{eff} involved the dark particles would have Compton lengths of the order of the size of Sun.

4. How could the charged particle and gamma rays emerge from the flux tubes? One can start from everyday experience. Car can fall off the road in sharp curve. Now the sharp curve would correspond to a kink in flux tube. By momentum conservation there should be a large exchange of momentum with the flux tube to keep the charged particle at the flux tube and this is improbable for sharp kinks. Since the charged particles are relativistic and gamma rays must be directed to the observer, the change of momentum direction must be large. In any case, this requires a large exchange of momentum with the collective flux tubes degrees of freedom. It is quite possible that several gamma rays are emitted at the kink. The charged particle can also leak out.

   A proper description of the situation might be in terms of dark cyclotron states. If the TGD view about dark matter as $h_{eff}/h_0 = n = n_1 n_2$ phases is true on can treat the bundle of flux tubes as single quantum coherent entity. In particular, the solar spots could be identified as this kind of quantum coherent flux tube bundles and n_2 could correspond to the number of elementary flux tubes.

5. The sharp kinks appear at two places. Near the North pole where dipole field lines/flux tubes make a sharp kink. Due to differential rotation the flux tubes associated with the dipole contribution follow the rotation of equator and develop tentacles. The shape of strongly flattened square implies instability against splitting of the tentacles and decay to flux loops by reconnection. This part of the magnetic field decays and leads to magnetic turbulence. Also in the standard picture differential rotation is expected to induce reconnections of field lines. The kinks at the ends would induce emission of gammas and leakage of charged particles. Even single gamma ray could be enough.

   Gamma radiation indeed has two components. Polar component is roughly constant and the equatorial component having sharp maximum during sunspot minimum.

   Spectral index is different for the energy distributions for cosmic rays and gamma rays from Sun: solar distributions are harder. Also the equatorial distribution is harder than polar distribution. One expects that the distribution depends on the energy of the gamma ray and on the sharpness of the kink. In the case of polar distribution two gammas is minimum whereas for equatorial distribution single ray can be enough. This softens the polar distribution as compared to equatorial one. Since several loops are possible even the cosmic ray distribution for charged particles can harden.

Where could the charged particles originate?

1. The basic observation is that flux of gammas is 5 times higher than predicted by the model identifying them as cosmic rays reflected in solar magnetic field fails. Roughly the same order of magnitude suggests that cosmic gamma rays could be the origin. Spectral distribution does not support this idea.

2. Charged particles could come from the solar core or along the long thickened cosmic string continuing as flux tubes of the magnetic field. Cosmic string would not accelerate the charged particles but only feed in the particles beams as kind of supra currents. Also cosmic rays could enter the flux tubes as assumed in the original model: in fact, cosmic rays would naturally arrive along the long flux tubes connecting Sun to sources of cosmic rays.

   This could explain why the upper bound for gamma ray energies for cosmic rays equals to the maximal detected energy (100 GeV). Instead of being reflected cosmic rays could rotate possibly several times around dipole flux tube and leak out in the kink. The emission of gamma rays at kinks reduces the energy gain for simple loop and for higher number of loops the reduction is larger. Saturation is quite possible.

3. The origin of galactic rays is still a mystery (see `http://tinyurl.com/psdp99h`). One proposal is that they originate from neutron stars. The proposed acceleration mechanism could be at work in the case of neutron stars so that neutron star could indeed provide the charged particles. As discussed there are also other options.

8.3.7 Surprises about the physics at the boundary of the heliosphere

I learned from interesting results about cosmic rays and behavior of magnetic field at the boundary of heliosphere (see the article "*Voyager Mission Reveals Unexpected Pressure at The Edge of The Solar System*" (see `http://tinyurl.com/y474zww4`). The article "*Pressure Runs High at Edge of Solar System*" (see `http://tinyurl.com/y5t258c8`) gives a more precise description of the findings.

There were two spacecrafts. Voyager2 was inside heliopause ad Voyager1 slightly outside it. They experienced different kind of reduction in cosmic ray flux. I picked up the following piece of text explaining the basic findings.

> *The scientists noted that the change in galactic cosmic rays wasn't exactly identical at both spacecraft. At Voyager 2 inside the heliosheath, the number of cosmic rays decreased in all directions around the spacecraft. But at Voyager 1, outside the solar system, only the galactic cosmic rays that were traveling perpendicular to the magnetic field in the region decreased. This asymmetry suggests that something happens as the wave transmits across the solar system's boundary.*

Consider first TGD based view about magnetosphere of Sun.

1. TGD allows two kinds of magnetic fields: those for which flux tubes carry monopole flux and those for which they do not. Monopole flux tubes are impossible in Maxwellian world and solve several problems related to magnetic fields such as the existence of magnetic fields in cosmic scales, and the maintenance problem of the Earth's magnetic field [L13]

   One of the latest applications is to the undertanding of the weird properties of the magnetic field of Mars identified in the model as consisting of monopole flux tubes [L71] and thus visible only through northern and southern lights involving reconnections of the monopole flux tubes. Also Mercury has unexpectely strong magnetic field and it could correspond to monopole flux tube tangle associated with flux tubes from Sun.

   The latest application is to a model of earthquakes and volcanic eruptions [L73] known to be induced by cosmic rays but quite too deep for them to penerate to the depths required. There is strong correlation with solar minima and it has turned out that the solar minimum corresponds to maximum of magnetic field. There is also a causal anomaly: electromagnetic fluctuations in upper atmosphere precede rather than follow these event. The new view about magnetic fields and zero energy ontology predicting that arrow of time changes in "big" (ordinary) state function reductions explains these anomalies. Causal anomalies involving change of also thermodynamical arrow of time are a generic signature of macroscopic state function reductions in TGD Universe.

2. Also a new view about cosmic rays emerges. Cosmic rays would travel along flux tubes of a gigantic fractal flux tube network defining analog of nervous system for the Universe [L83]. This picture leads to a rather detailed model for the formation of galaxies, stars and even planets as tangles along the flux tubes of this network having same topological structure as dipole magnetic field but with flux tubes carrying monopole flux [L63].

3. In TGD framework heliosphere corresponds to magnetically to U-shaped tentacles from Sun - flux tubes emanating from Sun radially and returning back to Sun and carrying solar wind and also cosmic rays. They look locally like parallel flux tubes carrying opposite magnetic fluxes. Flux tubes would extend to the heliopause and turn back and emit by reconnection narrow rectangle shaped closed flux tubes.By fractality these tentacles appear in all scales and are in crucial role in understanding of bio-catalysis and basic biochemical reactions like DNA replication, transcription of DNA to RNA, and translation of RNA to polypeptides.

4. Cosmic rays can travel as dark particles along them in TGD sense meaning that they would have effective Planck constant $h_{eff} = n \times h_0$, where h_0 is minimal value of h_{eff}. The flux tubes from Sun would thus bring dark particles along flux tubes. Suppose that the flux of cosmic rays arrive along these flux tubes, perhaps as dark particles.

Next one must translate various words to physical concepts in TGD framework.

1. Heliosheath (Voyager 2) is expected to be a turbulent boundary region. Magnetic turbulence means that the directions of U-shaped flux tubes coming from Sun are random. This is magnetic counterpart of a boiling liquid.

   Closed U-shaped flux tubes from Sun reach the heliopause before reconnection meaning emission of closed flux tubes looking like narrow rectangles travelling in radial direction: the direction of the flux is assumed to be along the radial flux tube and two directions are possible.

2. The region outside heliopause (Voyager 1) contains two kinds of monopole flux tubes, which need no current for their existence. Those of galactic magnetic field locally parallel to heliopause like in liquid flow around obstacle plus the closed flux tubes as outcomes of reconnection. They are assumed to be narrow rectangle-like objects in radial direction coming from the heliopause. There are also flux quanta of ordinary magnetic field generated by currents.

3. The wave called global merged interaction region (GMIR) caused by the activity of Sun means reconnections for the U-shaped flux tubes from the Sun at solar surface generating

ordinary magnetic fields giving rise to sunspots. This reduces the number of U-shaped flux tubes and therefore also solar wind and the amount of cosmic rays arriving along them. Thus the reduction of solar wind and of cosmic rays both inside and outside heliosphere.

4. If the local directions of solar flux U-shaped tubes inside heliosheath are random by turbulence the reduction of flux takes place in all directions. It the long sides of closed flux tube rectangles are radial (orthogonal to the dominating galactic magnetic field), the reduction of flux takes place only in directions orthogonal to the galactic magnetic field. This was observed.

5. The high pressure could be due to the presence of closed flux tubes formed in reconnection and would represent the contribution of solar wind.

8.3.8 About general implications of the pairing hypothesis

If wormhole magnetic fields appear in all scales, flux tube pairs and more general $n_1 = 2m_1$ multiplets of flux tubes decomposing to m_2 pairs should be universal aspect of the dynamics of TGD Universe. In the following the implications are considered only briefly. The basic consequence is of course that Universe becomes in all scales a quantum coherent object and the locality hypothesis of classical physics would be simply wrong.

Elementary particle physics

Wormhole magnetic fields appear already in elementary particle physics. Elementary particles correspond to at least 2-sheeted flux tube structures with wormhole throats containing the boundaries of string world sheets carrying fundamental fermions. I have already earlier considered the possibility that the M^4 projections of the sheets are disjoint.

Remark: In the general case one would have $n_1 = 2m_1$. Color symmetry for quarks could have as a remnant $m_1 = 3m_3$. For leptons m_1 would not be divisible by 3. Since n_1 corresponds to discrete subgroup for $SU(3)$, m_1 could correlate with the triality of $SU(3)$ partial wave defining the color quantum numbers of the particle.

Astrophysics and cosmology

The predictions in astrophysics and cosmology are in strong conflict with the locality principle of classical physics.

1. The model for magnetic spin flips in solar cycle leads to the conclusion that solar magnetic field could have doublet structure with parts related by inversion with respect to solar surface. Could the entire MB of Sun have copy somewhere. In principle this is an experimental question. The copy would be connected to Sun by wormhole magnetic flux tubes and this suggests long range correlations.

   Stars indeed very often appear as binaries (see `http://tinyurl.com/oooagma`). Could these pairs be related by approximate CP_2 symmetry inducing reflection of inversion in M^4? Could the planets of mirror paired stars be related by Z_2? Could there be correlations between the rotation planes for instance.

2. What about Earth could be invariant under inversion so that the radius of Earth could define the radius remaining invariant under inversion. This could make Earth so special as far as life is considered.

   Could Earth have a double in longer length scale? The least science fictive candidate would be another planet.

   Mars (see `http://tinyurl.com/mttm7h8`) has radius $.53R_E$, which is the radius that Earth would have had before the Cambrian Explosion according to TGD inspired variant of Expanding Earth model [L55]. Mass is 11 per cent of the Earth's mass. There are indications for life in Mars. Venus (see `http://tinyurl.com/72rz2g2`) has characteristics surprisingly near to those of Earth except that rotation is in opposite direction than for Earth: the rotation period is -243.025 days. The distances from Sun for (Venus,Earth,Mars) triplet are

$(.72, 1.00, 1.52)$ AU. Could Venus and Mars form a mirror pair with respect to inversion at radius R_E.

Recently Nasa found an exoplanet christened as Gliese 581d (see `http://tinyurl.com/yxdmpnbj` and `http://tinyurl.com/y2bwco6q`) located in constellation Lyra at distance of only 20.4 light years. The planet is almost exact copy of Earth as far the prerequisites of life are considered. Semimajor axis of the orbit is .22 from that of Earth. Mass is about 6.98 times higher than Earth mass, the radius is $2.20 R_E$. The Sun of the planet could be mirror image of Earth: if this is the case, the should be correlations such as common rotation planes.

3. I have considered [L13] also a model for the changes of the orientation of Earth's magnetic field involving the interaction of monopole flux tubes and ordinary magnetic field via magnetic torques, and the solar model probably generalizes almost as such. Now however the orientation of the magnetic field can vary. This could relate to the fact that the axis of rotation differs from the magnetic axis. Again inversion as an approximate symmetry is suggestive.

4. The most intriguing finding about CMB spectrum is anomaly known as "Axis of Evil" (see `http://tinyurl.com/yb6nabw4`). The anomaly appears to give for the plane of planetary system of Sun and the location of Sun a greater significance that one might expect by change. This violates the Copernican Principle. The effect resembles selection of spin quantization axis in quantum measurement of spin performed by the measurer. A possible explanation at the level of space-time is that by $h_{eff}/h_0 = n$ hierarchy disjoint space-time sheets even in cosmic length scales are related by discrete CP_2 symmetries implying correlations.

Biology

The binary structures populating biology might correspond to pairs of monopole flux tubes. The original motivation for the proposal that they are important comes from p-adic length scale hypothesis: primes $p \simeq 2^{k+2}$ and $p \simeq 2^k$, where k and $k+2$ are twin primes, could define structures with size scale $L(k+2)$ decomposing to a pair of structures with size scale $L(k)$ [K21]. The structures of twin pair would form quantum entangled structures.

1. DNA and RNA double strands are basic examples of these structures. Even single DNA and RNA molecules form mirror pairs with their conjugates and could be connected by long wormhole contacts. This would make them quantum coherent structures making possible the mysterious ability of bio-molecules to find each other in the molecular crowd. Bio-systems would be extremely organized structure rather than a soup of randomly moving molecules. Could this kind of symmetries characterize all molecules that are paired or form higher structures with $n_1 = 2m_1$?

2. Cell membranes are formed by pair of lipid layers and also these could be twin pair. Epithelial sheets consist of two cell layers. At the level of body and brain there is also a pairing of subs-structures in left and right brain. Pineal gland is a connected structure could itself be a pair. Also brain hemispheres form a pair. Even married (or even non-married!) couple could form this kind of pair and what looks like a random personal relationship could be something much deeper.

3. All multi-molecular structures in living matter at least could correspond to groups of n_1 disjoint space-time sheets, perhaps magnetic flux tubes. The value of n_1 would serve as a measure for the scale of coherence and complexity.

4. Inversion corresponds to the inversion of the polarity of the Earth's magnetic field but might happen also at the cell level. In biology involution turning cell inside-out occurs during the gastrulation phase (see `http://tinyurl.com/y4pvpxyr`) of the embryonic development and leads to a development of 2 (ectoderm,endoterm) or 3 cell layers (ectoderm, mesoderm, endeterm) giving later rise to different types of tissues. This process looks rather mysterious - at least to me. Could involution be induced by the inversion of the magnetic body of the developing embryo?

5. MB controls (also our) biological body (BB) and uses scaled variants of EEG consisting of dark photons for this purpose [K38]. It is natural to assume that our MB corresponds to the part of MB above the Earth's surface. If Z_2 acts as inversion with respect to the surface of Earth then also the part of MB below the surface of Earth should correspond to an intentional agent.

   Could these MBs be associated intra-terrestrials ITs or could they control same BBs as our usual MBs? Here one must consider the precise definition of inversion: is it with respect to the surface of Earth or the boundary of the dipole core of the Earth's B? Taking inversion in the first sense of the definition very literally, one could argue that plants having also roots are inversion invariant but animals are strictly speaking not inversion invariant in either sense. Therefore we would have separate personal mirror MBs and also BBs: analogs of Dr. Jekyll and Mr. Hyde. In fact, I have have-jokingly considered a model for crop circles, and this led to a crazy idea about IT life [K35, K36]. Could this idea be not so crazy as it looks first? Accepting dark matter as $h_{eff}/h_0 = n$ phases, the high temperature in Earth interior ceases to be an objection.

6. $n_1 = 2m_1$ implies also that conscious entity can have n_1 disjoint pieces. They could be MBs controlling the same BB (multiple personality disorder) or maybe even separate BBs. Could these possibly distinct BBs locate at different sides of globe or even cosmos? What comes in mind Kieslowski's trilogy "Three colors". When the connection between hemispheres is destroyed, brain hemispheres controlling different body halves would live effectively separate lives, and could even fight for the control of BB. This gives some ideas as one tries to image what it is to have several BBs. It is interesting that in dreams we often have different identities than in wake-up state.

Consciousness

The existence of twin pairs might have profound implications for consciousness [L44, L58].

1. I proposed for about 2 decades ago what I called magnetospheric consciousness [K62, K60, K35, K36]. The MB of not only Earth but also our MB would have parts assignable to the interior and exterior of the Earth. Even the structures of brain should have a scaled up MB image at both levels. The approximate inversion symmetry brings in exciting additional aspects. Maybe this division could provide the physical correlates for the Heaven-Hell dualism of religions and "as above-so below" dualism of perennial world views and mysticism.

2. Interior-exterior divisions are central for consciousness and the hierarchy of conscious entities in correspondence with the hierarchy of space-time sheets inspires the question whether also our biological bodies and environment could be related by an approximate symmetry at the level of MB at least so that one could speak of MBs assignable to the interior and exterior of BB. The sensory representations would reflect this approximate symmetry. Subsystem able to remain entangled at the passive boundary of CD defines the permanent part of self. But also its complement remains unentangled and should define permanent part of self: does this mean that the world outside me is a conscious entity?

3. One of the most dramatic predictions of TGD inspired theory of consciousness based on zero energy ontology (ZEO) is re-incarnation of self in death as a time-reversed self. There is indirect support for this: for instance, mental images identified as sub-selves die and re-incarnate and the period during which they are absent would correspond to the life with opposite arrow of time.

   Where could these ghostly time-reversed re-incarnations live? Or putting it more formally: what regions of space-time surface do these entities control and receive sensory input from? Could inversion with respect to Earth's surface relate the space-time regions associated with self and its time reversal. If personal MB is part of MB above the Earth's surface, its inversion would be the part of MB below it. When we die we get buried. Could this ritual reflect the sub-conscious idea that our life continues as IT lifeform?

8.4 Explanation For The High Temperature Of Solar Corona

The mysterious feature of the solar corona is its high temperature $T \sim 10^6\ K$, as compared with the temperature of the chromosphere of order $10^4\ K$ [E181] (the book of Zirin provides excellent introduction to the physics of Sun). The temperature rises very rapidly to $10^6\ K$ at height $h \sim 2 \cdot 10^6\ m$ from the surface of Sun. The problem is to identify the mechanism leading to the heating of the particles of the solar wind after leaving solar surface: no convincing mechanism has been identified and this suggests that many-sheeted space-time concept might be involved in an essential manner. Indeed, the high temperature matter in the solar corona can be interpreted as a dark matter leaked from the highly curved portions of magnetic flux tubes to the space-time sheets where it becomes visible.

8.4.1 Topological Model For The Magnetic Field Of Sun

The basic observation is that solar corona cannot behave like single homogenous object possessing high temperature $T \sim 10^6$ K: the effective black body temperature deduced from the net radiation flux is not larger than 7000 K [E181] corresponding energy density is more than 10^{-9} times smaller than the energy density associated with T. This suggests the existence of local high temperature regions giving rise to characteristic spectral lines in X ray region serving as a signature of the high temperature.

It is also known that the dynamics of the solar atmosphere and convective zone is very strongly correlated with magnetic fields, which from Zeeman splitting are known to have typical magnitudes of order .3 Tesla [E181]. Furthermore, only those stars which have convective zone, possess corona and the size and shape of corona varies during the sunspot cycle.

Also solar constant is found to vary during sunspot cycle, which is difficult to understand in the standard picture about solar energy transfer. Solar wind is known to be associated with the non-closed magnetic fields lines and with the coronal holes in which temperature is lower than in the surroundings. High temperature regions in corona in turn correspond to regions at which field lines tend to be tangential to the surface and temperature. This suggests that magnetic fields provide the basic mechanism of convective energy transfer and that magnetic fields somehow make it possible to heat the solar corona locally.

These considerations suggests that magnetic flux tubes realized as tube like space-time sheets having radius $\rho \geq \rho_0 = \sqrt{1/eB}$ provide a TGD based topological realization for the convective energy transfer. This hypothesis reduces the problem to microscopic level and rather precise quantitative predictions should become possible. Protons and electrons can topologically condense at the magnetic flux tubes and move along them. It is assumed that in good approximation all protons, electrons and also heavier elements are condensed at the magnetic flux tubes.

The magnetic field of the flux tube confines charged particles and in transversal degrees of freedom they behave quantum mechanically like 2-dimensional harmonic oscillators with wave functions localized around Landau orbits with radius of order $\sqrt{n}\rho_0$, $n = 0, 1, 2..$ whereas in longitudinal degrees of freedom they behave like free particles locally. If n is sufficiently large, classical description as continuous matter should become possible. In the classical description charged particles are confined around magnetic lines of force and rotate with frequency $\omega = eB/E$, where E is total relativistic energy. The radius of the orbit is $\rho = \beta/\omega$, where β is rotational velocity. For sufficiently small values of β the radius of orbit is so small that particle is confined inside the flux tube. The dominant component of velocity is along the direction of flux tube.

In magneto-hydrodynamical description the basic equations state the conservation of magnetic flux, of various particle numbers (electron and proton numbers for magnetic flux tubes and neutron and neutrino numbers for Z^0 magnetic flux tubes) and conservation of momentum and energy along the flow lines. Energy density contains the energy density σT^4 of from black body radiation, kinetic energy density $\rho v^2/2$ of the macroscopic motion, pressure contribution p and the density $B^2/2$ of the magnetic energy. Gravitation is assumed to couple to the size and shape of the flux tube rather than to individual particles inside the flux tube so that gravitational energy density does not contribute to energy conservation conditions. If the particles slow down somewhat as they approach to the highly curved portions of the flux tubes, the increase of the temperature along the flux tube is implied by the conservation of energy $\sigma T^4 + \rho v^2/2 \simeq constant$. This explains why the local temperature of the corona is higher than the temperature at the surface of

Sun and why the temperature is lowest and streaming velocity highest at the coronal holes with non-closed magnetic field lines extending to interplanetary space. The leakage of the particles to other space-time sheets at the highly curved portions of the flux tubes could in turn cause local heating of the matter.

Since the particles entering the closed flux tubes have some kinetic energy and since most of them return to the convective zone, there must be a momentum transfer from particles to the flux tube and flux tube must receive momentum. In equilibrium this force and gravitational force affecting the shape and size of the entire flux tube cancel each other. This is nothing but a topological representation for the freezing of magnetic field lines to moving matter. In this picture it is possible to understand the mysterious looking ability of the solar prominences to defy the force of gravity. Solar wind corresponds to particles glued to open flux tubes or closed flux tubes formed via the recombination of flux lines in solar atmosphere and having velocity larger than the escape velocity.

The model predicts correctly the basic qualitative properties of the solar wind [E181].

1. The highest velocity streams come from the coolest part of corona, coronal holes: these regions correspond to open magnetic field lines extending into interplanetary space. This follows from the energy conservation and from the fact that temperature is lower for coronal holes so that kinetic energy must be larger.

2. The velocity of the solar wind protons is found to decrease with the increasing density of electrons at the base of Corona [E181]. By charge neutrality inside flux tubes also proton density is reduced and conservation law for energy requires the increase of the velocity of protons. Streaming velocity is also found to increase with the electron temperature at the base of the corona [E181]. Assuming thermal equilibrium this means that the radiative contribution to energy is reduced so that kinetic energy density must increase.

If flux tube is closed, particles return to the convective zone and one can indeed speak about convective motion also in solar atmosphere. The confinement of radiative energy to the closed magnetic flux tubes (space-time sheets actually!) might explain why solar constant depends on the phase of the sunspot cycle being smallest at sunspot maximum when the number of closed field lines is maximum. Neutrinos and neutrons are expected to suffer topological condensation on Z^0 magnetic flux tubes and the obvious explanation for the solar neutrino deficit is that some fraction of neutrinos is confined to these tubes returns back to Sun. The reduction of the neutrino flux is possible even without absolute confinement inside flux tubes: already the dispersion of the neutrino flux caused by the change in the direction of motion during the travel inside the flux tube reduces neutrino flux from the solar core.

8.4.2 Quantitative Formulation

Magnetic flux tubes are assumed to have fractal "flux tubes inside flux tubes" structure and decompose ultimately into microscopically thin flux tubes. Furthermore that protons and electrons are assumed to suffer magnetic confinement inside these flux tubes. Classical rotational motion around field lines occurs with frequency $\omega = eB/m$ and the rotational velocity satisfies $\beta = \omega\rho$. For small values of rotational velocity the particle remains confined inside the flux tube. The observed Zeeman splitting suggests that B is of order .1 Tesla. Quantum mechanically the confined particle is essentially equivalent with a harmonic oscillator with frequency ω in transversal degrees of freedom and behaves like free particle in longitudinal degrees of freedom. $B \simeq .3$ Tesla gives in case of proton the estimate $\omega \sim 10^{-7}$ eV for the frequency ω serving as the energy unit of the harmonic oscillator in question. Clearly, quasi-continuous spectrum is in question. The width of the ground state Gaussian wave function is $\rho_0 = \sqrt{\frac{1}{eB}}$ giving $\rho_0 \sim 10^{-8}$ meters for $B \sim .3$ Tesla. This gives the constraint $\rho > \rho_0$ to the thickness of the flux tube.

Higher Landau levels correspond to the radii $\rho_n = \sqrt{n}\rho_0$, $n = 1, 2, ...$ with energy spectrum given by $E_{n,m} = (n + m/2)\omega$, with angular momentum quantum number m varying in the range $-2n \leq m \leq 2n$. Transversal excitations with energies up to thermal energy must be allowed and this allows excitations up to $n = 10^7$ and thermal stability against the transfer of proton to larger space-time sheets requires $\rho > 10^{-5}$ meters. Since rather large values of n are excited thermally, it is possible to treat the matter inside flux tubes as continuous matter obeying hydrodynamic equations and ordinary Boltzmann statistics (rather than behaving as degenerate Fermi gas). The dominant component of the velocity is along the flux tube. The requirement that the Compton wavelength of the thermal photon is smaller than ρ gives $\rho > 10^{-8}$ meters for $T \sim 10^2\ eV$.

The effective black body temperature for the radiation from corona determined from the entire energy flux is not larger than 7000 K and corresponding energy density is roughly a fraction 10^{-9} of black body radiation temperature associated with the real temperature of order $T \sim 10^6$ K. Near the solar surface the density of matter is roughly 10^9 times that in corona [E181]. In the approximation that the matter density inside flux tubes is same in the corona and at the solar surface these observations suggest that the matter inside the magnetic flux tubes behaves as a dark matter and that the matter visible in the corona corresponds to a fraction 10^{-9} of dark matter leaked out from the magnetic flux tubes to space-time sheets where it becomes visible. This interpretation is consistent with the TGD based explanation of dark energy and dark matter in terms of magnetic energy of magnetic and Z^0 magnetic flux tubes and particles residing inside them (see the chapter "Cosmic Strings").

The particle density in the corona is of order $10^{14}/m^3$ particles [E181]. This implies a density of order $10^{23}/m^3$ particles (protons dominate in the mass density) inside flux tubes in corona. The density of solar wind particles is roughly $10^6/m^3$ at the solar surface [E181] and forms a fraction of order 10^{-17} of the density of matter at solar surface. If all solar wind particles are condensed at magnetic flux tubes, this means that only a fraction 10^{-17} of all magnetic flux tubes runs out of Sun! If flux tube structure is described as ordinary classical magnetic field one would say that most of magnetic energy resides in turbulent magnetic fields.

The basic equations of the model state the conservation of magnetic flux, particle number, energy and momentum. The requirement that the magnetic flux is conserved implies that the magnitude of BS, where S is the transverse area of the flux tube, is constant along the flux tube. Together with the conservation of particle number this gives the conditions

$$\begin{aligned} BS &= B_0S_0 \ , \\ n_pvS &= n_p^0v_0S_0 \ . \end{aligned} \tag{8.4.1}$$

Since the flux tubes turns back to the solar surface in corona, the vertical component of v is reduced at the corona whereas the tangential component increases by energy conservation. If the particle density inside the flux tubes were much smaller at the solar surface than in corona, the fraction of volume occupied by the magnetic flux tubes at solar surface would be larger than one so that the changes of ρ and v must be rather small.

The conservation of energy, assuming that gravitational force couples to the flux tube geometry rather than the matter inside flux tube, gives

$$\sigma T^4 + \frac{1}{2}\rho v^2 + \frac{1}{2}B^2 + p = constant \ . \tag{8.4.2}$$

Here one has $\sigma \simeq 51.95/2\pi^2 \sim 3$. The pressure term associated with matter is in a good approximation negligible as compared to the energy density of the kinetic energy since the thermal velocity of proton at corona is about $10^{-3-1/2}$. The dominating part in the energy density at solar surface corresponds to the density of kinetic energy which is roughly 10^2 times larger than the thermal energy density of photons at corona and 10^4 times larger than the density of the magnetic energy. If one assumes that the thickness of the flux tubes does not change, magnetic energy remains constant and one has $\rho v = \rho_0 v_0$, and energy conservation gives

$$\sigma\Delta(T^4) = -\frac{1}{2}\rho_0v_0\Delta v \ ,$$

which gives

$$\frac{\Delta v}{v_0} = -\frac{2\sigma\Delta(T^4)}{\rho_0 v_0^2} \ . \tag{8.4.3}$$

For $T = 10^2$ eV and $v_0 = 10^{-2}$ [E181] and $\rho_0 = 10^{23} m_p/m^3$ this gives $|\Delta\rho/\rho| = |\Delta v/v_0| = 6 \cdot 10^{-2} \ll 1$ so that the scenario is internally consistent. The slowing down of the particles as they approach the highly curved portion of the flux tube inside corona is natural.

As such the matter inside flux tubes is invisible and the high temperature matter in the corona results from a partial leakage of the particles from the magnetic flux tubes to other space-time sheets. The leakage of a fraction 10^{-9} would be caused by the large centrifugal acceleration at the highly curved portion of the flux tube. This would also explain why coronal holes are cooler than other regions of the corona.

The conservation of momentum together with the assumption that (most) matter flowing around flux tube returns back to the Sun implies that the matter topologically condensed at the flux tube feeds momentum in the degrees of freedom characterizing the size and shape of the flux tube and this must give rise to over all cm motion of the flux tube. The net force acting on the flux tube is obtained by integrating the divergence of the energy momentum tensor over the entire flux tube. Assuming that the velocity of matter at the return end is not considerably reduced, the contributions from the two ends are roughly identical and the expression for the resulting force acting on the cm of the flux tube reads as

$$F \simeq 2\rho_0 v_0^2 A \ , \tag{8.4.4}$$

where A is the transverse area of the flux tube. Also gravitational force acts on the cm motion of the flux tube and in equilibrium the two forces must cancel each other.

$$GM(Sun)L\langle\frac{\rho}{(R(Sun)+h)^2}\rangle = \rho_0 v_0^2 \ , \tag{8.4.5}$$

where h is the height from the surface of Sun and brackets denote averaging along the length of the flux tube of length L.

It can quite well happen that the momentum feed is so large that equilibrium is not possible and flux tube rises gradually and, if recombination of the flux tube ends giving rise to a closed flux tube occurs, runs away. This effect is enhanced by the fact that at large values of distance from Sun, where gravitational force is weakest, the mass density of the flux tube is largest. From the dependence of the gravitational force on height h it is clear that the eruption should occur when the height of prominence is same order of magnitude as solar radius: solar prominences have indeed the mysterious looking property of being unstable against upwards rather than downwards perturbations.

8.5 A Quantum Model For The Formation Of Astrophysical Structures And Dark Matter?

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [E87] (I am grateful for Victor Christianito for informing me about the article). In particular, this model applies to planetary orbits. I learned later that also A. Rubric and J. Rubric have proposed a Bohr model for planetary orbits [E235] already 1998.

The model is simply Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

$$\hbar \rightarrow \hbar_{gr} = \frac{GmM}{v_0} \ . \tag{8.5.1}$$

Here I have used units $\hbar = c = 1$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is 142 ± 2 km/s whereas the average velocity is 156 ± 2 km/s. Also sub-harmonics and harmonics of v_0 seem to appear.

v_0 could quite generally correspond to some rotational velocity associated with the two particle system and h_{gr} can be assigned with flux tubes mediating gravitational interactions: massless extremals topologically condensed at the flux tubes are natural candidates for the analogs of Alfwen waves mediating gravitational interaction.

There are several alternative interpretations for v_0.

1. One could assume single value of v_0 for all planets and sub-harmonics $v_0 \rightarrow v_0/n$ could actually correspond to the scaling of the principal quantum number (also denoted by n - hopefully this does not cause confusion) for Bohr orbits by n.
2. One could also assume that all orbits correspond to $n = 1$ orbits and that but for varying parameter $v = v_0/n$ replacing v_0 identified as rotation velocity $v = v_0/n$ for the Bohr orbit. This does not reduce the hypothesis a mere parameterization since the basic prediction in TGD framework is macroscopic quantum coherence in astrophysical scales at flux tubes mediating gravitational interaction.

Some further general comments are in order.

1. The proposal generalizes also to electromagnetic interactions - maybe even color interactions inside hadrons - with h_{gr} replaced with $h_{em} = |Z_1Z_2|\alpha/v_0$ [K85, K86] with critical value $n = h_{em}/h = 1$. Systems involving large charge separations such as plasmas and living matter would be excellent candidates for carrying dark matter with $h_{eff} = h_{em}$. In the electromagnetic case second system is most naturally microscopic since EP does not hold true and Compton lengths depend on the mass of the particle.
2. It took long time to realize that Equivalence Principle (EP) implies that it is enough to assume that the notion of h_{gr} makes sense at microscopic level [K98, K86]. The reason is that the acceleration does not depend on the mass of particle. This obviously favors quantum coherence in absence of forces for which accelerations are different for various particles. EP also means that gravitational Compton length of particle is independent of particle's mass.

   Direct calculation [K98] shows that for planets the predicted gravitational Compton length varies has order of magnitude varying from one to two gravitational Compton lengths suggesting that at the level of dark matter planets could be quantum systems. For elementary particles and atom sized objects the values of h_{gr} are in the same range as $h_{eff} = n \times h$ proposed with motivation coming from quantum biology [K42, K86, K38]. $h_{gr} = h_{eff}$ is a natural proposal at least in microscopic scales.
3. The natural assumption is that the astroscopic quantum coherence holds true only for dark matter at the gravitational flux tubes. If dark matter serves as a template for the formation of planets from ordinary matter, the Bohr rules for dark matter apply in reasonable approximation to the visible matter too.
4. One can also consider a model using only Bohr orbitology: in TGD framework the analogs of Bohr rules are expected to hold true at space-time level so that this approach is theoretically justified. If astroscopic quantum coherence due to large values is realized then one can think that planetary space-time sheets correspond to wormhole throats for which M^4 projection has astroscopic size. In this framework description in terms of Schrödinger equation need not be appropriate.

The model makes fascinating predictions which hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (planets up to Mars) corresponds to v_0 and outer solar system to $v_0/5$.

The predictions for the distribution of major axis and eccentrities have been tested successfully also for exoplanets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the gravitational Schödinger equation.

What is important is that there are no free parameters besides v_0. In [E87] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified. In the following I shall discuss Nottale's model from the point of view of TGD.

8.5.1 TGD Based Estimates For The Parameter v_0

One of the basic questions is the origin of the parameter v_0.

1. The original guess was that v_0 [E87] might be a constant of Nature.

2. Second possibility is that v_0 can be deduced from the rotational velocity assignable to the 2-particle system in question by Bohr quantization rule for angular momentum: this is possible using hydrogen atom Bohr rules expressing quantization for angular momentum and mechanical equilibrium. One obtains $v/c = \sqrt{v_0/c}/2\pi n$. For spherical stellar objects one could consider the identification of v_0 with the rotation velocity v of the object obtained quantization of angular momentum and condition $mvR = n\hbar_{gr}$ and $R = k\hbar_{gr}/M$, $k > 0$ integer, to give $v_0/c = v/c = n/k$ and $R = GMk^2/n$.

It was already noticed that the first option could explain the data in solar system assuming Bohr quantization for hydrogen atom but assuming different value of n for inner and outer planets. There are many alternative scenarios however. The following argument was inspired by the idea that v_0 might be a constant of Nature.

One of the first applications of cosmic strings in TGD sense was an explanation of the velocity spectrum of stars in the galactic halo in terms of dark matter which could consists of cosmic strings. Cosmic strings could be orthogonal to the galactic plane going through the nucleus (jets) or they could be in galactic plane in which case the strings and their decay products would explain dark matter assuming that the length of cosmic string inside a sphere of radius R is or has been roughly R [K31]. The predicted value of the string tension is determined by the CP_2 radius whose ratio to Planck length is fixed by electron mass via p-adic mass calculations. The resulting prediction for the v_0 is correct and provides a working model for the constant orbital velocity of stars in the galactic halo.

The parameter $v_0 \simeq 2^{-11}$, which has actually the dimension of velocity unless on puts $c = 1$, and also its harmonics and sub-harmonics appear in the scaling of $\hbar$. v_0 corresponds to the velocity of distant stars in the model of galactic dark matter. TGD allows to identify this parameter as the parameter

$$\begin{aligned} v_0 &= 2\sqrt{TG} = \sqrt{\frac{1}{2\alpha_K}}\sqrt{\frac{G}{R^2}} \ , \\ T &= \frac{1}{8\alpha_K}\frac{\hbar_0}{R^2} \ . \end{aligned} \tag{8.5.2}$$

Here T is the string tension of cosmic strings, R denotes the "radius" of CP_2 ($2R$ is the radius of geodesic sphere of CP_2). α_K is Kähler coupling strength, the basic coupling constant strength of TGD, whose evolution as a function of p-adic length scale is fixed by quantum criticality. The condition that G is invariant in the p-adic coupling constant evolution and number theoretical arguments predict

$$\begin{aligned} \alpha_K(p) &= k\frac{1}{log(p) + log(K)} \ , \\ K &= \frac{R^2}{\hbar_0 G} = 2\times 3\times 5\times 7\times 11\times 13\times 17\times 19\times 23 \ , \quad k \simeq \pi/4 \ . \end{aligned} \tag{8.5.3}$$

The predicted value of v_0 depends logarithmically on the p-adic length scale and for $p \simeq 2^{127}-1$ (electron's p-adic length scale) one has $v_0 \simeq 2^{-11}$.

8.5.2 Model for planetary orbits without $v_0 \rightarrow v_0/5$ scaling

Also harmonics and sub-harmonics of v_0 appear in the model of Nottale and Da Rocha. The 4 inner planets Mercury, Venus, Earth, Mars correspond to $n = 3, 4, 5, 6$ with v_0 whereas the outer planets (Jupiter, Saturn, ...) correspond to $v_0/5$ with principal quantum number $n_P \geq 2$. Mars corresponds to $n_P = 1$ for $v_0/5$ and $n_P = 6$ for v_0 in a reasonable approximation.

Planet	Exp. R/R_M	T-B R/R_M	Bohr$_1$ $[n, R/R_M]$	Bohr$_2$ $[n, R/R_M]$
Mercury	1	1	[3, 1]	
Venus	1.89	1.75	[4, 1.8]	
Earth	2.6	2.5	[5, 2.8]	
Mars	3.9	4	[6, 4]	
Asteroids	6.1-8.7	7	[(7, 8, 9), (5.4, 7.1, 9)]	
Jupiter	13.7	13	[11, 13.4]	[2×5, 11.1]
Saturn	25.0	25	[3×5, 25]	[3×5, 25]
Uranus	51.5	49	[22, 53.8]	[4×5, 44.4]
Neptune	78.9	97	[27, 81]	[5×5, 69.4]
Pluto	105.2	97	[31, 106.7]	[6×5, 100]

Table 8.2: Table represents the experimental average orbital radii of planets, the predictions of Titius-Bode law (note the failure for Neptune), and the predictions of Bohr orbit model assuming a) that the principal quantum number n corresponds to best possible fit, b) the scaling $v_0 \rightarrow v_0/5$ for outer planets. Option a) gives the best fit with errors being considerably smaller than the maximal error $|\Delta R|/R \simeq 1/n$ except for Uranus. R_M denotes the orbital radius of Mercury. T-B refers to Titius-Bode law.

Quite generally, it is found that the values seem to come as harmonics and sub-harmonics of v_0: $v_n = nv_0$ and v_0/n, and the argument [E87] is that the different values of n relate to fractality. This scaling is not necessary for the planetary orbits in TGD based model. Effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question in the case of outer planets. If one accepts the interpretation that visible matter has concentrated around dark matter, which is in macroscopic quantum phase around Bohr orbits, this allows to consider also the possibility that $\hbar_{gr}$ has the same value for all planets.

1. Some gravitational perturbation has kicked dark matter from the region of the asteroid belt to $n \simeq 5k$, $k = 2,..,6$, orbits. The best fit is obtained by using values of n deviating somewhat from multiples of 5 which suggests that the scaling of v_0 is not needed. Gravitational perturbations might have caused the same for the visible matter. The fact that the tilt angles of Earth and outer planets other than Pluto are nearly the same suggests that the orbits of these planets might be an outcome of some violent quantum process for dark matter preserving the orbital plane in a good approximation. Pluto might in turn have experienced some violent collision changing its orbital plane.

2. There could exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter.

How to understand the harmonics and sub-harmonics of v_0 in TGD framework?

Also harmonics and sub-harmonics of v_0 appear in the model of Nottale and Da Rocha. In particular, the outer planets (Jupiter, Saturn, ...) correspond to $v_0/5$ and $n_P \geq 2$ whereas the 4 inner planets correspond to v_0 in this model. As already found, TGD allows also an alternative explanation.

Quite generally, it is found that the values seem to come as harmonics and sub-harmonics of v_0: $v_n = nv_0$ and v_0/n, and the argument [E87] is that the different values of n relate to fractality. This quantization is a challenge for TGD since v_0 certainly defines a fundamental constant in TGD Universe.

1. Consider first the harmonics of v_0. Besides cosmic strings of type $X^2 \times S^2 \subset M^4 \times CP_2$ one can consider also deformations of these strings defining their multiple coverings so that the deformation is n-valued as a function of S^2-coordinates (Θ, Φ) and the projection to S^2 is thus an $n \rightarrow 1$ map. The solutions are higher dimensional analogs of originally closed orbits

which after perturbation close only after n turns. This kind of surfaces emerge in the TGD inspired model of quantum Hall effect naturally [K6] and $n \rightarrow \infty$ limit has an interpretation as an approach to chaos [K108].

Using the coordinates (x, y, θ, ϕ) of $X^2 \times S^2$ and coordinates m^k for M^4 of the unperturbed solution the space-time surface the deformation can be expressed as

$$\begin{aligned} m^k &= m^k(x, y, \theta, \phi) \ , \\ (\Theta, \Phi) &= (\theta, n\phi) \ . \end{aligned} \tag{8.5.4}$$

The value of the string tension would be indeed n^2-fold in the first approximation since the induced Kähler form defining the Kähler magnetic field would be $J_{\theta\phi} = nsin(\Theta)$ and one would have $v_n = nv_0$. At the limit $m^k = m^k(x, y)$ different branches for these solutions collapse together.

2. Consider next how sub-harmonics appear in TGD framework. Cosmic strings are predicted to decay to magnetic flux tube structures by absolute minimization of Kähler action (, which of course is only one possible identification for what it is to be a preferred extremal). The Kähler magnetic flux $\Phi = BS$ is conserved in the process but the thickness of the M^4 projection of the cosmic string increases field strength is reduced. This means that string tension, which is proportional to B^2S, is reduced (so that also Kähler action is reduced). The fact that space-time surface is Bohr orbit in generalized sense means that the reduced string tension (magnetic energy per unit length) is quantized.

The task is to guess how the quantization occurs. There are two options.

1. The simplest explanation for the reduction of v_0 is based on the decay of a flux tube resembling a disk with a hole to n identical flux tubes so that $v_0 \rightarrow v_0/n$ results for the resulting flux tubes. It turns out that this mechanism is favored and explains elegantly the value of $\hbar_{gr}$ for outer planetary system. One can also consider small-p p-adicity so that n would be prime.

2. Second explanation is more intricate. Consider a magnetic flux tube. Since magnetic flux is quantized, the magnetic field strengths are quantized in integer multiples of basic strength: $B = nB_0$ and would rather naturally correspond to the multiple coverings of the original magnetic flux tube with magnetic energy quantized in multiples of n^2. The idea is to require internal consistency in the sense that the allowed reduced field strengths are such that the spectrum associated with B_0 is contained to the spectrum associated with the quantized field strengths $B_1 > B_0$. This would allow only field strengths $B = B_S/n^2$, where B_S denotes the field strength of the fundamental cosmic string and one would have $v_n = v_0/n$. Flux conservation requires that the area of the flux tube scales as n^2.

Sub-harmonics might appear in the outer planetary system and there are indications for the higher harmonics below the inner planetary system [E87]: for instance, solar radius corresponds to $n = 1$ orbital for $v_3 = 3v_0$. This would suggest that Sun and also planets have an onion like structure with highest harmonics of v_0 and strongest string tensions appearing in the solar core and highest sub-harmonics appearing in the outer regions. If the matter results as decay remnants of cosmic strings this means that the mass density inside Sun should correlate strongly with the local value of n characterizing the multiple covering of cosmic strings.

One can ask whether the very process of the formation of the structures could have excited the higher values of n just like closed orbits in a perturbed system become closed only after n turns. The energy density of the cosmic string is about one Planck mass per $\sim 10^7$ Planck lengths so that $n > 1$ excitation increasing this density by a factor of n^2 is obviously impossible except under the primordial cosmic string dominated period of cosmology during which the net inertial energy density must have vanished. The structure of the future solar system would have been dictated already during the primordial phase of cosmology when negative energy cosmic string suffered a time reflection to positive energy cosmic strings.

Nottale equation is consistent with the TGD based model for dark matter

TGD allows two models of dark matter. The first one is spherically symmetric and the second one cylindrically symmetric. The first thing to do is to check whether these models are consistent with the gravitational Schödinger equation/Bohr quantization.

1. Spherically symmetric model for the dark matter

The following argument based on Bohr orbit quantization demonstrates that this is indeed the case for the spherically symmetric model for dark matter. The argument generalizes in a trivial manner to the cylindrically symmetric case.

1. The gravitational potential energy $V(r)$ for a mass distribution $M(r) = xTr$ (T denotes string tension) is given by

$$V(r) = Gm\int_r^{R_0}\frac{M(r)}{r^2}dr = GmxTlog(\frac{r}{R_0}) \ . \tag{8.5.5}$$

   Here R_0 corresponds to a large radius so that the potential is negative as it should in the region where binding energy is negative.

2. The Newton equation $\frac{mv^2}{r} = \frac{GmxT}{r}$ for circular orbits gives

$$v = xGT \ . \tag{8.5.6}$$

3. Bohr quantization condition for angular momentum by replacing $\hbar$ with $\hbar_{gr}$ reads as $mvr = n\hbar_{gr}$ and gives

$$\begin{aligned} r_n &= \frac{n\hbar_{gr}}{mv} = nr_1 \ , \\ r_1 &= \frac{GM}{vv_0} \ . \end{aligned} \tag{8.5.7}$$

   Here v is rather near to v_0.

4. Bound state energies are given by

$$E_n = \frac{mv^2}{2} - xTlog(\frac{r_1}{R_0}) + xTlog(n) \ . \tag{8.5.8}$$

   The energies depend only weakly on the radius of the orbit.

5. The centrifugal potential $l(l+1)/r^2$ in the Schrödinger equation is negligible as compared to the potential term at large distances so that one expects that degeneracies of orbits with small values of l do not depend on the radius. This would mean that each orbit is occupied with same probability irrespective of value of its radius. If the mass distribution for the stars does not depend on r, the number of stars rotating around galactic nucleus is simply the number of orbits inside sphere of radius R and thus given by $N(R) \propto R/r_0$ so that one has $M(R) \propto R$. Hence the model is self consistent in the sense that one can regard the orbiting stars as remnants of cosmic strings and thus obeying same mass distribution.

2. Cylindrically symmetric model for the galactic dark matter

TGD allows also a model of the dark matter based on cylindrical symmetry. In this case the dark matter would correspond to the mass of a cosmic string orthogonal to the galactic plane and traversing through the galactic nucleus. The string tension would the one predicted by TGD. In the directions orthogonal to the plane of galaxy the motion would be free motion so that the orbits would be helical, and this should make it possible to test the model. The quantization of radii of the orbits would be exactly the same as in the spherically symmetric model. Also the quantization of inclinations predicted by the spherically symmetric model could serve as a sensitive test. In this kind of situation general theory of relativity would predict only an angle deficit giving rise to a lens effect. TGD predicts a Newtonian $1/\rho$ potential in a good approximation.

Spiral galaxies are accompanied by jets orthogonal to the galactic plane and a good guess is that they are associated with the cosmic strings. The two models need not exclude each other. The vision about astrophysical structures as pearls of a fractal necklace would suggest that the visible matter has resulted in the decay of cosmic strings originally linked around the cosmic string going through the galactic plane and creating $M(R) \propto R$ for the density of the visible matter in the galactic bulge. The finding that galaxies are organized along linear structures [E272] fits nicely with this picture.

MOND and TGD

TGD based model explains also the MOND (Modified Newton Dynamics) model of Milgrom [E212] for the dark matter. Instead of dark matter the model assumes a modification of Newton's laws. The model is based on the observation that the transition to a constant velocity spectrum seems in the galactic halos seems to occur at a constant value of the stellar acceleration equal to $a_0 \simeq 10^{-11}g$, where g is the gravitational acceleration at the Earth. MOND theory assumes that Newtonian laws are modified below a_0.

The explanation relies on Bohr quantization. Since the stellar radii in the halo are quantized in integer multiples of a basic radius and since also rotation velocity v_0 is constant, the values of the acceleration are quantized as $a(n) = v_0^2/r(n)$ and a_0 correspond to the radius $r(n)$ of the smallest Bohr orbit for which the velocity is still constant. For larger orbital radii the acceleration would indeed be below a_0. a_0 would correspond to the distance above which the density of the visible matter does not appreciably perturb the gravitational potential of the straight string. This of course requires that gravitational potential is that given by Newton's theory and is indeed allowed by TGD.

The MOND theory (see `http://tinyurl.com/qt875`) [E212] and its variants predict that there is a critical acceleration below which Newtonian gravity fails. This would mean that Newtonian gravitation is modified at large distances. String models and also TGD predict just the opposite since in this regime General Relativity should be a good approximation.

1. The $1/r^2$ force would transform to $1/r$ force at some critical acceleration of about $a = 10^{-10}$ m/s^2: this is a fraction of 10^{-11} about the gravitational acceleration at the Earth's surface.

2. The recent empirical study (see `http://tinyurl.com/ychyy3z3`) [E184] giving support for this kind of transition in the dynamics of stars at large distances and therefore breakdown of Newtonian gravity in MOND like theories.

In TGD framework critical acceleration is predicted but the recent experiment does not force to modify Newton's laws. Since Big Science is like market economy in the sense that funding is more important than truth, the attempts to communicate TGD based view about dark matter [K42, K93, K79, K94, K31] have turned out to be hopeless. Serious Scientist does not read anything not written on silk paper.

1. One manner to produce this spectrum is to assume density of dark matter such that the mass inside sphere of radius R is proportional to R at last distances [K31]. Decay products of and ideal cosmic strings (see `http://tinyurl.com/y8wbeo4q`) would predict this. The value of the string tension predicted correctly by TGD using the constraint that p-adic mass calculations give electron mass correctly [K63].

2. One could also assume that galaxies are distributed along cosmic string like pearls in necklace. The mass of the cosmic string would predict correct value for the velocity of distant stars. In the ideal case there would be no dark matter outside these cosmic strings.

   (a) The difference with respect to the first mechanism is that this case gravitational acceleration would vanish along the direction of string and motion would be free motion. The prediction is that this kind of motions take place along observed linear structures formed by galaxies and also along larger structures.

   (b) An attractive assumption is that dark matter corresponds to phases with large value of Planck constant is concentrated on magnetic flux tubes. Holography would suggest that the density of the magnetic energy is just the density of the matter condensed at wormhole throats associated with the topologically condensed cosmic string.

   (c) Cosmic evolution modifies the ideal cosmic strings and their Minkowski space projection gets gradually thicker and thicker and their energy density - magnetic energy - characterized by string tension could be affected

TGD option differs from MOND in some respects and it is possible to test empirically which option is nearer to the truth.

1. The transition at same critical acceleration is predicted universally by this option for all systems-now stars- with given mass scale if they are distributed along cosmic strings like like pearls in necklace. The gravitational acceleration due the necklace simply wins the gravitational acceleration due to the pearl. Fractality encourages to think like this.

2. The critical acceleration predicted would correspond to acceleration of the same order of magnitude as the acceleration caused by cosmic string. From $M^2/R_{cr} = GM/R_{cr}^2 = TG/R_{cr}$ (assuming that dark matter dominates) one obtains the estimate $R_{cr} = M/T$ and $a_{cr} = GT^2/M$, where M is the visible mass of the object - for instance the ordinary matter of a galaxy. If critical acceleration is always the same, one would have $T = (a_{cr}M/G)^{1/2}$ so that the visible mass would scale like $M \propto T^2$ if a_{cr} is constant of Nature.

3. If $1/r^2$ changes to $1/r$ in the MOND model, one obtains the same predictions as in TGD for the planar orbits orthogonal to the long string along which galaxies correspond to flux tube tangles. The models are not equivalent. In TGD, general orbit of the star corresponds to a helical motion of the star in the plane orthogonal to the cosmic string and along the cosmic string so that the observed concentration of visible matter on a preferred plane is predicted. This concentration of orbits in a single plane has been recently reported as an anomaly of dark matter models [L115].

TGD option explains also other strange findings of cosmology and astrophysics.

1. The basic prediction is the large scale motions of dark matter along cosmic strings. The characteristic length and time scale of dynamics is scaled up by the scaling factor of $\hbar$. This could explain the observed large scale motion of galaxy clusters - dark flow (see `http://tinyurl.com/ckfg25`) [E7] - assigned with dark matter in conflict with the expectations of standard cosmology.

2. Cosmic strings could also relate to the strange relativistic jet like structures (see `http://tinyurl.com/2x5od6`) [E28] meaning correlations between very distant objects. Universe would be a spaghetti of cosmic strings around which matter is concentrated.

3. The TGD based model for the final state of star (see `http://tinyurl.com/yantmeot`) [K111] actually predicts the presence of string like object defining preferred rotation axis. The beams of light emerging from supernovae would be preferentially directed along this lines- actually magnetic flux tubes. Same would apply to the gamma ray bursts (see `http://tinyurl.com/csd2an`) [E11] from quasars, which would not be distributed evenly in all directions but would be like laser beams along cosmic strings.

The existence of ultra diffuse galaxies for which the velocity of distant rotating stars is extremely low means difficulties for the cold dark matter scenario since in some cases there seems to be no dark matter at all, and in some cases there seems to be only dark matter. Also MOND has grave difficulties with them.

The problem in the case of galaxy AGC 114905 (`https://earthsky.org/space/dark-matter-missing-from-gala` is discussed in a popular article "In a Wild Twist, Physicists Have Revived an Alternative Theory of Gravity" published in Science-Astronomy (`https://cutt.ly/UZ9zBMh`). This galaxy is of the same size as Milky Way and seems to have very small amount of dark matter, if any.

Mancera Pina et al [E151] argue that both cold dark matter scenario and MOND fail to explain the anomalously low value of the rotation velocity of distant stars. The proposal of Banik et al [E103] is that the inclination between the galactic disc and skyplane is overestimated, which leads to a too small estimate for the estimate for the rotation velocity so that MOND could be saved.

In the TGD framework [L63, L69, L111], the rotation velocity is proportional to the square root of the product GT, where T is the string tension of a long magnetic flux tube formed from a cosmic string carrying dark energy and possibly also matter. In the ordinary situation, the flux tube would be considerably thickened only in a tangle associated with the galaxy as part of volume- and magnetic energies would have decayed to ordinary matter, in analogy with the decay of the inflaton field.

If the flux tube itself has a very long thickened portion such that ordinary matter has left this region by free helical motion along the string or by gravitational attraction of some other object, the string tension T is small and very small velocity is possible. Ordinary gravitational bound states of matter are not necessary since the gravitational force of the flux tubes binds the stars. This might explain why the galaxy can be ultra diffuse.

The asymmetry of tidal tails as a support for the TGD view of dark matter

The most recent puzzling discovery related to the galactic dynamics is that for certain star clusters associated with tidal tails there is an asymmetry with respect to the direction of the motion along the tail [E139] (`https://arxiv.org/abs/2210.13472`). The trailing tail directed to the galactic nucleus is thin and the leading tail is thick and there are many more stars in it. Stars also tend to leak out along the direction of motion along the tail. One would not expect this kind of asymmetry in the Newtonian theory since the contribution of the ordinary galactic matter to the gravitational potential possibly causing the asymmetry is rather small.

MOND theory [E212]is reported to explain the finding satisfactorily.

1. The tidal tails of the star cluster are directed towards (leading tail) and outwards from it (trailing tail). The standard explanation is that gravitational forces produce them as a purely gravitational effect. These tails can be however often thin and long, which has raised suspicions concerning this explanation.

2. MOND hypothesis assumes that gravitational acceleration starts to transform above some critical radius from $1/r^2$ form to $1/r$ form. This applies to galaxies and star clusters modelled as a point-like object. This idea is realized in terms of a non-linear variant of the Poisson equation by introducing a coefficient $\mu(a/a_0)$ depending on the ratio a/a_0 of the strength of gravitational acceleration a expressible as gradient of the gravitational potential. a_0 is the critical acceleration appearing as a fundamental constant in the MOND model. μ approaches unity at large accelerations and a linear function of a/a_0 at small accelerations. Note that MOND violates the Equivalence Principle.

3. For MOND, the effective gravitational potential of the galactic nucleus becomes logarithmic. Therefore the outwards escape velocity in the trailing tail is higher than the inwards escape velocity in the leading tail so that the stars tend to be reflected back from the trailing tail. This would cause tidal asymmetry implying that the tail directed to the galactic nucleus contains more stars than the outwards tail. The MOND model uses the effective gravitational mass of the galaxy to model the situation in a quasi-Newtonian way.

TGD allows us to consider both the variant of the MOND model. The model provides also a possible explanation for the formation of the star cluster itself.

1. In the TGD framework, cosmic strings are expected to form a network [L63, L69, L111]. In particular, one can assign to the tidal tails a cosmic string oriented towards the galactic nucleus, call it L_t to distinguish it from the long cosmic string along L along which galaxies are located. The thickening of a long string and the associated formation of a tangle generates ordinary matter as the dark energy of the string transforms to ordinary matter. This is the TGD counterpart for the transformation of the energy of an inflaton field to ordinary matter.

   This process can occur for both the galactic string L andL_t. In the first case it would give rise to galaxies along L and in the case of L_t to the formation of star clusters. Unlike in MOND, the gravitation remains Newtonian and the Equivalence Principle is satisfied in TGD.

2. The long cosmic string L along which the galaxies are located gives an additive logarithmic contribution to the total gravitational potential of the galaxy. This contribution explains the flat velocity spectrum of distant stars.

   At some critical distance, the contribution of L begins to dominate over the contribution of ordinary matter. The critical acceleration of the MOND model is replaced with the value of acceleration at which this occurs. In contrast to MOND, this acceleration is not a universal constant and depends on the mass of the visible part of the galaxy. TGD predicts a preferred plane for the galaxy and free motion in the direction of the cosmic string orthogonal to it. Also the absence of dark matter halo is predicted.

3. Concerning the formation of the tidal tails, the simplest TGD based model is very much the same as the MOND model except that one has 2-D logarithmic gravitational potential of string rather than modification of the ordinary 3-D gravitational potential of the galaxy. Therefore TGD allows a very similar model at qualitative level.

One can however challenge the assumption that the mechanism is purely gravitational.

1. The tidal tails tend to have a linear structure. Could they correspond to linear structures, long strings or tentacles extending towards the galactic nucleus? Could the formation of star clusters itself be a process, which is analogous to the formation of galaxies as a thickening of cosmic string leading to formation of a flux tube tangle?

2. Why more stars at the rear end rather than the frontal end of the moving star cluster? Could one have a phase transition transforming dark energy to matter proceeding along the cosmic L_t string rather than a star cluster moving. Dark energy would burn to ordinary matter and give rise to the star cluster.

3. The burning could proceed in both directions or in a single direction only. If the burning proceeds outwards from the galactic nucleus, the star formation is just beginning at the trailing end. In the leading end, the tangle formed by cosmic string has expanded and stretched due to the reduction of string tension. This could explain the asymmetry between trailing and leading ends at least partially.

   If the burning proceeds both outwards and inwards, only the MOND type explanation remains.

4. Second asymmetry is that the stars tend to leak out along the direction of motion. The gravitational field of the galaxy containing the logarithmic contribution explains this at least partially. Long cosmic string L_t creates a transversal gravitational field and this could strengthen this tendency. The motion along L_t is free so that the stars tend to leak out from the system along the direction of L_t.

8.5.3 The Challenge Of Six Planets

NASA has published the first list of exoplanets found by Kepler satellite. In particular, the NASA team led by Jack Lissauer reports a discovery of a system of six closely packed planets (see `http://tinyurl.com/66vn9k9`) [E50] around a Sun-like star christened as Kepler-11_a located in the direction of constellation Cygnus at distance of about 2000 light years. The basic data about the six planets Kepler-11_i, $i = b, c, d, e, f, g$ and star Kepler-11_a can be found in Wikipedia (see http://tinyurl.com/y8exe44b). Below I will refer to the star by Kepler-11 and planets with label $i = b, c, d, e, f, g$. Lissauer regards it as quite possible that there are further planets at larger distances. The fact that the radius of planet g is only.462AU together with what we know about solar system suggests that this could be the case. This leaves door for Earth like planet.

The conclusions from the basic data

Let us list the basic data.

1. The radius and mass and surface temperature of Kepler-11 are very near to those of Sun.

2. The orbital radii using AU as unit are given by

$$(.091, .106, .159, .194, .250, .462) \ .$$

   The orbital radii can be deduced quite accurately from the orbital periods by using Kepler's law stating that the squares of periods are proportional to cubes of orbital radii.The orbital periods of the 5 inner planets are between 10 and 47 days whereas g has a longer period of 118.37774 days (note the amazing accuracy). The orbital radii of e and f are.194 AU and.250 AU so that the temperature is expected to be much higher than at Earth so that life as we know it is not expected to be there. The average temperature of the radiation from Kepler-11 scaling as $1/r^2$ would be 4 times the temperature at Earth. The fact that gas forms a considerable fraction of the planet's mass could however mean that this does not give a good estimate for the temperature of the planet.

3. The mass estimates using Earth mass as unit are

$$(4.3, 13.5, 6.1, 8.4, 2.3, \leq 300) \ .$$

   There are considerable uncertainties involved here, of order factor of 1/2.

4. The estimates for the radii of the planets using the radius of Earth as unit are

$$(1.97, 3.15, 3.43, 4.52, 2.61, 3.66) \ .$$

   The uncertainties are about 20 per cent.

5. From the estimates for the radii and mass estimates one can conclude that the estimates for the densities of the planets are considerably lower than those for Earth. Density of (e, f) is about $(1/8, 1/4)$ of that for Earth. The surface gravitation for e and f is roughly 1/2 of that at Earth. For g it is same as for Earth if g has mass roughly $m(g) \simeq 15$. The upper bound $m(g) \leq 300$ implies that surface gravity is weaker than $20g$ for g.

The basic conclusions from the Wikipedia data are following. One cannot exclude the possibility that the planetary system could contain Earth like planets. Furthermore, the distribution of the orbital radii of the planets differs dramatically from that in solar system.

How to understand the tight packing of the inner planets?

The striking aspect of the planetary system is how tightly packed it is. The ratio for the radii of g and b is about 5. This is a real puzzle for model builders(see http://tinyurl.com/y7xtog56). TGD suggests three phenomenological approaches.

1. Titius-Bode law (see http://tinyurl.com/3cum7h7)

$$r(n) = r_0 + 2^n r_1$$

   is supported by p-adic length scale hypothesis. Stars would have onion-like structure consisting of spherical shells with inner and outer radii of the shell differing by factor two. The formation of planetary system involves condensation of matter to planets at these spherical shells. The preferred extremals of Kähler action describing stationary axially symmetric system corresponds to spherical shells containing most of the matter. A rough model for star would be in terms of this kind of spherical shells defined an onion-like structure defining a hierarchy of space-time sheets topologically condensed on each other. The value of the parameter r_0 could be vanishing in the initial situation but subsequent gravitational dynamics could make it positive reducing the ratio $r(n)/r(n-1)$ from its value 2.

2. Bohr orbitology suggested by the proposal that gravitonic space-time sheets assigned with a given planet-star pair correspond to a gigantic value of gravitational Planck constant given by

$$\hbar_{gr} = \frac{GMm}{v_0} \ ,$$

where v_0 has dimensions of velocity and actually equal to the orbital velocity for the lowest Bohr orbit. For the 4 inner planets in solar system one has $v_0/c \simeq 2^{-11}$.

The physical picture is visible matter concentrates around dark matter and in this matter makes it astroscopic quantum behavior visible. The model is extremely predictive since the spectrum of orbital radii would depend only on the mass of the star and planetary systems would be much like atoms with obvious implications for the probability of Earth like systems supporting life. This model is consistent with the Titius-Bode model only if the Bohr orbitology is a late-comer in the planetary evolution.

3. The third model is based on same general assumptions as the second one but only assumes that dark matter in astrophysical length scales associated with anyonic 2-surfaces (with light-like orbits in induced metric in accordance with holography) characterized by the value of the gravitational Planck constant. In this case the hydrogen atom inspired Bohr orbitology is just the first guess and cannot be taken too seriously. What would be important would be genuinely quantal dynamics for the formation of planetary system.

Can one interpret the radii in this framework in any reasonable manner?

1. Titius-Bode predicts

$$\frac{r(n)-r(n-1)}{r(n-1)-r(n-2)} = 2 \ ,$$

which works excellently for c, f, and g. For b, d and e the law fails. This suggests that the four inner planets a, b, c, d, whose radii span single 2-adic octave in good approximation (!) correspond to single system which has split from single plane or will fuse to single planet distant future.

2. Hydrogenic Bohr orbitology works only if g corresponds to $n = 2$ orbit. $n = 1$ orbit would have radius.116AU. From the proportionality $r \propto \hbar_{gr}^2 \propto 1/v_0^2$, one obtains that the value one must have

$$R \equiv \frac{v_0^2(Kepler)}{v_0^2(Sun)} \simeq 3.04 \ .$$

This would result as in reasonable approximation for $v_0(Kepler)/v_0(Sun) = 7/4$ (the values of Planck constant are predicted to integer multiples of the standard value) giving $R = 7/4^2 \simeq 3.06$.

Note that the planets would correspond to those missing in Earth-Sun system for which one has $n = 3, 4, 5, 6$ for the inner planets Mercury, Venus, Earth, and Mars.

One could argue that Bohr orbits result as the planets fuse to two planets at these radii. This picture is not consistent with Titius-Bode law which predicts three planets in the final situation unless $n = 2$ planet remains unrealized. By looking the graphical representation of the orbital radii (see `http://tinyurl.com/y8exe44b`) of the planet system one has tendency to say that b, c, d, e, and f form a single subsystem and could eventually collapse to single planet. The ratio of gravitational forces between g and f is larger than that between f and e for $m(g) \geq 6m_E$ so that one can ask whether f could be eventually caught be g in this case. Also the fact that one has $r(g)/r(f) \leq 2$ mildly suggests this.

8.6 Further Indications For Dark Matter

The notion of many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) has been continually receiving qualitative support from various anomalies. In the following some candidates for anomalies are summarized briefly.

8.6.1 Some Anomalies

New dark matter anomaly

One of the most radical parts of quantum TGD is the view about dark matter as a hierarchy of phases of matter with varying values of Planck constant realized in terms of generalization of the 8-D embedding space to a book like structure. The latest blow against existing models of dark matter is the discovery of a new strange aspect of dark matter discussed in New Scientist popular article "Galaxy study hints at cracks in dark matter theories" [E238]. The original article in Nature is titled as *Universality of galactic surface densities within one dark halo scale-length* [E129]. I glue here a short piece of the New Scientist article.

A galaxy is supposed to sit at the heart of a giant cloud of dark matter and interact with it through gravity alone. The dark matter originally provided enough attraction for the galaxy to form and now keeps it rotating. But observations are not bearing out this simple picture.

Since dark matter does not radiate light, astronomers infer its distribution by looking at how a galaxy's gas and stars are moving. Previous studies have suggested that dark matter must be uniformly distributed within a galaxy's central region - a confounding result since the dark matter's gravity should make it progressively denser towards a galaxy's centre.

Now, the tale has taken a deeper turn into the unknown, thanks to an analysis of the normal matter at the centres of 28 galaxies of all shapes and sizes. The study shows that there is always five times more dark matter than normal matter where the dark matter density has dropped to one-quarter of its central value.

In TGD framework both dark energy and dark matter are assumed to correspond to dark matter but with widely different values of Planck constant. The point is that very large value of Planck constant for dark matter implies that its density is in an excellent approximation constant as is also the density of dark energy. Effective value of Planck constant is indeed predicted to be gigantic at the space-time sheets mediating gravitational interaction. It must be however emphasized that the huge value of the gravitational Planck constant h_{gr} suggests that it can have different origin that associated with the hierarchy of Planck constant: I have discussed this possibility in [K93].

The appearance of number five as a ratio of mass densities sounds mysterious. Why the average mass in a large volume should be proportional to $\hbar$ if $\hbar$ is not too large? Intriguingly, number five appears also in the Bohr model for planetary orbits. The value of the gravitational Planck constant $\hbar_{gr} = GMm/v_0$ assignable to the space-time sheets mediating gravitational interaction between planet and star is gigantic: $v_0/c \simeq 2^{-11}$ holds true for the 4 inner planets. For outer planets v_0/c is by a factor 1/5 smaller so that corresponding gravitational Planck constant is 5 times larger. Do these two fives represent a mere coincidence?

1. In accordance with TGD inspired cosmology suppose that visible matter and also the matter which is conventionally called dark matter has emerged from the decay and widening of cosmic strings to magnetic flux tubes. Assume that the string tension can be written as $k \times \hbar/G$, k a numerical constant.

2. Suppose that the values of $\hbar$ come as pairs $\hbar = n \times \hbar_0$ and $5 \times \hbar$. Suppose also that for a given value of $\hbar$ the length of the cosmic string (if present at all) inside a sphere or radius R is given by $L = x(n)R$, $x(n)$ a numerical constant which can depend on the pair but is same

for the members of the pair $(\hbar, 5\times\hbar)$. This assumption is supported by the velocity curves of distant stars around galaxies.

3. These assumptions imply that the masses of matter for a pair $(\hbar, 5\times\hbar)$ corresponding to a given value of $\hbar$ in a volume of size R are given by $M(\hbar) = k\times x(\hbar)\times\hbar\times R/G$ and $M(5\times\hbar) = 5\times M(\hbar)$. This would explain the finding if visible matter corresponds to $\hbar_0$, and $x(n)$ is much smaller for pairs $(n>1, 5\times n)$ than for the pair $(1,5)$.

4. One can explain the pairing in TGD framework. Let us accept the earlier hypothesis that the preferred values of $\hbar$ correspond to number theoretically maximally simple quantum phases $q = exp(i2\pi/n)$ emerging first in the number theoretical evolution having a nice formulation in terms of algebraic extensions of rationals and p-adics and the gradual migration of matter to the pages of the book like structure labeled by large values of Planck constant. These number theoretically simple quantum phases correspond to n-polygons drawable by ruler and compass construction. This predicts that the preferred values of $\hbar$ correspond to a power of 2 multiplied by a product of Fermat primes $F_k = 2^{2^k}+1$. The list of known Fermat primes is short and given by $F_k, k = 0,1,2,3,4$ giving the Fermat primes $3,5,17,257,2^{16}+1$. This hypothesis indeed predicts that Planck constants $\hbar$ and $5\times\hbar$ appear as pairs.

5. Why the pair $(1, F_1 = 5)$ should be then favored? Could the reason be that $n = 5$ corresponds also to the smallest integer making possible universal topological quantum computer: the quantum phase $q = exp(i2\pi/5)$ characterizes the braiding coding for the topological quantum computer program. Or is the reason simply that this pair corresponds to the number theoretically simplest pair which must have emerged first in the number theoretic evolution?

6. This picture supports the view that ordinary matter and most what is usually called dark matter are characterized by Planck constants $\hbar_0$ and $5\times\hbar_0$, and that the space-time sheets mediating gravitational interaction correspond to dark energy because the density of matter at these space-time sheets must be constant in an excellent approximation since Compton lengths are so gigantic.

7. Using the fact that 4 per cent of matter is visible this means that $n = 5$ corresponds to 20 per cent of dark matter in standard sense. Pairs $(n>1, 5n)$ should contribute the remaining 2 per cent of dark matter. The fractal scaling law $x(n)\propto 1/n^r$ allowing pairs defined by all Fermat integers not divisible by 5 would give for the mass fraction of conventional dark matter with $n>1$ the expression

$$p = 6\times\sum_k 2^{-kr}[2^{-r}+\sum n_F^{-r}]\times\frac{4}{100} = \frac{24}{100}\times\frac{1}{1-2^{-r}}\times[2^{-r}+\sum n_F^{-r}] \ .$$

Here n_F denotes a Fermat integer which is product of some Fermat primes in the set $\{3,17,257,2^{16}+1\}$. The contribution from $n = 2^k$, $k>0$, gives the term not included to the sum over n_F. $r = 4.945$ predicts $p = 2.0035$ and that the mass density of dark matter would scale down as $1/\hbar^{r-1} = 1/\hbar^{3.945}$.

8. The prediction brings in mind the scaling $1/a^{r-1}$ for the cosmological mass density. a^{-4} scaling for radiation dominated cosmology is very near to this scaling. $r = 5$ (sic!) would predict $p = 1.9164$ which is of course consistent with the data. This inspires the working hypothesis that the density of the dark matter as function of $\hbar$ scales just like the density of matter as function of cosmic time during particular epoch. In matter dominated cosmology with mass density behaving as $1/a^3$ one would have $r = 4$ and $p = 4.4502$ and in asymptotic cosmology with mass density behaving as $1/a^2$ (according to TGD) one would have $r = 3$ and $p = 11.68$.

9. Living systems would represent a deviation from the "fractal thermodynamics" for $\hbar$ since for the typical values of $\hbar$ associated with the magnetic bodies in living systems (say $\hbar = 2^{44}\hbar_0$ for EEG to guarantee the energies of EEG photons are above the thermal threshold) the density of the dark matter would be extremely small. Bio-rhythms are assumed to come as powers of 2 in the simplest model for the bio-system: the above considerations raise the

question whether these rhythms could be accompanied by 5-multiples and perhaps also by Fermat integer multiples. For instance, the fundamental 10 Hz alpha frequency could be accompanied by 2 Hz frequency and the 40 Hz thalamocortical resonance frequency by 8 Hz frequency.

This model is an oversimplification obtained by assuming only singular coverings of CD. In principle both coverings and factor spaces of both CD and CP_2 are possible. If singular covering of both CP_2 and M^4 is involved and if one has $n = 5$ for both then the ratio of mass densities is 1/25 or about 4 per cent. This equals to the experimental ratio of about 4 per cent of the density of visible matter to the density of ordinary, dark matter and dark energy. I interpret this as an accident: dark energy can correspond to dark matter only if the Planck constant is very large and a natural place for dark energy is at the space-time sheets mediating gravitational interaction.

Some further observations about number five are in order. The angle $2\pi/5$ relates closely to Golden Mean appearing almost everywhere in biology. $n = 5$ makes itself manifest also in the geometry of DNA (the twist per single nucleotide is $\pi/5$ and aromatic 5-cycles appear in DNA nucleotides). Could it be that electron pairs associated with aromatic rings correspond to $\hbar = 5\times\hbar_0$ as I have proposed? Note that DNA as topological quantum computer hypothesis plays a key role in TGD inspired quantum biology.

The planet that should not exist

There is an interesting news story about an exoplanet that should not exist [E48]. The exoplanet is so called hot-Jupiter and so close to its Sun that it should have been torn by pieces by tidal forces and spiralled long ago to the Sun. For some reason this has not happened. The abstract of the article gives a more quantitative view about the discovery.

The "hot Jupiters" that abound in lists of known extrasolar planets are thought to have formed far from their host stars, but migrate inwards through interactions with the proto-planetary disk from which they were born, or by an alternative mechanism such as planet-planet scattering. The hot Jupiters closest to their parent stars, at orbital distances of only approximately 0.02 astronomical units, have strong tidal interactions and systems such as OGLE-TR-56 have been suggested as tests of tidal dissipation theory. Here we report the discovery of planet WASP-18b with an orbital period of 0.94 days and a mass of ten Jupiter masses (10 M Jup), resulting in a tidal interaction an order of magnitude stronger than that of planet OGLE-TR-56b. Under the assumption that the tidal-dissipation parameter Q of the host star is of the order of 106, as measured for Solar System bodies and binary stars and as often applied to extrasolar planets, WASP-18b will be spiralling inwards on a timescale less than a thousandth that of the lifetime of its host star. Therefore either WASP-18 is in a rare, exceptionally short-lived state, or the tidal dissipation in this system (and possibly other hot-Jupiter systems) must be much weaker than in the Solar System.

The finding brings in mind more than hundred year old problem: why the electron orbiting atom did not spiral into atomic nucleus? The solution of the puzzle was provided by the discovery of quantum theory. The postulate was that electron moves on Bohr orbits and can make only transitions between the Bohr orbits emitting light in these transitions. There is minimum value for the radius of Bohr orbit. Later wave mechanism emerged from Bohr model.

TGD view about dark matter suggests an analogous solution to the astrophysical variant of this puzzle. Planets correspond to Bohr orbits but for a gigantic value of Planck constant whose value is dictated by Equivalence Principle to high degree. This Planck constant could be assigned to the space-time sheet mediating gravitational interaction or even with matter. This means astroscopic quantum coherence and the interpretation is that astroscopic quantum coherence is associated with dark matter around which visible matter condenses and makes in this manner visible the quantum character of dark matter. That the planet does not spiral to the star means smallness of dissipation and this is guaranteed by the large value of $\hbar$. The naïve estimate is that dissipation rate is proportional to the inverse of $\hbar$ and anomalously small dissipation in astrophysical scales is basic prediction of quantum astrophysics. Also Mars-Phobos forms a similar mysterious system and the explanation would be the same.

A more refined view about the situation is in terms of light-like 3-surfaces, which are basic dynamical objects in quantum TGD. At elementary particle level their size is about CP_2 size (about 10^4 Planck lengths). Also macroscopic and even astroscopic sizes are possible and this would be the case for dark matter for which Planck constant and thus also quantum scales are scaled up. Note that light-like 3-surfaces are boundaries between regions of space-time with Euclidian and Minkowskian signature of metric. The recent TGD inspired vision about Universe is as a kind of Indra's net formed by light-like 3-surfaces appearing in all length scales and having extremely complex topology. Quantum Hall Effect is described in terms of macroscopic light-like 3-surfaces in [K81] and it is suggested that this kind of anyonic phases are realized also in astrophysical scales for dark matter. In this framework it is not necessary to Bohr rules are replaced by quantization rules for the light-like 3-surfaces satisfied by the preferred extremals of Kähler action and expressing quantum criticality.

Amusingly, the counterpart of Planck length scaling as $(\hbar G)^{1/2}$ is apart from numerical constant equal to $v_0^{-1/2}GM$ ($2GM$ is Schwarschild radius) if one assumes that $\hbar = GM^2/v_0$ is associated with an astrophysical system with mass M: $v_0/c \simeq 2^{-11}$ holds true for the gravitational space-time sheets mediating gravitational interaction between the 4 inner planets and Sun in the solar system. Planck length would be few orders of magnitude larger than Schwartscild radius so that Planck scale physics would be scaled up to astrophysical length scale. Black-hole entropy which is proportional to $1/\hbar$ is of order unity and would be extremely small for the ideally dark black-hole if this picture is correct. This looks strange. If one accepts the proposal that the hierarchy of Planck constants is implied by the basic TGD so that only covering spaces of $CD \times CP_2$ are possible [K79, K42], the natural interpretation of the scaled down blackhole entropy is as the entropy for single sheet of the covering. The total entropy would be given by the standard formula since the number of sheets is given by $\hbar/\hbar_0 = n_a n_b$. This would suggest that entropy serves as a control variable in the sense that when it exceeds the threshold value, the partonic 2-surfaces at the ends of CD split to a surfaces in the covering. Second law suggests the increase of the Planck constant not only for blackholes but quite generally. One the other hand, large values of Planck constant mean failure of second law below the time scale defined by the Planck constant so that the increase of entropy and evolution would accompany each other.

First dark matter galaxy found?

The propose model for dark matter suggests an existence of dark matter planets and even dark matter galaxies. Therefore the news about finding of the first dark galaxy in New Scientist [E10] came as a pleasant surprise. The galaxy is located at a distance of 10^7 light years. It contains 1 per cent hydrogen gasand99 per cent dark matter and is identified by 21 cm hydrogen line: hence the name VIRGOH21. The amount of dark matter counts as 10^8 average stars.

Anomalous chemical compositions at the surface of Sun as evidence for dark matter

Physics in Action, February 2005 contained the popular article "Chemical Controversy at the Solar Surface" by J. Bahcall in Physics in Action [E187]. The article describes the problems created by results reported in the article "The Solar Chemical Decomposition" by M. Asplund, N. Grevesse, J. Sauval [E39]. The abundances of C, N, O, Ne, Ar at the solar surface are about 30-40 per cent less than predicted by the standard solar model. If these abundances are fed into the standard solar model as input the predictions change in the range $.45R-.73R$ of distances from solar interior (R is solar radius). In particular, sound velocity is predicted incorrectly. Interestingly, these abundances are consistent with the abundances in the gaseous medium in the neighborhood of our galaxy.

In TGD framework a possible solution of the paradox comes from already old model of solar corona and solar magnetic field. Part of matter resides as dark matter at magnetic and Z^0 magnetic flux tubes of Sun (dark energy) and enters to the solar corona along these. That also gaseous medium in the neighborhood of our galaxy contains same abundances suggests that the formation of Sun has proceeded by a transformation of part of dark matter to a visible matter by leakage to space-time sheets visible to us. This is indeed what TGD inspired model for the formation of solar system based on quantal dark matter suggests.

Does Sun have a solid surface?

$n = 1$ Bohr orbit corresponds in a reasonable approximation to $L(276)/9 \simeq L(270)$ and thus to solar radius. This raises the question whether solar surface could contain spherical shell representing a topological condensate of dense matter around dark matter, kind of spherical preform of planet below the photosphere.

Recently new satellites have begun to provide information about what lurks beneath the photosphere. The pictures produced by Lockheed Martin's Trace Satellite and YOHKOH, TRACE and SOHO satellite programs are publicly available in the web. SERTS program for the spectral analysis suggest a new picture challenging the simple gas sphere picture [E213]. The visual inspection of the pictures combined with spectral analysis has led Michael Moshina to suggests that Sun has a solid, conductive spherical surface layer consisting of calcium ferrite. The article of [E213] [E213] provides impressive pictures, which in my humble non-specialist opinion support this view. Of course, I have not worked personally with the analysis of these pictures so that I do not have the competence to decide how compelling the conclusions of Moshina are. In any case, I think that his web article [E213] deserves a summary.

Before SERTS people were familiar with hydrogen, helium, and calcium emissions from Sun. The careful analysis of SERTS spectrum however suggest the presence of a layer or layers containing ferrite and other heavy metals. Besides ferrite SERTS found silicon, magnesium, manganese, chromium, aluminum, and neon in solar emissions. Also elevated levels of sulphur and nickel were observed during more active cycles of Sun. In the gas sphere model these elements are expected to be present only in minor amounts. As many as 57 different types of emissions from 10 different kinds of elements had to be considered to construct a picture about the surface of the Sun.

Moshina has visually analyzed the pictures constructed from the surface of Sun using light at wave lengths corresponding to three lines of ferrite ions (171, 195, 284 Angstroms). On basis of his analysis he concludes that the spectrum originates from rigid and fixed surface structures, which can survive for days. A further analysis shows that these rigid structures rotate uniformly.

The existence of a rigid structure idealizable as spherical shell in the first approximation could by previous observation be interpreted as a spherical shell corresponding to $n = 1$ Bohr orbit of a planet not yet formed. This structure would already contain the germs of iron core and of crust containing Silicon, Caandother elements.

There is also another similar piece of evidence [E224]. A new planet has been discovered orbiting around a star in a triple-star system in the constellation Cygnus. The planet is a so-called hot Jupiter but it orbits the parent star at distance of.05 AU, which much less that than allowed by current theories of planetary formation. Indeed, the so called migration theory predicts that the gravitational pull of the two stars should have stripped away the proto-planetary disk from the parent star. If an underlying dark matter structure serves as a condensation template for the visible matter, the planetary orbit is stabilized by Bohr quantization.

There is however a problem: ordinary iron and also ordinary iron topologically condensed at dark space-time sheets, becomes liquid at temperature 1811 K at atmospheric pressure. Using for the photospheric pressure p_{ph}, the ideal gas approximation $p_{ph} = n_{ph}T_{ph}$, the values of photospheric temperature $T_{ph} \sim 5800$ K and density $\rho_{ph} \sim 10^{-2}\rho_{atm}$, and idealizing photosphere as a plasma of hydrogen ions and atmosphere as a gas of O_2 molecules, one obtains $n_{ph} \sim .32n_{atm}$ giving $p_{ph} \sim 6.4p_{atm}$. This suggests that calcium ferrite cannot be solid at temperatures of order 5800 K prevailing in the photosphere (the material with highest known melting temperature is graphite with melting temperature of 3984 K at atmospheric pressure). Thus it would seem that dark calcium ferrite at the surface of the Sun cannot be just ordinary calcium ferrite at dark space-time sheets.

The following explanation for the solid surface is perhaps the simplest one found hitherto. Since the atomic energy spectrum is unaffected it seems that $n_a = n_b = 1$ holds true and the radii of Bohr orbitals are scaled up by the factor $n_a^2/n_b = n_a$. If the density of dark matter is roughly the same as that of ordinary matter, the larger size of atoms suggests that melting temperature must be higher than for ordinary matter. Ordinary photons would result via dark-visible phase transition from dark photons emitted by these atoms. Quite generally, spectral lines of molecules in environments in which they should not be thermally stable, would serve as a signature of dark matter with $n_a/n_b = 1$.

How to create dark matter in laboratory?

The creation of dark matter at laboratory is of course the crucial test. The hints for what to do come already from the findings of Tesla, which did not fit completely with Maxwell's electrodynamics (, which, using M-theory inspired jargon, had become “the only known classical theory of electromagnetism”) and were thus forgotten.

To transform visible matter to dark matter in laboratory one might try to generate conditions in which visible matter leaks to larger space-time sheets. What one could try is to generate pulsed current of electrons. For instance, current could flow to a circuit component acting as a charge reservoir. When the circuit is opened, and current cannot leave the charge reservoir, a situation analogous to a traffic jam occurs and some electrons might leak to larger space-time sheets via flux tubes generated in the process. Di-electric breakdown along larger space-time sheet would be in question. Recoil effects and zero point kinetic energy liberated as ionizing radiation would serve as a signature of the process. The production of dark matter might occur also in the usual di-electric breakdown and lead to the appearance of electrons in much larger volume after it partially re-enters original space-time sheets. The change of zero point kinetic energy would be liberated as radiation and would cause formation of plasma. Tesla detected dramatic effects of this kind in experiments utilizing sharp pulses.

..or has it already been done?

In their article “Investigation of high voltage discharges in low pressure gases through large ceramic super-conducting electrodes”, Modanese and [H9] [H8] report a fascinating discovery suggesting that some new form of radiation is generated in the di-electric breakdown of a capacitor at low temperature and having super-conductor as a second electrode. This radiation induces oscillatory motion of test penduli but, and this is very strange, its intensity is not reduced with distance.

The TGD based explanation [K40] would be in terms of either “topological light rays” or what I call in honor of Tesla “scalar wave pulses” (much like a capacitor moving with velocity of light predicted by TGD but not allowed by Maxwell’s ED). This radiation would induce the formation of flux tubes between atomic and larger space-time sheets and part of electrons from penduli would leak to larger space-time sheets and their motion would result as a recoil effect. The radiation would have only the role of control signal and this would explain why its intensity is not weakened.

From the point of view of single sheeted space-time an over-unity device would be in question since the zero point kinetic energy would be transformed to kinetic energy. The transformation of visible matter to dark matter is in TGD Universe the basic mechanism of metabolism predicting universality of metabolic energy currencies and living matter in TGD Universe has developed a refined machinery to recycle the dropped charges back to the atomic space-time sheets to be used again. Combined with time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) this makes, not a perpetuum mobile, but an extremely flexible mechanism of metabolism.

8.6.2 Anti-Matter And Dark Matter

The usual view about matter anti-matter asymmetry is that during early cosmology matter-antimatter asymmetry characterized by the relative density difference of order $r = 10^{-9}$ was somehow generated and that the observed matter corresponds to what remained in the annihilation of quarks and leptons to bosons. A possible mechanism inducing the CP asymmetry is based on the CP breaking phase of CKM matrix.

The TGD based view about energy [K111, K94] forces the conclusion that all conserved quantum numbers including the conserved inertial energy have vanishing densities in cosmological length scales. Therefore fermion numbers associated with matter and antimatter must compensate each other. Therefore the standard option as such is definitely excluded in TGD framework although CKM matrix might well relate to the generation of matter antimatter asymmetry as discussed in [**?**].

An early TGD based scenario explains matter antimatter asymmetry by assuming that antimatter is in topological vapor phase. This requires that matter and antimatter have slightly different topological evaporation rates with the relative difference of rates characterized by the parameter r. A more general scenario assumes that matter and antimatter reside at different space-time sheets.

The reader can easily guess the next step. The strict non-observability of antimatter finds an elegant explanation if matter and anti-matter are dark relative to each other. For instance, the masses of particles of antimatter could be scaled down so that antimatter could be practically everywhere without appreciably affecting the density of gravitational mass.

The matter antimatter asymmetry should be generated during cosmic evolution already before the formation of nucleons during the primordial synthesis of matter and antimatter. The number theoretical model for topological condensation based on formation of # contacts between space-time sheets of opposite time orientations (and thus opposite signs for energies) leads to a more detailed view about what might happen.

contacts can be modeled as CP_2 type extremals which simultaneously topologically condense to the two space-time sheets with Minkowskian signature of induced metric. The resulting two causal horizons are carriers of elementary particle quantum numbers and are identifiable as partons. The # contacts with vanishing net quantum numbers could be generated spontaneously and the splitting of # contact would create positive particle and negative energy particle at the two space-time sheets involved. The requirement that the net quantum numbers of Universe vanish is consistent with this kind of pairing of positive and negative energy space-time sheets.

Number theoretical vision [**?**, K99] leads to a vision in which elementary particles correspond to infinite primes, perhaps also integers, or even rationals which in turn can be mapped to finite rationals. To infinite primes, integers, and rationals is is possible to associate a finite rational $q = m/n$ by a homomorphism. q defines an effective q-adic topology of space-time sheet consistent with p-adic topologies defined by the primes dividing m and n ($1/p$-adic topology is homeomorphic to p-adic topology).m and n are exchanged by super-symmetry and the primes dividing m (n) correspond to space-time sheets with positive (negative) time orientation. The largest prime dividing m (n) determines the mass scale of the space-time sheet in p-adic thermodynamics. Two space-time sheets characterized by rationals having common prime factors can be connected by a $\#_B$ contact and can interact by exchange of particles characterized by divisors of m or n. Thus fundamental topological selection rules would be coded by the hierarchy of infinite primes.

A possible interpretation is that particle (in extremely general sense that even entire universe can be regarded as a particle) corresponds to a pair of positive and negative energy space-time sheets labeled by m and n characterizing the p-adic topologies consistent with $m-$ and n-adicities. This looks natural since Universe has necessary vanishing net quantum numbers. Unless one allows the non-uniqueness due to $m/n = mr/nr$, positive and negative energy space-time sheets can be connected only by # contacts so that positive and negative energy space-time sheets cannot interact via the formation of $\#_B$ contacts and would be therefore dark relative to each other. Negative energy antiparticles would also have different p-adic mass scales. If the rate for the creation of # contacts and their CP conjugates are slightly different, say due to the presence of electric components of gauge fields, matter antimatter asymmetry could be generated primordially.

8.7 Explanations Of Some Astrophysical And Cosmological Anomalies

In the sequel some astrophysical and cosmological anomalies such as the apparent shrinking of solar system observed by Masreliez, Pioneer anomaly, Flyby anomaly and new anomalies in cosmic microwave background.

8.7.1 Apparent Shrinking Of Solar System

The findings of Masreliez

There are two means of determining the positions of planets in the solar system [E271, E225]. The first method is based on optical measurements and determines the position of planets with respect to the distant stars. Already thirty years ago [E225] came the first indications that the planetary positions determined in this manner drift from their predicted values as if planets were in accelerated motion. The second method determines the relative positions of planets using radar ranging: this method does not reveal any such acceleration.

C. J. Masreliez [E78] has proposed that this acceleration could be due to a gradual scaling of the planetary system so that the sizes L of the planetary orbits are reduced by an over-all scale factor $L \rightarrow L/\lambda$, which implies the acceleration $\omega \rightarrow \lambda^{3/2}\omega$ in accordance with the Kepler's law $\omega \propto 1/L^{3/2}$. This scaling would exactly compensate the cosmological scaling $L \rightarrow (R(t)/R_0) \times L$ of the solar system size L, where $R(t)$ the curvature parameter of Robertson-Walker cosmology having the line element

$$ds^2 \quad = \quad dt^2 - R^2(t)\left(\frac{dr^2}{1+r^2} + r^2 d\Omega^2\right) \quad . \tag{8.7.1}$$

According to Masreliez, the model explains also some other anomalies in the solar system, such as angular momentum discrepancy between the lunar motion and the spin-down of the Earth [E78]. The model also changes the rate for the estimated drift of the Moon away from the Earth so that the Moon could have very well formed together with Earth some five billion years ago.

Bohr quantization of planetary orbits predicts that orbital radii are constant in Minkowski coordinates. Hence solar system would not participate cosmic expansion and the radii of planets shrink in Robertson-Walker coordinates. This model is definitely the simplest one.

The basic coordinate systems

Consider now the previous argument in more detail. The first task is to identify the coordinates appearing in the equations of motion of the planetary system. Denote the standard spherical Minkowski coordinates by (m^0, r_M, θ, ϕ). The line element reads as

$$ds^2 = d(m^0)^2 - dr_M^2 - r_M^2 d\Omega^2 \quad . \tag{8.7.2}$$

Light cone coordinates are related to these coordinates by the relationship

$$a = \sqrt{m_0^2 - r_M^2} \quad , \quad r = r_M/a \quad . \tag{8.7.3}$$

Here a is the light cone proper time along radii from the tip of the light cone $a = constant$ surfaces are hyperboloids. The line element is given

$$ds^2 = da^2 - a^2\left(\frac{dr^2}{1+r^2} + r^2 d\Omega^2\right) \tag{8.7.4}$$

and is nothing but the empty space Minkowski metric.

The Robertson-Walker metric for the space-time sheet reads as

$$ds^2 = g_{aa}da^2 - a^2(\frac{dr^2}{1+r^2} + r^2 d\Omega^2) \quad . \tag{8.7.5}$$

The space-time sheet possessing this metric as induced metric is obtained as a map $M^4_+ \rightarrow CP_2$ having the form $s^k = s^k(a)$, where s^k denote CP_2 coordinates satisfying the constraint

$$g_{aa} = 1 - s_{kl}\partial_a s^k \partial_a s^l \quad , \tag{8.7.6}$$

where s_{kl} denotes the metric tensor of CP_2.

One can introduce cosmic time as proper time coordinate t, or Hubble time as it is called, by the equation

$$\frac{dt}{da} = \sqrt{g_{aa}} \quad . \tag{8.7.7}$$

For the matter-dominated cosmology one as

$$\frac{t}{t_0} = (\frac{a}{a_0})^{3/2} \quad . \tag{8.7.8}$$

$t \simeq 1.5 \times 10^{10}$ ly is the value which explains the planetary acceleration in the model of Masreliez.

The basic question concerns the connection between cosmic coordinates and the radial and time coordinates (r_{PN}, t_{PN}) used in Post-Newtonian approximation. The correspondence $(t = t_{PN}, r = r_{PN})$ is the natural first approximation.

The cosmic time dilation would slow down the time scale of the planetary dynamics and cosmic expansion would lead to adiabatic expansion of the size of the solar system. This would predict the scaling $L(a)/L(a_0) = a/a_0$ for the sizes of the planetary orbits as measured using the r_M coordinate of M^4_+ metric whereas angular velocities of planets would remain constant $\omega(a)/\omega(a_0) = constant$. The solar system would gradually decay.

The condition that solar system does not participate cosmic expansion

If the solar system does not participate in cosmic expansion, one has $L(a)/L(a_0) = constant$ and the scalings

$$\frac{\omega(a)}{\omega(a_0)} = (\frac{a}{a_0})^{3/2} = \frac{t}{t_0} \quad , \quad \frac{v(a)}{v(a_0)} = (\frac{a}{a_0})^{1/2} = (\frac{t}{t_0})^{1/2} \tag{8.7.9}$$

for the angular velocity ωandtangential velocity v along the orbit. The equation for the angular acceleration is $d\omega/dt = \omega/t$. This result differs by a factor of 3 from the equation $d\omega/dt = 3\omega/t$ of [E77, E78]. On basis of work of Masreliez one can conclude this kind of scaling indeed explains the observed drift quite satisfactorily for $t \simeq 5$ billion years (instead of $t = 15$ billion years of [E78]). Thus the effect would allow to see the effects of the cosmic expansion in human time scale and would make possible to determine the value of cosmic time t from the planetary dynamics.

Compensation of cosmic expansion from Bohr quantization of planetary orbits?

The Bohr quantization for planetary orbits predicts that the orbital radii measured in terms of M^4 radial coordinate r_M are constant. This means that planetary system does not participate cosmic expansion so that the orbital radii expressed in terms of the coordinate $r = r_M/a$ shrinking. Therefore the stars accelerate with respect to the Robertson-Walker coordinates $(t, r, \Omega))$ defined by the distant stars since in this case the radii correspond naturally to the coordinate $r = r_M/a$ and time variable corresponds to the $dt/da = \sqrt{g_{aa}}$ giving $dr/dt = -Hr_M$ so that cosmic expansion is exactly compensated. This model for the anomaly brings in no additional assumptions besides Bohr quantization and is favored by Occam's razor.

There is an objection against the model based on the effective shift of the space-time sheet of solar system towards geometric future in each quantum jump so that cosmic expansion is compensated and time effectively ceases to flow. The simplest model for the arrow of psychological time found hitherto [K5] assumes however that this kind of effective shifting indeed occurs but in the reverse direction so that the radii would seem to increase rather than decrease. If the M^4 size remains constant, apparent reduction of radii is predicted.

Quite recently (August 2008) there appeared a new experimental claim related to the problem discussed. There is evidence that the value of astronomical unit AU (distance between Sun and Earth) is increasing with a rate about $dAU/dt = 7$ cm/year [E197]. Expressed in terms of the Minkowski proper time $a = R(t)$ the rate is about

$$\frac{dlog(AU)}{da} \simeq 4.6 \times 10^{-13} \quad .$$

If the solar system indeed participates cosmic expansion, one has $\frac{dlog(AU)}{da} = 1/a$ and the prediction for the recent Minkowski age of the Universe is $a_{now} = 2.2 \times 10^{12}$ years. If one assumes $a_R \simeq 3.3 \times 10^7$ y for the time when matter began to dominate, one obtains

$$t - t_R = \int_{a_R}^{a} \sqrt{g_{aa}} da \quad , \quad g_{aa} = (\frac{a}{a_R})^{1/2} \quad .$$

This would give $t_{now} \simeq 4 \times 10^{10}$ years which is about 8 times longer than the age $t_{now} = 0.5 \times 10^{10}$ ly explaining the claims of Mazreliez. The latter would give $a_{now} \simeq 4 \times 10^{11}$ y, which is ten times shorter than the value required by the interpretation of the increase of AU as being due to the cosmic expansion.

In any case, if the increase of AU is real, it challenges the hypothesis that the quantum size of the solar system remains exactly constant and increases only in the phase transitions increasing the value of the gravitational Planck constant. One could consider the possibility that some new effect which is by a factor 1/10 smaller than that caused by the cosmic expansion is present. A possible explanation consistent with the constant M^4 size of the solar system is based on the idea that the space-time sheet along which the radar radiation propagates, develops gradually riples. Also the emergence of new space-time sheets condensed to the space-time sheet along which radar photons propagate could be involved. This increasing metric noise would mean that the distance traveled by the radar photons along the space-time sheet in question gradually increases so that the time taken by the radar signal to travel from Earth to Sun and back increases.

8.7.2 In What Sense Speed Of Light Could Be Changing In Solar System?

There have been continual claims that the speed of light in solar system is decreasing. The latest paper about this is by Sanejouand [E183] and to my opinion must be taken seriously. The situation is summarized by an excerpt from the abstract of the article:

The empirical evidences in favor of the hypothesis that the speed of light decreases by a few centimeters per second each year are examined. Lunar laser ranging data are found to be consistent with this hypothesis, which also provides a straightforward explanation for the so-called Pioneer anomaly, that is, a time-dependent blue-shift observed when analyzing radio tracking data from distant spacecrafts, as well as an alternative explanation for both the apparent time-dilation of remote events and the apparent acceleration of the Universe.

Before one can speak about change of c seriously, one must specify precisely what the measurement of speed of light means. In GRT framework speed of light is by definition a constant in local Minkowski coordinates. It seems very difficult to make sense about varying speed of light since c is purely locally defined notion.

1. In TGD framework [K111] space-time as abstract manifold is replaced by 4-D surface in $H = M^4 \times CP_2$ (forgetting complications due to the hierarchy of Planck constants) and this brings in something new: the sub-manifold geometry allowing to look space-time surfaces "from outside", from H-perspective. The shape of the space-time surface appears as new degrees of freedom. This leads to the explanation of standard model symmetries, elementary particle quantum numbers and geometrization of classical fields, the dream of Einstein. Furthermore, CP_2 length scale provides a universal unit of length and p-adic length scale hypothesis brings in an entire hierarchy of fixed meter sticks defined by p-adic length scales. The presence of embedding space $M^4 \times CP_2$ brings in light-like geodesics of M^4 for which c is maximal and by suitable choice of units could be taken $c = 1$. These geodesics serve as universal comparison standards when one measures speed of light: something which GRT does not provide.

2. In TGD framework the operational definition for the speed of light at given space-time sheet is in terms of the time taken for light to propagate from point A to Balong space-time surface. The time to propagate along space-time sheet is in general longer than along light-like geodesic of M^4. Even if the space-time surface is only warped (no curvature), this time is longer than along a light-like geodesic of $M^4(\times CP_2)$ and the speed of light measured in this manner is reduced from its maximal value. Secondly, in TGD framework the propagation can occur via several routes because of many-sheeted structure and each sheet gives its own value for c.

What TGD then predicts?

1. TGD inspired cosmology predicts that c measured in this manner increases in cosmological scales, just the opposite for what Louise Riofrio [?] suggests. The reason is that strong gravitation makes space-surface strongly curved and it takes more time to travel from A to

Bduring early cosmology. This means that TGD based explanation has different cosmological consequences as that of Riofrio. For instance, Hubble constant depends on space-time sheet in TGD framework.

2. The paradox however disappears that *local systems* like solar system do not not normally participate in cosmic expansion as predicted by TGD. This is known also experimentally. In TGD Universe local systems could however participate cosmic expansion in average sense via phase transitions increasing Planck constant of the appropriate space-time sheet and thus increasing its size. The transition would occur in relatively short time scales: this provides new support for expanding Earth hypothesis needed to explain the fact that continents fit nicely together to form single super continent covering entire Earth if the radius of Earth is by a factor 1/2 smaller than its recent radius [K79].

3. If one measures the speed of light in local system and uses its cosmic value taken constant by definition (fixing particular coordinate time) then one indeed finds that the speed of light is decreasing locally and the decrease should be expressible in terms of Hubble constant.

4. TGD based explanation of Pioneer anomaly is also based on completely analogous reasoning.

8.7.3 Pioneer Anomaly

The data gathered during one quarter of century [C10] seem to suggest that spacecrafts do not obey the laws of Newtonian gravitation. What has been observed is anomalous constant acceleration of order $(8\pm3)\times10^{-11}g$ ($g = 9.81\ m/s^2$ is gravitational acceleration at the surface of Earth) for the Pioneer/10/11, Galileo and Ulysses ganomaly. The acceleration is directed towards Sun and could have an explanation in terms of $1/r^2$ long range force if the density of charge carriers of the force has $1/r$ dependence on distance from the Sun. From the data in [C10], the anomalous acceleration of the spacecraft is of order

$$\delta a \sim .8\times10^{-10}g \ ,$$

where $g \simeq 9.81\ m/s^2$ is gravitational acceleration at the surface of Earth. Using the values of Jupiter distance $R_J \simeq .8\times10^{12}$ meters, radius of Earth $R_E \simeq 6\times10^6$ meters and the value Sun to Earth mass ratio $M_S/M_E \simeq .3*10^6$, one can relate the gravitational acceleration

$$a(R) = \frac{GM_S}{R^2} = \frac{M_S}{M_E}\frac{R_E^2}{R^2}$$

of the spacecraft at distance $R = R_J$ from the Sun to g, getting roughly $a \simeq 1.6\times10^{-5}g$. One has also

$$\frac{\delta a}{a} \simeq 1.3\times10^{-4} \ .$$

The value of the anomalous acceleration has been found to be $a_F = (8.744\pm1.33)\times10^{-8}$ cm/s^2 and given by Hubble constant: $a_F = cH$. $H = 82$ km/s/Mpc gives $a_F = 8\times10^{-8}$ cm/s^2. It is very difficult to believe that this could be an accident. There are also diurnal and annual variations in the acceleration anomaly [E98]. These variations should be due to the physics of Earth-Sun system. I do not know whether they can be understood in terms of a temporal variation of the Doppler shift due to the spinning and orbital motion of Earth with respect to Sun.

The model of Pioneer anomaly based on Doppler shift

It came as a surprise that also Pioneer anomaly has a simple explanation in terms of Doppler shift assuming that solar system is not participating in cosmic expansion. This predicts that the measured wavelength behaves as

$$\lambda_{meas} = \frac{c(t)}{f} \simeq (1+\frac{a_c}{c_0}t)/f \ . \tag{8.7.10}$$

Here $c(t)$ is the local light velocity using as unit the light velocity in cosmological length scales. Since one has $a_c < 0$ in the lowest order, the measured wavelength behaves as if the source were accelerating towards observer with a constant acceleration. The value of a_c is consistent with that obtained from the argument explaining apparent reduction of light velocity in solar system.

Original model for the anomaly

The original explanation for the acceleration anomaly was based on the presence of dark matter increasing the effective solar mass at larger distances. Although this explanation did not survive Occam's razor, it deserves to be mentioned.

Since acceleration anomaly is constant, a dark matter density behaving like $\rho_d = (3/4\pi)(H/Gr)$, where H is Hubble constant giving $M(r) \propto r^2$, is required. For instance, at the radius R_J of Jupiter the dark mass would be about $(\delta a/a)M(Sun) \simeq 1.3 \times 10^{-4} M(Sun)$ and would become comparable to M_{Sun} at about $100R_J = 520$ AU. Note that the standard theory for the formation of planetary system assumes a solar nebula of radius of order 100AU having 2-3 solar masses. For Pluto at distance of 38 AU the dark mass would be about one per cent of solar mass. This model would suggest that planetary systems are formed around dark matter system with a universal mass density. For this option dark matter could perhaps be seen as taking care of the contraction compensating for the cosmic expansion by using a suitable dark matter distribution.

In [E98] the possibility that the acceleration anomaly for Pioneer 10 (11) emerged only after the encounter with Jupiter (Saturn) is raised. The model explaining Hubble constant as being due to a radial contraction compensating cosmic expansion would predict that the anomalous acceleration should be observed everywhere, not only outside Saturn. The model in which universal dark matter density produces the same effect would allow the required dark matter density $\rho_d = (3/4\pi)(H/Gr)$ be present only as a primordial density able to compensate the cosmic expansion. The formation of dark matter structures could have modified this primordial density and visible matter would have condensed around these structures so that only the region outside Jupiter would contain this density.

8.7.4 Flyby Anomaly

The so called flyby anomaly [E98] might relate to the Pioneer anomaly. Fly-by mechanism used to accelerate space-crafts is a genuine three body effect involving Sun, planet, and the space-craft. Planets are rotating around sun in an anticlockwise manner and when the space-craft arrives from the right hand side, it is attracted by a planet and is deflected in an anticlockwise manner and planet gains energy as measured with respect to solar center of mass system. The energy originates from the rotational motion of the planet. If the space-craft arrives from the left, it loses energy. What happens is analyzed in [E98] using an approximately conserved quantity known as Jacobi's integral $J = \mathcal{E} - \omega \overline{e}_z \cdot \overline{r} \times \overline{v}$. Here $\mathcal{E}$ is total energy per mass for the space-craft, ω is the angular velocity of the planet, $\overline{e}_z$ is a unit vector normal to the planet's rotational plane, and various quantities are with respect to solar cm system.

This as such is not anomalous and flyby effect is used to accelerate space-crafts. For instance, Pioneer 11 was accelerated in the gravitational field of Jupiter to a more energetic elliptic orbit directed to Saturn ad the encounter with Saturn led to a hyperbolic orbit leading out from solar system.

Consider now the anomaly. The energy of the space-craft in planet-space-craft cm system is predicted to be conserved in the encounter. Intuitively this seems obvious since the time and length scales of the collision are so short as compared to those associated with the interaction with Sun that the gravitational field of Sun does not vary appreciably in the collision region. Surprisingly, it turned out that this conservation law does not hold true in Earth flybys. Furthermore, irrespective of whether the total energy with respect to solar cm system increases or decreases, the energy in planet-spacecraft cm system increases during flyby in the cases considered.

Five Earth flybys have been studied: Galileo-I, NEAR, Rosetta, Cassina, and Messenger and the article of Anderson and collaborators [E98] gives a nice quantitative summary of the findings and of the basic theoretical notions. Among other things the tables of the article give the deviation $\delta\mathcal{E}_{g,S}$ of the energy gain per mass in the solar cm system from the predicted gain. The anomalous energy gain in rest Earth cm system is $\Delta\mathcal{E}_E \simeq \overline{v} \cdot \Delta\overline{v}$ and allows to deduce the change in velocity.

The general order of magnitude is $\Delta v/v \simeq 10^{-6}$ for Galileo-I, NEAR and Rosetta but consistent with zero for Cassini and Messenger. For instance, for Galileo I one has $v_{\infty,S} = 8.949$ km/s and $\Delta v_{\infty,S} = 3.92 \pm .08$ mm/s in solar cm system.

Many explanations for the effect can be imagined but dark matter looks at first the most obvious candidate in TGD framework. The model for the Bohr quantization of planetary orbits assumes that planets are concentrations of the visible matter around dark matter structures. These structures could be tubular structures around the orbit or a nearly spherical shell containing the orbit. The contribution of the dark matter to the gravitational potential increases the effective solar mass $M_{eff,S}$. This of course cannot explain the acceleration anomaly which has constant value. One can also consider dark matter rings associated with planets and perhaps even Moon's orbit is an obvious candidate now. It turns out that the tube associated with Earth's orbit and deformed by Earth's presence to equatorial plane of Earth explains qualitatively the known facts.

Roughly half year after writing this, a rather convincing and very simple model explaining the effect as a relativistic transverse Doppler effect appeared [E192] (see the comment at the end of this section). Therefore the dark matter ring - if present - can give only an additional contribution to the transverse Doppler effect. Therefore it seems that all anomalous effects are related to Doppler shifts and thus basically kinematical: the only new element is the fact that solar system does not participate in cosmic expansion.

Dark matter at a spherical cell containing Earth's orbit?

For instance, if the space-craft traverses shell structure, its kinetic energy per mass in Earth cm system changes by a constant amount not depending on the mass of the space-craft:

$$\frac{\Delta E}{m} \simeq v_{\infty,E}\Delta v = \Delta V_{gr} = \frac{G\Delta M_{eff,S}}{R} \ . \tag{8.7.11}$$

Here R is the outer radius of the shell and $v_{\infty,E}$ is the magnitude of asymptotic velocity in Earth cm system. This very simple prediction should be testable. If the space-craft arrives from the direction of Sun the energy increases. If the space-craft returns back to the sunny side, the net anomalous energy gain vanishes. This has been observed in the case of Pioneer 11 encounter with Jupiter [E98].

The mechanism would make it possible to deduce the total dark mass of, say, spherical shell of dark matter. One has

$$\begin{aligned} \frac{\Delta M}{M_S} &\simeq \frac{\Delta v}{v_{\infty,E}}\frac{2K}{V} \ , \\ K &= \frac{v_{\infty,E}^2}{2} \ , \ V = \frac{GM_S}{R} \ . \end{aligned} \tag{8.7.12}$$

For the case considered $\Delta M/M_S \geq 2\times 10^{-6}$ is obtained. Note that the amount of dark mass within sphere of 1 AU implied by the explanation of Pioneer anomaly would be about $6.2\times 10^{-6}M_S$ from Pioneer anomaly whereas the mass of Earth is $M_E \simeq 5\times 10^{-6}M_S$. Since the orders of magnitude are same one might consider the possibility that the primordial dark matter has concentrated in spherical shells in the case of the 4 inner planets as indeed suggested by the model for quantization of radii of planetary orbits. Of course, the total mass associated with $1/r$ density quite too small to explain entire mass of the solar system.

In the solar cm system the energy gain is not constant. Denote by $\overline{v}_{i,E}$ and $\overline{v}_{f,E}$ the initial and final velocities of the space-craft in Earth cm. Let $\Delta\overline{v}$ be the anomalous change of velocity in the encounter and denote by θ the angle between the asymptotic final velocity $\overline{v}_{f,S}$ of planet in solar cm. One obtains for the corrected $\mathcal{E}_{g,S}$ the expression

$$\mathcal{E}_{g,S} = \frac{1}{2}\left[(\overline{v}_{f,E} + \overline{v}_P + \Delta\overline{v})^2 - (\overline{v}_{i,E} + \overline{v}_P)^2\right] \ . \tag{8.7.13}$$

This gives for the change $\delta\mathcal{E}_{g,S}$

$$\begin{aligned}\delta\mathcal{E}_{g,S} &\simeq (\overline{v}_{f,E}+\overline{v}_P)\cdot\Delta\overline{v}\simeq v_{f,S}\Delta v\times cos(\theta_S)\\ &= v_{\infty,S}\Delta v\times cos(\theta_S)\ .\end{aligned} \quad (8.7.14)$$

Here $v_{\infty,S}$ is the asymptotic velocity in solar cm system and in excellent approximation predicted by the theory.

Using spherical shell as a model for dark matter one can write this as

$$\delta\mathcal{E}_{g,S} = \frac{v_{\infty,S}}{v_{\infty,E}}\frac{G\Delta M}{R}cos(\theta_S)\ . \quad (8.7.15)$$

The proportionality of $\delta\mathcal{E}_{g,S}$ to $cos(\theta_S)$ should explain the variation of the anomalous energy gain.

For a spherical shell $\Delta\overline{v}$ is in the first approximation orthogonal to v_P since it is produced by a radial acceleration so that one has in good approximation

$$\begin{aligned}\delta\mathcal{E}_{g,S} &\simeq \overline{v}_{f,S}\cdot\Delta\overline{v}\simeq\overline{v}_{f,E}\cdot\Delta\overline{v}\simeq v_{f,S}\Delta v\times cos(\theta_S)\\ &= v_{\infty,E}\Delta v\times cos(\theta_E)\ .\end{aligned} \quad (8.7.16)$$

For Cassini and Messenger $cos(\theta_S)$ should be rather near to zero so that $v_{\infty,E}$ and $v_{\infty,S}$ should be nearly orthogonal to the radial vector from Sun in these cases. This provides a clear cut qualitative test for the spherical shell model.

Dark matter at the orbit of Earth?

An alternative model is based on dark matter on the orbit of Earth. One can estimate the change of the kinetic energy in the following manner.

1. Assume that the orbit is not modified at all in the lowest order approximation and estimate the kinetic energy gained as the work done by the force caused by the dark matter on the space-craft.

$$\begin{aligned}\frac{\Delta E}{m} &= -G\frac{d\rho_{dark}}{dl}\int_{\gamma_E}dl_E\int_{\gamma_S}d\overline{r}_S\cdot\frac{\overline{r}_{SE}}{r_{SE}^3})\ ,\\ \overline{r}_{SE} &\equiv \overline{r}_S-\overline{r}_E\ .\end{aligned} \quad (8.7.17)$$

   Here γ_S denotes the portion of the orbit of space-craft during which the effect is noticeable and γ_E denotes the orbit of Earth.

   This expression can be simplified by performing the integration with respect to r_S so that one obtains the difference of gravitational potential created by the dark matter tube at the initial and final points of the portion of γ_S:

$$\begin{aligned}\frac{\Delta E}{m} &= V(\overline{r}_{S,f})-V(\overline{r}_{S,i})\ ,\\ V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl}\times\int_{\gamma_E}dl_E\frac{1}{r_{SE}}\ .\end{aligned} \quad (8.7.18)$$

2. Use the standard approximation (briefly described in [E98]) in which the orbit of the space-craft consists of three parts joined continuously together: the initial Kepler orbit around Sun, the piece of orbit which can be approximate with a hyperbolic orbit around Earth, and the final Kepler orbit around Sun. The piece of the hyperbolic orbit can be chosen to belong inside the so called sphere of influence, whose radius r is given in terms of the distance R of planet from Sun by the Roche limit $r/R=(3m/M_{Sun})^{2/5}$. γ_S could be in the first approximation taken to correspond to this portion of the orbit of spacecraft.

3. The explicit expression for the hyperbolic orbit can be obtained by using the conservation of energy and angular momentum and reads as

$$u = \frac{r_s}{r} = \frac{2GM}{r} = \frac{u_0^2}{2v_0^2}[1 + \sqrt{1 + 4u_0^2\frac{v_\infty^2 v_0^2}{sin^2(\phi)}}] \ ,$$
$$u_0 \equiv \frac{r_s}{a} \ , \ |v \times r| \equiv vr \times sin(\phi) \ . \quad (8.7.19)$$

The unit $c = 1$ is used to simplify the formulas. r_s denotes Schwartschild radius and v_∞ the asymptotic velocity. v_0 and a are the velocity and distance at closest approach and the conserved angular momentum is given by $L/m = v_0 a$. In the situation considered value of r_S is around 1 cm, the value of a around 10^7 m and the value of v_∞ of order 10 km/s so that the approximation

$$u \simeq u_0\frac{v_\infty}{v_0}sin(\phi) \quad (8.7.20)$$

is good even at the distance of closest approach. Recall that the parameters characterizing the orbit are the distance a of the closest approach, impact parameter b, and the angle 2θ characterizing the angle between the two straight lines forming the asymptotes of the hyperbolic orbit in the orbital plane P_E.

Consider first some conclusions that one can make from this model.

1. Simple geometric considerations demonstrate that the acceleration in the region between Earth's orbit and the part of orbit of spacecraft for which the distance from Sun is larger than that of Earth is towards Sun. Hence the distance of the spacecraft from Earth tends to decrease and the kinetic energy increases. In fact, one could also choose the portion of γ_S to be this portion of the spacecraft's orbit.

2. ΔE depends on the relative orientation of the normal n_S of the the orbital plane P_E of spacecraft with respect to normal n_O the orbital plane P_O of Earth. The orientation can be characterized by two angles. The first angle could be the direction angle Θ of the position vector of the nearest point of spacecraft's orbit with respect to cm system. Second angle, call it Φ, could characterize the rotation of the orbital plane of space-craft from the standard orientation in which orbital plane and space-craft's plane are orthogonal. Besides this ΔE depends on the dynamical parameters of the hyperbolic orbit of space-craft given by the conserved energy $E_{tot} = E_\infty$ and angular momentum or equivalently by the asymptotic velocity v_∞ and impact parameter b.

3. Since the potential associated with the closed loop defined by Earth's orbit is expected to resemble locally that of straight string one expects that the potential varies slowly as a function of $\overline{r}_S$ and that ΔE depends weakly on the parameters of the orbit.

The most recent report [E97] provides additional information about the situation.

1. ΔE is reported to be proportional to the total orbital energy E_∞/m of the space-craft. naïvely one would expect $\sqrt{E_\infty/m}$ behavior coming from the proportionality ΔE to $1/r$. Actually a slower logarithmic behavior is expected since a potential of a linear structure is in question.

2. ΔE depends on the initial and final angles θ_i and θ_f between the velocity $\overline{v}$ of the space-craft with respect to the normal $\overline{n}_E$ of the equatorial plane P_E or Earth and the authors are able to give an empirical formula for the energy increment. The angle between P_E and P_O is 23.4 degrees. One might hope that the formula could be written also in terms of the angle between v and the normal n_O of the orbital plane. For $\theta_i \simeq \theta_f$ the effect is known to be very small. A particular example corresponds to a situation in which one has $\theta_i = 32$ degrees and $\theta_f = 31$ degrees. Obviously the $P_O \simeq P_E$ approximation cannot hold true. Needless to say, also the model based on spherical shell of dark matter fails.

Is the tube containing the dark matter deformed locally into the equatorial plane?

The previous model works qualitatively if the interaction of Earth and flux tube around Earth's orbit containing the dark matter modifies the shape of the tube locally so that the portion of the tube contributing to the anomaly lies in a good approximation in P_E rather than P_O. In this case the minimum value of the distance r_{ES} between γ_E and γ_S is maximal for the symmetric situation with $\theta_i = \theta_f$ and the effect is minimal. In an asymmetric situation the minimum value of r_{ES} decreases and the size of the effect increases. Hence the model works at least qualitatively of the motion of Earth induces a moving deformation of the dark matter tube to P_E. One can actually write ΔE in a physically rather transparent form showing that it is consistent with the basic empirical findings.

1. By using linear superposition one can write the potential as sum of a potential associated with a tube associated with Earths orbit plus the potential associated with the deformed part minus the potential associated with corresponding non-deformed portion of Earth's orbit:

$$\begin{aligned}
\frac{\Delta E}{m} &= V(\overline{r}_{S,f}) - V(\overline{r}_{S,i}) \ , \\
V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl}Z(\overline{r}_S) \ , \\
Z(\overline{r}_S) &= X(\gamma_{orb};\overline{r}_S) + X(\gamma_d;\overline{r}_S) - X(\gamma_{nd};\overline{r}_S) \ , \\
X(\gamma_i;\overline{r}_S) &= \int_{\gamma_i} dl\frac{1}{r_{Si}} \ .
\end{aligned} \quad (8.7.21)$$

Here the subscripts "orb", "d" and "nd" refer to the entire orbit of Earth, to its deformed part, and corresponding non-deformed part. The entire orbit is analogous to a potential of straight string and is expected to give a slowly varying term which is however non-vanishing in the asymmetric situation. The difference of deformed and non-deformed parts gives at large distances dipole type potential behaving like $1/r^2$ and thus being proportional to v_∞^2 by the above expression for the $u = r_s/r$. The fact that ΔE is proportional to v_∞^2 suggests that dipole approximation is good.

2. One can therefore parameterize ΔE as

$$\begin{aligned}
\frac{\Delta E}{m} &= V(\overline{r}_{S,f}) - V(\overline{r}_{S,i}) \ , \\
V(\overline{r}_S) &= -G\frac{d\rho_{dark}}{dl}Z \ , \\
Z(\overline{r}_S) &= X(\gamma_{orb};\overline{r}_S) + \frac{dcos(\Theta)}{r_S^2} \ .
\end{aligned} \quad (8.7.22)$$

where Θ is the angle between $\overline{r}$ and the dipole $\overline{d}$, which now has dimension of length. The direction of the dipole is in the first approximation in the equatorial plane and and directed orthogonal to the Earth's orbit.

Consider now the properties of ΔE.

1. In a situation symmetric with respect to the equator E_d vanishes but E_{nd} is non-vanishing which gives as a result potential difference associated with entire Earth's orbit minus the part of orbit contributing to the effect so that the result is by the definition of the approximation very small.

2. As already noticed, dipole field like behavior that the large contribution to the potential is proportional to the conserved total energy $v_\infty^2/2$ at the limit of large kinetic energy.

3. From the fact that potential difference is in question it follows that the expression for the energy gain is the difference of parameters characterizing the initial and final situations. This conforms qualitatively with the observation that this kind of difference indeed appears in the empirical fit. $1/r^2$-factor is also proportional to $sin^2(\phi)$ which by the symmetry of the situation is expected to be same for initial and final situation. Furthermore, ΔE is proportional to the difference of the parameter $cos(\Theta_f) - cos(\Theta_i)$ and this should correspond to the reported behavior: it indeed does as I learned after having received the article in email (the prices of PRL on line articles are too dirty for me!). Note that the result vanishes for the symmetric situation in accordance with the empirical findings.

To sum up, it seems that the qualitative properties of ΔE are indeed consistent with the empirical findings. The detailed fit of the formula of [E97] should allow to fix the shape of the deformed part of the orbit.

What induces the deformation?

Authors suggest that the Earth's rotation is somehow involved with the effect. The first thing to notice is that the gravimagnetic field of Earth, call it B_E, predicted by General Relativity is quite too weak to explain the effect as a gravimagnetic force on spacecraft and fails also to explain the fact that energy increases always. Gravito-Lorentz force does not do any work so that the total energy is conserved and $\Delta E = -\Delta V = -\nabla V \cdot \Delta \overline{r}$ holds true, where $\Delta \overline{r}$ is the deflection caused by the gravimagnetic field on the orbit during flyby. Since $\Delta \overline{r}$ is linear in v, ΔE changes sign as the velocity of space-craft changes sign so that this option fails in several ways.

Gravimagnetic force of Earth could be however involved but in a different manner. The gravimagnetic force between Earth and flux tube containing the dark matter could explain this deformation as a kind of frame drag effect: dark matter would tend to follow the spinning of Earth.

1. If the dark matter inside the tube is at rest in the rest frame of Sun (this is not a necessary assumption), it moves with respect to Earth with a velocity $v = -v_E$, where v_E is the orbital velocity of Earth. If the tube is thin, the gravito-Lorentz force experienced by dark matter equals in the first approximation to $F = -v_E \times B_E$ with B_E evaluated at the axis of the tube. TGD based model for B_E [K111] does not allow B_E to be a dipole field. B_E has only the component B^θ and the magnitude of this component relates by a factor $1/sin(\theta)$ to the corresponding component of the dipole field and becomes therefore very strong as one approaches poles. The consistency with the existing experimental data requires that B_E at equator is very nearly equal to the strength of the dipole field. The magnitude of B_E and thus of F is minimal when the deformation of the tube is in P_E, and the deformation occurs very naturally into P_E since the non-gravitational forces associated with the dark matter tube must compensate a minimal gravitational force in dynamical equilibrium.

2. B_E^θ at equator is in the direction of the spin velocity ω of the Earth. The direction of v_E varies. It is convenient to consider the situation in the rest system of Sun using Cartesian coordinates for which the orbital plane of Earth corresponds to (x, y) plane with x- and y-axis in the direction of semi-minor and semi-major axes of the Earth's orbit. The corresponding spherical coordinates are defined in an obvious manner. v_E is parallel to the tangent vector $e_\phi(t) = -sin(\Omega t)e_x + cos(\Omega t)e_y$ of the Earth's orbit. The direction of B_E at equator is parallel to ω and can be parameterized as $e_\omega = cos(\theta)e^z + sin(\theta)(cos(\alpha)e_x + sin(\alpha)e_y)$. F is parallel to the vector $-cos(\theta)e_\rho(t) + sin(\theta)cos(\Omega t - \alpha)e_z$, where $e_\rho(t)$ is the unit vector directed from Sun to Earth. The dominant component is directed to Sun.

Flyby anomaly as transverse relativistic Doppler effect?

A new twist in the story of fly-by anomaly emerged at September twelfth 2007. The proposal of Jean-Paul Mbelek [E192] explains fly-by effect as a relativistic transverse Doppler effect and thus purely kinematic effect. Also the functional dependence of the parameter K characterizing the size of the effect on the kinematic parameters is predicted and the prediction is consistent with the empirical findings in the example considered. Therefore the story of fly-by anomaly might be finished and dark matter at the orbit of Earth could bring in only an additional effect. It is probably too much to hope for this kind of effect to be large enough if present.

8.7.5 Pioneer And Flyby Anomalies For Almost Decade Later

The article [E89] (see `http://tinyurl.com/avmndwa`) is about two old anomalies discovered in the solar system: Pioneer anomaly [E22] and Flyby anomaly [E98, E97, E85, E192] with which I worked for years ago.

I remember only the general idea that dark matter concentrations at orbits of planets or at spheres with radii equal that of orbit could cause the anomalies. So I try to reconstruct all from scratch and during reconstruction become aware of something new and elegant that I could not discover for years ago.

The popular article [E89] claims that Pioneer anomaly is understood. I am not at all convinced about the solution of Pioneer anomaly. Several "no new physics" solutions have been tailored during years but later it has been found that they do not work.

Suppose that dark matter is at the surface of sphere so that by a well-known text book theorem it does not create gravitational force inside it. This is an overall important fact, which I did not use earlier. The model explains both anomalies and also allow to calculate the total amount of dark matter at the sphere.

1. Consider first the Pioneer anomaly.

    (a) Inside the dark matter sphere with radius of Jupiter's orbit the gravitational force caused by dark matter vanishes. Outside the sphere also dark matter contributes to the gravitational attraction and Pioneer's acceleration becomes a little bit smaller since the dark matter at the sphere containing the orbit radius of Jupiter or Saturn also attracts the space-craft after the passby. A simple test for spherical model is the prediction that the mass of Jupiter effectively increases by the amount of dark matter at the sphere after passby.

    (b) The magnitude of the Pioneer anomaly is about $\Delta a/a = 1.3\times 10^{-4}$ [K93] and translates to $M_{dark}/M \simeq 1.3\times 10^{-4}$. What is highly non-trivial is that the anomalous acceleration is given by Hubble constant suggesting that there is a connection with cosmology fixing the value of dark mass once the area of the sphere containing it is fixed. This follows as a prediction if the surface mass density is universal and proportional to the Hubble constant.

    Could one interpret the equality of the two accelerations as an equilibrium condition? The Hubble acceleration H associated with the cosmic expansion (expansion velocity increases with distance) would be compensated by the acceleration due to the gravitational force of dark matter. The formula for surface density of dark matter is from Newton's law $GM_{dark} = H$ given by $\sigma_{dark} = H/4\pi G$. The approximate value of dark matter surface density is from $Hc = 6.7\times 10^{-10}$ m/s^2 equal to $\sigma = .8$ kg/m^2 and surprisingly large.

    (c) The value of acceleration is $a = .8\times 10^{-10}\times g$, $g = 9.81$ m/s^2 whereas the MOND model (see `http://tinyurl.com/32t9wt`) finds the optimal value for the postulated minimal gravitational acceleration to be $a_0 = 1.2\times 10^{-10}$ m/s^2. In TGD framework it would be assignable to the traversal through the dark matter shell. The ratio of the two accelerations is $a/a_0 = 6.54$.

    (d) TGD inspired quantum biology requiring that the universal cyclotron energy spectrum of dark photons $h_{eff} = h_{gr}$ transforming to to bio-photons is in visible and UV range for charged particles gives the estimate $M_{dark}/M_E \simeq 2\times 10^{-4}$ [K80] and is of the same order of magnitude smaller than for Jupiter. The minimum value of the magnetic field at flux tubes has been assumed to be $B_E = .2$ Gauss, which is the value of endogenous magnetic field explaining the effects of ELF em radiation on vertebrate brain. The two estimates are clearly consistent.

2. In Flyby anomaly spacecraft goes past Earth to gain momentum (Earth acts as a sling) for its travel towards Jupiter. During flyby a sudden acceleration occurs but this force is on only

during the flyby but not before or after that. The basic point is that the spacecraft visits near Earth, and this is enough to explain the anomaly.

The space-craft enters from a region outside the orbit of Earth containing dark matter and thus experiences also the dark force created by the sphere. After that the space craft enters inside the dark matter region, and sees a weaker gravitational force since the dark matter sphere is outside it and does not contribute. This causes a change in its velocity. After flyby the spacecraft experiences the forces caused by both Earth and dark matter sphere and the situation is the same as before flyby. The net effect is a change in the velocity as observed. From this the total amount of dark matter can be estimated. Also biology based argument gives an estimate for the fraction of dark matter in Earth.

This model supports the option in which the dark matter is concentrated on sphere. The other option is that it is concentrated at flux tube around orbit: quantitative calculations would be required to see whether this option can work. One can consider of course also more complex distributions: say $1/r$ distribution outside the sphere giving rise to constant change in acceleration outside the sphere.

A possible very simple TGD model for the sphere containing dark matter could be in terms of a boundary defined by a gigantic wormhole contact with large $h_{eff} = h_{gr}$ (at its space-time sheet representing "line of generalized Feynman diagram" one has deformation of CP_2 type vacuum extremal with Euclidian signature of induced metric) with radius given by the radius of Bohr orbit with gravitational Planck constant equal to $\hbar_{gr} = GMm/v_0$, where v_0 is a parameter with dimensions of velocity. This radius does not depend on the mass of the particle involved and is given by $r_n = GM/v_0^3$ where $r_S = 2GM$ is Schwartschild radius equal to 3 km for Sun [K93]. One has $v_0/c \simeq 2^{-11}$ for 4 inner planets. For outer planets v_0 is scaled down by a factor 1/5.

The sphere should also correspond to a magnetic flux sheet with field line topology of dipole field. By flux conservation the flux must arrive along flux tube parallel to a preferred axis presumably orthogonal to the plane of planets and flux conservation should must true. This kind of structure is predicted also by the TGD model in terms of cylindrically symmetric candidate for an extremal of Kähler action representing astrophysical object [K14].

An interesting possibility is that also Earth-Moon system contains a spherical shell of dark matter at distance given by the radius of Moon's orbit (about 60 Earth's radii). If so the analogs of the two effects could be observed also in Earth Moon system and the testing of the effects would become much easier. This would also mean understanding of the formation of Moon. Also interior of Earth (and also Sun) could contain spherical shells containing dark matter as the TGD inspired model for the spherically symmetric orbit constructed for more than two decades ago [K14] suggests. One can raise interesting questions. Could also the matter in small scale systems be accompanied by dark matter shells at radii equal to Bohr radii in the first approximation and could these effects be tested? Note that a universal surface density for dark matter predicts that the change of acceleration universally be given by Hubble constant H.

8.7.6 Further Progress In The Understanding Of Dark Matter And Energy In TGD Framework

The remarks below were inspired by an extremely interesting link to a popular article (see `http://tinyurl.com/ybjox4zb`) about a possible explanation of dark matter in terms of vacuum polarization associated with gravitation. The model can make sense only if the sign of the gravitational energy of antimatter is opposite to that of matter and whether this is the case is not known. Since the inertial energies of matter and antimatter are positive, one might expect that this is the case also for gravitational energies by Equivalence Principle but one might also consider alternative and also I have done this in TGD framework.

The popular article lists four observations related to dark matter that neither cold dark matter (CMD) model nor modified gravitation model (MOND) can explain, and the claim is that the vacuum energy model is able to cope with them.

Consider first the TGD based model.

1. The model assumes that galaxies are like pearls along strings defined by cosmic strings expended to flux tubes during cosmic expansion survives also these tests. This is true also in

longer scales due to the fractality if TGD inspired cosmology: for instance, galaxy clusters would be organized in a similar manner.

2. The dark magnetic energy of the string like object (flux tube) is identifiable as dark energy and the pearls would correspond to dark matter shells with a universal mass density of.8 kg/m^2 estimated from Pioneer and Flyby anomalies assuming to be caused by spherical dark matter shells assignable to the orbits of planets. This value follows from the condition that the anomalous acceleration is identical with Hubble acceleration. Even Moon could be accompanied by this kind of shell: if so, the analog of Pioneer anomaly is predicted.

3. The dark matter shell around galactic core could have decayed to smaller shells by h_{eff} reducing phase transition. This phase transition would have created smaller surfaces with smaller values of $h_{eff} = h_{gr}$. One can consider also the possibility that it contains all the galactic matter as dark matter. There would be nothing inside the surface of the gigantic wormhole throat: this would conform with holography oriented thinking.

I checked the four observations listed in the popular article (see `http://tinyurl.com/ybjox4zb`) some of which CMD (cold dark matter) scenario and MOND fail to explain. TGD explains all of them.

1. It has been found that the effective surface mass density $\sigma = \rho_0 R_0/3$ (volume density times volume of ball equals to effective surface density times surface area of the ball for constant volume density) of galactic core region containing possible halo is universal and its value is .9 kg/m^2 (see the article (see `http://tinyurl.com/y864lfyx`). Pioneer and Flyby anomalies fix the surface density to.8 kg/m^2. The difference is about 10 per cent! One must of course be cautious here: even the correct order of magnitude would be fine since Hubble acceleration parameter might be different for the cluster than for the solar system now.

   Note that in the article the effective surface density is defined as $\sigma = \rho_0 r_0$, where r_0 is the radius of the region and ρ_0 is density in its center. The correct definition for a constant 3-D density inside ball is $\sigma = \rho_0 r_0/3$.

2. The dark matter has been found to be inside core region within few hundred parsecs. This is just what TGD predicts since the velocity spectrum of distant stars is due to the gravitational field created by dark energy identifiable as magnetic energy of cosmic string like object - the thread containing galaxies as pearls.

3. It has been observed that there is no dark matter halo in the galactic disk. Also this is an obvious prediction of TGD model.

4. The separation of matter - now plasma clouds between galaxies - and dark matter in the collisions of galaxy clusters (observed for instance for bullet cluster consisting of two colliding clusters) is also explained qualitatively by TGD. The explanation is qualitatively similar to that in the CMD model of the phenomenon. Stars of galaxies are not affected except from gravitational slow-down much but the plasma phase interacts electromagnetically and is slowed down much more in the collision. The dominating dark matter component making itself visible by gravitational lensing separates from the plasma phase and this is indeed observed: the explanation in TGD framework would be that it is macroscopically quantum coherent ($h_{eff} = h_{gr}$) and does not dissipate so that the thermodynamical description does not apply.

   In the case of galaxy clusters also the dark energy of cosmic strings is involved besides the galactic matter and this complicates the situation but the basic point is that dark matter component does not slow down as plasma phase does.

   CMD model has the problem that the velocity of dark matter bullet (smaller cluster of bullet cluster) is higher than predicted by CMD scenario. Attractive fifth force acting between dark matter particles becoming effective at short distances has been proposed as an explanation: intuitively this adds to the potential energy negative component so that kinetic energy is increased. I have proposed that gravitational constant might vary and be roughly twice the standard value: I do not believe this explanation now.

The most feasible explanation is that the anomaly relates to the presence of thickened cosmic strings carrying dark energy as magnetic energy and dark matter shells instead of 3-D cold dark matter halos. This additional component would contribute to gravitational potential experienced by the smaller cluster and explain the higher velocity.

8.7.7 Variation Of Newston's Constant And Of Length Of Day

J. D. Anderson *et al* [L16] have published an article discussing the observations suggesting a periodic variation of the measured value of Newton constant and variation of length of day.

According to the article, about a dozen measurements of Newton's gravitational constant, G, since 1962 have yielded values that differ by far more than their reported random plus systematic errors. Authors find that these values for G are oscillatory in nature, with a period of $P = 5.899 \pm 0.062$ yr , an amplitude of , $S = 1.619 \pm 0.103 \times 10^{-14}$ m^{3}kg^{-1} s^{-2} and mean-value crossings in 1994 and 1997. The relative variation $\Delta G/G \sim 2.4 \times 10^{-4}$. Authors suggest that the actual values of G does not vary but some unidentified factor in the measurement process is responsible for an apparent variations.

According to the article, of other recently reported results, the only measurement with the same period and phase is the Length of Day (LOD —defined as a frequency measurement such that a positive increase in LOD values means slower Earth rotation rates and therefore longer days). The period is also about half of a solar activity cycle, but the correlation is far less convincing. The 5.9 year periodic signal in LOD has previously been interpreted as due to fluid core motions and inner-core coupling. We report the G/LOD correlation, whose statistical significance is 0.99764 assuming no difference in phase, without claiming to have any satisfactory explanation for it. Least unlikely, perhaps, are currents in the Earth's fluid core that change both its moment of inertia (affecting LOD) and the circumstances in which the Earth-based experiments measure G. In this case, there might be correlations with terrestrial-magnetic-field measurements.

In the popular article "Why do measurements of the gravitational constant vary so much?" (see `http://tinyurl.com/k5onwoe`) Anderson states that there is also a possible connection with Flyby anomaly [E98], which also shows periodic variation.

In the following TGD inspired model for the findings is developed. The gravitational coupling would be in radial scaling degree of freedom and rigid body rotational degrees of freedom. In rotational degrees of freedom the model is in the lowest order approximation mathematically equivalent with Kepler model. The model for the formation of planets around Sun suggests that the dark matter shell has radius equal to that of Moon's orbit. This leads to a prediction for the oscillation period of Earth radius: the prediction is consistent with the observed 5.9 years period. The dark matter shell would correspond to $n = 1$ Bohr orbit in the earlier model for quantum gravitational bound states based on large value of Planck constant if the velocity parameter v_0 appearing in $\hbar_{gr} = GM_E M_D/v_0$ equals to the rotation velocity of Moon. Also $n > 1$ orbits are suggestive and their existence would provide additional support for TGD view about quantum gravitation. There are further amazing co-incidences. The gravitational Compton length GM/v_0 of particle is very near to the Earth's radius in case Earth if central mass is Earth mass. For the mass of dark matter shell it is the variation ΔR_E. This strongly suggest that quantum coherence in astrophysical scales has been and perhaps still is present.

Coupled oscillations of radii of Earth and dark matter shell as an explanation for the variations

A possible TGD explanation for the variation emerges from the following arguments.

1. By angular momentum conservation requiring $I\omega = L = constant$ the oscillation of the length of day (LOD) can be explained by the variation of the radius R_E of Earth since the moment of inertia is proportional to R_E^2. This gives $\Delta LOD/LOD = 2\Delta R/R$. This explains also the apparent variation of G since the gravitational acceleration at the surface of Earth is $g = GM/R_E^2$ so that one has $\Delta g/g = 2\Delta R/R$. Note that the variations have opposite phase.

2. Flyby and Pioneer anomalies [K2] relies on the existience of dark matter shell with a universal surface mass density, whose value is such that in the case of Earth the total mass in the shell would be $M_D \sim 10^{-4} M_E$. The value $M_D/M_E \simeq 1.3 \times 10^{-4}$ suggested by TGD is of the

same order of magnitude as $\Delta R/R$. Even galactic dark matter around galactic core could correspond to a shell with this surfaces density of mass [K2]. This plus the claim that also Flyby anomaly has oscillatory character suggest a connection. Earth and dark mass shell are in a collective pulsation with a frequency of Earth pulsation about 6 years and the interaction is gravitational attraction. Note that the frequencies need not be the same. Momentum conservation in radial direction indeed requires that both of them participate in oscillation.

A detailed model

One can construct a model for the situation.

1. Earth and dark matter shell are modelled as rigid bodies with spatially constant density except that their radii can change. Earth and dark matter shell are characterized by moments of inertia $I_E = (3/5) \times M_E r_E^3$ and $I_D = (2/3) \times M_D r_D^2$. If one restricts the consideration to a rigid body rotation around fixed axis (call it z-axis), one has effective point masses $M_1 = 3M_E/5$ and $M_2 = 2M_D/3$ and the problem is mathematically very similar to a motion point like particles with these effective masses in plane subject to the mutual gravitational force obtained by averaging the gravitational $1/r$ potential over the volumes of the two mass distributions. In the lowest order the problem is very similar to a central force problem with $1/r$-potential plus corrections coming as series in r_E/r_D. This problem can be solved by using angular momentum conservation and energy conservation.

2. In the lowest order approximation $r_E/r_D = 0$ one has just Kepler problem in $1/r_D$ force between masses M_1 and M_2 for M_D and one obtains the analogs of elliptic orbit in the analog of plane defined by r_D and ϕ. Kepler's law $T_D^2 \propto r_D^3$ fixes the average value of r_D, call this value R_D.

3. In the next approximation one feeds this solution to the equations for r_E by replacing r_D with its average value R_D to obtain the interaction potential depending on the radius r_E. It must be harmonic oscillator potential and the elastic constant determines the oscillation period of r_E. The value of this period should be about 6 yr.

The Lagrangian is sum of kinetic terms plus potential term

$$L = T_E + T_D + V_{gr} \ ,$$

$$T_E = \frac{1}{2}M_E(\frac{dR_E}{dt})^2 + \frac{1}{2}I_E(\frac{d\Phi_E}{dt})^2 \ , \quad T_D = \frac{1}{2}M_D(\frac{dR_D}{dt})^2 + \frac{1}{2}I_D(\frac{d\Phi_D}{dt})^2 \ . \tag{8.7.23}$$

One could criticize the choice of the coefficients of the kinetic terms for radial coordinates R_E and R_D as masses and one could indeed consider a more general choices. One can also argue, that the rigid bodies cannot be completely spherically since in this case it would not be possible to talk about rotation - at least in quantum mechanical sense.

Gravitational interaction potential is given by

$$\begin{aligned} V_{gr} &= -G\int dV_E \int dA_D \rho_E \sigma_D \frac{1}{r_{D,E}} \ , & r_{D,E} &= |\overline{r}_D - \overline{r_E}| \ , \\ dA_D &= r_D^2 d\Omega_D & dV_E &= r_E^2 dr_E d\Omega_E \ , \\ \rho_E &= \frac{3M_E}{4\pi R_E^3} \ , & \sigma_D &= \frac{M_D}{4\pi R_D^2} \ . \end{aligned} \tag{8.7.24}$$

The integration measures are the standard integration measures in spherical coordinates.

One can extract the r_D factor from $r_{D,E}$ (completely standard step) to get

$$\frac{1}{r_{D,E}} = \frac{1}{r_D}X \quad ,$$
$$X = \frac{1}{|\overline{n}_D - x\overline{n}_E|} = \frac{1}{[1+x^2-2xcos(\theta)]^{1/2}} = \frac{1}{(1+x^2)^{1/2}}\frac{1}{(1-2xcos(\theta)/(1+x^2))^{1/2}} \quad ,$$
$$x = \frac{r_E}{r_D} \quad , \quad cos(\theta) = \overline{n}_D \cdot \overline{n}_E \quad . \tag{8.7.25}$$

Angular integration over θ is trivial and only the integration over r_E remains.

$$V_{gr} = -GM_DM_E\frac{3r_D^2}{r_E^3}\int_0^{r_E/r_D} F(\epsilon(x))\frac{x^2}{(1-x^2)^{1/2}}dx \quad ,$$
$$F(\epsilon) = \frac{(1+\epsilon)^{1/2}-(1-\epsilon)^{1/2})}{\epsilon} \simeq 1 - \frac{\epsilon}{8} \quad ,$$
$$\epsilon = \frac{2x}{1+x^2} \quad , \quad x = \frac{r_E}{r_D} \quad . \tag{8.7.26}$$

In the approximation $F(\epsilon) = 1$ introducing error of few per cent the outcome is

$$V_{gr} = -\frac{3GM_DM_E}{r_D} \times \left[arcsin(x) - x\sqrt{1-x^2}\right] = \frac{3GM_DM_E}{r_D}\left[\frac{2}{3} + \frac{x^2}{5} + O(x^3) + ...\right] \quad ,$$
$$x = \frac{r_E}{r_D} \quad . \tag{8.7.27}$$

The physical interpretation of the outcome is clear.

1. The first term in the series gives the gravitational potential between point like particles depending on r_D only giving rise to the Kepler problem. The orbit is closed - an ellipse whose eccentricity determines the amplitude of $\Delta R_D/R_D$. In higher orders one expects that the strict periodicity is lost in the general case. From the central force condition $M_2\omega_d^2 r_D = GM_DM_E/r_D^2$ one has

$$T_D = \sqrt{\frac{2}{3}} \times \sqrt{\frac{R_D}{r_{S,E}}}\frac{2\pi R_D}{c} \quad , \quad r_{S,E} = 2GM_E \quad . \tag{8.7.28}$$

   $r_{S,E} \simeq 8.87$ mm is the Earth's Schwartschild radius. The first guess is that the dark matter shell has the radius of Moon orbit $R_{Moon} \simeq 60.33 \times R_E$, $R_E = 6.731 \times 10^6$ m. This would give $T_D = T_{Moon} \simeq 30$ days.

2. Second term gives harmonic oscillator potential $k_E R_E^2/2$, $k_E = 6GM_DM_E/5R_D^3$ in the approximation that r_D is constant. Oscillator frequency is

$$T\omega_E^2 = \frac{k_E}{M_E} \times \frac{6GM_D}{5R_D^3} \quad . \tag{8.7.29}$$

   The oscillator period is given by

$$T_E = 2\pi \times \sqrt{\frac{5R_D^3}{6GM_D}} = 2\pi \times \sqrt{5}3 \times \sqrt{\frac{R_D}{R_{S,D}}} \times \frac{R_D}{c} \quad . \tag{8.7.30}$$

In this approximation the amplitude of oscillation cannot be fixed but the non-linearity relates the amplitude to the amplitude of r_D.

3. One can estimate the period of oscillation by feeding in the basic numbers. One has $R_D \sim R_{Moon} = 60.34 R_E$, $R_E = 6.371 \times 10^6$ m. A rough earlier estimate for M_D is given by $M_D/M_E \simeq 1.3 \times 10^{-4}$. The relative amplitude of the oscillation is $\Delta G/G = 2\Delta R/R \simeq 2.4 \times 10^{-4}$, which suggests $\Delta R/R \simeq M_D/M_E$.

   The outcome is $T_E \simeq 6.1$ yr whereas the observed period is $T_E \simeq 5.9$ yr. The discrepancy could be due to non-linear effects making the frequency continuous classically.

An interesting question is whether macroscopic quantal effects might be involved.

1. The applicability of Bohr rules to the planetary motion [K93] first proposed by Nottale [E87] encourages to ask whether one could apply also to the effective Kepler problem Bohr rules with gravitational Planck constant $\hbar_{gr} = GM_E M_D/v_0$, where v_0 is a parameter with dimensions of velocity. The rotation velocity of Moon $v_0/c = 10^{-5}/3$ is the first order of magnitude guess. Also one can ask whether also $n > 1$ other dark matter layers are possible at Bohr orbits so that one would have the analog of atomic spectroscopy.

2. From angular momentum quantization requires $L = m\omega^2 R = n\hbar_{gr}$ and from central force condition one obtains the standard formula for the radius of Bohr orbit $r_n = n^2 GM_E/v_0^2$. For $n = 1$ the radius of the orbit would be radius of the orbit of Moon with accuracy of 3 per cent. Note that the mass of Moon is about 1 per cent of the Earth's mass and thus roughly by a factor 100 higher than the mass of the spherical dark matter shell.

Clearly, the model might have caught something essential about the situation. What remains to be understood is the amplitude $\Delta R/R$. It seems that $\Delta R/R \simeq M_D/M_E$ holds true. This is not too surprising but one should understand how this follows from the basic equations.

8.7.8 The new findings about the structure of Milky from TGD viewpoint

I learned about two very interesting findings forcing to update the ideas about to the structure of Milky Way and allowing to test the TGD inspired Bohr model of galaxy based on the notion of gravitational Planck constant [K93, K79, ?, K80].

The first popular article (see `http://tinyurl.com/gwj5ybv`) tells about a colossal void extending from radius $r_0 = 150$ ly to a radius of $r_1 = 8,000$ ly (ly=light year) around galactic nucleus discovered by a team led by professor Noriyuki Matsunaga. What has been found that there are no young stars known as Cepheids in this region. For Cepheids luminosity and the period of pulsation in brightness correlate and from the period for pulsation one can deduce luminosity and from the luminosity the distance. There are however Cepheids in the central region with radius about 150 ly.

Second popular article (see `http://tinyurl.com/ztdzs9x`) tells about the research conducted by an international team led by Rensselaer Polytechnic Institute Professor Heidi Jo Newberg. Researchers conclude that Milky Way is at least 50 per cent larger than estimated extending therefore to $R_{gal} = 150,000$ ly and has ring like structures in galactic plane. The rings are actually ripples in the disk having a higher density of matter. Milky way is said to be corrugated: there are at least 4 ripples in the disk of Milky Way. The first apparent ring of stars about at distance of $R_0 = 60,000$ ly from the center. Note that R_0 is considerably larger than $r_1 = 8,000$ ly: the ratio is $R_0/r_1 = 15/2$ so that this findings need not have anything to do with the first one.

Consider now the TGD based quantum model of galaxy. Nottale [E87] proposed that the orbits of planets in solar system are actually Bohr orbits with gravitational Planck constant (different for inner and outer planets and proportional to the product of masses of Sun and planet). In TGD this idea is developed further [K93]: ordinary matter would condense around dark matter at spherical cells or tubes with Bohr radius. Bohr model is certainly over-simplification but can be taken as a starting point in TGD approach.

Could Bohr orbitology apply also to the galactic rings and could it predict ring radii as radii with which dark matter concentrations - perhaps at flux tubes assignable to Bohr orbits -

are associated? One can indeed apply Bohr orbitology by assuming TGD based model for galaxy formation.

1. Galaxies are associated with long cosmic string like objects carrying dark matter and energy (as magnetic energy) [K31, K93]. Galaxies are like pearls along necklace and experience gravitational potential which is logarithmic potential. Gravitational force is of form $F = mv_1^2/\rho$, where ρ is the orthogonal distance from cosmic string. Here v_1^2 has dimensions of velocity squared being proportional to $v_1^2 \propto GT$, $T = dM/dl$ the string tension of cosmic string.

2. Newtons law $v^2/r = v_1^2/r$ gives the observed constant velocity spectrum

$$v = v_1 \quad . \tag{8.7.31}$$

The approximate constancy originally led to the hypothesis that there is dark matter halo. As a matter of fact, the velocity tends to increase (see `http://tinyurl.com/hqzzpfs`)). Now there is no halo but cosmic string orthogonal to galactic plane: the well-known galactic jets would travel along the string. The prediction is that galaxies are free to move along cosmic string. There is evidence for large scale motions.

This was still just classical Newtonian physics. What comes in mind that one could apply also Bohr quantization for angular momentum to deduce the radii of the orbits.

1. This requires estimate for the gravitational Planck constant

$$h_{gr} = \frac{GMm}{v_0} \tag{8.7.32}$$

assignable to flux tubes connecting mass m to central mass M.

2. The first guess for v_0 would be as

$$v_0 = v_1 \quad . \tag{8.7.33}$$

The value of v_1 is approximately $v_1 = 10^{-3}/3$ (unit $c = 1$ are used) (see `http://tinyurl.com/hqzzpfs`).

3. What about mass M? The problem is that one does not have now a central mass M describable as a point mass but an effective mass characterizing the contributions of cosmic string distributed along string and also the mass of galaxy itself inside the orbit of star. It is not clear what value of central mass M should be assigned to the galactic end of the flux tubes.

One can make guesses for M.

(a) The first guess for M would be as the mass of galaxy $x \times 10^{12} \times M(Sun)$, $x \in [.8 - 1.5]$. The corresponding Schwartschild radius can be estimated from that of Sun (3 km) and equals to .48 ly for $x = 1.5$. This would give for the mass independent gravitational Compton length the value

$$\Lambda_{gr} = \frac{h_{gr}}{m} = \frac{GM}{v_0} = \frac{r_S}{2v_0} \quad (c = 1) \quad . \tag{8.7.34}$$

For $v_0 = v_1$ this would give $\Lambda_{gr} = 4.5 \times 10^3$ ly for $x = 1.5$. Note that the colossal void extends from 150 ly to 8×10^3 ly. This guess is very probably too large since M should correspond to a mass within R_0 or perhaps even within r_0.

(b) A more reasonable guess is that the mass corresponds to mass within $R_0 = 60,000$ ly or perhaps even radius $r_0 = 150$ ly. r_0 turns out to make sense and gives a connection between the two observations.

4. The quantization condition for angular momentum reads as

$$mv_1\rho = n \times \frac{h_{gr}}{2\pi} \quad . \tag{8.7.35}$$

This would give

$$\rho_n = n \times \rho_0 \quad , \quad \rho_0 = \frac{GM}{2\pi v_1 \times v_0} = \frac{\Lambda_{gr}}{2\pi v_1} \quad . \tag{8.7.36}$$

The radii ρ_n are integer multiples of a radius ρ_0.

(a) Taking $M = M_{gal}$, the value of ρ_0 would be for the simplest guess $v_0 = v_1$ about $\rho_0 = 2.15 \times 10^6$ ly. This is roughly 36 times larger than the value of the radius $R_0 = 6 \times 10^4$ ly for the lowest ring. The use of the mass of the entire galaxy as estimate for M of course explains the too large value.

(b) By scaling M down by factor 1/36 one would obtain $R_0 = 6 \times 10^4$ ly and $M = M_{gal}/36 = .033. \times M_{gal}$: this mass should reside within R_0 ly, actually within radius Λ_{gr}. Remarkably, the estimate for $\Lambda_{gr} = 2\pi v_1 M$ gives $\Lambda_{gr} = 127$ ly, which is somewhat smaller than $r_0 = 150$ ly associated with void. The model therefore relates the widely different scales r_0 and R_0 assignable with the two findings to each other in terms of small parameter v_0 appearing in the role of dimensionless gravitational "fine structure constant" $\alpha_{gr} = GMm/2h_{gr} = v_0/2$.

The TGD inspired prediction would be that the radii of the observed rings are integer multiples of basic radius. 4 rings are reported implying that the outermost ring should be at distance of 240,000 ly, which is considerably larger than the claimed updated size of 150,000 ly. The simple quantization as integer multiples would not be quite correct. Orders of magnitude are however correct.

This would suggest that visible matter has condensed around dark matter at Bohr quantized orbits or circular flux tubes. This dark matter would contribute to the gravitational potential and imply that the velocity spectrum for distance stars is not quite constant but increases slowly as observed (see `http://tinyurl.com/hqzzpfs`).

8.7.9 Is Dragonfly a "failed" galaxy?

In Phys.Org (see `http://tinyurl.com/zycob9x`) there was an article telling about the discovery of a dark galaxy - Dragonfly 44 - with mass, which is of the same order of magnitude as that of Milky Way from the estimate based on standard model of galactic dark matter, for which the region within half-light radius is deduced to be 98 per cent dark. The dark galaxies found earlier have been much lighter. Dragonfly 44 posesses 94 globular clusters and in this respects remembles ordinary galaxies in this mass range.

The abstract of the article [E255] (see `http://tinyurl.com/y8z3n8o3`) gives a more quantitative summary about the finding.

Recently a population of large, very low surface brightness, spheroidal galaxies was identified in the Coma cluster. The apparent survival of these Ultra Diffuse Galaxies (UDGs) in a rich cluster suggests that they have very high masses. Here we present the stellar kinematics of Dragonfly 44, one of the largest Coma UDGs, using a 33.5 hr integration with DEIMOS on the Keck II telescope. We find a velocity dispersion of 47 km/s, which implies a dynamical mass of $M_{dyn} = 0.7 \times 10^{10} M_{sun}$ *within its deprojected half-light radius of* $r_{1/2} = 4.6$ *kpc. The mass-to-light ratio is*

$M/L = 48M_{sun}/L_{sun}$, and the dark matter fraction is 98 percent within the half-light radius. The high mass of Dragonfly 44 is accompanied by a large globular cluster population. From deep Gemini imaging taken in 0.4" seeing we infer that Dragonfly 44 has 94 globular clusters, similar to the counts for other galaxies in this mass range. Our results add to other recent evidence that many UDGs are "failed" galaxies, with the sizes, dark matter content, and globular cluster systems of much more luminous objects. We estimate the total dark halo mass of Dragonfly 44 by comparing the amount of dark matter within $r = 4.6$ kpc to enclosed mass profiles of NFW halos. The enclosed mass suggests a total mass of $\sim 10^{12}M_{sun}$, similar to the mass of the Milky Way. The existence of nearly-dark objects with this mass is unexpected, as galaxy formation is thought to be maximally-efficient in this regime.

To get some order of manitude perspective it is good to start by noticing that $r_{1/2} = 4.6$ kpc is about 15,000 ly - the distance of Sun from galactic center is about 3 kpc. The diameter of Milky Way is 31-55 kpc and the radius of the blackhole in the center of Milky Way, which is smaller than 17 light hours.

The proposed interpretation is as a *failed* galaxy. What could this failure mean? Did Dragonfly 44 try become an ordinary galaxy but dark matter remained almost dark inside the region defined by half radius? It is very difficult to imagine what the failure of dark matter to become ordinary matter could mean. In TGD framework this could correspond to phase transition transforming dark identified as $h_{eff} = n \times h$ phases to ordinary matter but this option is not considered in the following. Could the unexpected finding challenge the standard assumption that dark matter forms a halo around galactic center?

The mass of Dragonfly 44 is deduce from the velocities of stars. The faster they move, the larger the mass. The model for dark matter assumes dark matter halo and this in turn gives estimate for the total mass of the galaxy. Here a profound difference from TGD picture emerges.

1. In TGD most of dark matter and energy are concentrated at long cosmic strings transformed to magnetic flux tubes like pearls along string. Galaxies are indeed known to be organized to form filaments. Galactic dark energy could correspond to the magnetic energy. The twistor lift of TGD predicts also cosmological constant [L20]. Both forms of dark energy could be involved. The linear distribution of dark matter along cosmic strings implies a effectively 2-D gravitational logarithmic potential giving in Newtonian approximation and neglecting the effect of the ordinary matter constant velocity spectrum serving as a good approximation to the observed velocity spectrum. A prediction distinguishing TGD from halo model is that the motion along the cosmic string is free. The self-gravitation of pearls however prevents them from decaying.

2. Dark matter and energy at galactic cosmic string (or flux tube) could explain most of the mass of Dragonfly 44 and the velocity spectrum for the stars of Dragonfly 44. No halo of dark stars would be needed and there would be no dark stars within $r_{1/2}$. Things would be exactly what they look like apart from the flux tube!

   The "failure" of Dragonfly 44 to become ordinary galaxy would be that stars have not been gathered to the region within $r_{1/2}$. Could the density of the interstellar gas been low in this region? This would not have prevented the formation of stars in the outer regions and feeling the gravitational pull of cosmic string.

This extremely simple explanation of the finding for which standard halo model provides no explanation would distinguish TGD inspired model from the standard intuitive picture about the formation of galaxies as a process beginning from galactic nucleus and proceeding outwards. Dragonfly 44 would be analogous to a hydrogen atom with electrons at very large orbits only. This analogy goes much further in TGD framework since galaxies are predicted to be quantal objects (see `http://tinyurl.com/zgstd9q`).

8.7.10 TGD interpretation for the new discovery about galactic dark matter

A very interesting new result related to the problem of dark matter has emerged: see the ScienceDaily article "In rotating galaxies, distribution of normal matter precisely determines gravitational acceleration" (see http://tinyurl.com/htcgpqe). The original article [E218] can be found at arXiv.org (see http://tinyurl.com/julxz4b).

What is found that there is rather precise correlation between the gravitational acceleration produced by visible baryonic dark matter and the observed acceleration usually though to be determined to a high degree by the presence of dark matter halo. According to the article, this correlation challenges the halo model model and might even kill it.

It turns out that the TGD based model in which galactic dark matter is at long cosmic strings having galaxies along it like pearls in necklace [K94, K31, K79] allows to interpret the finding and to deduce a formula for the density from the observed correlation.

1. The model contains only single parameter, the rotation velocity of stars around cosmic string in absence of baryonic matter defining asymptotic velocity of distant stars, which can be determined from the experiments. Besides this there is the baryonic contribution to matter density which can be derived from the empirical formula. In halo model this parameter is described by the parameters characterizing the density of dark halo.

2. The gravitational potential of baryonic matter deduced from the empirical formula behaves logarithmically, which conforms with the hypothesis that baryonic matter is due to the decay of short cosmic string. Short cosmic strings be along long cosmic strings assignable to linear structures of galaxies like pearls in necklace.

3. The critical acceleration appearing in the empirical fit as parameter corresponds to critical radius. The interpretation as the radius of the central bulge with size about 10^4 ly in the case of Milky Way is suggestive.

The formula for the correlation between the observed acceleration and the contribution of baryonic mass to it

The article represents a nice formula expressing the correlation. The empirical result states that gravitational acceleration created by dark matter correlates very precisely with that produced by baryonic matter.

1. Denote by a_{obs} the observed acceleration of stars. At large distances, where the density of baryonic matter satisfies $\rho_B \sim 0$, the contribution of total baryonic mass M_B to the acceleration is small one has $v^2 = v_{obs}^2$ reflecting the fact that the gravitational potential behaves like v_{obs}^2/R as function of distance.

   Denote by a_B the acceleration created by the baryonic matter. In the region $\rho_B \simeq 0$ a_B is due the total baryonic mass M_B and given by

$$a_B = \frac{v_B^2}{R} = -\partial_R \Phi_B = \frac{GM_B}{R^2} \quad . \tag{8.7.37}$$

2. Newton's law with a spherically symmetric mass distribution requires $v^2/R = -\partial_R \Phi_R$, which requires that gravitational potential behaves as $log(R/R_0)$ for large distances. To understand this in terms of halo model, one must assume that the dark mass inside sphere of radius R behaves like $M(R) \propto R$ so that gravitational potential $\Phi(R)$ behaves like $log(R/R_0)$.

3. The empirical formula expressing the finding goes as follows:

$$a_{obs}(R) = \frac{a_B(R)}{1-exp(-x)} \quad , \quad v_{obs}^2(R) = \frac{v_B^2(R)}{1-exp(-x)} \quad , \quad x = \sqrt{\frac{a_B}{a_{cr}}} \quad . \tag{8.7.38}$$

   .

   What this says that the observed acceleration is related to the acceleration that would be created by mere baryonic matter by an algebraic formula in the quite long range of distances: this is something unexpected. For large distances a_B approaches zero like $1/R^2$ and the first two terms in the Taylor expansion of the exponent are important. This gives the approximation

$$a_{obs}(R) \simeq \sqrt{a_B a_{cr}} \ . \tag{8.7.39}$$

This formula is consistent with $a_{obs} = v_{obs}^2/R$. If the baryonic mass density vanishes above R_{cr} corresponding to $a_{cr} = GM_B/R_{cr}^2$, one obtains for $R > R_{cr}$ in approximation $1 - exp(-x_{cr}) = x_{cr}$

$$v_{as}^2 = \frac{GM_B}{R_{cr}(1-exp(-x_{cr}))} = \frac{R_{S,B}}{2R_{cr}(1-exp(-x_{cr}))} \ . \tag{8.7.40}$$

Here $R_{S,B} = 2GM_B$ is the Schwartchild radius assignable to the baryonic matter. If one has $\rho_B \sim 0$ at R_{cr} , one has $a_{cr} \equiv -\partial_R \Phi_B = GM_B/R_{cr}^2$. Otherwise one expects a different value of a_{cr}.

4. There are two cases to consider. Baryonic mass density is non-vanishing above R_{cr} (General case) or vanishes in good approximation above R_{cr} (Special case). Accordingly, one has

$$\begin{aligned} v_{obs}^2 &= R\sqrt{a_B a_{cr}} \ \text{ for } \ R \geq R_{cr} \ \text{ (General case)} \ , \\ v_{obs}^2 &= v_{as}^2 = \tfrac{R_{S,B}}{2R_{cr}(1-exp(-x_{cr}))} \ \text{ for } \ R \geq R_{cr} \ \text{ (Special case)} \ . \end{aligned} \tag{8.7.41}$$

TGD based model

Can one interpret the finding in TGD Universe and what implications it has for a model of galaxy?

1. In TGD Universe dark matter does not form a halo but is concentrated at dark cosmic string (thickened magnetic flux tube) along which galaxies are organized like pearls in necklace. The cosmic string corresponds to a geodesic sphere of CP_2, which can be either homologically trivial or non-trivial. In the first case both Kähler action and volume term contribute to string tension T, in the latter case only volume term. Criticality hypothesis states that the string tensions are same: this condition relates their transverse cross-sectional areas [L22].

2. The basic implication is that the gravitational potential depends on the orthogonal distance ρ from the cosmic string only and has a logarithmic dependence so that constant velocity spectrum follows automatically at large distances. The motion along cosmic string is free apart from self-gravitation of baryonic matter. Constant velocity spectrum is modified by the presence of the baryonic matter but the modification is small at large distances. The general prediction for the velocity in the region with $\rho_B = 0$ is

$$v_{as}^2 = nTG \ . \tag{8.7.42}$$

where n is numerical constant. If one takes seriously the quantum criticality hypothesis [L22], T is expressible in terms of the basic parameters of TGD (cosmological constant Λ in recent cosmology, CP_2 radius, Kähler coupling strength $\alpha_K \simeq \alpha_{U(1)}$ [L12], and the area S of transversal section of cosmic string, which approaches the area S of CP_2 geodesic sphere in primordial cosmology for homologically non-trivial (magnetically charged) cosmic strings [L20] [L22].

3. This gives for the two options

$$v_{as}^2 = nTG = \sqrt{\frac{R_{S,B}a_{cr}}{2}} \text{ (General case) },$$
$$v_{as}^2 = \frac{R_{S,B}}{2R_{cr}(1-exp(-x_{cr}))} \text{ (Special case) }. \tag{8.7.43}$$

   From either formula one could estimate the value of T and R_{cr} if M_B and v_{obs}^2 are known. The assumption that the value of T is universal need not hold true but would predict that R_{cr} is proportional to $R_{S,B}$ and thus to the baryonic mass M_B. This prediction could be tested by studying velocity spectra for galaxies along big cosmic string.

4. The general condition gives in the region with $\rho_B \sim 0$ the equation

$$v_{obs}^2(R) = v_B^2 \times f(x) \ , \qquad f(x) = \frac{1}{1-exp(-x)} = \frac{1+\frac{x}{2}+\frac{x^2}{12}+...}{x} \ ,$$
$$x = x_a = \sqrt{\frac{a_B}{a_{cr}}} \text{ (General case) }, \quad x = x_b = \frac{R_{cr}}{R} \text{ (Special case) }. \tag{8.7.44}$$

5. In the region $\rho_B \sim 0$ Newton's equations allow to solve $v_{obs}^2(R)$

$$v_{obs}^2(R) = v_{as}^2 + v_B^2 = v_{as}^2 + \frac{R_{S,B}}{2R} \ , \tag{8.7.45}$$

   Note that in halo model v_{as}^2 is replaced with the velocity squared associated with the dark model halo and is function of R.

   Comparing with the previous formula one obtains in this region the consistency condition

$$f(x) = 1 + \frac{v_{as}^2}{v_B^2} = 1 + \frac{2v_{as}^2 R}{R_{S,B}} \ . \tag{8.7.46}$$

   The expression for $v_{obs}^2(R)$ can be written in the region $\rho_B \sim 0$ in terms of x

$$v_{obs}^2 = v_{as}^2 + Kx \ ,$$
$$K = \sqrt{\frac{R_{S,B}a_{cr}}{2}} \ , \quad x = x_a = \sqrt{\frac{a_B}{a_{cr}}} \text{ (General case) },$$
$$K = \frac{R_{S,B}}{2R_{cr}} \ , \quad x = x_b = \frac{R_{cr}}{R} \text{ (Special case) }. \tag{8.7.47}$$

6. At smaller distances one can express v^2/R as sum of stringy and baryonic accelerations require consistency with the empirical formula:

$$v_{as}^2 + Ra_{cr}x^2 = v_B^2 f(x) = Ra_{cr}x^2 f(x) \ , \quad x = \sqrt{\frac{a_B}{a_{cr}}} \tag{8.7.48}$$

   giving a highly non-linear transcendental equation for x. This allows a numerical determination of x.

7. One can deduce also ρ_B as the source of the baryonic gravitational potential in terms of the Laplace equation

$$\partial_R a_B + \frac{2}{R} a_B = kG\rho_B \ . \tag{8.7.49}$$

Here k is a numerical constant. Note that spherical symmetry is assumed for ρ_B. Expressing this equation in terms of $x_a = \sqrt{a_B a_{cr}}$ using $a_B = x_a^2/a_{cr}$ one obtains

$$\rho_B = 2\frac{a_{cr}}{kG}\left[x_a \frac{dx_a}{dR} + \frac{x_a^2}{R}\right] \ . \tag{8.7.50}$$

Therefore it is possible to solve ρ_B numerically essentially uniquely. One must also use the approximate condition of Eq. **??** determining a_{cr}.

Consistency condition for large distances

The first thing coming in mind is that one could solve ρ_B iteratively from Eqs. 8.7.48 and 8.7.50. Consider first the lowest order approximation at large distances.

Recall that the general consistency condition reads as

$$\begin{aligned} & v_{as}^2 + Kx = v_B^2 f(x) = Rx^2 a_{cr} f(x) \ , \quad f(x) = \frac{1}{1-e^{-x}} \ . \\ & K = \sqrt{\frac{R_{S,B}a_{cr}}{2}} \ , \qquad x = x_a = \sqrt{\frac{a_B}{a_{cr}}} \ \text{(General case)} \ , \\ & K = \frac{R_{S,B}}{2R_{cr}} \ , \qquad x = x_b = \frac{R_{cr}}{R} \ \text{(Special case)} \ . \end{aligned} \tag{8.7.51}$$

Consider first this condition for large values of R for which the approximation $f(x) \simeq 1/x$ holds true.

1. Using the approximation $f(x) \simeq 1/x$ one obtains

$$\begin{aligned} & x = \frac{v_{as}^2}{a_{cr}}\frac{1}{R-R_{min}} \ , \qquad R_{min} = \frac{K}{a_{cr}} \ , \\ & K = \sqrt{\frac{R_{SB}a_{cr}}{2}} \ \text{(General case)} \quad K = \frac{R_{SB}}{R_{cr}} \ \text{(Special case)} \ , \\ & a_B = a_{cr}x^2 = \frac{v_{as}^4}{a_{cr}}\frac{1}{(R-R_{min})^2} \ . \end{aligned} \tag{8.7.52}$$

In the region, where one has $\rho_B \sim 0$ the expression for a_B must reduce to $R_{S,B}/2R^2$ in good approximation and this gives the consistency condition

$$a_{cr} = \frac{2v_{as}^4}{R_{S,B}} \ , \quad a_B = \frac{R_{SB}}{2(R-R_{min})^2} \ \text{(General case)} \ . \tag{8.7.53}$$

The expression differs from the acceleration field of point mass M_B only by the shift $R \rightarrow R - R_{min}$. One expects that the emergence of of singularity at R_{min} is due to the failure of the fact that the first term in the Taylor expansion of $1 - exp(-x)$ is not a good approximation. R_{min} could however have physical counterpart too.

For the (Special case) one obtains and additional consistency condition allowing to determine the value of R_{cr}

$$R_{cr} = \frac{R_{SB}}{2v_{as}} \quad \text{(Special case)} \ . \tag{8.7.54}$$

For Milky Way (see `http://tinyurl.com/hqr6m27`) one has $M_B \sim 10^{10}$ solar masses. From $R_{S,Sun} \sim 3$ km one has $R_{S,B} \sim 1$ ly. For Milky with $R_{SB} \sim 1$ ly one has $R_{cr} \sim 10^3$ ly to be compared with the radius of high density bulk about 10^4 ly. This looks rather reasonable. For the general solution $R_{cr} = R_{min}$ is a free parameter and the natural guess is $R_{cr} = R_{min} \sim 10^4$ ly. Note that R_{cr} is of same order of magnitude as the smallest radius in the determination of the correlation between v_{obs} and v_B [E218].

The solution becomes singular at $R = R_{min} = R_{cr}$. This gives

$$R_{min} = R_{cr} \ \text{(General case)} \ , \quad R_{min} = R_{cr} = \frac{R_{SB}}{2v_{as}} \ \text{(Special case)} \ . \tag{8.7.55}$$

Taking the limit $R \to \infty$ the equation for a_B should should give $a_B \simeq R_{S,B}/2R^2$. This is true for (Special case) in this region. It seems however that in this case is predicts too small R_{min}. This suggests that R_{min} as a free parameter should have identification as the radius of galactic bulk. The formulas for R_{cr} and a_{cr} depend only on string tension and galactic Schwartschild radius. Interestingly, the proposal for the Bohr quantization of planetary orbits using gravitational Planck constant $h_{gr} = GMm/v_{obs}$ leads to analogous formulas for their radii [K93].

2. One obtains an estimate for ρ_B from Eq. 8.7.50 as

$$\rho_B = \frac{2v_{as}^2 R_{SB}}{|k|G} \frac{R_{min}}{R(R-R_{min})^3} \ , \quad R_{min} = R_{cr} = \frac{R_{SB}}{2v_{as}} \ \text{(Special case)} \ . \tag{8.7.56}$$

Near R_{min} the density would become singular as $1/(R-R_{min})^3$, a symptom about the failure of the approximation. At distances $R >> R_{min}$ one has

$$\rho_B = \frac{2v_{as}^2 R_{SB} R_{cr}}{|k|G} \frac{1}{R^4} = \frac{v_{as} R_{SB}^2}{|k|G} \frac{1}{R^4} \ . \tag{8.7.57}$$

The total baryonic mass $M_B(R_1, R_2)$ for any region $R_{min} < R_1 < R < R_2$ is finite and for $R_1 >> R_{min}$ one can express it has

$$\frac{M_B(R_1,R_2)}{M_B} = C\frac{R_{SB}(R_2-R_1)}{R_1R_2} \ , \quad C = 8\pi\frac{v_{as}^2 R_{cr}}{R_{SB}M_B} \ \text{for (General case)}$$
$$C = \frac{4\pi}{3}\frac{v_{as}M_B}{|k|} \ \text{(Special case)} \ . \tag{8.7.58}$$

The fraction is very small since the size scale of say Milky way is 10^5 ly and the formula states that the contribution to the total baryonic mass from the regions, where the approximation makes sense, is essentially zero. It is certainly not sensible to assume that most of the baryonic mass comes from region near R_{min}. The higher order contributions must be crucial since the expression for $f(x)$ is proportional to the factor $1/(1-exp(-x))$ diverging for large values of x (small values of R).

Consistency condition for small distances

One can study the consistency condition in the lowest order approximation also for small radii (large value of x).

1. At the limit of small radii one has $f(x) = 1$. Substituting this to the consistency condition of Eq. 8.7.48, one obtains

$$v_{obs}^2 + Kx = Rx^2 a_{cr} \ , \qquad K = \sqrt{\frac{R_{SB}a_{cr}}{2}} \text{ for (General case)} \ , \qquad K = \frac{R_{SB}}{2R_{cr}} \text{ (Special case)} \ . \tag{8.7.59}$$

allowing to solve x and a_B as

$$x = \frac{R_{SB}}{4v_{as}R}\left[1+\epsilon\sqrt{1+z}\right] \quad z = \frac{8v_{as}^2}{R_{SB}}R \ , \quad \epsilon = \pm 1 \ . \tag{8.7.60}$$

Here also the option $\epsilon = -1$ is excluded because it leads to negative density.

2. Acceleration $a_B$andthe baryonic contribution to the velocity squared $v_B^2 = Ra_B$ are given as

$$a_B = \frac{R_{SB}}{8R^2}\left[1+\sqrt{1+z}\right]^2 \ , \quad v_B^2(R) = \frac{R_{SB}}{8R}\left[1+\sqrt{1+z}\right]^2 \ . \tag{8.7.61}$$

Note that their is no dependence on R_{cr}. a_B approaches zero roughly like $1/R^2$ for small values of z: the interpretation is in terms of the gravitational field of point like mass. a_B behaves like $1/R$ large values of R: the interpretation is in terms of cosmic string dominance. The result conforms with the observed slow gradual increase of $v_{obs}^2(R)$. Φ_B can be integrated from a_B as $\Phi = -\int a_B dR$.

3. Only the terms involving square root term in a_B contribute to ρ_B, and one obtains the expression

$$\rho_B = \frac{v_{as}^2 m_P}{|k| l_P R^2} \times \left[1 + \frac{1}{\sqrt{1+z}}\right] \ , \quad z = \frac{8v_{as}^2}{R_{SB}}R \ , \ . \tag{8.7.62}$$

ρ_B is proportional to $1/R^2$ but for the physically acceptable option $\epsilon = 1$ it becomes infinite at R_{cr} suggesting in TGD framework the presence of dark matter shell around which baryonic dark matter is condensed.

In the case of Milky Way the order of magnitude for ρ_B near $R = R_{S,B}$, where the contribution from z-dependent term is small, is

$$\rho_B \sim \frac{v_{as}^2 m_P}{2 l_P R_{S,B}^2 |k|} \ .$$

For $v_{obs} = 2^{-11}$ one would have $\rho_B \sim 8 \times 10^{16} m_p$ per cubic meter. At smaller radii the density increases as $1/R^2$.

The numerical iteration of the consistency condition Eq. 8.7.48 combined with the mass formula 8.7.50 is possible by solving x at the left hand side of the consistency condition by substituting the previous value for x_a to the right hand side of Eq. 8.7.48.

Velocity curves of galaxies decline in the early Universe

A new twist in the galactic dark matter puzzles emerged as Sabine Hossenfelder gave a link to a popular article "Declining Rotation Curves at High Redshift" (see http://tinyurl.com/l6lpgk2) telling about a new strange finding about galactic dark matter. The rotation curves are declining in the early Universe meaning distances about 10 billion light years [E130] (see http://tinyurl.com/jvp6fey). In other words, the rotation velocity of distant stars decreases with radius rather than approaching constant - as if dark matter would be absent and galaxies were baryon dominated. This challenges the halo model of dark matter. For the illustrations of the rotation curves see the article. Of course, the conclusions of the article are uncertain.

Some time ago also a finding about correlation of baryonic mass density with density of dark matter emerged: the ScienceDaily article "In rotating galaxies, distribution of normal matter precisely determines gravitational acceleration" can be found at http://tinyurl.com/htcgpqe. The original article [E218] can be found in arXiv.org (see http://tinyurl.com/julxz4b). TGD explanation involves only the string tension of cosmic strings and predicts the behavior of baryonic matter on distance from the center of the galaxy.

In standard cosmology based on single-sheeted GRT space-time large redshifts mean very early cosmology at the counterpart of single space-time sheet, and the findings are very difficult to understand. What about the interpretation of the results in TGD framework? Let us first summarize the basic assumptions behind TGD inspired cosmology and view about galactic dark matter.

1. The basic difference between TGD based and standard cosmology is that many-sheeted space-time brings in fractality and length scale dependence. In zero energy ontology (ZEO) one must specify in what length scale the measurements are carried out. This means specifying causal diamond (CD) parameterized by moduli including the its size. The larger the size of CD, the longer the scale of the physics involved. This is of course not new for quantum field theorists. It is however a news for cosmologists. The twistorial lift of TGD allows to formulate the vision quantitatively.

2. TGD view resolves the paradox due to the huge value of cosmological constant in very small scales. Kähler action and volume energy cancel each other so that the effective cosmological constant decreases like inverse of the p-adic length scale squared because these terms compensate each other. The effective cosmological constant suffers huge reduction in cosmic scales and solves the greatest (the "most gigantic" would be a better attribute) quantitative discrepancy that physics has ever encountered. The smaller value of Hubble constant in long length scales finds also an explanation [K66]. The acceleration of cosmic expansion due to the effective cosmological constant decreases in long scales.

3. In TGD Universe galaxies are located along cosmic strings like pearls in necklace, which have thickened to magnetic flux tubes. The string tension of cosmic strings is proportional to the effective cosmological constant. There is no dark matter hallo: dark matter and energy are at the magnetic flux tubes and automatically give rise to constant velocity spectrum for distant stars of galaxies determined solely by the string tension. The model allows also to understand the above mentioned finding about correlation of baryonic and dark matter densities [L28].

What could be the explanation for the new findings about galactic dark matter?

1. The idea of the first day is that the string tension of cosmic strings depends on the scale of observation and this means that the asymptotic velocity of stars decreases in long length scales. The asymptotic velocity would be constant but smaller than for galaxies in smaller scales. The graphs of http://tinyurl.com/l6lpgk2 show that in the velocity range considered the velocity decreases. One cannot of course exclude the possibility that velocity is asymptotically constant.

   The grave objection is that the scale is galactic scale and same for all galaxies irrespective of distance. The scale characterizes the object rather than its distance for observer. Fractality suggests a hierarchy of string like structures such that string tension in long scales decreases and asymptotic velocity associated with them decreases with the scale.

2. The idea of the next day is that the galaxies at very early times have not yet formed bound states with cosmic strings so that the velocities of start are determined solely by the baryonic matter and approach to zero at large distances. Only later the galaxies condense around cosmic strings - somewhat like water droplets around blade of grass. The formation of these gravitationally bound states would be analogous to the formation of bound states of ions and electrons below ionization temperature or formation of hadrons from quarks but taking place in much longer scale. This model explains the finding about the decline of the rotation velocities [E130]: the early galaxies are indeed baryon dominated.

Further support for TGD view about galactic dark matter

The newest finding is described in popular article "This Gigantic Ring of Galaxies Could Bring Einstein's Gravity Into Question" (see http://tinyurl.com/jwnfanl). What has been found that in a local group of 54 galaxies having Milky Way and Andromeda near its center the other dwarf galaxies recede outwarts as a ring. The local group is in good approximation in plane and the situation is said to look like having a spinning umbrella from which the water droplets fly radially outwards.

The authors of the article "Anisotropic Distribution of High Velocity Galaxies in the Local Group" [E185] (see http://tinyurl.com/mtm5vcm) argue that the finding can be understood aif Milky Way and Andromeda had nearly head-on collision about 10 billion light-years ago. The Milky Way and Andromeda would have lost the radially moving dwarf galaxies in this collision during the rapid acceleration turning the direction of motion of both. Coulomb collision is good analog.

There are however problems. The velocities of the dwards are quite too high and the colliding Milky Way and Andromeda would have fused together by the friction caused by dark matter halo.

What says TGD? In TGD galactic dark matter (actually also energy) is at cosmic strings thickened to magnetic flux tubes like pearls along necklace. The finding could be perhaps explained if the galaxies in same plane make a near hit and generate in the collision the dwarf galaxies by the spinning umbrella mechanism.

In TGD Universe dark matter is at cosmic strings and this automatically predicts constant velocity distribution. The friction created by dark matter is absent and the scattering in the proposed manner could be possible. The scattering event could be basically a scattering of approximately parallel cosmic strings with Milky Way and Andromeda forming one pearl in their respective cosmic necklaces.

But were Milky Way and Andromeda already associated with cosmic strings at that time? The time would be about 10 billion years. One annot exclude this possibility. Note however that the binding to strings might have helped to avoid the fusion. The recent finding [E130] (see http://tinyurl.com/l6lpgk2) about effective absence of dark matter about 10 billion light years ago - velocity distributions decline at large distances - suggests that galaxies formed bound states with cosmic strings only later. This would be like formation of neutral atoms from ions as energies are not too high!

8.7.11 Bullet cluster, cold dark matter, and MOND

Sabine Hossenfelder (see http://tinyurl.com/jm4kevp) wrote about Bullet Cluster (see http://tinyurl.com/jm4kevp). Usually Bullet Cluster is seen to favor dark matter and disfavor MOND theory (see http://tinyurl.com/pu36kqgs) introducing a modification of Newtonian gravity. Sabin Hossenfelder saw it differently.

Cold dark matter model (ΛCDM) and MOND are two competing mainstream models explaining the constant velocity spectrum of stars in galaxies.

1. ΛCDM (see http://tinyurl.com/zv6wg4s) assumes that dark matter forms a spherical halo around galaxy and that its density profile is such that it gives the observed velocity spectrum of distant stars approaching to constant and even increasing at large distances (see http://tinyurl.com/ohbdqj6). The problem of the model is that dark matter distribution can have many shapes and it is not easy to understand why approximately constant velocity spectrum is obtained. Also the attempts to find dark matter particles identified as some

exoticons have failed one after another. The recent finding that the velocity spectrum of distant stars around galaxies correlates strongly with the density of baryonic matter (see http://tinyurl.com/julxz4b) also challenges this model: it is difficult to believe that the halo would have so universal baryonic mass density (for TGD view see [L28].

2. MOND does not assume dark matter but makes an ad hoc modification of gravitational force for small accelerations. The problem of MOND is that it is indeed an ad hoc modification and it is not easy to see how to make it consistent with general relativity: it is difficult to do cosmology using MOND. For small accelerations (small space-time curvatures) one would expect Newtonian theory to be an excellent approximation.

Consider now how Bullet Cluster relates to these two options. Bullet cluster is a pair of galaxy clusters which has emerged from collision (see the figure at http://tinyurl.com/jamzykd). There exists data at optical wave lengths about stars. Stars experience only a small gravitational slowing down and are expected to go through the collision region rather fast. Data from X-ray measurements give information about the intergalactic gas associated with clusters. This gas interacts electromagnetically and is slowed down much more and remains in the collision region for a longer time. The *red* region regions in the figure correspond to the gas. Gravitational lensing in turn gives information about space-time curvature and these two regions are farthest away from the collision center. These regions are *blue* and would naturally correspond to dark matter in ΛCDM model.

Both models have severe problems.

1. In cold dark matter model the event would require too high relative velocity for colliding clusters - about c/100. The probability for this kind of collision in cold dark matter model is predicted to be very low - about 6.4×10^{-6}. Something seems to be wrong with ΛCDM model.

2. In MOND the relative collision velocities are argued to be much more frequent. Bee however forgot to mention that in MOND the lensing is expected to be associated with X-ray region (hot gas in the center of figure) rather than with the blue regions disjoint from it. This observation is a very severe blow against MOND model.

The logical conclusion is that there indeed seems to be dark matter there but it is something different from the cold dark matter. What it could be?

What could be the interpretation in TGD?

1. In TGD galaxies are associated with cosmic string or more general string like objects like pearls with necklace [K111, K31, K93, L22]: that this is the case is known for decades but for some mysterious reason to me has not been used as guideline in dark matter models. Maybe it is very difficult to see things from bigger perspective than galaxies.

   The flux tubes carry Kähler magnetic energy, dark energy, and dark matter in TGD sense having $h_{eff}/h = n$. The galactic matter experiences transversal $1/\rho$ gravitational force predicting constant velocity spectrum for distant stars when baryonic matter is neglected. Note that one avoids a model for the profile of the halo altogether. The motion of the galaxy along the flux tube is free apart from the forces caused by galaxy. The presence of baryonic matter implies that the velocity increases slowly with distance up to some critical radius. By recent findings correlating observed velocity spectrum with density of baryonic matter one can deduce the density of baryonic matter [L28](see http://tinyurl.com/gvdclqg). A possible interpretation is as remnants of cosmic string like object produced in its decay to ordinary matter completely analogous to the decay of the vacuum energy of inflaton field to matter in inflation theory.

   The order of magnitude for velocity v_{gal} for distant stars in galaxies is about $v_{gal} \sim c/1000$. In absence of baryonic matter it is predicted to be constant and proportional satisfy $v \propto (TG)^{1/2}$, T string tension and G Newton's constant ($c = 1$). T in turn is proportional to $1/R^2$, where R is CP_2 radius. Maximal velocity is obtained for cosmic strings. For magnetic flux tubes resulting when cosmic strings develop 4-D M^4 projection string tension T and thus v_{gal} is reduced. One obtains larger velocities if there are several parallel flux tubes forming a gravitational bound state so that tensions add.

2. By fractality also galaxy clusters are expected to form similar linear structures. Concerning the interpretation of the Bullet Cluster one can imagine two options.

   (a) The two colliding clusters could belong to the same string like object and move in opposite directions along it. In this case gravitational lensing would be most naturally associated with the flux tube and there would be single linear blue region instead of the two blue spots of the figure.

   (b) The clusters could also belong to different flux tubes, which pass by each other and induce the collision of clusters and the gas associated with them. If the flux tubes are more or less parallel and orthogonal to the plane of the figure, the gravitational lensing would be from the two string like objects and two disjoint blue spots would appear in the figure. This option conforms with the figure.

3. The collision velocity would correspond to the relative velocity of flux tubes. Can one say anything about the needed collision velocities? The naïve first guess of dimensional analyst is that the rotation velocity $v_{gal} \propto (TG)^{1/2}$ determining galactic rotation spectrum determines also the typical relative velocity between galaxies. Here T would be the string tension of flux tubes containing galaxy clusters along it. T would gradually decrease during the cosmic evolution as flux tubes gets thicker and magnetic energy density is reduced. The velocity $v \sim c/100$ suggested by ΛCDM model is 10 times larger than $v \sim c/1000$ for distant stars in galaxies.

   By fractality similar view would apply to galaxy clusters assigned to flux tubes. Cluster flux tubes containing clusters along them could correspond to bound states of parallel galactic flux tubes containing galaxies along them.

4. The simplest model for collision of flux tubes treats them as parallel rigid strings so that dimensional reduction to $D = 2$ occurs. The gravitational potential is logarithmic potential: $V = Klog(\rho)$. One can use conservation laws of angular momentum and energy to solve the equations of motion just as in 3-D central force problem. The initial and final angular momentum per mass equals to $J = v_0 a$, where a is the impact parameter and v_0 the initial velocity. The initial energy per unit mass equals to $e = v_0^2/2$ and is same in the final state. Conservation law for e gives $e = v^2/2 + Klog(\rho) = v_0^2/2$.

   Conservation law for angular momentum reads $j = v\rho sin(\phi) = v_0 a$ and gives $v = j/(\rho sin(\phi))$. Velocity is given from $v^2 = (d\rho/dt)^2 + \rho^2(d\phi/dt)^2$ and leads together with conservation laws a first order differential equation for $d\rho/dt$.

   Since the potential is logarithmic, there is rather small variation of energy in the collision so that the clusters interact rather weakly. This could produce the same effect as larger relative collision velocity in ΛCDM model with kinetic energy dominating over gravitational potential.

8.7.12 TGD view about universal galactic rotation curves for spiral galaxies

8.8 TGD view about universal galactic rotation curves for spiral galaxies

The TGD inspired model for galaxy formation [L28, L46, L30] [K31, K93, L30] describes spiral galaxies as pearls in necklace defined by long cosmic string, whose gravitational field explains asymptotically constant rotation curve. In its recent form does not however say much about the situation near the galactic center.

1. Is all dark matter associated with the long cosmic strings defining the necklace around which galaxies are bound? Do also galaxies contain dark matter? If so, do galaxies correspond to separate closed dark cosmic strings or do they correspond to knots of long cosmic strings?

2. Is galactic center a reconnection point of two cosmic strings, which led to the formation of galaxies as some findings suggest? Or does it correspond to self-intersection of long knotted cosmic string?

3. What happened to the cosmic strings if the reconnection happened? Who ordinary galactic matter emerged Did the cosmic string thicken? If so, the conservation of monopole magnetic flux would have reduced dark magnetic energy density of the string density by a factor, which is roughly the ratio of original and final transversal area. Did the liberated dark energy give rise to the ordinary matter?

4. Could TGD based model say something interesting about constant density core region for which there is now more empirical evidence [L47] but which is not consistent with the halo model of dark matter nor with the idea about un-knotted cosmic string.

5. Could TGD provide some ideas about the origin of Fermi bubbles [E270, E51] and super-massive blackhole at galactic center?

The observed universality rotation curves for mini spiral galaxies [L47] led to a considerable progress in TGD inspired model of galaxy formation. In TGD universality reduces to scaling invariance of the rotation curves natural since TGD Universe is quantum critical. The study of mini spiral galaxies supports the conclusion that they have a dark matter core of radius of few parsecs - 2-3 times the optical radius. This is a problem in the halo models. The simplest TGD based explanation is that galaxies correspond to knots or even spaghetti like tangles of long dark strings defining a kind of necklace containing galaxies as pearls. The model also suggests that dark matter core gives rise to Fermi bubble. Dark cosmic ray protons from supermassive galactic black hole containing dark matter would scatter from dark matter and some fraction of the produced dark photons would transform to ordinary ones. This would take place only inside the dark matter sphere and double sphere structure would be due to the fact that cosmic rays would not proceed far in galactic plane.

8.8.1 Universal rotation curves for mini spirals

There was an interesting popular article “Beyond the standard model through ’mini spirals’” in ScienceDaily (see `http://tinyurl.com/j7mbeyt`), which gave the stimulus for posing the above questions. Mini spirals with size scale about 1 tenth of Milky Way were studied statistically by Professor Paolo Salucci of the International School for Advanced Studies (SISSA) in Trieste, and Ekaterina Karukes, who recently earned her PhD at SISSA.

The abstract of their article [L47] (see `http://tinyurl.com/yac5gpo3`) gives idea about what is involved.

> *We use the concept of the spiral rotation curves universality to investigate the luminous and dark matter properties of the dwarf disc galaxies in the local volume (size $\sim$ 11 Mpc). Our sample includes 36 objects with rotation curves carefully selected from the literature. We find that, despite the large variations of our sample in luminosities ($\sim$ 2 of dex), the rotation curves in specifically normalized units, look all alike and lead to the lower-mass version of the universal rotation curve of spiral galaxies found in Persic et al.*
>
> *We mass model the double normalized universal rotation curve $V(R/R_{opt})/V_{opt}$ of dwarf disc galaxies: the results show that these systems are totally dominated by dark matter whose density shows a core size between 2 and 3 stellar disc scale lengths. Similar to galaxies of different Hubble types and luminosities, the core radius R_0 and the central density ρ_0 of the dark matter halo of these objects are related by $\rho_0 R_0 \sim 100M(Sun)pc^2$.*
>
> *The structural properties of the dark and luminous matter emerge very well correlated. In addition, to describe these relations, we need to introduce a new parameter, measuring the compactness of light distribution of a (dwarf) disc galaxy. These structural properties also indicate that there is no evidence of abrupt decline at the faint end of the baryonic to halo mass relation. Finally, we find that the distributions of the stellar disc and its dark matter halo are closely related.*

Authors assume dark halo model in their analysis. Core radius R_0 defined as radius below which mass density is constant and central density ρ_0 of dark matter appears as parameters of the model. Authors conclude that the properties of dark and visible parts of mini spirals are closely correlated, dark matter dominates and has core size about 2-3 times the stellar disk size, and that standard models of dark matter cannot explain this: mini spirals could serve as "portals" to new physics.

The work gives additional support for the proposal that the rotation curves of all spiral galaxies are universal obeying scaling invariance typical for critical systems. The parameters in the rotation curve are optical radius R_{opt} characterizing the visible size of the galaxy and the velocity $v(R_{opt})$ of star at distance R_{opt} defining the size of the region containing start. Authors report the function

$$\frac{v(\frac{R}{R_{opt}})}{v_{opt}} = f(x) \ , \ x = \frac{R}{R_{opt}} \ . \tag{8.8.1}$$

us universal, that is the shape of the $f(x)$ does not depend on mini spiral and differs only by the unit v_{opt} of velocity and unit R_{opt} of distance of different galaxies.

The authors try to explain the universal shape using dark matter halo model and conclude that the core radius is 2-3 times the stellar disk size so that dark matter density would be constant below this radius and give to gravitational potential a harmonic oscillator contribution proportional to R^2 predicting rigid body rotation. The presence of constant density sphere is in conflict with halo models predicting typically density dependence of form $1/R$ at small radii. This is known as halo-cusp problem [E266].

8.8.2 TGD view about mini spirals

One can approach the situation also from TGD point of view. Consider first how to obtain scaling invariant velocity spectrum if the gravitational force in galactic plane as sum of dark matter/energy contribution from string with string tension T and a contribution from visible matter? If dark matter dominates, how it is possible to obtain constant density of matter. One option is that there is pearl defined by closed magnetic flux tube containing dark matter but in this case the long string would give a large and dominating contribution to the velocity. Second option is that the long string is "knotted": the pearl would be actually a knot.

Scaling law

Consider first the situation for $R > R_0$.

1. Flux tube has some radius about which is expected to be of the order of CP_2 radius as it is for ideal cosmic strings. Thickening however increases the radius but not much.

2. Newton's law gives

$$v^2 = kTG + \frac{GM(R)}{R} \tag{8.8.2}$$

giving

$$\frac{v^2}{v_{opt}^2} = \frac{kTG + GM(R)/R}{kTG + GM(R_{opt})/R_{opt}} \ . \tag{8.8.3}$$

3. To get scaling invariance one must assume

$$M(R) = M_{opt}x^{n+1} \ , \ x = \frac{R}{R_{opt}} \ . \tag{8.8.4}$$

The density of visible matter should therefore satisfy $\rho_{vis} \propto x^{n-2}$. This gives universal velocity spectrum

$$\frac{v^2}{v_{opt}^2} = \frac{kTG + GM(R_{opt})x^n}{kTG + GM(R_{opt})} \ , \tag{8.8.5}$$

which is very natural since string tension is the only parameter characterizing the density of dark matter and TGD Universe is quantum critical. The value of the exponent n can be determined from the shape of the rotation curve. Since the density must decrease with distance, one must have $n < 2$. Note that the value of n cannot be same below R_0 and for $R \geq\geq R_0$. Below R_0 one has $n = 3$ for constant density and for large values of R_0 one as $n < 0$.

How to understand the dark matter core in TGD framework?

The second finding is that the core radius R_0 and the central density ρ_0 of the dark matter halo of these objects are related by the condition

$$\rho_0 \sim \frac{9.4M_S}{ly^2 R_0} \ , \tag{8.8.6}$$

where M_S is the mass of the Sun. If the density of dark matter is constant for $R < R_0$, this gives rise to rigid body rotation $v = \omega R$ inside the sphere of radius R_0. Halo models however predicts that the density of dark matter behaves like $1/R$ for small distances. This is known as core-cusp problem [E266] (see `http://tinyurl.com/yabhmxdm`).

This finding about mini spirals relates to TGD based model of galaxy in very interesting manner.

1. Since the dark matter dominates over the visible matter in mini spiral galaxies, the matter associated with this region must be modtly dark also in TGD based model. If there is mere cosmic string and if it dominates, the rotational curve would be constant rather than depending linearly on R as for solid body rotation. This cannot be the case.

2. Constant density of dark matter could be due to a formation of a knot- or spaghetti-like structure to the necklace containing galaxies as pearls. Also a thickening of the flux tube could take place. The thickening of the flux tube would reduce by the conservation of magnetic flux its energy density by ratio $T_i/T_f = (R_f/R_{CP_2})^2$. If the length of cosmic string inside R_0 is $R_1 = xR_0$, the total dark mass of this string enclosed inside volume R_0 would

$$M = T_f R_1 = T_f x R_0 = \frac{4\pi}{3} \times \rho_0 R_0^3 = \frac{4\pi}{3} \times \frac{9.4M(Sun)R_0^2}{ly^2} \ , \tag{8.8.7}$$

and one would have effective blackhole like entity but with T_f replacing $1/G$. This gives

$$T_f G = \frac{4\pi}{3} \times \frac{9.4 r_S(Sun) x R_0}{ly^2} \tag{8.8.8}$$

giving $T_f G = 1.22 \times 10^{-6}/x$. If the string tension is same as that of long string (the necklace), the value of x is about $x = 3.6$. If the thickening occurs the length of the knotted structure is longer and looks like spaghetti and the modelling as constant density of dark matter is better approximation. Note that the total length of knotted string portion behaves as R_0^2 and increases like the area of the dark sphere.

3. The model also explains why the dark matter inside R_0 does not have the same constant velocity spectrum as at large distances. Without the knotting one ends up with contradiction with empirical facts since constant velocity in this region would be much larger than the observed velocities.

4. Also the proposal that stars could be associated with long cosmic strings with possibly reduced string tension due to thickening finds support. Most stars of minimi galaxies reside within region defined by optical radius $R_D/R = \in [.3 - .5]$. If this is the case also for Milky Way, they could correspond to sub-knots in the galactic knot in long cosmic string. This string might become visible in pulsars: the light beam would naturally propagate along the cosmic string. This is consistent with the fact that Sun has distance about 8 kpc from the center of Milky Way and the size of Milky Way is about 10 times larger than the size of the minispirals studied.

   Also the interiors of TGD counterparts of blackholes would be knots and have magnetic structure, which could predict unexpected features such as magnetic moments not possible for GRT blackholes. Already the model for the first LIGO event [**?**]xplained the unexpected gamma ray bursts in terms of twisting of the rotating flux tubes as an effect analogous to what causes sunspots: twisting and finally reconnection. What about collisions of blackholes? Could they correspond to two knots moving along same string and colliding or two cosmic strings with possible self-intersect or are very near to each other: galactic traffic accident?

Could one consider instead of constant density of dark matter a genuine spherical surface with surface mass density $\sigma = \rho_0 R_0/3$? It could be present but cannot explain velocity spectrum for $R < R_0$: knotted long string is necessary. I have earlier considered the possibility of this kind of spherical shell consisting of dark matter around galactic nucleus. The key motivation for the idea about surface density is that σ would be universal - at least for mini spirals. This kind of surface associated with Earth and with radius about distance of Moon could explain Flyby anomaly. This kind of dark matter shells could also induce the formation of moons and planets in solar system.

Knotted strings, Fermi bubble, and supermassive blackholes

Galactic centers involve poorly understood phenomena, which TGD based vision should be able to cast some light.

1. Fermi bubbles [E270] (see `http://tinyurl.com/y9z3doj9` and `http://tinyurl.com/y9qkjdau`) detected by Fermi telescope above and below the plane of Milky Way have radius about 2-3 kpc, whereas the optical radii for mini spirals are slightly below 1 kpc and R_0 is reported to be 2-3 times larger - about 2-3 kpc too. Milky Way is not a mini spiral but there could be a connection.

   Could Fermi bubbles be a universal phenomenon and relate to the dark matter sphere? Could the radius of the dark matter sphere define the size scale of Fermi bubbles? Fermi bubble is probably related to cosmic ray radiation emerging from the center of the galaxy and inducing in collisions with visible and possibly also dark matter gamma rays, X-ray and microwaves. Since cosmic rays cannot not propagate far in the galactic plane, one has two spheres rather than one. The radius of dark matter sphere defines the upper bound for the propagation distance.

   If cosmic rays interact also with dark matter and induce dark radiation such that part of it transforms to ordinary radiation, the radius of the dark matter sphere would naturally define the upper limit for the distance at which radiation is generated. The simplest option is that the cosmic rays propagate as dark particles from the blackhole and transform only later to ordinary particles. The mechanism transforming dark photons to ordinary ones would be analogous to that producing biophotons [K13].

2. Could there be a connection with the supermassive galactic blackhole in Milky Way (see http://tinyurl.com/y9fhabdk)? One particular model for Fermi bubbles [E51] (see http://tinyurl.com/y6vjw6ej and http://tinyurl.com/yafcz2lh and) assumes that they are remnants of stars eaten by galactic blackhole with mass about 4×10^6 solar masses with Schwartschildt radius about 40 ls (for Sun one gas $r_S = 3$ km): one has roughly $r_S \sim 10^{-6} R_0$. Blackhole would devour part of the stars and burp the rest back out as cosmic ray radiation.

3. One can also wonder about the origin of galactic super-massive blackhole. Could galactic blackhole be a reconnection point of two cosmic strings, which led to the formation of galaxies as some empirical findings such as satellite galaxies in plane nearly orthogonal to the galactic plane suggest? If this is the case the matter of the galactic blackhole could be dark and would emit dark cosmic rays. Or could the blackhole correspond to self-intersection and knotting of a long cosmic string so that second cosmic string would not be necessary?

New view about blackhole like objects and galaxy formation?

I had very interesting discussions with Gareth Lee Meredith who has founded the discussion group Beyond Standard Model. One of the topics of discussion were results related to supermassive blackholes at the centers of galaxies. Gareth gave a link to a popular article (see http://tinyurl.com/jbn56ul) telling about correlations between supermassive blackhole in galactic center and the evolution of galaxy itself.

1. The size of the blackhole like object - that is its mass if blackhole in GRT sense is in question - correlates with the constant rotation velocity of distant stars for spiral galaxies.

2. The relationship between the masses of black hole and galactic bulge are in constant relation: the mass ratio is about 700.

3. A further finding is that galactic blackholes of very old stars are much more massive than the idea about galactic blackhole getting gradually bigger by "eating" surrounding stars would suggests.

This looks strange if one believes in the standard dogma that the galactic blackhole started to form relatively lately. What comes in mind is rather unorthodox idea. What if the large blackhole like entity was there from the beginning and gradually lost its mass? In TGD framework this could make sense!

1. In TGD Universe galaxies are like pearls in a necklace defined by a long cosmic string. This explains the flat rotational spectrum and predicts essentially free motion along the string related perhaps to coherent motions in very long length scales. This explains also the old observation that galaxies form filament like structures and the correlations between spin directions of galaxies along the same filament since one expects that the spin is parallel to the filament locally. Filament can of course change its direction locally so that charge of direction of rotation gives information about the filament shape.

2. The channelling of gravitational flux in the radial direction orthogonal to the string makes gravitational force very long ranged ($1/\rho$, ρ the transversal distance, instead of $1/r^2$, r the radial distance) and also stronger and predicts rotational spectrum. This model of dark matter differs dramatically from the fashionable halo model and involves only the string tension as a parameter unlike the halo model.

   The observed rigid body rotation within radius 2-3 times the optical radius (region inside which most stars are) can be understood if the long cosmic string is either strongly knotted or has closed galactic string around long cosmic string. The knotted portion would formed a highly knotted spaghetti like structure giving approximately constant mass density. Stars would be associated with the knotted structure as sub-knots. Light beams from supernovas could be along the string going through the star. Maybe even planets might be associated with thickened strings! One can also imagine intersections of long cosmic strings and Milky Way could contain such.

3. Galactic black hole like object could correspond to a self intersection of the long cosmic string or of closed galactic cosmic string bound to it. There could be several intersections. They would contain both dark matter and energy in TGD sense and located inside the string. Matter antimatter asymmetry would mean that there is slightly more antimatter inside string and slightly more matter outside it. Twistor lift of TGD predicts the needed new kind of CP breaking. What is new that the galactic blackhole like objects would be present from the beginning and lose their dark mass gradually. Time evolution would be opposite to what it has been usually thought to be!

   Most of the energy of the cosmic string would be magnetic energy identifiable as dark energy. During the cosmic evolution various perturbations would force the cosmic string to gradually thicken so that in M^4 projection ceases to be pointlike. Magnetic monopole flux is conserved ($BS=$ constant, S the transversal area), which forces magnetic energy density per unit length - string tension - to be reduced like $1/S$. The lost energy becomes ordinary matter: the energy of inflaton field would be replaced with dark magnetic energy and the TGD counterpart for inflationary period would be transition from cosmic string dominated period to radiation dominated cosmology and also the emergence of space-time in GRT sense.

   The primordial cosmic string dominated phase would consist of cosmic strings in $M^4 \times CP_2$. The explanation for the constancy of CMB temperature would suggest quantum coherence in even cosmic scales made possible by the hierarchy of dark matters labelled by the valued of Planck constant $h_{eff}/h = n$. Maybe characterization as a super-fluid rather than gas discussed with Gareth is more precise manner to say it. What would be fantastic that these primordial structures would be directly visible nowadays.

4. The dark matter particles emanating from the dark supermassive blackhole would transform gradually to ordinary matter so that galaxy would be formed. This would explain the correlation of the bulge size with the mass (and size) of the blackhole correlating with the string tension. The rotational velocity of distant stars with string tension so that the strange correlation between velocity of distant stars and size of galactic blackhole is implied by a common cause.

   This also explains the appearance of Fermi bubbles visible above and below the plane of Milky Way at X ray and gamma energies. Fermi bubbles are formed when dark particles from the blackhole scatter with dark matter and partially transform to ordinary cosmic rays and produce dark photons transformed to visible photons partially. This occurs only within the region where the spaghetti like structure containing dark matter inside the cosmic string exists. Fermi bubbles indeed have the same size as this region.

5. While writing this I realized that also the galactic bar (2/3 of spiral galaxies have it) should be understood (see `http://tinyurl.com/p5xez38`). This is difficult if there is nothing breaking the rotational symmetry around the long cosmic string. The situation changes if one has a portion of cosmic string along the plane of galaxy.

   There is indeed evidence for the second straight string portion: in Milky Way there are mini-galaxies rotating in the plane forming roughly 60 degrees angle with respect to galactic plane and the presence of two cosmic strings portions roughly orthogonal to each other could explain this [L30]. Galactic blackhole could be associated with the intersection of string portions. The horizontal string portion could be part of long cosmic string, a separate closed cosmic string, or even another long cosmic string. One can imagine two basic options for the formation of the bar.

   (a) The first option is that galactic bar is formed around the straight portion of string. The gravitational force orthogonal to the string portion would create the bar. The ordinary matter in rigid body rotation would be accelerated while approaching the bar and then slow down and dissipate part of its energy in the process. The slowed down stars would after a further rotation of π tend to stuck around the string portion forming bound states with it and start to rotate around it: a kind of galactic traffic jam. Bars would be asymptotic outcomes of the galactic dynamics. Recent studies have confirmed the idea that bars are now are signs of full maturity as the "formative years" end (see `http://tinyurl.com/p5xez38`).

(b) Second option is that bar is formed as dark matter inside bar is transformed to ordinary matter as the portion thickens and loses dark energy identified as Kähler magnetic energy by a process analogous to the decay of inflaton vacuum energy. Bars would be transients in the evolution of galaxies rather than final outcomes. This option is not consistent with the idea that that only the galactic blackhole serves as the source of dark matter transforming to ordinary matter.

6. The pearls in string model explains also why elliptic galaxies have declining rotational velocity. They correspond to "free" closed strings which have not formed bound states with long cosmic strings transforming them to spiral galaxies. The recently found 10 billion old galaxies with declining rotational velocity could correspond to elliptical galaxies of this kind.

   One can also imagine the analog of ionization. The bound state of closed cosmic string and long cosmic string decays and spiral galaxy starts to decay under centrifugal force not anymore balanced by the gravitational force of the long cosmic strings and would transform to elliptic galaxy. Also the central bulge would start to increase in size.

   It would also lose its central blackhole if is associated with the long cosmic string. I am grateful for Gareth for giving a link to a popular article (see `http://tinyurl.com/komloy8`) telling about this kind of elliptic galaxy with very large size of one million light years and without central blackhole and unusually large bulge region.

This view about galactic blackholes also suggests a profound revision of GRT based view for the formation of blackholes. Note that in TGD one must of course speak about blackhole like objects differing from their GRT counterparts inside Schwartschildt radius and also outside it in microscopic scales (gravitational flux is mediated by magnetic flux tubes carrying dark particles). Perhaps also ordinary blachholes were once intersections of dark cosmic strings containing dark matter which gradually produce the stellar matter! If so, old blackholes would be more massive than the young ones.

1. This new thinking conform with the findings of LIGO [K93] [L24]. All the three stellar blackholes have been by more than order of magnitude massive than expected. There are also indications that the members of the second blackhole pair merging together did not have parallel spin directions. This does not fit with the idea that a twin pairs of stars was in question. It is very difficult to understand how two blackholes, which do not form bound system could find each other. Similar problem is encountered in bio-catalysis: who to biomolecules manage to find each other in the molecular crowd. The solution to the both problem is very similar.

2. TGD suggests that the collision could have occurred when to blackholes travelling along strings or portions of the same knotted string arrived from different directions. The gravitational attraction between strings would have helped to generate the intersection and strings would have guided the blackholes together. In biological context even a phase transition reducing Planck constant to the flux tube connecting the molecules could occur and bring the molecules together.

Are stars borne in pairs?

Stars seem to be born in pairs! For a popular article see `http://tinyurl.com/ybto4tux`. The research article "Embedded Binaries and Their Dense Cores" [E241] is at `http://tinyurl.com/ycnye48y`.

For instance, our nearest neighbor, Alpha Centauri, is a triplet system. Explanation for this have been sought for for a long time. Does star capture occur leading to binaries or triplets. Or does its reverse process in which binary splits up to become single stars occur? There has been even a search for a companion of Sun christened Nemesis.

The new assertion is based on radio survey of a giant molecular cloud filled with recently formed sunlike stars (with age less than 4 million years) in constellation Perseus, a star nursery located 600 ly from us in Milky Way. All singles and twins with separations above 15 AUs were counted.

The proposed mathematical model was able to explain the observations only if all sunlike stars are born as wide binaries. "Wide" means that the mutual distance is more than 500 AU, where AU is the distance of Earth from Sun. After the birth the systems would shrink or split t within time about million years. It was found that wide binaries were not only very young but also tended to be aligned along the long axes of an egg-shaped dense core. Older systems did not have this tendency. For instance, triplets could form as binary captures a single star.

The theory says nothing about why the stars should born as binaries and what could be the birth mechanism. Could TGD say anything interesting about the how the binaries are formed?

1. TGD based model for galaxies leads to the proposal that the region in which dark matter has constant density corresponds to a very knotted and possibly thickened cosmic string portion or closed very knotted string associated with long cosmic string. There would be an intersection of separate cosmic strings or self-intersection of single cosmic string giving rise to a galactic blackhole from which dark matter emerges and transforms to ordinary matter. Star formation would take place in this region 2-3 times larger than the optical region.

2. Could an analogous mechanism be at work in star formation? Suppose that there is cosmic string in galactic plane and it has two nearby non-intersecting portions roughly parallel to each other. Deform the other one slightly locally so that it forms intersections with another one. The minimal number of stable intersections is 2 and even number in the general case. Single intersection corresponding to mere touching is a topologically unstable situation. If the intersections give rise to dark blackholes generating later the stars would have explanation for why stars are formed as twin pairs.

This would also explain why the blackholes possibly detected by LIGO are so massive (there is still debate about this going on): they would have not yet produced ordinary stars, a process in which part of dark matter and dark energy of cosmic strings transforms to ordinary matter.

1. Suppose that these blackhole like objects are indeed intersections of two portions of cosmic string(s). The intersections have gravitational interaction and could move along the second cosmic string towards each other and eventually collide.

2. More concretely, one can imagine a straight horizontal starionary string A (at x-axis with $y = 0$ in (x,y)-coordinates) and a folded string B with a shape of an inverted vertical parabola ($y = -ax^2 + y_0(t)$, $a > 0$, and moving downwards. In other words, $y_0(t)$ decreases with time. The strings A and B have two nearby intersections $x_\pm = \pm\sqrt{y_0(t)/a}$. Their distance decreases with time and eventually the intersection points fuse together at $y_0(t) = 0$ and give rise to the fusion of two black-hole like entities to single one.

Death blow to dark matter disks

The standard view about dark matter is as a halos associated with galaxies and also other astrophysical objects. Nature however seems to be reluctant to behave according to the dictates of halo theorists. The reproduction of the simple flat velocity spectrum for distant stars in galactic plane requires tuning of the parameters characterizing the dark mass distribution in the halo. There is also a small constant density core around the center of galaxy behaving like rigid body rather than a density peak with maximum at the center. Also the attempts to detect various exotic particles proposed to serve as building bricks of dark matter have chronically failed. Quite recently very old galaxies which do not have dark matter have been found.

The latest trouble of the model, one might say a death blow, is that dark matter disks do not seem to exist at all (see `http://tinyurl.com/y7o6fmfe`)! I am afraid that this means serious funding problems for the model builders.

The death of one idea is the victory of second one. I have been preaching for almost two decades that galactic dark matter along cosmic string containing galaxies like pearls in necklace: there would be no dark matter halo [L46, L30]. The model predicts correct velocity profile for distant stars without furher assumptions: the value of string tension determines the value of the velocity. The model solvs a multitude of anomalies of halo model, and leads to a rather detailed model for evolution of galaxies and also provides insights to problems like matter-antimatter asymmetry.

8.8.3 Further problems of the halo model of dark matter

8.8.4 Further problems of the halo model of dark matter

The anomalies of the halo model of dark matter have begun to accumulate rapidly. MOND is the most well-known competitor of the halo model for dark matter but has its own problems. TGD is less known alternative for the halo model.

In the following brief comments about some of anomalies about which I did not know before are discussed. They are discussed in detail in the blog "Dark matter crisis" of Prof. Pavel Kroupa and Marcel S. Pawlowski (see `http://tinyurl.com/l73ztp8`).

Zwicky paradox

Zwicky paradox (see `http://tinyurl.com/mltvwmz`) implies that neither cold nor warm dark matter particles in the usual sense of the word (different from that in TGD based model) can play a significant role in cosmology.

The standard/concordance model of dark matter relies on two hypothesis formulated originally by Zwicky assuming that a) GRT is correct in all scales and b) all matter is created during Big Bang. Zwicky formulated two hypothesis (for references see the article) leading to the halo model of dark matter and also to Zwicky paradox.

1. Zwicky noticed (1937) that galaxies must about 500 heavier in the Coma galaxy cluster than judged from their light emission: cold or hot dark matter must exist. Note that this does not require that the dark matter consists of some exotic particles or that the dark matter forms halos. To get historical perspective note also that Vera Rubin published 1976 an article about the flatness of velocity curves for distant stars for Andromeda, which is spiral galaxy.

2. Zwicky noticed (1956) that when galaxies collide, the expelled matter can condense in new regions and form new smaller dwarf galaxies. These so called tidal galaxies are thus formed from the collisional debris of other galaxies.

From these observations one ends up with a computer model allowing to simulate the formation of galaxies (for details see `http://tinyurl.com/mltvwmz`this). The basic elements of the model are collisions of galaxies possibly leading to a fusion and formation of tidal galaxies. The model assumes a statistical distribution of dark matter lumps defining the halos of the dwarf galaxies formed in the process.

The model predicts a lot of dark matter dominated dwarf galaxies formed around the dark matter lumps: velocity spectrum should approach constant. There are also tidal dwarf galaxies formed from collision debris of other galaxies. Unless also now condensation around a dark matter lump is involved, these should not contain dark matter and velocity spectrum for tidal dwarfs should be declining.

It turns out that tidal dwarfs alone are able to explain the observed dwarf galaxies, which are typically elliptic. Furthermore, there is no empirical manner to distinguish between tidal dwarfs and other dwarfs.

Do the elliptic galaxies contain dark matter? What does one know about the rotation curves of elliptic galaxies? There is an article "The rotation curves of elliptic galaxies" of J. Binney published around 1979 about the determination of the rotation curves of elliptic galaxies giving also some applications (see`http://tinyurl.com/l7qrlho`). The velocity curves are declining as if no dark matter were present in tidal dwarfs. Therefore dark matter would not be present in dwarf galaxies so that the prediction of the halo model would be wrong.

Could this finding be also a problem for MOND? Assuming that the laws governing gravitation are modified for small accelerations, shouldn't elliptic and spiral galaxies have similar velocity curves?

What about TGD?

1. In TGD Universe dark energy and matter reside at flux tubes along which disk galaxies condense like pearls in string.

2. The observation about velocity curves suggests a TGD based explanation for the difference between elliptic and spiral galaxies. Elliptic galaxies - in particular tidal dwarfs - are not associated with a flux tube containing dark matter. Spiral galaxy can form as elliptic galaxy if it becomes bound with flux tube as the recent finding about declining velocity curves for galaxies with age about 10 Gy suggest. This also conforms with the fact that the stars in elliptic galaxies are much older than in spiral galaxies (see `http://tinyurl.com/ayyvg9n`).

3. Dwarf galaxies produced from the collision debris contain only ordinary matter. Elliptic galaxies can later condense around magnetic flux tubes so that velocity spectrum approaches constant at large distances. The breaking of spherical symmetry to cylindrical symmetry might allow to understand why the oblate spheroidal shape is flattened to that of disk.

Vast polar structure

The vast polar structure (VPS) is a planar structure nearly orthogonal to galactic plane (see `http://tinyurl.com/k553545` and `http://tinyurl.com/lk53s3v`) [E53] is also a blow against halo theory. I have already commented this structure [K31] and I add my earlier comments below essentially as such.

The observation is that Milky Way has a distribution of satellite galaxies and star clusters, which rotate around the Milky Way in plane orthogonal to Milky Way's plane. One can visualize the situation in terms of two orthogonal planes such that the second plane contains Milky Way and second one the satellite galaxies and globular clusters. The Milky Way itself has size scale of .1 million light years whereas the newly discovered structure extends from about 33, 000 light years to 1 million light years. The study is carried out by astronomers in Bonn University and will be published in journal Monthly Notices of the Royal Astronomical Society. The lead author is Ph. D. student Marcel Pawlowski.

According to the authors, it is not possible to understand the structure in terms of the standard model for dark matter. This model assumes that galactic dark matter forms a spherical halo around galaxy. The problem is the planarity of the newly discovered matter distribution. Not only satellite galaxies and star clusters but also the long streams of material left - stars and also gas - behind them as they orbit around Milky Way move in this plane. Planarity seems to be a basic aspect of the internal dynamics of the system. As a matter fact, quantum view about the formation of also galaxies predicts planarity and this allows also to understand approximate planarity of solar system [K79]: common quantization axis of angular momentum defined by the direction of string like object in the recent case with a gigantic value of gravitational Planck constant defining the unit of angular momentum would provide a natural explanation for planarity.

TGD explanation for different anomaly led few years ago to the proposal that Milky Way is in the crossing of two magnetic flux tubes (cosmic strings), whose mass density explains the constant velocity spectrum. Quite generally, ordinary matter would be formed in reconnections of flux tubes inducing transformation of the energy of flux tubes to ordinary matter. This does not conform with LambdaCDM model. The so called vast polar structures are in plane nearly orthogonal to the plane of Milky Way which conforms with the hypothesis.

The third blow (see `http://tinyurl.com/lk53s3v`) [E53] against the theory comes from the observation that Milky Way has a distribution of satellite galaxies and star clusters, which rotate around the Milky Way in plane orthogonal to Milky Way's plane. One can visualize the situation in terms of two orthogonal planes such that the second plane contains Milky Way and second one the satellite galaxies and globular clusters. The Milky Way itself has size scale of .1 million light years whereas the newly discovered structure extends from about 33, 000 light years to 1 million light years. The study is carried out by astronomers in Bonn University and will be published in journal Monthly Notices of the Royal Astronomical Society. The lead author is Ph. D. student Marcel Pawlowski.

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The proposal of the researchers is that the situation is an outcome of a collision of two galaxies.

1. An amusing co-incidence is that the original TGD inspired model for the formation of spiral galaxies [K31] assumed that they result when two primordial cosmic strings intersect each other. This would be nothing but the counterpart of closed string vertex giving also rise to reconnection of magnetic flux tubes. Later I gave up this assumption and introduced the model in which galaxies are like pearls in necklace defined by primordial cosmic strings which since then have thickened to magnetic flux tubes. These pearls could themselves correspond to closed string like objects or their decay products. Magnetic energy would transform to matter and would be the analog for the decay of inflaton field energy to particles in inflationary scenarios.

2. As already noticed, in TGD Universe galactic dark matter would correspond to the matter assignable to the magnetic flux tube defining the necklace creating $1/\rho$ gravitational accelerating explaining constant velocity spectrum of distant stars in galactic plane.

Could one interpret the findings by assuming two big cosmic strings which have collided and decayed after that to matter? Or should one assume that the galaxies existed before the collision.

1. The collision would have induced the decay of portions of these cosmic strings to ordinary and dark matter with large value of Planck constant. The magnetic energy of the cosmic strings identifiable as dark energy would have produced the matter. It is however not clear why the decay products would have remained in the planes orthogonal to the colliding orthogonal flux tubes. According to the researchers the planar structures must have existed before the collision. This would support the idea about cosmic traffic accident. This supports the view about cosmic collision.

2. This suggests that the two flux tubes pass near each other and the galaxies have moved along the flux tubes and collided and remained stuck to each other by gravitational attraction. The probability of this kind of galactic collisions depends on what one assumes about the distribution of string like objects. Due to their mutual gravitational attraction the flux tubes could be attracted towards each other to form web like structures forming a network of cosmic highways. Milky Way would represent on particular node at which two highways form a cross-road. In this kind of situation the collisions resulting s cross-road crashes could be more frequent than those resulting from encounters of randomly moving strings. The galaxies arriving to this kind of nodes would tend to form a bound state and remain in the node. It could also happen that the second galaxy continues its journey but leaves matter behind in the form of satellite galaxies and globular clusters.

A further blow against dark matter halo paradigm

The following is essentially a comment about the the most recent finding (see `http://tinyurl.com/ybxnycmz`) challenging the dark matter halo paradigm. The article titled "*A whirling plane of satellite galaxies around Centaurus A challenges cold dark matter cosmology*" by Mueller O *et al* published in Science [E148] can be found also in Archive (see `http://tinyurl.com/yblckuqv`).

The halo model for dark matter encounters continually lethal problems as I have repeatedly tried to tell in my blog postings and articles. But still this model continues to add items to the curriculum vitae of the specialists - presumably as long as the funding continues. Bad ideas never die.

Halo model predicts that the dwarf galaxies around massive galaxies like Milky should move randomly. The newest fatal blow comes from the observation that dwarf galaxies move along neat circular orbits in the galactic plane of Centaurus A.

Just like the TGD based pearls-in-necklace model of galaxies as knots (the pearls) of long cosmic strings [L47] (see `http://tinyurl.com/yagh95q4`) predicts! The long cosmic string creates gravitational field in transversal direction and the dwarf galaxies move along nearly circular orbits. The motion along long cosmic string would be free motion and would give rise to streams. The prediction is that at large distances the rotational velocities approach constant just as in the case of distant stars.

Missing matter and dark matter

One problem of ΛCDM scenario is missing of matter and dark matter in some places (see `http://tinyurl.com/k5bu445`). There missing dark matter in the scale of $R = .2$ Gy and also in the vicinity of solar system in the scale 1.5-4 kpc.

In the work titled "Missing Dark Matter in the Local Universe", Igor D. Karachentsev studied a sample of 11,000 galaxies in the local Universe around the MW (see `http://tinyurl.com/mnzxhyu`). Karachentsev summed up the masses of individual galaxies and galaxy-groups and used this to test a very fundamental prediction of ΛCDM.

1. Standard cosmology predicts the average fraction of matter to be $\Omega_{m,glob} = 28 \pm 3$ per cent of critical mass density (83 percent matter would be dark and 17 per cent visible matter). 72 per cent of total density would be dark energy, 28 per cent dark matter, and 4.8 per cent visible matter.

   To test this one can simply sum up all the galactic masses in some volume Karachentsev chose the volume to be a sphere of radius $R = .2$ Gy surrounding Milky Way and containing 11,000 galaxies. In this scale the density is expected to fluctuate only 10 per cent. Note that horizon radius is estimated to be about $R_H = 14$ Gly giving $R_H = 70R$.

2. The visible galactic mass in certain large enough volume of space was estimated as also the sum of galactic dark masses estimated as so called virial mass (see `http://tinyurl.com/lfm8msr`). The sum of these masses gave the estimate for the total mass.

3. The estimate for the total galactic was $\Omega_{m,glob} = 8 \pm 3$ per cent from critical mass, which is only 28 per cent of the fraction predicted by concurrent cosmology. The predicted fraction of visible matter is 4.8 per cent and marginally consistent with 8 ± 3 per cent but it seems plausible that also dark matter is present although its amount is small. The total contribution to the dark matter could be at most of the same size as that of visible matter.

4. One explanation is that all matter has not been included. Second not very plausible explanation is that the measurement region corresponds to a region with abnormally low density.

Can on understand the finding in TGD framework?

1. In TGD based model part of dark energy/matter would reside at the long flux tubes with which galaxies form bound states. Constraints come from accelerated expansion and galactic velocity curves allowing to determine string tension for given galaxy. Let us assume that the GRT limit of TGD and its predictions hold true.

   The estimate for the virial mass assumes that galaxy's dark mass forms a halo. The basic observation is that in TGD flux tubes give the dark energy and mass and virial mass would underestimate the dark mass of the galaxy.

2. How long length of the flux tube effectively corresponds to the dark and visible mass of disk galaxy? This length should be roughly the length containing the dark mass and energy estimated from cosmology: $L = M_{dark}/T$. If GRT limit of TGD makes sense, one has $M_{dark} = xM_{vis}/T$, where M_{dark} is the amount of dark energy + matter associated with the flux tube, M_{vis} is visible mass, $x \simeq \rho_{dark}/\rho_{vis} \simeq 83/17$, and T is string tension deduced from the asymptotic rotation velocity.

   If these segments do not cover the entire flux tubes containing the galaxies along it, the amount of dark matter and energy will be underestimated. By the above argument elliptic galaxies would not have considerable amount of dark matter and energy so that only disk galaxies should contribute unless there are flux tubes in shorter scales inside elliptic galaxies.

Also larger and smaller scale flux tube structures contribute to the dark energy + dark matter. Fractality suggests the presence of both larger and smaller flux tube structures than those associated with spiral galaxies (even stars couldbe associated with flux tubes).

One should have estimates for the lengths of various flux tubes involved. Unfortunately this kind of estimate is not available.

3. If GRT limit makes sense then the total dark mass then the dark energy and matter obtained in this manner should give 95 per cent of critical mass density. The fraction of dark matter included would be at most a fraction $5/28 \simeq 18$ per cent of the total dark matter. 82 per cent of dark matter and energy would be missed in the estimate. This could allow to get some idea about the lengths of flux tubes and density of galaxies along flux tubes.

The amount of dark matter in the solar neighborhood was investigated in the work "Kinematical and chemical vertical structure of the Galactic thick disk II. A lack of dark matter in the solar neighborhood" by Christian Moni Bidin and collaborators (see `http://tinyurl.com/yapbqnwo`). Moni Bidin *et al* have studied as sample of 400 red giants in the vicinity of solar system at vertical distances 1.5 to 4 kpc and deduce 3-D kinematics for these start. From this data they estimate the surface mass density of the Milky Way within this range of heights from the disk. This surface density should be sum of both visual and dark mass.

According to their analysis, the visible mass is enough to explain the data. No additional mass is needed. Only highly flattened dark matter halo would be consistent with the findings. This conforms with the TGD prediction that dark mass/energy are associated with magnetic flux tubes.

Low surface brightness galaxies as additional support for pearls-in-necklace model for galaxies

Sabine Hossenfelder had an inspiring post (see `http://tinyurl.com/ybmbzczr`) about the problems of the halo dark matter scenario. My attention was caught by the title "Shut up and simulate". It was really to the point. People stopped first to think, then to calculate, and now they just simulate. Perhaps AI will replace them at the next step.

While reading I realized that Sabine mentioned a further strong piece of support for the TGD view about galaxies as knots along cosmic strings, which create cylindrically symmetric gravitational field orthogonal to the string rather than spherically symmetric field as in halo models. The string tension determines the rotation velocity of distant stars predicted to be constant constant up to arbitrarily long distances (the finite size of space-time sheet of course brings in cutoff length).

To express it concisely: Sabine told about galaxies, which have low surface brightness. In the halo model the density of both matter and dark matter halo should be low for these galaxies so that the velocity of distant stars should decrease and lead to a breakdown of so called Tully-Fisher relation. It doesn't.

I am not specialist in the field of astrophysics and it was nice to read the post and refresh my views about the problem of galactic dark matter.

1. Tully-Fisher-relation (TFR) (see `http://tinyurl.com/ybhaat64`) is an empirically well-established relation between the brightness of a galaxy and the velocity of its outermost stars. Luminosity L equals to apparent brightness (luminosity per unit area) of the galaxy multiplied by the area $4\pi d^2$ of sphere with radius equal to the distance d of the observed galaxy. The luminosity of galaxy is also proportional to the mass M of the galaxy. TFR says that luminosity of spiral galaxy - or equivalently its mass - is proportional to the emission line width, which is determined by the spectrum of angular velocities of stars in the spiral galaxy. Apparent brightness and line width can be measured, and from these one can deduce the distance d of the star: this is really elegant.

2. It is easy to believe that the line width is determined by the rotation velocity of galaxy, which is primarily determined by the mass of the dark matter halo. The observation that the rotational velocity is roughly constant for distant stars of spiral galaxies - rather than decreasing like $1/\rho$ - this led to the hypothesis that there is dark matter halo around galaxy. By fitting the density of the dark matter properly, one obtains constant velocity. Flat velocity

spectrum implies that the line width is same also for distant stars as for stars near galactic center.

To explain this in halo model, one ends up with complex model for the interactions of dark matter and ordinary matter and here simulations are the only manner to deduce the predictions. As Sabine tells, the simulations typically take months and involve huge amount of bits.

3. Since dark matter halo is finite, the rotation velocity should decrease at large enough distances like $1/R$, R distance from the center of the galaxy. If one has very dilute galaxy - so called low surface brightness galaxy, which is very dim - the rotational velocities of distant stars should be smaller and therefore also their contribution to the average line width assignable to the galaxy. TFR is not expected to hold true anymore. The surprising finding is that it does!

The conclusion seems to be that there is something very badly wrong with the halo model. This is the message that the observational astrophysicist Stacy McGaugh is trying to convey in his blog (see `http://tinyurl.com/y9rwjjve`): about this the post of Sabine told.

Halo model of dark matter has also other problems.

1. Too many dwarf galaxies tend to be predicted.
2. There is also so called cusp problem: the density peak at the center of the galaxy tends to be too high. Observationally the density seems to be roughly constant in the center region, which behaves like rotating rigid body.

The excuses for the failures claim that the physics of normal matter is not well enough understood: the feedback from the physics of ordinary matter is believed to solve the problems. Sabine lists some possibilities.

1. There is the pressure generated when stars go supernovae, which can prevent the formation of the density peak. The simulations however show that practically 100 per cent of energy liberated in the formation of supernovas should go to the creation of pressure preventing the development of the density peak.
2. One can also claim that the dynamics of interstellar gas is not properly understood.
3. Also the accretion and ejection of matter by supermassive black holes, which are at the center of most galaxies could reduce the density peak.

One can of course tinker with the parameters of the model and introduce new ones to get what one wants. This is why simulations are always successful!

1. For instance, one can increase the relative portion of dark matter to overcome the problems but one ends up with fine tuning. The finding that TFR is true also for low surface brightness galaxies makes the challenge really difficult. Mere parameter fit is not enough: one should also identify the underlying dynamical processes allowing to get rid of the normal manner, and this has turned out to be difficult.
2. What strongly speaks against the feedback from the ordinary matter is that the outcome should be the same irrespective of how galaxies were formed: directly or through mergers of other galaxies. The weak dependence on the dynamics of ordinary matter strongly suggests that stellar feedback is not a correct manner to overcome the problem.

One can look at the situation also in TGD framework.

1. In pearls-in-necklace model galaxies are knots of long cosmic strings [K31, K93] [L47]. Knots have constant density and this conforms with the observation: the cusp problem disappears.

2. The long string creates gravitational field orthogonal to it and proportional to $1/\rho$, ρ the orthogonal distance from the string. This cylindrically symmetric field creates correlations in much longer scales than the gravitational field of spherical halo, which for long distances is proportional to $1/r^2$, r the distance from the center of the galaxy.

   Pearls-in-necklace model predicts automatically constant velocity spectrum at *arbitrary long*(!) distances. The velocity spectrum is independent of the details of the distribution of the visible matter and is proportional to the square root of string tension. There is almost total independence of the velocity spectrum of the ordinary matter as also the example of low surface brightness galaxies demonstrates. Also the history for the formation of the galaxy matters very little.

3. From TFR one can conclude that the mass of the spiral galaxy is (proportional to the luminosity proportional to the line width) and also proportional to the string tension. Since galactic mass varies also string tension must vary. This is indeed predicted. String tension is essentially the energy per unit length for the thickened cosmic string and would characterize the contributions of dark matter in TGD sense (phases of ordinary matter with large $h_{eff}h = n$ as well as dark energy, which contains both Kähler magnetic energy and constant term proportional to the 3-volume of the flux tube.

   Cosmology suggests that string thickness increases with time: this would reduce the Kähler magnetic contribution to the string tension but increase the contribution proportional to the 3-volume. There is also the dependence of the coefficient of the volume term (essentially the formal counterpart of cosmological constant), which depends on p-adic length scale like the inverse of the p-adic length scale squared $L(k) \propto 2^{k/2}$, where k must be positive integer, characterizing the size scale involved (this is something totally new and solves the cosmological constant problem) [L22]. It is difficult to say which contribution dominates.

4. Dwarf galaxies would require small string tension, hence the strings with small string tension should be rather rare.

If this picture is correct, the standard views about dark matter are completely wrong, to put it bluntly. Dark matter corresponds to $h_{eff}/h = n$ phases of ordinary matter rather than some exotic particle(s) having effectively only gravitational interaction, and there is no dark matter halo. TGD excludes also MOND. Dark energy and dark matter reside at the thickened cosmic strings, which belong to the simplest extremals of the action principle of TGD [K31, K9]. It should be emphasized that flux tubes are not ad hoc objects introduced to understand galactic velocity spectrum: they are a basic prediction of TGD and by fractality of TGD Universe present in all scales and are fundamental also for the TGD view about biology and neuroscience.

Maybe it might be a good idea to start to think again. Using brains instead of computers is also must a more cost-effective option: I have been thinking intensely for four decades, and this hasn't cost a single coin for the society! Recommended!

Dark matter and 21-cm line of hydrogen

Dark matter in TGD sense corresponds to $h_{eff}/h = n$ phases of ordinary matter associated with magnetic flux tubes. These flux tubes would be n-sheeted covering spaces, and n would correspond to the dimension of the extension of rationals in which Galois group acts. The evidence for this interpretation of dark matter is accumulating. Here I discuss one of the latest anomalies - so called 21-cm anomaly.

Sabine Hossenfelder (see `http://tinyurl.com/y7h5ys2r`) told about the article [E110] discussing the possible interpretation (see `http://tinyurl.com/yasgfgq8`) of so called 21-cm anomaly associated with the hyperfine transition of hydrogen atom and observed by EDGES collaboration [E112].

The EDGES Collaboration has recently reported the detection of a stronger-than-expected absorption feature in the global 21-cm spectrum, centered at a frequency corresponding to a redshift of $z \sim 17$. This observation has been interpreted as evidence that the gas was cooled during this era as a result of scattering with dark matter. In this study, we explore this possibility, applying constraints from the cosmic microwave background, light element abundances, Supernova 1987A, *and a variety of laboratory experiments. After taking these constraints into account, we find that the vast majority of the parameter space capable of generating the observed 21-cm signal is ruled out. The only range of models that remains viable is that in which a small fraction, $\sim 0.3-2$ per cent, of the dark matter consists of particles with a mass of $\sim$ 10-80 MeV and which couple to the photon through a small electric charge, $\epsilon \sim 10^{-6}-10^{-4}$. Furthermore, in order to avoid being overproduced in the early universe, such models must be supplemented with an additional depletion mechanism, such as annihilations through a $L_\mu - L_\tau$ gauge boson or annihilations to a pair of rapidly decaying hidden sector scalars.*

What has been found is an unexpectedly strong absorption feature in 21-cm spectrum: the redshift is about $z = \Delta f/f \simeq v/c \simeq 17$, which from Hubble law $v = HD$ corresponds to a distance $D \sim 2.3 \times 10^{11}$ ly. Dark matter interpretation would be in terms of scattering of the baryons of gas from dark matter at lower temperature. The anomalous absorption of 21 cm line could be explained with the cooling of gas caused by the flow of energy to a colder medium consisting of dark matter. If I understood correctly, this would generate a temperature difference between background radiation and gas and consequent energy flow to gas inducing the anomaly.

The article excludes large amount of parameter space able to generate the observed signal. The idea is that the interaction of baryons of the gas with dark matter. The interaction would be mediated by photons. The small em charge of the new particle is needed to make it "dark enough". My conviction is that tinkering with the quantization of electromagnetic charge is only a symptom about how desperate the situation is concerning interpretation of dark matter in terms of some exotic particles is. Something genuinely new physics is involved and the old recipes of particle physicists do not work.

In TGD framework the dark matter at lower temperature would be $h_{eff}/h = n$ phases of ordinary matter residing at magnetic flux tubes. This kind of energy transfer between ordinary and dark matter is a general signature of dark matter in TGD sense, and there are indications from some experiments relating to primordial life forms for this kind of energy flow in lab scale [L39] (see `http://tinyurl.com/yassnhzb`) .

The ordinary photon line appearing in the Feynman diagram describing the exchange of photon would be replaced with a photon line containing a vertex in which the photon transforms to dark photon. The coupling in the vertex - call it m^2 - would have dimensions of mass squared. This would transform the coupling e^2 associated with the photon exchange effectively to e^2m^2/p^2, where p^2 is photon's virtual mass squared. The slow rate for the transformation of ordinary photon to dark photon could be see as an effective reduction of electromagnetic charge for dark matter particle from its quantized value.

Remark: In biological systems dark cyclotron photons would transform to ordinary photons and would be interpreted as bio-photons with energies in visible and UV.

To sum up, the importance of this finding is that it supports the view about dark matter as ordinary particles in a new phase. There are electromagnetic interactions but the transformation of ordinary photons to dark photons slows down the process and makes these exotic phases effectively dark.

Strange finding about galactic halo as a possible further support for TGD based model of galaxies

A team led by Maria Bergemann from the Max Planck Institute for Astronomy in Heidelberg, has studied a small population of stars in the halo of the Milky Way (MW) and found its chemical composition to closely match that of the Galactic disk [E109] (see `http://tinyurl.com/yb34t2kz`). This similarity provides compelling evidence that these stars have originated from within the disc, rather than from merged dwarf galaxies. The reason for this stellar migration is thought to be theoretically proposed oscillations of the MW disk as a whole, induced by the tidal interaction of the MW with a passing massive satellite galaxy.

One can divide the stars in MW to the stars in the galactic disk and those in the galactic halo. The halo has gigantic structures consisting of clouds and streams of stars rotating around the center of the MW. These structures have been identified as a kind of debris thought to reflect the violent past of the MW involving collisions with smaller galaxies.

The scientists investigated 14 stars located in two different structures in the Galactic halo, the Triangulum-Andromeda (Tri-And) and the A13 stellar over-densities, which lie at opposite sides of the Galactic disc plane. Earlier studies of motion of these two diffuse structures revealed that they are kinematically associated and could relate to the Monoceros Ring, a ring-like structure that twists around the Galaxy. The position of the two stellar over-densities could be determined as each lying about 5 kiloparsec (14000 ly) above and below the Galactic plane. Chemical analysis of the stars made possible by their spectral lines demonstrated that they must must originate from MW itself, which was a complete surprise.

The proposed model for the findings is in terms of vertical vibrations of galactic disk analogous to those of drum membrane. In particular the fact that the structures are above and below of the Monoceros Ring supports this idea. The vibrations would be induced by the gravitational interactions of ordinary and dark matter of galactic halo with a passing satellite galaxy. The picture of the article [E109] (see `http://tinyurl.com/yb34t2kz`) illustrates what the pattern of these vertical vibrations would look like according to simulations.

In TGD framework this model is modified since dark matter halo is replaced with cosmic string. Due to the absence of the dark matter halo, the motion along cosmic string is free apart from gravitational attraction caused by the galactic disk. Cosmic string forces the migrated stars to rotate around to the cosmic string in plane parallel to the galactic plane and the stars studied indeed belong to ring like structures: the prediction is that these rings rotate around the axis of galaxy.

One can argue that if one has stars are very far from galactic plane - say dwarf galaxy - the halo model of dark matter suggests that the orbital plane arbitrary but goes through galactic center since spherically symmetric dark matter halo dominates in mass density. TGD would predict that the orbital plane is parallel to to the galactic plane.

Are the oscillations of the galactic plane necessary in TGD framework?

1. The large size of and the ring shape of the migrated structures suggests that oscillations of the disk could have caused them. The model for the oscillations of MW disk would be essentially that for a local interaction of a membrane (characterized by tension) with its own gravitational field and with the gravitational field of G passing by. Some stars would be stripped off from the membrane during oscillations.

2. If the stars are local knots in a big knot (galaxy) formed by a long flux tube as TGD based model for galaxy formation suggests, one can ask whether reconnections of the flux tube could take place and split from the flux tube ring like structures to which migrating stars are associated. This would reduce the situation to single particle level and it is interesting to see whether this kind of model might work. One can also ask whether the stripping could be induced by the interaction with G without considerable oscillations of MW.

The simplest toy model for the interaction of MW with G would be following: I have proposed this model of cosmic traffic accidents already earlier. Also the fusion of blackholes leading could be made probable if the blackholes are associated with the same cosmic string (stars would be subknots of galactic knots) [L24].

1. G moves past the MW and strips off stars and possibly also larger structures from MW: denote this kind of structures by O. Since the stripped objects at the both sides of the MW are at the same distance, it seems that the only plausible direction of motion of G is along the cosmic string along which galaxies are like pearls in necklace. G would go through MW! If the model works it gives support for TGD view about galaxies.

   One can of course worry about the dramatic implications of the head on collisions of galaxies but it is interesting to look whether it might work at all. On the other hand, one can ask whether the galactic blackhole for MW could have been created in the collision possibly via fusion of the blackhole associated with G with that of MW in analogy with the fusion of blackholes detected by LIGO.

2. A reasonable approximation is that the motions of G and MW are not considerably affected in the collision. MW is stationary and G arrives with a constant velocity v along the axis of cosmic string above MW plane. In the region between galactic planes of G and MW the constant accelerations caused by G and MW have opposite directions so that one has

$$\begin{array}{lll} g_{tot} = g_G - g_{MW} \ , & \text{between the galactic planes and above MW plane} \ , \\ g_{tot} = -g_G + g_{MW} \ , & \text{between the galactic planes and below MW plane} \ , \\ g_{tot} = -g_G - g_{MW} \ , & \text{above both galactic planes} \ , \\ g_{tot} = g_G + g_{MW} \ , & \text{below both galactic planes} \ . \end{array} \quad (8.8.9)$$

The situation is completely symmetric with respect to the reflection with respect to galactic plane if one assumes that the situation in galactic plane is not affected considerably. Therefore it is enough to look what happens above the MW plane.

3. If G is more massive, one can say that it attracts the material in MW and can induce oscillatory wave motion, whose amplitude could be however small. This would induce the reconnections of the cosmic string stripping objects O from MW, and O would experience upwards acceleration $g_{tot} = g_G - g_{MW}$ towards G (note that O also rotates around the cosmic string). After O has passed by G, it continues its motion in vertical direction and experiences deceleration $g_{tot} = -g_G - g_{MW}$ and eventually begins to fall back towards MW.

   One can parameterize the acceleration caused by G as $g_G = (1+x) \times g_{MW}$, $x > 1$ so that the acceleration felt by O in the middle regions between the planes is $g_{tot} = g_G - g = x \times g_{MW}$. Above planes of both G and MW the acceleration is $g_{tot} = -(2+x)g_{MW}$.

4. Denote by T the moment when O and G pass each other. One can express the vertical height h and velocity v of O in the 2 regions above MW as

$$\begin{array}{lll} h(t) = \frac{(g_G - g_{MW})}{2} t^2 \ , & v = (g_G - g_{MW})t \ , & t < T \ , \\ h(t) = -\frac{(g_G + g_{MW})}{2}(t-T)^2 + v(T)(t-T) + h(T) \ , & v(T) = (g_G - g_{MW})T \ , & \\ h(T) = \frac{(g_G - g_{MW})}{2} T^2 & t > T \ . & \end{array} \quad (8.8.10)$$

   Note that time parameter T tells how long time it takes for O to reach G if its has been stripped off from MW. A naïve estimate for the value of T is as the time scale in which the gravitational field of galactic disk begins to look like that of point mass.

   This would suggest that $h(T)$ is of the order of the radius R of MW so that one would have using $g_G = (1+x)g_{MW}$

$$T \sim \sqrt{\frac{1}{x}}\sqrt{\frac{2R}{g_{MW}}} \ .$$

5. The direction of motion of O changes at $v(T_{max}) = 0$. One has

$$\begin{array}{l} T_{max} = (\frac{2g_G}{g_G + g_{MW}} T \ , \\ h_{max} = -\frac{(g_G + g_{MW})}{2}(T_{max} - T)^2 + v(T)(T_{max} - T) + h(T) \ . \end{array}$$

6. For $t > T_{max}$ one has

$$h(t) = -\frac{(g_G + g_{MW})}{2}(t - T_{max})^2 + h_{max} \ , \quad h_{max} = -\frac{(g_G + g_{MW})}{2}(T_{max} - T)^2 + h(T) \quad (8.8.11)$$

   Expressing h_{max} in terms of T and parameter $x = (g_G - g_{MW})/g_{MW}$ one has

$$\begin{aligned} h_{max} &= y(x) g_{MW} \frac{T^2}{2} \ , \\ y(x) &= x \frac{5x+4}{2(2+x)} \sim x \ \text{for small values of } x \ . \end{aligned} \tag{8.8.12}$$

7. If one assumes that $h_{max} > h_{now}$, where $h_{now} \sim 1.4 \times 10^5$ ly the recent height of the objects considered, one obtains an estimate for the time T from $h_{max} > h_{now}$ giving

$$T > \sqrt{\frac{2(2+x)}{x(5x+4)}} T_0 \ , \quad T_0 = \frac{h_{now}}{g_{MW}} \ . \tag{8.8.13}$$

Note that $T_{max} < 2T$ holds true.

It is interesting to see whether the model really works.

1. It is easy to find (one can check the numerical factors at `http://tinyurl.com/t0om`) that g_{MW} can be expressed at the limit of infinitely large galactic disk as

$$g_{MW} = 2\pi G \frac{dM}{dS} = \frac{2GM}{R^2} \ ,$$

where R is the radius of galactic disk and $dM/dS = M/\pi R^2$ is the density of the matter of galactic disk per unit area. This expression is analogous to $g = GM/R_E^2$ at the surface of Earth.

2. One can express the estimate in terms of the acceleration $g = 10$ m/s^2 as

$$g_{MW} \simeq 2g (\frac{R_E}{R})^2 (\frac{M}{M_E}) \ .$$

The estimate for MW radius has lower bound $R = 10^5$ ly, MW mass $M \sim 10^{12} M_{Sun}$, using $M_{Sun}/M_E = 3 \times 10^6$ and $R_{Earth} \sim 6 \times 10^6$ m, one obtains $g_{MW} \sim 2 \times 10^{-10} g$.

3. Using the estimate for g_{MW} one obtains $T > \sqrt{2(2+x)/[x(5x+4)]} T_0$ with

$$T_0 \sim 3 \times 10^9 \ \text{years} \ . \tag{8.8.14}$$

The estimate $T \sim \sqrt{1/x} \sqrt{\frac{2R}{g_{MW}}}$ proposed above gives $T > \sqrt{1/x} \times 10^8$ years. The fraction of ordinary mass from total mass is roughly 10 per cent of the contribution of the dark energy and dark particles associated with the cosmic string. Therefore $x < .1$ is a reasonable upper bound for x parametrizing the mass difference of G and MW. For $x \simeq .1$ one obtains T in the range $1 - 10$ Gy.

TGD based explanation for why the rotation periods of galaxies are same

I learned in FB about very interesting finding about the angular rotation velocities of stars near the edges of the galactic disks [E147] (see `http://tinyurl.com/y7jlmkka`). The rotation period is about one giga-year. The discovery was made by a team led by professor Gerhardt Meurer from the UWA node of the International Centre for Radio Astronomy Research (ICRAR). Also a population of older stars was found at the edges besides young stars and interstellar gas. The expectation was that older stars would not be present.

The rotation periods are claimed to in a reasonable accuracy same for all spiral galaxies irrespective of the size. The constant velocity spectrum for distant stars implies $\omega \propto 1/r$ for

$r > R$. It is important do identify the value of the radius R of the edge of the visible part of galaxy precisely. I understood that outside the edge stars are not formed. According to Wikipedia, the size R of Milky Way is in the range $(1 - 1.8) \times 10^5$ ly and the velocity of distant stars is $v = 240$ km/s. This gives $T \sim R/v \sim .23$ Gy, which is by a factor 1/4 smaller than the proposed universal period of $T = 1$ Gy at the edge. It is clear that the value of T is sensitive to the identification of the edge and that one can challenge the identification $R_{edge} = 4 \times R$.

In the following I will consider two TGD inspired arguments. The first argument is classical and developed by studying the velocity spectrum of stars for Milky Way, and leads to a rough view about the dynamics of dark matter and rigid matter. Second argument is quantal and introduces the notion of gravitational Planck constant $\hbar_{gr}$ and quantization of angular momentum as multiples of $\hbar_{gr}$. It allows to predict the value of T and deduce a relationship between the rotation period T and the average surface gravity of the galactic disk.

In the attempts to understand how T could be universal in TGD framework, it is best to look at the velocity spectrum of Milky Way depicted in a Wikipedia article about Milky Way (see `http://tinyurl.com/hqr6m27`).

1. The illustration shows that the $v(\rho)$ has maximum at $r \sim 1$ kpc. The maximum corresponds in a reasonable approximation to $v_{max} = 250$ km/s, which is only 4 per cent above the asymptotic velocity $v_{rot} = 240$ km/s for distant stars as deduced from the figure.

   Can this be an accident? This would suggest that the stars move under the gravitational force of galactic string alone apart from a small contribution from self-gravitation! The dominating force could be due to the straight portions of galactic string determining also the velocity v_{rot} of distant stars.

   It is known that there is also a rigid body part of dark matter having radius $r \sim 1$ kpc (3.3×10^3 ly) for Milky Way, constant density, and rotating with a constant angular velocity ω_{dark} to be identified as the ω_{vis} at r. The rigid body part could be associated with a separate closed string or correspond to a knot of a long cosmic string giving rise to most of the galactic dark matter.

   Remark: The existence of rigid body part is serious problem for dark matter as halo approach and known as core-cusp problem.

   For $\rho < r$ stars could correspond to sub-knots of a knotted galactic string and v_{rot} would correspond to the rotation velocity of dark matter at r when self-gravitation of the knotty structure is neglected. Taking it into account would increase v_{rot} by 4 per cent to v_{max}. One would have $\omega_{dark} = v_{max}/r$.

2. The universal rotation period of galaxy, call it $T \sim 1$ Gy, is assigned with the edge of the galaxy and calculated as $T = v(R)/R$. The first guess is that the radius of the edge is $R_{edge} = R$, where $R \in (1 - 1.8) \times 10^5$ ly (30-54 kpc) is the radius of the Milky Way. For $v(R) = v_{rot} \sim 240$ km/s one has $T \sim .225$ Gy, which is by a factor 1/4 smaller that $T = 1$ Gy. Taking the estimate $T = 1$ Gy at face value one should have $R_{edge} = 4R$.

3. The velocity spectrum of stars for Milky Way is such that the rotation period $T_{vis} = \rho/v_{vis}(\rho)$ is quite generally considerably shorter than $T = 1$ Gy. The discrepancy is from 1 to 2 orders of magnitude. The $v_{vis}(\rho)$ varies by only 17 per cent at most and has two minima (200 km/s and 210 km/s) and eventually approaches $v_{rot} = 240$ km/s.

   The simplest option is that the rotation $v(\rho)$ velocity of dark matter in the range $[r, R]$ is in the first approximation same as that of visible matter and in the first approximation constant. The angular rotation ω would decrease roughly like r/ρ from ω_{max} to $\omega_{rot} = 2\pi/T$: for Milky Way this would mean reduction by a factor of order 10^{-2}. One could understand the slowing down of the rotation if the dark matter above $\rho > r$ corresponds to long - say U-shaped as TGD inspired quantum biology suggests - non-rigid loops emanating from the rigid body part. Non-rigidity would be due to the thickening of the flux tube reducing the contribution of Kähler magnetic energy to the string tension - the volume contribution would be extremely small by the smallness of cosmological constant like parameter multiplying it.

   If the stars form sub-knots of the galactic knot, the rotational velocities of dark matter flux loops and visible matter are same. This would explain why the spectrum of velocities is so different from that predicted by Kepler law for visible matter as the illustration of the Wikipedia article shows (see http://tinyurl.com/y8k6l6su). Second - less plausible - option is that visible matter corresponds to closed flux loops moving in the gravitational field of cosmic string and its knotty part, and possibly de-reconnected (or "evaporated") from the flux loops.

What about the situation for $\rho > R$? Are stars sub-knots of galactic knot having loops extending beyond $\rho = R$. If one assumes that the differentially rotating dark matter loops extend only up to $\rho = R$, one ends up with a difficulty since $v_{vis}(\rho)$ must be determined by Kepler's law above $\rho = R$ and would approach v_{rot} from above rather from below. This problem is circumvented if the loops can extend also to distances longer than R.

4. Asymptotic constant rotation velocity v_{rot} for visible matter at $r > R$ is in good approximation proportional to the square root of string tension T_s defining the density per unit length for the dark matter and dark energy of string. $v_{rot} = (2GT_s)^{1/2}$ is determined from Kepler's law in the gravitational field of string. In the article R is identified as the size of galactic disk containing stars and gas.

5. The universality of T (no dependence on the size R of the galaxy) is guaranteed if the ratio R/r is universal for given string tension T_s. This would correspond to scaling invariance. To my opinion one can however challenge the idea about universality of T since its identification is far from obvious. Rather, the period at r would be universal if the angular velocity ω and perhaps also r are universal in the sense that they depend on the string tension T_s of the galactic string only.

The above argument is purely classical. One can consider the situation also quantally.

1. The notion of gravitational Planck constant h_{gr} introduced first by Nottale [E87] is central in TGD, where dark matter corresponds to a hierarchy of Planck constants $h_{eff} = n \times h$. One would have

$$\hbar_{eff} = n \times \hbar = \hbar_{gr} = \frac{GMm}{v_0} \tag{8.8.15}$$

for the magnetic flux tubes connecting masses M and m and carrying dark matter. For flux loops from M back to M one would have

$$\hbar_{gr} = \frac{GM^2}{v_0} . \tag{8.8.16}$$

v_0 is a parameter with dimensions of velocity.

The first guess is $v_0 = v_{rot}$, where v_{rot} corresponds to the rotation velocity of distant stars - roughly $v_{rot} = 4 \times 10^{-3} c/5$. Distant stars would be associated with the knots of the flux tubes emanating from the rigid body part of dark matter, and $T = .25$ Gy is obtained for $v_0 = R/v_{rot}$ in the case of Milky Way. The universality of r/R guaranteeing the universality of T would reduce to the universality of v_0.

2. Assume quantization of dark angular momentum with unit h_{gr} for the galaxy. Using $L = I\omega_{dark}(R)$, where $I = MR^2/2$ is moment of inertia and ω is short hand for $\omega_{dark}(R)$, this gives

$$\frac{MR^2\omega}{2} = L = m \times \hbar_{gr} = 2m \times \frac{GM^2}{v_0} \tag{8.8.17}$$

giving

$$\omega = 2m \times \frac{\hbar_{gr}}{MR^2} = 2m \times \frac{GM}{R^2 v_0} = m \times 2\pi \frac{g_{gal}}{v_0} \quad , \quad m = 1, 2, .., \tag{8.8.18}$$

where $g_{gal} = GM/\pi R^2$ is the average surface gravity of galactic disk.

If the average surface mass density of the galactic disk and the value of m do not depend on galaxy, one would obtain constant $\omega_{dark}(R)$ as observed ($m = 1$ is the first guess but also other values can be considered).

3. For the rotation period one obtains

$$T = \frac{v_0}{m \times g_{gal}} \quad , \quad m = 1, 2, ... \tag{8.8.19}$$

Does the prediction make sense for Milky Way? For $M = 10^{12} M_{Sun}$ represents a lower bound for the mass of Milky Way (see `http://tinyurl.com/hqr6m27`). The upper bound is roughly by a factor 2 larger. For $M = 10^{12} M_{Sun}$ the average surface gravity g_{gal} of Milky Way would be approximately $g_{gal} \simeq 10^{-10} g$ for $R = 10^5$ ly and by a factor 1/4 smaller for $R = 2 \times 10^5$ ly. Here $g = 10$ m/s^2 is the acceleration of gravity at the surface of Earth. $m = 1$ corresponds to the maximal period.

For the upper bound $M = 1.5 \times 10^{12} M_{Sun}$ of the Milky Way mass (see `http://tinyurl.com/hqr6m27`) and larger radius $R = 2 \times 10^5$ ly one obtains $T \simeq .23/m$ Gy using $v_0 = v_{rot}(R/r)$, $R = 180r$ and $v_{rot} = 240$ km/s.

4. One can criticize this argument since the rigid body approximation fails. Taking into account the dependence $v = v_{rot} R/\rho$ in the integral defining total angular momentum as $2\pi(M/\pi R^2) \int v(\rho)\rho\rho d\rho = M\omega R^2$ rather than $M\omega R^2/2$ so that the value of ω is reduced by factor 1/2 and the value of T increases by factor 2 to $T = .46/m$ Gy which is rather near to the claimed value of 1 Gy.

To sum up, the quantization argument combined with the classical argument discussed first allows to relate the value of T to the average surface gravity of the galactic disk and predict correctly the value of T.

Did you think that star formation is understood?

In Cosmos Magazine there is an interesting article about (see`http://tinyurl.com/ybglb7t4`) about the work [E125] of a team of astronomers led by Fatemeh Tabatabaei published in Nature Astronomy (see `http://tinyurl.com/yc3mngtq`).

The problem is following. In the usual scenario for the star formation the stars would have formed almost instantaneously and star formation would not continue anymore. The mystery is that stars with the age of our sun even exist at all. Star formation is indeed still taking place: more than one half of galaxies is forming stars. So called starburst galaxies do this very actively. The standard story is that since stars explode as supernovae, the debris from supernovae condenses to stars of later generations. This does not seem to be the whole story.

Remark: It seems incredible that astrophysics would still have unsolved problems at this level. During years I have learned that standard reductionistic paradigm is full of holes.

The notion of star-formation quenching has been introduced: it would slow down the formation of stars. It is known that quenched galaxies mostly have a super-massive blackhole in their center and that quenching starts at their centers. Quenching would preserve star forming material for future generations of stars.

To study this process a team of astronomers led by Tabatabaei turned their attention to NCG 1079 located at distance of 45 million light years. It is still forming stars in central regions but shows signs of quenching and has a super-massive blackhole in its center. What was found that large magnetic fields, probably enhanced by the central black hole, affect the gas clouds that would normally collapse into stars, thereby inhibiting their collapse. These forces can even break big clouds into smaller ones, ultimately leading to the formation of smaller stars.

This is highly interesting from TGD point of view. In the simplest TGD based model galaxies are formed as knots of long cosmic strings. Stars in turn would be formed as sub-knots of these galactic knots. There is also alternative vision in which knots are just closed flux tubes bound to long strings containing galaxies as closed flux tubes like pearls in necklace. These closed flux tubes could emerge from long string by reconnection and form elliptic galaxies. The signature would be non-flatness for the velocity spectrum of distant stars. Also in the case of stars similar reconnection process splitting star as sub-knot of galactic string can be imagined.

If stars are sub-knots in knots of galactic string representing the galaxies, the formation of star would correspond to a formation of knot. This would involve reconnection process in which some portions of knot go "through each other". This is the manner how knots are reduced to trivial knot in knot cobordism used to construct knot invariants in knot theory [K54]. Now it would work in opposite direction: to build a knots.

This process is rather violent and would initiate star formation with dark matter from the cosmic string forming the star. This process would continue forever and would allow avoid the instantaneous transformation of matter into stars as in the standard model. At deeper level star formation would be induced by a process taking place at the level of dark matter for magnetic flux tubes: similar vision applies in TGD inspired biology. One could perhaps see these knots as seeds of a phase transition like process leading to a formation of star. This reconnection process could take place also in the formation of spiral galaxies. In Milky Way there are indeed indications for the reconnection process, which could be related to the formation of Milky as knot which has suffered or suffering reconnection.

The role of strong magnetic fields supposed to be amplified by the galactic blackhole is believed to be essential in quenching. These magnetic fields would be associated with dark flux tubes, possibly as return fluxes (flux lines must be closed). These magnetic fields would prevent the collapse of gas clouds to stars. These magnetic fields could also induce a splitting of the gas clouds to smaller cloud. The ratio of mass to magnetic flux ratio for clouds is studied and the clouds are found to be magnetically critical or stable against collapse to a core regions needed for the formation of star. The star formation efficiency of clouds drops with increasing magnetic field strength.

Star formation would begin, when the magnetic field has strength below a critical value. If the reconnection plays a role in the process, this would suggest that reconnection is probable for magnetic field strengths below critical value. Since the thickness of the magnetic flux tube associated with its M^4 projection increases as magnetic field strength decreases, one can argue that the reconnection probability and thus also star formation rate increases. The development of galactic blackhole would amplify the magnetic fields. During cosmic evolution the flux tubes would thicken so that also the field strength would be reduced and eventually the star formation would begin if the needed gas clouds are present. This is just what observations tell.

A natural model for the galactic blackhole is as a highly wounded portion of cosmic string. The blackhole Schwartschild radius would be $R = 2GM$ and the mass due to dark energy of string (there would be also dark matter contribution) to mass would be $M \sim TL$, where T is roughly $T \sim 2^{-11}$. This would give the estimate $L \sim 2^{10}R$.

8.8.5 Large scale fluctuations in metagalactic ionizing background for redhsift six

I learned about a very interesting result related to early cosmology and challenging the standard cosmology. The result is described in popular article "*Early opaque universe linked to galaxy scarcity*" (see `http://tinyurl.com/y74xe4jr`). The original article "*Evidence for Large-scale Fluctuations in the Metagalactic Ionizing Background Near Redshift Six*" of Becker *et al* [E106] is published in Astrophysical Journal (see `http://tinyurl.com/y7ho454e`).

The abstract of the article is following.

The observed scatter in intergalactic Lyα opacity at $z \leq 6$ requires large-scale fluctuations in the neutral fraction of the intergalactic medium (IGM) after the expected end of reionization. Post-reionization models that explain this scatter invoke fluctuations *in either the ionizing ultraviolet background (UVB) or IGM temperature. These models make very different predictions, however, for the relationship between Lyα opacity and local density. Here, we test these models using Lyα-emitting galaxies (LAEs) to trace the density field surrounding the longest and most opaque known Lyα trough at $z < 6$. Using deep Subaru Hyper Suprime-Cam narrowband imaging, we find a highly significant deficit of $z \simeq 5.7$ LAEs within 20 $\mathrm{h}^{-1}\,\mathrm{Mpc}$ of the trough. The results are consistent with a model in which the scatter in Lyα opacity near $z \sim 6$ is driven by large-scale UVB fluctuations, and disfavor a scenario in which the scatter is primarily driven by variations in IGM temperature. UVB fluctuations at this epoch present a boundary condition for reionization models, and may help shed light on the nature of the ionizing sources.*

The basic conclusion is that the opaque regions of the early Universe about 12.5 billion years ago (redshift $z \sim 6$) correspond to small number of galaxies. This is in contrast to standard model expectations. Opacity is due to the absorption of radiation by atoms and the UV radiation generated by galaxies, which ionizes atoms and makes Universe non-transparent. In standard cosmology the radiation would arrive from rather large region. The formation of galaxies is estimated to have begun .5 Gy years after Big Bang but there is evidence for galaxies already for .2 Gy after Big Bang (see `http://tinyurl.com/y9c75t2b`). Since the region studied corresponds to a temporal distance about 12.5 Gly and the age of the Universe is around 13.7 Gy, UV radiation from a region of size about 1 Gly should have reached the intergalactic regions and have caused the ionization.

Second conclusion is that there are large fluctuations in the opacity. What is suggested is that either the intensity of the UV radiation or that the density of intergalactic gas fluctuates. The fluctuations in the intensity of UV radiation could be understood if the radiation from the galaxies propagates only to finite distance in early times. Why this should be the case is difficult to understand in standard cosmology.

Could TGD provide the explanation.

1. In TGD framework galaxies would have born as cosmic strings thickened to flux tubes. This causes reduction of the string tension as energy per unit length. The liberated dark energy and matter transformed to ordinary matter and radiation. Space-time emerges as thickened magnetic flux tubes. Galaxies would correspond to knots of cosmic strings and stars to their sub-knots.

2. If the UV light emerging from the galaxies did not get far away from galaxies, the ionization of the intergalactic gas did not occur and these regions became opaque if distance to nearest galaxies was below critical value.

3. Why the UV radiation at that time would have been unable to leave some region surrounding galaxies? The notion of many-sheeted space-time suggests a solution. Simplest space-time sheets are 2-sheeted structure if one does not allow space-time to have boundaries. The members of the pair with boundary are glued to together along their common boundary. The radiation would have left this surface only partially. Partial reflection should occur as the radiation along first member of pair is reflected as a reflected signal propagating along second member. This model could explain the large fluctuations in the opacity as fluctuations in the density of galaxies.

4. A more concrete confinement mechanism would be based on the propagation of light from galaxy along magnetic monopole flux loops. If the loop is closed, it can confine the radiation. This confinement could occur also at the level of stars. In [L83] I discuss a model for the solar cycle and observed anomalously high emission of gamma rays in 1-100 GeV range. The model involves confinement of charged particles to dipole loops represented as space-time surfaces. Confinement is possible also for gamma rays.

   Gamma rays could be also produced by charged particles accelerated in the flux loop carrying electric field. One would obtain a characteristic band structure corresponding to the number of loops before the emission occurring most probably at sharp kind of the dipole loop.This mechanism could produce cosmic rays in very general systems involved monopole flux loops.

5. Cosmic expansion occurring in TGD framework in jerk-wise manner as rapid phase transitions would have expanded the galactic space-time sheets and in the recent Universe this confinement of UV radiation would not occur and intergalactic space would be homogenously ionized and transparent.

The echo phenomenon could be completely general characteristic of the many-sheeted space-time.

1. The popular article "*Evidence in several Gamma Ray Bursts of events where time appears to repeat backwards*" (see `http://tinyurl.com/y89j6u2y`) tells about the article "*Smoke and Mirrors: Signal-to-Noise and Time-Reversed Structures in Gamma-Ray Burst Pulse Light Curve*" of Hakkila *et al* (see `https://arxiv.org/pdf/1804.10130.pdf`). The study of gamma ray bursts (GRBs) occurring in the very early Universe with distance of few billion light years (smaller than for opacity measurements by an order of magnitude) has shown that the GRB pulses have complex structures suggesting that the radiation is reflected partially back at some distance and then back in core region.The duration of these pulses varies from 1 ms to 200 s.

   Could also this phenomenon be caused by the finite size of the space-time sheets assignable to the object creating GRBs? Perhaps the simplest explanation would be in terms of confinement of gamma rays inside monopole flux loops asociated with the source of the radiation such as quasar of blackhole. This predict periodic re-appearance of pulses.

2. There is also evidence for blackhole echoes, which could represent example of a similar phenomenon. Sabine Hossenfelder (see `http://tinyurl.com/ybd9gswm`) tells about the new evidence for blackhole echoes in the fusion of blackholes for GW170817 event observed by LIGO reported by Niayesh Afshordi, Professor of astrophysics at Perimeter Institute in the article "*Echoes from the Abyss: A highly spinning black hole remnant for the binary neutron star merger GW170817*" (see `https://arxiv.org/abs/1803.10454`). The earlier 2.5 sigma evidence has grown into 4.2 sigma evidence. 5 sigma is regarded as a criterion for discovery. A possible TGD based comments can be found in [K23] (see `http://tinyurl.com/y9suamjl`).

   The confinement of gravitational radiation inside monopole flux loops asociated with blackhole like object would explain the findings. This however forces to replace the standard view about blackholes having no hair with TGD based view [L63] allowing magnetic fields represented in terms of monopole flux tubes.

8.9 Do We Really Understand The Solar System?

The recent experimental findings have shown that our understanding of the solar system is surprisingly fragmentary. As a matter fact, so fragmentary that even new physics might find place in the description of phenomena like the precession of equinoxes and the recent discoveries about the bullet like shape of heliosphere and strong magnetic fields near its boundary bringing in mind incompressible fluid flow around obstacle.

The TGD inspired model is based on the heuristic idea that stars are like pearls in a necklace defined by long magnetic flux tubes carrying dark matter and strong magnetic field responsible for dark energy and possibly accompanied by the analog of solar wind. Heliosphere would be like bubble in the flow defined by the magnetic field inside the flux tube inducing its local thickening. A possible interpretation is as a bubble of ordinary and dark matter in the flux tube containing dark energy. This would provide a beautiful overall view about the emergence of stars and their helio-spheres as a phase transition transforming dark energy to dark and visible matter. Among other things the magnetic walls surrounding the solar system would shield the solar system from cosmic rays. The model leads to a vision about formations of stars and galaxies as "boiling" of dark energy to matter. Also a model for the cosmic rays emerges allowing to identify the acceleration mechanism using recent findings about cosmic rays.

8.9.1 Motivations

The inspiration to this little contribution came from a discussion with my friend Pertti Kärkkainen who told me about the work of Walter Cruttenden (see http://tinyurl.com/o7453p5) [E259]. Cruttenden is a free researcher working with an old problem related to the astronomy of the solar system, namely the precession of equinoxes (see http://tinyurl.com/y7mmojcd) [E25]. Equinoxes (see http://tinyurl.com/zebl7) [E9] correspond to the two points at the orbit of Earth at which the Sun is in the plane of the equator (if Earth's spin axes were not tilted this would be the case always). What has been observed is an apparent movement of fixed stars relative to the Earth bound observer. The period of the equinox precession is about 26, 000 years. The angular radius of the precession cone is about 23.5 degrees. The rate of precession is approximately 50 arc seconds per year but is not strictly constant.

The precession of equinoxes reduces to precession which is a well-known phenomenon associated with the motion of a rigid body with one point fixed. Precession (see http://tinyurl.com/cm2jz) [E24] means that the spin axis of the spinning system rotates around fixed axis along the surface of a cone. One can distinguish between a torque free precession and precession induced by torque. Precession can be accompanied by a nutation (see http://tinyurl.com/5fv5xu) [E20]: the tilt angle of the spin axes with respect to fixed axes varies with time. The nutation for Earth is well-understood process determined by the local gravitational physics. In the case of precession the situation is not so clear.

Two basic theories explaining the precession of equinoxes

There are two basic theories of precession.

1. The precession of equinoxes could be governed by a local dynamics being due to the precession of the Earth with respect to solar system. Earth is indeed a prolate ellipsoid and the precession would be caused mainly by the gravitational fields of Sun and Moon (lunisolar model). According to the summary of Cruttenden (see http://tinyurl.com/o7453p5) [E259], Newton's equations did not work and d'Alembert and others have added and changed input values to fit the observed precession. The latest 2000A version includes almost 1400 terms but it still fails to accurately predict variations in the precession rate. The theory is also plagued by a "measurement paradox". Studies show that the changes in Earth's orientation relative to Sun and other planets are small (few arc seconds per year instead of 50 arc seconds) as compared to the equinox precession.

2. The precession of equinoxes could be also due to the precession of the entire solar system regarded as a rigid body with one point fixed and would be caused by some hypothetical binary companion of Sun. Usually the binary companion is thought to be star of planet like system but this is not necessary. This model is known as binary model and was first proposed by Indian astronomer Sri Yukteswar (see http://tinyurl.com/ycfx87zr). The predicted period was 24, 000 years. According to the summary of Cruttenden (see http://tinyurl.com/o7453p5), the binary model of Yukteswar has turned out to be more accurate over 100 year period [E259].

In principle the observation of the precession from some other planet could select between the two approaches. If the precession were similar at two planets then the precession of the entire solar system would be strongly favored as an explanation of the equinox precession.

Some hints

The basic challenge for the binary theory is of course the identification of the binary. There are some hints (see http://tinyurl.com/ych6y4c3) in this respect listed by W. Cruttenden in the articles at his homepage. Consider first what has been learned from the structure of heliosphere during last years.

1. The data from Voyager 1 and Voyager 2 have revealed that heliosphere is asymmetric (see http://tinyurl.com/ycuhbsf6) [E258]. The edge of the heliosphere (the place where the solar wind slows down to sub-sonic speeds and is heated) appears to be 1.2 billion kilometers

shorter on the south side of the solar system than it is on the edge of the planetary plane. This indicates the heliosphere is not a sphere but has a shape of a bullet. In a sharp contrast with the naïve expectations, the magnetosphere of Sun would not be like that of Earth which is compressed on the day side by solar wind and has a long tail on the night side.

2. There is also evidence from Voyager 2 for a strong magnetic field (see http://tinyurl.com/ycowpzqe) [E83]. Also the temperature just outside the boundary zone defining the boundary of the solar inner magnetosphere was ten times cooler than expected. The presence of the strong magnetic field is not easy to understand since the interstellar space consists of extremely tenuous gas. The proposal is that the interstellar magnetic field could be forced to flow around the helio-magnetosphere much like fluid flows around obstacle. This increases the density of flux lines and interstellar magnetic field would become stronger locally. Heliosphere would be like a bubble inside magnetic flux tube expanding it locally.

   The direction of the local magnetic field at the edge of the heliosphere differs considerably from that for the interstellar magnetic field thought to be parallel to the galactic plane. The tilt angle is about 60 degrees. Therefore one can challenge the identification of the strong local magnetic field as galactic magnetic field.

3. Between June and October 2007, the STEREO spacecraft (see http://tinyurl.com/69asv9j) [E37] "detected atoms originating from the same spot in the sky: the shock front and the helio-sheath beyond, where the sun plunges through the interstellar medium", and found "energetic neutral particles from beyond the heliosphere" that are moving towards the sun [E41]. This would suggest magnetic flux tube like structure and the flow of neutral particles along the flux tube towards the Sun so that an analog of solar wind would be in question.

Also the behavior of comets suggests that the understanding of the solar system is far from complete. The behavior of the comet Sedna thought to belong to the inner Oort cloud (see http://tinyurl.com/cx2yd) [E21] cannot be explained in terms of theory assuming only solar and planetary gravitational fields. Typically comets move along periodic orbits returning repeatedly near some planet of solar system (typically Neptune) which has kicked the comet to its highly eccentric orbit. Sedna (see http://tinyurl.com/pvz6j) [E2] (thought to be a "dwarf planet") seems to be an exception in this respect. Sedna has an exceptionally long and elongated orbit (aphelion about 937 AU and perihelion about 89.6 AU), period is estimated to be 11, 400 years, and Sedna does not return near any planet periodically as the assumption that it belongs to the scattered disk would require.

What could be the origin of Sedna?

1. It has been suggested that Sun has an dim binary companion - christened as Nemesis (see http://tinyurl.com/676c7s7) [E19] - at a distance of thousands of AUs. This companion could explain the behavior of Sedna, and has been also proposed to be responsible for the conjectured periodicity of mass extinctions, the lunar impact record, and the common orbital elements of a number of long period comets.

2. Second proposal is that Sedna has been kicked to its orbit by some object. This object could be an unseen planet much beyond the Kuiper belt (see http://en.wikipedia.org/wiki/Kuiper_belt) [E14] (Kuiper belt is outside planet Neptune and extends from 30 AU to 55 AU). It would have mass about 5 times the mass of Jupiter and be at distance of roughly 7850 AU from the Sun in the inner Oort cloud. It could be a single passign star or one of the young stars embedded with the Sun in the stellar cluster in which it formed. This might have happened already in the Sun's birth cluster (cluster of stars).

3. Also the behavior of the comets in outer Oort cloud (very eccentric orbits and long orbital periods) might reflect the influence of a binary companion whose mass distribution is such that this kind of orbits are generic. For spherical objects one would expect nearly circular orbits. String like object would satisfy this condition as will be found.

The identification of the companion of the Sun in the framework of standard physics

Consider first the identification of the companion of the Sun responsible for the precession of the solar system as a whole but staying in the framework of the standard physics. In this context only objects with a spherical symmetry can be considered.

1. The strange behavior of Sedna suggests that binary could be an unseen planet at distance of about 7850 AU in the inner Oort cloud. Note that Oort could extend up to 50, 000 AUs which corresponds to.75 ly whereas the closest star - Proxima Centauri- is at distance of about 4.2 light years.

2. The identification of the binary as the hypothetical Nemesis might explain the analog of the solar wind. If the dim Nemesis is at the same distances as the hypothetical planet, its mass would be only.5 per cent of solar mass.

3. An analog of solar wind flowing along magnetic flux tubes could also come from some other star, say Proxima Centauri (see `http://tinyurl.com/csarf`) [E26]. Proxima Centauri is however too light as red dwarf and too distant to induce the precession of the solar system as whole.

The identification of the companion of the Sun in TGD framework

In TGD framework one can consider more speculative ideas concerning the identification of the binary of the Sun.

1. In TGD Universe dark matter and dark energy can be understood as phases of matter with large Planck constant [K42]. For the dark energy assignable to the flux tubes mediating gravitational interaction between Sun and given planet the value of the Planck constant is of order $\hbar_{gr} = GMm/v_0$, where $v_0/c \simeq 2^{-11}$ holds true for the inner planets. For dark matter the value of Planck constant is much smaller integer multiple of its minimal value identified as the ordinary Planck constant. Whether only magnetic energy should be counted as dark energy or whether also dark particles with a gigantic value of Planck constant should be identified as dark energy is not quite clear.

2. Magnetic flux tubes are identified as carriers of dark matter. This hypothesis plays a key role in TGD inspired quantum biology and cosmology. The flux tubes can have arbitrary large length scales. During the cosmology space-time would have consisted of cosmic strings of form $X^2 \times Y^2 \subset M^4 \times CP_2$ with X^2 minimal surface and Y^2 complex sub-manifold of CP_2. In the course of the cosmic evolution their M^4 projection would have become 4-dimensional and they would have become magnetic flux tubes. The proposal is that galaxies are like pearls in a necklace formed by flux tubes [K31].

   The density ρ_{dark} of the magnetic energy is enormous for cosmic strings: the length L of cosmic string corresponds to a mass which is a fraction $G/\hbar_0 R^2 \sim 10^{-4}$ of the mass of a black hole with radius L. The thickening of the cosmic string to a flux tube respects the conservation of the magnetic flux so that the strength of the magnetic field scales down like $B \propto 1/S$, where S is the area for the transversal cross section of the flux tube. By a simple scaling argument the density of the magnetic energy per unit length of the flux tube scales down like $dE_m/dl \propto 1/S$.

   If energy is conserved if the length of the cosmic string scales up like S in the cosmic expansion: $d \propto \sqrt{L}$ proportionality analogous to that encountered in the case of diffusion would relate to each other flux tube radius and length. Also the primary p-adic length scales L_p assignable to particles and the secondary p-adic length scales $L_{p,2}$ characterizing the corresponding causal diamond CD relate in a similar manner. This would suggest that the p-adic length scale assignable to a given particle (of order Compton length) corresponds to the thickness of the magnetic flux tube(s) assignable to the particle and the size of CD to the length of the(se) magnetic flux tube(s). Similar scaling holds true for the density of dark matter per unit length of the flux tube.

   The dark matter associated with the flux tubes would generate transversal $1/\rho$ gravitational field explaining the constant velocity spectrum of distance stars in the galactic halo. The basic prediction is free motion along the direction of the cosmic string perturbed only by the mass of the galaxy itself.

3. The fractality of the TGD Universe suggests the pearls in the necklace model applies also to stars. The magnetic flux tube idealizable straight string would be roughly orthogonal to the plane of the planetary system possibly associated with the star and the spin axis of the star would be nearly parallel to the flux tube. If one combines this picture with the previous discussion, the simplest proposal is obvious. The binary companion of the Sun is the magnetic flux tube containing dark matter. An analog of the solar wind could blow from the nearest star associated with the flux tube.

Newtonian theory for the gravitation in planetary system works excellently and this poses strong constraints on the pearls in a necklace model will be discussed in more detail.

1. If the magnetic flux tube idealizable as a straight string carries dark matter, this dark matter gives an additional transversal $1/\rho$ contribution to the gravitational field in the exterior of the flux tube experienced by comets and also by planets. Near the Sun this contribution should be small as compared to the contribution of the Sun but this is not obvious. Inside the flux tube the gravitational potential would be apart from a constant proportional to ρ^2. It could affect much the gravitational potential of Sun in a detectable manner.

2. The contribution of the gravitational potential of dark matter to the dynamics of the solar system is certainly negligible if the heliosphere is a bubble inside the magnetic flux tube having fluid flow as an analog. Stars could be bubbles of ordinary and dark matter inside flux tubes containing dark energy with a gigantic value of Planck constant. Fractality suggests that this picture might apply also to galactic magnetospheres and even in biological systems where TGD inspired quantum biology predicts that the flux tubes containing dark matter use visible matter as sensory receptor and motor instrument [K37, K38]. Cell would be a fractal analog of the solar heliosphere in this framework!

3. At long distances the transversal gravitational field created by the dark matter at the magnetic flux tube begins to dominate and the situation is very much like in the case of galaxies. In particular, for circular orbits the rotation velocity is constant. The logarithmic behavior of the gravitational potential implies that the orbits tend to be highly eccentric and the it might be that the behavior of comets in the outer Oort cloud at least could be dictated by the gravitational field of the flux tube.

How thick the flux tube in question is and is its thickness affected by the presence of Sun and heliosphere?

1. The magnetic flux tube should have transversal dimensions not must larger than those of planetary system or heliosphere. The heliosphere has radius of about 80-100 AU to be compared to the distance 40 AU of Neptune. The distance of Neptune about 30 AU gives the first guess for the thickness of the flux tube. Kuiper belt extends from 30 AU to 55 AU and would surround the flux tube in this case.

2. Second guess is that the flux tube is so thick that it contains also Kuiper belt.

3. Third guess motivated by the above experimental findings is that the magnetic flux flows past the heliosphere like fluid flow: this would apply also to the dark matter matter inside flux tube. Heliosphere corresponds to a hollow bullet like bubble of ordinary and dark matter formed inside the flux tube carrying dark energy and carrying only the magnetic fields of Sun and planets.

   The dark energy and possible dark matter inside the flux tube (particular kind of space-time sheet) would have no effect on the gravitational field inside heliosphere so that no modifications of the existing model of solar system would be needed. Outside the heliosphere the effect would be in a good approximation described by a logarithmic gravitational potential created by an infinitely thin string like structure. The strong magnetic field of the flux wall surrounding the heliosphere would form a shield against the effects of cosmic rays coming from interstellar space.

The third guess seems to be consistent with the recent findings about the heliosphere boundary.

1. The strong magnetic field detected by Voyager 2 (see http://tinyurl.com/osddsvw) [E38] has been identified as galactic magnetic field which has changed its direction locally and for which the density of flux tubes has increased. Near the helio-sheath heliosphere would have deformed it locally inducing a tilt angle of 60 degrees with respect to the galactic plane.

   The article contains a video (see http://tinyurl.com/y7zjs3yb) giving an artist's view about the magnetic field suggesting strongly that flux tube develops a hole representing heliosphere. Could the magnetic field actually correspond to the dark magnetic field associated with the proposed magnetic flux tube? Helio-sheath has radius of order 80-100 AU so that this interpretation could make sense. This would challenge the interpretation as a galactic magnetic field unless the galactic magnetic field itself decomposes into flux tubes some of which contain stars as bubbles of ordinary and dark matter.

2. The findings of STEREO suggest that neutral atoms - presumably hydrogen atoms- arrive from a spot in the sky. It is not clear to me whether the spot refers to something in interstellar space (say another star) or just to the tip of the bullet like structure defined by the heliosphere. The simplest guess is that Proxima Centauri belongs to the same flux tube as Sun: this hypothesis is easy to kill if one assumes that the flux tube connecting Sun and Proxima Centauri is straight. The red dwarf character of Proxima Centauri does not however favor this hypothesis. Unfortunately I could not find any data about the direction of of the analog of the solar wind.

3. Interstellar Explorer (see http://tinyurl.com/ybb6lhot) discovered a narrow ribbon (see http://tinyurl.com/obuex7j) in heliosphere [E18]. This ribbon could correspond to the locus in which the deflection for the magnetic magnetic flux tubes caused by the heliosphere is such that the neutral particle of the solar wind can return back. The proposal is that magnetic walls act as mirrors. The reflection would involve ionization of neutral particle following by a confinement around flux tube plus possible motion in the direction of the flux tube and subsequent neutralization followed by a free linear motion possible back to Sun. Only when the neutral particle arrives to the magnetic flux wall in approximately orthogonal direction, the reflection would occur via this process. Otherwise the particle would leak out along the magnetic flux wall.

An interesting question concerns the criteria for what it is to be pearls in the same necklace.

1. One possible criterion would be correlated motion in the absence of gravitational binding. The moving groups of stars (see http://tinyurl.com/7rtndu9) [E36] not bound by gravitational interaction would satisfy this criterion.

2. Another criterion that one can imagine is that the stars are in the same developmental stage. Maybe stellar nurseries contain tangled magnetic flux tubes inside which bubbles of ordinary and dark matter are formed in a phase transition transforming dark energy to ordinary and dark matter: the flux tubes mediating gravitational interaction would still carry dark energy as magnetic energy and have a gigantic value of Planck constant.

One can imagine also other dark options besides the proposed one: such as dark planets or dark Nemesis but these options are more speculative and might fail to explain the analog of the solar wind. Also the proposed dark matter matter at the orbits of the planets might have some role and fractality suggests that dark matter is present in in all scales so that one has bubbles inside bubbles inside....

In the following the idea that magnetic flux tube containing dark matter is tested by building simple models for the orbits of comets in the gravitational field of the flux tube and for the precession of the solar system in this field. The models are oversimplified and can be taken only as first steps to test whether the proposed vision might work.

8.9.2 A Model For The Motion Of Comet In The Gravitational Field Of Flux Tube

One should derive tests for the idea that also stars are mass concentrations around magnetic flux tube like structures evolved from extremely thin cosmic strings forming linear structures analogous to pearls in a necklace.

1. One possible signature might be the motion of comets. If the general structure of the orbits of comets in outer (at least) Oort cloud (see `http://tinyurl.com/cx2yd`) [E21] are determined by the gravitational field of the magnetic flux tube structure their general characteristics should reflect the very slowly variation of the logarithmic gravitational potential of the flux tube. What one would expect is typically very eccentric orbits in the plane of the solar system orthogonal to the flux tube and having very long orbital periods. Comet orbits in the outer Oort cloud indeed have these characteristics.

2. Second characteristic signature is free motion in direction parallel to the flux tube apart from effects caused by the solar gravitational field. This could imply the leakage of the comets from the system if the velocity is higher than the escape velocity from the solar system in presence of only solar gravitational field. Also the concentration of comets strongly in the plane of the solar system would imply that the total number of comets is much lower than predicted by the spherically symmetric model for the Oort cloud: this conforms with experimental facts [E21]. A more complex situation corresponds to a motion to which the gravitational fields of Sun and flux tube are both important. This could be relevant for motions which are not in the plane of planetary system.

Gravitational potential of a straight flux tube with constant mass density

The gravitational potential for a straight flux tube with constant density of dark energy (or matter) ρ_{dark} will be needed in the sequel.

1. Gravitational potential satisfies the Poisson equation

$$\nabla^2\phi_{gr} = 4\pi G\rho_{dark} \ . \tag{8.9.1}$$

2. For a straight flux tube of radius d the mass density is constant and the situation is cylindrically symmetric and the solution inside the flux tube reads as

$$\begin{aligned} \phi_{gr} &= G\pi\rho_{dark}\rho^2 = GT\frac{\rho}{d}^2 \ , \\ T &= \frac{dM}{dl} \ . \end{aligned} \tag{8.9.2}$$

T is the linear mass density.

Outside the straight flux tube the potential is given by Gauss theorem as

$$\phi_{gr} = 2TG \times log(\frac{\rho}{\rho_0}) \ . \tag{8.9.3}$$

The choice of the value ρ_0 is dictated by boundary conditions at the boundary of the flux tube if one assumes that the potential energy vanishes at origin. Its change induces only an additive constant to the total energy and does not effect equations of motion.

Motion of a test particle in the region exterior to the flux tube

One can construct a model for the motion of comet in gravitational field of flux tube by idealizing it with an infinitely thin straight string with string tension kept as a free parameter. For simplicity the motion will be assumed to take place in the plane orthogonal to the flux tube.

1. The gravitational potential energy of mass in the field of straight string like object is given by

$$V(\rho) = klog(x) \ , \ x = \frac{\rho}{\rho_0} \ , \ k = 2TG \tag{8.9.4}$$

Here ρ_0 is a parameter which can be chosen rather freely since only the value of the conserved energy changes as ρ_0 is changed. One possible choice is $\rho_0 = \rho_{min}$, the minimum value of the radial distance from the flux tube idealized to be infinitely thin.

2. Conserved quantities are angular momentum

$$L = m\rho^2\frac{d\phi}{dt} \ , \tag{8.9.5}$$

and energy

$$E = \frac{m}{2}(\frac{d\rho}{dt})^2 + \frac{L^2}{2m\rho^2} + V(\rho) \ . \tag{8.9.6}$$

3. One can integrate these equations to get for the period of the motion the expression

$$\begin{aligned} \frac{T}{\rho_0}\sqrt{2Em} &= 2\int_{x_-}^{x_+} \frac{dx}{\sqrt{1 - \frac{L^2}{E^2\rho_0^2x^2} - klog(x)}} \ , \\ x_- &= \frac{\rho_-}{\rho_0} \ , \ x_+ = \frac{\rho_+}{\rho_0} \ . \end{aligned} \tag{8.9.7}$$

4. The turning points of the motion corresponds to the vanishing of the argument of the square root. At x_+ the logarithmic term dominates under rather general conditions whereas logarithmic term can be neglected at x_-, and one has in good approximation

$$x_+ \simeq e^{\frac{L}{k}} \ , \ x_- = \frac{L}{E\rho_0} \ . \tag{8.9.8}$$

Without a loss of generality one can choose $\rho_0 = L/E$ giving $x_- = 1$ which gives

$$\rho_- \simeq \frac{L}{E} \ , \ \rho_+ \simeq \rho_- \times e^{\frac{L}{k}} \ , \ . \tag{8.9.9}$$

For large values of L/k the orbits is very eccentric since one has $\rho_+/\rho_- \simeq exp(L/k)$.

A highly eccentric orbit with a very long orbital period is expected to represent the generic situation so that the model could indeed explain the characteristics of the comets in the outer Oort cloud. In the inner Oort cloud the eccentricities are smaller and the natural explanation would be that the gravitational field of Sun determines the characteristics of these orbits in good approximation.

8.9.3 A Model For The Precession Of The Solar System In The Gravitational Field Of Flux Tube

The model for the precession of the solar system in the gravitational field of the flux tube is obtained by idealizing the solar system with a cylindrically symmetry top with one point fixed in the gravitational field of the flux tube. The calculation is a little modification of that appearing in any text book of classical mechanics: I have used Herbert Goldstein's "Classical Mechanics" familiar from my student days [B33].

1. The model above requires that the solar system is a bullet like bubble inside the flux tube and dark energy induces no gravitational interaction inside the bubble. The bubble is approximated as a rigid body with one point fixed, which can thus perform precession. The torque must be due to the dependence of the total gravitational potential energy on the tilt angle θ of the bubble with respect to the axis of the flux tube.

2. One can apply the same trick as in the case of estimating the force on levitating super-conductor in external magnetic field. Since the magnetic field does not penetrate the super-conductor, the interaction energy is the negative of the magnetic energy of the external field in the volume occupied by the super-conductor. Now one obtains the *negative* of the interaction energy of the dark matter with its own gravitational potential. This can be written as

$$E_{gr} = -\frac{1}{8\pi G}\int (\nabla\phi_{gr})^2 dV \ . \tag{8.9.10}$$

The value of the interaction energy depends on the orientation of the heliosphere which gives rise to a torque.

Calculation of the gravitational potential energy

The value of the potential energy must be calculated for various orientations of the bubble. Cylindrical coordinates (ρ, z, ϕ) are obviously the proper choice of coordinates. Cylindrical rotational symmetry implies that the potential energy depends on the inclination angle θ only characterizing the cone of precession. Potential energy is defined as an integral over the bubble. Potential energy is proportional to the transverse distance from the axis of the magnetic flux tube and this simplifies the analytical calculations considerably.

1. The change of the orientation of the bubble by a rotation which can be taken to be a rotation in (y, z) plane by angle (θ means that the expression for the transverse distance squared - call it $(\rho')^2$ - from the axis of the flux tube is given by

$$\begin{aligned} (\rho')^2 &= x^2 + (sin(\theta)z + cos(\theta)y)^2 \\ &= \rho^2 cos^2(\phi) + \rho^2 cos^2(\theta) sin^2(\phi) + z^2 sin^2(\theta) + 2z\rho cos(\theta) sin(\theta) sin(\phi) \end{aligned} \tag{8.9.11}$$

By the rotational symmetry the contribution of the term linear in $sin(\phi)$ vanishes in the integral and the integral of $\rho')^2$ over ϕ can be done trivially so that one obtains the integral of quantity

$$I = \pi \left[\rho^2 + \rho^2 cos^2(\theta) + 2z^2 sin^2(\theta)\right] \ . \tag{8.9.12}$$

over z and ρ. The integral of the ρ^2 gives a term which does not depend on θ and therefore does not contribute to torque and can be dropped and one obtains

$$I = \int dV \left[\rho^2 cos^2(\theta) + 2z^2 sin^2(\theta)\right] \quad . \quad (8.9.13)$$

To simplify the situation one can assume that bullet is hemisphere so that one has $z^2 = d^2 - \rho^2$ at the upper boundary. It is convenient to introduce scaled coordinates $x = \rho/d$ and $y = z/d$.

The integration over ϕ can be carried out trivially so that apart from additive constant term one has

$$\begin{aligned} I &= \pi d^5 (I_1 cos^2(\theta) + I_2 sin^2(\theta)) \ , \\ I_1 &= \int_0^1 dy \int_0^{\sqrt{1-y^2}} x^3 dx = \frac{1}{4}\int_0^1 dy(1-y^2)^2 = \frac{44}{45} \ , \\ I_2 &= 2\int_0^1 dxx \int_0^{\sqrt{1-x^2}} dyy^2 = \frac{2}{3}\int_0^1 dxx(1-x^2)^{3/2} = \frac{2}{15} \end{aligned} \quad (8.9.14)$$

2. By replacing the upper limit of x integral with $z = f(\rho)$ one obtains the more general situation.

3. The value of the integral I is given by

$$\begin{aligned} I &= \pi d^5 \left[\frac{44}{45} cos^2(\theta) + \frac{2}{15} sin^2(\theta)\right] \equiv \frac{38}{45}\pi u^2 \ , \\ u &= cos(\theta) \ . \end{aligned} \quad (8.9.15)$$

Here a constant term not contributing to the torque has been dropped away.

4. By substituting the explicit expression for the gravitational potential one obtains the following expression for the gravitational potential

$$V = V_1 u^2 \ , \ V_1 = -\frac{19}{15} \times \frac{3}{8\pi}\frac{GM_{dark}^2}{d} \quad . \quad (8.9.16)$$

The proportionality to GM_{dark}^2/d could have been guessed using dimensional analysis.

Solving the equations of motion from conservation laws

The equations of motion can be solved using standard procedure applicable to cylindrically symmetry top with one point fixed. The potential has the following general form for the bubble model;

$$V(u) = V_1 u^2 \ \text{(bubble)} \quad . \quad (8.9.17)$$

Note that one has $V_1 < 0$ is by previous arguments more realistic than the potential when the magnetic flux penetrates the solar system (note that solar system would repel the magnetic flux like super-conductor). In the latter case analytical calculation would be also impossible although also now the potential depends on u only.

The calculation proceeds in the following manner [B33].

1. The Lagrangian is given in terms of Euler angles (θ, ϕ, ψ) by

$$L = \frac{I_1}{2}\left[(\frac{d\theta}{dt})^2 + (1-u^2)(\frac{d\phi}{dt})^2\right] + \frac{I_3}{2}(\frac{d\psi}{dt} + u\frac{d\phi}{dt})^2 - V_1 u^2 \ . \tag{8.9.18}$$

   Here $I_1 = I_2$ *resp.* I_3 are the eigen values of the inertia tensor in the directions orthogonal *resp.* parallel to symmetry axis. In the recent case I_1 and I_2 correspond to the two directions orthogonal to the symmetry axis of the bullet like heliosphere and I_3 to the direction of the symmetry axis of the heliosphere.

2. ϕ and ψ are cyclic coordinates and give rise to two conserved quantities corresponding to conserved angular momentum components

$$p_\psi = I_3(\frac{d\psi}{dt} + u\frac{d\phi}{dt}) \equiv I_1 a \ ,$$
$$p_\phi = \left[I_1(1-u^2) + I_3 u^2\right]\frac{d\phi}{dt} + I_3 u\frac{d\psi}{dt} \equiv I_1 b \ . \tag{8.9.19}$$

   From these equations one can solve $d\psi/dt$ and $d\phi/dt$ (recession velocity) in terms of u and various parameters and integrate this equations with respect to time if $u(t)$ is known.

3. Energy conservation gives an additional condition. By noticing that also the quantity $p_\psi^2/2I_3$ is conserved and one obtains

$$E' = E - \frac{p_\psi^2}{2I_3} = \frac{I_1}{2}(\frac{d\theta}{dt})^2 + (1-u^2)(\frac{d\phi}{dt})^2 + V_1 u^2 \tag{8.9.20}$$

   is conserved. By little manipulations one can integrate θ or equivalently t from this equation and one obtains for the period T of motion the expression of form

$$T = 2\int_{u_-}^{u_+} \frac{du}{\sqrt{(1-u^2)(\alpha - \beta u^2) - (b-au)^2}} \ ,$$
$$\alpha = \frac{2E'}{I_1} \ , \ \beta = \frac{2V_1}{I_1} \ , \ V_1 = -\frac{19}{15}\times\frac{3}{8\pi}\frac{GM_{dark}^2}{d} \ . \tag{8.9.21}$$

   The coefficients α and β can be deduced from the conservation laws for p_ψ and p_ϕ. Note that for the cylindrically symmetric rotating rigid body in Earth's magnetic field the negative V_1u^2 term is replaced with $2GMl \times u$ term having positive sign. By replacing u_+ with u as the upper integration limit one obtains the relationship $t = t(u)$ and can in principle invert this relationship to get $u = u(t)$.

The integral in question is elliptic integral (see `http://tinyurl.com/ycmwzs6y`) [A4, A3], whose general form is

$$P(a,b) = \int_a^b R(u, \sqrt{P(u)})du \ , \tag{8.9.22}$$

where R is rational function of its arguments and $P(t)$ is a polynomial with degree not higher than 4. Now the degree of P is maximal and the rational function reduces to a rational function $R(u, \sqrt{P(u)}) = 1/\sqrt{P(u)}$ of single variable. The limits are given by $(a, b) = (u_-, u)$ in the general case. By an appropriate change of variables elliptic integrals can be always reduced to three canonical elliptic integrals known as Legendre forms (see http://tinyurl.com/ycbpwcfc) [A11].

1. In the recent case the elliptic integral is of the standard form

$$\begin{aligned} t &= \int_{u_-}^{u} dv \frac{1}{\sqrt{P_4(v)}} \ , \ P_4(v) = a_4 v^4 + a_3 v^3 + a_2 v^2 + a_1 v + a_0 \ , \\ a_4 &= -\beta \ , \ a_3 = 0 \ , \ a_2 = -\alpha - a^2 \ , \ a_1 = 2ab \ , \ a_0 = \alpha - b^2 \ . \end{aligned} \tag{8.9.23}$$

It can be computed analytically (see http://tinyurl.com/2u7zflo) [A3] in terms of Weierstrass elliptic function (see http://tinyurl.com/czov55b) $\mathcal{P}(t; g_2, g_3)$ [?, ?] with invariants

$$\begin{aligned} g_2 &= a_0 a_4 - 4a_1 a_3 + 3a_2^2 \ , \\ g_3 &= a_0 a_2 a_4 - 2a_1 a_2 a_3 - a_4 a_1^2 - a_3^2 a_0 \ . \end{aligned} \tag{8.9.24}$$

2. Weierstrass elliptic function is the inverse of the function defined by the elliptic integral

$$t = \int_t^{\infty} \frac{ds}{4s^3 - g_2 s - g_3} \ . \tag{8.9.25}$$

g_2 and g_3 are expressible in terms of zeros e_1, e_2, e_3 of $4s^3 - g_2 s + g_3$ satisfying $e_1 + e_2 + e_3 = 0$ (the quadratic term in the polynomial vanishes)

$$\begin{aligned} g_2 &= -4(e_1 e_2 + e_1 e_3 + e_2 e_3 = 2(e_1^2 + e_2^2 + e_3^2) \ , \\ g_3 &= 4e_1 e_2 e_3 \ . \end{aligned} \tag{8.9.26}$$

The zeros of this polynomial must correspond to the zeros of the third order polynomial obtained when the zero u_- of P_4 is factorized out but for variable which is not u anymore.

Either all the zeros are real or one os real and two complex conjugates of each other. This depends on the sign of the discriminant $\Delta = g_2^3 - 27g_3^2$. The possibly complex half periods ω_i (in the generic case) are related to the roots by $\mathcal{P}(\omega_1) = e_1$, $\mathcal{P}(\omega_2) = e_2$,, $\mathcal{P}(\omega_3) = e_3 = -e1 - e_2$ and satisfy $\omega_3 = -\omega_1 - \omega_2$. For real roots e_i ω_1 is real and ω_3 purely imaginary so that $\omega_2 = -\omega_1 - \omega_3$ is complex.

The ratio $\tau = \omega_1/\omega_2$ defines so called modular parameter τ characterizing the periodicity properties of the Weierstrass function in complex plane (or effectively on torus whose conformal structures is characterized by τ).

3. If u_- is root of the P_4 as in the recent case, the expression for integral is given by

$$u = u_- + \frac{1}{4} P_4'(u_-) \left[\mathcal{P}(t; g_2, g_3) - \frac{1}{24} P_4''(u_-) \right]^{-1} \ . \tag{8.9.27}$$

Here $\mathcal{P}(t; g_2, g_3)$ is the Weierstrass elliptic function. This expression gives $u = cos(\theta)$ as function of time t. The period T corrresponds to the situation $u = u_+$ and must correspond to the $t = \omega_1$ (real period in the argument of $\mathcal{P}$. The values of this function can be calculated numerically using Mathematica.

4. The relationship $u = u(t)$ giving by the above expression allows to integrate the equations for ψ and ϕ from the corresponding conservation laws by substituting the expression for $u(t)$ to these equations. Note that if nutation is absent so that $d\theta/dt = 0$ holds true and the above description fails since P_4 has a pair of degenerate real roots $u_+ = u_-$ meaning that nutation amplitudes becomes vanishing. This situation must be treated separately.

Exact solution when nutation is neglected

In the recent case the nutation can be neglected in the first approximation so that one has $d\theta/dt = 0$. In this case the two roots of the fourth order polynomial whose roots define the turning points are degenerate. This situation must be treated separately since the previous treatment fails.

1. The Lagrange equations of motion for θ give $\partial L/\partial\theta = 0$ stating that the torque vanishes in the equilibrium position for θ. The condition allows three solutions

$$\begin{aligned} u &= \pm 1 \ \text{(no precession)} \ , \\ u &= \frac{1}{r_{13}-1} \times \frac{(\frac{d\psi}{dt})^2}{(\frac{d\phi}{dt})^2} \ \text{(precession)} \ , \\ r_{13} &\equiv \frac{I_1}{I_3} \ . \end{aligned} \tag{8.9.28}$$

   If the bubble were a hemisphere with constant mass density one would have $r_{13} = 1/2$. Since the mass is concentrated in the orbital plane of planets, the value of I_3 is however smaller than I_1 and r_{13} is large suggesting that $r_{31} \equiv 1/r_{13}$ is a more convenient parameter for numerical calculations. If dark matter and energy do not contribute significantly inside heliosphere, Jupiter would give the dominating contribution to I_1 and Sun to I_3 inside planetary system. Kuiper belts are expected to give a large contribution to I_1. A rough estimate for r_{31} using various masses, solar radius, and planetary distances as basic data and neglecting Kuiper belt would give $r_{31} \sim 10^{-3}$. The actual value would be smaller than this unless dark matter changes the situation.

2. The conservation laws for p_ψ and p_ϕ read as

$$\begin{aligned} p_\psi &= I_3(\tfrac{d\psi}{dt} + u\tfrac{d\phi}{dt}) \equiv I_1 a \ , \\ p_\phi &= \left[I_1(1-u^2) + I_3u^2\right]\tfrac{d\phi}{dt} + I_3 u \tfrac{d\psi}{dt} \equiv I_1 b \ , \end{aligned} \tag{8.9.29}$$

   and give

$$\begin{aligned} \begin{pmatrix} \frac{d\psi}{dt} \\ \frac{d\phi}{dt} \end{pmatrix} &= \frac{1}{1-u^2}\begin{pmatrix} a\left[r_{13}(1-u^2)+u^2\right] - bu \\ b - au \end{pmatrix} \ , \\ \frac{\frac{d\psi}{dt}}{\frac{d\phi}{dt}} &= \pm\frac{a\left[r_{13}(1-u^2)+u^2\right] - bu}{b-au} \ . \end{aligned} \tag{8.9.30}$$

   Note that $d\psi/dt$ and $d\phi/dt$ are constants.

3. By substituting the expression for the ratio of these angular velocities to the equation for the equilibrium value of u, one obtains

$$u(b-au)^2 = \frac{1}{r_{13}-1}\{a\left[r_{13}(1-u^2)+u^2\right] - bu\}^2 \ . \tag{8.9.31}$$

This is fourth order polynomial and the number of real roots is at most four. $u \rightarrow -u, b \rightarrow -b$ is a symmetry of this equation. The interpretation is as change of the direction of spin axis and precession axis.

4. By feeding $d\theta/dt = 0$ into the conservation law of energy, one obtains an expression for the conserved energy

$$E = \frac{I_1}{2}\left[(1-u^2)(b-au)^2 + r_{13}b^2\right] + V_1u^2 \ . \tag{8.9.32}$$

An interesting possibility is that the rotational motion of the bubble is stabilized against dissipation by the negativity of even the total energy E. The problem is that r_{13} is large and b is non-vanishing for precession so that the negativity of the total energy does not seem plausible.

A weaker condition is that $E' = E - p_{\psi}^2/2I_3$ is negative. This gives

$$E' = \frac{I_1}{2}\left[(1-u^2)(b-au)^2 + r_{13}(b^2-a^2)\right] + V_1u^2 < 0 \ . \tag{8.9.33}$$

For $b^2 < a^2$ the sign of the large term in the kinetic energy changes. What this would mean that the rate of rotation of solar system around the instantaneous precessing instantaneous rotation axis is large as compared to the precession rate.

5. The estimate for the period of precession given by $T = 2.6 \times 10^4$ years. In the approximation that nutation is absent $d\phi/dt = \omega$ is constant, and one has $d\phi/dt = 2\pi/T = 2.4 \times 10^{-4}$/year. The actual precession rate is not constant but its order of magnitude is same as the estimate obtained neglecting the nutation. Nutation would induce a time dependence of the precession rate. A reasonable expectation is that nutation represents a small oscillation around the solution representing mere precession.

Approximate solution when nutation is allowed

The model for non-nutating precession and the fact that precession rate is not quite constant suggest that a small nutation is present and induces the variation of the precession rate. A natural guess is that nutation represents a small perturbation around of non-nutating solutions. If this the case one can consider a standard treatment using standard perturbation theory assuming $u = u-0+\Delta u(t)$ and assuming that angular velocities are not affected at all so that only the u is perturbed.

1. The Lagragian for small perturbations of this kind is

$$\Delta L = \frac{I_1}{2}(\frac{d\Delta u}{dt})^2 + \left[\frac{(I_3-I_1)}{2}\omega_{\phi}^2 - \frac{V_1}{2}\right]\Delta u^2 \ . \tag{8.9.34}$$

Here the shorthand notation $d\phi/dt \equiv \omega_{\phi}$ is introduced.

2. The equation for small oscillations is

$$\begin{aligned} \frac{d^2\Delta u}{dt^2} + \omega_0^2\Delta u &= 0 \ , \\ \omega_0^2 &= \left[(1-r_{31})\omega_{\phi}^2 + \frac{V_1}{I_1}\right]\Delta \ . \end{aligned} \tag{8.9.35}$$

3. Stability requires $\omega_0^2 > 0$. Since r_{13} is small the first term in ω_0^2 is positive. The second term is negative and this poses an upper bound for the magnitude of V_1 or alternatively lower bound for the magnitude of ω_ϕ:

$$\frac{I_1\omega_\phi^2}{|V_1|} > \frac{1}{1-r_{31}} = \frac{r_{13}}{r_{13}-1} \quad . \tag{8.9.36}$$

   A possible interpretation of this condition that sufficiently high precession rate prevents the instability causing the value of u to increase. Note that V_1u^2 is analogous to harmonic oscillator potential with a wrong sign. Note that for $\omega_\phi = 0$ which corresponds to $u_0 = 0$ the situation is unstable so that precession is necessary to stabilize the system against gravitational torque.

4. The period of nutation defines the period of oscillation for the rate of precession and this condition gives additional constraint on the parameters of the model.

8.10 Appendix: Orbital Radii Of Exoplanets As A Test For The Theory

In this appendix the orbital radii of exo-planets as test of the theory are considered.

Orbital radii of exoplanets serve as a test for the theory. Hundreds of them are already known and in [E17] tables listing basic data for for 136 exoplanets can be found. Tables provide also references and links to sources giving data about stars, in particular star mass M using solar mass M_S as a unit. Hence one can test the formula for the orbital radii given by the expression

$$\begin{aligned}
\frac{r}{r_E} &= \frac{n^2}{5^2}\frac{M}{M_S}X \ , \\
X &= (\frac{n_1}{n_2})^2 \ , \\
n_i &= 2^{k_i}\times\prod_{s_i}F_{s_i} \ , \quad F_{s_i}\in\{3,5,17,257,2^{16}+1\} \ .
\end{aligned} \tag{8.10.1}$$

Here a given Fermat prime F_{s_i} can appear only once.

It turns out that the simplest option assuming $X = 1$ fails badly for some planets: the resulting deviations of order 20 per cent typically but in the worst cases the predicted radius is by factor of $\sim .5$ too small. The values of X used in the fit correspond to $X \in \{(2/3)^2, (3/4)^2, (4/5)^2, (5/6)^2, (15/17)^2, (15/16)^2, (16/17)^2\} \simeq \{.44, .56, .64, .69, .78, .88, .89\}$ and their inverses. The tables summarizing the resulting fit using both $X = 1$ and value giving optimal fit are given below. The deviations are typically few per cent and one must also take into account the fact that the masses of stars are deduced theoretically using the spectral data from star models. I am not able to form an opinion about the real error bars related to the masses.

Tables 8.3, **8.4**, and **8.5** represent the fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers". The data about radii of planets are from tables at `http://tinyurl.com/y7j6tns7` and star masses from the references contained by the tables.

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Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD73256	0.037	1.05	1	0.042	1.14	16	15	1.00
HD83443	0.040	0.79	1	0.032	0.79	15	17	1.01
HD46375	0.040	1.00	1	0.040	1.00	1	1	1.00
HD179949	0.040	1.24	1	0.050	1.24	17	15	0.97
HD187123b	0.040	1.06	1	0.042	1.06	1	1	1.06
HD120136	0.050	1.30	1	0.052	1.04	1	1	1.04
HD330075	0.046	0.70	1	0.028	0.61	4	5	0.95
BD103166	0.050	1.10	1	0.044	0.88	15	16	1
HD209458	0.050	1.05	1	0.042	0.84	16	17	0.95
HD76700	0.050	1.00	1	0.040	0.8	15	17	1.03
HD217014	0.050	1.06	1	0.042	0.85	15	16	0.96
HD9826b	0.059	1.30	1	0.052	0.88	15	16	1.00
HD49674	0.060	1.00	1	0.040	0.67	5	6	0.96
HD68988	0.070	1.20	1	0.048	0.69	5	6	0.99
HD168746	0.065	0.88	1	0.035	0.54	3	4	0.96
HD217107	0.070	0.98	1	0.039	0.56	3	4	1
HD162020	0.074	0.75	1	0.030	0.41	2	3	0.91
HD130322	0.088	0.79	1	0.032	0.36	3	5	1
HD108147	0.102	1.27	1	0.051	0.50	3	4	0.89
HD38529b	0.129	1.39	1	0.056	0.43	2	3	0.97
HD75732b	0.115	0.95	1	0.038	0.33	3	5	0.92
HD195019	0.140	1.02	2	0.163	1.17	16	15	1.02
HD6434	0.150	0.79	2	0.126	0.84	15	16	0.96
HD192263	0.150	0.79	2	0.126	0.84	15	16	0.96
GJ876c	0.130	0.32	3	0.115	0.89	15	16	1.01
HD37124b	0.181	0.91	2	0.146	0.80	15	17	1.03
HD143761	0.220	0.95	2	0.152	0.69	5	6	0.99
HD75732c	0.240	0.95	2	0.152	0.63	4	5	0.99
HD74156b	0.280	1.27	2	0.203	0.73	5	6	1.05
HD168443b	0.295	1.01	2	0.162	0.55	3	4	0.97
GJ876b	0.210	0.32	4	0.205	0.98	1	1	0.98
HD3651	0.284	0.79	3	0.284	1.00	1	1	1
HD121504	0.320	1.18	2	0.189	0.59	3	4	1.05
HD178911	0.326	0.87	3	0.313	0.96	1	1	0.96
HD16141	0.350	1.00	3	0.360	1.03	1	1	1.03
HD114762	0.350	0.82	3	0.295	0.84	15	16	0.96
HD80606	0.469	1.10	3	0.396	0.84	15	16	0.96
HD117176	0.480	1.10	3	0.396	0.83	15	16	0.94
HD216770	0.460	0.90	3	0.324	0.70	5	6	1.01

Table 8.3: Fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers".

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD52265	0.49	1.13	3	0.41	0.83	15	16	0.94
HD73526	0.65	1.02	4	0.65	1	1	1	1.00
HD82943c	0.73	1.05	4	0.67	0.92	16	17	1.04
HD8574	0.77	1.17	4	0.75	0.97	1	1	0.97
HD169830	0.82	1.40	4	0.90	1.09	17	16	0.97
HD9826c	0.83	1.30	4	0.83	1.00	1	1	1.00
HD202206	0.83	1.15	4	0.74	0.89	15	16	1.01
HD89744	0.89	1.40	4	0.9	1.01	1	1	1.01
HD134987	0.81	1.05	4	0.67	0.83	15	16	0.94
HD12661b	0.82	1.07	4	0.68	0.84	15	16	0.95
HD150706	0.82	0.98	5	0.98	1.20	16	15	1.05
HD40979	0.81	1.08	4	0.69	0.85	15	16	0.97
HD92788	0.95	1.06	5	1.06	1.12	16	15	0.98
HD142	0.97	1.10	5	1.1	1.13	16	15	1.00
HD28185	1.03	0.99	5	0.99	0.96	1	1	0.96
HD142415	1.07	1.03	5	1.03	0.96	1	1	0.96
HD108874b	1.06	1.00	5	1.00	0.94	1	1	0.94
HD4203	1.09	1.06	5	1.06	0.97	1	1	0.97
HD177830	1.14	1.17	5	1.17	1.03	1	1	1.03
HD128311b	1.02	0.80	6	1.15	1.13	1	1	1.13
HD27442	1.18	1.20	5	1.20	1.02	1	1	1.02
HD210277	1.12	0.99	5	0.99	0.88	15	16	1.01
HD82943b	1.16	1.05	5	1.05	0.91	15	16	1.03
HD20367	1.25	1.17	5	1.17	0.94	1	1	0.94
HD114783	1.19	0.92	6	1.32	1.11	1	1	1.11
HD137759	1.28	1.05	5	1.05	0.82	15	17	1.05
HD19994	1.42	1.34	5	1.34	0.94	1	1	0.94
HD147513	1.26	1.11	5	1.11	0.88	15	16	1.00
HD222582	1.35	1.00	6	1.44	1.07	1	1	1.07
HD65216	1.31	0.92	6	1.32	1.01	1	1	1.01
HD141937	1.52	1.10	6	1.58	1.04	1	1	1.04
HD41004A	1.31	0.70	7	1.37	1.05	1	1	1.05
HD160691b	1.87	1.08	7	2.12	1.13	16	15	0.99

Table 8.4: Fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers".

Star Name	R	M	n	R1	R1/R	r	s	R2/R
HD23079	1.65	1.10	6	1.58	0.96	1	1	0.96
HD186427	1.67	1.01	6	1.45	0.87	15	16	0.99
HD4208	1.67	0.93	7	1.82	1.09	16	15	0.96
HD114386	1.62	0.68	8	1.74	1.07	17	16	0.95
HD213240	2.03	1.22	6	1.76	0.87	15	16	0.98
HD10647	2.10	1.07	7	2.10	1.00	1	1	1
HD10697	2.13	1.10	7	2.16	1.01	1	1	1.01
HD95128b	2.09	1.03	7	2.02	0.97	1	1	0.97
HD190228	2.00	0.83	8	2.12	1.06	1	1	1.06
HD114729	2.08	0.93	7	1.82	0.88	15	16	1
HD111232	1.97	0.78	8	2.00	1.01	1	1	1.01
HD2039	2.19	0.98	7	1.92	0.88	15	16	1
HD136118	2.40	1.24	7	2.43	1.01	1	1	1.01
HD50554	2.32	1.07	7	2.09	0.9	15	16	1.02
HD9826d	2.53	1.30	7	2.55	1.01	1	1	1.01
HD196050	2.43	1.10	7	2.16	0.89	15	16	1.01
HD216437	2.43	1.07	8	2.74	1.13	17	15	0.88
HD216435	2.70	1.25	7	2.45	0.91	1	1	0.91
HD169830c	2.75	1.40	7	2.74	1	1	1	1
HD106252	2.54	0.96	8	2.46	0.97	1	1	0.97
HD12661c	2.60	1.07	8	2.74	1.05	1	1	1.05
HD23596	2.86	1.30	7	2.55	0.89	15	16	1.01
HD168443c	2.87	1.01	8	2.59	0.9	15	16	1.03
HD145675	2.85	1.00	8	2.56	0.9	15	16	1.02
HD11964b	3.10	1.10	8	2.82	0.91	16	17	1.03
HD39091	3.29	1.10	9	3.56	1.08	17	16	0.96
HD38529c	3.71	1.39	8	3.56	0.96	1	1	0.96
HD70642	3.30	1.00	9	3.24	0.98	1	1	0.98
HD33636	3.56	0.99	9	3.21	0.9	15	16	1.03
HD95128c	3.73	1.03	10	4.12	1.1	16	15	0.97
HD190360	3.65	0.96	10	3.84	1.05	1	1	1.05
HD74156c	3.82	1.27	9	4.11	1.08	1	1	1.08
HD22049	3.54	0.80	11	3.87	1.09	16	15	0.96
HD30177	3.86	0.95	10	3.80	0.98	1	1	0.98
HD89307	4.15	0.95	10	3.80	0.92	1	1	0.92
HD72659	4.50	0.95	11	4.60	1.02	1	1	1.02
HD75732d	5.90	0.95	13	6.42	1.09	16	15	0.96

Table 8.5: Fit of the Bohr model to the radii of the associated exoplanets. R denotes the value of minor semiaxis of the planetary orbit using AU as a unit and M the mass of star using solar mass M_S as a unit. n is the value of the principal quantum number and R_1 the radius assuming $X = (r/s)^2 = 1$ and R_2 the value for the best choice of X as ratio of "ruler and compass integers".

Chapter 9

Quantum Astrophysics

9.1 Introduction

The mechanisms behind the formation of planetary systems, galaxies and larger systems are poorly understood but planar structures seem to define a common denominator and the recent discovery of dark matter ring in a galactic cluster in Mly scale [E137] suggest that dark matter rings might define a universal step in the formation of astrophysical structures.

Also the dynamics in planet scale is poorly understood. In particular, the rings of Saturn and Jupiter are very intricate structures and far from well-understood. Assuming spherical symmetry it is far from obvious why the matter ends up to form thin rings in a preferred plane. The latest surprise [E34] is that Saturn's largest, most compact ring consist of clumps of matter separated by almost empty gaps. The clumps are continually colliding with each other, highly organized, and heavier than thought previously.

The situation suggests that some very important piece might be missing from the existing models, and the vision about dark matter as a quantum phase with a gigantic Planck constant [K42] is an excellent candidate for this piece. The vision that the quantum dynamics for dark matter is behind the formation of the visible structures suggests that the formation of the astrophysical structures could be understood as a consequence of Bohr rules [K93].

9.1.1 Generalization Of The Notion Of Imbedding Space

Quite generally, the hierarchy of Planck constants is realized by generalizing the notion of embedding space such that one has a book like structure with various almost-copies of embedding space glued together like pages of book. Each page of book correspond to a particular level of dark matter hierarchy and darkness means that there are no Feynman diagrams in which particles with different value of Planck constant would appear. The interactions between different levels of hierarchy involve the transfer of the particles mediating the interaction between different pages of the book. Physically this means a phase transition changing the value of Planck constant assignable to the particle so that particle's quantum size is scaled. At classical level the interactions correspond to the leakage of magnetic and electric fluxes and radiation fields between different pages of the book.

The development of the view about generalized imbedding space

The development of precise formulation of the realization of Planck constants in terms of the book like structure of embedding space has been a sequence of improved trials.

1. Since space-time surfaces are 4-surfaces in the generalized embedding space, Bohr rules can be formulated in a way which is general coordinate invariant and Lorentz invariant. The rules are actually for dark matter structures obeying Z_n symmetry for very large n characterizing a symmetry of field bodies associated with the structure in question. Z_n was identified as a maximal cyclic subgroup for any subgroup $G \subset SO(3)$ appearing in the series of Jones inclusions with index $\mathcal{M}/\mathcal{N} < 4$ but also $\mathcal{M}/\mathcal{N} \geq 4$ can be considered. Two questions arise. What distinguishes between these two cases and what is the precise action of G.

2. The first generalization of the embedding space assigned Z_n to rotations in M^4 degrees of freedom acting as symmetries of factor space obtained dividing with subgroup of $G \subset SO(3)$ having Z_n as maximal cyclic subgroup. The outcome was a book like structure associated with $M^4 \backslash M^2$ with M^2 defining the back of the book and characterizing the direction of quantization axes for spin. The choice of M^2 has interpretation as fixing choice of the direction of quantization axes. The world of classical worlds (WCW) would be union over different choices of M^2.

3. This generalization was not enough to really understand the physics behind gravitational Planck constant, and the next generalization assigned the groups associated with Jones inclusions also with CP_2 degrees of freedom and acting also now as invariance group of orbifold structure associated with CP_2. In CP_2 degrees of freedom the back of the book is defined by homologically trivial geodesic sphere S^2 of CP_2. Therefore one has book like structure in both M^4 and CP_2 degrees of freedom.

4. The attempts to understand Quantum Hall effect suggested a generalization, which allowed both factor spaces and coverings of both M^4 and CP_2. In the case of coverings the action of Z_n contained by the group assignable to Jones inclusion permutes the sheets of the singular covering space of $M^4 \backslash M^2$ ($CP_2 \backslash S^2$). In the similar way the group acts in the singular factor space associated with $M^4 \backslash M^2$ ($CP_2 \backslash S^2$). The coverings were assigned with Jones inclusions having index $\mathcal{M}/\mathcal{N} \geq 4$.

5. The emergence of zero energy ontology induced further detail to this picture. In zero energy ontology causal diamond (CD) of M^4 defined as the intersection of future and past directed light-cones is basic structure. $CD \times CP_2$ contains positive (negative) energy parts of the zero energy state at the lower (upper) light-like boundary δM^4_+ δM^4_-. Each CD defines sector in the world of classical worlds (WCW) consisting of light-like 3-surfaces and corresponding 4-surfaces inside $CD \times CP_2$. Each sector of this kind in turn corresponds a union over copies of CDs corresponding to different choices of quantization axes for Poincare and color quantum numbers so that the selection of quantization axis means a localization to one particular variant of given CD. Temporal and spatial localization in turn fixes the lower tip of CD: the location of upper tip is fixed by the condition that the temporal distance between upper and lower tip is quantized in powers of two: this assumption implies p-adic length scale hypothesis. The singular covering and factor spaces of CD:s become the pages of the book like structures. One can say that these books are like rigid bodies located in $M^4 \times CP_2$ and that they have also rotational and color rotational degrees of freedom so that WCW is kind of gigantic quantum library.

6. The most tortuous piece of the tortuous development of the ideas were the guesses for the formula for Planck constant in terms of integers n_a and n_b characterizing the orders of maximal cyclic subgroups of G_a and G_b. The realization that the formula could be interpreted as homomorphism from the set of pages of the book left still two options for which expressions for the Planck constant were inverses of each other. Four options are possible and it seems that the correct option was found in the fourth trial! A heuristic argument based on $1/\hbar$ proportionality of the fine structure constant combined with the earlier condition that Compton length is proportional to n_a led to what I believe is the correct formula. For the Cartesian product of n_a resp. n_b-fold coverings of CD and CP_2 one has $\hbar = n_a n_b$. When covering is replaced with a factor space, n_i goes to $1/n_i$ in the formula. The model for quantum Hall effect is consistent with this [K81]. and this option is also favored by the gravitational Bohr orbitology and the model for dark graviton emission. The notion of generalized embedding space is describe in detail in Appendix.

7. For this identification of the Planck constant the huge value of h_{gr} requires that CD or CP_2 or both correspond to a singular covering space. These options can be denoted by $C-C$, $C-F$ and $F-C$. Rotational symmetries Z_{n_a} with small n_a are possible for $F-C$ option for very large value of n_b. For $C-F$ option dark matter symmetries with large Z_n acts in the covering of CD so that no discrete rotational invariance in CD is predicted. The $F-F$ option for which both G_a and G_b act as orbifold symmetries is not favored in gravitation nor living matter since one $\hbar/\hbar_0 = 1/n_a n_b$.

The extension of embedding space to a book-like structure

The allowance of coverings means an extension of the embedding space by allowing also G_a *resp.* G_b-fold coverings of $\hat{CD} = CD \backslash M^2$ *resp.* $\hat{CP}_2 = CP_2 \backslash S^2$. Here M^2 corresponds to 2-D Minkowski space defined by the fixing of rest frame and direction of quantization axis of angular momentum and S^2 to a homologically trivial geodesic sphere of CP_2 which corresponds to a particular choice of group $SO(3) \subset SU(3)$ and thus fixing of quantization axes of color isospin. The surfaces $X^4 \subset M^4 \times S^2$ are vacuum extremals as required by internal consistency of the theory. The leakage between different pages of book occurs via manifolds $CD \times S^2$ and $(M^2 \cap CD) \times CP_2$ which correspond to quantum criticality. The extreme form of quantum criticality corresponds to leakage through $M^2 \times S^2$.

There are four options corresponding to $C - C$, $F - F$, $C - F$ and $F - C$.

1. Options $C-C$ and $C-F$ for which G_a acts in the covering space of CD are perhaps the most promising candidates for the modelling of dark gravitons and gravitational Bohr orbitology but also $F - C$ option can be considered. $C - C$ maximizes the value of $\hbar$. Also fractional quantum Hall effect is possible only for these options (see Appendix). These options allow large values of Planck constant and could be involved also with living matter.

2. G_a could act as factor space symmetries in living matter for $F - C$ option. Molecular rotational symmetries correspond typically to small groups G_a $G_a = Z_n$, $n = 5, 6$ are favored for molecules containing aromatic cycles and could correspond to factor spaces in M^4 degrees of freedom and coverings in CP_2 degrees of freedom ($r = n_b/n_a$). Also genuinely 3-dimensional tetrahedral, octahedral, and icosahedral symmetries appear in living matter. Even the symmetries of snow flakes could be understood for $F - C$ option if n_b is large enough so that quantum scale proportional to n_b/n_a is macroscopic.

3. Also astrophysical systems might possess small G_a as orbifold symmetries and one an ask whether the hexagonal structure at the North Pole of Saturn could be an example of $n_a = 6$ fold symmetry. One must remember that these symmetries are exact at the level of dark matter but need not be so at the level of visible matter.

It must be emphasized that this interpretation differs quite a lot from the earlier ones which assumed different formulae of Planck constant.

Does the hierarchy follow from the basic quantum TGD?

One can consider also the possibility that the hierarchy of Planck constants follows from the basic quantum TGD rather than being assumed as a separate postulate. The argument goes as follows.

1. By the extreme non-linearity of the Kähler action the correspondence between the time derivatives of the embedding space coordinates and canonical momentum densities is many-to-one. This leads naturally to the introduction of covering spaces of $CD \times CP_2$, which are singular in the sense that the sheets of the covering co-incide at the ends of CD and at wormhole throats. One can say that quantum criticality means also the instability of the 3-surfaces defined by the throats and the ends against the decay to several space-time sheets and consequent charge fractionization. The interpretation is as an instability caused by too strong density of mass and making perturbative description possible since the matter density at various branches is reduced. The nearer the vacuum extremal the system is, the lower the mass density needed to induce the instability is and the larger is the number of sheets resulting in this way is.

2. The singular regions of the covering are regions in which the integer characterizing the multiple-valuedness of the time derivatives of the embedding space coordinates as functions of canonical momentum densities is reduced from the maximal value. The reduction to single sheeted covering could (but need not!) take place over any Lagrangian manifold of CP_2 rather than only over a homologically trivial geodesic sphere and would thus directly correspond to the vacuum degeneracy of Kähler action. One can also imagine the reduction of the integer characterizing multi-valuedness to a smaller value different from one in non-vacuum regions.

3. In M^4 degrees of freedom branching to a single sheeted covering can occur over any partonic 2-surface which does not enclose the tip of CD. In this case the Kähler gauge potential would contain a singular gauge term having an archetypal form $\Delta A = d\phi/n_a$ at say upper hemisphere so that the magnetic flux would receive a non-vanishing contribution from North pole and give rise to a fractionized Kähler magnetic and therefore also to Kähler electric charge. This term is pure gauge for all partonic 2-surface not containing the tip of CD. Thus one species of anyons would be associated with this kind of partonic 2-surfaces. Second species would correspond to singular gauge transforms about which example would be $\Delta A = d\Psi/n_b$, where Ψ is the angle coordinate associated with a homologically non-trivial geodesic sphere. The modification of the Kähler gauge potential could be interpreted in terms of a measurement interaction term added to the Dirac action and their sum at the ends would give rise to the non-fractional contribution to the measurement interaction term. This kind of term would be also associated with Noether charges such as 4-momentum. Depending on whether one considers the end of space-time sheet or at wormhole throat, the measurement interaction term would be given as $1/n_b$ or $1/n_a$ multiple of the measurement interaction term in absence of branching and would be more complex than the simple archetypal forms.

4. Classically the fractional Noether charges would emerge from Chern-Simons representation of Kähler function with the Lagrangian multiplier term realizing the weak form of electric-magnetic duality as a constraint. The latter term would be responsible for the non-vanishing values of four-momentum and angular momentum. The isometry charges in CP_2 degrees of freedom would receive a contribution also from the Chern-Simons term.

5. The situation can be described mathematically either by using effectively only single sheet but an integer multiple of Planck constant or many-sheeted covering and ordinary value of Planck constant. In [K42] the argument that this indeed leads to hierarchy of Planck constants including charge fractionization is developed in detail. The restriction to singular coverings is consistent with the experimental constraints and means that only integer valued Planck constants are possible. A given value of Planck constant corresponds only to a finite number of the pages of the Big Book and that the evolution by quantum jumps is analogous to a diffusion at half-line and tends to increase the value of Planck constant.

6. The following argument would suggest a direct connection between vacuum degeneracy, coverings, and the hierarchy of infinite primes. For vacuum extremal the number of sheets is formally infinite but the sheets are in a well-define sense "passive". The numbers n_a and n_b for sheets correspond to powers p^{n_a} and p^{n_b} for a prime appearing in infinite prime characterizing the partonic 3-surface and having interpretation as particle numbers. The unit infinite primes $X \pm 1$ correspond to the two basic infinite primes having interpretation as fermionic vacua are interpreted as Dirac sea: the numbers of bosons and fermions are vanishing for them. This suggests that the fermions of Dirac sea correspond to the "passive" sheets. This raises the question whether one could characterize the infinite degeneracy associated with vacuum extremals by these two infinite primes and non-vacuum extremals by infinite primes for which boson and fermion numbers are non-vanishing. The two infinite primes would correspond to CD and CP_2 degrees of freedom. They could also correspond to the space-time sheets of Euclidian and Minkowskian signature of the induced metric meeting at the wormhole throat at which the induced 4-metric is degenerate. Bose-Einstein condensate of n_i bosons ($i = a, b$) or fermion plus $n_i - 1$ bosons would correspond to n_i sheets of covering.

   Arithmetic quantum field theory allows infinite number of conservation laws corresponding to the conservation of the number theoretic momentum $p = \sum_i n_i log(p_i)$ which forces separate conservation of each number theoretical momentum $n_i log(p_i)$ since the logarithms of primes are linearly independent in the realm of rationals. This conservation law could correlate the partonic lines arriving in the interaction vertices and state that the total number of sheets of the covering is conserved although it can be shared by several partonic space-time sheets in the final state.

The reduction of the hierarchy of Planck constants to basic quantum TGD is of course only an interesting idea and the best strategy to proceed is to develop objections against it.

1. The branching of partonic 2-surfaces at the ends of space-time sheets and wormhole throats is analogous to the branching of the line of Feynman graph. The 3-D lines of generalized Feynman graphs indeed branch at the vertices and this leads to the basic objection against the proposed interpretation of the fractionization. Could one consider the possibility that branching corresponds to what happens in the vertices of Feynman diagrams? This cannot not seem to be the case. The point is that canonical momentum densities are identical so that also the conserved classical Noether and Kähler charges associated with various branches should be the same.

2. The value of gravitational Planck constant is enormous and one would mean enormously many-fold branching of partonic 2-surfaces of astrophysical size. Does this really make sense? Is this simply due the fact that the basic parameter GM_1M_2 characterizing the strength of gravitational interaction is much larger than unity so that perturbation theory in terms of it fails to converge and the splitting to $\hbar_{gr}/\hbar_0$ sheets guarantees that the perturbation theory at each sheet converges.

3. One can also ask whether the fractional charges can be observed directly since it seems that only the partonic 2-surfaces at the ends of the space-time sheet are observable.

4. Perhaps the most serious objection relates to the basic intuition about scaling of quantum lengths by $\hbar$ since this scaling is fundamental for all predictions in the model of quantum biology. It is not obvious why the basic quantum lengths in M^4 degrees of freedom - in particular the size scale of CD - should be scaled up by n_an_b. Could this scaling up result dynamically or can one find some simple kinematic argument forcing the size scale spectrum of CDs? Kinematic argument is more plausible and indeed exists. Suppose that one can speak about plane waves $exp(inEt/\hbar_0)$, where t is proper time coordinate associated with the line connecting the tips of CD. Periodic boundary conditions at $t = T$ imply $E = n\hbar_0/2\pi T$ where T is the proper time distance between the tips of CD. Suppose that $\hbar_0$ is replaced with its n_an_b multiple in the plane wave. As a consequence, the plane waves for sheets and for same value of E do not anymore satisfy periodic boundary conditions at $t = T$ anymore. These conditions are however satisfied for $t = n_an_bT$.

Equivalence Principle allows also to assume the formula for h_{gr} to apply for elementary particles only but does not exclude it in longer scales. The restriction to elementary particle and atomic scales supports to the identification $h_{gr} = h_{eff}$ unifying the two views to the hierarchy of Planck constants inspired by Nottale's findings on one hand, and by tge effects of ELF em fields on vertebrate brain on the other hand. The gravimagnetic anomaly proposed by Tajmar *et al* [E162, E250] gives support for this identification [K98], and leads to rather detailed view about the role of large h_{eff} phases in TGD inspired quantum biology.

9.1.2 Gravitational Bohr Orbitology

The basic question concerns justification for gravitational Bohr orbitology. The basic vision is that visible matter identified as matter with $\hbar = \hbar_0$ ($n_a = n_b = 1$) concentrates around dark matter at Bohr orbits for dark matter particles. The question is what these Bohr orbits really mean. Should one in the improved approximation relate Bohr orbits to 3-D wave functions for dark matter as ordinary Bohr rules would suggest or do the Bohr orbits have some deeper meaning different from that in wave mechanics.

The first vision

The first vision about gravitational Bohr orbitology was inspired by the finding that surprisingly complex geometric structures possessing relatively small subgroups of rotational group as approximate symmetry groups appear in astrophysical scales (say the hexagonal structure associated with Saturnus). This would suggest circles and spokes representing dark matter structures, gravi-electric flux quanta, and also circles representing gravi-magnetic flux tubes orthogonal to the quantization plane become are building blocks of dark matter structures. This makes sense for $F - C$ option and the group G_a acting as orbifold symmetries would be behind these symmetries. This would require very large G_b acting as covering space symmetry in CP_2 degrees of freedom. Simplest of these structures are rings and cart-wheel like structures with rather small symmetry groups which are however badly broken. One could however argue that this breaking occurs only at the level of visible way.

Z_{n_a} would act as rotational symmetries of magnetic body and its subgroups could act as approximate symmetries of the visible matter and if one accepts ruler-and-compass hypothesis powerful predictions follow. On the other hand,

This option works nicely in the case of quantum Hall effect if spin fractionization is involved. If one assumes that the dark space-time sheets associated with gravitons and matter correspond to same page of the Big Book, this picture leads to difficulties since large n_b for covering and small n_a for orbifold does not lead to a plausible picture about what dark gravitons should be.

Quantum criticality and quantum chaos

TGD Universe is quantum critical and quantum criticality corresponds very naturally to what has been identified as the transition region to quantum chaos. The basic formulation of quantum TGD is indeed consistent with what has been learned from the properties of quantum chaotic systems and quantum chaotic scattering [B37]. Wave functions are concentrated around Bohr orbits in the limit of quantum chaos, which is just what dark matter picture assumes. In this framework the chaotic motion of astrophysical object becomes the counterpart of quantum chaotic scattering and classical description is predicted to fail. By Equivalence Principle the value of the mass of the object does not matter at all so that the motion of sufficiently light objects in solar system might be understandable only as quantum chaotic scattering. The motion of gravitationally unbound comets and rings of Saturn and Jupiter and the collisions of galactic structures known to exhibit the presence of cart-wheel like structures define possible applications.

The description of gravitational radiation provides a stringent test for the idea about dark matter hierarchy with arbitrary large values of Planck constants. In accordance with quantum classical correspondence, one can take the consistency with classical formulas as a constraint allowing to deduce information about how dark gravitons interact with ordinary matter. The standard facts about gravitational radiation are discussed first and then TGD based view about the situation is sketched in two cases corresponding to large value of n_a characterizing singular CD covering or orbifold and n_b characterizing singular CP_2 covering.

This discussion forces an important conclusion. The sequential de-coherence leading from dark gravitons with $(n_a > 1, n_b > 1)$ in stepwise way to visible gravitons having $(n_a = 1, n_b = 1)$ necessary involves steps in which the frequency of the resulting lower level gravitons is subharmonic of the original frequency. Ruler and compass hypothesis favors period doubling since powers of two are favored for n_a and n_b. The generation of sub-harmonics is one of the basic routes to chaos which suggests that chaos in astrophysical systems corresponds to large values of n_b with powers of 2 favored. Quite generally, the approach to quantum chaos would transform $\hbar/\hbar_0$ from integer to a rational with increasing denominator.

The planetary Bohr orbitology has been already discussed in the chapter "TGD and Astrophysics" [K93] with applications solar system and exo-planets. This discussion is not based on the full generalization of the embedding space but the general results are not changed since they depend on the value of Planck constant only. Instead of repeating this discussion, a formulation of these rules which is general coordinate invariant and Lorentz invariant is proposed.

About the spectrum of v_0

The proposed generalization of the embedding space allows in principle any rational multiple of $\hbar_0$ as the value of Planck constant and given value of Planck constant is realized by very many pages of the book like structure. For instance, for $F - C$ and $C - F$ options all integer multiples of (n_a, n_b) produce the same Planck constant.

The dependence of the gravitational Planck constant on masses is fixed by Equivalence Principle. Its strongest form would require a universal value of $v_0/c \equiv v_0$ (although in the following units with $c = 1$ are used, it is important to remember that v_0 is basically velocity like parameter). This form is not realized.

1. Different value of v_0 is required for inner and outer planets. I have discussed a simple model explaining why inner and outer planets must have different values of v_0 by taking into account cosmic string contribution to the gravitational potential which is negligible nowadays but was not so in primordial times. Among other things this implies that planetary system has a finite size, at least about 1 ly in case of Sun (nearest star is at distance of 4 light years). The proposed anyonic picture would suggest that the anyonic 2-surface assignable to outer and inner planets is different.

2. Quantization rules have been applied to exoplanets in the case that the central mass and orbital radius are known (the discussion is moved from the chapter "Astrophysics" to the the Appendix of this chapter). Errors are around 10 per cent for the most favored value of $v_0 = 2^{-11}$. The "anomalous" planets with very small orbital radius correspond to $n = 1$ Bohr orbit ($n = 3$ is the lowest orbit in solar system). The universal velocity spectrum $v = v_0/n$ in simple systems perhaps the most remarkable prediction and certainly testable: this alone implies that the Bohr radius GM/v_0^2 defines the universal size scale for systems involving central mass. Obviously this is something new and highly non-trivial.

3. The recently observed dark ring in MLy scale is a further success and also the rings and Moons of Saturn and Jupiter obey the same universal length scale ($n \geq 5$ and $v_0 \to (16/15) \times v_0$ and $v_0 \to 2 \times v_0$).

4. For our own Moon orbital radius is much larger than Bohr radius for $v_0 = 2^{-11}$: one would have $n \simeq 138$. $n \simeq 7$ results for $v_0 \to v_0/20$ giving $r_0 \simeq 1.2R_E$. The small value of v_0 could be understood to result from a sequence of phase transitions reducing the value of v_0 to guarantee that solar system participates in the average sense to the cosmic expansion and from the fact inner planets are older than outer ones in the proposed scenario. The findings of Masreliez [E77] discussed in the last section of [K93] support the prediction that planetary system does not participate cosmic expansion in a smooth way.

The question becomes how to explain what is the correct way to weaken Equivalence Principle and why the values of v_0 are what they are. The simplest hypothesis is that v_0 has a fixed value for orbits connected by radial flux tubes to a given anyonic 2-surface. If the value of v_0 characterizes different anyonic 2-surfaces to which flux tubes around planetary orbits are connected by radial flux tubes then inner and outer planets would correspond to different anyonic two-surfaces. This would also give a precise characterization for the weakened form of Equivalence Principle. One could see outer planets as planets of the central object formed by Sun and inner planets. This picture would raise spherical surface at the distance of Earth to a very special role as the boundary of this central object and one can wonder whether the very special properties of Earth relate to this special role.

Planetary Bohr orbitology was born as a generalization of atomic Bohr orbitology. One can however turn the situation upside down and ask whether also atom could be seen as an anyonic system in which flux tubes surrounding classical electronic orbits are connected to an anyonic 2-surface assignable to nucleus by radial flux tubes mediating Coulomb interaction. Charge and spin fractionization do not support this idea and anyonic systems are also many-particle systems. It is indeed quite conceivable that atoms in electrons corresponds to CP_2 sized partonic 2-surfaces with atomic wave function assignable to the position of this 2-surface in the interior of larger 3-surface.

There is still one question to be considered. Could one understand why the values of v_0 are what they are?

1. The condition that $\hbar = GM^2/v_0$ gives for the dark Planck length $L_P = \sqrt{\hbar G}$ a value of order Schwartschild radius $r_S = 2GM$ forces $v_0 = 1/4$. The Planck length for $\hbar = GM(sun)M(Planet)/v_0$ corresponds to

$$L_P(\hbar) = \sqrt{\frac{r_S(Sun)r_S(Planet)}{4v_0}} = r_S(Sun)\sqrt{\frac{M(Planet)}{M(Sun)}}\sqrt{\frac{1}{4v_0}} \ .$$

The smaller mass of planet is compensated by the smallness of v_0 so that $G(\hbar)$ is not too far from $r_S(Sun)$: maybe this condition might fix at least the order of magnitude of v_0

somehow. In the case of Earth and Jupiter having $v_0 = 2^{-11}/5$ one has $G(\hbar) \simeq .27 r_S(Sun)$ and $G(\hbar) \simeq 1.6 r_S(Sun)$.

2. One can also try to find justification for why just $v_0 = 2^{-11}$ is preferred for inner planets. By Bohr quantization v_0 corresponds to a typical rotational velocity of mass m with respect to the cm of mass M. This gives a good idea about feasible values of v_0. This number also happens to correspond to the rotation velocity v/c of matter around cosmic string like objects assignable to galaxies and is expressible in terms of basic constants of quantum TGD (CP_2 length and Kähler coupling strength) appearing in the expression of string tension of cosmic strings.

9.1.3 How General Coordinate Invariance And Lorentz Invariance Are Achieved?

The basic objection of General Relativist against the planetary Bohr orbitology model is the lack of the manifest General Coordinate invariance and Lorentz symmetry. In GRT context this objection would be fatal. In TGD framework the lack of these symmetries is only apparent.

One can use Minkowski coordinates of the M^4 factor of the imbedding space $H = M^4 \times CP_2$ as preferred space-time coordinates. The basic aspect of dark matter hierarchy is that it realizes quantum classical correspondence at space-time level by fixing preferred M^4 coordinates as a rest system. This guarantees preferred time coordinate and quantization axis of angular momentum. The physical process of fixing quantization axes thus selects preferred coordinates and affects the system itself at the level of space-time, embedding space, and configuration space (world of classical worlds). This is definitely something totally new aspect of observer-system interaction.

One can identify in this system gravitational potential Φ_{gr} as the g_{tt} component of metric and define gravi-electric field E_{gr} uniquely as its gradient. Also gravi-magnetic vector potential A_{gr} and and gravi-magnetic field B_{gr} can be identified uniquely.

Quantization condition for simple systems

Consider now the quantization condition for angular momentum with Planck constant replaced by gravitational Planck constant $\hbar_{gr} = GMm/v_0$ in the simple case of point like central mass. The condition is

$$m \oint v \bullet dl = n \times \hbar_{gr} \quad . \tag{9.1.1}$$

The condition reduces to the condition on velocity circulation

$$\oint v \bullet dl = n \times \frac{GM}{v_0} \quad . \tag{9.1.2}$$

In simple systems with circular orbits the condition reduces to a universal velocity spectrum $v = v_0/n$ so that only the radii of orbits depend on mass distribution. For systems for which cosmic string dominates only $n = 1$ is possible. This is the case in the case of stars in galactic halo if primordial cosmic string going through the center of galaxy in direction of jet dominates the gravitational potential. The velocity of distant stars is correctly predicted.

For circular orbits there is no need to apply the condition for other canonical momenta (radial canonical momentum in Kepler problem). The nearly circular orbits of visible matter objects would be naturally associated with dark matter rings or more complex structures dark matter rings could suffer partial or complete phase transition to visible matter.

Generalization of the quantization condition

By Equivalence Principle dark ring mass disappears from the quantization conditions and the left hand side of the quantization condition equals to a generalized velocity circulation applying when central system rotates

$$\oint (v - A_{gr}) \bullet dl. \tag{9.1.3}$$

Note that the geodesic motion of visible matter does not mean closed orbit (perihelion shift of Mercury) and cannot therefore correspond exactly to a motion concentrated at partonic 2-surface containing anyonic dark matter unless dark matter itself is rotating slowly. This is not a problem if the dark matter is concentrated at flux tube surrounding the orbit in turn connected by flux tubes to an anyonic 2-surface assignable to Sun.

The right hand side of the quantization condition would be the generalization of GM by the replacement

$$GM \rightarrow \oint e \bullet r^2 E_{gr} \times dl. \tag{9.1.4}$$

e is a unit vector in direction of quantization axis of angular momentum, $\times$ denotes cross product, and r is the radial M^4 coordinate in the preferred system. Everything is Lorentz and General Coordinate Invariant and for Schwartschild metric this reduces to the expected form and reproduces also the contribution of cosmic string to the quantization condition correctly.

9.1.4 Topics Of The Chapter

The topics discuss in this chapter are following.

1. An updated view about hierarchy of Planck constants is discussed and the connection $h_{eff} = h_{gr}$ is shown to be consistent with TGD inspired quantum biology. The implication is that quantum gravity would be in key role in biology as intuited also by Penrose.

2. Vision about formation of structures and quantum chaos is astrophysical scales is discussed. Also a speculative view about gravitational radiation based on h_{gr} is considered.

3. TGD suggests that cosmological evolution involves a series of phase transitions changing the value of h_{gr} occurring via periods of quantum criticality. The critical cosmology is fixed apart from its duration. This suggests a piecewise accelerated expansion. Also inflationary period would be example of this phenomenon as also accelerating expansion much later.

4. Expanding Earth model has been proposed for long time ago to explain whyt the continents seem to fit nicely to form a complete covering of the Earth's surface. The model however makes sense if the radius of Earth is one half of its recent value. TGD based interpretation for the expansion is is in terms of a phase transition increasing h_{gr} by factor 2.

5. Blackholes in TGD is the topic of the last two sections.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L7].

9.2 Updated View About The Hierarchy Of Planck Constants

The original hypothesis was that the hierarchy of Planck constants is real. In this formulation the embedding space was replaced with its covering space assumed to decompose to a Cartesian product of singular finite-sheeted coverings of M^4 and CP_2.

Few years ago came the realization that it could be only effective but have same practical implications. The basic observation was that the effective hierarchy need not be postulated separately but follows as a prediction from the vacuum degeneracy of Kähler action. In this formulation Planck constant at fundamental level has its standard value and its effective values come as its integer multiples so that one should write $\hbar_{eff} = n\hbar$ rather than $\hbar = n\hbar_0$ as I have done. For most practical purposes the states in question would behave as if Planck constant were an integer multiple of the ordinary one. In this formulation the singular covering of the embedding space became only a convenient auxiliary tool. It is no more necessary to assume that the covering reduces to a Cartesian product of singular coverings of M^4 and CP_2 but for some reason I kept this assumption.

The formulation based on multi-furcations of space-time surfaces to N branches. For some reason I assumed that they are simultaneously present. This is too restrictive an assumption. The N branches are very much analogous to single particle states and second quantization allowing all $0 < n \leq N$-particle states for given N rather than only N-particle states looks very natural. As a matter fact, this interpretation was the original one, and led to the very speculative and fuzzy notion of N-atom, which I later more or less gave up. Quantum multi-furcation could be the root concept implying the effective hierarchy of Planck constants, anyons and fractional charges, and related notions- even the notions of N-nuclei, N-atoms, and N-molecules.

9.2.1 Basic Physical Ideas

The basic phenomenological rules are simple and there is no need to modify them.

1. The phases with non-standard values of effective Planck constant are identified as dark matter. The motivation comes from the natural assumption that only the particles with the same value of effective Planck can appear in the same vertex. One can illustrate the situation in terms of the book metaphor. Embedding spaces with different values of Planck constant form a book like structure and matter can be transferred between different pages only through the back of the book where the pages are glued together. One important implication is that light exotic charged particles lighter than weak bosons are possible if they have non-standard value of Planck constant. The standard argument excluding them is based on decay widths of weak bosons and has led to a neglect of large number of particle physics anomalies [K109].

2. Large effective or real value of Planck constant scales up Compton length - or at least de Broglie wave length - and its geometric correlate at space-time level identified as size scale of the space-time sheet assignable to the particle. This could correspond to the Kähler magnetic flux tube for the particle forming consisting of two flux tubes at parallel space-time sheets and short flux tubes at ends with length of order CP_2 size.

   This rule has far reaching implications in quantum biology and neuroscience since macroscopic quantum phases become possible as the basic criterion stating that macroscopic quantum phase becomes possible if the density of particles is so high that particles as Compton length sized objects overlap. Dark matter therefore forms macroscopic quantum phases. One implication is the explanation of mysterious looking quantal effects of ELF radiation in EEG frequency range on vertebrate brain: $E = hf$ implies that the energies for the ordinary value of Planck constant are much below the thermal threshold but large value of Planck constant changes the situation. Also the phase transitions modifying the value of Planck constant and changing the lengths of flux tubes (by quantum classical correspondence) are crucial as also reconnections of the flux tubes.

   The hierarchy of Planck constants suggests also a

   new interpretation for FQHE (see `http://tinyurl.com/y89xp4bu`) (fractional quantum Hall effect) [K81] in terms of anyonic phases with non-standard value of effective Planck constant realized in terms of the effective multi-sheeted covering of embedding space: multi-sheeted space-time is to be distinguished from many-sheeted space-time.

3. In astrophysics and cosmology the implications are even more dramatic if one believes that also $\hbar_{gr}$ corresponds to effective Planck constant interpreted as number of sheets of multi-furcation. It was Nottale (see `http://tinyurl.com/ya6f3s4l`) [E87] who first introduced the notion of gravitational Planck constant as $\hbar_{gr} = GMm/v_0$, $v_0 < 1$ has interpretation as velocity light parameter in units $c = 1$. This would be true for $GMm/v_0 \geq 1$. The interpretation of $\hbar_{gr}$ in TGD framework is as an effective Planck constant associated with space-time sheets mediating gravitational interaction between masses M and m. The huge

value of $\hbar_{gr}$ means that the integer $\hbar_{gr}/\hbar_0$ interpreted as the number of sheets of covering is gigantic and that Universe possesses gravitational quantum coherence in super-astronomical scales for masses which are large. This would suggest that gravitational radiation is emitted as dark gravitons which decay to pulses of ordinary gravitons replacing continuous flow of gravitational radiation.

It must be however emphasized that the interpretation of $\hbar_{gr}$ could be different, and it will be found that one can develop an argument demonstrating how $\hbar_{gr}$ with a correct order of magnitude emerges from the effective space-time metric defined by the anti-commutators appearing in the Kähler-Dirac equation.

4. Why Nature would like to have large effective value of Planck constant? A possible answer relies on the observation that in perturbation theory the expansion takes in powers of gauge couplings strengths $\alpha = g^2/4\pi\hbar$. If the effective value of $\hbar$ replaces its real value as one might expect to happen for multi-sheeted particles behaving like single particle, α is scaled down and perturbative expansion converges for the new particles. One could say that Mother Nature loves theoreticians and comes in rescue in their attempts to calculate. In quantum gravitation the problem is especially acute since the dimensionless parameter $GMm/\hbar$ has gigantic value. Replacing $\hbar$ with $\hbar_{gr} = GMm/v_0$ the coupling strength becomes $v_0 < 1$.

9.2.2 Space-Time Correlates For The Hierarchy Of Planck Constants

The hierarchy of Planck constants was introduced to TGD originally as an additional postulate and formulated as the existence of a hierarchy of embedding spaces defined as Cartesian products of singular coverings of M^4 and CP_2 with numbers of sheets given by integers n_a and n_b and $\hbar = n\hbar_0$. $n = n_a n_b$.

With the advent of zero energy ontology, it became clear that the notion of singular covering space of the embedding space could be only a convenient auxiliary notion. Singular means that the sheets fuse together at the boundary of multi-sheeted region. The effective covering space emerges naturally from the vacuum degeneracy of Kähler action meaning that all deformations of canonically imbedded M^4 in $M^4 \times CP_2$ have vanishing action up to fourth order in small perturbation. This is clear from the fact that the induced Kähler form is quadratic in the gradients of CP_2 coordinates and Kähler action is essentially Maxwell action for the induced Kähler form. The vacuum degeneracy implies that the correspondence between canonical momentum currents $\partial L_K/\partial(\partial_\alpha h^k)$ defining the Kähler-Dirac gamma matrices [K116] and gradients $\partial_\alpha h^k$ is not one-to-one. Same canonical momentum current corresponds to several values of gradients of embedding space coordinates. At the partonic 2-surfaces at the light-like boundaries of CD carrying the elementary particle quantum numbers this implies that the two normal derivatives of h^k are many-valued functions of canonical momentum currents in normal directions.

Multi-furcation is in question and multi-furcations are indeed generic in highly non-linear systems and Kähler action is an extreme example about non-linear system (see **Fig.** `http://tgdtheory.fi/appfigures/planckhierarchy.jpg`, or **Fig. ??** in the appendix of this book). What multi-furcation means in quantum theory? The branches of multi-furcation are obviously analogous to single particle states. In quantum theory second quantization means that one constructs not only single particle states but also the many particle states formed from them. At space-time level single particle states would correspond to N branches b_i of multi-furcation carrying fermion number. Two-particle states would correspond to 2-fold covering consisting of 2 branches b_i and b_j of multi-furcation. $N-$particle state would correspond to N-sheeted covering with all branches present and carrying elementary particle quantum numbers. The branches coincide at the partonic 2-surface but since their normal space data are different they correspond to different tensor product factors of state space. Also now the factorization $N = n_a n_b$ occurs but now n_a and n_b would relate to branching in the direction of space-like 3-surface and light-like 3-surface rather than M^4 and CP_2 as in the original hypothesis.

In light of this the working hypothesis adopted during last years has been too limited: for some reason I ended up to propose that only N-sheeted covering corresponding to a situation in which all N branches are present is possible. Before that I quite correctly considered more general option based on intuition that one has many-particle states in the multi-sheeted space. The erratic form of the working hypothesis has not been used in applications.

Multi-furcations relate closely to the quantum criticality of Kähler action. Feigenbaum bifurcations (see `http://tinyurl.com/2swb2p`) represent a toy example of a system which via successive bifurcations approaches chaos. Now more general multi-furcations in which each branch of given multi-furcation can multi-furcate further, are possible unless on poses any additional conditions. This allows to identify additional aspect of the geometric arrow of time. Either the positive or negative energy part of the zero energy state is “prepared” meaning that single n-sub-furcations of N-furcation is selected. The most general state of this kind involves superposition of various n-sub-furcations.

9.2.3 Basic Phenomenological Rules Of Thumb In The New Framework

It is important to check whether or not the refreshed view about dark matter is consistent with existent rules of thumb.

1. The interpretation of quantized multi-furcations as WCW anyons explains also why the effective hierarchy of Planck constants defines a hierarchy of phases which are dark relative to each other. This is trivially true since the phases with different number of branches in multi-furcation correspond to disjoint regions of WCW so that the particles with different effective value of Planck constant cannot appear in the same vertex.

2. The phase transitions changing the value of Planck constant are just the multi-furcations and can be induced by changing the values of the external parameters controlling the properties of preferred extremals. Situation is very much the same as in any non-linear system.

3. In the case of massless particles the scaling of wavelength in the effective scaling of $\hbar$ can be understood if dark n-photons consist of n photons with energy E/n and wavelength $n\lambda$.

4. For massive particle it has been assumed that masses for particles and they dark counterparts are same and Compton wavelength is scaled up. In the new picture this need not be true. Rather, it would seem that wave length are same as for ordinary electron.

   On the other hand, p-adic thermodynamics predicts that massive elementary particles are massless most of the time. ZEO predicts that even virtual wormhole throats are massless. Could this mean that the picture applying on massless particle should apply to them at least at relativistic limit at which mass is negligible. This might be the case for bosons but for fermions also fermion number should be fractionalized and this is not possible in the recent picture. If one assumes that the n-electron has same mass as electron, the mass for dark single electron state would be scaled down by $1/n$. This does not look sensible unless the p-adic length defined by prime is scaled down by this fact in good approximation.

   This suggests that for fermions the basic scaling rule does not hold true for Compton length $\lambda_c = \hbar_m$. Could it however hold for de-Broglie lengths $\lambda = \hbar/p$ defined in terms of 3-momentum? The basic overlap rule for the formation of macroscopic quantum states is indeed formulated for de Broglie wave length. One could argue that an $1/N$-fold reduction of density that takes place in the de-localization of the single particle states to the N branches of the cover, implies that the volume per particle increases by a factor N and single particle wave function is de-localized in a larger region of 3-space. If the particles reside at effectively one-dimensional 3-surfaces - say magnetic flux tubes - this would increase their de Broglie wave length in the direction of the flux tube and also the length of the flux tube. This seems to be enough for various applications.

One important notion in TGD inspired quantum biology is dark cyclotron state.

1. The scaling $\hbar \rightarrow k\hbar$ in the formula $E_n = (n+1/2)\hbar eB/m$ implies that cyclotron energies are scaled up for dark cyclotron states. What this means microscopically has not been obvious but the recent picture gives a rather clearcut answer. One would have k-particle state formed from cyclotron states in N-fold branched cover of space-time surface. Each branch would carry magnetic field B and ion or electron. This would give a total cyclotron energy equal to kE_n. These cyclotron states would be excited by k-photons with total energy $E = khf$ and for large enough value of k the energies involved would be above thermal threshold. In

the case of Ca^{++} one has $f = 15$ Hz in the field $B_{end} = .2$ Gauss. This means that the value of $\hbar$ is at least the ratio of thermal energy at room temperature to $E = hf$. The thermal frequency is of order 10^{12} Hz so that one would have $k \simeq 10^{11}$. The number branches would be therefore rather high.

2. It seems that this kinds of states which I have called cyclotron Bose-Einstein condensates could make sense also for fermions. The dark photons involved would be Bose-Einstein condensates of k photons and wall of them would be simultaneously absorbed. The biological meaning of this would be that a simultaneous excitation of large number of atoms or molecules can take place if they are localized at the branches of N-furcation. This would make possible coherent macroscopic changes. Note that also Cooper pairs of electrons could be $n = 2$-particle states associated with N-furcation.

There are experimental findings suggesting that photosynthesis involves de-localized excitations of electrons and it is interesting so see whether this could be understood in this framework.

1. The TGD based model relies on the assumption that cyclotron states are involved and that dark photons with the energy of visible photons but with much longer wavelength are involved. Single electron excitations (or single particle excitations of Cooper pairs) would generate negentropic entanglement automatically.

2. If cyclotron excitations are the primary ones, it would seem that they could be induced by dark N-photons exciting all N electrons simultaneously. N-photon should have energy of a visible photon. The number of cyclotron excited electrons should be rather large if the total excitation energy is to be above thermal threshold. In this case one could not speak about cyclotron excitation however. This would require that solar photons are transformed to n-photons in N-furcation in biosphere.

3. Second - more realistic looking - possibility is that the incoming photons have energy of visible photon and are therefore $n = 1$ dark photons de-localized to the branches of the N-furcation. They would induce de-localized single electron excitation in WCW rather than 3-space.

9.2.4 Charge Fractionization And Anyons

It is easy to see how the effective value of Planck constant as an integer multiple of its standard value emerges for multi-sheeted states in second quantization. At the level of Kähler action one can assume that in the first approximation the value of Kähler action for each branch is same so that the total Kähler action is multiplied by n. This corresponds effectively to the scaling $\alpha_K \rightarrow \alpha_K/n$ induced by the scaling $\hbar_0 \rightarrow n\hbar_0$.

Also effective charge fractionization and anyons emerge naturally in this framework.

1. In the ordinary charge fractionization (see `http://tinyurl.com/26tmhoe`) the wave function decomposes into sharply localized pieces around different points of 3-space carrying fractional charges summing up to integer charge. Now the same happens at at the level of WCW ("world of classical worlds") rather than 3-space meaning that wave functions in E^3 are replaced with wave functions in the space-time of 3-surfaces (4-surfaces by holography implied by General Coordinate Invariance) replacing point-like particles. Single particle wave function in WCW is a sum of N sharply localized contributions: localization takes place around one particular branch of the multi-sheeted space time surface. Each branch carries a fractional charge q/N for teh analogs of plane waves.

   Therefore all quantum numbers are additive and fractionization is only effective and observable in a localization of wave function to single branch occurring with probability $p = 1/N$ from which one can deduce that charge is q/N.

2. The is consistent with the proposed interpretation of dark photons/gravitons since they could carry large spin and this kind of situation could decay to bunches of ordinary photons/gravitons. It is also consistent with electromagnetic charge fractionization and fractionization of spin.

3. The original - and it seems wrong - argument suggested what might be interpreted as a genuine fractionization for orbital angular momentum and also of color quantum numbers, which are analogous to orbital angular momentum in TGD framework. The observation was that a rotation through 2π at space-time level moving the point along space-time surface leads to a new branch of multi-furcation and $N+1$: th branch corresponds to the original one. This suggests that angular momentum fractionization should take place for M^4 angle coordinate ϕ because for it 2π rotation could lead to a different sheet of the effective covering.

   The orbital angular momentum eigenstates would correspond to waves $exp(i\phi m/N)$, $m = 0, 2, ..., N-1$ and the maximum orbital angular momentum would correspond the sum $\sum_{m=0}^{N-1} m/N = (N-1)/2$. The sum of spin and orbital angular momentum be therefore fractional.

   The different prediction is due to the fact that rotations are now interpreted as flows rotating the points of 3-surface along 3-surface rather than rotations of the entire partonic surface in embedding space. In the latter interpretation the rotation by 2π does nothing for the 3-surface. Hence fractionization for the total charge of the single particle states does not take place unless one adopts the flow interpretation. This view about fractionization however leads to problems with fractionization of electromagnetic charge and spin for which there is evidence from fractional quantum Hall effect.

9.2.5 What About The Relationship Of Gravitational Planck Constant To Ordinary Planck Constant?

Gravitational Planck constant is given by the expression $\hbar_{gr} = GMm/v_0$, where $v_0 < 1$ has interpretation as velocity parameter in the units $c = 1$. Can one interpret also $\hbar_{gr}$ as effective value of Planck constant so that its values would correspond to multi-furcation with a gigantic number of sheets. This does not look reasonable.

Could one imagine any other interpretation for $\hbar_{gr}$? Could the two Planck constants correspond to inertial and gravitational dichotomy for four-momenta making sense also for angular momentum identified as a four-vector? Could gravitational angular momentum and the momentum associated with the flux tubes mediating gravitational interaction be quantized in units of $\hbar_{gr}$ naturally?

1. Gravitational four-momentum can be defined as a projection of the M^4-four-momentum to space-time surface. It's length can be naturally defined by the effective metric $g_{eff}^{\alpha\beta}$ defined by the anti-commutators of the modified gamma matrices. Gravitational four-momentum appears as a measurement interaction term in the Kähler-Dirac action and can be restricted to the space-like boundaries of the space-time surface at the ends of CD and to the light-like orbits of the wormhole throats and which induced 4- metric is effectively 3-dimensional.

2. At the string world sheets and partonic 2-surfaces the effective metric degenerates to 2-D one. At the ends of braid strands representing their intersection, the metric is effectively 4-D. Just for definiteness assume that the effective metric is proportional to the M^4 metric or rather - to its M^2 projection: $g_{eff}^{kl} = K^2 m^{kl}$.

   One can express the length squared for momentum at the flux tubes mediating the gravitational interaction between massive objects with masses M and m as

$$g_{eff}^{\alpha\beta} p_\alpha p_\beta = g_{eff}^{\alpha\beta} \partial_\alpha h^k \partial_\beta h^l p_k p_l \equiv g_{eff}^{kl} p_k p_l = n^2 \frac{\hbar^2}{L^2} \quad . \tag{9.2.1}$$

   Here L would correspond to the length of the flux tube mediating gravitational interaction and p_k would be the momentum flowing in that flux tube. $g_{eff}^{kl} = K^2 m^{kl}$ would give

$$p^2 = \frac{n^2 \hbar^2}{K^2 L^2} \quad .$$

   $\hbar_{gr}$ could be identifed in this simplified situation as $\hbar_{gr} = \hbar/K$.

3. Nottale's proposal requires $K = GMm/v_0$ for the space-time sheets mediating gravitational interacting between massive objects with masses M and m. This gives the estimate

$$p_{gr} = \frac{GMm}{v_0}\frac{1}{L} \quad . \tag{9.2.2}$$

For $v_0 = 1$ this is of the same order of magnitude as the exchanged momentum if gravitational potential gives estimate for its magnitude. v_0 is of same order of magnitude as the rotation velocity of planet around Sun so that the reduction of v_0 to $v_0 \simeq 2^{-11}$ in the case of inner planets does not mean that the propagation velocity of gravitons is reduced.

4. Nottale's formula requires that the order of magnitude for the components of the energy momentum tensor at the ends of braid strands at partonic 2-surface should have value GMm/v_0. Einstein's equations $T = \kappa G + \Lambda g$ give a further constraint. For the vacuum solutions of Einstein's equations with a vanishing cosmological constant the value of h_{gr} approaches infinity. At the flux tubes mediating gravitational interaction one expects T to be proportional to the factor GMm simply because they mediate the gravitational interaction.

5. One can consider similar equation for gravitational angular momentum:

$$g^{\alpha\beta}_{eff}L_\alpha L_\beta = g^{kl}_{eff}L_k L_l = l(l+1)\hbar^2 \quad . \tag{9.2.3}$$

This would give under the same simplifying assumptions

$$L^2 = l(l+1)\frac{\hbar^2}{K^2} \quad . \tag{9.2.4}$$

This would justify the Bohr quantization rule for the angular momentum used in the Bohr quantization of planetary orbits.

Maybe the proposed connection might make sense in some more refined formulation. In particular the proportionality between $m^{kl}_{eff} = Km^{kl}$ could make sense as a quantum average. Also the fact, that the constant v_0 varies, could be understood from the dynamical character of m^{kl}_{eff}.

9.3 General Quantum Vision About Formation Of Structures

The basic observation is that in the case of a straight cosmic string creating a gravitational potential of form v_1^2/ρ Bohr quantization does not pose any conditions on the radii of the circular orbits so that a continuous mass distribution is possible.

This situation is obviously exceptional. If one however accepts the TGD based vision [K94] that the very early cosmology was cosmic string dominated and that elementary particles were generated in the decay of cosmic strings, this situation might have prevailed at very early times. If so, the differentiation of a continuous density of ordinary matter to form the observed astrophysical structures would correspond to an approach to a stationary situation governed by Bohr rules and in the first approximation one could neglect the intermediate stages.

Cosmic string need not be infinitely long: it could branch into flux tubes or flux sheets carrying the return flux. For large distances the whole structure would behave as a single mass point creating ordinary Newtonian gravitational potential. Also phase transitions in which the system emits magnetic flux tubes so that the contribution of the cosmic string to the gravitational force is reduced, are possible.

What is of utmost importance is that the cosmic string induces a breaking of the rotational symmetry selecting a unique preferred orbital plane in which gravitational acceleration is parallel to the plane. This is just what is observed in astrophysical systems and not easily explained in the Newtonian picture. In TGD framework this relates directly to the choice of quantization axis of angular momentum at the level of dark matter. This mechanism could be behind the formation of planar systems in all length scales including planets and their moons, planetary systems, galaxies, galaxy clusters in the scale of Mly, and even the concentration of matter at the walls of large voids in the scale of 100 Mly.

9.3.1 Simple Quantitative Model

The following elementary model allows to see how the addition of central mass forces the matter to quantized Bohr orbits via the formation of dark matter rings.

The equation for gravitational acceleration

The elementary model for circular orbits involves two equations: the identification radial kinetic acceleration with the acceleration due to the gravitational force and the condition stating quantization of the angular momentum, which requires some additional thought when cosmic string has infinite length.

In cylindrical coordinates the gravitational acceleration due to cosmic string is given by

$$\begin{aligned} a &= \frac{v_1^2}{\rho} , \\ v_1^2 &= G\frac{dM}{dL} . \end{aligned} \quad (9.3.1)$$

Here v_1 is the rotational velocity of the matter around cosmic string neglecting its own gravitational effects.

The condition for the radial acceleration gives

$$u = \frac{1}{\rho} = \frac{v^2 - v_1^2}{GM} . \quad (9.3.2)$$

Quantization of angular momentum

The condition for the quantization of angular momentum is not quite obvious since taking into account the mass of entire cosmic string would give an infinite Planck constant. The resolution of the problem relies on the effective 2-dimensionality and Z_n symmetry of the dark matter for $F-C$ option meaning that it forms rings.

Consider first the situation when only cosmic is present. For dark matter rings it is angular momentum per unit length which is quantized so that Planck constant is replaced with Planck constant per unit length. Hence one has

$$\frac{d\hbar}{dl} = G \times \frac{m}{2\pi} \times \frac{dM}{dL} \times \frac{1}{v_0} = \frac{m}{2\pi} \times \frac{v_1^2}{v_0} . \quad (9.3.3)$$

where m is the mass of dark matter ring. The inclusion of 2π is necessary in order to obtain internal consistency.

The quantization condition for the circular orbits in the presence of only cosmic string would read as

$$\frac{dm}{dl} \times v\rho = n \times \frac{d\hbar}{dl} = n \times \frac{m}{2\pi} \times \frac{v_1^2}{v_0} . \quad (9.3.4)$$

By using $dm/dl = m/2\pi\rho$, one obtains

$$v = n\frac{v_1^2}{v_0} \ . \tag{9.3.5}$$

Only $n = 1$ is consistent with $v = v_1^2/v_0$ resulting from the condition for the radial acceleration and there is no condition on ρ.

The contribution of the cosmic string to the Planck constant can be identified as

$$\hbar(string) = m \times \frac{v_1^2}{v_0}\rho \ . \tag{9.3.6}$$

One can say that a length ρ of cosmic string contributes to the Planck constant, and that the active part of that cosmic string and point on ring define an equilateral triangle with sides 1 and $\sqrt{5}$ so that Golden Mean emerges.

The generalization of this equation to the case when also central mass is present reads as

$$v\rho = n\frac{GM + \frac{v_1^2}{v_0}\rho}{v_0} \ . \tag{9.3.7}$$

This gives the quantization condition

$$u = \frac{vv_0 - nv_1^2}{nGM} \ . \tag{9.3.8}$$

Combination of the conditions

The two equations for $u = 1/\rho$ fix the spectrum of velocities and orbital radii. By introducing the parameter $v_1/v_0 = \epsilon$ and the variable $x = v/v_0$ one can write the basic equation as

$$x^2 - \frac{x}{n} = 0 \ . \tag{9.3.9}$$

The solutions are $x = 0$ and $x = 1/n$. Only the latter solution corresponds to $u > 0$. The same spectrum $v = v_0/n$ of velocities is obtained as in the case of hydrogen atom model so that only the radii are modified. The universality of the velocity spectrum corresponds to the reduction of the quantization of angular momentum to that of circulation implied by the Equivalence Principle.

The radii of the orbits are given by

$$\begin{aligned} \rho(n) &= \frac{n^2}{1-n^2\epsilon^2} \times r_0 \ , \\ r_0 &= \frac{GM}{v_0^2} \ . \end{aligned} \tag{9.3.10}$$

For small values of n one obtains Bohr orbits for hydrogen atom like model. For $n = 1$ there is an upwards scaling of Bohr radius by $1/(1-\epsilon^2)$. For large values of n the distances between sub-sequent radii begin to rapidly increase and at the limit $n \rightarrow 1/\epsilon$ the radius becomes infinite. Hence only $n < 1/\epsilon$ orbits are possible meaning that the system has necessarily a finite size for a given value of v_0. Several values of v_0 are however suggested by the Bohr orbit model for the solar system.

9.3.2 Formation Of Ring Like Structures

One can consider an initial situation in which one has a continuous mass density rotating with a constant velocity around cosmic string defining the rotation axis of the planet. The situation is inherently unstable and a small perturbation forces the accumulation of both dark and visible matter to Bohr orbits and the upper bound for the value of n implies finite size of the system proportional to the central mass.

Rings of Saturn and Jupiter

The rings of Saturn and Jupiter [E31, E30] could be seen a intermediate states in the process leading to the formation of satellites. Both planets indeed possess a large number of satellites [E31, E30]. This would suggest that Saturn and Jupiter and outer planets in general are younger than the 4 inner planets in accordance with the different values of v_0. The orbital radii for lowest satellites correspond to $v_0 \rightarrow 16/15v_0$, and $n = 5$ for Saturn and $v_0 \rightarrow 2v_0$ and $n = 5$ for Jupiter from the requirement that the two lowest satellites correspond in a reasonable approximation to the two lowest Bohr orbits. The radii of satellites do not directly correspond to the radii for Bohr orbits. Also the formation of inner and outer satellite systems differing by a fractal scaling from each other can be considered. Same mechanism would be at work in all length scales and the recently observed dark matter ring associated with a galactic cluster could result by a similar mechanism [E137].

The hierarchy of dark matters continues to elementary particle level and the differentiation by Bohr rules continues down to these levels. In particular, the formation of clumps of matter in Saturn rings [E34] could be seen as a particular instance of this process.

NASA Hubble Space Telescope Detects Ring of Dark Matter

The following announcement caught my attention during my morning webwalk.

NASA will hold a media teleconference at 1 p.m. EDT on May 15 to discuss the strongest evidence to date that dark matter exists. This evidence was found in a ghostly ring of dark matter in the cluster CL0024+17, discovered using NASA's Hubble Space Telescope. The ring is the first cluster to show a dark matter distribution that differs from the distribution of both the galaxies and the hot gas. The discovery will be featured in the May 15 issue of the Astrophysical Journal.

"Rings" puts bells ringing! Recall that in TGD Universe dark matter characterized by a gigantic value of constant [K42] making dark matter a macroscopic quantum phase in astrophysical length and time scales. In the model of planetary orbits the rings of dark matter around Bohr orbits force the visible matter at Bohr orbits. Rings- and also shell like structures - connected by radial flux tubes to central anyonic surface are expected in all length scales, even that for galaxy clusters and large voids.

Recall that the number theoretic hypothesis for the preferred values of Planck constants states that the gravitational Planck constant

$$\hbar = \frac{GMm}{v_0}$$

equals to a ruler-and-compass rational which is ratio $q = n_1/n_2$ of ruler-and-compass integers n_i expressible as a product of form $n = 2^k \prod F_s$, where all Fermat primes F_s are different. Only four of them are known and they are given by 3, 5, 17, 257, $2^{16}+1$. $v_0 = 2^{-11}$ applies to inner planets and $v_0 = 2^{-11}/5$ to outer planets and the conditions from the quantization of $\hbar$ are satisfied.

The obvious TGD inspired hypothesis is that the dark matter ring corresponds to Bohr orbit. If so, the radius of the ring is given by

$$r_n = n^2 r_0 \ ,$$

where r_0 is Bohr radius and n is integer. The Bohr radius is given

$$r_0 = \frac{GM}{v_0^2} \ ,$$

where one has $1/v_0 = k \times 2^{11}$, k a small integer with preferred value $k = 1$. M is the total mass in the dense core region inside the ring. This would give a radius of about 2000 times Schwartschild radius for the lowest orbit.

This prediction can be confronted with the data [E137] .

1. From the "*Summary and Conclusions* " of the article the radius of the ring is about.4 Mpc, which makes in a good approximation r=1.2 Mly. The ring corresponds actually to a bump in the interval 60"-85" centered at 75" (figure 10 of [E137] gives idea about the bump). The mass in the dense core within radius which is almost half of the ring radius is about $M = 1.5 \times 10^{14} \times M_{Sun}$. The mass estimate based on gravitational lensing gives $M =$

$1.8 \times 10^{14} \times M_{Sun}$. If the gravitational lensing involves dark mass not in the central core, the first value can be used as the estimate. The Bohr radius this system is therefore

$$r_0 = 1.5 \times 10^{14} \times r_0(Sun) \ ,$$

where I have assumed $v_0 = 2^{-11}$ as for the inner planets in the model for the solar system.

2. The Bohr orbit for our planetary system predicts correctly Mercury's orbital radius as n=3 Bohr orbit for $v_0 = 2^{-11}$ so that one has

$$r_0(Sun) = \frac{r_M}{9} \ ,$$

where r_M is Mercury's orbital radius. This gives

$$r_0 = 1.5 \times 10^{14} \times \frac{r_M}{9} \ .$$

Mercury's orbital radius is in a good approximation $r_M = .4$ AU =.016 ly. This gives $r_0 = 11$ Mly to be compared with $r_0 = 1$ 1.2 Mly deduced from the observations. The result is 9 times too large.

3. If one replaces v_0 with $3v_0$ one obtains downwards scaling by a factor of 1/9, which gives $r_0 = 1.2$ Mly which can be found from the Summary and Conclusions of [E137]. The general hypothesis indeed allows to scale v_0 by a factor 3.

4. If one considers instead of Bohr orbits genuine solutions of Schrödinger equation then only $n > 1$ structures can correspond to rings like structures. Minimal option would be $n = 2$ with v_0 replaced with $6v_0$.

The conclusion would be that the ring could correspond to the lowest possible Bohr orbit for $v_0 = 3 \times 2^{-11}$. I would have been really happy if the favored value of v_0 had appeared in the formula but the consistency with the ruler-and-compass hypothesis serves as a consolation. Skeptic can of course always argue that this is a pure accident. If so, it would be an addition to long series of accidents (planetary radii in solar system and radii of exoplanets). One can of course search rings at radii corresponding to $n = 2, 3, ...$

9.3.3 A Quantum Model For The Dark Part Of The Central Mass And Rings

It is interesting to look for a simple quantum model for the dark part of the central mass and possibly also of rings. As a first approximation one can consider a cylindrically symmetric pancake of height L and radius R. Approximate spherical symmetry suggest $L = 2R$.

The governing conditions are

$$\begin{aligned} v^2(\rho) &= G(dM/dl)(\rho) + v_1^2 \ , \\ v(\rho) &= \frac{v_0}{n} \ . \end{aligned} \tag{9.3.11}$$

Previous considerations suggest that the v_1^2 term from the cosmic string can be neglected. The general prediction is that the system has finite size and mass irrespective of the form of the distribution.

Four options

One can consider four kinds of mass distributions.

1. The scaling law $(dM/dl)(\rho) \propto K(\rho/\rho_0)^k$, $k \geq 0$, implies

$$\begin{aligned} v(\rho) &= \sqrt{GK}(\rho/\rho_0)^{k/2} \ , \\ \omega(\rho) &= \sqrt{GK}(\rho/\rho_0)^{k/2-1} \ , \\ \rho(n) &= \rho_0(v_0/\sqrt{GK})^{2/k} \times n^{-2/k} \ . \end{aligned} \quad (9.3.12)$$

   The radii decrease as $n^{-2/k}$ and largest radius is $\rho_0(v_0^2/GK)$. For constant mass density one obtains $k = 2$, rigid body rotation, and $\rho = \rho_0/n$ so that kind of reverted harmony of spheres would result. Quite generally, $v(\rho)$ is a non-decreasing function of ρ from the first condition. This reflects the 2-dimensionality of the situation.

2. If the mass distribution is logarithmic $M(\rho) = Klog^2(\rho/\rho_0)$ one has $v = \sqrt{GK}log(\rho/\rho_0)$ and $\rho(n) = \rho_0 exp(k/n)$, $k = v_0/\sqrt{GK}$. One obtains what might be regarded as a cylindrical shell $\rho/\rho_0 \in [1, e^k]$ and with density $dM/dl \propto 2log(\rho)/\rho$. This kind of distribution could work in the case of planetary rings if the tidal effects of the central mass can be neglected.

3. p-Adic length scale hypothesis suggest the distribution $\rho(n) = 2^{-k}\rho_0$ for the radii of the "mass shells". This would give $v(\rho) = v_0/|log_2(\rho/\rho_0)|$ and

$$(dM/dl)(\rho) = \frac{v_0^2}{G|log_2(\rho/\rho_0)|^2} = \frac{M}{r_0|log_2(\rho/\rho_0)|^2} \ .$$

   Note that the most general form of p-adic length scale hypothesis allows $\rho(n) = 2^{-k/2}\rho_0$ This option defines the only working alternative for the dark central mass. Note that this would explain Titius-Bode law [E40] if planets have formed around dark matter shells or rings which have formed part of Sun during primordial stage.

4. The distribution of radii of form $\rho(n)/\rho_0 = x - n$ might serve as a model for planetary rings if the tidal effects of the central mass can be neglected. In this case one as

$$(dM/dl)(\rho) = \frac{M}{r_0(x - \frac{\rho}{\rho_0})^2} \ .$$

   The radius R must satisfy $R < x\rho_0$. The masses of the annuli must increase with ρ.

Only the p-adic variant works as a model for central mass

It is interesting to look what the three variants of the model would predict for the radius of Earth. If the pancake has height $2R$, the relationship between radius and total mass can be expressed as $M = 2\pi(dM/dl)R^3$. Using $M_E = 3 \times 10^{-6}M_{Sun}$, and $r_0(Sun) \simeq R_M/9$, where $r_M = 5.8 \times 10^4$ Mm is the orbital radius of Mercury, one obtains by scaling $r_0 = GM_E/v_0^2 \simeq 20$ km for $v_0 = 2^{-11}$.

1. The options 1) and 2) fail. Constant density would give $R = 140$ km, which is about 2 per cent of the actual radius $R_E = 6.372797$ Mm and 10 percent about the radius 1.2 Mm of the inner core. The "inner inner core" of Earth happens to have radius of 300 km. For the logarithmic mass distribution one would obtain $R = r_0/2 \simeq 10$ km.

2. The option 3) inspired by the p-adic length scale hypothesis works and predicts $k^2|log_2(R/\rho_0)|^2 = 2R/r_0$. $\rho_0 = 2R$ gives $k \simeq 25$. This alternative works also in the more general case since one can make the radius arbitrarily large by a proper choice of the integer k. The universal prediction would be that dark matter appears as shells corresponding to decreasing p-adic length scales coming as powers $p \simeq 2^k$. The situation would be very much analogous to that in atomic physics. The prediction conforms with the many-sheeted generalization of the model for the asymptotic state of the star for which the matter is concentrated on a thin cell [K111]. The model brings in mind also the large voids of size about 100 Mly.

3. The suspiciously small value of r_0 forces to ask whether the value of v_0 for Earth should be much smaller than $v_0 = 2^{-11}$. Also the radius of Moon's orbit would require $n \sim 138$ for this value to be compared with $n \geq 5$ for the moons of Saturn and Jupiter. If the age of Earth is much longer than that of outer planets, one would expect that more phase transitions reducing v_0 forced by the cosmic expansion in average sense have taken place. $v_0 \rightarrow v_0/20$ would give $r_0 \simeq 8$ Mm to be compared with $R_E = 6.4$ Mm. Moon's orbit would correspond to $n = 7$ in a reasonable approximation. This choice of v_0 would allow $k = 1$.

The small value of v_0 might be understood from the fact that inner planets are older than outer ones so that the cosmic expansion in the average sense has forced larger number of phase transitions reducing the value of v_0 inducing a fractal scaling of the system. Ruler-and-compass hypothesis [K93] suggests preferred values of cosmic times for the occurrence of these transitions. Without this hypothesis the phase transitions could form almost continuum. For this option the failure of options 1) and 2) is even worse.

9.3.4 Two Stellar Components In The Halo Of Milky Way

Bohr orbit model for astrophysical objects suggests that also galactic halo should have a modular structure analogous to that of planetary system or the rings of Saturn rather than that predicted by continuous mass distribution. Quite recently it was reported that the halo of Milky Way - earlier thought to consist of single component - seems to consist of two components [E115, E248]. Even more intriguingly, the stars in these halos rotate in opposite directions. The average velocities of rotation are about 25 km/s and 50 km/s for inner and outer halos respectively. The inner halo corresponds to a range 10-15 kpc of orbital radii and outer halo to 15-20 kpc. Already the constancy of rotational velocity is strange and its increase even stranger. The orbits in inner halo are more eccentric with axial ratio $r_{min}/r_{max} \simeq .6$. For outer halo the ratio varies in the range $.9 - 1.0$. The abundances of elements heavier than Lithium are about 3 times higher in the inner halo which suggests that it has been formed earlier.

Bohr orbit model would explain halos as being due to the concentration of visible matter around ring like structures of dark matter in macroscopic quantum state with gigantic gravitational Planck constant. This would explain also the opposite directions of rotation.

One can consider two alternative models predicting constant rotation velocity for circular orbits. The first model allows circular orbits with arbitrary plane of rotation, second model and the hybrid of these models only for the orbits in galactic plane.

1. The original model assumes that galactic matter has resulted in the decay of cosmic string like object so that the mass inside sphere of radius R is $M(R) \sim kR$.

2. In the second model the gravitational acceleration is due to gravitational field of a cosmic string like object transversal to the galactic plane. String creates no force parallel to string but $1/\rho$ radial acceleration orthogonal to the string. Of course, there is the gravitational force created by galactic matter itself. One can also associate cosmic string like objects with the circular halos themselves and it seems that this is needed in order to explain the latest findings.

The big difference in the average rotation velocities $\langle v_\phi \rangle$. or inner and outer halos cannot be understood solely in terms of the high eccentricity of the orbits in the inner halo tending to reduce $\langle v_\phi \rangle$. Using the conservation laws of angular momentum ($L = mv_{min}\rho_{max}$) and of energy in Newtonian approximation one has $\langle v_\phi \rangle = \rho_{max} v_{min} \langle \langle 1/\rho \rangle$. This gives the bounds

$$v_{min} < \langle v_\phi \rangle < v_{max} = v_{min} \frac{\rho_{max}}{\rho_{min}} \simeq 1.7 v_{min} \quad .$$

For both models $v = v_0 = \sqrt{k}$, $k = TG$, (T is the effective string tension) for circular orbits. Internal consistency would require $v_{min} < \langle v_\phi \rangle \simeq .5v_0 < v_{max} \simeq 1.7v_{min}$. On the other hand, $v_{max} > v_0$ and thus $v_{min} > .6v_0$ must hold true since the sign of radial acceleration for ρ_{min} is positive. $.5v_0 > v_{min} > .6v_0$ means a contradiction.

The big increase of the average rotation velocity suggests that inner and outer halos correspond to closed cosmic string like objects around which the visible matter has condensed. The inner string like object would create an additional gravitational field experienced by the stars of the outer halo. The increase of the effective string tension by factor x corresponds to the increase of $\langle v_\phi \rangle$ by a factor $\sqrt{x}$. The increase by a factor 2 plus higher eccentricity could explain the ratio of average velocities.

9.4 Quantum Chaos In Astrophysical Length Scales

The stimulus for writing this section came from the article "Quantum Chaos" by Martin Gurtzwiller [B37]. Occasionally it can happen that even this kind of a masterpiece of scientific writing manages to stimulate only an intention to read it more carefully later. When you indeed read it again years later it can shatter you into a wild resonance. Just this occurred at this time.

9.4.1 Brief Summary About Quantum Chaos

The article discusses of Gurtzwiller the complex regime between quantal and classical behavior as it was understood at the time of writing (1992). As a non-specialist I have no idea about possible new discoveries since then.

The article introduces the division of classical systems into regular (R) and chaotic (P in honor of Poincare) ones. Besides this one has quantal systems (Q). There are three transition regions between these three realms.

1. R-P corresponds to transition to classical chaos and KAM theorem is a powerful tool allowing to organize the view about P in terms of surviving periodic orbits.

2. Quantum-classical transition region R-Q corresponds to high quantum number limit and is governed by Bohr's correspondence principle. Highly excited hydrogen atom - Rydberg atom - defines a canonical example of the situation.

3. Somewhat surprisingly, it has turned out that also P-Q region can be understood in terms of periodic classical orbits (nothing else is available!). P-Q region can be achieved experimentally if one puts Rydberg atom in a strong magnetic field. At the weak field limit quantum states are de-localized but in chaotic regime the wave functions become strongly concentrated along a periodic classical orbits.

   At the level of dynamics the basic example about P-Q transition region discussed is the chaotic quantum scattering of electron in atomic lattice. Classical description does not work: a superposition of amplitudes for orbits, which consist of pieces which are fragments of a periodic orbit plus localization around atom is necessary.

   The fractal wave function patterns associated with say hydrogen atom in strong magnetic field are extremely beautiful and far from chaotic. Even in the case of chaotic quantum scattering one has interference of quantum amplitudes for classical Bohr orbits and also now Fourier transform exhibits nice peaks corresponding to the periods of classical orbits. The term chaos seems to be an unfortunate choice referring to our limited cognitive capacities rather than the actual physical situation and the term quantum complexity would be more appropriate.

4. For a consciousness theorist the challenge is to try to formulate in a more precise manner this fact. Quantum measurement theory with a finite measurement resolution indeed provide the mathematics necessary for this purpose.

9.4.2 What Does The Transition To Quantum Chaos Mean?

The transition to quantum chaos in the sense the article discusses it means that a system with a large number of virtually independent degrees of freedom (in very general sense) makes a transition to a phase in there is a strong interaction between these degrees of freedom. Perturbative phase becomes non-perturbative. This means emergence of correlations and reduction of the effective dimension of the system to a finite fractal dimension. When correlations become complete and the system becomes a genuine quantum system, the dimension of the system is genuinely reduced and again non-fractal. In this sense one has transition via complexity to new kind of order.

The level of stationary states

At the level of energy spectrum this means that the energy of system which correspond to sums of virtually independent energies and thus is essentially random number becomes non-random. As a consequence, energy levels tend to avoid each other, order and simplicity emerge but at the collective level. Spectrum of zeros of Zeta has been found to simulate the spectrum for a chaotic system with strong correlations between energy levels. Zeta functions indeed play a key role in the proposed description of quantum criticality associated with the phase transition changing the value of Planck constant.

The importance of classical periodic orbits in chaotic scattering

Poincare with his immense physical and mathematical intuition foresaw that periodic classical orbits should have a key role also in the description of chaos. The study of complex systems indeed demonstrates that this is the case although the mathematics and physics behind this was not fully understood around 1992 and is probably not so even now. The basic discovery coming from numerical simulations is that the Fourier transform of a chaotic orbits exhibits peaks at frequencies which correspond to the periods of closed orbits. From my earlier encounters with quantum chaos I remember that there is quantization of periodic orbits so that their periods are proportional to $log(p)$, p prime in suitable units. This suggests a connection of arithmetic quantum field theory and with p-adic length scale hypothesis.

The chaotic scattering of electron in atomic lattice is discussed as a concrete example. In the chaotic situation the notion of electron consists of periods spend around some atom continued by a motion along along some classical periodic orbit. This does not however mean loss of quantum coherence in the transitions between these periods: a purely classical model gives non-sensible results in this kind of situation. Only if one sums scattering amplitudes over all piecewise classical orbits (not all paths as one would do in path integral quantization) one obtains a working model.

In what sense complex systems can be called chaotic?

Speaking about quantum chaos instead of quantum complexity does not seem appropriate to me unless one makes clear that it refers to the limitations of human cognition rather than to physics. If one believes in quantum approach to consciousness, these limitations should reduce to finite resolution of quantum measurement not taken into account in standard quantum measurement theory.

In the framework of hyper-finite factors of type II_1 finite quantum measurement resolution is described in terms of inclusions $\mathcal{N} \subset \mathcal{M}$ of the factors and sub-factor $\mathcal{N}$ defines what might be called $\mathcal{N}$-rays replacing complex rays of state space. The space $\mathcal{M}/\mathcal{N}$ has a fractal dimension characterized by quantum phase and increases as quantum phase $q = exp(i\pi/n)$, $n = 3, 4, ...$, approaches unity which means improving measurement resolution since the size of the factor $\mathcal{N}$is reduced.

Fuzzy logic based on quantum qbits applies in the situation since the components of quantum spinor do not commute. At the limit $n \to \infty$ one obtains commutativity, ordinary logic, and maximal dimension. The smaller the n the stronger the correlations and the smaller the fractal dimension. In this case the measurement resolution makes the system effectively strongly correlated as n approaches its minimal value $n = 3$ for which fractal dimension equals to 1 and Boolean logic degenerates to single valued totalitarian logic.

Non-commutativity is the most elegant description for the reduction of dimensions and brings in reduced fractal dimensions smaller than the actual dimension. Again the reduction has interpretation as something totally different from chaos: system becomes a single coherent whole with strong but not complete correlation between different degrees of freedom. The interpretation would be that in the transition to non-chaotic quantal behavior correlation becomes complete and the dimension of system again integer valued but smaller. This would correspond to the cases $n = 6$, $n = 4$, and $n = 3$ ($D = 3, 2, 1$).

9.4.3 Quantum Chaos In Astrophysical Scales?

The following considerations represent an updated form of the first sketch about how quantum chaos could emerge in astrophysical length scales.

Transition to quantum chaos as reduction of the symmetry groups G_a and G_b

Anyonic 2-surfaces formed by flux tubes around orbits of massive objects connected to the central nearly spherical anyonic 2-surfaces by radial flux tubes and characterized by a fixed value of v_0 is the first key element of the picture. Second key element is the general formula for Planck constant forcing to conclude that the sequential de-coherence reducing (n_a, n_b) gradually to $(n_a, n_b) = (1, 1)$ requires generation of sub-harmonics of the original graviton frequency in the situation when $r = \hbar/\hbar_0$ is genuine rational $r = m/n$.

The transition to chaos must always correspond to a reduction of the symmetries so that $(n_a, n_b) = (1, 1)$ phase is maximally chaotic. Only for $C - C$ option this process corresponds always to a reduction of Planck constant. There are two mechanisms of de-coherence: the first one is favored for the factor space option and second one for the covering space option.

1. Assuming conservation of energy and number of quanta in phase transitions (so that quanta leak between the pages of the Big Book) one has $E = \hbar\omega = \hbar_0\omega_0$ giving $\omega = \omega_0/r$, $r = \hbar/\hbar_0$. For $C - C$ *resp.* $F - C$ option this gives $\omega = \omega_0/(n_a n_b)$ *resp.* $\omega = \omega_0 \times (n_a/n_b)$. For $C - C$ option de-coherence process would mean a sequence of transitions in which frequencies steadily increase: this does not look plausible in the case of large $\hbar$ gravitons. For $F - C$, $C - F$ and $F - F$ options de-coherence can also reduce frequencies. If n_i are proportional to multiples of 2^k as ruler and compass hypothesis implies, period doubling regarded as a possible route to chaos is also involved but the number of period doublings is always finite. For classical orbits this would correspond to the emergence of small perturbations with n-fold period spoiling exact periodicity. Ruler-and-compass hypothesis implies very powerful predictions for the resulting frequency spectrum. This mechanism is natural for the reduction of n_i in the case of factor space option.

2. For the second mechanism frequencies are not affected so that energy conservation requires the decay of quantum to a bundle of quanta with a smaller value of Planck constant. The reduction factor for the energy is $R = r_f/r_i$ and the number of quanta is $N = r_i/r_f$ and integer if the reduction of Planck constant occurs only for the reduction of n_i for covering space option, which is thus favored.

Quantum criticality and chaos

1. TGD Universe is quantum critical. The most important implication of quantum criticality of TGD Universe is that it fixes the value of Kähler coupling strength, the only free parameter appearing in definition of the theory as the analog of critical temperature. The dark matter hierarchy characterized partially by the increasing values of Planck constant allows to characterize more precisely what quantum criticality might means. By quantum criticality space-time sheets are analogs of Bohr orbits. Since quantum criticality corresponds to P-Q region, the localization of wave functions around generalized Bohr orbits should occur quite generally in some scale.

2. Elementary particles are maximally quantum critical systems analogous to H_2O at tri-critical point and can be said to be in the intersection of embedding spaces labeled by various values of Planck constants. Planck constant does not characterize the elementary particle proper. Rather, each field body of particle (em, weak, color, gravitational) is characterized by its own Planck constant and this Planck constant characterizes interactions. The generalization of the notion of the embedding space allows to formulate this idea in precise manner and each sector of embedding space is characterized by discrete symmetry groups G_a and G_b acting in CD and CP_2 degrees of freedom either on covering or orbifold.

3. Dark matter hierarchy makes TGD Universe an ideal laboratory for studying P-Q transitions with chaos identified as quantum critical phase between two values of Planck constant with

larger value of Planck constant defining the "quantum" phase and smaller value the "classical" phase. Dark matter is localized near Bohr orbits and is analogous to quantum states localized near the periodic classical orbits. Planetary Bohr orbitology provides a particularly interesting astrophysical application of quantum chaos.

4. The above described picture applies about chaotic quantum scattering applies quite generally in quantum TGD. Path integral is replaced with a functional integral over classical space-time evolutions and the failure of the complete classical non-determinism is analogous to the transition between classical orbits. Functional integral also reduces to perturbative functional integral around maxima of Kähler function.

Dark matter structures as generalization of periodic orbits

The matter with ordinary or smaller value of Planck constant can form bound states with these dark matter structures. The dark matter circles would be the counterparts for the periodic Bohr orbits dictating the behavior of the quantum chaotic system. Visible matter (and more generally, dark matter at the lower levels of hierarchy behaving quantally in shorter length and time scales) tends to stay around these periodic orbits and in the ideal case provides a perfect classical mimicry of quantum behavior. Dark matter structures would effectively serve as selectors of the closed orbits in the gravitational dynamics of visible matter.

As one approaches classicality the binding of the visible matter to dark matter gradually weakens. Mercury's orbit is not quite closed, planetary orbits become ellipses, comets have highly eccentric orbits or even non-closed orbits. For non-closed quantum description in terms of binding to dark matter does not makes sense at all.

The classical regular limit (R) would correspond to a decoupling between dark matter and visible matter. A motion along geodesic line is obtained but without Bohr quantization in gravitational sense since Bohr quantization using ordinary value of Planck constant implies negative energies for $GMm \geq 1$. The preferred extremal property of the space-time sheet could however still imply some quantization rules but these might apply in "vibrational" degrees of freedom.

Quantal chaos in gravitational scattering?

The chaotic motion of astrophysical object becomes the counterpart of quantum chaotic scattering. By Equivalence Principle the value of the mass of the object does not matter at all so that the motion of sufficiently light objects in solar system might be understandable only by assuming quantum chaos.

The orbit of a gravitationally unbound object such as comet could define the basic example. The rings of Saturn and Jupiter could represent interesting shorter length scale phenomena possible involving quantum scattering. One can imagine that the visible matter object spends some time around a given dark matter circle (binding to atom), makes a transition along a radial spoke to the next circle, and so on.

The prediction is that dark matter forms rings and cart-wheel like structures of astrophysical size. These could become visible in collisions of say galaxies when stars get so large energy as to become gravitationally unbound and in this quantum chaotic regime can flow along spokes to new Bohr orbits or to gravi-magnetic flux tubes orthogonal to the galactic plane. Hoag's object represents a beautiful example of a ring galaxy [E136]. Remarkably, there is direct evidence for galactic cart-wheels (for pictures of them see [E3]). There are also polar ring galaxies consisting of an ordinary galaxy plus ring approximately orthogonal to it and believed to form in galactic collisions [E23]. The ring rotating with the ordinary galaxy can be identified in terms of gravi-magnetic flux tube orthogonal to the galactic plane.

9.5 Gravitational Radiation And Large Value Of Gravitational Planck Constant

The description of gravitational radiation provides a stringent test for the idea about dark matter hierarchy with arbitrary large values of Planck constants. In accordance with quantum classical correspondence, one can take the consistency with classical formulas as a constraint allowing to deduce information about how dark gravitons interact with ordinary matter. In the following standard facts about gravitational radiation are discussed first and then TGD based view about the situation is sketched.

9.5.1 Standard View About Gravitational Radiation

Gravitational radiation and the sources of gravitational waves

Classically gravitational radiation corresponds to small deviations of the space-time metric from the empty Minkowski space metric [E12]. Gravitational radiation is characterized by polarization, frequency, and the amplitude of the radiation. At quantum mechanical level one speaks about gravitons characterized by spin and light-like four-momentum.

The amplitude of the gravitational radiation is proportional to the quadrupole moment of the emitting system, which excludes systems possessing rotational axis of symmetry as classical radiators. Planetary systems produce gravitational radiation at the harmonics of the rotational frequency. The formula for the power of gravitational radiation from a planetary system given by

$$P = \frac{dE}{dt} = \frac{32}{5}\frac{G^4M_1^2M_2^2(M_1+M_2)}{R^5} \quad . \tag{9.5.1}$$

This formula can be taken as a convenient quantitative reference point.

Planetary systems are not very effective radiators. Because of their small radius and rotational asymmetry supernovas are much better candidates in this respect. Also binary stars and pairs of black holes are good candidates. In 1993, Russell Hulse and Joe Taylor were able to prove indirectly the existence of gravitational radiation. Hulse-Taylor binary [E13] consists of ordinary star and pulsar with the masses of stars around 1.4 solar masses. Their distance is only few solar radii. Note that the pulsars have small radius, typically of order 10 km. The distance between the stars can be deduced from the Doppler shift of the signals sent by the pulsar. The radiated power is about 10^{22} times that from Earth-Sun system basically due to the small value of R. Gravitational radiation induces the loss of total energy and a reduction of the distance between the stars and this can be measured.

How to detect gravitational radiation?

Concerning the detection of gravitational radiation the problems are posed by the extremely weak intensity and large distance reducing further this intensity. The amplitude of gravitational radiation is measured by the deviation of the metric from Minkowski metric, denote by h.

Weber bar [E12] provides one possible manner to detect gravitational radiation. It relies on a resonant amplification of gravitational waves at the resonance frequency of the bar. For a gravitational wave with an amplitude $h \sim 10^{-20}$ the distance between the ends of a bar with length of 1 m should oscillate with the amplitude of 10^{-20} meters so that extremely small effects are in question. For Hulse-Taylor binary the amplitude is about $h = 10^{-26}$ at Earth. By increasing the size of apparatus one can increase the amplitude of stretching.

Laser interferometers provide second possible method for detecting gravitational radiation. The masses are at distance varying from hundreds of meters to kilometers [E12]. LIGO (the Laser Interferometer Gravitational Wave Observatory) consists of three devices: the first one is located with Livingston, Lousiana, and the other two at Hanford, Washington. The system consist of light storage arms with length of 2-4 km and in angle of 90 degrees. The vacuum tubes in storage arms carrying laser radiation have length of 4 km. One arm is stretched and one arm shortened and the interferometer is ideal for detecting this. The gravitational waves should create stretchings not longer that 10^{-17} meters which is of same order of magnitude as intermediate gauge boson Compton length. LIGO can detect a stretching which is even shorter than this. The detected amplitudes can be as small as $h \sim 5 \times 10^{-22}$.

9.5.2 Quantum Mechanisms For The Emission Of Gravitational Radiation

Whether the classical gravitational radiation corresponds to that coming from the transitions between Bohr orbits is far from being a trivial question. At this moment it is not possible to calculate the transition rates but it turns out that $n = 3 \rightarrow 1$ transition is consistent with classical radiation formula for Hulse-Taylor binary [E13] under reasonable assumption about the reaction rate. Ordinary gravitational radiation could be also associated with the sequence of phase transitions reducing h_{gr}. Under same assumption the rate is of the same order of magnitude. Both options force to consider the possibility that gravitational radiation generated in spontaneous transitions is a rather rare phenomenon.

Some quantitative estimates for gravitational quantum transitions in planetary system

To get a concrete grasp about the situation it is useful to study the energies of dark gravitons in the case of planetary system assuming Bohr model.

The expressions for the energies of dark gravitons can be deduced from those of hydrogen atom using the replacements $Ze^2 \rightarrow 4\pi GMm$, $\hbar \rightarrow GMm/v_0$. The energies are given by

$$\begin{aligned} E_n &= \frac{1}{n^2}E_1 \ , \\ E_1 &= (Z\alpha)^2\frac{m}{4} = (\frac{Ze^2}{4\pi\hbar})^2 \times \frac{m}{4} \rightarrow \frac{m}{4}v_0^2 \ . \end{aligned} \tag{9.5.2}$$

E_1 defines the energy scale. Note that v_0 defines a characteristic velocity if one writes this expression in terms of classical kinetic energy using virial theorem $T = -V/2$ for the circular orbits. This gives $E_n = T_n = mv_n^2/2 = mv_0^2/4n^2$ giving

$$v_n = \frac{v_0}{\sqrt{2}n} \ .$$

Orbital velocities are quantized as sub-harmonics of the universal velocity $v_0/sqrt2 = 2^{-23/2}$ and the scaling of v_0 by $1/n$ scales does not lead out from the set of allowed velocities.

Bohr radius scales as

$$r_0 = \frac{\hbar}{Z\alpha m} \rightarrow \frac{GM}{v_0^2} \ . \tag{9.5.3}$$

For $v_0 = 2^{11}$ this gives $r_0 = 2^{22}GM \simeq 4 \times 10^6 GM$. In the case of Sun this is below the value of solar radius but not too much.

The frequency $\omega(n, n-k)$ of the dark graviton emitted in $n \rightarrow n-k$ transition and orbital rotation frequency ω_n are given by

$$\begin{aligned} \omega(n, n-k) &= \frac{v_0^3}{GM} \times (\frac{1}{n^2} - \frac{1}{(n-k)^2}) \simeq 2k\omega_n \ . \\ \omega_n &= \frac{v_0^3}{GMn^3} \ . \end{aligned} \tag{9.5.4}$$

The emitted frequencies at the large n limit are harmonics of the orbital rotation frequency so that quantum classical correspondence holds true. For low values of n the emitted frequencies differ from harmonics of orbital frequency.

The energy emitted in $n \rightarrow n-k$ transition would be

$$E(n, n-k) = mv_0^2 \times (\frac{1}{n^2} - \frac{1}{(n-k)^2}) \ , \tag{9.5.5}$$

and obviously enormous. Single giant (spherical) dark graviton would be emitted in the transition and should decay to gravitons with smaller values of $\hbar$. Bunch like character of the detected radiation might serve as the signature of the process. The bunch like character of liberated dark gravitational energy means coherence and might play role in the coherent locomotion of living matter. For a pair of systems of masses $m = 1$ kg this would mean $Gm^2/v_0 \sim 10^{20}$ meaning that exchanged dark graviton corresponds to a bunch containing about 10^{20} ordinary gravitons. The energies of graviton bunches would correspond to the differences of the gravitational energies between initial and final configurations which in principle would allow to deduce the Bohr orbits between which the transition took place. Hence dark gravitons could make possible the analog of spectroscopy in astrophysical length scales.

The power of graviton radiation emitted in the transition between two Bohr orbits

If dark matter is at stationary states and does not leak between pages of the Big Book with different Planck constant, it does not radiate at all except during the transitions reducing the value of n. Gravitational radiation would be emitted as bursts and these transitions need not have anything to do with quadrupole radiation.

The shortening of the orbital period of Hulse-Taylor binary can be explained with.2 per cent accuracy in terms of energy loss due to gravitational radiation so that the task is to check whether the average power from the transitions between Bohr orbits is consistent with the classical formula or not. To achieve this, one must estimate the average power associated with the transition $n \to n+k$ for the Bohr orbit model of a two-body system.

1. For the energy liberated energy as gravitational radiation one obtains

$$E_{tot} = E_n - E_{n-k} = \hbar_{gr}\omega = \frac{mv_0^2}{4}((n-k)^{-2} - n^{-2}) \simeq \frac{2kmv_0^2}{n^3} \quad . \tag{9.5.6}$$

2. In order to estimate the average power of radiation one must have an estimate for the time T during which the radiation is emitted. $T \sim 2\pi/\omega$ gives lower bound for T. A more general guess is $T \simeq a(2\pi/\omega)v_0^{-p}$, where a is a numerical constant of order unity. This gives estimate for the total average power

$$\begin{aligned} P_q &\sim \frac{E_{tot}}{T} = \frac{\hbar_{gr}\omega^2 v_0^p}{2\pi a} = \frac{GMmv_0^{p+1}}{2\pi a r_n^2}F(n) \ , \\ F(n,k) &= ((\frac{n}{n-k})^2 - 1)^2 \simeq \frac{4k^2}{n^2} \ , \ r_n = n^2\frac{GM}{v_0^2} \ . \end{aligned} \tag{9.5.7}$$

r_n denotes the radius of n: th Bohr orbit. Note that P_q increases as n^2 for large values of n.

3. If the radius R in the formula for the quadrupole radiation powers is identified as Bohr radius r_{n-1}, the ratio of the power P_{cl} emitted by quadrupole radiation to P_q is

$$\begin{aligned} R \equiv \frac{P_{cl}}{P_q} &\simeq ax \times y \times F(n,k)^{-1} \times v_0^{5-p} \ , \\ x &= \frac{2^6\pi}{5} \ , \ y = \frac{(M+m)m}{M^2} \ . \end{aligned} \tag{9.5.8}$$

The dependence on v_0 disappears for $p = 5$. For a binary system with $m = M$ the orders of magnitude are same so that $p = 5$ is the the unique choice of one wants an approximate consistency with the classical formula. For $M = m$, $(n,k) = (3,2)$, $n = 3$, $(a,p) = (.796, 5)$ gives $R = 1$. For $(n,k) = (3,1)$ $a = .112$ is required for $R = 1$. For larger values of n the needed value of a increases because R degreases as $1/n^4$.

For the Hulse-Taylor binary [E13] the masses are $1.441M_S$ and $1.387M_S$ and nearly identical. The semi-major axis is $R = 1.95\times10^6$ km and the orbital period is $T = 7.75$ hr. From $T = 2\pi/\omega = 2\pi GM(n/v_0)^3$ one can estimate $(n/v_0)^3$ using the mnemonic $r_s = 2GM = (M/M_S)\times 2.95$ km. This gives $v_0 = n\times1.2\times10^{-3}$. From $r_n = n^2GM/v_0^2 \sim R$ one obtains $v_0 = n\times1.0\times10^{-3}$. These conditions are not actually independent. Assuming that $n = 3 \rightarrow 1$ transition is in question one has $v_0 \simeq 3\times10^{-3}$. That v_0 is larger for Hulse-Taylor binary than solar system conforms with the general expectation that at black-hole limit v_0 approaches to $v_0 = 1$.

The estimated time before the final spiral takes place is $\tau = 3\times10^8$ years. For the estimated value of v_0 the time for the transition between states n and $n-1$ would be $\tau \sim av_0^{-5}5T \simeq 2.8972\times10^9$ years, which is consistent with the classical estimate. It seems that the interpretation as quantum transition could make sense. If the interpretation is correct it could mean that gravitational radiation is rather rare phenomenon since the quantum transitions between stationary states are expected to be rare occurrences.

Could ordinary gravitational radiation be radiation emitted in the reduction of gravitational Planck constant

The Bohr model for Hulse-Taylor binary predicts a reasonable value of v_0 and the interpretation as a transition between Bohr orbits makes sense if the transition in question is $n = 3 \rightarrow 1$ transition leading to the ground state. One can consider also other mechanism producing gravitational radiation.

1. The model for Hulse-Taylor and also other data suggest that v_0 increases as the planetary system gets older. This raises the possibility that gravitational radiation is emitted in transitions increasing the value of the velocity parameter v_0 as as dark matter leaks to the pages of the Big Book with smaller Planck constant. This assumption is consistent with second law and with the vision about how system approaches to chaos. If $1/v_0$ is integer the number of these transitions would be relatively small. If v_0 is a ratio of very big integers situation changes. v_0 cannot exceed light velocity so that in the limiting situation $v_0 \leq 1$ holds true. The asymptotic value $\hbar_{gr} \geq GMm$ and would make possible to avoid gravitational collapse. $v_0 = 1$ might have interpretation in terms of the light-likeness of the asymptotic wormhole throat containing only dark matter.

   After the asymptotic value of v_0 has been reached, the transitions could occur as transitions between Bohr orbits if one has $n > 1$ in the original situation. This picture conforms with the idea that genuine quantum realm is realized only at the radii comparable to gravitational Planck length $L_{Pl} = \sqrt{\hbar_{gr}G} = G\sqrt{Mm}$. For $M = m$ this length is one half of Schwartschild radius.

2. Assume that all energy liberated in the transitions goes to gravitational radiation, and that the rate is determined by the condition $\tau = a\times 2\pi v_0^5/\omega$. This gives

$$\hbar_{gr}\omega = \frac{m}{4}\frac{\Delta v_0^2}{n^2} \ . \tag{9.5.9}$$

   This gives for the ratios of transition times and radiation powers in the two kinds of transitions the estimates

$$\frac{\tau_{\Delta v_0}}{\tau_{\Delta n}} = \frac{v_0^2}{n^2}\frac{\Delta(\frac{1}{n^2})}{\Delta v_0^2} \ ,$$
$$\frac{P_{\Delta v_0}}{P_{\Delta n}} = (\frac{v_0^2}{n^2}\frac{\Delta(\frac{1}{n^2})}{\Delta v_0^2})^2 \ . \tag{9.5.10}$$

   The ratio is of order u power of radiated energy is of same order as in the previous case.

A couple of further remarks about the model are in order.

1. Bohr energies are proportional to $(\hbar_{gr}n)^{-2}$. In case of $F-C$ option this allows to consider the possibility that common factor drops out from both n and $1/\hbar_{gr}$ without any change in the energy of the state since the Bohr orbit is not affected. The Planck constant for the outer planets in solar system is by a factor 5 larger than for inner planets and this kind of transition is in principle possible.

2. At formal level at least one can also consider gravitationally bound states of light particles. For $GMm<1$ the value of gravitational Planck constant would becomes smaller than $\hbar_0$ for $v_0\rightarrow 1$. In this case the asymptotic situation would correspond to $v_0=GMm$.

One can consider also an alternative model in which one treats the change of v_0 as an effectively continuous process, drops the assumption about τ, and equates the radiation power to the classically predicted power.

1. The condition that $\hbar$ changes almost continuously combined with the condition $\hbar$ is reduced by dividing factors out from n_a and n_b requires that $\hbar$ contains a product of ratios of almost identical integers associated with n_a and n_b: $n_a/n_b=\prod_i(r_i/s_i)$, $r_i/s_i<1$. This condition is quite stringent and one can argue that it makes the model un-natural.

2. Using $E_n=mv_0^2/4n^2$ for circular Bohr orbits, the power radiated as gravitational radiation would be

$$P_n = \frac{dE_n}{dt}=2E_n\frac{dlog(v_0)}{dt} . \tag{9.5.11}$$

This gives

$$\frac{dlog(E_n)}{dt} = 2\frac{dlog(v_0)}{dt}=2\frac{dlog(\frac{v_0}{n})}{dt} . \tag{9.5.12}$$

Note that the formula is scaling invariant.

3. Using classical radiation formula for which the radiated power is proportional to $1/r_n^5$ and $r_n=GMn^2/v_0^2$ one has $P_n\propto(v_n/n)^{10}$ and $P_n/E_n\propto(v_n/n)^8/n^2$. Combining this with the above result one has

$$\begin{aligned}\frac{dlog(x_n)}{dt} &= \frac{k}{GMn^2}x_n^8 ,\\ x &= \frac{v_0}{n} , \quad k=\frac{2^6}{5}(\frac{m}{M})^2\frac{M+m}{m} .\end{aligned} \tag{9.5.13}$$

This gives

$$v_0 = n(\frac{v_0(0)}{n}^{-7}-7k\frac{t}{GM})^{-1/7} . \tag{9.5.14}$$

The time devolution of v_0 depends on Bohr orbit. This conforms with the fact that to each planet there corresponds a particular space-time sheet mediating gravitational interaction. The different time dependence of v_0 for different Bohr orbits however implies that Bohr model with single value of v_0 cannot explain the radii of planetary orbits for large values of t. For $v_0(0)=2^{-11}$ $v_0(0)^{-7}$ equals to 2^{77} so that the rate for the change is very slow.

4. The velocity becomes infinite in time

$$t_\infty = \frac{GM}{8k}\frac{v_0(0)}{n}^{-8} \quad .$$

Light velocity of course sets an upper bound for the velocity and is never achieved and the formula most break down at relativistic velocities. A rough estimate for the time during which light velocity is achieved is as

$$t_1 = \frac{GM}{8k}(\frac{v_0(0)}{n}^{-8} - 1) \quad .$$

The time depends on Bohr orbit.

5. The model does not say anything about the emission process itself. Gravitons could be also emitted as dark gravitons. The value of Planck constant for them must be however considerably smaller than the value of $\hbar_{gr}$.

9.5.3 Model For Dark Gravitons

If one wants to understand how dark gravitons possibly affect the standard predictions for graviton detection, one must develop a model for dark gravitons and their transformation to ordinary gravitons.

Gravitons in TGD

Unlike the naïve application of Mach's principle would suggest, gravitational radiation is possible in empty space in general relativity. In TGD framework it is not possible to speak about small oscillations of the metric of the empty Minkowski space imbedded canonically to $M^4 \times CP_2$ since Kähler action is non-vanishing only in fourth order in the small deformation and the deviation of the induced metric is quadratic in the deviation. Same applies to induced gauge fields. Even the induced Dirac spinors associated with the Kähler-Dirac action fixed uniquely by super-symmetry allow only vacuum solutions in this kind of background. Mathematically this means that both the perturbative path integral approach and canonical quantization fail completely in TGD framework. This led to the vision about physics as Kähler geometry of "world of classical worlds" with quantum states of the universe identified as the modes of classical WCW spinor fields.

The resolution of various conceptual problems is provided by the parton picture and the identification of elementary particles as light-like 3-surfaces associated with the wormhole throats. Gauge bosons correspond to pairs of wormholes and fermions to topologically condensed CP_2 type extremals having only single wormhole throat.

Gravitons are string like objects in a well defined sense. This follows from the mere spin 2 property and the fact that partonic 2-surfaces allow only free many-fermion states. This forces gauge bosons to be wormhole contacts whereas gravitons must be identified as pairs of wormhole contacts (bosons) or of fermions connected by flux tubes. The strong resemblance with string models encourages to believe that general relativity defines the low energy limit of the theory. Of course, if one accepts dark matter hierarchy and dynamical Planck constant, the notion of low energy limit itself becomes somewhat delicate.

The number of states is conserved in the phase transitions changing Planck constant

The number of states is conserved in phase transitions changing Planck constant as the following argument demonstrates.

1. The units of charges are scaled by $1/n_i$ for the covering space option (C) and by n_i for factor space option (F). Without any constraints the number of states would be scaled by n_i for C and $1/n_i$ for F. The modification of fermionic anti-commutation (bosonic commutation) relations involving $\hbar$ at the right hand side implies that particle numbers become as multiples of $\hbar/\hbar_0$ so that particle number is fractionized in the general case. This implies a change in

the number of states which compensates the change caused by the change of the charge units so that the total number of states remains unchanged in the phase transitions affecting the value of $\hbar$.

2. For F-option particle number becomes fractional implying that angular momentum and charge units are not changed. If the anyonic state is created from an ordinary one in a phase transition, the total particle number for the entire anyonic state must be integer, which gives rise to a confinement mechanism. For C-option the charge units are fractional but since particle numbers become as integer multiples of n_i, the net result is that total charges have the standard spectrum. Single particle states can however have fractional charges. In anyonic many-particle states this kind of spin and charge fractionization can take place at single particle level [K81].

3. If one assumes G_i-singletness for the states of the covering, the unit of angular momentum is scaled up by n_i and the interpretation is in terms of n_i copies of ordinary single particle states at the sheets of the covering. For factor space option already single particle states are by definition G_i singlets.

What kind of dark gravitons can one consider?

First of all one must decide what sector of the generalized embedding space dark graviton correspond to. There are four options of which two ($C-C$ and $F-C$) can give rise to large angular momentum and only these options will be discussed in the sequel. It should be noticed that if one accepts the proposal that the hierarchy of Planck constants follows from basic TGD then only the $C-C$ option remains. This option is favored also because it implies evolution as increase of Planck constants and because for given value of Planck constant there is only a finite number of different pages of the Big Book corresponding to the factorizations of $n = n_a n_b$ of the integer $n = \hbar/\hbar_0$.

1. $C-C$ option corresponds to Planck constant $r \equiv \hbar/\hbar_0 = n_a n_b$. Both G_a and G_b would act in their respective covering spaces assignable to the gravitational field body. Either n_a or n_b or both must be very large. For large n_b G_a singletness implies that the unit of angular momentum of the giant graviton is proportional to n_b and thus very large and the interpretation is as a bundle of ordinary gravitons. In this case also gravitons with small net angular momentum are possible.

2. $F-C$ option: corresponds to $\hbar/\hbar_0 = n_b/n_a$ with very large value of n_b. In this case graviton has G_a-fold rotational symmetry and would have very large angular momentum proportional to n_b.

Consider first the general view about de-coherence process assumed to reduce the symmetries defined by G_a and G_b.

1. Assuming singletness with respect to G_a and G_b, de-coherence could be seen as a sequence of symmetry breakdowns for both coverings and factor spaces. At given step the orders of the resulting symmetry groups G_a and G_b are divisors of the orders of the original groups. The final step would lead to trivial covering and factor spaces. Number theoretically the process is like determining the factors of a very large number by dividing them away in the de-coherence process.

2. Once the sector of the generalized embedding space is selected, one has still two options corresponding to spherical and plane waves. Spherical dark gravitons could be emitted in quantum transitions of the dark part of the astrophysical object. Emission process could also yield a sufficiently large number of MEs (massless extremals/ topological light rays [K14]) with large value of $\hbar$.

3. Spherical dark graviton can de-cohere into spherical gravitons with smaller groups G_a and G_b. Sooner or later spherical giant graviton must de-cohere into topological light rays ("MEs") defining the TGD counterparts of plane waves of finite width and define second model for dark graviton. They are expected to be detectable by human built detectors. Note that for $F-C$ option the meaning of G_a for the MEs is different from that for spherical gravitons since the directions of quantization axes of angular momentum are in general different.

Emission of dark gravitons

One must answer several non-trivial questions if one is to defend dark gravitational radiation.

Frequencies of dark gravitons turn out to correspond to orbital frequencies at large quantum number limit. However, if gravitational radiation is emitted as dark gravitons, they have enormous energies since the energy must correspond to the change of the energy of an astrophysical object jumping to a smaller Bohr orbit.

Hulse-Taylor binary system was used to demonstrate that the energy loss of the binary system equals to the classically predicted power of gravitational radiation. The power of gravitational radiation was deduced from the gradual reduction of the distance between the two stars. The obvious question is whether the consistency of the power emitted by Hulse-Taylor binary with the prediction of the classical theory kills the hypothesis about gigantic gravitational Planck constant.

1. If one assumes that v_0 is of same order of magnitude as for planetary systems as the value of the orbital radius indeed suggests, single spherical dark graviton emitted in the transition would carry away an essentially astrophysical energy. If MEs are emitted and one assumes that sufficiently high number of them is emitted so that the total recoil momentum is small.

2. If dark graviton is spherical or -more generally - corresponds to a partial wave with a definite value of angular momentum (in a sense to be specified), it must decay gradually to spherical or ME type gravitons with smaller values of Planck constant. The measurement process should induce this kind of decay.

3. The prediction that energy is emitted in bunches should have testable experimental implications. The case of hydrogen atom inspires the question whether the lowest orbit is stable and does not emit gravitational radiation meaning that the binary ends up to the stable state rather than collapsing. Of course, the idealization as hydrogen atom like system might fail. The identification of dark gravitons as dark topological light rays (massless extremals, MEs) containing topologically condensed ordinary gravitons will be discussed later.

By quantum classical correspondence this process must have a space-time description.

1. The natural proposal is that below the time scale associated with the emission process the space-time picture about the emission process looks like a continuous process, at least asymptotically when the space-time itself is replaced repeatedly with a new one. Thus the transition between orbitals at the level of space-time correlates must occur continuously below the time scale assigned to it classically. Quantum emission would quite generally mean in sub-quantum time scales continuous classical process at space-time level.

2. TGD based quantum model for living system suggests that the transition occurs in a fractal manner proceeding from long to short dark time scales. First a quantum jump in the longest time scale occurs and induces the replacement of the entire space-time with a new one differing dramatically from the previous one. This quantum jump is followed by quantum jumps in shorter time scales. At each step space-time sheet characterizing the system is replaced by a new one and eventually by a space-time surface which describes the process as more or less continuous one. The final space-time could be regarded as symbolic description of the process as a classical continuous process.

3. The time interval for the occurrence of the transition at space-time level should correspond to a dark p-adic time scale and in the case of Hulse-Taylor binary be of same order as the lifetime of the period during which the system ends up to a stable state. In the Hulse-Taylor case the emission would correspond to small values of n, most naturally $n = 2 \rightarrow n = 1$ transition so that the frequency of the gravitational radiation would not correspond to the orbital frequency. This might some day be used as a test for the theory. The time duration T for the transition can be estimated from $T = \Delta E/P$, where P is the classical formula for the emission power.

Model for the spherical graviton

Detector, giant graviton, source, and topological light ray will be denoted simply by D, G, and S, and ME in the following. Consider first the model for the giant graviton.

1. Orbital plane defines the natural quantization axis of angular momentum for spherical graviton. Spherical graviton corresponds to a graviton with very large unit of angular momentum corresponding to G_a invariance acting in covering space degrees of freedom but can be regarded as a Bose-Einstein condensate like state of ordinary gravitons.

2. The total angular momentum of the giant graviton(s) must correspond to the change of angular momentum in the quantum transition between initial and final orbit. Orbital angular momentum in the direction of quantization axis should be a small multiple of dark Planck constant associated with the system formed by giant graviton and source. These states correspond to Bose-Einstein condensates of ordinary gravitons in eigen state of orbital angular with ordinary Planck constant. Unless S-wave is in question the intensity pattern of the gravitational radiation depends on the direction in a characteristic non-classical manner. The coherence of dark graviton regarded as Bose-Einstein condensate of ordinary gravitons is what distinguishes the situation in TGD framework from that in GRT.

Dark graviton as topological light ray

Second kind of dark graviton is analog for plane wave with a finite transversal cross section. TGD indeed predicts what I have called topological light rays, or massless extremals (MEs) as a very general class of solutions to field equations [K14].

MEs are typically cylindrical structures carrying induced gauge fields and gravitational field without dissipation and dispersion and without weakening with the distance. These properties are ideal for targeted long distance communications which inspires the hypothesis that they play a key role in living matter [K78, K17] and make possible a completely new kind of communications over astrophysical distances. Large values of Planck constant allow to resolve the problem posed by the fact that for long distances the energies of these quanta would be below the thermal energy of the receiving system.

Giant gravitons are expected to decay to this kind of dark gravitons having smaller value of Planck constant via de-coherence and that it is these gravitons which are detected. Quantitative estimates indeed support this expectation.

The same general picture that applies to spherical gravitons applies to MEs. The only difference is that quantization axis of angular momentum left point-wise invariant under G_a is parallel to the direction of propagation. Thus the de-coherence of a spherical graviton into MEs means dispersion to a sector of the world of classical worlds possessing different quantization axes.

9.5.4 Detection Of Gravitational Radiation

One should also understand how the description of the gravitational radiation at the space-time level relates to the picture provided by general relativity to see whether the existing measurement scenarios really measure the gravitational radiation as they appear in TGD. There are more or less obvious questions to be answered (or perhaps obvious after a considerable work).

What is the value of dark gravitational constant which must be assigned to the pair formed by the measuring system and gravitational radiation from a given source? Is the detection of primary giant graviton possible by human means or is it possible to detect only dark gravitons produced in the sequential de-coherence of giant graviton? Do dark gravitons enhance the possibility to detect gravitational radiation as one might expect? What are the limitations on detection due to energy conservation in de-coherence process?

TGD counterpart for the classical description of detection process

The oscillations of the distance between the two masses defines a simplified picture about the receival of gravitational radiation.

Now ME would correspond to n_a-sheeted covering of M^4 analogous to Riemann space associated with n_a:th root of z with each sheet oscillating with the same frequency: simply a stack of ordinary MEs defining a bundle of ordinary gravitons. Classical interaction would suggest that the measuring system topologically condenses at the topological light ray so that the distance between the test masses measured along the topological light ray in the direction transverse to the direction of propagation starts to oscillate. This (or these) topological light rays must however result via de-coherence to $n_a = n_b = 1$ sector of the embedding space unless measurement system itself corresponds to dark matter. If only single topological light ray results it must carry large number of gravitons. Topological light rays can be indeed regarded as space-time correlates for massless collinear bosons of various kinds. One can also consider the possibility that measurement system is quantum critical itself.

Obviously the classical behavior is essentially the same as predicted by general relativity. If all elementary particles are maximally quantum critical systems and therefore also gravitons, then gravitons can be absorbed at each step of the process, and the number of absorbed gravitons and energy is N-fold.

One can ask whether one should treat the detector as a $(n_a, n_b) = (1, 1)$ system or whether one could assume that the Planck constant is large and given by a formula $\hbar(D)/\hbar_0 = GM^2(D)/v_D$ so that the gravitational field body would catch the incoming dark graviton. In this case the value of $\hbar$ for incoming gravitons should be equal to $\hbar(D)$. This number theoretic condition is not in general true. Unless the gravitational field body of the detector is quantum critical in the sense of having branches in a large number of pages of the Big Book, this kind of detection is not possible in general and gravitons must end up to ordinary gravitons or gravitons with relatively small value of $\hbar$ before they can be detected.

The time interval during which the interaction with dark graviton takes place?

If the duration of the bunch is $T = E/P$, where P is the classically predicted radiation power in the detector and T the detection period, the average power during bunch is identical to that predicted by GRT. Also T would be proportional to r, and therefore code information about the masses appearing in the sequential de-coherence process.

An alternative, and more attractive possibility, is that T is same always and correspond to $r = 1$. The intuitive justification is that absorption occurs simultaneously for all r "Riemann sheets". This would multiply the power by a factor r and dramatically improve the possibilities to detect gravitational radiation. The measurement philosophy based on standard theory would however reject these kind of events occurring with $1/r$ time smaller frequency as being due to the noise (shot noise, seismic noise, and other noise from environment). This might relate to the failure to detect gravitational radiation.

9.5.5 Quantitative Model

In this subsection a rough quantitative model for the de-coherence of giant (spherical) graviton to topological light rays (MEs) is discussed and the situation is discussed quantitatively for hydrogen atom type model of radiating system. The basic assumption is irreversibility in the sense that the integers n_a and n_b approach to unity in the de-coherence process.

Restrictions of the model

The model has important restriction, which is obvious after ten years from its formulation.

1. It is assumed that the emitter begins as a coherent object with mass m, which is astrophysical. Equivalence Principle allows also to consider emission by individual microscopic particles by just replacing the mass of the astrophysical object with the mass of microscopic particle and summing over the emissions of individual particles. The energy carried by dark graviton would correspond to the change of energy for particle dropping from Bohr orbit to a lower one: this is clearly much smaller. The important aspect is quantization of the energies of the emitted radiation which might be of importance as far as detection of the emitted radiation is considered if the value of the principal quantum number is not very large.

2. The order of magnitude is $\Delta E \sim m\Delta v^2$. The formula $\Delta E = \hbar_{gr}\omega$ gives $\omega \sim 2v_0\Delta(v^2/c^2)/r_S$, where Schwartschild radius $r_S = 2GM$ appears ($c = 1$ in the units used). Since all particles

are transferred simultaneously to the lower orbit, the energy changes associated with individual particles add up to the energy resulting also by assuming quantum coherence for the entire object but now emitted as single giant graviton.

3. Obviously the model assuming a large number of dark gravitons associated with individual particles conforms better with physical intuitions but still predicts that gravitons are energetic and decay to bunches of ordinary gravitons in detector.

The following discussion is for giant gravitons but easily adapted to the situation in which microscopic objects are the emitters. The model also applies on the dark portion of matter in the rotating object. For ordinary matter the standard classical description of emission can be applied.

De-coherence of spherical dark gravitons to ordinary gravitons

The proposed general model for de-coherence can be applied to build a model for the de-coherence of spherical dark gravitons to ordinary spherical gravitons.

1. For $C-C$ option one can assume that de-coherence occurs through the decays of gravitons to multi-graviton states with smaller $\hbar$. These decay sequences correspond to all possible factorizations of the integer $N = n_a n_b$ to a product $N = \prod n_i$ of factors (same factor can appear several times) and taken in all possible orders distinguishable from each other. A particular decay sequence means following. At the first step any factor n_i is divided from N producing a bundle of n_i gravitons with energy E/n_i. Briefly: $N \rightarrow N/n_i$, $E \rightarrow E/n_i$. This corresponds to a node of a tree with incoming graviton defining the root and having n_i branches. This process repeats itself for each new branch independently creating new branches at each node. This process repeats itself until only ordinary gravitons are left. Note that the last decay could take place at detector. This picture suggests that the flow of ordinary gravitons is not steady but takes place in bunches of ordinary gravitons so that standard detector arrangements might regard these bunches as noise.

2. For $F-C$ option one has $r = n_b/n_a$ which corresponds to non-integer valued graviton number. n_a is eliminated by a sequence of divisions of n_a by its factors and also now all possible sequences are possible. In this case graviton does not decay to multi-graviton state but suffers only a leakage to a sector with a smaller value of n_a so that frequency is scaled as $f \rightarrow f/n_i$, n_i a factor of n_a. The eventual replacement of the original frequency with its sub-harmonic f/n_a means that at least for large enough values of n_a the standard measurement arrangements estimating the typical value of f from orbital period fail to detect gravitons. If ruler and compass rule holds true, the analogy with the approach to chaos by period doubling is obvious.

3. The estimate for the number of ordinary gravitons gives estimate for the radiated energy per solid angle. This estimate follows also from the energy conservation for the transition. The requirement that average power equals to the prediction of GRT allows to estimate the geometric duration associated with the transition. The condition $\hbar\omega = E_f - E_i$ is consistent with the identification of $\hbar$ for the pair of systems formed by giant-graviton and emitting system.

Transformation of spherical giant gravitons to topological light-rays

The model for the transformation of dark spherical gravitons to ordinary gravitons via a transition to MEs differs from the above model only in that there is a step in which a transformation to MEs takes place.

1. Giant graviton leaks to sectors of H with a smaller value of Planck constant via quantum critical points common to the original and final sector of H. If ordinary gravitons are quantum critical they can be regarded as leakage points.

2. It is natural to assume that the resulting dark graviton corresponds to a radial topological light ray (ME).

3. Energy should be conserved in the leakage process. The secondary dark graviton receives the fraction $\Delta\Omega/4\pi = S/4\pi r^2$ of the energy of giant graviton, where $S(ME)$ is the transversal area of ME, and r the radial distance from the source, of the energy of the giant graviton. Energy conservation gives

$$\frac{S(ME)}{4\pi r^2}\hbar(G,S)\omega = \hbar(G,ME)\omega \ , \tag{9.5.15}$$

where S and ME refer to spherical and ME. From this one obtains

$$\frac{S(ME)}{4\pi r^2} = \frac{\hbar(G,ME)}{\hbar(G,S)} \simeq \frac{E(ME)}{M(S)} \ . \tag{9.5.16}$$

The larger the distance is, the larger the area of ME. This means a restriction to the measurement efficiency at large distances for realistic detector sizes since the number of gravitons must be proportional to the ratio $S(D)/S(ME)$ of the areas of detector and ME.

4. After the transformation to MEs the MEs decay to bundles of MEs with smaller value of $\hbar$ just as spherical gravitons would do. The values of $\hbar$ appearing in the sequence are same as for spherical cascade.

Estimate for the total number of detected ordinary gravitons

For $F-C$ option the frequencies of detected gravitons are sub-harmonics f/n_a. For $C-C$ option the frequency is the original one. Suppose that the detector has a disk like shape with disk radius d. This gives for the total number $n(D)$ of ordinary gravitons going to the detector the estimate

$$n(D) = \frac{\Delta\Omega}{4\pi \times n_b(G,S)} = \frac{1}{4} \times (\frac{d}{r})^2 \times n_b(G,S) \ , \tag{9.5.17}$$

This implies

$$n(D) = x\frac{GMm}{v_0}\frac{1}{4} \times (\frac{d}{r})^2 \ , \tag{9.5.18}$$

$$x = 1 \ \text{for } C-C \text{ option}, \ \ x = n_a \ \text{for } F-C \text{ option} \ . \tag{9.5.19}$$

If the actual area of detector is smaller than d^2 by a factor x one has

$$n(D) \rightarrow xn(D) \ .$$

$$E(D) = E_{tot} \times \frac{1}{4}(\frac{d}{r})^2 \ , \ E_{tot} = \hbar_{gr}\omega \ , \ \frac{GMm}{v_0} \ . \tag{9.5.20}$$

Assuming that the radiation is emitted during time $T \sim 2\pi/\omega$ on obtains the estimate for the total power

$$P_q \sim \frac{E_{tot}}{T} = \frac{1}{2\pi}\hbar_{gr}\omega^2 \ . \tag{9.5.21}$$

9.5.6 Generalization To Gauge Interactions

The situation is expected to be essentially the same for gauge interactions. The first guess is that one has $r = Q_1Q_2g^2/v_0$, were g is the coupling constant of appropriate gauge interaction. v_0 need not be same as in the gravitational case. The value of $Q_1Q_2g^2$ for which perturbation theory fails defines a plausible estimate for v_0. The basic constraint is $v_0 \leq 1$. In the case of gravitation this interpretation would mean that perturbative approach fails for $GM_1M_2 = v_0$. For $r > 1$ Planck constant is quantized with rational values with ruler-and-compass rationals as favored values. For gauge interactions r would have rather small values. The above criterion applies to the field body connecting two gauge charged systems. One can generalize this picture to self interactions assignable to the "personal" field body of the system. In this case the condition would read as $\frac{Q^2g^2}{v_0} > 1$.

Some applications

One can imagine several applications.

1. A possible application would be to electromagnetic interactions in heavy ion collisions.

2. Gamma ray bursts might be one example of dark photons with very large value of Planck constant. The MEs carrying gravitons could carry also gamma rays and this would amplify the value of Planck constant form them too.

3. Atomic nuclei are good candidates for systems for which electromagnetic field body is dark. The value of $\hbar$ would be $r = Z^2e^2/v_0$, with $v_0 \sim 1$. Electromagnetic field body could become dark already for $Z > 3$ or even for $Z = 3$. This suggest a connection with nuclear string model [L2] in which $A \leq 4$ nuclei (with $Z < 3$) form the basic building bricks of the heavier nuclei identified as nuclear strings formed from these structures which themselves are strings of nucleons.

4. Color confinement for light quarks might involve dark gluonic field bodies.

5. Dark photons with large value of $\hbar$ could transmit large energies through long distances and their phase conjugate variants could make possible a new kind of transfer mechanism [K56] essential in TGD based quantum model of metabolism and having also possible technological applications. Various kinds of sharp pules [H2] suggest themselves as a way to produce dark bosons in laboratory. Interestingly, after having given us alternating electricity, Tesla spent the rest of his professional life by experimenting with effects generated by electric pulses. Tesla claimed that he had discovered a new kind of invisible radiation, scalar wave pulses, which could make possible wireless communications and energy transfer in the scale of globe (for a possible but not the only TGD based explanation [K40]). This notion of course did not conform with Maxwell's theory, which had just gained general acceptance so that Tesla's fate was to spend his last years as a crackpot. Great experimentalists seem to be able to see what is there rather than what theoreticians tell them they should see. They are often also visionaries too much ahead of their time.

In what sense dark matter is dark?

The notion of dark matter as something which has only gravitational interactions brings in mind the concept of ether and is very probably only an approximate characterization of the situation. As I have been gradually developing the notion of dark matter as a hierarchy of phases of matter with an increasing value of Planck constant, the naïvete of this characterization has indeed become obvious.

If the proposed view is correct, dark matter is dark only in the sense that the process of receiving the dark bosons (say gravitons) mediating the interactions with other levels of dark matter hierarchy, in particular ordinary matter, differs so dramatically from that predicted by the theory with a single value of Planck constant that the detected dark quanta are unavoidably identified as noise. Dark matter is there and interacts with ordinary matter and living matter in general and our own EEG in particular provide the most dramatic examples about this interaction. Hence we could consider the dropping of "dark matter" from the glossary altogether and replacing the attribute "dark" with the spectrum of Planck constants characterizing the particles (dark matter) and their field bodies (dark energy).

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

9.5.7 Can Graviton Have Mass?

The latest news from LIGO is that it has not detected gravitational waves from black holes with masses in the range 25-100 solar masses [E49]. This conforms with theoretical predictions. Earlier searches from Super Novae give also null result: in this case the searches are already at the boundaries of resolution so that one can start to worry.

The reduction of the spinning rate of Hulse-Taylor binary (see `http://tinyurl.com/yc8gmood`) [E13] is consistent with the emission of gravitational waves with the predicted rate so that it seems that gravitons are emitted. One can however ask whether gravitational waves might remain undetected for some reason.

Massive gravitons is the first possibility. For a nice discussion see the article of Goldhaber and Nieto (see `http://tinyurl.com/ycwr2v2d`) [E179] giving in their conclusions a table summarizing upper bounds on graviton mass coming from various arguments involving model dependent assumptions. The problem is that it is not at all clear what massive graviton means and whether a simple Yukawa like behavior (exponential damping) for Newtonian gravitational potential is consistent with the general coordinate invariance. In the case of massive photons one has similar problem with gauge invariance. One can of course naïvely assume Yukawa like behavior for the Newtonian gravitational potential and derive lower bounds for the Compton wave length of gravitons. The bound is given by $\lambda_c \geq 100$ Mpc.

Second bound comes from the pulsar timing measurements (see `http://tinyurl.com/ydhbbfd7`) [E105]. The photons emitted by the pulsar are assumed to surf in the sea of gravitational waves created by the pulsar. If gravitons are massive in Yukawa sense they arrive with velocities which are below light velocity, a dispersion of both graviton and photon arrival times is predicted. This gives a much weaker lower bound $\lambda_c \geq 1$ pc. Note that the distance of Hulse-Taylor binary is 6400 pc so that this upper bound for graviton mass could explain the possible absence of gravitational waves from Hulse-Taylor binary. There are also other bounds on graviton mass (see `http://tinyurl.com/ycwr2v2d`) [E179] but all are plagued by model dependent assumptions.

Also in TGD framework one can imagine explanations for the possible absence of gravitational waves. I have already discussed the possibility that gravitons are emitted as dark gravitons with gigantic value of $\hbar$, which decay eventually to bunches of ordinary gravitons meaning that continuous stream of gravitons is replaced with bursts which would not be interpreted in terms of gravitons but as noise.

One of the breakthroughs of the last year was related to the twistor approach to TGD [K106] in zero energy ontology (ZEO).

1. This approach leads to the vision that all building blocks (light-like wormhole throats) of physical particles -including also virtual particles and also string like objects- are massless. On mass shell particles are bound states of massless particles but virtual states do not satisfy bound state constraint and because negative energies are possible, also space-like virtual momenta are possible.

2. Massive physical particles are identified as bound states of massless wormhole throats: since the three momenta can have different (as a special case opposite) directions, the bound states of light-like wormhole throats can be indeed massive.

3. Masslessness of the fundamental objects saves from problems with gauge invariance and general coordinate invariance. It also makes it possible to apply twistor formalism, implies the

absence of UV divergences, and yields an enormous simplification of generalized Feynman diagrammatics since mass shell constraints are satisfied at lines besides momentum conservation at vertices.

4. A simple argument forces to conclude that all spin one and spin two particles- in particular graviton- identified in terms of multi-wormhole throat states must have arbitrary small but non-vanishing mass. The resulting physical IR cutoff guarantees the absence of IR divergences. This allows to preserve the exact Yangian symmetry of the M-matrix. One implication is that photon eats the TGD counterpart of the neutral Higgs and that only pseudo-scalar counterpart of Higgs survives. The scalar counterparts of gluons suffer the same fate whereas their pseudo-scalar partners would survive.

Is the massivation of gauge bosons and gravitons in this sense consistent with the Yukawa type behavior?

1. The first thing to notice is that this massivation would be essentially a non-local quantal effect since both emitter and receiver both emit and receive light-like momenta. Therefore the description of the massivation in terms of Yukawa potential and using ordinary QFT might well be impossible or be a good approximation at best.

2. If the massive gauge bosons (gravitons) correspond to wormhole throat pair (pair of these) such that the three-momenta are light-like but in exactly opposite directions, no Yukawa type screening and velocity dispersion should take place.

3. If the three momenta are not exactly opposite as is possible in quantum theory, Yukawa screening could take place since the classical cm velocity calculated from the total momentum for a massive particle is smaller than maximal signal velocity. The massivation of intermediate gauge bosons and the fact that Yukawa potential description works for them satisfactorily supports this interpretation.

4. If the space-time sheets mediating gravitational interaction have gigantic values of gravitational Planck constant Compton length of graviton is scaled up dramatically so that screening would be absent but velocity dispersion would remain. This leaves open the possibility that gravitons from Hulse-Taylor binary could reveal the velocity dispersion if they are detected some day.

9.6 The TGD view of the recently discovered gravitational hum as gravitational diffraction

Year 2022 initiated a revolution in cosmology when James Webb telescope started to function [L111] [L143]. This is not the only big step of progress. The latest breakthrough related to the detection of gravitational hum was announced June 29 2023 [L144] (`rb.gy/e226v`: see also `rb.gy/vcm28` and `rb.gy/i4msf`).

9.6.1 The discovery

Scientists from the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) have now officially made the first detections of the gravitational wave background. This gravitational hum was not detected by Earth bound instruments. Rather, they make themselves manifest as periodic changes of the spinning rates of pulsars with the frequencies of the gravitational waves involved. The periods are of order year. In the LIGO experiment the periods are measured as fractions of a second.

The wavelength of the oscillations makes itself visible as correlations between the variations of the spinning rates for pulsars having relative distances measured using a light year as a unit. The wavelength of the oscillations is measured in light years. Where could this length scale come from? What might make bells ringing is that the star nearest to the Sun is at a distance of 4 light years and the typical distance between stars is 5 light years.

The unexpectedly large amplitude of the oscillations motivates the hypothesis that pairs of galactic supermassive blackholes or interacting groups of them could generate the gravitational hum. There are candidates for these pairs but no established pair. The group hypothesis seems to work better.

9.6.2 TGD explanation in terms of astrophysical gravitational quantum coherence and diffraction in hyperbolic tessellation

TGD suggests a radically different hypothesis based on TGD view of gravitational quantum coherence an diffraction in a hyperbolic tessellation.

1. TGD predicts quantum gravitational coherence in astrophysical scales characterized by gravitational Planck constants $h_{gr} = GMm/\beta_0$ characterizing big mass M and small mass m. $\beta_0 = v_0/c < 1$ ia velocity parameter. The Equivalence Principle is realized as the independence of the gravitational Compton length $\Lambda_{gr} = GM/\beta_0 = r_s/2\beta_0$ on mass m.

    (a) For the Sun with $\beta_0 \simeq 2^{-11}$ gravitational Λ_{gr} is 1/2 of Earth radius. According to the TGD proposal, which explains the Cambrian explosion in terms of rapid increase of the Earth radius by factor 2, this scale is the radius of Earth before the explosion [L55].

    (b) For Earth with $\beta_0 = 1$, the scale is .45 cm and the size scale of a snowflake, which is a zoomed version of the unit cell of the ice crystal: a fact which still remains a mystery.

    (c) For the galactic black hole with $\beta_0 = 1$, Λ_{gr} is about $1.2 \times 10^7 km = 1.2 \times 10^{-2}$ light seconds and corresponds to a frequency of about 100 Hz, the upper bound of EEG frequencies by the way (which might put bells ringing!). For $\beta_0 = 1$, Λ_{gr} happens to correspond to the radius of the lowest Bohr orbit for Sun Λ_{gr} in the Bohr orbit model for planetary orbit (another bell ringing!) and defines a lower bound for the quantum coherence scale.

    (d) For the Milky Way with a mass of $2 \times 10^{12} M_{Sun}$, Λ_{gr} is about 2×10^4 second and still much shorter than a few years' scale.

2. Where does the wavelength of order of distance between stars emerge? TGD strongly suggests that the tessellations (lattices) associated with hyperbolic 3-spaces define light-cone proper time a= constant surface play a key role in all scales, in particular in biology.

    There could exist a fractal hierarchy of tessellations (`rb.gy/yqd11`) formed by astrophysical objects of various mass scales. Could the stars with average distance of 5 light years form tessellations of this kind analogous to lattices in a condensed matter system. The wavelength for the diffracted gravitational waves in cubic tessellation would have the upper bound 2d, d the lattice constant, which would be now about 5 light years.

3. There is empirical evidence for these tessellations. So called cosmic fingers, discovered by Halton Arp [L114] [K94], correspond to astrophysical objects appearing at single light of sight (first mystery) and having redshift coming as multiples of a basic redshift (second mystery). This could serve as a direct signature of the hyperbolic counterpart for a line of atoms located along a lattice. Redshift is proportional to distance and also to the recession velocity, which would therefore be quantized in the observed manner.

4. What kind of tessellations could be involved? There is an infinite number of tessellations for H^3 but only 4 regular uniform honeycombs. For two of them the unit cell is dodecahedron, for the remaining two it is icosahedron (I) or cube (C). Note that in Euclidian 3-space one has just one regular honeycomb consisting of cubes.

    There are also more general uniform honeycombs involving several cell types. There is a unique "multicellular" honeycomb for which all cells are Platonic solids: for other tessellations all cells are not Platonic solids (`rb.gy/t3c88`) . This is icosatetrahedral (or more officially, tetrahedral-icosatetrahedral) honeycomb for which the cells are tetrahedrons, octahedrons, and icosahedrons. All faces are triangles and I have proposed a universal realization of genetic code in which genetic codons correspond to the triangular faces of icosahedra and tetrahedra.

Gravitational diffraction as an amplification and guiding mechanism

The key prediction is gravitational diffraction in this cosmic lattice.

1. In lattice diffraction, the diffracted amplitude concentrates in specific directions corresponding to the reciprocal lattice. Something analogous should happen for tessellations in hyperbolic 3-space. Already the concentration to beams would mean an amplification effect (note that the lowest order prediction for the intensity of the radiation does not depend on the value of effective Planck constant).

   Furthermore, by quantum coherence the scattered amplitude is proportional to N^2 rather than N, where N is the number of atoms in the lattice, now stars in the tessellation. Could these two amplification effects explain why the observed effect is so much larger than expected? Professionals could easily find whether this idea fails at the quantitative level.

   The TGD view suggests that the dark gravitational radiation propagates along the monopole flux tubes connecting stars.

2. In the ordinary diffraction from a cubic lattice in Euclidean space E^3 , the condition of constructive interference for the two rays scattered from to neighboring points of the cubic lattice states, requires that the difference of lengths for the paths travelled is a multiple of the wavelength of the incoming radiation. This gives the Bragg condition: $sin(\theta) = n\lambda/2d$, where θ is the glance angle defined as the angle of incoming ray with respect to the normal direction of the lattice plane. The condition gives $\lambda < 2d/n$ and implies $\lambda < 2d$ for $n = 1$. Therefore the diffraction occurs only for frequency $\omega \geq n\omega_n$, $\omega_n > c/2d$.

   In the case of gravitational radiation, this would give for a cubic lattice $\lambda < 2d/n$, $d \sim 5$ light years, which conforms with the scale of a few years for the periods. The lower bound for the period T would be about $T_{min} = 10$ years. The condition that the scattered beams connect lattice points, gives an additional quantization condition to the glance angle θ. Most naturally it would correspond to a line connecting lattice points.

Trillions of stars mysteriously disappearing from the sight of James Webb Telescope!

James Webb Telescope is revolutionizing our world view. Now it tells about disappearing stars (see this). Trillions of stars suddenly disappear from the infrared sight of the JWT!

A possible explanation for the mysterious disappearance is that the violent collisions of galaxies lead to re-organization of stars and change their observable characteristics so that they effectively disappear. But there are also stars, which look completely stable and then disappear and these are recently studied systematically.

What says TGD?

1. The TGD based explanation for the vanishing stars relies on the prediction that astrophysical objects of various scales, stars, galaxies, etc.. appear as nodes of networks formed from 3-surfaces, which can be thought of as regions of hyperbolic 3-space (cosmic time=constant), which are connected by monopole flux tube pairs.

2. These 3-surfaces form cosmic lattice-like structures, tessellations as they are called by mathematicians [L130]). The connection by flux tube pair is not stable: reconnection (or rather de-reconnection) can occur and lead to a splitting of the pair to two disjoint U-shaped flux tubes assignable to the two originally connected objects. This general mechanism works also outside astrophysics and in the TGD inspired view of quantum biology biocatalysis and biochemical reactions relies on this mechanism.

3. The radiation from stars arrives along the flux tubes connecting astrophysical objects to a network. Diffraction takes place and the signals propagating along the flux tubes are amplified and travel in specific directions only and only between the objects of the network. This applies also to gravitational radiation and could explain the recently observed gravitational hum as being associated with the network of stars.

4. The explanation for the vanishing stars could be very simple: the splitting of the U-shaped flux tube contact between regions containing trillions of stars and Earth, solar system, or even Milky Way. The violent events in the source region could induce these splittings.

9.6.3 About honeycombs in hyperbolic 3-space

This section, written in 2023, represents some new understanding related to the tessellations of H^3 known as honeycombs.

Some preliminaries

Some preliminaries are needed in order to understand Wikipedia articles related to tessellations in general.

1. Schläfli symbol $\{p, r\}$ (rb.gy/j36tg) tells that the possibly existing Platonic solid $\{p, r\}$ has r p-polygons as faces meeting at each vertex. For instance, icosahedron $\{3, 5\}$ has 5 triangles as faces meeting at each vertex.

   Schläfli symbol generalizes to higher dimensions. The analog of Platonic solid $\{p, r, q\}$ possibly in 4-dimensions and assignable to 3-sphere has q 3-faces which are Platonic solids $\{p, r\}$. This description is purely combinatorial and is recursive. For instance, one can start from 3-D dimensional Platonic solid $\{p, q\}$ with 3-D objects in dimension 4 by replacing p with p, r. One can also project this object to dimension 3. In this manner one obtains a projection of 4-cube (tesseract) $\{4, 3, 3\}$ for which 3 cubes $\{4, 3\}$ meet at each vertex ($2^4 = 16$ of them) and which has 8 3-cubes as faces as a 3-D object.

   In the case of hyperbolic tessellations also strange looking Schläfli symbols $\{(p, q, r, s)\}$ are encountered: icosa-tetrahedral tessellation involving only Platonic solids has symbol $\{(3, 3, 5, 3)\}$. My understanding is that this object corresponds to $\{3, 3, 5, 3\}$ as an analogue of Platonic solid associate with 4-sphere in 5-D Euclidian space and that the fundamental region of this tessellation in H^3 is analogous to a 3-D projection of this object. At a given vertex 3 objects $\{3, 3, 5\}$ meet. For these objects 5 tetrahedrons meet at a given vertex.

2. Vertex figure is a further central notion. It represents a view of the fundamental region of tessellation from a given vertex. The vertices of the figure are connected to this vertex. It does not represent the entire fundamental region. For instance, for a cube (octahedron) it contains only the 3 (4) nearest vertices. For icosa-tetrahedral tessellation the vertex figure is icosidodecahedron (rb.gy/3u4pq). The interpretation of the vertex symbol of the hyperbolic icosa-tetrahedral honeycomb (htrb.gy/3u4pq) is a considerable challenge.

3. One cannot avoid Coxeter groups and Coxeter symbols (rb.gy/48qhg) in the context of tessellations. They code the structure of the symmetry group of say Platonic solid (tessellation of S^2). This symmetry group is generated by reflections with respect to some set of lines, usually going through origin. For regular polygons and Platonic solids is its discrete subgroup of rotation group.

   The Coxeter group is characterized by the number of reflection hyperplanes H_i and the reflections satisfying $r_i^2 = 1$. The products $r_{ij} = r_i r_j$ define cyclic subgroups of order c_{ij} satisfying $r_{ij}^{c_{ij}} = 1$. Coxeter group is characterized by a diagram in which vertices are labelled by i. The orders of the cyclic subgroups satisfy $c_{ij} \geq 3$. For c_{ij} the generators r_i and r_{ij} commute. For $c_{ij} = 2$ the vertices are not connected, for $c_{ij} = 3$ there is a line and for $c_{ij} > 3$ the number c_{ij} is assigned with the line. For instance, hyperbolic tessellations are characterized by 4 reflection hyperplanes.

   For instance, for p-polygon the Coxeter group has 2 generators and the cyclic group has order p. For Platonic solids the Coxter group has 3 generators and the orders of cyclic subgroups are 3, 4, or 5. For icosa-tetrahedral tessellation the order is 4.

The most interesting honeycombs in hyperbolic 3-space

H^3 allows an infinite number of tessellations. There are 9 types of honeycombs. This makes 76 uniform hyperbolic honeycombs involving only a single polyhedron (hrb.gy/rs9h5).

4 of these honeycomes are *regular*, which means that they have identical regular faces (Platonic solids) and the same numbers of faces around vertices. The following list gives the regular uniform honeycombs and their Schläfli symbols $\{p,q,r\}$ telling that each edge has around it regular polygon $\{p,q\}$ for which each vertex is surrounded by q faces with p vertices.

1. H1: 2 regular forms with Schläfli symbol {5,3,4} (dodecahedron) and {4,3,5} (cube).
2. H2: 1 regular form with Schläfli symbol {3,5,3}(icosahedron)
3. H5: 1 regular form with Schläfli symbol {5,3,5} (dodecahedron).

There is a large number of uniform honeycombs involving several cell types. There exists however a "multicellular" honeycomb, which is completely unique in the sense that for it all cells are Platonic solids. This icosa-tetrahedral (or more officially, tetrahedral-icosahedral) honeycomb has tetrahedrons, octahedrons, and icosahedrons as its cells. All faces are triangles. The icosa-tetrahedral honeycomb is of special interest since it might make possible the proposed icosa-tetrahedral realization of the genetic code (rb.gy/h8xx0).

From the Wikipedia article about icosa-tetrahedral honeycomb (htrb.gy/3u4pq) one learns the following.

1. The Schläfli symbol of icosa-tetrahedral honeycomb is $\{(3,3,5,3)\}$. This combinatorial symbol allows several geometric representations. The inner brackets would refer to the interpretation as an analogue of the Platonic solid assignable to a 4-sphere of Euclidian 5-space. At each vertex 3 objects of type $\{3,3,5\}$ would meet. At the vertex of $\{(3,3,5)\}$ in turn 5 tetrahedrons meet.
2. Icosa-tetrahedral honeycomb involves tetrahedron $\{(3,3\}$, octahedron $\{(3,4)\}$, an icosahedron $\{(3,5)\}$ as cells. That there are no other honeycombs involving several Platonic solids and only them as cells makes this particular honeycomb especially interesting. Octahedron with Schläfli symbol $\{3,4\}$ can be also regarded as a rectified tetrahedron havig Schläfli symbol $r\{3,3\}$.
3. The vertex figure of icosa-tetrahedral honeycomb (htrb.gy/3u4pq), representing the vertices a lines connecting them is icosidodecahedron (rb.gy/q5w62), which is a "fusion" of icosahedron and dodecahedron having 30 vertices with 2 pentagons and 2 triangles meeting at each, and 60 identical edges, each separating a triangle from pentagon. From a given vertex VF=60 vertices connected to this vertex by an edge can be seen. In the case of cube, octahedron, and dodecahedron the total number of vertices in the polyhedron is 2(VF+1). It is true also now, one would have 122 vertices in the basic structural unit. The total number of vertices for the disjoint polyhedra is 6+4+12= 22 and since vertices are shared, the number of polyhedra in the basic unit must be rather large.
4. The numbers called "cells by location" could correspond to numbers 30, 20, and 12 for octahedrons, tetrahedrons and icosahedrons respectively inside the fundamental region of the tessellation defining the honeycomb. That the number of icosahedrons is smallest, looks natural. These numbers are quite large. The counts around each vertex are given by (3.3.3.3), (3.3.3), *resp.* (3.3.3.3) for octahedra, tetrahedra, *resp.* icosahedra and tell the numbers of vertices of the faces meeting at a given vertex.
5. What looks intriguing is that the numbers 30, 20, and 12 for octahedrons (O), tetrahedrons (T) and icosahedrons (I) correspond to the numbers of vertices, faces, and edges for I. As if the fundamental region would be obtained by taking an icosahedron and replacing its 30 vertices with O, its 20 faces with T and its 12 edges with I, that is by using the rules *vertex* $\rightarrow$ *octahedron*; *edge* $\rightarrow$ *I*, *face* $\rightarrow$ *T*. These 3-D objects would be fitted together along their triangular faces.

Do the statements about the geometry and homology of I translate to the statements about the geometry and homology of the fundamental region? This would mean the following replacements:

(a) ”2 faces meet at edge” $\rightarrow$ ”2 T:s share face with an I”.

(b) ”5 faces meet at vertex” $\rightarrow$ ”5 T:s share face with an O”.

(c) ”Edge has 2 vertices as ends” $\rightarrow$ ”I shares a face with 2 different O:s”.

(d) ”Face has 3 vertices $\rightarrow$ ”T shares a face with 3 different O:s”.

(e) ”Face has three edges” $\rightarrow$ ”T has a common face with 3 I:s”.

An attempt to understand the hyperbolic honeycombs

The following general observations might help to gain some understanding of the honeycombs.

The tessellations of E^3 and H^3 are in many respects analogous to Platonic solids as 2-D objects. The non-compactness implies that there is an infinite number of cells for tessellations. It is important to notice that the radial coordinate r for H^3 corresponds very closely to the hyperbolic angle and its values are quantized for the vertices of tessellation just like the values of spherical coordinates are quantized for Platonic solids. The tessellations for E^3 are scale covariant. For a fixed radius of H^3 characterized by Lorentz invariance cosmic time this is not the case. One can however scale the value of a. What distinguishes between regular tessellations in E^3 and H^3 is that the metric of H^3 is non-flat and has negative curvature. H^3 is homogeneous space meaning that all points are metrically equivalent (this is the counterpart of cosmological principle in cosmology). Since both spaces have rotations as symmetries, this does not affect basic Platonic solids as 2-D structures assignable with 2-sphere if the edges are identified as geodesic lines of S^2. Quite generally, isometries characterize the tessellations, whose fundamental region corresponds to coset space of H^3/Γ by a discrete group of the Lorentz group acting as isometries of H^3. The modifications induced by the replacement $E^3 \rightarrow H^3$ relate to the 3-D aspects of the tessellation. This is because the metric is non-flat in the radial direction. The negative curvature implies that the geodesic lines diverge. One can use a counterpart of the standard spherical coordinates and in these coordinates the solid angles assignable to the vertices of Platonic solid are smaller than in E^3. Also the hyperbolic planes H^2 emerging from edges of the tessellation of H^3 diverge in normal direction the angles involved are smaller.

It is useful to start from the description of the Platonic solids. They are characterized combinatorially by integers and geometrically by various kinds of angles. Denote by p the number of vertices/edges of the face and by q the number of faces meeting at vertex.

1. Important constraints come from the topology and combinatorics. Basic equations for the numbers V ,E, and F for the number of vertices, edges and faces are purely topological equations $VE + F = 2$, and the equation $pF = 2E = qV$. Manipulation of these equations gives $1/r + 1/p = 1/2 + 1/E$ implying $1/r + 1/p > 1/2$. Since p and q must be at least 3, the only possibilities for $\{p, q\}$ are $\{3, 3\}$, $\{4, 3\}$, $\{3, 4\}$, $\{5, 3\}$, and $\{3, 5\}$.

2. The angular positions of the vertices at S^2 are basic angle variables. In H^3 hyperbolic angle assignable to the radial coordinate is an additional variable of this kind analogous to the position of the unit cell in the E^3 tessellation. The cosmological interpretation is in terms of redshift.

3. There is the Euclidian angle ϕ associated with the vertex of the face given by π/p. Here there is no difference between E^3 and H^3.

4. The angle deficit δ associated with the faces meeting at a given vertex due to the fact that the faces are not in plane in which case the total angle would be 2π. δ is largest for tetrahedron with 3 faces meeting at vertex and therefore with the sharpest vertex and smallest for icosahedron with 5 triangles meeting at vertex. This notion is essentially 3-dimensional, being defined using radial geodesics, so that the δ is not the same in H^3. In H^3 δ is expected to be larger than in E^3.

5. There is also the dihedral angle θ associated with the faces as planes of E^3 meeting at the edges of the Platonic solid. θ is smallest for a tetrahedron with 4 edges and largest for a dodecahedron with 20 edges so that the dodecahedron is not far from the flat plane and this angle is not far from π. The H^3 counterpart of θ is associated faces identified as hyperbolic planes H^2 and is therefore different.

6. There is also the vertex solid angle Ω associated with each vertex of the Platonic solid $\{p, q\}$ given by $\Omega = q\theta - (q-2)\pi$. For tessellations in E^3 the sum of these angles is 4π. In H^3 its Euclidian counterpart is larger than 4π.

7. The face solid angle is the solid angle associated with the face when seen from the center of the Platonic solid. The sum of the face solid angles is 4π. For Platonic solid with n vertices, one has $\Omega = 4\pi/n$. The divergence of the geodesics of H^3 implies that this angle is smaller in H^3: there is more volume in H^3 than in E^3.

E^3 allows only single regular tessellation having cube as a unit cell. H^3 allows cubic and icosahedral tessellations plus two tessellations having a dodecahedron as a unit cell. Why does E^3 not allow icosahedral and dodecahedral tessellations and how the curvature of H^3 makes them possible? Why is the purely Platonic tetra-icosahedral tessellation possible in H^3?

The first guess is that these tessellations are almost but not quite possible in E^3 by looking at the Euclidian constraints on various angles. In particular, the sum of dihedral angles θ between faces should be 2π in E^3, the sum of the vertex solid angles Ω at the vertex should be 4π. Note that the scaling of the radial coordinate r decreases the dihedral angles θ and solid angles Ω. This flexibility is expected to make possible so many tessellations and honeycombs in H^3. The larger the deviation of the almost allowed tessellation, the larger the size of the fundamental region for fixed a.

Consider now the constraints on the basic parameters of the Platonic solids (`rb.gy/1cuav`) in E^3 while keeping their H^3 counterparts in mind.

1. The values of didedral angle for tetrahedron, cube, octahedron, dodecahedron, and icosahedron are

$$[\theta(T), \theta(C), \theta(O), \theta(D), \theta(I)] \approx [70.3^\circ,\ 90^\circ, 109.47^\circ,\ 116.57^\circ, 138.19^\circ]\ .$$

Note that $r = 5$ tetrahedra meeting at a single edge in E^3 would almost fill the space around the edge. In E^3 $r = 4$ cubes can meet at the edge. In H^3 r should be larger. This is indeed the case for the cubic honeycomb $\{4, 3, 5\}$ having $r = 5$. For $r = 3$ icosahedrons the sum dihedral angles exceeds 2π which conforms with the that $\{3, 5, 3\}$ defines an icosahedral tessellation in H^3. For the $r = 4$ dodecahedra meeting at the edge the total dihedral angle is larger than 360°: $r = 4$ is therefore a natural candidate in H^3. There are indeed regular dodecahedral honeycombs with Schläfli symbol $\{5, 3, r\}$, $r = 4$ and $r = 5$. Therefore it seems that the intuitive picture is correct.

2. The values of the vertex solid angle Ω for cube, dodecahedron, and icosahedron are given by the formula $\Omega = q\theta - (q-2)\pi$ giving

$$[\Omega(C), \Omega(D), \Omega(I)] \approx [1.57080, 2.96174, 2.63455].$$

The sum of these angles should be 4π for a tessellation in E^3. In E^3 This is true only for 8 cubes per vertex ($\Omega = \pi/2$) so that the cubic honeycomb is the only Platonic honeycomb in E^3. The minimal number of cubes per vertex is 9 in H^3. It is convenient to write the values of the vertex solid angles for D and I as

$$[\Omega(D), \Omega(I)] = [0.108174,\ 0.209651] \times 4\pi \ .$$

The number of D:s *resp.* I:s must be at least 10 *resp.* 5 for dodecahedral *resp.* icosahedral honeycombs in H^3.

3. The basic geometric scales of the Platonic solids are circumradius R, surface area A and volume V. The circumradius is given by $R = (a/2)\tan(\pi/q)\tan(\theta/2)$, where a denotes the edge length. The surface area A of the Platonic solid $\{p,q\}$ equals the area of face multiplied by the number F of faces: $A = (a/2)^2 Fpcot(\pi/p)$. The volume V of the Platonic time is F times the volume of the pyramid whose height is the length a of the face: that is $V = FaA/3$.

   Choosing $a/2$ as the length unit, the circumradii R , total face areas A an the volumes V of the Platonic solids are given by

$$[R(T), R(C), R(O), R(D), R(I)] = [\sqrt{3}/2, \sqrt{3}, \sqrt{2}, \sqrt{3}\phi, \sqrt{3-\phi}\phi] \ ,$$

$$[A(T), A(C), A(O), A(D), A(I)] = [4\sqrt{3}, 24, 2\sqrt{3}, 12\sqrt{25+10\sqrt{5}}, 20\sqrt{3}] \ ,$$

   and

$$[V(T), V(C), V(O), V(D), V(I)] \approx [\sqrt{8}/3, 8, \ \sqrt{128}/3, \ 20\phi^3/(3-\phi), 20\phi^2/3] \\ \approx [.942809, 8, 3.771236, 61.304952, 17.453560] \ .$$

What can one say about icosa-tetrahedral tessellation?

1. Consider first the dihedral angles θ. The values of dihedral angles associated T, O, and I in H^3 are reduced from that in E^3 so that their sum in E^2 scene must be larger than 2π. Therefore at least one of these cells must appear twice in H^3. It could be T but also O can be considered. For $2T+O+I$ and $T+2O+I$ the sum would be $388.26°$ *resp.* $427.43°$ in E^3. $2T+O+I$ *resp.* $T+2O+I$could correspond to 4 cells ordered cyclically as ITOT resp. IOTO.

2. The values of the vertex solid angle Ω for tetrahedron, octahedron, and icosahedron are given by $[\Omega(T), \Omega(O), \Omega(I)] = [0.043870, 0.108174, 0.209651]4\pi$ If the numbers of T, O and I are $[n(T), n(O), n(I)]$, one must have $[n(T)\Omega(T), +n(O)\Omega(O) + n(I)\Omega(I) > 4\pi$ in H^3.

   If the number of the cells for the fundamental domain are really $[N(T), N(O), N(I)] = [30, 20, 12]$, the first guess is that $[n(T), n(O), n(I)] \propto [N(T), N(O), N(I)$ is approximately true. For $[n(T), n(O), n(I)] = [2, 3, 1]n(I)$, one obtains $\Omega = n(T)\Omega(T) + n(O)\Omega(O) + n(I)\Omega(I) = n(I) \times .629 \times 4\pi$. This would suggest $n(I) = 2$ giving $[n(T), n(O), n(I)] = [4, 6, 2]$

9.6.4 Trillions of stars mysteriously disappearing from the sight of James Webb Telescope!

James Webb Telescope is revolutionizing our world view. Now it tells about disappearing stars (see this). Trillions of stars suddenly disappear from the infrared sight of the JWT! This gives support for the vision that astrophysical objects form networks with communications based on radition propagating along the flux tube connections.

A possible standard physics explanation for the mysterious disappearance is that the violent collisions of galaxies lead to re-organization of stars and change their observable characteristics so that they effectively disappear. But there are also stars, which look completely stable and then disappear and these are recently studied systematically.

It is rather easy to guess what the TGD based explanation could be.

1. The TGD based explanation for the vanishing stars relies on the prediction that astrophysical objects of various scales, stars, galaxies, etc.. appear as nodes of networks formed from 3-surfaces, which can be thought of as regions of hyperbolic 3-space (cosmic time=constant), which are connected by monopole flux tube pairs.

2. These 3-surfaces form cosmic lattice-like structures, tessellations as they are called by mathematicians [L130]). The connection by flux tube pair is not stable: reconnection (or rather de-reconnection) can occur and lead to a splitting of the pair to two disjoint U-shaped flux tubes assignable to the two originally connected objects. This general mechanism works also outside astrophysics and in the TGD inspired view of quantum biology biocatalysis and biochemical reactions relies on this mechanism.

3. The radiation from stars arrives along the flux tubes connecting astrophysical objects to a network. Diffraction takes place and the signals propagating along the flux tubes are amplified and travel in specific directions only and only between the objects of the network. This applies also to gravitational radiation and could explain the recently observed gravitational hum as being associated with the network of stars.

4. The explanation for the vanishing stars could be very simple: the splitting of the U-shaped flux tube contact between regions containing trillions of stars and Earth, solar system, or even Milky Way. The violent events in the source region could induce these splittings.

9.7 Piece-Wise Accelerated Cosmic Expansion As Basic Prediction Of Quantum Cosmology

Quantum cosmology predicts that astrophysical objects do not follow cosmic expansion except in jerk-wise quantum leaps increasing the value of the gravitational Planck constant. This assumption provides explanation for the apparent cosmological constant. Also planets are predicted to expand in this manner. This provides a new version of Expanding Earth theory originally postulated to explain the intriguing findings suggesting that continents have once formed a connected continent covering the entire surface of Earth but with radius which was one half of the recent one.

9.7.1 Experimental Evidence For Accelerated Expansion Is Consistent With TGD Based Model

There are several pieces of evidence for accelerated expansion, which need not mean cosmological constant, although this is the interpretation adopted in [E45, E15]. It is interesting to see whether this evidence is indeed consistent with TGD based interpretation.

The four pieces of evidence for accelerated expansion

1. Supernovas of type Ia

Supernovas of type Ia define standard candles since their luminosity varies in an oscillatory manner and the period is proportional to the luminosity. The period gives luminosity and from this the distance can be deduced by using Hubble's law: $d = cz/H_0$, H_0 Hubble's constant. The observation was that the farther the supernova was the more dimmer it was as it should have been. In other words, Hubble's constant increased with distance and the cosmic expansion was accelerating rather than decelerating as predicted by the standard matter dominated and radiation dominated cosmologies.

2. Mass density is critical and 3-space is flat

It is known that the contribution of ordinary and dark matter explaining the constant velocity of distance stars rotating around galaxy is about 25 per cent from the critical density. Could it be that total mass density is critical?

From the anisotropy of cosmic microwave background one can deduce that this is the case. What criticality means geometrically is that 3-space defined as surface with constant value of cosmic time is flat. This reflects in the spectrum of microwave radiation. The spots representing small anisotropies in the microwave background temperature is 1 degree and this correspond to flat 3-space. If one had dark matter instead of dark energy the size of spot would be.5 degrees!

Thus in a cosmology based on general relativity cosmological constant remains the only viable option. The situation is different in TGD based quantum cosmology based on sub-manifold gravity and hierarchy of gravitational Planck constants.

3. The energy density of vacuum is constant in the size scale of big voids

It was observed that the density of dark energy would be constant in the scale of 10^8 light years. This length scale corresponds to the size of big voids containing galaxies at their boundaries.

4. Integrated Sachs-Wolf effect

Also so called integrated Integrated Sachs-Wolf effect supports accelerated expansion. Very slow variations of mass density are considered. These correspond to gravitational potentials. Cosmic expansion tends to flatten them but mass accretion to form structures compensates this effect so that gravitational potentials are unaffected and there is no effect of CMB. Situation changes if dark matter is replaced with dark energy the accelerated expansion flattening the gravitational potentials wins the tendency of mass accretion to make them deeper. Hence if photon passes by an over-dense region, it receives a little energy. Similarly, photon loses energy when passign by an under-dense region. This effect has been observed.

Comparison with TGD

The minimum TGD based explanation for accelerated expansion involves only the fact that the embeddings of critical cosmologies correspond to accelerated expansion. A more detailed model allows to understand why the critical cosmology appears during some periods.

1. Accelerated expansion in classical TGD

The first observation is that critical cosmologies (flat 3-space) imbeddable to 8-D embedding space H correspond to negative pressure cosmologies and thus to accelerating expansion. The negativity of the counterpart of pressure in Einstein tensor is due to the fact that space-time sheet is forced to be a 4-D surface in 8-D embedding space. This condition is analogous to a force forcing a particle at the surface of 2-sphere and gives rise to what could be called constraint force. Gravitation in TGD is sub-manifold gravitation whereas in GRT it is manifold gravitation. This would be minimum interpretation involving no assumptions about what mechanism gives rise to the critical periods.

2. Accelerated expansion and hierarchy of Planck constants

One can go one step further and introduce the hierarchy of Planck constants. The basic difference between TGD and GRT based cosmologies is that TGD cosmology is quantum cosmology. Smooth cosmic expansion is replaced by an expansion occurring in discrete jerks corresponding to the increase of gravitational Planck constant. At space-time level this means the replacement of 8-D embedding space H with a book like structure containing almost-copies of H with various values of Planck constant as pages glued together along critical manifold through which space-time sheet can leak between sectors with different values of $\hbar$. This process is the geometric correlate for the phase transition changing the value of Planck constant.

During these phase transition periods critical cosmology applies and predicts automatically accelerated expansion. Neither genuine negative pressure due to "quintessence" nor cosmological constant is needed. Note that quantum criticality replaces inflationary cosmology and predicts a unique cosmology apart from single parameter. Criticality also explains the fluctuations in microwave temperature as long range fluctuations characterizing criticality.

3. Accelerated expansion and flatness of 3-cosmology

Observations 1) and 2) about super-novae and critical cosmology (flat 3-space) are consistent with this cosmology. In TGD dark energy must be replaced with dark matter because the mass density is critical during the phase transition. This does not lead to wrong sized spots since it is the increase of Planck constant which induces the accelerated expansion understandable also as a constraint force due to embedding to H.

4. The size of large voids is the characteristic scale

The TGD based model in its simplest form model assigns the critical periods of expansion to large voids of size 10^8 ly. Also larger and smaller regions can express similar periods and dark space-time sheets are expected to obey same universal "cosmology" apart from a parameter characterizing the duration of the phase transition. Observation 3) that just this length scale defines the scale below which dark energy density is constant is consistent with TGD based model.

The basic prediction is jerk-wise cosmic expansion with jerks analogous to quantum transitions between states of atom increasing the size of atom. The discovery of large voids with size of order 10^8 ly but age much longer than the age of galactic large voids conforms with this prediction. One the other hand, it is known that the size of galactic clusters has not remained constant in very long time scale so that jerk-wise expansion indeed seems to occur.

5. Do cosmic strings with negative gravitational mass cause the phase transition inducing accelerated expansion

Quantum classical correspondence is the basic principle of quantum TGD and suggest that the effective antigravity manifested by accelerated expansion might have some kind of concrete space-time correlate. A possible correlate is super heavy cosmic string like objects at the center of large voids which have negative gravitational mass under very general assumptions. The repulsive gravitational force created by these objects would drive galaxies to the boundaries of large voids. At some state the pressure of galaxies would become too strong and induce a quantum phase transition forcing the increase of gravitational Planck constant and expansion of the void taking place much faster than the outward drift of the galaxies. This process would repeat itself. In the average sense the cosmic expansion would not be accelerating.

Does TGD allow description of accelerated expansion in terms of cosmological constant?

The introduction of cosmological constant seems to be the only manner to explain accelerated expansion and related effects in the framework of General Relativity. TGD allows different explanation of these effects. It is however interesting to look whether TGD allows a description based on finite cosmological constant as a small deformation of De Sitter space represented as a vacuum extremal. Before this a clarifying comment about the term "vacuum energy".

The term vacuum energy density is bad use of language since De Sitter space [B4] is a solution of field equations with cosmological constant at the limit of vanishing energy momentum tensor carries *vacuum curvature* rather than vacuum energy. Thus theories with non-vanishing cosmological constant represent a family of gravitational theories for which vacuum solution is not flat so that Einstein's basic identification matter = curvature is given up. No wonder, Einstein regarded the introduction of cosmological constant as the biggest blunder of his life.

De Sitter space is representable as a hyperboloid $a^2 - u^2 = -R^2$, where one has $a^2 = t^2 - r^2$ and $r^2 = x^2 + y^2 + z^2$. The symmetries of de Sitter space are maximal but Poincare group is replaced with Lorentz group of 5-D Minkowski space and translations are not symmetries. The value of cosmological constant is $\Lambda = 3/R^2$. The presence of non-vanishing dimensional constant is from the point of view of conformal invariance a feature raising strong suspicions about the correctness of the underlying physics.

1. Embeddings of De Sitter space

De Sitter space is possible as a vacuum extremal in TGD framework. There exists infinite number of embeddings as a vacuum extremal into $M^4 \times CP_2$. Take any infinitely long curve X in CP_2 not intersecting itself (one might argue that infinitely long curve is somewhat pathological) and introduce a coordinate u for it such that its induced metric is $ds^2 = du^2$. De Sitter space allows the standard embedding to $M^4 \times X$ as a vacuum extremal. The embedding can be written as $u = \pm[a^2 + R^2]^{1/2}$ so that one has $r^2 < t^2 + R^2$. One example is curve in S^2 which spirals around chosen point infinitely many times so that at the vicinity of point it almost fills 2-dimensional region of S^2. One can also combine spirals associated with two distinct points so that u coordinate spans range $[-\infty, \infty]$.

The curve in question can also fill 2-D or higher-dimensional sub-manifold of CP_2 densely. An example is torus densely filled by the curve $\phi = \alpha\psi$ where α is irrational number. Note that even a slightest local deformation of this object induces an infinite number of self-intersections. Space-time sheet fills densely 5-D set in this case. One can ask whether this kind of objects might be analogs of $D > 4$ branes in TGD framework. As a matter fact, CP_2 projections of 1-D vacuum extremals could give rise to both the analogs of branes and strings connecting them if space-time surface contains both regular and "brany" pieces. Perhaps this might provide a new (possibly) approach to the understanding of branes in M-theory context.

It might be that the 2-D Lagrangian manifolds representing CP_2 projection of the most general vacuum extremal, can fill densely $D > 2$-dimensional sub-manifold of CP_2. One can imagine construction of very complex Lagrange manifolds by gluing together pieces of 2-D Lagrangian sub-manifolds by arbitrary 1-D curves. One could also rotate 2-Lagrangian manifold along a 2-torus - just like one rotates point along 2-torus in the above example - to get a dense filling of 4-D volume of CP_2.

The M^4 projection of the embedding corresponds to the region $a^2 > -R^2$ containing future and past light-cones. If u varies only in range $[0, u_0]$ only hyperboloids with a^2 in the range $[-R^2, -R^2 + u_0^2]$ are present in the foliation. In zero energy ontology the space-like boundaries of this piece of De Sitter space, which must have $u_0^2 > R^2$, would be carriers of positive and negative energy states. The boundary corresponding to $u_0 = 0$ is space-like and analogous to the orbit of partonic 2-surface. For $u_0^2 < R^2$ there are no space-like boundaries and the interpretation as a zero energy state is not possible. Note that the restriction $u_0^2 \geq R^2$ plus the choice of the branch of the embedding corresponding to future or past directed light-cone is natural in TGD framework.

2. Could negative cosmological constant make sense in TGD framework?

The questionable feature of slightly deformed De Sitter metric as a model for the accelerated expansion is that the value of a would be same order of magnitude as the recent age of the Universe. Why should just this value of cosmic time be so special? In TGD framework one could of course consider space-time sheets having De Sitter cosmology characterized by a varying value of R. Also the replacement of one spatial coordinate with CP_2 coordinate implies very strong breaking of translational invariance. Hence the explanation relying on quantization of gravitational Planck constant looks more attractive to me.

It is however always useful to make an exercise in challenging the cherished beliefs.

1. Could the complete failure of the perturbation theory around canonically imbedded M^4 make De Sitter cosmology natural vacuum extremal. De Sitter space appears also in the models of inflation and long range correlations might have something to do with the intersections between distant points of 3-space resulting from very small local deformations. Could both the slightly deformed De Sitter space and quantum critical cosmology represent cosmological epochs in TGD Universe?

2. Gravitational energy defined as a non-conserved Noether charge in terms of Einstein tensor TGD is infinite for de-Sitter cosmology (Λ as characterizer of vacuum energy). If one includes to the gravitational momentum also metric tensor gravitational four-momentum density vanishes (Λ as characterizer of vacuum curvature). TGD does not involve Einstein-Hilbert action as fundamental action and gravitational energy momentum tensor should be dictated by finiteness condition so that negative cosmological constant might make sense in TGD.

3. The embedding of De Sitter cosmology involves the choice of a preferred light-cone as does also quantization of Planck constant. Quantization of Planck constant involves the replacement of the light-cones of $M^4 \times CP_2$ by its finite coverings and orbifolds glued to together along quantum critical sub-manifold. Finite pieces of De Sitter space are obtained for rational values of α and there is a covering of light-cone by CP_2 points. How can I be sure that there does not exist a deeper connection between the descriptions based on cosmological constant and on phase transitions changing the value Planck constant?

Note that Anti de Sitter space [B1] having similar embedding to 5-D Minkowski space with two time like dimensions does not possess this kind of embedding to H. Very probably no embeddings exist so that TGD would allow only embeddings of cosmologies with correct sign of Λ whereas M-theory in its basic form predicts a wrong sign for it. Note also that Anti de Sitter space appearing in AdS-CFT dualities contains closed time-like loops and is therefore also physically questionable.

The mystery of mini galaxies and the hierarchy of Planck constants

New Scientist [E210] informs that a team led by Pieter van Dokkum at Yale University measured the light of distant galaxies from around 3 billion years after the big bang. They had the same mass as the Milky Way, but were 10 times smaller (The Astrophysical Journal, vol. 677, p. L5). Peering at younger regions of the sky shows that galaxies this size are no longer around, but it's not clear what happened to them. "This is a very puzzling result" says Simon White of the Max Planck Institute for Astrophysics in Garching, Germany. "Galaxies cannot disappear." Team member Marijn Franx of Leiden Observatory, the Netherlands, suspects they have since merged with extremely massive galaxies. The disappearance of the mini galaxies would be due to this mechanism. From the assumption that this mechanism gives rise to the same outcome as smooth expansion within factor of two at given moment, one could estimate their recent size. If the galaxies are assumed to have roughly the size of Milky Way now, an upwards scaling would be roughly by a factor 8. This would mean that recent age of Universe would be about 24 billion years.

9.7.2 Quantum Version Of Expanding Earth Theory

TGD predicts that cosmic expansion at the level of individual astrophysical systems does not take place continuously as in classical gravitation but through discrete quantum phase transitions increasing gravitational Planck constant and thus various quantum length and time scales. The reason would be that stationary quantum states for dark matter in astrophysical length scales cannot expand. One would have the analog of atomic physics in cosmic scales. Increases of $\hbar$ by a power of two are favored in these transitions but also other scalings are possible.

This has quite far reaching implications.

1. These periods have a highly unique description in terms of a critical cosmology for the expanding space-time sheet. The expansion is accelerating. The accelerating cosmic expansion can be assigned to this kind of phase transition in some length scale (TGD Universe is fractal). There is no need to introduce cosmological constant and dark energy would be actually dark matter.

2. The recently observed void which has same size of about 10^8 light years as large voids having galaxies near their boundaries but having an age which is much higher than that of the large voids, would represent one example of jerk-wise expansion.

3. This picture applies also to solar system and planets might be perhaps seen as having once been parts of a more or less connected system, the primordial Sun. The Bohr orbits for inner and outer planets correspond to gravitational Planck constant which is 5 times larger for outer planets. This suggests that the space-time sheet of outer planets has suffered a phase transition increasing the size scale by a factor of 5. Earth can be regarded either as n=1 orbit for Planck constant associated with outer planets or n= 5 orbit for inner planetary system. This might have something to do with the very special position of Earth in planetary system. One could even consider the possibility that both orbits are present as dark matter structures. The phase transition would also explain why n=1 and n=2 Bohr orbits are absent and one only n=3, 4, and 5 are present.

4. Also planets should have experienced this kind of phase transitions increasing the radius: the increase by a factor two would be the simplest situation.

The obvious question - that I did not ask - is whether this kind of phase transition might have occurred for Earth and led from a completely granite covered Earth - Pangeia without seas - to the recent Earth. Neither it did not occur to me to check whether there is any support for a rapid expansion of Earth during some period of its history.

Situation changed when my son visited me last Saturday and told me about a Youtube video [F44] by Neal Adams, an American comic book and commercial artist who has also produced animations for geologists. We looked the amazing video a couple of times and I looked it again yesterday. The video is very impressive artwork but in the lack of references skeptic probably cannot avoid the feeling that Neal Adams might use his highly developed animation skills to cheat you. I found also a polemic article [F1] of Adams but again the references were lacking. Perhaps the reason of polemic tone was that the concrete animation models make the expanding Earth hypothesis very convincing but geologists refuse to consider seriously arguments by a layman without a formal academic background.

The claims of Adams

The basic claims of Adams were following.

1. The radius of Earth has increased during last 185 million years (dinosaurs [I2] appeared for about 230 million years ago) by about factor 2. If this is assumed all continents have formed at that time a single super-continent, Pangeia, filling the entire Earth surface rather than only 1/4 of it since the total area would have grown by a factor of 4. The basic argument was that it is very difficult to imagine Earth with 1/4 of surface containing granite and 3/4 covered by basalt. If the initial situation was covering by mere granite -as would look natural- it is very difficult for a believer in thermodynamics to imagine how the granite would have gathered to a single connected continent.

2. Adams claims that Earth has grown by keeping its density constant, rather than expanded, so that the mass of Earth has grown linearly with radius. Gravitational acceleration would have thus doubled and could provide a partial explanation for the disappearance of dinosaurs: it is difficult to cope in evolving environment when you get slower all the time.

3. Most of the sea floor is very young and the areas covered by the youngest basalt are the largest ones. This Adams interprets this by saying that the expansion of Earth is accelerating. The alternative interpretation is that the flow rate of the magma slows down as it recedes from the ridge where it erupts. The upper bound of 185 million years for the age of sea floor requires that the expansion period - if it is already over - lasted about 185 million years after which the flow increasing the area of the sea floor transformed to a convective flow with subduction so that the area is not increasing anymore.

4. The fact that the continents fit together - not only at the Atlantic side - but also at the Pacific side gives strong support for the idea that the entire planet was once covered by the super-continent. After the emergence of subduction theory this evidence as been dismissed.

5. I am not sure whether Adams mentions the following objections [F5]. Subduction only occurs on the other side of the subduction zone so that the other side should show evidence of being much older in the case that oceanic subduction zones are in question. This is definitely not the case. This is explained in plate tectonics as a change of the subduction direction. My explanation would be that by the symmetry of the situation both oceanic plates bend down so that this would represent new type of boundary not assumed in the tectonic plate theory.

6. As a master visualizer Adams notices that Africa and South-America do not actually fit together in absence of expansion unless one assumes that these continents have suffered a deformation. Continents are not easily deformable stuff. The assumption of expansion implies a perfect fit of *all* continents without deformation.

Knowing that the devil is in the details, I must admit that these arguments look rather convincing to me and what I learned from Wikipedia articles supports this picture.

The critic of Adams of the subduction mechanism

The prevailing tectonic plate theory [F26] has been compared to the Copernican revolution in geology. The theory explains the young age of the seafloor in terms of the decomposition of the litosphere to tectonic plates and the convective flow of magma to which oceanic tectonic plates participate. The magma emerges from the crests of the mid ocean ridges representing a boundary of two plates and leads to the expansion of sea floor. The variations of the polarity of Earth's magnetic field coded in sea floor provide a strong support for the hypothesis that magma emerges from the crests.

The flow back to would take place at so called oceanic trenches [F19] near continents which represent the deepest parts of ocean. This process is known as subduction. In subduction oceanic tectonic plate bends and penetrates below the continental tectonic plate, the material in the oceanic plate gets denser and sinks into the magma. In this manner the oceanic tectonic plate suffers a metamorphosis returning back to the magma: everything which comes from Earth's interior returns back. Subduction mechanism explains elegantly formation of mountains [F20] (orogeny), earth quake zones, and associated zones of volcanic activity [F35] .

Adams is very polemic about the notion of subduction, in particular about the assumption that it generates steady convective cycle. The basic objections of Adams against subduction are following.

1. There are not enough subduction zones to allow a steady situation. According to Adams, the situation resembles that for a flow in a tube which becomes narrower. In a steady situation the flow should accelerate as it approaches subduction zones rather than slow down. Subduction zones should be surrounded by large areas of sea floor with constant age. Just the opposite is suggested by the fact that the youngest portion of sea-floor near the ridges is largest. The presence of zones at which both ocean plates bend down could improve the situation. Also jamming of the flow could occur so that the thickness of oceanic plate increases with the distance from the eruption ridge. Jamming could increase also the density of the oceanic plate and thus the effectiveness of subduction.

2. There is no clear evidence that subduction has occurred at other planets. The usual defense is that the presence of sea is essential for the subduction mechanism.

3. One can also wonder what is the mechanism that led to the formation of single super continent Pangeia covering 1/4 of Earth's surface. How probable the gathering of all separate continents to form single cluster is? The later events would suggest that just the opposite should have occurred from the beginning.

Expanding Earth theories are not new

After I had decided to check the claims of Adams, the first thing that I learned is that Expanding Earth theory [F5], whose existence Adams actually mentions, is by no means new. There are actually many of them.

The general reason why these theories were rejected by the main stream community was the absence of a convincing physical mechanism of expansion or of growth in which the density of Earth remains constant.

1. 1888 Yarkovski postulated some sort of aether absorbed by Earth and transforming to chemical elements (TGD version of aether could be dark matter). 1909 Mantovani [F43] postulated thermal expansion but no growth of the Earth's mass.

2. Paul Dirac's idea about changing Planck constant led Pascual Jordan in 1964 to a modification of general relativity predicting slow expansion of planets. The recent measurement of the gravitational constant imply that the upper bound for the relative change of gravitational constant is 10 time too small to produce large enough rate of expansion. Also many other theories have been proposed but they are in general conflict with modern physics.

3. The most modern version of Expanding Earth theory is by Australian geologist Samuel W. Carey. He calculated that in Cambrian period (about 500 million years ago) all continents were stuck together and covered the entire Earth. Deep seas began to evolve then.

Summary of TGD based theory of Expanding Earth

TGD based model differs from the tectonic plate model but allows subduction which cannot imply considerable back-flow of magma. Let us sum up the basic assumptions and implications.

1. The expansion is or was due to a quantum phase transition increasing the value of gravitational Planck constant and forced by the cosmic expansion in the average sense.

2. Tectonic plates do not participate to the expansion and therefore new plate must be formed and the flow of magma from the crests of mid ocean ridges is needed. The decomposition of a single plate covering the entire planet to plates to create the mid ocean ridges is necessary for the generation of new tectonic plate. The decomposition into tectonic plates is thus prediction rather than assumption.

3. The expansion forced the decomposition of Pangeia super-continent covering entire Earth for about 530 million years ago to split into tectonic plates which began to recede as new non-expanding tectonic plate was generated at the ridges creating expanding sea floor. The initiation of the phase transition generated formation of deep seas.

4. The eruption of plasma from the crests of ocean ridges generated oceanic tectonic plates which did not participate to the expansion by density reduction but by growing in size. This led to a reduction of density in the interior of the Earth roughly by a factor 1/8. From the upper bound for the age of the seafloor one can conclude that the period lasted for about 185 million years after which it transformed to convective flow in which the material returned back to the Earth interior. Subduction at continent-ocean floor boundaries and downwards double bending of tectonic plates at the boundaries between two ocean floors were the mechanisms. Thus tectonic plate theory would be more or less the correct description for the recent situation.

5. One can consider the possibility that the subducted tectonic plate does not transform to magma but is fused to the tectonic layer below continent so that it grows to an iceberg like structure. This need not lead to a loss of the successful predictions of plate tectonics explaining the generation of mountains, earthquake zones, zones of volcanic activity, etc...

6. From the video of Adams it becomes clear that the tectonic flow is East-West asymmetric in the sense that the western side is more irregular at large distances from the ocean ridge at the western side. If the magma rotates with slightly lower velocity than the surface of Earth (like liquid in a rotating vessel), the erupting magma would rotate slightly slower than the tectonic plate and asymmetry would be generated.

7. If the planet has not experienced a phase transition increasing the value of Planck constant, there is no need for the decomposition to tectonic plates and one can understand why there is no clear evidence for tectonic plates and subduction in other planets. The conductive flow of magma could occur below this plate and remain invisible.

The biological implications might provide a possibility to test the hypothesis.

1. Great steps of progress in biological evolution are associated with catastrophic geological events generating new evolutionary pressures forcing new solutions to cope in the new situation. Cambrian explosion indeed occurred about 530 years ago (the book "Wonderful Life" of Stephen Gould [I22] explains this revolution in detail) and led to the emergence of multicellular creatures, and generated huge number of new life forms living in seas. Later most of them suffered extinction: large number of phylae and groups emerged which are not present nowadays.

   Thus Cambrian explosion is completely exceptional as compared to all other dramatic events in the evolution in the sense that it created something totally new rather than only making more complex something which already existed. Gould also emphasizes the failure to identify any great change in the environment as a fundamental puzzle of Cambrian explosion. Cambrian explosion is also regarded in many quantum theories of consciousness (including TGD) as a revolution in the evolution of consciousness: for instance, micro-tubuli emerged at this time. The periods of expansion might be necessary for the emergence of multicellular life forms on planets and the fact that they unavoidably occur sooner or later suggests that also life develops unavoidably.

2. TGD predicts a decrease of the surface gravity by a factor 1/4 during this period. The reduction of the surface gravity would have naturally led to the emergence of dinosaurs 230 million years ago as a response coming 45 million years after the accelerated expansion ceased. Other reasons led then to the decline and eventual catastrophic disappearance of the dinosaurs. The reduction of gravity might have had some gradually increasing effects on the shape of organisms also at microscopic level and manifest itself in the evolution of genome during expansion period.

3. A possibly testable prediction following from angular momentum conservation ($\omega R^2 = constant$) is that the duration of day has increased gradually and was four times shorter during the Cambrian era. For instance, genetically coded bio-clocks of simple organisms during the expansion period could have followed the increase of the length of day with certain lag or failed to follow it completely. The simplest known circadian clock is that of the prokaryotic cyanobacteria. Recent research has demonstrated that the circadian clock of Synechococcus elongatus can be reconstituted in vitro with just the three proteins of their central oscillator. This clock has been shown to sustain a 22 hour rhythm over several days upon the addition of ATP: the rhythm is indeed faster than the circadian rhythm. For humans the average innate circadian rhythm is however 24 hours 11 minutes and thus conforms with the fact that human genome has evolved much later than the expansion ceased.

4. Scientists have found a fossil of a sea scorpion with size of 2.5 meters [I6], which has lived for about 10 million years for 400 million years ago in Germany. The gigantic size would conform nicely with the much smaller value of surface gravity at that time. The finding would conform nicely with the much smaller value of surface gravity at that time. Also the emergence of trees could be understood in terms of a gradual growth of the maximum plant size as the surface gravity was reduced. The fact that the oldest known tree fossil is 385 million years old [I14] conforms with this picture.

Did intra-terrestrial life burst to the surface of Earth during Cambrian expansion?

Intra-terrestrial hypothesis [?] is one of the craziest TGD inspired ideas about the evolution of life and it is quite possible that in its strongest form the hypothesis is unrealistic. One can however try to find what one obtains from the combination of the IT hypothesis with the idea of pre-Cambrian granite Earth. Could the harsh pre-Cambrian conditions have allowed only intra-terrestrial multicellular life? Could the Cambrian explosion correspond to the moment of birth for this life in the very concrete sense that the magma flow brought it into the day-light?

1. Gould emphasizes the mysterious fact that very many life forms of Cambrian explosion looked like final products of a long evolutionary process. Could the eruption of magma from the Earth interior have induced a burst of intra-terrestrial life forms to the Earth's surface? This might make sense: the life forms living at the bottom of sea do not need direct solar light so that they could have had intra-terrestrial origin. It is quite possible that Earth's mantle contained low temperature water pockets, where the complex life forms might have evolved in an environment shielded from meteoric bombardment and UV radiation.

2. Sea water is salty. It is often claimed that the average salt concentration inside cell is that of the primordial sea: I do not know whether this claim can be really justified. If the claim is true, the cellular salt concentration should reflect the salt concentration of the water inside the pockets. The water inside water pockets could have been salty due to the diffusion of the salt from ground but need not have been same as that for the ocean water (higher than for cell interior and for obvious reasons). Indeed, the water in the underground reservoirs in arid regions such as Sahara is salty, which is the reason for why agriculture is absent in these regions. Note also that the cells of marine invertebrates are osmoconformers able to cope with the changing salinity of the environment so that the Cambrian revolutionaries could have survived the change in the salt concentration of environment.

3. What applies to Earth should apply also to other similar planets and Mars [L71] is very similar to Earth. The radius is .533 times that for Earth so that after quantum leap doubling the radius and thus Schumann frequency scale (7.8 Hz would be the lowest Schumann frequency)

would be essentially same as for Earth now. Mass is.131 times that for Earth so that surface gravity would be.532 of that for Earth now and would be reduced to.131 meaning quite big dinosaurs! have learned that Mars probably contains large water reservoirs in it's interior and that there is an un-identified source of methane gas usually assigned with the presence of life. Could it be that Mother Mars is pregnant and just waiting for the great quantum leap when it starts to expand and gives rise to a birth of multicellular life forms. Or expressing freely how Bible describes the moment of birth: in the beginning there was only darkness and water and then God said: Let the light come!

To sum up, TGD would not only provide the long sought mechanism of expansion of Earth but also a possible connection with the biological evolution. It would be indeed fascinating if Planck constant changing quantum phase transitions in planetary scale would have profoundly affected the biosphere.

9.8 Implications Of Expanding Earth Model For The Pre-Cambrian Evolution Of Continents, Of Climate, And Of Life

Expanding Earth hypothesis is by no means not new. It was proposed by Mantovani and I learned about it from the video animations of [F44, F1] demonstrating that the continents fit nicely to form a single continent covering entire Earth if the radius is one half of the recent radius. What TGD has to give is a new physics justification for Expanding Earth hypothesis: cosmic expansion is replaced with a sequence of fast expansion periods increasing the value of Planck constant and these transitions occur in all scales.

If Expanding Earth hypothesis is correct it forces to modify dramatically the view about pre-Cambrian period. The super-continent theory could be replaced by much simpler theory and it might be possible to give up the assumption about hypothetical super continents and super oceans. The view about glaciations [F7] must be modified dramatically. Concerning the evolution of life the natural hypothesis is that it escaped to the underground seas formed as a consequence of expansion during pre-Cambrian era and returned back to the surface in Cambrian Explosion. In this section super-continent and super-ocean theory is discussed from TGD point of view. A model for glaciations based on the assumption that the radius of Earth was in good approximation one half of the recent radius during pre-Cambrian era is developed and shown to reduce to a sequence of ordinary glaciations initiated at pole caps. Snowball theory serves as a convenient reference. Expanding Earth theory is discussed also from paleomagnetic point of view and some experimental signatures of $R/2$ scenario differentiating it from standard scenarios are developed. Finally the hypothesis about underground evolution is discussed.

9.8.1 Super-Continent Theory

Super-continent theory assumes a cyclic formation of hypothetical super continents [F30]. Rodinia [F28], Pannotia [F24], and Pangea [F23] might have preceded by earlier super-continents. The period would be roughly 250 Myr.

1. The super-continent Rodinia [F28] is assumed to have existed during interval: 1100-750 Myr. 750 Myr ago Rodinia rifted into three continents: Proto-Laurasia which broke up and eventually reformed to form Laurasia (North America and Asia), the continental craton of Congo (part of Africa), and Gondwana (now southern hemisphere plus India).

2. Pannotia [F24] existed during time interval 600-540 Myr. Pannotia rifted in the beginning of Cambrian era to Laurentia (North America), Baltica, Siberia and Gondwana. See the illustration of Pannotia at [F13].

3. Wegener [F2] ended up to postulate that super-continent Pangea should have existed about 250 Myr ago [F23]. The support for its existence is rather strong since tectonic plate model and paleo-magnetic methods allows to trace the drift of the tectonic plates.

One can criticize the cyclic model. The concentration of land mass to Southern Hemisphere during Rodinia period does not look very probable event. The cyclically occurring formation of connected land mass surrounded by much larger ocean looks even less probable unless one can develop some very good physical mechanism forcing this. The basic motivation for super-continent theory are various correlations between distant parts of Earth which would cannot be understood otherwise. In $R/2$ model the continents would have been quite near to each other during the expansion and the notion of cyclic formation of super-continents becomes un-necessary since land bridges between the continents could explain the correlations. There would have been just single super-continent all the time.

9.8.2 Standard View About Oceans

In the standard model the total area covered by oceans has reduced since pre-Cambrian era due to the increase of the continental cover, which is nowadays 29 per cent. Oceans cover the remaining 71 per cent with Antarctica and Arctica included. The evolution of Oceans in standard model requires the introduction of hypothetical oceans which left no trace about their existence (subduction mechanism provides perhaps too convenient trash bin for hypothetical theoretical constructs).

1. Proto-Atlantic Ocean was introduced to explain some contradictions with Wegener's Pangea model allowing to conclude which parts at opposite sides of Atlantic Ocean had been in contact. Proto-Atlantic Ocean closed as Pangea formed and opened again in slightly different manner to form Atlantic Ocean. This process implied mixing of older pieces of the continents and explained the contradictions. Large inland sea is a natural counterpart of the Proto-Atlantic Ocean in $R/2$ option.

2. Mirovia [F17] was the super-ocean surrounding Rodinia. It transformed to Pan-African Ocean surrounding Pannotia. Pan-African ocean was then closed so that the ocean floor of Mirovia disappeared by subduction and left no signs about its existence.

3. In the rifting [F27] of Pannotia Panthalassic ocean [F25] emerged and was the precedessor of the Pacific ocean.

The presence of super-oceans is forced by the assumption that the radius of Earth was the recent one during the pre-Cambrian era plus the local data related to the evolution of continents. The questionable aspect is that these oceans did not leave any direct trace about their existence. In $R/2$ model there is no need for these super-oceans except possibly the counterpart of Panthalassic Ocean [F25].

9.8.3 Glaciations During Neoproterozoic Period

Glaciations dominated the Neoproterozoic period [F18] between 1-.542 billion years. The period is divided into Tonian [F34], Cryogenian [F3], and Ediacaran periods [F4]. The most severe glaciations occurred during Cryogenian period.

It is believed that during Cryogenian period [F3] two worldwide glaciations -Sturtian and Marinoan glaciations- took place. This involves extrapolation of continental drift model and plate tectonics theory. Also hypothesis about hypothetical super-continents is needed so that one must take these beliefs with some skepticism. In $R/2$ model the world wide glaciations are replaced with ordinary glaciations proceeding from poles.

1. Sturtian glaciation occurred 750-700 Myr. The breakup of Rodinia is believed to have occurred at this time. One can wonder whether there is a correlation between these events. $R/2$ model suggest that the energy needed to compensate the reduction of gravitational energy in expansion could have caused the cooling.

2. Marinoan (Varanger) glaciation ended around 635 Myr ago.

Deposits of glacial tillites [F32] at low latitudes serve as support for the claim that these glaciations were world wide. In $R/2$ model Equator corresponds to North pole in TGD framework where Rodinia covered entire Earth and the interpretation would as ordinary glaciations.

After the end of Marinoan glaciation followed Ediacaran period during 635-542 Myr [F4]. The first multicellular fossils appeared at this time. Their relationship to Cambrian fossils is unclear. The standard interpretation for the small number of fossils in pre-Cambrian period is that hard shells needed for fossilization were not yet developed. The problem is that these shells should have developed almost instantaneously in Cambrian explosion.

9.8.4 Snowball Earth Model For The Glaciation During Pre-Cambrian Era

Snowball Earth [F42, F37, F29] is recently the leading model for the glaciations [F8] during Proterozoic era. The term is actually somewhat misleading: Iceball Earth would more to the point. Slushball earth [F39] is a variant of Snowball Earth which does not assume total freezing near equator.

The history behind the Snowball Earth concept is roughly following [F29].

1. Mawson studied the Neoproterozoic stratigraphy of South Australia and identified extensive glacial sediments and speculated with the possibility of global glaciation. He did not know anything about continental drift hypothesis and plate tectonic theory and thought that the ancient position of Australia was the same as it is today. Continent drifting hypothesis however explained the finding as sediments deposited at the higher latitudes the hypothesis was forgotten.

2. Later Harland suggested on basis of geomagnetic data that glacial tillites [F32] in Svalbard and Greenland were deposited at tropical latitudes. In TGD framework with with $R \rightarrow R/2$ these tillites would have been at higher latitudes towards North Pole.

3. The facts are that Sun was 6 per cent fainter at that time and glaciations are known to occur. The question is whether they were global and long-lasting or a sequence of short-lasting possibly local glaciations. The Russian climatologist Budyko constructed a model based on energy balance and found that it is possible to have a global glaciation if the ice sheets proceeded enough from polar regions (to about 30 degree latitude). The model was based on the increased reflectiveness (albedo) of the Earth's surface due to the ice covering giving rise to positive feedback loop. Budyko did not believe that global glaciation had occurred since the model offered no way to escape eternal glaciation.

4. Kirschwink introduced the term Snowball Earth, which is actually misleading. Iceball Earth would be more to the point. He found that the so called banded iron formations are consistent with a global glaciation. He also proposed a mechanism for melting the snowball. The accumulation of CO_2 from volcanoes would have caused ultra-greenhouse effect causing warming of the atmosphere and melting of the ice.

5. Slushball Earth [F39] differs from Snowball Earth in that only a thin ice cover or even its absence near equator is assumed. The model allows to explain various findings in conflict with Snowball Earth, such as the evidence for the presence of melt-water basins.

6. Zipper rift model [F38] assumes that there was a sequence of glaciations rather similar to the glaciations that have occurred later. The model assumes that the rifts [F27] of the supercontinent Rodinia occurred simultaneously with glaciations. The associated tectonic uplift led to the formation of high plateaus hosting the glaciers. The iron band formation can be assigned with inland seas allowing complex chemistries and anoxicity near the sea floor.

The basic ideas of the Snowball Earth model

Snowball Earth [F42, F37, F29] differs from ordinary glaciations in that only oceans are frozen whereas in the ordinary glaciation land mass is covered by ice. The basic ideas of the snowball Earth relate to the mechanism initiating the global freezing and melting.

1. The glaciation would have been initiated by some event, say a creation of super-volcano. Also astrophysical mechanism might be involved. Somewhat paradoxically, tropical continents

during cryogenian period [F3] are needed for the initiation because they reflect the solar radiation more effectively than tropical oceans.

2. The positive ice-albedo feedback is an essential concept: the more ice the larger the fraction of the radiation reflected back so that the more ice is generated. If the glaciation proceeds over a critical latitude about 30 degrees positive feedback forces a global glaciation.

3. The problem of the model is how to get rid of the glaciation. The proposal of Kirschvink was that the accumulation of CO_2 from volcanoes could have led to a global super-warming. The time scale for CO_2 emissions is measured in millions of years. The needed atmospheric concentration of CO_2 is by a factor 350 higher than the recent concentration. Due the ice cover the CO_2 could not be absorbed to the siliceous rocks and concentration would increase. The melting of the ice meant higher absorbtion of heat by uncovered land. Positive feedback loop was at work again but in different direction.

Evidence for and objections against Snowball Earth

Wikipedia article about Snowball Earth [F29] discusses both evidence for and objections against Snowball Earth. Low latitude sediments at tropical latitudes and tropical tillites at Equatorial latitudes provide strong piece of evidence for Snowball Earth. Calcium carbonate deposits having ^{13}C signature (per cent for the depletion of ^{13} isotope and large for organic material) consistent with that for mantle meaning abiotic origin is second evidence. Iridium anomaly located at the base of Calcium Carbonate deposits is third piece of evidence. The evidence for Snowball Earth will be discussed in more detail later since it is convenient to relate the evidence to $R/2$ model for glaciations.

1. Paleomagnetic data [F22] used to the dating of sediments assuming tectonic plane theory and super-continent drifting might be misleading. No pole wandering maps exist and the polarity of the magnetic field must be deduced by statistical methods. The primary magnetization could have been reset and the orientation of the magnetic minerals could have changed from the original one. It is also possible that magnetic field patterns were not dipolar. Also the assumption of hypothetical super-continents and oceans brings in uncertainties. In $R/2$ model of course the determination of the positions changes completely.

2. Carbon isotope ratios are not what they should be. There are rapid variations of $^{12}C/^{13}C$ ratio with organic origin. Suggests that freezing and melting followed each other in rapid succession. In standard framework this would suggest Slushball Earth meaning ice-free and ice-thin regions around the equator and hydrological cycles. In $R/2$ model the regions at Equator are near North Pole and the explanation would be in terms of ordinary glaciations.

3. The distribution of isotopes of element Boron suggest variations of pH of oceans. The explanation is in terms of buildup of carbon dioxide in atmosphere dissolved into oceans/seas. In $R/2$ model a sequence of glaciations would explain the findings.

4. Banded iron formations providing support for the model are actually rather rare and absent during Marinoan glaciation.

5. Wave-formed ripples, far-traveled ice-rafted debris and indicators of photosynthetic activity, can be found throughout sediments dating from the "Snowball Earth" periods. This serves a evidence open-water deposits. In snow-ball model these could be "oases" of melt-water but computer simulations suggest that large areas of oceans would have left ice-free. in $R/2$ model these would be signatures of ordinary glaciations.

6. Paleomagnetic data have led to the conclusion that Australia was at Equator. In $R/2$ model it would have been near North Pole. Namibia was also thought to be near Equator [F31]. Indirect arguments forced the conclusion that it at 75 degree Southern latitude. In $R/2$ model this corresponds to 60 degrees Southern latitude and ordinary glaciation proceeding from South Pole is a natural explanation and ordinary glaciation would be in question in both cases.

7. There is evidence for the continental ice cover does not fit with Snowball Earth predicts that there should be no continental ice-cover. The reason is that freezing of the ocean means that there is no evaporation from oceans and no water circulation so that ice-cover cannot develop on continents. There is considerable evidence that continents were covered by thick ice [F29]. This suggests ordinary glaciations possible in $R/2$ model.

9.8.5 TGD Point Of View About Pre-Cambrian Period

What is new in TGD based view about pre-Cambrian period is basically due to the $R/2$ hypothesis.

TGD view about evolution of continents

The hypothesis about the existence of the super-continent Pangea [F23] was inspired by the work of Wegener [F2]. The hypothesis about the existence of former super-continents were forced by the correlations with fossil records suggesting connected continent. This is not necessary if the gigantic ocean was absent during $R/2$ era. The continent Rodinia [F28] could look much like the Rodinia of standard geology except that they formed single connected region with radius $R/2$.

1. It is possible that there was only single super-continent with widening inland seas all the time until 250 billion Myr. The first option is R increased slowly and that inland lake formed. Rifts could have got wider gradually during this era. If there were land bridges between the continents there would be no need for postulating the cyclic re-formation of super-continent.

2. One can pose many questions about the character of the expansion.

   (a) What was the duration of the expansion? Could the expansion have occurred in the time period 750-100 Myr (100 Myr corresponds to the age of dinosaurs with large body size made possible by the reduced gravitation and oxygenation of the atmosphere)? Duration would have been about 650 Myr in this case. Or did it began already at the beginning of Neoproterozoic period [F18] when super-continent Rodinia began to break up? In this case the duration would be about 1 Myr. The estimate based on the quantum model of gravitational radiation predicts that the transition lasted for about 1.1 Gy so that the latter option would be more plausible in this framework.

   (b) Did the expansion accelerate as does also cosmic expansion in TGD based universal model for the expansion periods containing only the duration of the expansion period as a parameter [K94] and applying in alls scales? It seems that accelerated expansion is the only sensible option since around 540 Myr the size of Earth should have been rather near to $R/2$ (perhaps so even at the period of Pangea around 250 My) unless one assumes that super-continent re-formed again.

3. One can also consider the possibility that the continents indeed broke up and reformed again during Cambrian era. One should however have a good physical reason for why this happened. Something must have connected the pieces together and created correlations. Gravitational magnetic flux tubes and phase transitions increasing and reducing Planck constant? Or could it be that the bridges connecting the continents acted like strings inducing oscillation of the distance between continents so that Pangea was surrounded by a large ocean?

4. The formation of the rift [F27] feeding magma from core to the surface would be due to the expansion leading to the formation of fractures. The induced local elevations would be like mountains. As in zipper-rift model ice could have covered these plateaus because the temperature was lower. This is not however essential for TGD based model of glaciations.

5. TGD based variant of Expanding Earth allows subduction but its role could have been small before the Pangeia period if the expansion was accelerating and led only to a relatively small increase of the radius before the Mesozoic period [F16] and continued with an accelerating rate during Mesozoic from 250 Myr to 65 Myr. It is interesting that Mesozoic period begins with the most intensive known extinction of history- so called Permian-Triassic extinction event [I4] - known as Great Dying. About 95 of marine species and 70 percent of terrestrial

species became extinct. Maybe genetically determined bio-rhythms could not follow the rapidly changing circadian rhythm. Another explanation for the extinction is the warming of the climate. For this there is indeed support: there is evidence that Antarctica was climate refuge during the extinction [I21]. Perhaps both factors were involved and were not independent of each other since rapid expansion might have generated massive methane leakages from underground seas and lakes.

TGD based view about evolution of oceans

Continents would have covered most of the area during $R/2$ era and the covered fraction was slightly smaller than $1/4$ of the recent area of Earth. This depends on the area taken by inland seas and polar caps. Nowadays the area covered by continents and inland seas is about 31 per cent so that continental area has increased and would be due to the expansion in vertical direction and deepening of the oceans. The area covered by oceans has increased from a small value to about 70 per cent. Only a small fraction of ocean floor would be subduced in Expanding Earth model. The Proto-Atlantic would have been only a small inland sea. Panthalassic Ocean was inland sea, which expanded to Pacific Ocean during expansion. Pacific Ocean could contain data about ancient ice ages if it was frozen. It however seems that data are consistent with the absence of global glaciation.

Model for glaciations

In TGD framework single super continent covering most of Earth becomes the counterpart of Rodinia [F28]. The hypothetical oceans are replaced with inland seas and polar caps. The super-continent covering most of Earth absorbs less solar heat than tropical oceans so that glaciations become more probable. Snowball Earth is replaced with a series of ordinary glaciations proceeding from poles since the places at Equator were near North Pole. There is no need for the glaciations to progress to the equator. The rifting for the counterpart of Rodinia is consistent with the formation of fractures due to the expansion of Earth. The reduction of gravitational binding energy due to the increase of the radius requires feed of energy and this could be one reason for the cooling and initiation of the glaciation.

There are several questions which must be answered if one wants to gain a more detailed understanding.

1. How does $R/2$ model modify the view about glaciations? Very probably there was a frozen polar cap. Snowball Earth could be replaced with ordinary glaciations proceeding from North and South Pole.

2. How does the predicted 3+3 hour diurnal cycle modify the ordinary picture? Certainly 3-hour day reduces the amplitude of the diurnal temperature variations. Could this period have left genetic traces to the mono-cellulars, say biological clocks with this period?

3. How does the predicted four times stronger surface gravity affect the glaciation process? Could strong gravity leave detectable signatures such as anomalously strong effects on the shape of surface of Earth or deeper signatures about the motion of ice.

There are also questions related to the energetics of the expansion.

1. The expansion required energy and could have induce glaciations in this manner. Energy conservation would hold for the total mechanical and gravitational energy of Earth given by

$$E = \frac{L^2}{2I} - k\frac{GM^2}{R} < 0 \ . \qquad (9.8.1)$$

Here L is the conserved angular momentum of order $L \simeq I\omega$ and ω increases from $1/4\omega_{now}$ to ω_{now} during the expansion. The moment of inertia I is of order of magnitude $I \sim MR^2$ and k is a numerical constant not too far from unity. The kinetic energy is actually negligible as compared to the gravitational potential energy. The reduction of the gravitational binding energy requires a compensating energy, which could come both from Earth interior or from the Earth's surface. Both effects would induce a cooling possibly inducing glaciations.

2. One expects that in the initial stages of the expansion there was just an expansion. This meant stretching requiring also energy. The formation of rifts leading to the formation of oceans as magma flowed out would have started already in the beginning of Proterozoic period. Eventually fractures were formed and in TGD framework one might expect that the distribution of fractures could have been fractal. A considerable fraction of fractures was probably volcanoes so that CO_2 begun to leak to the atmosphere and local "oasis" were formed. Also hot springs liberating heat energy from Earth crust could have been formed as in Island. The pockets inside Earth increased in size and were filled with water. Life started to escaped to the walls of the fractures and to the water pockets. Also the recent oceans can be seen as widened cracks which transformed to the expanding sea floors whereas continents did not expand. As the continental crust ceased to expand no heat was needed for the expansion and this together with increased CO_2 content of atmosphere would explain why there was no further glaciations and heating of the Earth. At this period the flow of the magma from Earth core provided the energy needed to compensate the reduction of gravitational energy.

3. It must be emphasized that TGD variant of Expanding Earth theory is not in conflict with tectonic plate theory. It explains the formation of tectonic plates and the formation of magma flow from rifts giving also rise to subduction and is therefore a natural extension of the tectonic plate theory to times before the expansion ceased.

Estimate for the duration of the transition changing gravitational Planck constant

The reader without background in quantum physics and TGD can skip this section developing an estimate for the duration of the transition changing Planck constant and inducing the scaling of the radius of Earth by a factor two. The estimate is about 1.1 Gy. It must be emphasized that the estimate is not first principle calculation and relies strongly on quantum classical correspondence.

The duration of the quantum transition inducing the expansion of the gravitational space-time sheet of Earth and thus of Earth itself by a factor two can be estimated by using the same general formula as used to estimate the power of gravitational radiation emitted in a transition in which gravitational Planck constant assignable to star-planet system is reduced [K79].

1. The value of gravitational Planck constant characterizing the gravitational field body of Earth is GM^2/v_0, where the velocity parameter $v_0 < 1$ ($c = 1$) is expected to be larger than $v_0 \simeq 2^{-11}$ characterizing Sun-Earth system.

2. Assuming a constant mass density for Earth the gravitational potential energy of Earth is given by

$$V = \frac{M}{2}\omega^2 r^2 \ , \ \omega = \sqrt{\frac{6GM}{R^3}} \ . \tag{9.8.2}$$

As far as radial oscillations are considered, the system is mathematically equivalent with a harmonic oscillator with mass M. The energies for the radial oscillations are quantized as $E = (n + 1/2)\hbar_{gr}\omega$.

3. The radii of Bohr quantized orbits for the harmonic oscillator scale like $\sqrt{\hbar}$ so that $\hbar \rightarrow 4\hbar$ is needed to obtain $R \rightarrow 2R$ rather than $\hbar \rightarrow 2\hbar$ as the naïve Compton length argument would suggest. This requires the scaling $v_0 \rightarrow v_0/4$. The change of the ground state energy in this quantum transition is

$$
\begin{aligned}
\Delta E &= \frac{1}{2}(\hbar_{gr,f}\omega_f - \hbar_{gr,i}\omega_i) \ , \\
\hbar_{gr,f} &= 4\hbar_{gr,i} = \frac{4GMm}{v_{0,i}} \ , \\
\omega_i &= 2^{3/2}\omega_f = 2^{3/2}\sqrt{\frac{6GM}{R_f^3}} \ .
\end{aligned} \tag{9.8.3}
$$

$R_f = R$ denotes the recent radius of Earth.

4. From the estimate for the power of gravitational radiation in similar transition the estimate for the duration τ of the quantum transition is

$$
\begin{aligned}
\tau &= a(v_{0,i}v_{0f})^{-k/2} \times \frac{(\hbar_{gr,i}+\hbar_{gr,f})}{2\Delta_E} \ , \\
&= a2^{-k}v_{0f}^{-k} \times \frac{1+r}{r\omega_f - \omega_i} \ , \ r = \frac{\hbar_f}{\hbar_i} = 4 \ .
\end{aligned} \tag{9.8.4}
$$

The average of Planck constants associated with the initial and final states and geometric mean of the parameters v_{0i} and v_{0f} is dictated by time reversal invariance. The exponent k is chosen to be same as that obtained for from the condition that the ratio of the power to the classical radiation power emitted in the transition between planetary Bohr orbits does not depend on v_0 (quantum classical correspondence). This gives $k = 5$. The condition that the power of gravitational radiation from Hulse-Taylor binary is same as the power predicted by the classical formula (quantum classical correspondence) gives $a = .75$.

5. The explicit expression for τ reads as

$$
\begin{aligned}
\tau &= K \times av_{0,f}^{-5} \times (\frac{R}{2GM})^{1/2} \times \frac{R}{c} \ , \\
K &= \frac{5 \times 2^{-7} \times (2+2^{1/2})}{3^{1/2}} \ .
\end{aligned} \tag{9.8.5}
$$

6. The basic data are $M_{Sun} = 332900M$ (mass of Sun using Earth's mass as unit) and the mnemonic $r_{S,Sun} = 2GM_{Sun} = 2.95 \times 10^3$ m: together with $R = 6371 \times 10^3$ m these data allow a convenient estimation of $R/2GM$. For $k = 10$ and $a = .75$ this gives $\tau = 1.17$ Gyr. This is twice the estimate obtained by requiring that the transition begins at about 750 Myr (the beginning of Sturtian glaciation) and ends around 100 My (the age of gigantic animals whose evolution would be favored by the reduction of surface gravity). The estimate would suggest that the quantum transition began already around 1.1 Gyr, which in the accuracy used corresponds to the beginning of Neoproterozoic at 1 Gyr [F18]. The breaking of super-continent Rodinia indeed began already at this time.

7. Note that the value of v_{0f} for the gravitational field body of Earth as it is now would be $v_{0f} = 2^{-10}$ to be compared with $v_0 \simeq 2^{-11}$ for Sun-Earth gravitational field body.

Snowball Earth from TGD point of view

In TGD framework the main justification for Snowball Earth disappears since the samples believed to be from Equator would be from North pole and glaciation could be initiated from pole caps. Consider next in more detail the evidence for Snowball Earth from TGD point of view.

1. Low latitude glacial deposits, glacial sediments at tropical latitudes, tropical tillites, etc. providing support for snowball Earth [F29] would be near North pole of at Northern latitudes. Ordinary glaciations proceeding from poles would explain the findings [F10]. If total glaciations were present, a rough scaling suggests that the evidence from them should be found from southern latitudes around 45 degrees in the standard model framework.

   The testable prediction is that the evidence for glaciations in ice-ball Earth framework should be found only below Equator and near South Pole. This finding would be of course extremely weird and would strongly favor $R/2$ option. Interestingly, in Southern Brasil all indicators for glaciations are absent (see [F45] and references therein). This region belonged to Godwana continent and there is evidence that its location was at middle latitudes at Southern Hemisphere.

2. Banded iron formations [F29] are regarded as evidence for Snowball Earth and occur at tropical levels (near North Pole in $R/2$ model). Iron dissolved in anoxic ocean would have become in a contact with photosynthetically produced oxygen and implied the formation of iron-oxide. The iron formation would have been produced at the tipping points of anoxic and oxygenated ocean. One can consider also an explanation in terms of deep inland seas, which become stagnant and anoxic near the sea floor.

   In TGD framework sea floor near North Pole could contain banded iron formations. This would explain also why the banded iron formations are rather rare. The oxygen could have come also from underground after the formation of cracks and led to the oxygenation of inland seas from bottom. The assumption that oxygenation took place already during the first glaciation, could explain why banded iron formations are absent during the second glaciation.

3. Calcium carbonate deposits [F29] have ^{13}C signature (per cent for the depletion of ^{13} isotope and large for organic material) is consistent with that for mantle meaning abiotic origin. The explanation of Calcium carbonate deposits in TGD framework could be the same as in Snowball Earth model. Atmospheric CO_2 could come from the volcanoes and react with the silicates during the ice-free periods to form calcium carbonate which then formed the deposits. CO_2 could have also biological origin and come from the underground life at the walls of the expanding fractures/volcanoes or in underground seas or lakes. In this case also methane is expected. This option would predict ^{13}C signature characteristic for organic matter. Also this kind of signatures have been observed and support ordinary glaciations. Also rapid fluctuations of the signature from positive to negative take place and might have signatures of temporary melting induced organic contribution to the calcium carbonate.

4. Iridium anomaly [F29] is located at the base of Calcium Carbonate deposits. In Snowball Earth model Iridium deposits derive from the Iridium of cosmic rays arriving at the frozen ice surface. As the ice melts, Iridium deposits are formed. In $R/2$ model the condensation of Iridium would proceed through the same mechanism. The possible problem is whether the time is long enough for the development of noticeable deposits. Near poles (Equator and South pole in standard model) this could be the case.

9.8.6 Paleo-Magnetic Data And Expanding Earth Model

Paleomagnetic data from pre-Cambrian period might allow to test $R/2$ hypothesis. This data could in principle help to trace out the time development $R(t)$ from $R/2$ to R if the non-dipole contribution to magnetic field depends on $R(t)$.

About paleo-magnetism

Paleomagnetism [F22] provides quantitative methods to determine the latitude at which the sample of sedimentary rock was originally. Magnetic longitude cannot be determined because of rotational symmetry so that other information sources must be used. There are several methods allowing to deduce the direction and also the magnitude of the local magnetic field and from this the position of the sample during the time the sample was formed.

1. Below the Curie point thermal remanent magnetization is preserved in basalts of the ocean crust and not affected by the later magnetic fields unless they are too strong. This allows to deduced detail maps from continental drifting and polar wander maps after 250 Myr (Pangea period). During pre-Cambrian period the ocean floors of hypothetical oceans would have disappeared by subduction. In $R/2$ model there are no oceans: only inland seas.

2. In the second process magnetic grains in sediments may align with the magnetic field during or soon after deposition; this is known as detrital remnant magnetization (DRM). If the magnetization is acquired as the grains are deposited, the result is a depositional detrital remnant magnetization (dDRM); if it is acquired soon after deposition, it is a post-depositional detrital remnant magnetization (pDRM).

3. In the third process magnetic grains may be deposited from a circulating solution, or be formed during chemical reactions, and may record the direction of the magnetic field at the time of mineral formation. The field is said to be recorded by chemical remnant magnetization (CRM). The mineral recording the field commonly is hematite, another iron oxide. Red-beds, clastic sedimentary rocks (such as sandstones) that are red primarily because of hematite formation during or after sedimentary diagenesis, may have useful CRM signatures, and magnetostratigraphy [F15] can be based on such signatures. Snowball model predicts that nothing came to the bottoms of big oceans! How can we know that they existed at all!

During pre-Cambrian era the application of paleomagnetic methods [F22] is much more difficult.

1. Reliable paleomagnetic data range up to 250 My, the period of Pangaea, and magnetization direction serves as a reliable information carrier allowing detailed polar wander maps. During pre-Cambrian era one cannot use polar wander maps and the polarity of the magnetic field is unknown. Therefore theoretical assumptions are needed including hypothetical super-continents, hypothetical oceans, and continental drift and plate tectonics. All this is on shaky grounds since no direct information about super-continents and ancient oceans exists. $R/2$ model suggests that continental drift and plate tectonics have not been significant factors before the expansion period when only inland seas and polar ice caps were present. Measurements have been however carried out about magnetization for pre-Cambrian sediments at continents recently and gives information about the strength of the magnetic field [F14]: the overall magnitude of the magnetic field is same as nowadays.

2. At Precambrian period the orientation of iron rich materials can serve as a record. The original records can be destroyed by various mechanisms (diagenesis). Also the orientations of the sediments can change in geological time scales.

3. Tens of thousands of reversals of the magnetic polarity [F6] have occurred during Earth's history. There have been long periods of stability and periods with a high frequency of reversals. The average duration of glaciation is around one Myr. The determination of the polarity of B possible by using samples from different points.

4. Mountain building orogeny [F21] releases hot water as a byproduct. This water can circulate in rocks thousands of kilometers and can reset the magnetic signature. The formation of fractures during the expansion of Earth could have released hot water having the same effect.

Could paleomagnetic data kill or prove $R/2$ model?

The first question is how one might kill $R/2$ model using data from pre-Cambrian era. Paleomagnetic data could do the job.

1. Remanent magnetization is proportional to the value of magnetic field causing it in weak magnetic fields. Therefore the magnetization in principle gives information about the magnetic fields that prevailed in early times.

2. Suppose that the currents generating the magnetic field can be idealized to conserved surface currents K around cylindrical surfaces of radius r and height h scaled down to to $r/2$ and $h/2$ and that the value of K is not affected in the process. With this assumptions the magnetic moment behaves $\mu \sim Ir^2h \rightarrow \mu/8$. A continuous current vortices with $j = k/\rho$, which is ir-rotational outside the symmetry axis, produce a similar result if the radius of the vortices scales as $r \rightarrow r/2$. Since dipole magnetic field scales as $1/r^3$ and is scaled up by a factor 8 in $R \rightarrow R/2$, the scalings compensate and the dipole magnetic fields at surface do not allow to distinguish between the two options. Non-dipole contributions might allow to make the distinction.

3. The group led by Lauri J. Pesonen in Helsinki University [F14] has studied paleomagnetic fields at pre-Cambrian era. The summary of results is a curve at the home page of the group and shows that the scale of the magnetic during pre-Cambrian era is same as nowadays. On the other hand, the recent thesis by Johanna Salminen- one of the group members- reports abnormally high values of magnetization in Pre-Cambrian intrusions and impact structures in both Fennoscandia and South Africa [F41]. No explanation for these values has been found but it is probably not the large value of primary magnetization.

Another manner to do test the $R/2$ model is by comparing the signs of the magnetizations at magnetic equator and poles. They should be of opposite sign for dipole field. The polarity of magnetic field varies and there are no pre-Cambrian polar wander maps. One can deduce from the condition $B_r/rB_\theta = 2cot(\theta)$ holding true for dipole field the azimutal distance $\Delta\theta$ along the direction of the measured magnetic field to the pole along geodesic circle in the direction of the tangential component of B. One cannot however tell the sign of $\Delta\theta$, in other words whether a given pre-Cambrian sample belongs to Norther or Southern magnetic hemisphere. There are however statistical methods allowing to estimate the actual pole position using samples from several positions (for an excellent summary see [F41]).

For instance, if the magnetic field is in North-South direction during Rodinian period [F28], standard model would predict that the sign at the Equator is opposite to that at South Pole. In $R/2$ model the sample would be actually near North Pole and polarizations would have same sign. The sign of magnetization at apparent southern latitude around 45 degrees would have been opposite to that at South pole which is in conflict with dipole field character. Maybe the global study of magnetization directions when magnetic field was approximately in North-South direction could allow to find which option is correct. Also the dependence of the strength of the magnetic field as function of θ could reveal whether $R/2$ model works or not. The testing requires precise dating and position determination of the samples and a detailed model for the TGD counterpart of Rodinia and its construction requires a specialist.

If the expansion continued after 250 Myr with an accelerating rate and Earth radius was still considerably below its recent value, the comparison of pole wandering charts deduced from ocean floor paleomagnetic data at faraway locations might allow to show that the hypothesis about dipole field is not globally consistent for R option. Even information about the time evolution of the radius could be deduced from the requirement of global consistency.

9.8.7 Did Life Go Underground During Pre-Cambrian Glaciations?

The basic idea of Expanding Earth model is that the life developed in underground seas and emerged to the surface of Earth in Cambrian explosion. The series of pre-Cambrian glaciations explains why the life escaped underground and how the underground seas were formed.

1. If one believes that the reduction of gravitational binding energy was responsible the cooling, then the expansion of Earth could have begun at the same time as Sturtian glaciation [F3] . On the other hand, the TGD estimate for the duration of the expansion period giving 1.1 Gyr, suggests that the breakup of the Rodinia, which began in the beginning of Proterozoic period corresponds to the beginning of the expansion. The simplest assumption is that the radius of R at the beginning of Cambrian period was not yet much larger than $R/2$ and continued to increase during Cambrian period and ended up around 100 My, when dinosaurs and other big animals had emerged (possibly as a response to the reduction of gravity). This means that there were land bridges connecting the separate continents.

2. One must explain the scarcity of fossils during pre-Cambrian era. If the more primitive life forms at the surface of Earth did not have hard cells and left no fossils one can understand the absence of highly evolved fossils before Cambrian explosion [I1]. If life-forms emerged cracks and underground seas there would be no fossils at the surface of Earth. In the case of volcanoes dead organisms would have ended to gone to the bottom of the water containing volcano and burned away.

3. The expansion had formed the underground pockets and fractures made possible for the water to flow from the surface to the pockets. Life would have evolved in fractures and pockets. The first multicellular fossils appeared during Ediacaran period (segmented worms, fronds, disks, or immobile bags) [F4] and have little resemblance to recent life forms and their relationship with Cambrian life forms is also unclear. Ediacaran life forms could have migrated from the fractures and Cambrian fossils from from the underground seas and lakes. The highly evolved life-forms in Cambrian explosion could have emerged from underground seas through fractures.

One can make also questions about the underground life.

1. The obvious question concerns the sources of metabolic energy in underground seas. In absence of solar radiation photosynthesis was not possible plants were absent. The lowest levels in the metabolic hierarchy would have received their metabolic energy from the thermal or chemical energy of Earth crust or from volcanoes. The basic distinction between plants and animals might be that the primitive forms of plants developed at the surface of Earth and those of animals in underground seas.

2. At first it seems strange that the Cambrian life-forms had eyes although there was no solar radiation in the underground seas. This is actually not a problem. These life-forms had excellent reasons for possessing eyes and in absence of sun-light the life forms had to invent lamp. Indeed, many life forms in deep sea and sea trenches produce their own light [I3]. It would be interesting to try to identify from Cambrian fossils the body parts which could have served as the light source.

9.8.8 Great Unconformity As A New Piece Of Support For Expanding Earth Model

I hope that this chapter demonstrates convincingly that single hypothesis - a sudden phase transition increasing the radius of Earth by a factor 2 natural in the many-sheeted space-time of TGD - explains Cambrian explosion in biology (a sudden emergence of huge number of life forms after very slow Precambrian evolution), and also provides a model for Precambrian evolution of continents, climate and life.

Already Darwin realized that the absence of fossils from Precambrian era (see `http://tinyurl.com/65zeh5`) is a deep problem for his theory and assumed that this is an artefact due to the incomplete fossil record. Fossils of Precambrian origin have been indeed found after Darwin's time but they are simple and very rare, and the conclusion is that Cambrian explosion (see `http://tinyurl.com/3flhcw`) [I1] meaning a huge diversification was real. Two mysteries therefore remain. Why the development of life was so slow during Precambrian era? Why the diversification was so incredibly fast during Cambrian explosion? Various explanations have been proposed. Did the oxygen content of the atmosphere reach a critical value and lead to the diversification? Or did predation pose the evolutionary pressure making the pace of evolution dramatically faster?

In New Scientist (see `http://tinyurl.com/nenk8nq`) [F40] geologists Robert Gaines and Shanan Peters describe a geological finding perhaps related to the Cambrian Explosion: the mysterious "Great Unconformity" (see `http://tinyurl.com/bqm9ndz`) [F9], which is a juxtaposition of two different types of rock of very different geological ages along a prominent surface of erosion. This surface represents a very long span of "missing" time. More than 1 billion years of geological record is missing in many places! From the figure (see `http://tinyurl.com/y8tnbneb`) of the Wikipedia article [F9] about Great Unconformity visible in Grand Canyon the thickness of the missing layer can be estimated to be about 12.6 km. Somehow before the Cambrian the uppermost rocks of the continents were stripped away exposing the underlying crystalline basement rocks. The cause of this gap remains a complete mystery so that we have three mysteries! Plus the mysteries related to the evolution of climate (problems of Snowball Earth model).

The authors suggest that the formation of Great Unconformity relates to the Cambrian explosion. Large scale erosion and chemical weathering of the exposed crystalline rock caused mineralization of the sea water. The hypothesis is that this led to bio-mineralization: animal groups possessing mineral skeletons - such as silica shells and calcium carbonate shells - emerged. This hypothesis looks rather plausible but does not solve the three great mysteries.

The authors indeed leave open the question about the origin of Great Unconformity and of Cambrian explosion. The TGD based explanation of Cambrian explosion comes from the model realizing the old idea about Expanding Earth in terms of TGD inspired new physics. Already Wegener observed that continents can be fit together nicely and this led to the recent view about plate tectonics. Wegener's model however fits only "half" of the continent boundaries together. One could however do much better: the observation is that the continents would fit nicely to cover the entire surface of Earth if the radius of Earth were 1/2 of its recent value! Expanding Earth model postulates that the radius of Earth grows slowly. Geologists have not taken Expanding Earth model seriously: one good reason is that there is no physics allowing it.

As has been found, TGD predicts a candidate for the needed new physics.

1. At given sheet of the many-sheeted space-time cosmic expansion is predicted to take place as sudden phase transitions in which the size of some space-time sheet suddenly increases. By p-adic length scale hypothesis the preferred scaling factors are powers of 2 and the most favored scaling factor is just two. The proposal is that during the Precambrian era life resided in underground seas being thus shielded from meteor bombardment and cosmic rays. This explains the scarcity of the fossil records and the simplicity of the fossils found. The sudden phase transition was a very violent process increasing the area of the Earth's surface by a factor of 4. The area of continents is 29.1 per cent from the recent area of the Earth's surface - not too far from the naïvely predicted fraction 1/4.

2. It is easy to imagine that the uppermost rocks of the continent covering the entire Earth were stripped away and correspond nowadays to 100 km thick continental tectonic plates consisting of mainly silicon and aluminium). This expansion created split first the topmost layer as continental plates and regions between them giving rise to oceans. The magma which was uncovered by the process cooled down and solidified and the continued expansion gave rise to ocean plates with different composition (mainly silicon and magnesium).

3. The expansion phase corresponds to criticality so that fractality of the expansion is expected. At least for continental plates this process could have been fractal occurring in various length scales characterizing the thickness and the area of the sub-plates generated in the process. p-Adic length scale hypothesis suggests that the scales involved should appear as powers of $\sqrt{2}$ or 2. Generation of Great Unconformity as a process in which the underlying crystalline basement rocks were uncovered could correspond to a splitting of a layer of the continental plates to pieces. The length scale characterizing the thickness is 12.6 km from the above estimate and with 1 per cent accuracy by a factor 1/8 shorter than 100 km length scale for tectonic plates. This conforms with p-adic fractality. If the process of expansion involved a cascade of scalings by factor 2, one can wonder whether it proceeded from long to short length scales or vice versa. In other words: did continental and oceanic tectonic plates form first and after than the smaller structures such as the Great Unconformity or vice versa?

4. Note that the Compton scale $L_e(237)$ corresponding $p \simeq 2^{237}$ is 88 km - ten per cent smaller than 100 km. Maybe thermal expansion could account the discrepancy if the original thickness was $L(237)$. Second interpretation could be that besides electron Compton scale $L_e(239)$ the p-adic scale $L(239) = L_e(239)/\sqrt{5} \simeq 78.7$ km matters. The importance of $L(k)$ does not implicate that of scaled up electron, and the following argument suggests that it is p-adic length scale rather than corresponding electron Compton scale that matters now. Remarkably, also M_{241} is Gaussian Mersenne and corresponding electronic Compton scale is $L_e(241) = 154.7$ km.

   Note that 88 km is rather precisely the thickness of the atmosphere above which there is ionosphere (see `http://tinyurl.com/lqr85j`) [F11]. The thickness of Kennelly–Heaviside layer (see http://tinyurl.com/25ur2tl) [F12] inside which radio waves used in terrestrial radio communications propagate, has thickness about 150 km which roughly corresponds to $L(239)$. Note that Continental litosphere (see http://tinyurl.com/d96kw) [F26] has typical thickness of 200 km ($L(239)$) whereas oceanic litosphere is 100 km thick ($L(237)$). This fits at least qualitatively with the proposed formation mechanism of continental tectonic plates.

There is a nice fractal analogy with cell membrane and connection with Gaussian Mersennes (see http://tinyurl.com/pptxe9c) [A5] expected to be of special importance in TGD Universe. The scales $L(239)$ and $L(241)$ would be in the same relation as the thickness $L_e(149)$ of the lipid layer of cell membrane to the cell membrane thickness $L_e(151)$ characterized by Gaussian Mersenne $M_{151,G}$. The two kinds of tectonic plates (continental and oceanic) would be analogous to the lipid layers of cell membrane.

5. The rapid expansion process could have also brought in daylight the underground seas and the highly developed life in them so that Cambrian diversification would have been only apparent. Skeptic can of course ask whether it is necessary to assume that life resided in underground seas during Precambrian era. Could just the violent geological process be enough to induce extremely fast diversification? This might of course be true.

6. There is one further argument in favor of the Expanding Earth model. The fact that the solar constant was during proto Earth period (see http://tinyurl.com/pc83uvt) [F33] only 73 per cent from its recent value, is a problem for the models of the very early evolution of life. If the radius of Earth was 1/2 of its recent value the duration of day and night was from conservation of angular momentum only 1/4: th of the recent value and thus 3 hours. This could have made the environment much more favorable for the evolution of life even at the surface of the Earth since the range for the temperature variation would have been much narrower.

9.8.9 Where Did The Oceans Come From?

TGD based vision about life has been developing rapidly thanks to the realization that hierarchy of Planck constants and dark matter could relate directly to criticality: consider only long range correlations, phase separation, and classical non-determinism near critical point as common aspects [?]. The article "Half of the Earth's water formed before the sun was born" (http://news.sciencemag.org/earth/2014/09/half-earths-water-formed-sun-was-born) describes research results proving additional support for the TGD inspired idea about the occurrence of prebiotic evolution in underground water reservoirs shielded from meteorites and cosmic rays. The idea relies on TGD inspired variant of Expanding Earth hypothesis [K79, L55].

1. Article represents first a standard argument in favor of late formation of oceans. The collisions by astreroids and meteorites could have evaporated the water or blown off it in to space. Hence surface water at Earth should have emerged much later. Note that one can replace "water" with "life" in the argument.

2. The researchers end up to propose that the water emerged already before Sun, and also oceans did so rather early. Carbonaceous chondrites (http://tinyurl.com/75fh74p), which formed at the same time as Sun and well before the planets, could have served as a source of water. These meteorites were formed very early, already earlier than Sun. Their composition resembles that of bulk solar system composition. By studying basaltic meteorites from asteroid Vesta, which is known to be formed in the same region as Earth, the reaserachers found that they contain same hydrogen isotopic composition as carbonaeous chondrites.

   This motivates the proposal that chondrites contained the water. A further proposal is that the water reservoirs formed at the surface of Earth as it formed. Here I beg to disagree: the objection represented in the beginning is difficult to circumvent!

The article stimulates several interestig questions in TGD based conceptual framework.

1. Why not to assume formation of underground water reservoir? Here meteorites and UV radiation did not form a problem. And there is indeed recent evidence for the previous

existence of large underground reservoirs (http://tinyurl.com/k2d2ttj). The formation process for Earth could have naturally led to the evaporation of of chondrite water from the interior of Earth and its transfer nearer to surface and getting caught inside reservoirs.

Also prebiotic life could have evolved in the underground water reservoirs and already in chondrites (DNA, RNA, aminoacids, tRNA represented as dark proton sequences at flux tubes) and transformed to the life as we know. Mother Gaia's womb was nice place: no meteorite bombardment, no cosmic rays, and metabolic energy provided by Mother Gaia as dark photons. Cambrian explosion as Earth's radius increased by a factor of two was the birthday of the life as we identify it, the (child) water burst to the surface and seas were formed and life began to evolve at the surface of Earth.

Recall that in TGD continous cosmological expansion at level of space-time sheets is at quantum level replaced with a sequence of phase transitions increasing $h_{eff} = n \times h$ and/or p-adic length scale of the space-time sheet - by p-adic length scale hypothesis most naturally by a factor of two. This kind of transition explains why the continents of Earth fit nicely together to cover entire Earth if the radius is half of its recent value, the emergence of gigantic life forms, etc... [L55].

2. The basic objection relates to the basic mechanisms of metabolism. What replaced plants receiving metabolic energy from solar light as source of metabolic energy? What replaced Sun? Did the dark photon radiation generated by Earth - or maybe also Sun - and penetrating ordinary matter as dark radiation, replace sun light? Any critical system could generate this radiation and it should not be difficult to identify this kind of system: the boundary between core and mantle is the most obvious candidate for a critical system as also for a rapid self-organization process). I proposed for more than decade ago this option half-jokingly as metabolic sources of IT (intraterrestrial) life as I called it.

3. Dark photon radiation would have had a universal energy spectrum - the spectrum of biophotons in visible and UV range. Part of it would have transformed to biophotons (http://tinyurl.com/yb9hnmu7) taking the role of solar radiation as a metabolic energy source. An interesting question is whether the life at the bottom of oceans could give some hints about the counterpart of photosynthesis based on bio-photons? The discovery that the metabolic reactions thought to require complex catalytic maschinery can take place in the environment simulating ocean bottom (http://tinyurl.com/ydc8g7r4) supports the idea about the evolution of life from prebiotic life forms in the womb of Mother Gaia. In TGD framework these prebiotic life forms could correspond to dark proton sequences (dark nuclei) at magnetic flux tubes associated with the negatively charged exclusion zones discovered by Pollack [L9] (http://tinyurl.com/oyhstc2).

9.9 Do Blackholes And Blackhole Evaporation Have TGD Counterparts?

The blackhole informationparadox (see http://tinyurl.com/9a58c) is often believed to have solution in terms of holography stating in the case of blackholes that blackhole horizon can serve as a holographic screen representing the information about the surrounding space as a hologram. The situation is however far from settled. The newest challenge is so called firewall paradox proposed by Polchinsky *et al* (see http://tinyurl.com/oqfwf27) [B27]. Lubos Motl has written several postings about firewall paradox and they inspired me to look the situation in TGD framework.

These paradoxes strengthen the overall impression that the blackhole physics indeed represent the limit at which GRT fails and the outcome is recycling of old arguments leading nowhere. Something very important is lacking. On the other hand, some authors like Susskind claim that the physics of this century more or less reduces to that for blackholes. I however see this endless tinkering with blackholes as a decline of physics. If super string had been a success as a physical theory, we would have got rid of blackholes.

If TGD is to replace GRT, it must also provide new insights to blackholes, blackhole evaporation, information paradox and firewall paradox. This inspired me to look for what blackholes and blackhole evaporation could mean in TGD framework and whether TGD can avoid the paradoxes.

This kind of exercises allow also to sharpen the TGD based view about space-time and quantum and build connections to the mainstream views.

9.9.1 Background

Hawking radiation and information paradox

A theoretical argument supporting the existence of Hawking radiation (see http://tinyurl.com/bohvd) from blackhole was suggested by Hawking in 1974. Before this Bekenstein had proposed that blackhholes are characterized temperature and entropy. The implication is that blackholes radiate their mass gradually as thermal radiation. Since thermal radiation carries no information, this leads to black hole information paradox (see http://tinyurl.com/9a58c) if one assumes that the blackhole evolves unitarily.

Hawkings's original conclusion - which he later gave up - was that information is indeed lost. Susskind and t'Hooft proposed holographic principle stating that the information is actually contained in the radiation emitted from the blackhole. There are several approaches to the information paradox: information is destroyed, information gradually leaks out, information suddenly escapes in the final states of evaporation, or is stored in Planck sized remnant. Basic assumptions have been Equivalence Principle and unitary of the emission process of blackhole evolution. Penrose's disagreed about the necessity of assuming unitary evolution: state function reduction is non-unitary process and his proposal was that gravitation induces state function reductions.

Firewall paradox

The firewall paradox was introduced by Polchinski *et al* (see http://tinyurl.com/oqfwf27). One considers two observers: distant observer and observer falling in late stage blackhole. If one assumes both Equivalence principle in the sense that M^4 QFT applies in low curvature regions (therefore also somewhat below the horizon) and requires unitary of emission of Hawking radiation, one ends up with the prediction that falling observer must encounter a firewall at horizon (quite concretely destroying her) or there is new non-local long length scale dynamics involved. EP however predicts that no such firewall should be encountered since low curvature regions are in question and M^4 QFT should work. Therefore unitary and EP lead to conflicting predictions.

In the following Bob refers to distant observer and Alice is the observer jumping into blackhole. The core of the argument goes as follows.

1. Bob: Unitarity requires maximal entanglement BR, R early Hawking radiation. If one assumes that entanglement matrix is unitary or product of projection operator and unitary matrix then this is the case but I do not quite understand why this should be the case.

2. Alice: Horizon approximated by Rindler wedge (see http://tinyurl.com/msr3p4) [B9, B23, B6]. Minkowski vacuum superposition of state pairs at different sides of the Rindler wedge. Nearly maximal entanglement for Minkowski vacuum represented in terms of states associated with the right and left wedges is easy to understand. EP requires maximal entanglement BA, A inside blackhole. Therefore B is maximally entangled with both A and R. This is contradiction by the monogamy of maximal entanglement (more precisely with the subadditivity of entanglement entropy).

There has been an intense debate about the firewall paradox. For instance, Bouzzo has written two articles with different conclusions.

Bouzzo's first article has title "Observer complementary resolves firewall paradox" (see http://tinyurl.com/yc752cuj) [B43]. The argument goes as follows. By EP Alice falling in blackhole can approximate local physics in low curvature regions by the physics in empty Minkowski space: the region above and also somewhat below horizon is low curvature region. Blackhole looks like membrane for Bob. Alice observers no membrane. Therefore the descriptions of the two observers are inconsistent. Observer complementarity is claimed to save the situation. Observers are not able to communicate to each other their contradictory findings concerning the existence horizon, and therefore cannot discover the inconsistency. The measurements of Alice and Bob are analogous to measurement of non-commuting observables. These are to my opinion lawyer arguments. Laws of physics could be violated when no-one is seeing it!

Bouzzo's second article is titled Observer complementarity is not enough (see http://tinyurl.com/y97qz8jw) [B42]. The new argument developed by Bouzzo states that Alice can actually gather information about the existence of horizon and avoid falling into blackhole and therefore communicate the information to Bob so that paradox becomes observable.

To my opinion observer complementary and blackhole complementarity (see http://tinyurl.com/ybkrtsoc) suggested by Susskind [B45] and involves the assumption of stretched horizon with thickness of Planck length sound questionable hypothesis.

9.9.2 About Basic Assumptions About Blackhole Evaporation As Seen In TGD Context

1. For GRT blackholes the interior does not allow geodesic lines to escape to blackhole exterior: in other words the escape velocity is larger than light velocity. Also the roles of time coordinate and radial coordinate are exchanged.

   In TGD sub-manifold gravity leads the replacement of blackhole interior with an Euclidian region [L5] (see http://tinyurl.com/hzkldnb. Motivation for this comes from the study of small perturbations of the Reissner-Nordström metric transforming horizon to light-like 3-surfaces and making 4-metric degenerate at horizon so that Euclidian metric signature becomes natural in the interior. This leads to a new view about the microscopic origin of cosmological constant: there are actually many ways to interpret cosmological constant and the recent progress in the understanding of preferred extremals predicts Einstein's equations with cosmological constant which - like also Newton's constant- can in principle depend on extremal [K116], and perhaps be even replaced with several analogs of cosmological constant which are position dependent: it seems that this option is not promising.

   Horizon property is preserved since nothing can escape from Euclidian region to Minkowskian region. The reason is that in Euclidian region the square of four-velocity is negative and in Minkowskian region positive or zero unless a tachyon is in question. Note that the 4-metric becomes degenerate at horizon in time direction. Minkowskian QFT description inside TGD blackhole is definitely lost. As a matter of fact, it seems that any physical object by definition corresponds to a system with horizon in which the signature of the induced metric changes. One can also say that any physical object can appear as a line of generalized Feynman diagram understood as Euclidian space-time region whose M^4 projection can be arbitrarily large. Blackholes would be replaced with a much larger variety of objects with horizon to which an appropriate generalization of the ideas of blackhole physics might apply. This would represent TGD counterpart for AdS/CFT correspondence with AdS replaced with space-time surface and conformal field theory assigned with light like 3-surface and partonic 2-surface and tangent space data by strong form of holography.

2. The assumption about fixed space-time might be unacceptable in the case of blackhole even in the length scales of order Schwarzschild radius.

   In TGD framework the notion of many-sheeted space-time (see **Fig. ??** in the appendix of this book) leads to the hierarchy of effective Planck constants [L6]. This hierarchy suggests that black holes could be macroscopic quantum systems. In particular, the degrees of freedom associated with the "world of classical worlds" (WCW) could not be approximated as being frozen anymore so that QFT description would fail. Even outside the blackhole the presence of magnetic flux quanta suggested to mediate gravitational and also other interactions [K93] brings in new highly non-trivial essentially non-local degrees of freedom.

3. In GRT framework EP is assumed in the form that M^4 QFT describes physics locally in the low curvature regions, and applies also below horizon as long as curvature is not too large.

   In TGD framework this form of EP need not make sense in TGD, and certainly not so at the boundary of Minkowskian and Euclidian regions defining the TGD counterpart of blackhole horizon. EP as Einstein's equations makes sense in TGD although the equations do not follow from a variational principle but as a property of preferred extremals guaranteeing a generalization of 2-D conformal invariance to 4-D context. Gravitational constant and parameter Λ are predictions of classical theory rather than inputs.

4. Blackhole thermodynamics suggests that information about the state of matter collapsed into blackhole is lost. This leads to blackhole information paradox (see http://tinyurl.com/9a58c).

   The Unruh effect (see http://tinyurl.com/28xm9o) [B9, B23] (see http://tinyurl.com/msr3p4) suggests a possible solution to the problem.

   (a) Consider a system accelerated with constant acceleration a. A convenient coordinate system is $M^2 \times E^2$ such that acceleration in M^2. The coordinates for M^2 are 2-D variant of Robertson-Walker coordinates: $(t, x) = a(sinh(\eta), \pm cosh(\eta))$, where $\pm$ corresponds to the two disjoint components L and R of the set $t^2 - x^2 < 0$ of M^2. The orbit of the accelerated system correspond to the $a = constant$ hyperbola with a proportional to the inverse of acceleraton. At the limit of infinite acceleration one obtains orbit at the boundary of 2-D light-cone defining Rindler horizon (see http://tinyurl.com/y7k4vvwq) [B6].

   (b) For an accelerated observer it is natural to quantize field theory in the right wedge R and the vacuum of full M^4 QFT is sum over products of state in L and R. For large values of acceleration these states have nearly maximal entanglement. The tracing over L or R yields thermal density matrix with temperature equal to $a/2\pi$, a the acceleration.

   (c) The analogies with blackhole horizon are obvious, which leads to the idea that Hawking radiation is like Unruh radiation and Hawking temperature is analogous to Unruh temperature. The problem is that speaking about acceleration in Minkowski space in GRT, where geodesic motion corresponds to a vanishing acceleration, does not seem to make sense.

   TGD can be seen as sub-manifold gravity and this changes the situation. The geodesic lines at space-time surface are not geodesic lines of the embedding space, and therefore have non-vanishing trace of second fundamental form as curves of embedding space rather than space-time surface. The M^4 part of the second fundamental form defines acceleration. What is also intriguing that $M^4 = M^2 \times E^2$ decomposition appears in quantum TGD at fundamental level having both purely physical and number theoretical justification. Could this decomposition define also the analogs of Rindler wedges and Unruh decomposition? Could one see the TGD counterpart of Hawking gravitation as a "kinematic effect" very much analogous to Unruh radiation?

5. Blackhole time evolution is assumed to be unitary and Hawking evaporation is assumed to be a unitary process.

   In TGD M-matrix replaces S-matrix identifiable as a product of hermitian square root of density matrix and unitary universal S-matrix [K71]. M-matrices and thus hermitian square roots define an orthonormal basis. The original mathematically attractive idea that U-matrix reduces to a unitary U-matrix constructed from M-matrices by taking them as rows turned out to be wrong.

   The M-matrices associated with CDs obtained by a discrete scaling characterized by integer n from the minimal CD are naturally proportional to S^n, where S is the S-matrix associated with the minimal CD. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power S^n of S.

   U-matrix elements between M-matrices for various CDs are proportional to the inner products $Tr[S^{-n_1} \circ H^i H^j \circ S^{n_2} \lambda]$, where λ represents unitarily the discrete Lorentz boost relating the moduli of the active boundary of CD and H^i form an orthonormal basis of Hermitian square roots of density matrices. $\circ$ tells that S acts at the active boundary of CD only. I turns out possible to construct a general representation for the U-matrix reducing its construction to that of S-matrix.

   Quantum dynamics can be seen as a sequence of quantum jumps to which one can assign state preparation, state function reduction and unitary process. At ensemble level (for sub-CDs of CD) one has dissipation and blackhole like system is like any other macroscopic quantum system. There is also hierarchy of space-time sheets and small space-time sheets defined dissipating ensembles. The entire system however behaves unitarily. In reality one must take also the interactions of blackhole with environment into account so that exact unitary holds only for this system.

In TGD based quantum theory state function reduction (describe in more detail in the chapter "About the Nature of time" (see `http://tinyurl.com/yblbzk6x`) [K8] is the basic element of quantum dynamics. One has sequences of unitary evolutions followed by state function reductions. TGD space-time is many-sheeted so that these evolutions appear in many scales characterized by the size scales of causal diamonds (CDs). In the scale of CD assignable to blackhole the time scale characterizing the unitary evolution at the space-time sheet of blackhole is certainly very long so that unitary at this space-time sheet should be a good approximation. For small sub-CDs situation changes and one can assign the ensembles formed by them growing entropy.

6. In quantum gravity Planck length scale is often assumed to be something fundamental. This could quite well be an illusion produced by dimensional analysis.

   In TGD framework CP_2 length scale which is of order 10^4 times Planck length scale defines the fundamental length scale with concrete geometric interpretation and Planck length scale emerge only as formal scale which need not have any geometrical correlate.

7. In TGD framework the replacement of fixed space-time with WCW spinor field defined as quantum superposition of space-times resolves the problems related to black holes according to general relativity and string theory. One can say that unique space-time "emerges" as a useful but fictitious notion analogous to electron's orbit in hydrogen atom.

9.9.3 Relating The Terminology Of Blackhole Evaporation To TGD Framework

It is useful to consider the terminology related to blackhole, black hole evaporation, and entanglement from TGD point of view.

Blackhole and observers

1. *Horizon*: the surface inside which the escape velocity for particles larger than c. Time coordinate and radial coordinate change their roles. For the embedding of Schwarzschild metric in $M^4 \times CP_2$ this happens quite concretely.

   In TGD interior of blackhole like state has Euclidian metric and the boundary between Minkowskian and Euclidian regions acts like a causal horizon.

2. *Stretched horizon*: Horizon replaced with a layer of thickness Planck length.

   This notion could has a counterpart in TGD although the scale in question is much larger than Planck length. Particles just outside the TGD horizon as wormhole contacts connected by magnetic flux tubes to the horizon which is very large wormhole contacts as far as M^4 projection is considered.

3. *Rindler wedges*: Blackhole horizon approximated as Rindler horizon in GRT. One approximates the situation using QFT in $M^4 = M^2 \times E^2$ where M^2 has hyperbolic coordinates motivated by the fact that the orbit of particle with constant acceleration is hyperbola. Minkowski vacuum in the accelerating system described by right Rindler wedge is seen as almost maximally entangled state in tensor product of the two sides of the wedge. In GRT framework this approximation is questionable since acceleration is questionable notion: it vanishes for geodesic lines.

   What about TGD?

   (a) In TGD framework blackhole horizon cannot be approximated as Rindler horizon since the interior of TGD blackhole is Euclidian. What is how intriguing that $M^2 \subset M^4$ inclusion appears in TGD framework in key role. Also Rindler wedge involves preferred

M^2 determined by the direction of acceleration. The trace of the second fundamental form defines acceleration like variable for any sub-manifold and for 1-D curve in particular. Only the right Rinder wedge is realized as Minkowskian region at wormhole throats. Therefore it does not make sense to speak about Unruh effect and Hawking radiation at horizon since Minkowski vacuum is not a sensible approximation here.

(b) Generalized form of holography however suggests that horizon is mathematically and physically equivalent with any parallel light-like 3-surfaces forming a slicing around the horizon. For them Rindler wedges make sense and one would obtain the analog of Hawking radiation as Unruh effect.

(c) Rindler edges could be also interpreted as outside of the CD and the motion of particle in this region as motion in gravitational field created by matter outside CD. CD resembles blackhole at the level of embedding space. Outside has also interpretation in terms of interior of another CD.

Entanglement

There are some notions related to entanglement. Purifying entanglement for density matrix of system B means existence of a system R_B such that R_BB is pure - in other worlds the density matrix of B is obtained by tracing over R_B.

Almost maximal entanglement means that the density matrix of second entangled system obtained by tracing is in near unit matrix. The monogamy of maximal entanglement states that a given system cannot have maximal entanglement with to disjoint systems is the core of the argument leading to the firewall paradox.

Alice is argued to see a mirror system inside horizon maximally entangled with Bob: $A\heartsuit B$ in the notation half-jokingly introduced by Lubos Motl Notl who seems maximal entanglement as love (personally I prefer see negentropic entanglement as correlate of love and various kinds of positive emotions such as experience of understanding).

Hawking radiation

Early radiation R and late radiation R' are assumed to combine to form a pure state RR', which is maximally entangled. If a unitary matrix multiplied by a projection operators to R and R' (P_1SP_2) defines the entanglement coefficients, maximal entanglement is obtained.

What could this correspond in TGD? Zero energy ontology (ZEO) implies that density matrix is replaced with M-matrix defining time-like entanglement coefficients. M-matrix as counterpart of S-matrix is not unitary. Unitary matrix U however exists and has M-matrices as its rows. Quantum evolution is a sequence of quantum jumps reducing to state function reductions at the upper and lower boundaries of CD. Unitary evolution relates to each other the two basis of zero energy associated with opposite boundaries. These differ in that positive/zero energy part of state is prepared whereas the second part of state is superposition of states with different particle numbers and with ill-defined single particle quantum numbers.

9.9.4 Could Blackhole Evaporation Have A TGD Counterpart?

Basically any burning process is analogous to blackhole evaporation in TGD framework since Euclidian region defines a space-time counterpart for a system in any length scale. Blackhole is different only because the gravitational field outside horizon is so strong that its stability with respect to small perturbations forced the generation of Euclidian region. This is enough to explain what we can observe about blackholes.

TGD counterpars of blackholes

In TGD based on ZEO the description of the TGD counterpart of blackhole looks different.

1. The TGD counterpart of blackhole is described by zero energy state to which one can assign a causal diamond (CD). At embedding space level of CD is very much like horizon since the induced metric is degenerate. The region outside CD is like Rindler wedge for $M^2 \subset M^4$.

For sub-CDs these wedges would look natural and gravitational field could correspond to that created by sub-CD. Therefore it seems that horizons are obtained both at embedding space level and space-time level.

2. Wormhole throats are counterparts of black hole like states at space-time level. Blackhole horizon is replaced by horizon at which the induced metric becomes Euclidian. This horizon is also a causal horizon: nothing leaks from the interior since 4-metric becomes degenerate at the horizon. One cannot anymore apply Rindler wedge argument at the horizon and the argument that Alice sees a state in which blackhole interior and distant observer are maximally entangled is lost. One gets rid of firewall paradox since one does not anymore have maximal entanglement of same system B with two different systems.

3. Strong form of holography holds true. Partonic 2-surfaces and their 4-D tangent space data (string world sheets) code for physics. Generalized blackhole horizon can be said to carry the matter. Particles can condense around horizon (see `http://tinyurl.com/y89xp4bu`). Elementary particles correspond to structures involving wormhole contacts connected by Minkowskian magnetic flux tubes at parallel space-time sheets and combining to form a closed magnetic flux tube. The wormhole contact at the second end of the flux tube can attach to the horizon. This gives rise to a real firewall [K81], and the simplest model for blackhole would be as this kind of hollow spherical structure. The topology of Euclidian region can be more complex than that of the interior of sphere since wormhole flux tubes with Minkowskian signature can be present in interior.

4. The interior of the ordinary blackhole can be isolated from the external world. In TGD framework one cannot assume this. Magnetic flux tubes can connect the wormhole contacts associated with particles very near to horizon and horizon itself to distant system. Gravitational and also other interactions are mediated along this kind of flux tubes and make possible for black hole to exchange energy with external world. At the microscopic level the description in the case of fermions (right handed neutrino is an exception) reduces to string world sheets at which the fermionic modes are localized [K116] by very general arguments. Hence the analog of AdS/CFT duality is realized.

5. The exterior of TGD counterpart of genuine blackhole like in general relativity apart from embedding to $M^4 \times CP_2$. Also the interior of blackhole allows embedding down to some critical radius. At horizon, where $g_{tt} = 1/g_{rr} = 0$ holds true, a small deformation of g_{rr} makes the horizon a light-like surface and 4-metric degenerate. Hence it is natural to assume that blackhole interior has Euclidian metric in TGD framework. In the simplest case matter resides very near to the causal horizon which is now light-like 3-surface at which space-time surface is effectively 3-dimensional metrically. Approximation by Minkowskian physics certainly fails at horizon and below it. The argument leading to firewall paradox is lost.

6. In TGD framework evolution by quantum jumps realized as state function reductions is a key element of quantal evolution. Also blackhole evolution takes place as a sequence of quantum jumps between zero energy states assignable to light-like boundaries of causal diamond (CD) accompanying blackhole. Therefore loss of information is not a problem. TGD view about quantum jump leads to a rather radical revision of views about the relationship between geometric time and experienced time as well as about the notion of arrow of time already characterizing zero energy states in the sense that positive/negative energy state at upper/lower boundary of CD is prepared and the state at opposite boundary is superposition of states with different particle numbers and ill defined single particle quantum numbers.

7. Density matrix is replaced by M-matrix defined as a product of a hermitian square root of density matrix and unitary S-matrix. One can say that TGD is square root of thermodynamics. The series of state function reductions thermalizes ensembles and now subsystems defined by sub-CDs become thermal ensemble. CD itself can be said to evolve unitarily at the level of U-matrix. If density matrix is projection operator, then maximal entanglement is obtained between positive and negative energy states.

What blackholes could be in TGD Universe?

The first question is what blackholes in TGD are. One can consider this question at level of pure TGD and at the GRT limit of TGD for which space-time metric in standard Minkowski coordinates is obtained as sum of Minkowski metric and deviations of the metrics of space-time sheets from M^4 metric having non-empty projection to the M^4 region considered. This picture fails when one cannot represent space-time surface as graph of a map from M^4 to CP_2.

1. Cosmic strings dominating during primordial cosmology are objects of this kind and the transition from cosmic string dominated cosmology to radiation dominated one corresponds to the analog of inflationary period in TGD.

2. Also the CP_2 type vacuum extremals and their deformations representing lines of generalized Feynman diagrams fail to have description in terms of GRT unless one allows generalization of GRT allowing also Euclidian signature of space-time metric. CP_2 indeed represents a solution of Einstein-Maxwell equations with cosmological constant determined by CP_2 size scale. The natural microscopic counterparts of blackholes in TGD Universe would the lines of generalized Feynman diagrams for which the projection of deformed CP_2 type extremal has astrophysical size so that blackhole would be very much like elementary particle.

The notion of gravitational Planck constant h_{gr} inspired by the work of Nottale and identical with h_{eff} inspired by the findings of bio-electromagnetism is what distinguishes quantum TGD sharply from other theories of quantum gravitation where Planck constant has its ordinary value.

1. The proposal is that the value of $h_{eff} = h_{gr}$ equals to the sheets of the effective covering of embedding space allowing to represent preferred extremals connecting space-like 3-surfaces at the ends of causal diamond and having same Kähler action and possibly also conserved classical isometry charges. This is essentially sub-manifold gravity. Furthermore, second quantization occurs for these multi-furcations in the sense that one can speak of many particle states having discrete wave function in the set of branches of the multi-furcation.

   h_{gr} can be assigned with the magnetic flux tube connecting two massive objects with masses M and m and Equivalence Principle implies the general formula $\hbar_{gr} = GMm/v_0$, where v_0 is a characteristic rotational velocity scale associated with the two-particle system.

2. Notice that similar formula is expected to hold true for the flux tubes mediating other interactions so that for electromagnetic interaction one would have $h_{eff} = h_{em} = Z_1Z_1e^2/v_0$. The formula could make sense even for color interaction. Since the generic dimensionless coupling $\alpha_g = g^2/4\pi h_{eff}$ is inversely proportional to h_{eff}, this implies that perturbation theory converges in this phase. $h_{eff}/h \geq 1$ follows if one assumes the quantization rule $h_{eff} = nh$ so that the transition to dark matter phase would occur only when perturbation theory fails.

   Plasma phase would be excellent candidate for a system where strong electromagnetic interaction between highly charged plasma regions leads to the formation of dark matter. The finding of Pollack that the irration of water bounded by gel phase leads to a formations of negatively charged exclusion zones with positive charge outside would be a good example of the phenomenon. h_{em} would be proportional to the square of the total charged generated in exclusion zone. h_{gr} for the pair of systems involved would be product of their masses.

3. The Universal value for gravitational Compton length is given by GM/v_0 and does not depend on the mass of the test particles. This realizes Equivalence Principle and implies quantum coherence in the sense that one obtains same result by applying the Bohr quantization rules to elementary particles forming the system or to the entire system. Gravitational interaction is clearly optimal for macroscopic quantum coherence.

4. Since the velocity parameter satisfies $v_0/c < 1$, the Compton length is larger than Schwartschild radius for $v_0 > 1/\sqrt{2}$ so that quantal effects would make themselves visible even above the Schwartschild radius. Clearly, it might be more appropriate to identify gravitational quantum Compton length as the scale in which quantum gravitation becomes important. It also seems that the notion of blackhole must be replaced with quantum gravitational object with

this radius. For instance, Earth's radius is roughly twice the gravitational Compton length for Earth-Sun system.

For Sun the assumption that v_0 corresponds to the rotation velocity of the particle at the surface of Sun implies that the radius at which transition to quantum phase occurs equals roughly to the radius of solar core inside which nuclear fusion takes place.

Blackholes are characterized by temperature and entropy. Zero energy ontology leads to the idea about quantum TGD as square root of thermo- dynamics and suggests strongly that even ordinary temperature and entropy have space-time correlates.The fact that M-matrices are products of unitary S-matrices and hermitian square roots of density matrices, supports this guess. Square roots of Boltzmann weights involving a phase factor could provide a simple phenomenological description of cell membrane as Josephson junction [K38] having ordinary thermodynamical description as limit.

If there indeed is a connection with ordinary thermodynamics, one expects that TGD counterpart of blackhole evaporation corresponds to ordinary thermal radiation. Gravitational radiation would escape along massless extremals glued to (gravi)- magnetic flux tubes connecting the stellar objects to environment. Em radiation should escape along magnetic flux tubes with Planck constant equal to h_{em}. The geometric differences between the flux tubes would be reflected by the value of n.

Could TGD counterparts of blackholes evaporate?

Could TGD counterparts of blackholes evaporate? The above summary written years after what follows in the sequel already answers this question affirmatively. The following discussion gives a different point without mentioning h_{gr}.

1. One could see the most general TGD counterparts of blackholes as ordinary macroscopic bodies with the space-time sheet representing the object having Euclidian signature of metric in the space-time region defined by the body. As noticed, this region can be topologically a sphere with handles represented as Minkowskian wormholes connecting separate parts of spherical horizon. Therefore the analog of thermal radiation would make sense. Hawking evaporation poses much stronger condition. Elementary particles represent limiting cases of Euclidian regions and electron is stable against decays and also against evaporation of this kind. General TGD blackholes need not have any special gravitational properties. In the case of genuinely blackhole like states, one can also restrict the situation so that the exterior metric is Reissner-Nordström vacuum in good approximation.

2. An attractive manner to interpret Hawking evaporation in the standard framework is by approximating the horizon by Rindler horizon. This leads the study of effectively 2-D Rindler wedge in Minkowski space assignable to accelerated system. The two sides of the wedge correspond to their own Rindler vacua and Minkowski vacuum is sum over pairs of states at both sides so that one obtains thermal spectrum of particle states with Unruh temperature. Accelerated observer would be continually boosted so that the hyperbolic angle η would grow. Accelerated observer would see Hawking radiation.

Does it make sense to speak about accelerated observers at fundamental level? The following little argument suggests that one cannot speak about Hawking radiation at horizon. This conforms with the intuitive idea that Hawking radiation is created outside the horizon.

1. One can assign to each point of space-time surface a generalization of acceleration vector as M^4 part of the trace of second fundamental form. For preferred extremals the trace of the second fundamental form would actually vanish since they are minimal surfaces.

   One can also consider second fundamental form for curves - say geodesics. This has both M^4 and CP_2 parts and does not vanish in general. The orbit of the boundary of string world sheet along light-like 3-surface is one possible identification. Braid strands, which can be both time-like and space-like, could be seen as analogs of accelerated observers with acceleration defined by M^k. The decomposition $M^4 = M^2 \times E^2$ with Rindler coordinates and Rindler decomposition of the M^4 vacuum at each point of the curve would give one further function for $M^2 \subset M^4$ dictated by several general arguments.

2. At the horizon of TGD blackhole the metric changes to Euclidian. Also the dimension of M^4 projection becomes at most $D = 3$ if the proposed

   general solution ansatz for preferred extremals is correct [K116]. Hence the description as Rindler horizon and the approximation by M^4 QFT fails at and below the horizon. This is counterpart for the firewall. This holds true for all braid strands defining orbits along wormhole throats. For space-like string curves situation is different but now a tachyon would be in question. Hence one cannot speak about Unruh radiation and Hawking radiation at horizons and below them.

Could one generalize the notion of hologram from wormhole orbit so that Hawking radiation would result as Unruh radiation? This is possible to imagine.

1. One can consider a slicing of space-time sheet by "parallel" light-like 3-surfaces in the vicinity of given wormhole throat. If it is possible to make measurements at these light-like 3-surfaces, one could have QFT in M^4 as an approximation and have Rindler decomposition, Unruh effect, and Hawking radiation beyond Schwarzschild radius r_s.

2. In WCW geometry strong form of GCI implying strong form of holography suggests that any choice of light-like 3-surface in a slicing of space-time sheet by light-like 3-surfaces is equally goo, and means only a transformation of the Kähler function of WCW by adding to it a real part of holomorphic function induced gauge transformation of Kähler gauge potential of WCW . This does not affect WCW metric and should not affect physics either. Wormhole throats would be of course in a preferred position physically.

3. More precisely, at the wormhole throat the vacuum state is right Rindler vacuum R. At larger distances Minkowski vacuum makes sense approximately and is in reasonable approximation expressible as a sum over tensor products of states of R and L, and both L and R have thermal density matrix resulting in tracing with acceleration defining the Unruh temperature given by the trace of the second fundamental form for the curve (geodesic in question) [B9, B23]. At very small distances from wormhole throat QFT approximation works only for very high energies at the left hand side.

Final remark: I have suggested a p-adic version of Hawking-Bekenstein formula holding true at elementary particle level [K76]. Maybe p-adic thermodynamics could replace blackhole thermodynamics in the case of elementary particles at least.

The conclusion is that blackhole and blackhole evaporation have TGD based generalization. The notion of blackhole like state would be very general and can be assigned with any physical system with a well-defined geometric shape (defined by the Euclidian space-time sheet). Gravitational blackholes would be only special cases. The notion of Hawking radiation identified as Unruh radiation could also make sense, and one could understand Rindler coordinates in terms of $M^2 \subset M^4$ decomposition central for quantum TGD. It is however essential that the acceleration parameter characterizing this radiation is defined by the trace of second fundamental form in the embedding space: here GRT approach can be criticized of internal inconsistency. Since the interior of any TGD blackhole is Euclidian - this is absolutely essential- the argument leading to the firewall paradox fails. Horizon is in TGD framework a genuine firewall but this does not mean a failure of Equivalence Principle which only says only that Einstein's equations hold true for preferred extremals: Minkowskian QFT is always a good local approximation. A further important notion is astroscopic quantum coherence characterized by h_{gr}. Quantum gravitational Compton length GM/v_0, v_0 the rotational velocity of astrophysical object suggests itself as a proper parameter characteristizing the boundary quantum gravitational realm.

9.10 New View About Black-Holes

In TGD framework the embedding of the interior metric of ordinary black-holes fails and there is a good argument suggesting that horizon is transformed to a "partonic" light-like 3-surface at which the signature of the induced metric changes [K111]. Black-hole would be replaced by a gigantic particle having no electro-weak interactions since the state would be created using super-symplectic generators and generate its mass via p-adic thermodynamics. Schwartschild radius equals to Compton length if the generalization of Nottale formula for Planck constant holds true. Super-symplectic black-holes behave as dark matter and are very natural final states of the star and follow naturally neutron star phase. Also a microscopic description of black-hole as a gigantic hadron emerges. $\mathcal{N} = \infty$ SUSY formulated in [?] is a good candidate for the formulation of a first principle theory for the description of the anyonic state.

9.10.1 Anyonic View About Blackholes

A new element to the model of black hole comes from the vision that black hole horizon as a light-like 3-surface corresponds to a light-like orbit of light-like partonic 2-surface. This allows two kinds of black holes. Fermion like black hole would correspond to a deformed CP_2 type extremal which Euclidian signature of metric and topologically condensed at a space-time sheet with a Minkowskian signature. Boson like black hole would correspond to a large wormhole contact connecting two space-time sheets with Minkowskian signature. Wormhole contact would be a piece deformed CP_2 type extremal possessing two light-like throats defining two black hole horizons very near to each other. It does not seem absolutely necessary to assume that the interior metric of the black-hole is realized in another space-time sheet with Minkowskian signature.

Second new element relates to the value of Planck constant. For $\hbar_{gr} = 4GM^2$ the Planck length $L_P(\hbar) = \sqrt{\hbar G}$ equals to Schwartschild radius and Planck mass equals to $M_P(\hbar) = \sqrt{\hbar/G} = 2M$. If the mass of the system is below the ordinary Planck mass: $M \leq m_P(\hbar_0)/2 = \sqrt{\hbar_0/4G}$, gravitational Planck constant would be smaller than the ordinary Planck constant. If only coverings are allowed -as is the case if the hierarchy of Planck constants follows from basic TGD- these values of Planck constant are not possible.

Blackhole surface contains ultra dense matter so that perturbation theory is not expected to converge for the standard value of Planck constant but do so for gravitational Planck constant. If the phase transition increasing Planck constant is a friendly gesture of Nature making perturbation theory convergent, one expects that only the black holes for which Planck constant is such that $GM^2/4\pi\hbar < 1$ holds true are formed. Black hole entropy for given sheet of the covering -being proportional to $1/\hbar$- is of order unity so that TGD black holes are not very entropic. The entire blackhole entropy is just the standard black hole entropy since there are $\hbar/\hbar_0$ sheets in the covering. This would suggest that entropy serves as a control variable in the sense that when it exceeds the threshold value, the partonic 2-surfaces at the ends of CD split to a surfaces in the covering.

The model of anyons and fractional quantum Hall effect [K81] leads to the conclusion that various charges are fractionized so that a partonic 2-surface possessing given charges splits in the interior of space-time surface to $n_a n_b$ components with same fractional charge $1/n_a n_b$. The ends of space-time sheet split to n_b components with charges coming as multiples of $1/n_b$ and wormholes to n_a components with charges coming as multiples of $1/n_a$. In CD degrees of freedom fractionization can occur only if the partonic 2-surface enloses the tip of CD. This would mean spin fractionization.

If the partonic 2-surface surrounds the tip of causal diamond CD, the matter at its surface is in anyonic state with fractional M^4 charges and CP_2. Otherwise only CP_2 charges are fractional. Anyonic black hole can be seen as single gigantic elementary particle stabilized by fractional quantum numbers of the constituents preventing them from escaping from the system and transforming to ordinary visible matter. For F-C option a huge number of different black holes are possible for a given value of $\hbar$ since there is infinite variety of pairs (n_a, n_b) of integers giving rise to same value of $\hbar$. For C-C option possibly - which possibly reduces to the basic quantum TGD - the number of black holes corresponds to the number of decompositions of $n = n_a n_b$ to a product.

One can imagine that the partonic surface is not exact sphere except for ideal black holes but contains large number of magnetic flux tubes giving rise to handles. Also a pair of spheres with different radii can be considered with surfaces of spheres connected by braided flux tubes. The braiding of these handles can represent information and one can even consider the possibility that black hole can act as a topological quantum computer. There would be no sharp difference between the dark parts of black holes and those of ordinary stars. Only the volume containing the complex flux tube structures associated with the orbits of planets and various objects around star would become very small for black hole so that the black hole might code for the topological information of the matter collapsed into it.

9.10.2 Super-Symplectic Bosons

TGD predicts also exotic bosons which are analogous to fermion in the sense that they correspond to single wormhole throat associated with CP_2 type vacuum extremal whereas ordinary gauge bosons corresponds to a pair of wormhole contacts assignable to wormhole contact connecting positive and negative energy space-time sheets. These bosons have super-conformal partners with quantum numbers of right handed neutrino and thus having no electro-weak couplings. The bosons are created by the purely bosonic part of super-symplectic algebra [K29, K116], whose generators belong to the representations of the color group and 3-D rotation group but have vanishing electro-weak quantum numbers. Their spin is analogous to orbital angular momentum whereas the spin of ordinary gauge bosons reduces to fermionic spin. Recall that super-symplectic algebra is crucial for the construction of WCW Kähler geometry. If one assumes that super-symplectic gluons suffer topological mixing identical with that suffered by say U type quarks, the conformal weights would be (5, 6, 58) for the three lowest generations. The application of super-symplectic bosons in TGD based model of hadron masses is discussed in [K74] and here only a brief summary is given.

As explained in [K74], the assignment of these bosons to hadronic space-time sheet is an attractive idea.

1. Quarks explain only a small fraction of the baryon mass and that there is an additional contribution which in a good approximation does not depend on baryon. This contribution should correspond to the non-perturbative aspects of QCD. A possible identification of this contribution is in terms of super-symplectic gluons. Baryonic space-time sheet with $k = 107$ would contain a many-particle state of super-symplectic gluons with net conformal weight of 16 units. This leads to a model of baryons masses in which masses are predicted with an accuracy better than 1 per cent [K63].

2. Hadronic string model provides a phenomenological description of non-perturbative aspects of QCD and a connection with the hadronic string model indeed emerges. Hadronic string tension is predicted correctly from the additivity of mass squared for $J = 2$ bound states of super-symplectic quanta. If the topological mixing for super-symplectic bosons is equal to that for U type quarks then a 3-particle state formed by 2 super-symplectic quanta from the first generation and 1 quantum from the second generation would define baryonic ground state with 16 units of conformal weight. A very precise prediction for hadron masses results by assuming that the spin of hadron correlates with its super-symplectic particle content.

3. Also the baryonic spin puzzle caused by the fact that quarks give only a small contribution to the spin of baryons, could find a natural solution since these bosons could give to the spin of baryon an angular momentum like contribution having nothing to do with the angular momentum of quarks.

4. Super-symplectic bosons suggest a solution to several other anomalies related to hadron physics. The events observed for a couple of years ago in RHIC [C9] suggest a creation of a black-hole like state in the collision of heavy nuclei and inspire the notion of color glass condensate of gluons, whose natural identification in TGD framework would be in terms of a fusion of hadronic space-time sheets containing super-symplectic matter materialized also from the collision energy. In the collision, valence quarks connected together by color bonds to form separate units would evaporate from their hadronic space-time sheets in the collision, and would define TGD counterpart of Pomeron, which experienced a reincarnation for few years ago [C12]. The strange features of the events related to the collisions of high energy cosmic rays with hadrons of atmosphere (the particles in question are hadron like but the penetration length is anomalously long and the rate for the production of hadrons increases as one approaches surface of Earth) could be also understood in terms of the same general mechanism.

5. RHIC events have features which suggest that color glass condensate is very much analogous to a black-hole. This analogy has a precise formulation. Super-symplectic matter has no electro-weak interactions and is therefore dark matter in a strict sense. The exchange of super-symplectic $J = 2$ quanta brings in gravitation and string mass formula holds true. The value of the gravitational constant is however determined by hadronic p-adic length

scale rather than CP_2 length scale so that strong gravitation is in question. This picture leads naturally to the question whether ordinary black-holes should be replaced by super-symplectic black-holes in TGD Universe as a natural final step of stellar evolution after the neutron star phase during which star already behaving like a gigantic hadron in super-symplectic degrees of freedom.

9.10.3 Are Ordinary Black-Holes Replaced With Super-Symplectic Black-Holes In TGD Universe?

Some variants of super string model predict the production of small black-holes at LHC. I have never taken this idea seriously but in a well-defined sense TGD predicts black-holes associated with super-symplectic gravitons with strong gravitational constant defined by the hadronic string tension. The proposal is that super-symplectic black-holes have been already seen in Hera, RHIC, and the strange cosmic ray events [K68].

Baryonic super-symplectic black-holes of the ordinary M_{107} hadron physics would have mass 934.2 MeV, very near to proton mass. The mass of their M_{89} counterparts would be 512 times higher, about 478 GeV. "Ionization energy" for Pomeron, the structure formed by valence quarks connected by color bonds separating from the space-time sheet of super-symplectic black-hole in the production process, corresponds to the total quark mass and is about 170 MeV for ordinary proton and 87 GeV for M_{89} proton. This kind of picture about black-hole formation expected to occur in LHC differs from the stringy picture since a fusion of the hadronic mini black-holes to a larger black-hole is in question.

An interesting question is whether the ultrahigh energy cosmic rays having energies larger than the GZK cut-off of 5×10^{10} GeV are baryons, which have lost their valence quarks in a collision with hadron and therefore have no interactions with the microwave background so that they are able to propagate through long distances.

In neutron stars the hadronic space-time sheets could form a gigantic super-symplectic black-hole and ordinary black-holes would be naturally replaced with super-symplectic black-holes in TGD framework (only a small part of black-hole interior metric is representable as an induced metric). This obviously means a profound difference between TGD and string models.

1. Hawking-Bekenstein black-hole entropy would be replaced with its p-adic counterpart given by

$$S_p = (\frac{M}{m(CP_2)})^2 \times log(p) \ , \tag{9.10.1}$$

   where $m(CP_2)$ is CP_2 mass, which is roughly 10^{-4} times Planck mass. M is the contribution of p-adic thermodynamics to the mass. This contribution is extremely small for gauge bosons but for fermions and super-symplectic particles it gives the entire mass.

2. If p-adic length scale hypothesis $p \simeq 2^k$ holds true, one obtains

$$S_p = klog(2) \times (\frac{M}{m(CP_2)})^2 \ . \tag{9.10.2}$$

   Here one has $m(CP_2) = \hbar_0/R$, R the length of the geodesic of CP_2.

3. Hawking-Bekenstein area law gives in the case of Schwartschild black-hole

$$S = \frac{A}{4G\hbar} = \frac{\pi G M^2}{\hbar} \ . \tag{9.10.3}$$

For the p-adic variant of the law Planck mass is replaced with CP_2 mass and $klog(2) \simeq log(p)$ appears as an additional factor. Area law is obtained in the case of elementary particles if k is prime and wormhole throats have M^4 radius given by p-adic length scale $L_k = \sqrt{k}R$ which is exponentially smaller than L_p. For macroscopic super-symplectic black-holes modified area law results if the radius of the large wormhole throat equals to Schwartschild radius. Schwartschild radius is indeed natural: in [K111] I have shown that a simple deformation of the Schwartschild exterior metric to a metric representing rotating star transforms Schwartschild horizon to a light-like 3-surface at which the signature of the induced metric is transformed from Minkowskian to Euclidian. For large values of $\hbar$ the Hawking-Bekenstein entropy becomes very small.

4. The formula for the gravitational Planck constant appearing in the Bohr quantization of planetary orbits and characterizing the gravitational field body mediating gravitational interaction between masses M and m [K93] reads as

$$\hbar_{gr} = \frac{GMm}{v_0}\hbar_0 \ .$$

$v_0 = 2^{-11}$ is the preferred value of v_0. One could argue that the value of gravitational Planck constant is such that the Compton length $\hbar_{gr}/M$ of the black-hole equals to its Schwartshild radius. This would give

$$\hbar_{gr} = \frac{GM^2}{v_0}\hbar_0 \ , \quad v_0 = 1/2 \ . \tag{9.10.4}$$

The requirement that $\hbar_{gr}$ is a ratio of ruler-and-compass integers expressible as a product of distinct Fermat primes (only four of them are known) and power of 2 would quantize the mass spectrum of black hole [K93]. Even without this constraint M^2 is integer valued using p-adic mass squared unit and if p-adic length scale hypothesis holds true this unit is in an excellent approximation power of two.

5. The gravitational collapse of a star would correspond to a process in which the initial value of v_0, say $v_0 = 2^{-11}$, increases in a stepwise manner to some value $v_0 \leq 1/2$. For a supernova with solar mass with radius of 9 km the final value of v_0 would be $v_0 = 1/6$. The star could have an onion like structure with largest values of v_0 at the core as suggested by the model of planetary system. Powers of two would be favored values of v_0. If the formula holds true also for Sun one obtains $1/v_0 = 3 \times 17 \times 2^{13}$ with 10 per cent error.

For $\hbar_{gr} = GM^2/v_0$ assignable to binary star with identical masses and for $v_0 = 1/2$ the black-hole entropy for an ideal dark black-hole would be

$$S = \pi \tag{9.10.5}$$

6. Black-hole evaporation could be seen as means for the super-symplectic black-hole to get rid of its electro-weak charges and fermion numbers (except right handed neutrino number) as the antiparticles of the emitted particles annihilate with the particles inside super-symplectic black-hole. This kind of minimally interacting state is a natural final state of star. Ideal super-symplectic black-hole would have only angular momentum and right handed neutrino number.

7. In TGD light-like partonic 3-surfaces are the fundamental objects and space-time interior defines only the classical correlates of quantum physics. The space-time sheet containing the highly entangled cosmic string might be separated from environment by a wormhole contact with size of black-hole horizon.

This looks the most plausible option but one can of course ask whether the large partonic 3-surface defining the horizon of the black-hole actually contains all super-symplectic particles so that super-symplectic black-hole would be single gigantic super-symplectic parton. The interior of super-symplectic black-hole would be a space-like region of space-time, perhaps resulting as a large deformation of CP_2 type vacuum extremal. Black-hole sized wormhole contact would define a gauge boson like variant of the black-hole connecting two space-time sheets and getting its mass through Higgs mechanism. A good guess is that these states are extremely light.

9.10.4 Blackholes do not absorb dark matter so fast as they should

Astronomers claim that blackholes do not absorb dark matter as fast as they should [E267] (see the popular article at `http://tinyurl.com/h6pjxpn` and article at `http://tinyurl.com/ybqzbzhz`). The claim is based on a model for dark matter: if the absorption rate were what one would expect by identifying dark matter as some exotic particle, the rate would be quite too fast and the Universe would look very different.

How could this relate to the vision that dark matter is ordinary matter in large Planck constant phase with $h_{eff} = n \times h = h_{gr} = GMm/v_0$ proposed to be generated at quantum criticality [**?**]? Gravitational Planck constant h_{gr} was originally introduced by Nottale [E87]. In this formula M is some mass, say that of black hole or astrophysical object, m is much smaller mass, say that of elementary particle, and v_0 is velocity parameter, which is assumed to be in constant ratio to the spinning velocity of M in the model for quantum biology explaining biophotons as decay products of dark cyclotron photons.

Could the large value of Planck constant force dark matter be delocalized in much longer scale than blackhole size and in this manner imply that the absorption of dark matter by blackhole is not a sensible notion unless dark matter is transformed to ordinary matter? Could it be that the transformation does not occur at all or occurs very slowly and is therefore the slow bottle neck step in the process leading to the absorption to the interior of the blackhole? This could be the case! The dark Compton length would be $\Lambda_{gr} = h_{gr}/m = GM/v_0 = r_S/2v_0$, and for $v_0/c << 1$ this would give dark Compton wavelength considerable larger than the radius $r_S = 2GM$ of blackhole. Note that dark Compton length would not depend on m in accordance with Equivalence Principle and natural if one accepts gravitational quantum coherence is astrophysical scales. The observation would thus suggest that dark matter around blackhole is stable against phase transition to ordinary matter or the transition takes place very slowly. This in turn would reflect Negentropy Maximization Principle favoring the generation of entanglement negentropy assignable to dark matter.

Chapter 10

Magnetic Bubbles in TGD Universe: Part I

10.1 Introduction

I received a link to a video summarizing the properties of the Local Bubble surrounding the solar system (https://rb.gy/m8slm3). The Local Bubble represents only one example of magnetic bubbles. The magnetic bubble carries a magnetic field with field lines along its surface. Star formation and interstellar gas seems to concentrate on the bubble.

10.1.1 Basic facts about the Local Bubble

The article "*Star formation near the Sun is driven by expansion of the Local Bubble*" by Zucker et al published in Nature [E172] (https://rb.gy/7hdoyo gives basic facts about the Local Bubble surrounding the solar system. The Local Bubble has a radius of about 500 ly. Within 500-light-years of Earth, all stars and star-forming regions sit on the surface of the Local Bubble, but not inside. The total mass is about 10^6 solar masses. The Local bubble is accompanied by magnetized molecular clouds, which reveal the existence of the bubble via the polarization of radio wave radiation.

It is believed that the Local Bubble has been formed in a burst of star formation in the center of the bubble. These stars would have died as supernovae and the matter from supernova explosions would have pushed gas and compressed it to form the Local Bubble. According to the Nature article [E172], the research team calculated that at least 15 supernovae have gone off over millions of years and pushed gas outward, creating a bubble where seven star-forming regions dot the surface.

10.1.2 Magnetic bubbles and TGD view of cosmic expansion as rapid "jerks"

These bubbles bring in mind the large voids (http://tinyurl.com/jyqcjhl), whose boundaries carry galaxies. They are discussed from the TGD point of view in [K2]. One ends up with the question, whether galaxies are formed at the surfaces of large voids and stars at the surfaces of the magnetic bubbles. Could also the formation of planets be understood in this way? TGD predicts that cosmic expansion takes place as rapid "jerks", and this view has application to the mystery of Cambrian Explosion [L55, L113, L102, L131]. Could these local Big-Bangs give rise to a universal mechanism for the formation of structures? If so, then Earth and Moon must have the same composition. The finding that this is indeed the case (https://rb.gy/4sq5ho, came as a total surprise.

The fusion of dark protons at monopole flux tubes to dark proton sequences identified as dark nuclei, which then transform to ordinary nuclei and liberate nuclei binding energy and in this way induce explosion, is the basic step in the formation of astrophysical objects. Dark fusion was originally proposed as a model of "cold fusion" but later generalized to a model for the first step in the formation of stars not yet involving ordinary fusion [L82]. The recently found candidates for population III stars could correspond to these prestellar objects.

Galactic blackholes have been recently found to receive a new contribution to their mass from dark energy identifiable as the energy of cosmic strings in the TGD framework [E126]. The second discovery is that galaxies, which should be the oldest ones on the basis of their distance, are oldest ones on the basis of their age [E140]: zero energy ontology explains this.

A detailed model emerges for the formation of a planetary system as a series of solar explosions as analogs of supernova explosions throwing out a layer of dark matter transforming to ordinary matter, possibly forming a planet. Both the generalization of Nottale's model [E87] for planetary orbits involving gravitational Planck constant and a generalization of the Expanding Earth model are involved. The model explains the composition differences between giant planets and Earth-like planets and also the Kuiper belt as a failed planet and is also applied to giant exoplanets.

10.2 TGD view of magnetic bubbles

The TGD view of magnetic bubbles relies on the prediction that smooth cosmological expansion decomposes to rapid "jerks": this conforms with the fact that individual astrophysical objects do not participate in cosmic expansion. These jerks correspond to local Big-Bangs and explosive events of which supernova explosion is one example. The notion of local Big-Bang means local cosmology characterized by local values of Hubble constant H and cosmological constant Λ characterizing the size scale of the local cosmology.

Explosions create magnetic bubbles as tangles of monopole flux tubes carrying dark matter as a phase of ordinary matter characterized by effective Planck constant $h_{eff} = nh_0$. The notion of gravitational Planck constant $h_{eff} = \hbar_{gr}$, originally introduced originally by Nottale [E87], characterizes the matter at the flux tubes of the magnetic bubble.

10.2.1 Questions about magnetic bubbles

What could be the TGD inspired explanation of the magnetic bubble? Could the standard view of star formation explain it or could TGD provide the new physics possibly needed? One can start by asking questions.

1. The proposed mechanism of formation of the Local Bubble is based on supernova explosions driving the gas to the boundaries of the expanding bubble. Supernova explosions look an attractive idea also in the TGD framework. But is it necessary to assume that the have driven the matter from environment to the boundary of the Local Bubble?

2. What could be the origin of the magnetic fields? Magnetic fields are actually a key mystery of both cosmology and astrophysics according to the standard model. Magnetic fields in cosmological scales should not exist since the currents creating them should have disappeared. Also the understanding of the stability of Earth's magnetic field remains a challenge: also now dissipation should destroy the needed convective currents [L13].

3. TGD leads to the topologization of Maxwellian fields by topological field quantization. The Maxwellian electromagnetic fields of a system are replaced with the field body and TGD counterparts for radiation fields. One can speak of magnetic and electric bodies. Electric bodies are connected by the flux tubes defining the magnetic body. This would give rise to a network having electric bodies as its nodes.

4. Magnetic flux tubes can carry monopole flux and this makes them stable. In particular, no currents are needed to maintain monopole fluxes. If the monopole flux vanishes, the flux tube is unstable against splitting. In the TGD framework the monopole flux tubes have a role analogous to wormholes in general relativity. Flux tubes are necessarily closed and this makes possible flux tube pairs with opposite fluxes assumed to be basic structures somewhat analogous to DNA double strands. These flux tube pairs can also form helical structures.

Origin of magnetic bubbles?

In the TGD picture, galaxies would reside along long monopole flux tubes. Could the proposed general picture allow us to understand the origin of the magnetic bubbles suggesting a description as flux tube-like structures parallel to the surface of the bubble? Could the newly formed stars at the magnetic bubbles reside along the monopole flux tubes at the magnetic bubbles?

1. In the TGD framework, galaxies are associated with long cosmic strings [L63, L69, L111] and would be formed in the thickening of cosmic strings producing flux tubes with a reduced string tension, which induces the decay of the string energy to ordinary matter as an analogue of inflation.

2. Cosmic strings can form local tangles, in particular when they intersect. In these tangles strings thicken and the string tension decreases as the energy transforms to galactic matter. Also stars could be regarded as local tangles of cosmic strings, which are always closed but can also close in short scales.

3. Could the flux tubes associated with the magnetic bubbles correspond to monopole flux tubes that would have induced the observed magnetization of the molecular clouds. In the TGD inspired model for stars [L69], stellar cores involve a flux tube spaghetti [L82]. Could supernova explosions throw out part of this spaghetti as an expanding shell-like structure carrying the flux tubes?

Magnetic bubbles seem to serve seats for the formation of stars and contain concentrations of interstellar gas. Could the magnetic fields in the TGD framework correspond to monopole flux tubes connecting nodes of a network such that nodes are electric bodies to which the stars which are formed can be assigned? Could the monopole flux tubes assignable to the magnetic bubbles serve as seeds for the formation of stars by the standard mechanism in which they attract the interstellar gas which becomes confined to the flux tubes? How do the monopole flux tubes end up on the surface of the bubbles?

Why do the bubbles expand?

It has been found that the bubbles expand. What could be the origin of this expansion?

1. The many-sheeted space-time of TGD is a fractal having space-time sheets with a spectrum of size scales L with possible length scales given in terms of p-adic length scale hypothesis. Cosmological constant is predicted to have a spectrum and depends on L like $\Lambda \propto 1/L^2$ and have large values for short scales. The local expansion would be faster and also its acceleration higher than those associated with the cosmic expansion.

2. Could the expanding bubble be analogous to a local expanding Universe with its own cosmological constant? Local Bubble with radius $R = 10^3$ ly is known to expand with velocity of 6.4 km/s. The cosmic expansion velocity v at distance L from the origin of Robertson-Walker coordinates is given by Hubble law and corresponds $v = HL$ with $H =$ 72 kms^{-1}Mpc^{-1}. The expansion velocity at the radius of the local bubble would be $(7.2/3.26) \times 10^{-2}$ km/s. This would give the estimate $H_{loc} \sim 10^2 H$ for the local Hubble constant H_{loc} assignable to the space-time sheet of the bubble.

3. One can argue that the large value of the local Λ prevents the formation of gravitationally bound structures in the center of the void. This could explain the formation of voids and bubbles.

4. In the TGD Universe the smooth cosmological expansion of astrophysical objects is replaced by a sequence of "jerks" increasing the size of the system and reducing to a phase transition in which the flux tube thickness increases and energy associated with the flux tube is liberated. In this picture the description in terms of the Hubble constant applies only to the rapid expansion periods. The average expansion rates in various scales need not correspond to the cosmic Hubble constant.

Could supernova explosions be understood as this kind of phase transitions inducing accelerated expansion? Could the material thrown out of supernovae correspond to flux tube tangles for which this kind of transition has occurred?

Magnetic bubble as a local cosmology with a scaled up value of cosmological constant?

One can ask whether the bubble could be modelled as a scaled down variant of cosmology with non-vanishing cosmological constant.

1. The cosmic mass density ρ_c of cosmology (`https://rb.gy/hs0xup`), which is dominated by the dark energy density $\Lambda/8\pi G$ and scales with bubble size and radius of cosmology as R_B^2/R_c^2, is roughly one proton mass per cubic meter. This contribution dominates in the mass density.

2. The scale dependence of Λ_B allows us to expect that dark energy dominance holds true also for the scaled down versions of cosmology. Therefore one can estimate the density for bubbles if one assumes that the bubble size R_B defines the size of the local Universe as an analog of horizon size. One obtains a scaling law:

$$\frac{\rho_B}{\rho_c} = \frac{\Lambda_B}{\Lambda_c} = \frac{R_c^2}{R_c^2} \quad .$$

   Here R_c corresponds to the size scale of the Universe and is about 28 billion ly. This would give the estimate $\frac{\Lambda_B}{\Lambda_c} \sim 7.8 \times 10^{12}$.

3. The contribution from the Hubble constant is proportional to $3H^2/8\pi G$. The estimate for the value of the Hubble constant from the expansion velocity of the bubble gives $H_B \sim 10^2 H$. The contribution of dark matter would be by a factor of order 10^8 larger than that of ordinary matter. One could perhaps interpret this in terms of the presence of monopole flux tubes carrying the dark energy, which has decayed to ordinary matter at the magnetic bubble and induced the star formation. Monopole flux tubes decay to ordinary matter either in the supernova explosion or at the magnetic bubble.

One can test whether this ultra-simple picture gives a reasonable prediction for the thickness of the bubble.

1. For the mass of the bubble of thickness ΔR_B one obtains the estimate

$$M_B = 4\pi R_B^2 \Delta R_B (\frac{R_B}{R_c})^2 \rho_c \quad .$$

   This gives for the thickness of the bubble the estimate

$$\Delta R_B = \frac{M_B L_c^2}{4\pi R_B^4 \rho_c} \quad .$$

2. For the Local Bubble, the radius is about $R_B = 1000$ ly. This gives the estimate $\rho_B \sim (\Lambda_B/\Lambda_c)\rho_c = (R_B^2/R_c^2)\rho_c \simeq 10^{14} m_p/m^3$ for the density of matter in the magnetic bubble. From the thickness ΔR_B and radius $R_B = 10^3$ ly of the bubble, one can estimate the total mass which is estimated to be 10^6 solar masses. Thus gives $\Delta R_B \sim 10^{-2}$ ly. The thickness of the local bubble is estimated to be at least 300 ly.

3. The average density of the Local Bubble is estimated to be roughly 1/10 of the interstellar mass density of the Milky Way about $\rho_{MW} = .5 \times 10^6 \times m_p$ m^3. Could the reduction of ρ_{MW} by factor .1 explain the mass of the Local Bubble as being due to transfer of mass $M = .9\rho 4\pi R^3/3$ of the volume to the Local Bubble of radius $R = 10^3$ ly? This would gives $M \simeq 10^3 M_{Sun}$.

   The actual mass of the bubble is 10^3 times larger so that the idea that this structure is formed by the gravitational condensation of mass inside this volume does not look attractive.

Some other source of mass should be involved. A burst of stars should produce a much larger average density than ρ_{MW} would be needed. One can imagine that the primary stars, which became later supernovae, took place via the thickening of cosmic strings.

On can also look what one obtains for possible other bubble like systems.

1. The radii of Fermi bubbles are about 2.5×10^3 ly and thus have the same size scales as the Local Bubble surrounding the Sun. The density would be by factor $(2.5)^2 \simeq 6$ higher than for the Local Bubble. Could also Fermi Bubbles carry magnetic fields? Interestingly, the IceCube array in Antarctica has reported 10 super-high-energy neutrinos sourced from the bubbles, which suggests that there is some new physics involved with the Fermi bubbles.

2. Could Earth be associated with a magnetic bubble surrounding the Sun having radius of AU. Scaling argument allows to estimate for the density associated with the bubble and if the bubble mass has concentrated to form Earth one obtains that the thickness of the bubble has been of order $\Delta R_B \sim 1$ meter. One can also ask whether other planets could involve bubbles. I have actually proposed that planets have formed by the concentration of mass at membrane-like surfaces to planets and also to ring like structures in turn forming Moons.

   The expansion rate of the planetary radii allows to make this proposal more quantitative. Does the value of the local Hubble constant have a reasonable size? There is evidence for the increase of the Earth-Moon distance with a rate 3.8×10^{-7} m/s. This is by a factor of order 10^{-10} lower than cosmic expansion rate so that the local Hubble constant should be by a factor of order 10^{-5} smaller than H. Earth-Sun distance increases with rate 1.5×10^{-7} m/s and the local value of H would be of the same order as in the case of the Moon. This is consistent with the general vision that the expansion takes place as jerks. The recent situation would correspond to very slow expansion.

3. Fractality inspires the question whether the large voids are formed by analogues of supernova explosions at the center of the large void driving flux tube tangles to the surface of the large void. The large value of the local Λ would prevent the formation of structures in the interior of the void. Could one imagine that there is a cosmic string or cosmic strings through the center of the void and that these cosmic strings have formed tangles and intersections causing an explosion and formation of ordinary matter driven to the surface of the large void?

Local Big-Bangs as a universal mechanism for the formation of astrophysical structures?

The above considerations suggest that the local Big-Bang cosmologies characterized by local Hubble constant H_B and cosmological constant Λ_B could serve as a universal mechanism for the formation of structures including also planets and even moons. These local Big-Bangs would correspond to "jerks" as fast local expansions. Expanding Earth model explaining the mysterious Cambrian Explosion in biology is an application of this idea in Earth scale [L55, L113, L102, L131].

Interestingly, already the TGD interpretation of the Nottale's hypothesis [E87] of gravitational Planck constant $\hbar_{gr}) = GMm/v_0$, where M and m are masses of objects, say Sun and Earth, led to the question whether the planets could have formed from the dark matter in the TGD sense, and thus characterized by $\hbar_{gr}$ assignable with Sun.

1. The mass would have concentrated at spherical surfaces around the Sun having quantized radii corresponding to radii of planetary orbits. This mechanism would have worked for the moons of various planets. The formation mechanism would have been gravitational concentration of mass from spherical surfaces orbits and from orbits to planets and planets [K93, K79, L82].

2. Since the dark matter is assumed to reside at monopole flux tubes, the identification of the spherical surfaces as magnetic bubbles carrying dark matter at the flux tubes characterized by $\hbar_{gr}$ would be very natural. That the flux tubes are parallel to the bubble surfaces rather than being radial flux tubes conforms with the fact that the absence of real monopoles does not allow radial magnetic fields. Gravitational interaction could be however mediated

by the propagation of gravitons along U-shaped radial flux tubes forming loops. These U-shaped tentacles play a key role in the TGD inspired quantum biology and are crucial for understanding bio-catalysis in the TGD framework [L14, L31, L100, L126, L119].

3. Explosions analogous to supernova explosions could have generated the magnetic bubbles. The explosion could be assigned to a phase transition representing a single step in a step-wise cosmic expansion by rapid "jerks". If this is the case, one could time order the planets according to their temporal distance and from the recent local Hubble constant for a planet one could also estimate the time when the corresponding solar explosion occurred. The number of planets gives the first estimate for the number of explosions that have occurred hitherto.

4. The basic prediction is that the composition of planets should be the same as that for the Sun near its surface. Also the composition of moons should be the same as the composition of planets. That this is indeed the case for the Moon came as a total surprise (`https://rb.gy/4sq5ho` and this challenges the standard theory for the formation of Moon (`https://rb.gy/18satf`).

5. One can argue that the idea that all dark matter at the magnetic bubble of radius defined by the distance to the Sun would have concentrated to form a single planet, is implausible.

   This inspires a crazy quantum idea of quantum explosion inspired by the fact that the quantum coherence length can be of the same order of magnitude as the distance to the Sun. The quantum states could indeed be like the quantum states of, say hydrogen atoms in the scale of the planetary system. The wave functions could make sense at the level of single particle states. The particles would form an analog of Bose-Einstein condensate describable by an order parameter satisfying nonlinear Schrödinger equation as in the case of superconductivity.

   This would conform with the idea that dark matter parts of planets indeed possessed wave functions in some early proposed originally by Nottale [E87], which was in the TGD framework cautiously reduced to a Bohr model of planetary orbits. One could think of a quantum superposition of radial jets at single particle level and a collective state function reduction as a phase transition involving a collective localization to a single radial jet occurring in, say, nuclear physics experiments! After that dark matter with a large value of $\hbar_{gr}$ transformed to ordinary matter.

   This would be analogous to a state function reduction of angular momentum eigenstate to a momentum eigenstate. After the localization h_{gr} would have reduced to ordinary Planck constant and led to the formation of a planet.

10.2.2 A more detailed model for the formation of magnetic bubble

The following argument tries to describe the physics of the TGD based model first. I have not evaluated the local Hubble constant before and try to do it. I will concentrate on the TGD inspired model for the formation of Earth. The idea that Earth was formed as the gravitationally dark matter at the magnetic bubble transformed to ordinary matter. This mechanism would explain also the formation of stars at the Local Bubble.

What happens in rapid local cosmic expansion pulses that replace the uniform expansion in TGD?

This rapid local expansion is essentially an explosion. A supernova explosion throwing out a shell of matter, and as the interpretation of Local Bubble suggests, also the magnetic bubble, is a good starting point in the modelling.

1. A flux tube containing dark matter (in the sense of TGD) expands rapidly. The thickness of the flux tubes increases rapidly and then settles to a constant value as a new minimum energy situation is found.

2. The cross-sectional area S of the flux tube serves as a parameter. The magnetic energy $E_m \propto 1/S$ and the volume energy $E_V \propto S$ (its coefficient is analogous to the cosmological constant) associated with the monopole flux are the energies. In equilibrium, the sum E_n+E_V is minimized as a function of S [L43]. The total density for the flux tube determines the effective cosmological constant Λ_{loc}, i.e. the effective string tension, which decreases as the flux tube thickens. This means energy release, which causes an explosion.

The Big Bang analogy as a model

It is tempting to apply Big-Bang analogy to the explosion phase.

1. The density $\rho_d = 3\Lambda/8\pi G$ of dark energy would define a map between very long and short length scales identified as $L_c = \Lambda^{-1/2}$ and $R_d = \rho_d^{-1/4}$. L_c could correspond correspond to the horizon radius or age of the local Universe identifiable as the size of associated causal diamond (CD) in zero energy ontology (ZEO) [K119] [?]. At the microscopic level, L_c could correspond to the length of the flux tube and R_c to its thickness.

   These identifications would relate macroscopic and even astrophysical scales and elementary particle mass scales. I have considered the possible consequences of this map earlier.

2. As the energy minimum is reached, the expansion of the flux tube ceases. It can be also thought that H_{loc} and Λ_{loc} approach cosmological values. Therefore one could model the emerging expanding space sheet as a local Big-Bang with the help of the parameters Λ_{loc}, L_{loc}, and H_{loc}, which have large values at the beginning of the explosion. The explosion would be a scaled down analog for the TGD counterpart of inflation, which would have led to effectively 2-D cosmic strings with 2-D M^4 projection to Einsteinian space-time with 4-D M^4 projection.

3. The dark energy density would be $\rho_d = 3\Lambda_{loc}/8\pi G$ with $\Lambda_{loc} \propto 1/L_{loc}^2$. L_{loc} would be the scale of the space-time sheet determined by the length of the flux extending to a horizon which would correspond to light-like 3-surface, whose possible role as space-time boundaries was understood only quite recently [L125]. L_{loc} would quite concretely be the radius of the horizon. The horizon would correspond to the edge of a spacetime sheet.

4. For the usual Planck's constant $\hbar$, one would have the usual cosmological $\Lambda \propto 1/L_c^2$, where L_c would be the radius of the horizon and of the order of 10^{10} ly. The scale $R_c \propto (8\pi G/3\Lambda)^{-1/4}$ would be much smaller than Λ_c and from the estimate $\rho_c \sim m_p/m^3$ and proton Compton length $3.48 \times 10^{-15} m$ would roughly correspond to a wavelength of $.75 \times 10^{-4}$ meters. The peak wavelength of the microwave background is 1 mm. This suggests a biology-cosmology connection.

5. If Λ_{loc} scales as $1/L_{loc}^2$, and $L_{loc} \sim AU$ corresponds to the scale of the Earth-Sun system, L_{loc} in the Sun-Earth system would be smaller by the factor $AU/L_c \simeq 1.610^{-15}$ than at the level of cosmology.

   The scaling of $R_c \sim 10^{-4}$ m by this factor would give $R_{loc} \sim 10^{-19}$ m. This is by factor 1/100 smaller than the Compton scale of intermediate bosons. What could this mean?

   TGD predicts [K68, K69] scaled up variants of strong interaction physics assignable at p-adic primes identifiable as Mersenne primes $M_n = 2^n - 1$ or their Gaussian counterparts $M_{n,G} = (1 + i)^{n-1}$, M_{107} would correspond to ordinary hadron physics and M_{89} would correspond LHC energy scale higher by factor 512 than that of ordinary hadron physics. There are several indications for M_{89} hadron physics as dark variants of M_{89} hadrons with scaled up Compton length. Gaussian Mersennes $M_{G,79}$ and $M_{G,73}$ would correspond to scales, which are by factor 2^{14} resp. 2^{17} that of ordinary hadron physics. The Compton radius of proton for the $M_{G,73}$ hadron physics be of the order of $R_{loc} \sim 10^{-19}$ m.

Matter at the magnetic bubbles is dark

I have not yet taken into account the fact that monopole flux tubes associated with the magnetic bubble carry dark matter in the TGD sense.

1. TGD predicts a hierarchy of large Planck's constant $h_{eff} = nh_0$ labelling phases of ordinary matter, which behave like dark matter at the flux tubes. In particular, the gravitation Planck's constant $\hbar_{gr} = GMm/\beta_0$, $\beta_0 < 1$, which Nottale [E87] originally suggested, would make possible quantum gravitational coherence in astrophysical scales in the TGD Universe.

2. The gravitationally dark monopole flux tubes would be naturally associated with the magnetic bubble corresponding to the Earth (analogous to the one created in a supernova) and also connect the magnetic bubble with the Sun and mediate gravitational interaction with it. Matter at the magnetic bubble would have been dark before condensing to form Earth for which matter mostly corresponds to the usual value of Planck's constant.

3. For gravitationally dark matter, the gravitational Compton wavelength is $\Lambda_{gr} = GM/\beta_0 = r_S/2\beta_0$ and does not depend on the mass of the particle m at all. This is in accordance with the Equivalence Principle. That particles of all masses have the same Compton wavelength makes gravitational quantum coherence possible and is essential in the TGD inspired quantum biology.

4. For the Sun, the Schwartschild radius is 3 km and $\beta_0 = v_0/c$ is of order 2^{-11} on basis of Nottale's estimates, which came from the model for planetary orbits as Bohr orbits. The Compton wavelength Λ_{gr} would be about 6000 km, about the radius of the Earth! Is this a mere accident? The thickness of the dark gravitational flux tube R_{loc} would therefore be of the order of the Earth's radius R_E, and the length L_{loc} would be of the order of AU.

   The parameters of the local Big-Bang would therefore be $R_{loc} = R_E$ and $L_{loc} = AU$ at the beginning of the explosion that led to the creation of the Earth as dark gravitationally dark matter transformed to ordinary. The slowing down of the explosion would be due to the transformation of the gravitationally dark matter to ordinary matter.

What about the value of local Hubble constant?

The previous arguments have not said anything about the value of the local Hubble's constant H_{loc} in the beginning of the explosion. Here the formula for $\hbar_{gr}$ serves as a guideline.

1. $\beta_0 = v_0/c$ is the velocity parameter appearing in the gravitational Planck constant $\hbar_{gr}$. It could correspond to a typical expansion rate at a distance $L_{loc} \sim AU$.

   In the case of the Sun, $\beta_0 = v_0/c \simeq 2^{-11}$ applies. Could it be the rate of expansion for the Earth-related dark magnetic bubble during the *initial stages* of the explosion, which would later slow down as dark matter is transformed to ordinary?

2. The counterpart of Hubble's formula would give a prediction for the local recession velocity at Earth-Sun distance $L_{loc} = AU = 4.4 \times 10^{-6}$ pc as $v_{loc} = \beta_0 c = H_{loc} \times L_{loc}$ i.e. $H_{loc} = \beta_0 \times c/L_{loc}$. This gives $H_{loc} \simeq 3 \times 10^7$ kms^{-1} pc^{-1}. Cosmic Hubble constant $H_c \simeq 72$ km s^{-1} Mpc^{-1} is 11 orders of magnitude smaller.

3. The naive L_{loc}/L_c scaling would give a value of H_{loc}, which is 15 orders of magnitude smaller. For $\beta_0 = 1$, i.e. its maximum value which seems to be valid ate the surface of the Earth in quantum biology, the value would be give 14-15 orders smaller, so that the L_{loc}/L_c scaling would seem to make sense in this case.

10.3 Applications related to the physics of galaxies

In this section, the proposed general model is applied to the age problem of galaxies, dark energy problem, and to Fermi bubbles.

10.3.1 Paradox: the galaxies that should be youngest ones are the oldest ones

James Webb telescope (JWST) continues to revolutionize the view about the formation of early cosmology and the formation of galaxies. Now the Astronomers have detected 6 massive galaxies in the very early universe [E140] (see `https://rb.gy/kbfqlc`). The mass of one galaxy is 10^5 times larger than the mass of the Milky Way! This is impossible in the recent models for the formation of galaxies, and even more so in the very early Universe.

There seems to be only one way out of a paradox. One must admit that the recent views of galaxy formation and of what time is, are wrong.

In the TGD framework, new view of the space-time leads to a new quantum view about the formation of astrophysical objects involving gravitational quantum coherence even in cosmological scales. This view also allows to understand galactic dark matter [L63, L69, L111].

Zero energy ontology in turn solves the basic paradox of standard quantum measurement theory. ZEO predicts that the arrow of time changes in the ordinary state function reductions. These weird galaxies would have lived forth and back in geometric time and would be much older than the universe when age is defined as the evolutionary stage.

The paradoxical looking prediction of TGD is that the youngest galaxies in standard view are the oldest galaxies in the TGD view!

10.3.2 Galactic blackholes and dark energy

Observations of supermassive black holes at the centers of galaxies point to a likely source of dark energy the "missing" 70 % of the universe [E126] (`hhttps://rb.gy/trta9j`). The conclusion was reached by a team of 17 researchers in nine countries, led by the University of Hawai'i and including Imperial College London and STFC RAL Space physicists. The work is published in two papers in the journals The Astrophysical Journal and The Astrophysical Journal Letters.

Findings and their proposed interpretation

Elliptic galaxies were studied. The reason is that they do note generate stars anymore and accretion, which is regarded as the basic mechanism for the growth of galactic black holes, should not occur. The time span of the study was nine billion years. It was found that the masses of the gigantic galactic blackholes, which extend from 10^6 to 10^9 solar masses, were 7-20 times higher than expected if the mass growth had been due to accretion of stars to the blackhole or by merging with other blackholes.

The proposed interpretation was that blackholes carry dark energy and this energy has increased. The conclusion was that nothing has to be added to our picture of the universe to account for vacuum energy. Einstein's equations with a cosmological term were assumed to be a fundamental description and that blackholes are responsible for the cosmological constant.

In general relativity (GRT), one must give up the conservation of energy and it is difficult to propose any alternative for this proposal without leaving the framework of GRT. If one has a theory of gravitation for which Poincare invariance is exact, the situation changes completely. One must ask where the blackholes get their mass. Is it dark energy and/or mass or is it dark energy/mass transformed to ordinary mass?

TGD view of the situation

In the TGD framework Poincare invariance is exact so that the situation indeed changes.

1. TGD approach [L63, L69, L111] forces to ask whether the objects that we call galactic blackholes, or at least those assignable to quasars, could be actually galactic white hole-like objects (GWOs), which emit energy to their environment and give rise to the formation of the ordinary matter of galaxies. The should exist a source feeding mass and energy to GWOs.

   The source of mass of the GWO would be the energy of a cosmic string or more generally a cosmic string thickened to a flux tube but with large enough string tension. The dark energy would consist of volume energy characterized by a scale dependent cosmological constant Λ and Kähler magnetic energy.

2. Cosmic strings with 2-D M^4 projection are indeed unstable against a phase transition transforming them to monopole flux tubes with 4-D M^4 projection. This transformation reduces their gigantic string tension and leads to a liberation of energy leading to the formation of the ordinary matter of the galaxy.

The monopole flux tubes can carry dark matter having a large value of the effective Planck constant h_{eff}. Whether one has $h_{eff} = h$ or even $h_{eff} = nh_0 < h$ for the cosmic string (or the initial object) so that h_{eff} would increase in the phase transition thickening of the cosmic string to the flux tube, has remained an open question. If the value increase, the quasar white hole would be apart from the arrow of time in many respects similar to a blackhole.

The simplest assumption is that the cosmic string is either pure energy, or if it also carries matter, the matter has $h_{eff} = nh_0 \leq h$. The energy liberated in the increase of the thickness of the cosmic string (or flux tube with a very small thickness) produces matter and provides the energy needed to increase h_{eff} so that the the blackhole matter should be dark.

3. The values of the $\hbar_{eff}$ could correspond to the values of $\hbar_{gr} = GMm/\beta_0$, where M is the mass of the galactic blackhole, m is the particle mass, and $\beta_0 = v_0/c < 1$ is velocity parameter. These values of h_{eff} are gigantic . The gravitational Compton length Λ_{gr} is $GM/\beta_0 = r_S/2\beta_0$ and for $\beta_0 = 1$ it is equal to one half of the Scwartschild radius of the galactic blackhole, which in the range $(10^6 - -10^9) \times r_S(Sun)$, $r_S(Sun) = 3$ km. Note that the distance of Earth to Sun is $AU = .15 \times 10^9$ km and is in this range.

   The gravitational Bohr radius for Sun in Nottale model with $\beta_0 \simeq 2^{-11}$ is obtained from the radius of Earth's orbit with principal quantum number $n = 5$ as $a_{0,gr} = AU/5^2 \simeq 6 \times 10^9$ m [K93]. The gravitational Compton length for the Sagittarius A* is $\Lambda_{gr} = r_S/2 = 6.2 \times 10^9$ m and equal to the solar Bohr radius. Is this a mere coincidence or is there strong coupling between the galactic quantum dynamics and solar quantum dynamics and does this coincidence reflect the very special role of the Earth in the galactic biosphere?

   What this co-incidence suggests in the TGD framework, is a wavelength resonance in communications and control by dark photons or gravitons over scales larger than the radius of the galactic blackhole. These signals would propagate along monopole flux tubes in a precisely targeted way. These communications are central in the TGD based model of biomatter [**?**]

   In the TGD inspired quantum biology, living matter is controlled by phases with a large value of $\hbar_{gr}$, in particular those associated with the gravitational flux tubes of Earth and Sun and quantum gravitation plays a key role in metabolism. This, and the fact that h_{eff}/h_0 serves as a kind of IQ for living matter, strongly suggests that galactic blackholes are living super intelligent systems controlling matter in very long scales.

4. Galaxies would have formed as local tangles of long cosmic strings. The simplest cosmic string is an extremely thin 3-D object identifiable as a Cartesian product of complex 2-sub-manifold of CP_2 homologically non-trivial geodesic sphere S^2 of CP_2 and of a string-like object X^2 in Minkowski space. This object can form a local tangle and its M^4 projection would be thickened in this process.

   In the formation of galaxy, the string tension would decrease and part of the dark energy and matter would transform to ordinary matter forming a galaxy. Also stars and planets would be formed by a similar mechanism. The process transforming dark energy and matter to ordinary matter would be the TGD counterpart for the decay of the inflaton field and drive accelerating cosmic expansion.

   Galactic dark matter, as opposed to dark matter as $h_{eff} > h$ phases, is identified as the dark energy of the long cosmic string containing galaxies along it as local tangles, and predicts correctly the flat velocity spectrum. Also ordinary stars would have flux tube spaghettis in their core but they would not be volume filling.

5. The TGD interpretation does not imply that all dark matter would be associated with galactic blackholes as the article suggests. This is as it should be. The mass of the galactic blackhole is only a small fraction of the visible mass of the galaxy and dark energy is about 70 % of the total mass of the Universe. The long cosmic strings having galaxies as tangles contain most of the dark energy. TGD only predicts that most of the mass of the galactic blackhole, be it dark or ordinary, comes from dark energy of the cosmic string.

How would the transformation of the dark matter at monopole flux tubes to ordinary matter take place?

1. The TGD view of "cold fusion" [L10, L31, L94] is as a dark fusion giving rise to dark proton sequences at monopole flux tubes followed by their transformation to ordinary nuclei with $h_{eff} = h$. Most of the nuclear binding energy would be liberated and induced an explosion generating the expanding flux tube bubble or jet. This mechanism plays a central role in the model for the formation of various astrophysical structures.

2. The TGD inspired model for the star formation would explain the formation of stars of galaxies in terms of explosive emissions of magnetic bubbles consisting of monopole flux tubes, whose dark matter transforms to ordinary matter by the proposed mechanism and gives rise to stars. Galactic jets could correspond to the emissions of magnetic bubbles. Prestellar objects would be formed by this process. Ordinary nuclear fusion would start above critical temperature lead to the generation of population II stars.

An open question has been whether galactic blackholes should be interpreted as galactic blackhole-like objects (GBOs) or their time-reversals, which would be white hole-like objects (GWOs). Whatever the nomenclature, the GWOs and GBOs would however have opposite arrows of time.

1. GWOs can eject dark matter magnetic bubbles creating transforming to ordinary matter such as stars: this suggests the term GWO. They calso "eat" ordinary matter, such as stars, which suggests the term GBO. But this is possible also with their time reversals.

2. The long cosmic string could serve in the case of spiral galaxies as a metabolic source, which continually feeds matter to GWO/GBO so that it could remain dark and increase in size.

   In the case of elliptic galaxies, the mass growth by "eating" matter from the environment has stopped. In this case the cosmic string could be closed and imply that the mass of GWO/GBO does not grow anymore. One could say that elliptic galaxies are dead.

The outcome of the stellar evolution should correspond to a genuine blackhole-like object (BO).

1. This would suggest that BOs carry at the monopole flux tubes only ordinary matter with $h_{eff} = h$ or even $h_{eff} < h$. In the TGD inspired model for for stellar BOs, the thickness of the flux tube would be given by proton Compton length [L69] and the flux tubes would be long proton sequences as analogs of nuclei. Therefore they would contain matter. In zero energy ontology (ZEO), one BOs could transform to their time reversals (WOs).

2. Are genuine GBOs as time reversals of GWOs possible? In zero energy ontology (ZEO), one can imagine that a "big" state function reduction (BSFR) in the galactic scale takes place and GWO gradually transforms to a GBO. If the cosmic strings have $h_{eff} = h$ or even $h_{eff} < h$, a possible interpretation is that the magnetic flux tubes carrying dark matter have transformed during the stellar evolution to those carrying only matter having $h_{eff} \leq h$. In BSFR they would become initial states for a time reversed process leading to generation of galaxies in the reverse time direction. Galaxies would be "breathing". GWOs could be also formed by a fusion of stellar WOs as time reversals of stellar BOs.

3. This allows to imagine an evolutionary process in which each evolutionary step gives rise to flux tubes, whose thickness is larger than the initial flux tube thickness. Also the value of h_{eff} of the final state of a given step could increase gradually.

   The differences with respect to the previous initial state would be the arrow of time, the thickness of the flux tubes, and the fact that they contain matter, and possibly also the value of h_{eff}, which could increase.

Many properties of the quasars suggest that they feed energy to the environment rather than vice versa. In this respect they look like GWOs.

1. If one can assign to quasars genuine GWOs, their mass would come from the dark energy and matter of the cosmic string rather than from the environment by the usual mechanisms. This conforms with the findings of [E126]

Objects known as galactic black holes would consist of a thickened cosmic string, which suggests an explosive expansion generating $h_{eff} > h$ dark matter so that the interpretation as GWOs would make sense. If star formation near the galactic blackhole takes place, this could be due to an explosive magnetic bubble emission from GWO identified as a monopole flux tube bundle carrying dark matter.

2. Star generation near the galactic blackhole would support the interpretation of the galactic blackhole. The region near the galactic blackhole contains a lot of stars. Have they entered this region from more distant regions or are they produced by the mission of magnetic bubbles from the galactic black hole? Star formation near a galactic blackhole associated with a dwarf galaxy (`https://rb.gy/buk2zj` has been reported.

   There is also evidence for a fast moving galactic blackhole-like object leaving a trail of newborn stars behind it (`https://rb.gy/yofbh4`). If a GWO emitting magnetic bubbles is in question, the motion could be a recoil effect due to this emission.

   There is also evidence for a galaxy, which consists almost entirely (99.9 %) of dark matter (`https://rb.gy/khuryk`). Could the explanation be as a passive galactic whitehole as a flux tube tangle, which has sent only very few magnetic bubbles?

The mysterious behaviour of gas clouds near the galactic blackholes allows to sharpen the picture.

1. The temperature of the clouds is much higher than expected (`https://rb.gy/tpdgis`). The gas in the core of some galaxies is extremely hot with temperature in the range $10^3 - 10^4$ eV.

   These systems are billions of years old and have had plenty of time to cool. Why has the gas not cooled down and fallen down into the blackhole? Where does the energy needed for heating come from? Is there something wrong with the views about star formation and blackholes?

2. The upper bound 10^4 eV corresponds to the ignition temperature of nuclear fusion when the pressure and density are high enough. This could explain why ordinary nuclear fusion has not started. This suggests that when the temperature gets higher, stars are formed and they are eventually devoured by the blackhole-like object.

   Could the galactic blackhole-like object be actually a GWO and be heating the gas forming dark nuclei as dark proton sequences from the hydrogen atoms or ions of the gas? The interpretation as GWO would also explain galactic jets [L111]. Note however that the gas clouds could get heated also spontaneously by dark nuclear fusion taking place at magnetic flux tubes: for this option GWO could provide the flux tubes as a magnetic bubble.

3. The dark nuclei would first transform to ordinary nuclei at monopole flux tubes and liberate energy. As the ignition temperature for ordinary nuclear fusion is reached, stellar cores start to form. An imaginative biology inspired manner to express this (`https://rb.gy/yo3ed3`) is that the galactic blackhole cooks its meal first so that it becomes easier to digest it.

4. Why gas cannot fall into the blackhole and why is this possible only for stars? Gravitationally stars and gas particles are equivalent so that other interactions than gravitation must be involved. Magnetic interactions would indeed confine gas particles to monopole flux tubes as dark proton sequences so that they could not fall into GWO. The rotational motion of stars would make the process of falling into the GWO very slow and they would do so as entire flux tube spaghettis and fuse to the spaghetti defining the GWO.

10.3.3 Einstein rings give support for the TGD view of dark matter

There was an interesting popular article in Science-Astronomy.com with the title "Einstein rings says dark matter behaves more like a wave,not particle" (`https://rb.gy/e6fgo`). The article told about the article published by Amruth and his team published in Nature Astronomy as an article with title "Einstein rings modulated by wavelike dark matter from anomalies in gravitationally lensed images" (`https://rb.gy/mw7cq`). Unfortunately, the article is hidden behind paywall.

Dark matter is known to exist but its real character has remained a mystery. The models assume that its interactions with ordinary matter are very weak so that it makes itself visible only via its gravitational interactions. Two basic kinds of particles have been proposed: weakly interacting massive particles (WIMPs) and light particles, of which axions are the basic example. WIMPs behave like point-like particles whereas axions and light particles in general behave like waves. This difference can be used in order to find which option is more favoured. Axion option is favored by the behavior of dark matter in dwarf galaxies and by its effects on CMB.

The study of Amruth and his team found further support for the axion option from the study of gravitational lensing.

1. As light passes by a massive object, it bends both by the visible and dark matter associated with the object. This leads to a formation of Einstein rings: as if the light source would be a ring instead of a point-like object. If dark matter particles have some interactions with the photons , this causes additional effects on the Einstein rings. For instance, in the case of axions this interaction is known and corresponds to the electromagnetic analog of instanton term.

2. The effect of point-like particles on light is different for WIMPs and light particles such as axions. From the abstract of the article one learn that WIMP option referred to as ρ_{DM} option leaves well documented anomalies between the predicted and observed brightnesses and positions of multiply lensed images, whereas axion option referred to as ψ_{DM} option correctly predicts the level of anomalies remaining with ρ_{DM} lens models. Therefore the particles of dark matter behave as if they were light particles, that is having a long Compton length.

What TGD allows us to conclude about the findings?

1. TGD predicts that dark matter corresponds to phases of ordinary matter labelled by a hierarchy of Planck constants $h_{eff} = nh_0$. The Compton length of dark particles with given mass is scaled up by factor h_{eff}/h. Could this be more or less equivalent with the assumption that dark particles are light?

2. Gravitational Planck constant is an especially interesting candidate for h_{eff} since it plays a key role in the TGD based view of quantum gravitation. Gravitational Planck constant obeys the formula $\hbar_{gr} = GMm/\beta_0$ for two-particle system consisting of large mass M and small mass m ($\beta_0 \leq 1$ is velocity parameter) and is very large.

   The gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0$, which does not depend on the mass m of light particle (Equivalence Principle), is very large and and gives a lower bound for quantum gravitational coherence length. For instance, for the Sun it is rather near to Earth radius, probably not an accident.

3. Gravitational Compton length for particles at the gravitational magnetic body, which for stars with solar mass is near to Earth radius if the velocity β_0 in $\hbar_{gr}$ has the same value $\beta_0 \sim 2^{-11}$, makes dark variants of ordinary particles to behave like waves in astrophysical scales.

4. What happens in the scattering of a photon on a dark particle in the TGD sense. It seems that the photon must transform temporarily to a dark photon with the same value of h_{eff}. Photon wavelength is scaled up h_{eff}/h but photon energy is not affected in the change of Planck constant.

   Suppose that the scattering takes place like in quantum mechanics but with a modified value of Planck constant. In the lowest order in expansion in powers of $\alpha_{em} = e^2/4\pi\hbar_{eff}$ the scattering cross section is the same and whereas the higher corrections decrease. This provides actually a good motivation for the dark matter in TGD sense: the phase transition increasing the value of Planck constant reduces the value of gauge coupling strength and makes perturbation series convergent. One could say that Nature is theoretician friendly and takes care that his perturbation theory converges.

In the lowest order of perturbation theory the scattering cross section is given by the classical cross section and independent of $\hbar_{eff}$. The Nishijina formula for Compton scattering (https://rb.gy/n28zk) indeed shows that the scattering cross section is proportional to the square of the classical radius of electron and does not depend on $\hbar_{eff}$. The result is somewhat disappointing.

1. On the other hand, for large values of $\hbar_{eff}$, in particular $\hbar_{gr}$, one can argue that the scattering takes place on the entire many-particle states at the flux tubes of the magnetic body so that superposition of scattering amplitudes on different charged particles at the flux tube gives the cross section. This can lead to interference effects.

   If the charged dark matter at the flux tube has a definite sign of charge this would give rise to amplification of the scattering amplitude and it would be proportional to the square N^2 of the number N of charged particles rather than to N. Scattering amplitudes could also interfere to more or less zero if both signs of charges are involved.

   One can also argue that only particles with a single value of mass are allowed since $\hbar_{gr}$ is proportional to m so that particles would be like books in the shelves of a library labelled by $\hbar_{gr}$.

2. The effects of axion Bose-Einstein condensates have been indeed studied and it has been found that the scattering of photons on cold axion Bose-Einstein condensate could cause what is called caustic rings for which there is some evidence (https://rb.gy/2bubj). Could the quantum coherent many-particle states at gravitational flux tubes cause the same effect?

The optimistic conclusion would be that astrophysicists are gradually ending up with the TGD view of dark matter. One must of course that the above argument only suggests that the effects of scattering on Einstein's ring could be large for a large value of h_{eff}.

10.3.4 Is the 60 year old mystery of quasars solved?

The following considerations were motivated by a Sciencedaily article telling about a possible solution of 60 year old problem related to the huge intensity of radiation arriving from quasars (https://rb.gy/889hk). The article tells about the article "Galaxy interactions are the dominant trigger for local type 2 quasars" of Pierce et al published in Monthly Notices of the Royal Astronomical Society (https://rb.gy/1wnfo).

The proposed explanation of quasars is in terms of the collision of galaxies in which matter, which usually stays at circular orbits, falls into the galactic blackhole-like objects (BHOs) having huge gravitational fields. In this process a huge amount of radiation is emitted.

The key problem of this view is that the radii of the orbits of stars are measured in kiloparsecs: somehow the matter should get to a distance of order parsecs. This requires that the orbiti matter gets rid of the conserved angular momentum somehow. The proposal is that the collision of galaxies generates tidal forces making this possible. My impression from the article was that this is one possibility and they support this option but certainly do not prove it.

The researchers claim that the finding could be understood if the colliding objects are BHOs. Tidal forces in collisions would make it possible for them to draw matter from their surroundings and this process would generate huge radiation power. They do not do this usually but only because the collision creates the circumstances causing the ordinary matter at their circular orbits to fall to the BHO(s). I am not specialist enough to decide how convincing the calculations of the researchers are.

Consider now the TGD based explanation baed on the general view of the formation of astrophysical object dicussed in [L136, L137].

1. In TGD, galactic blackhole-like objects (BHOs) could be associated with cosmic string-like objects, which thicken to monopole flux tubes by phase transitions. The phase transition is analogous to the decay of inflaton field producing ordinary matter. In this process dark energy would transform the energy of the cosmic string to dark matter assignable to BHOs. This would also explain the quite recent finding that dark energy seems to transform to galactic BHOs. Part of the dark matter of BHO would transform to the ordinary galactic matter in a transition reducing gravitational Planck constant and liberating energy as an explosion.

2. This explosive process would involve new physics predicted by TGD involving the transformation of dark matter to ordinary matter in a transition reducing the value of gravitational Planck constant $\hbar_{gr} = GMm/beta_0$: here M is large mass and m a small mass and $\beta_0 = v/c \leq 1$ is a velocity parameter. This transformation could be also behind the formation of both stars and planets in explosions producing magnetic bubbles. This mechanism would replace the standard model assuming gravitational condensation. Quasars could be similar expolosions perhaps preducing BHOs.

3. The most conservative assumption is that quasars a BHOS are analogs of ordinary blackholes. The new physics would correspond to an analog of inflaton decay transforming dark energy to dark matter and in turn to ordinary galactic matter. Quasar would be produced by an explosion analogous to inflaton decay proposed to also produce other astrophysical objects.

4. The collision of galaxies could have led to an intersection of cosmic strings orthogonal to the galactic planes assignable to galaxies. The intersection would have induced a formation of dark BHO and its explosion by $\hbar_{gr} \rightarrow \hbar$ phase transition producing ordinary matter. this process could involve several steps reducing the value of h_{eff}. The distant ordinary matter circulating the galaxies would have nothing to do with the formation of quasars.

   These kinds of collisions are unavoidable for moving string-like objects in 3-D space. There is evidence that also the Milky Way center involves 2 cosmic strings which have collided. The structure MW would reflect the ancient occurrence of an analog of inflaton decay.

10.3.5 Two findings possibly related to cosmic strings in TGD sense

I learned recently of two very interesting findings, which relate to the TGD views about dark energy and galactic dark matter, about quasars and formation of galaxies.

A finding providing support for the TGD view of galaxy formation

The discovery challenges the standard view of quasars as blackholes and provides additional support for the TGD view of quasars and galaxy formation. Here is the abstract of the article published in Nature.

Quasars feature gas swirling towards a supermassive black hole inhabiting a galactic centre. The disk accretion produces enormous amounts of radiation from optical to ultraviolet (UV) wavelengths. Extreme UV (EUV) emission, stemming from the energetic innermost disk regions, has critical implications for the production of broad emission lines in quasars, the origin of the correlation between linewidth and luminosity (or the Baldwin effect) and cosmic reionization.

Spectroscopic and photometric analyses have claimed that brighter quasars have on average redder EUV spectral energy distributions (SEDs), which may, however, have been affected by a severe EUV detection incompleteness bias.

Here, after controlling for this bias, we reveal a luminosity-independent universal average SED down to a rest frame of ~ 500 *Angstrom for redshift* $z \sim 2$ *quasars over nearly two orders of magnitude in luminosity, contrary to the standard thin disk prediction and the Baldwin effect, which persists even after controlling for the bias.*

Furthermore, we show that the intrinsic bias-free mean SED is redder in the EUV than previous mean quasar composite spectra, while the intrinsic bias-free median SED is even redder and is unexpectedly consistent with the simply truncated wind model prediction, suggesting prevalent winds in quasars and altered black hole growth. A microscopic atomic origin is probably responsible for both the universality and redness of the average SED.

What does TGD say about the discovery?

1. In the standard accretion disk theory inner luminosity is determined by the mass of the accretion disk entering into the blackchole. What is however found that the spectral energy distribution of light from quasar does *not* depend on the inner luminosity at all in the extreme UV (EUV) range! It can even decrease when the intrinsic luminosity increases! These paradoxical findings challenge the standard accretion disk theory.

2. TGD based view of quasars [L63, L69, L111, L136, L137] suggests an explanation of the anomaly. The galactic matter would be formed as dark energy and dark matter from a cosmic string like objects thickening to a monopole flux tube tangle with reduced string tension would emit dark particles transforming to ordinary matter forming the galaxy. Cosmic strings would be transversal to the galactic plane and their dark energy energy predicts the flat velocity spectrum of galaxies.

3. The radiation from the thickened flux tube (rather than from the energy liberated as matter of the accretion disk falls into the blackhole) could give rise to the spectral energy distribution in EUV and the inner luminosity at longer wavelengths would be determined by the accretion disk emission. The article suggests that galactic wind explains the energy spectrum: galactic wind would correspond to this EUV radiation from the monopole flux tube. This energy spectrum would be universal in the sense that it would reflect only the properties of the thickened cosmic string and universality is indeed claimed. Galactic wind would correspond to the flow of matter from the cosmic string tangle which is not stopped by the accretion disk.

The model of the quasar as a portion of a cosmic string thickened to a flux tube tangle and emitting dark energy and matter transforming to ordinary matter challenges the standard model as a blackhole. The outflowing matter would create an accretion disk as a kind of traffic jam and at least part of the luminosity of the accretion disk would be due to the heating of the accretion disk caused by the flow of the particles colliding with the accretion disk. Also now the gravitational field of the cosmic string and of the flux tangle associated with it is present and a natural classical expectation is that the matter in the accretion disk tends to flow back to the quasar.

In atomic physics the quantization prevents the fall of electron to atomic nucleus. Could the same happen now and prevent the fall of matter from the accretion disk back to the quasar.

1. One can argue that a realistic quantum model for the matter around quasar is based on the treatment of the flux tube tangle as spherically symmetric mass distribution with the mass of the blackhole assigned to the quasars. Indeed, the straight portion of cosmic strings gives a large contribution to the gravitational force only at large distances so that the contribution of the tangle dominates.

2. The mechanism preventing the fall of matter to blackholes would be identical with that in the case of atoms. Also in the accretion disk model, the angular momentum of rotating matter in the accretion disk tends to prevent the fall into the blackhole and the angular momentum must be transferred away.

3. The orbital radii would be given by the Nottale model for planetary orbits with $r_n = n^2 a_{gr}$, where $a_{gr} = \frac{4\pi GM}{\beta_0^2} = 2\pi r_S/\beta_0^2$ is gravitational Bohr radius, and M is the mass M of the quasar blackhole estimated to be in the range $M/M_{Sun} \in [10^7, 3\times 10^9]$ predicting that the Schwartschild radius r_S is in the range $3\times 10^7 - 10^{10}$ km. The radius of r_{acc} should be larger than a_{gr}: $a_{gr} < a_{acc}$. Note that the size of the accretion disk is in some cases estimated to be few light-days: 1 light-day $\simeq 10^{10}$ km whereas the visible size of quasar is measured in light years.

4. The condition $a_{gr} < r_{acc}$ gives the condition $2\pi/\beta_0^2 < r_{acc}/r_S$ giving for β_0 an upper bound in the range $\beta_0 \in [.02, .2]$. The values of β_0 in this range are considerably larger than the value $\beta_0 \simeq 2^{-11}$ predicted by the Bohr model for the orbits of inner planets. Note that for the Earth the estimate for β_0 is $\beta_0 \simeq 1$.

Do cosmic strings with large string tension exist?

There is some empirical support for cosmic strings with a rather large string tension from gravitational lensing. Cosmic string tension T and string deficit angle $\Delta\theta$ for lensing related bia the formula $\Delta\theta = 8\pi \times TG$ if general relativity is assumed to be a good description. The value of TGD deduced from data is $TG = .05$ and is very large and corresponds to an angle deficit $\Delta\theta \sim 1$.

For the ordinary value of Planck constant, TGD predicts the value of TG has upper bound in the range $10^{-7} - 10^{-6}$. The flat velocity spectrum for distant stars around galaxies determines the value of TG: one has $v^2 = 2TG$ from Kepler law so that the value of TG is determined from the measured value of the velocity v. The value of TG can be also deduced from the energy density of cosmic string-like objects predicted by TGD and is consistent with this estimate. If one takes the empirical evidence for a large value of TG seriously one must ask whether TGD can explain the claimed finding.

Could a large value of h_{eff} solve the discrepancy? String tension T as the linear energy density of the cosmic string is determined by the sum of Kähler action and volume term. The contribution of Kähler action to T is proportional to $1/\alpha_K = g_K^2/4\pi\hbar$. If cosmic string represents dark matter in TGD sense, one must make the replacement $\hbar \rightarrow \hbar_{eff}$ so that the Kähhler contribution to T is proportional to $\hbar_{eff}/\hbar$. If the two contributions are of same order of magnitude or Kähler contribution dominates, $\hbar_{eff}/\hbar = n \simeq 10^5$ would give the needed large value TG.

The physical interpretation would be that the cosmic string is an n-sheeted structure with each sheet giving the same contribution so that the value of T is scaled up by $n \simeq 10^5$. There are two options. The n-sheetedness is with respect to M^4 so that one has a n-fold covering of M^4 or with respect to CP_2 in which case one quantum coherent structure consisting of n parallel flux tubes.

It is intereting to consider in more detail the quantum model for the particles in the gravitational field of cosmic string.

1. The gravitational field of a straight cosmic string behaves like $1/\rho$ as a function of the radial distance ρ from string, and Kepler's law predicts a constant velocity $v^2 = 2TG$ for circular orbits irrespective of their radius. This explains the flat velocity spectrum of stars rotating around galaxies.

2. Nottale proposed that planetary orbits obey Bohr quantization for the value of gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ assignable to a pair of masses M and M associated with the gravitational flux tube mediating the gravitational interaction between M and m.

3. If the mass M corresponds to a cosmic string idealized as straight string with an infinite length, the definition of $\hbar_{gr}$ is problematic since M diverges. Therefore the application of Nottale's quantization to a distant star rotating cosmic string is problematic.

   What is however clear that $\hbar_{gr}$ should be proportional to m by Equivalence Principle and one should have $\hbar_{gr} = GM_{eff}m/\beta_0$ for the cosmic string. $M_{eff} = TL_{eff}$, where L_{eff} is the effective length of the cosmic string is also a reasonable parametrization.

4. Kepler law does not tell anything about the value of the radius r of the circular orbit. If the value of $\hbar_{gr}$ is fixed somehow, one can apply the Bohr quantization condition $\oint pdq = nh_{gr}$ of angular momentum to circular orbits to obtain $vr = nGM_{eff}/\beta_0$ giving

$$r_n = nr_1 \quad , \quad r_1 = \frac{r_{S,eff}}{2\sqrt{2TG}\beta_0} \quad .$$

A reasonable guess is that β_0 and the rotation velocity $v/c = 2TG$ have the same order of magnitude. $v/c = x\beta_0 \leq 1$ would give $\beta_0 = \sqrt{2TG}/x$. The minimal value of the orbital radius would be $r_1 = r_{S,eff}/2x\beta_0^2$.

An interesting question relates to the size scale of the n-sheeted structure interpreted as a covering of CP_2 by parallel cosmic strings or flux tubes. The gravitational Compton length $\Lambda_{gr} = r_{S,eff}/2\beta_0$ could give an estimate for the size scale of this structure, which as flux tube bundle would be naturally 2-D. There would be about 10^5 flux tubes per gravitational Compton area with scale Λ_{gr}.

10.3.6 Fermi bubbles as expanding magnetic bubbles?

Could one apply the proposed picture to Fermi bubbles [E269] (`https://rb.gy/uncffb`)?

Basic facts about Fermi bubbles

Consider first the basic facts.

1. Fermi bubbles are located at the opposite sides of the galactic plane at the center of the galaxy. The radii of the bubbles are 12.5 kly and they expand at a rate of a few Mm/s $(oforder10^{-2}c)$.

2. Fermi bubbles consist of very hot gas, cosmic rays and magnetic fields. They are characterized by very bright diffuse gamma ray emissions.

3. Quite recently, so-called eRosita bubbles were discovered [E269]. They have a size scale, which is twice that for Fermi bubbles. Both Fermi bubbles, eRosita bubbles and microwave haze are believed to be associated with an emission of jets.

4. Fermi bubbles could involve new exotic physics. The IceCube array in Antarctica [E207] (`https://rb.gy/qslgq4`) has reported 10 hyper-high-energy neutrinos sourced from the bubbles with highest energies in 20-50 TeV range.

The most natural identification of Fermi bubbles is as a pair of jets emitted in the explosion associated with the galactic blackhole Sagittarius A*. According to the model represented in [E269] (`https://rb.gy/qwzvnz`), they were born roughly 2.6 million years ago and the process lasted about 10^5 years.

One particular rough estimate for the release of energy from Sagittarius A* is 10^{50} Joules, which corresponds to $10^3 M_{Sun}$ (solar mass is $M_{Sun} \simeq 10^{30}$ kg). The estimate of [E269] for the energy would correspond to $10^2 M_{Sun}$.

Fermi bubbles as local Big-Bangs?

Could Fermi bubbles be magnetic bubbles produced by the general mechanism already discussed and perhaps even modellable as local Big Bangs?

1. From the data summarized above, one can deduce that the mass concentrated at the bubbles is below the total energy released from Sagittarius A*. It is in the range of $10^2 - 10^3$ solar masses. This mass need not of course correspond to mass of the Fermi sphere.

2. The conservative option is that the expanding bubble has driven mass to the Fermi sphere as in the standard model of the Local Bubble. Recall that Local Bubble has a mass of 10^6 solar masses and is suggested to be caused by 15 supernova explosions emitting typically 10^{44} Joules: 10^{45} Joules corresponds to mass about $10^{-2} M_{Sun}$. For this option the mass lost by Sagittarius A* would be completely negligible with that of the Fermi bubble.

3. The TGD inspired option is that the mass of Fermi Bubble is dark gravitational mass $(10^2 - 10^3)M_{Sun}$ at the gravitational flux tubes of the dark flux tube tangles emitted by the Sagittarius A* as a pair of jets formed by the expanding Fermi spheres. These tangeles would be characterized by gravitational Planck constant.

The parameters of the local Big-Bang model of Fermi bubbles would be following.

1. The gravitational Planck constant is partially determined by the mass of the galactic blackhole, which is about $4 \times 10^6 M_{Sun}$. The value of gravitational Planck constant would be huge and gravitational Compton length $r_S/2\beta_0$, where $r_S = 1.2 \times 10^7$ km is the Schwartschild radius.

2. $L_{loc} = 12.5$ kly corresponds to the radius of the bubble and the length of a typical flux tube .

3. $R_{loc} = (3/8\pi G L_{loc})^{-1/4}$ corresponds to the thickness of the flux tubes and would be of order μm from $(L_{loc}/L_c)^{1/4}$ scaling and $R_c \sim 10^{-4}$ m.

4. Local Hubble constant corresponds to $H_{loc} = v/L_{loc} \simeq x10^3 H_c$, where $v = (x/3) \times 10^{-2}c$, x of order 1, is the estimate for the expansion velocity of the bubble. The TGD based model suggests that the identification $\beta_0 = v/c$ makes sense in the beginning of the expansion. Note that for the Sun-Earth model the value of β_0 is of order $.5 \times 10^{-3}$.

10.3.7 Bubbletrons as magnetic bubbles?

The popular article in Livescience (`rebrand.ly/hdaqw08`) told about giant "bubbletrons", which in the article "Bubbletrons" (`rebrand.ly/cq3mhe2`) are proposed to have played a key role in the early universe. Bubbletrons would be walls generated in first-order phase transitions. First order phase transition requires free energy or liberates it.

Note: First order means that the derivative of the free energy with respect to some variable is discontinuous: the usual phase transitions in condensed matter are first order. Magnetization is second order phase transition. Magnetization as the first derivative of free energy with respect to the external magnetic field is continuous but magnetic susceptibility as its second derivative is discontinuous.

The inner and outer surfaces of bubblerons could contain high energy particles and the collisions of bubbletrons would liberate energy accelerating particles to huge energies. These explosions could also generate dark matter assumed to be some exotic particles. In the fractal TGD Universe, magnetic bubbles generated in local analogs of the Big Bang, would have been basic structures in the emergence of astrophysical objects. They would serve as analogs of bubbletrons and would play a key role in the formation of all astrophysical structures, including even the formation of planets. I wrote in the beginning of this year two articles describing this vision in various scales [L136, L137].

The production of ordinary and dark matter from the TGD counterpart of dark energy associated with monopole flux tubes, in particular cosmic strings, would be an essential part of the mini big bang and give rise to the TGD analog of inflation. In TGD dark matter would correspond to $h_{eff} = nh_0 \geq h$ phases of ordinary matter and no exotic dark matter particles are needed.

The proposal is that the collisions of bubbletrons could have created gravitational waves causing the gravitational hum. This might be the case also for the magnetic bubbles of TGD but I think that this is not enough. TGD predicts tessellations of cosmic time=constant hyperboloids H^3: they are hyperbolic spaces. They appear in all scales. The tessellations are hyperbolic analogs of crystal lattices in E^3. There are 4 regular tessellations consisting of cubes, icosahedrons and dodecahedrons. In E^3 only the cubic regular tessellation is possible.

There is also the completely unique icosa-tetrahedral tessellation having tetrahedra, octahedra and icosahedra in its fundamental region: this tessellation is essential in the TGD based model of genetic code as a universal piece of quantum information processing, not only related to chemical life.

The large voids could correspond to the fundamental regions of icosahedral tessellations: icosahedrons are indeed the Platonic solids nearest to sphere. Also tessellations having stars with a typical distance of about 5 light years at their nodes can be considered. Hyperbolic diffraction guides the gravitational fields to preferred directions and amplifies them: just as in X-ray diffraction. Quantum coherence in astrophysical scales predicted by the TGD view of dark matter also amplifies the radiation in these directions [L144].

10.3.8 Large voids and CMB cold spot as magnetic bubbles?

Quanta Magazine post "How (Nearly) Nothing Might Solve Cosmology's Biggest Questions" (`rebrand.ly/21wz4w7`) tells about the mysterious large voids. There was also another interesting link to a popular article (`rebrand.ly/pxjx0cu`) in Big Think with the title "Our Universe is normal! Its biggest anomaly, the CMB cold spot, is now explained!"

TGD view of large voids

I have considered the problem of cosmic voids in the TGD framework for decades. I assumed that voids involve cosmic strings going through their center. At that time I did not realize that TGD allows us to consider a considerably simpler solution, which is not possible in general relativity.

In the TGD Universe, space-time consists of 4-D surfaces in $H = M^4 \times CP_2$. Einsteinian space corresponds to space-time surface with 4-D M^4 projections, I call them space-time sheets and they can be connected by extremely tiny wormhole contacts, which are in the simplest situation isometric with a region of CP_2 having 1-D light-like geodesic as M^4 projection. Wormhole contacts serve as basic building bricks of elementary particles. Space-time surfaces or at least their M^4 projections have outer boundaries. The boundaries of physical objects correspond to boundaries of 3-surfaces or of their M^4 projections so that we can see the TGD space-time directly with our bare eyes!

Also other kinds of space-time surfaces, such as cosmic strings with 2-D M^4 and CP_2 projections, are predicted and play a fundamental role in the TGD inspired view of the formation of astrophysical objects.

Concerning the problem of large voids, the key point is that it is possible to have voids in M^4 as regions of M^4 (or E^3) which contain very few or no 3-surfaces. Gravitational attraction could have drawn the 3-surfaces inside the voids to the boundaries of the voids. Could it be that we have been seeing TGD space-time directly for decades?

Also tessellations at the cosmic time= constant hyperboloids would be in a key role and one can imagine that they give rise to tessellations of voids with matter near the walls of the voids. There are 4 regular tessellations involving either cubes, icosahedron of dodecahedron (in E^3 only a cubic regular tessellation is possible) plus the icosa-tetrahedral tessellation consisting of tetrahedrons, octahedrons, and icosahedrons. This tessellation is completely unique and plays a key role in the TGD inspired model of the genetic code, which raises the question whether genetic code could be universal and realized in all scales at the level of the magnetic body [L130].

Could CMB could spot be a super void?

The article [E94] (see also the popular article at `rebrand.ly/pxjx0cu`) proposes the identification of the CBM cold spot as a supervoid. CMB cold spot is a huge region inside which the temperature of CMB background is about 70 μKelvin below the average temperature. What adds to the mystery is that it is surrounded by a hotter region. The idea is that the CMB cold spot corresponds to an expanding supervoid. I am however not at all sure whether our Universe is normal in the sense of general relativity.

Consider first the Sachs-Wolfe effect (`rebrand.ly/i2lpwy7`) which leads to the formation of cold and hot spots. Assume that a photon arrives at a gravitational well due to a mass distribution. The presence of matter induces first a blueshift as the photon falls in the gravitational potential of the region and then a redshift as it climbs out of it. The expansion however flattens the potential that there is a net reduction of the overall redshift due the average density of matter.

Since the local temperature depends on the local matter density, the low density region corresponds to a cold spot. If the cold spot corresponds to a region, which has a small density and expands during the period that photon uses to go through the cold spot, the redshift inside the region vanishes and is smaller than the redshift caused by the average region. The region appears to have lower density and lower temperature. There are a lot of these kinds of hot and cold spots and they induce fluctuations of the CMB temperature. But there is also a really big cold spot surrounded by hotter regions. This cold spot has been problematic.

The idea is that the CMB cold spot could correspond to an expanding supervoid. It is not however obvious to me how this explains the higher temperature at the boundaries of the supervoid. In the TGD framework, one can however ask whether the supervoid could correspond to a magnetic bubble caused by a local big bang, which has feeded energy to the boundaries of the resulting void forming a magnetic bubble so that the temperature at the boundaries would be higher than inside the void. One can even consider the possibility that the supervoid is in a reasonable approximation a void in M^4 sense so that very few 4-D space-time surfaces would exist in that region.

Could M^4 voids allow to test the TGD view of space-time?

The existence of M^4 voids might allow to test TGD view of space-time. The physics predicted by TGD is extremely simple in the case of a single-sheeted space-time sheet. The observed space-time is however many-sheeted. One can think using analogy with extremely thin glass plates with M^4 corresponding to the 2-D plane and CP_2 corresponding to its thickness. Einsteinian space-time sheets correspond to 2-D surfaces inside the plate, which are slightly curved and are connected by wormhole contacts. At the QFT limit one must replace the many-sheeted structure with a region of M^4 and define gauge and gravitational fields as sums of the induced fields associated with various sheets (and determined by the surface geometry alone). The extreme simplicity is lost.

However, if M^4 vacua exists one could test TGD at the single-sheeted limit to see the predicted fundamental physics in its extreme simplicity. Things would indeed be simple. Not only are the induced fields determined by the minimal surface property of the space-time region but also holography holds and is realized in terms of a generalization of the 2-D holomorphy to 4-D case.

10.4 Applications to the physics of stars and planetary systems

In this section the proposed general picture is applied to the physics of stars and planetary systems.

10.4.1 Population III stars in the TGD framework

I received link to an interesting popular article (`https://rb.gy/m7qlzg`) telling about a possible detection of population III stars [E166] (`https://rb.gy/sz0fw7`), which are believed to have emerged in the first stage of the stellar formation and generating only "non-metallic" nuclei, which by definition are not heavier than He^4.

Wang's team analyzed spectroscopy data for more than 2,000 of JWST's targets. One is a distant galaxy seen as it appeared just 620 million years after the Big Bang. According to the researchers, the galaxy is split into two pieces.

The analysis showed that one half seems to have the key signature of helium II mixed with light from other elements, potentially pointing to a hybrid population of thousands of Population III and other stars. Spectroscopy of the second half of the galaxy has yet to be done, but its brightness hints at a more Population III-rich environment.

Population III stars

If the standard model for the formation of stars population III stars would represent the first generation of stars. They should exist because we exist. The problem is that population III stars containing only elements not heavier than ^4He have not been observed.

Is the standard model for the star formation wrong so that population III stars would not exist at all? Or have we not been able to observe them. Now evidence for the existence of these stars have been reported [E166] but the evidence is controversial.

Let us list some properties that population III stars of the standard model should have.

1. In the standard model of star formation, the very hot gas prevents the formation of small stars. Population III stars would have immense sizes $10^2 - 10^5$ times the ordinary star size. By their large mass they would deplete the hydrogen gas very rapidly and would have a very short lifetime. Large volume of hydrogen and helium gas is available in the early universe so that this option looks plausible in the early universe.

2. The population III stars would have a high surface temperature of about 50,000 degrees Celsius, compared to the temperature of 5,500 degrees for the Sun. This provides a possible explanation for the high luminosity of very early galaxies. In the TGD framework, the concentration of irradiation to flux tubes connecting astrophysical objects would explain the high luminosity [L123].

3. The signature of the population III stars would be He II emission lines from a gas surrounding star when UV light from the hot surface of the star ionizes the He atoms of the environment (note that "II" refers to singly ionized He^4 rather than the "He II" appearing as superfluid phase in the model of helium superfluidity).

   The heat or explosions of population III stars could have caused reionization of the Universe. Evidence for them was found at about .62 billion years after BB. CMB temperature was at that time roughly 1 meV.

4. The ionization energy of He^4 is about 24.5 eV and in the UV region. Solar surface temperature .55 eV and by factor 1/50 lower. The surface temperature of population III stars is

estimated to be 55 eV. The He II emission would not originate in stars themselves but created when energetic photons from the star's hot surface are absorbed by the gas surrounding the star.

Are population III stars needed at all in the TGD framework?

The TGD picture about formation of stars [L10, L94, L31, L69] suggests that population III stars are not needed at all but are replaced with prestellar objects in which dark fusion followed by transformation of dark nuclei to ordinary nuclei leads to a prestellar object which eventually reaches the ignition temperature for ordinary nuclear fusion.

This allows to escape the problematic assumption about giant size population III stars and explains the apparent mixture of population III and population II stars as well as the Helium II lines appearing at some stage of the heating of the prestellar object.

The TGD based model relies on the following general assumptions.

1. The notion of local Bib-Bang with local values of Hubble constant H, cosmological constant Λ, age a, and parameter v_0 associated with gravitational Planck constant. This picture is suggested by the vision of how the monopole flux tubes carrying dark energy and dark matter transformed to ordinary matter in explosive events analogous to local big bangs.

   Large local values of H and Λ are needed and expected. Scaling gives naive estimates and they are expected to be too small.

   Temperature of the local big bang higher than that of the environment. Light-cone proper time a_{loc} assignable to local CD approaches cosmic time a for very large values of a since at this limit it does not depend on the position of the tip.

2. The local Big-Bang is analogous to a supernova explosion and throws out a magnetic monopole flux tube tangle, magnetic buble, with dark matter transforming to ordinary matter.

The transformation of dark matter at monopole flux tubes to ordinary nuclei is based on the TGD view of "cold fusion" as being due to the formation of dark nuclei which transform to ordinary nuclei [L10, L94, L31, L69].

1. In the TGD framework, dark fusion would precede ordinary fusion. Dark protons and neutrons would fuse to dark nuclei at monopole flux tubes and transforme to ordinary nuclei and liberate practically all nuclear binding energy leading to the heating and eventually initiation of ordinary nuclear fusions.

2. There is no need to assume that dark fusion stopped at He^4 so that for the simplest option population III stars are not needed at all. The pre-stellar objects as predecessors of the ordinary stars could have been obtained by dark fusion and gradually the cold fusion would have led to the ignition temperature of ordinary fusion and population II stars would have formed. The observed He II lines originate from these pre-stellar objects?

3. Dark fusion could have also produced elements heavier than He^4. This could allow us to understand the production of elements heavier than Iron as being due to dark fusion. Also the anomalies related to the abundances of some light elements could be understood. Dark fusion would proceed outside stars. Also the explosion producing supernova shells as dark magnetic bubbles involving dark fusion could explain the production of elements heavier than Fe in terms of dark fusion. Also the reported identification of heavy elements in the claimed "cold fusion" could be explained in this way [L10, L94].

If the mechanism for the formation of stars is the same as for the star formation in the Local Bubble, one expects that the stars are formed at the Local Bubble as dark matter transforms to ordinary matter by dark fusion followed by transformation to ordinary matter. This would lead to formation of local pre-stellar objects, which in some cases would reach the ignition temperature for the ordinary nuclear fusion.

10.4.2 Janus faced white dwarf

Science Daily release (`rb.gy/jkoun`) told about a really weird object reported in [E113]: the surface of the white dwarf is made of hydrogen on one side and helium on the other. The organization of particles with different masses to layers occurs by gravitation but only in vertical direction.

It is believed that hydrogen is able to diffuse into the interior of the dwarf so that its surface density is reduced so that effectively helium begins to dominate. This would be analogous to a phase transition. But why would this take place only for the other side of the white dwarf and why such a sharp division to two regions.

Magnetic fields are proposed as a possible explanation.

1. Whether the surface layer or atmosphere as it is called in the article is dominated by hydrogen or helium depends on temperature and pressure. At lower temperatures a transition to helium atmosphere is expected to take place. A weak magnetic field could induce a reduction of pressure or temperature and also prevent mixing.

2. At the surface layer the magnetic fields tend to prevent the mixing of hydrogen and helium ions by forcing the ions to cyclotron orbits. Mixing requires that hydrogen, helium or both are ionized.

   Whether this is the case depends on temperature. Wikipedia article claims that white dwarf temperatures are in the range 150,000 K-4000 K (15 eV -.1 eV). The upper limit 15 eV is slightly above 13.7 eV which is the ionization energy of hydrogen in ground state so that hydrogen could be ionized. Helium would not be ionized. If there is no ionization, the magnetic moment of hydrogen is what matters. Helium nucleus has a vanishing magnetic moment. Non-ionized helium looks magnetically inert but not hydrogen, which could also be at cyclotron orbits.

3. The popular article informs that the temperature of the white dwarf is around 35,000 K (35 eV). For helium the ground state energy, proportional to Z^2 is 54.8 eV in the simplest model, which suggests that helium is not ionized and cyclotron orbits are not possible.

Two options are considered.

1. If hydrogen is ionized, it moves along cyclotron orbits and tends to be magnetically confined. Also the higher magnetic field strength at the hydrogen side reduces the mixing. Since helium is not ionized, it is not magnetically confined and will mix more easily. This is true in the standard physics picture, in which one has no monopole flux tubes, which confine even non-charged particles.

2. The higher value of the magnetic field implies a lower pressure and this would imply slower diffusion of the hydrogen to the interior. If the sum of the magnetic and ordinary pressures is constant, hydrogen oceans with a higher magnetic field strength and lower pressure could be formed.

Also I tend to believe that magnetic fields could solve the puzzle but not necessarily in the proposed way. What comes to mind after a minute of thinking is the following.

1. In the TGD framework, magnetic fields correspond to flux tubes and flux sheets. There are monopole flux tubes, something new, and ordinary flux tubes possible also in the Maxwellian world. There would be confinement inside the flux tubes. The flux tubes can also flatten to flux sheets.

2. In particular, the gravitational magnetic monopole flux tubes and sheets are possible. This is a purely TGD based phenomenon. The gravitational Planck constant $\hbar_{gr} = GMm/\beta_0$ ($\beta;_0 = v_0/c \leq 1$ is velocity parameter) is proportional to the mass M of the white dwarf and to the mass m of the particle, now helium or hydrogen.

The longstanding question has been whether a gravitational flux tube/sheet characterized by $\hbar_{gr}$

1. attaches only to/contains only particles with a fixed mass m,
2. or whether it attaches to particles with varying mass m. If so, the gravitational Planck constant would be 2-particle property and depend on m for a gravitational flux tube/sheet associated with mass m.

If the first option is true, the particles with different masses m would be arranged like books in the library, each in its own shelf defined by the gravitational flux tube/sheet (M,m). In the case of the weird white dwarf, helium and hydrogen would be on their own shelves located at different sides of the star as a gravitational library. For flux tube option there could be a mixing of the flux tubes. For large sheets the mixing would be absent.

What does the first option imply in the case of the weird white dwarf? One can consider two options.

1. Monopole flux tubes form roughly parallel layers along the surface of the white dwarf. The layers associated with hydrogen and helium should be disjoint: but why?
2. There are separate flux sheets associated with either hydrogen or helium but not both. If the flux sheets have boundaries orthogonal to the rotation axis, the hydrogen and helium layers are static. Since helium can mix in the tangential direction, it would prefer flux sheets. Hydrogen would not mix and could be also associated with flux tubes.

In quantum biology the first option would imply that at the level of dark matter associated with the magnetic bodies the biomatter would be extremely organized, in a complete contrast to the view that biomatter is a chaotic soup of biomolecules. The interaction by cyclotron frequency resonance occurs only between charged particles with the same h_{eff} and the same flux tube field strength: this requires the same mass in the case of gravitational flux tubes. Note that one can also talk about electromagnetic Planck constant. This supports the library like organization.

Charged particles with different gravitational Planck constant (masses m) can have gravitational cyclotron *energy* resonance but not *frequency* resonance: this reflects Equivalence Principle.

10.4.3 TGD view of the planetary system

Could TGD based quantum vision of planetary system [K93, K79] [L50, L55, L113, L102, L131] provide some insights to this problem? One can start from some observations related to the planetary sizes in the solar system.

1. Earth size 6,371 km is not far from the gravitational Compton length of Sun $GM/\beta_0 = r_S/2\beta_0$ which for $\beta_0 = v_0/c = 2^{-11}$ is about $\Lambda_{gr} = 3,000$ km, which is amazingly near to half radius of Earth about $r_E = 6371$ km. Expanding Earth model in turn proposes that the Earth radius was $r_E/2$ before the Cambrian Expansion and therefore roughly the same as the radii of Mercury and Mars.
2. In the Nottale's model [E87], the value of the parameter $\beta_0 = v_0/c$ appearing in $\hbar_{gr}$ is by a factor 1/5 smaller for outer planets than for inner, Earth-like planets, including Mars. This means that the value of the gravitational Compton length is scaled up by a factor 5: $\Lambda_{gr} \rightarrow 5\Lambda_{gr}$. If the radius is roughly equal to a multiple of Λ_{gr}. The radii of planets would scale like β_0 and their distances like $1/\beta_0^2$ and one could speak of kinds of proto planets corresponding to some maximum value of β_0.
3. Using the gravitational Compton length $\Lambda_{gr} = GM/v_0$ for the Sun as a unit, Using Mkm as a unit, the radii of the planets (`https://rb.gy/w8e7zb`) are given by

$$[r_E = 6.371, r_{Ju} = 69.911, r_{Ur} = 25.362, r_{Me} = 2.4397, r_{Ma} = 3.3893, r_{Ne} = 24.622, r_{Sa} = 58.232; r_{Ve} = 6.0518] \ .$$

If one uses $2\Lambda_{gr} = 6000$ km as a unit, the radii are given by

$$[r_E = 1.0618, r_{Ju} = 11.6518, r_{Ur} = 4.2270, r_{Me} = 0.4066, r_{Ma} = 0.5649, r_{Ne} = 4.1037, r_{Sa} = 9.7053, r_{Ve} = 1.0086] \ .$$

4. Giant planets of the solar system come in two varieties. Jupiter and Saturn, known also as gas giants, consist primarily of hydrogen and helium and have a radius of roughly $10r_E$). Uranus and Neptune, also known as ice giants, consist of ice, rock, hydrogen, and helium and have a radius nearly to $4r_E$ not too far from $5r_E$). Gas giants are also called failed stars because their composition resembles that of young stars consisting of light elements. Helium makes roughly one half of the mass of the atmosphere.

   Remarkably, the radii of giant planets are not very far from $2\Lambda_{gr,\beta_0/5}$ and $4\Lambda_{gr,\beta_0/5}$, and would very roughly correspond to first and second octaves of solar gravitational Compton length for $\beta_0/5$ in the model of Nottale [E87]. In fact, the radii of inner planets radii are not far octaves for the radius of Mars. Does this mean that the expansion by a power of 2 proposed by Expanding Earth model [L131] has occurred for all planets except Mars and Mercury?

The following summarizes the TGD based model for the formation of planets by dark fusion and subsequent transformation of dark nuclei to ordinary nuclei.

1. In the TGD based model [K93, K79], planets could have formed by dark fusion [L10, L31, L94] as the dark matter at the magnetic flux tubes characterized by $\hbar_{gr} = GMm/v_0$. Dark matter would have consisted of dark proton (possibly nucleon with neutron as dark proton having charged color bond with the dark proton preceding it) sequences. These dark nuclei would have transformed to ordinary matter liberating almost all nuclear binding energy in this process. This would have induced an explosion.

2. First He and possibly also heavier elements would have formed by dark fusion. The process would have involved an explosion analogous to a supernova explosion, kind of a local Big Bang. The energy would have come from the liberation of nuclear binding energy. Due to the liberation of nuclear binding energy, the process would have led to a high temperature. Ordinary nuclear fusion starts if the temperature increases above the ignition temperature of ordinary fusion. In the proposed TGD based model, this would have led to a formation of a population II star.

The simplest assumption is that ordinary nuclear fusion has not started for planets although one cannot exclude this possibility in the case of the Earth-like planets with inner core.

1. If a spherical shell of dark matter was emitted, a gravitationally induced spontaneous breaking of spherical symmetry could be in question. The flow of the matter along magnetic flux tubes of the magnetic bubble to the spot, which became a planet, would have heated it. Also Moons could be these kinds of hot spots and planetary rings. The fact that largest exoplanet HD 100546 b (`https://rb.gy/doyii7`) is accompanied by a spherical shell supports this option.

2. The quantum option, which might be too radical, is that the dark planet would not have a spherical mass shell but a quantum version of a radial jet delocalized over angular degrees of freedom as, say, angular momentum eigenstate. The formation of a planet would have been a collectve localization of single particle wave functions in momentum space so that the collective wave function would have been replaced by a time dependent wave function localized at a positing describing Kepler orbit. The mass would be concentrated at the slowly increasing orbital radius. This picture would conform with the Bohr orbit model.

3. An option, which is more in line with the standard view, is that the inner core is not due to planetary dark or nuclear fusion. Rather, the dark fusion at the spherical surface would have produced matter, whichwas gravitationally attracted by the pre-existing core region.

A rough sketch for the planetary evolution

Could one understand the differences between Earth like giant planets and giant exoplanets in this framework? One must answer at least the following questions.

1. Why the giant planets contain mostly helium?

2. How giant exoplanets can have very small orbital radii in contrast to the solar giant planets? Have the giant exoplanets migrated near their stars or could some other mechanism explain their small orbital radii?

Perhaps the following rough sketch could catch some elements of truth. Suppose that the formation of planets indeed involves a local Big-Bang throwing a layer or stellar surface outwards, which is induced by the liberation of nuclear binding energy in the transformation of dark nuclei to ordinary matter after dark fusion producing dark nuclei.

The fact that outer planets are older and thrown out of Sun earlier suggests a general view of the planetary evolution.

1. The outer planets are oldest and for them the dark fusion at the surface of Sun would not have had enough time to produce dark variants of heavier elements. As the transformation to ordinary nuclei occurred in the formation of planet, only relatively light elements were produced.

2. For the Earth-like planets, dark fusion occurring at the surface of the star would have had enough time to produce a spherical layer or pre-planetary spot of dark variants of heavier elements before the explosion accompanying the transformation of the dark nuclei to ordinary nuclei, occurred.

   What would be new as compared to the standard model would be that elements like Fe of planetary inner cores would have been generated by dark fusion following by an explosion of spherical shell rather than coming from decay proecuts of supernovas and thrown out in the formation of planets at the surface of the expanding magnetic bubbles.

3. Could ordinary nuclear fusion play any role? The temperature at the surface of Sun was certainly too low for the ordinary nuclear fusion to start. If the heating induced by the transformation to ordinary nuclei was not enough to initiate ordinary fusion in the planetary core, the planet would be a failed star. Even if the ordinary fusion was initiated, the increase of the planetary radius by a process analogous to what Expanding Earth model proposes, could have made the density of the fuel too small for nuclear fusion to continue.

One should understand also the sizes of planets.

1. Why should the solar giant planets have large orbital radii? Could the radius of the planet increase in discrete steps as the model for Expanding Earth suggests? If the size increases in discrete steps, the large size could be due to the fact that the explosion from them has reached a considerably later stage for the solar system as compared to the exoplanetary systems. Could giant exoplanets with small orbital radii accompany very young stars?

   Or does the size remain constant as the existence of giant planets with very small orbital radius suggests?

2. Could the smaller value of β_0 for outer planets imply a larger radius as is suggested by the fact that giant planets have radii, which are roughly 5 and 10 times the radius of Earth?

Ingredients of a more concrete model

Since the orbital radius of the planet correlates with the duration of expansion, outer planets would have formed before the inner planets. Planets would been emitted as magnetic bubbles containing dark matter or as quantum jets described above. Planetary systems would tell the story of planetary evolution: an astrophysical variant of the phylogeny recapitulates ontogeny principle would be realized.

To build a more concrete model, assume that the value of the parameter β_0 characterizes the Sun-planet pair. Second parameter would be an integer k characterizing the radius of planet as multiple of Λ_{gr}. This assumption is inspired by the observation that the planetary radii are multiples of $\Lambda_{gr} \sim r_{Mars}$.

1. Assume that the Bohr model makes sense so that the radius of planetary orbits is given by

$$r_n = \frac{n^2 GM(star) 4\pi}{\beta_0^2} \quad .$$

2. The condition suggested by a standing wave in the radial direction

$$r_{plan} = k\Lambda_{gr} = \frac{kGM(star)}{\beta_0} \quad , \quad k = 1, 2...$$

is certainly approximate but would conform roughly with the radii of solar giants planets for $k = 2, 4$ suggesting that k is power of two as Expanding Earth model assumes. All planets except Mercury and Mars would have experienced the transition $k = 1 \rightarrow 2$.

3. For the inner planets, one obtains the condition

$$\frac{r_{orb}}{r_{plan}} = \frac{n^2 4\pi}{k\beta_0} \quad .$$

An appropriate generalization holds true for outer planets with different values of β_0 and n. The small value of r_{orb} and large value of r_{plan} for the giants with small orbital period, favors small values of n, and large values of $\beta_0 < 1$ and k.

For $\beta_0 = 1$, this gives the lower bound

$$\frac{r_{orb}}{r_{plan}} \leq \frac{n^2 4\pi}{k} \quad .$$

Note that the solar radius is $r(Sun) = 696.340$ Mm and roughly 10 times the radius $r_{Ju} = 69.911$ Mm of Jupiter. The largest known exoplanet HD 100546 b has radius about $6.9 r_{Ju}$ and is probably a brown dwarf (`https://rb.gy/doyii7`).

4. The empirical input from the very short periods of giant planets, which are a few days (`https://rb.gy/doyii7`), gives an additional condition. For a circular orbit, the period T relates to the orbital radius via Kepler's law

$$T^2 = 4\pi^2 \times \frac{r^3(orbit)}{GMc^2} \quad .$$

Using $r_{orb} = n^2(4\pi GM/\beta_0^2)$, one obtains

$$T = 8\pi^{5/2} \frac{n^3}{\beta_0^3} \frac{r_s}{c} \quad .$$

For a given period T and stellar mass M, this gives

$$\beta_0 = 8 \times 2^{1/3} \pi^{5/6} \frac{1}{n} \frac{cT}{r_s})^{1/3} \quad .$$

$n = 1$ is natural for the lowest Bohr orbit. For solar mass one has $r_S = 3$ km. For $T = 24$ hours this would give $\beta_0 = 2.53 * 10^(-3) = 1.295 \times 2^{-9}$ to be compared with the estimate $\beta_0 = 2^{-11}$ for Sun. The result conforms with the idea that β_0 decreases gradually during the evolution of the planetary system, perhaps in powers of 1/2.

If the radius of the planet is given by $r_{plan} = kGM/\beta_0$ and the giant planet has the radius of Jupiter about 70,000 km, one has $k = 2(r_{plan}\beta_0/r_S \simeq 59$. In this case the planet could be regarded as a brown dwarf (`https://rb.gy/she7el`), which had too low mass to reach the temperature making possible nuclear fusion.

5. One might end up with problems with the idea of orbital expansion since the Bohr radius is given by $r_n = 4\pi n^2 GM(Sun)/\beta_0^2$, where n is the principal quantum number n. n should be small for a giant exoplanet with very small orbital radius. Too small orbital radii are not however possible for a given value of β_0.

   The Nottale model suggests that β_0 is dynamical, quantized, and decreases in discrete steps during the expansion for some critical values orbital radius so that also r_{plan} increases for certain critical values of r_{orb}. I have earlier developed an argument that β_0 is quantized as $\beta_0 = 1/n$, n integer. It must be emphasized however that outer and inner planets could also correspond to the same value of β_0 if values of n for them come as multiples of 5.

6. The reduction $\beta_0 \rightarrow \beta_0/5$ appearing in $\Lambda_{gr} = GM/\beta_0$ appearing in the formula for r_{plan} would induce the increase of the planetary radius.

   Does value of the parameter k need change during the orbital expansion? The existence of giant planets with very small orbital radii would conform with the assumption that the value of k does not change during evolution. On the other hand, the idea that planets should participate cosmic expansion in discrete jerks and the observation that the radii of planets are roughly power of 2 multiples of $\Lambda_{gr} \sim r_{Mars}$, suggest that k can increase in discrete steps coming as power of 2.

Why is the water in the solar system older than the Sun?

It has been found that water in the solar system is older than the Sun (see https://rb.gy/3noqn4). By looking at the water on protostar V883 Orion, at a distance of 1,305 light-years from Earth, scientists found a "probable link" between the water in the interstellar medium and the water in our solar system. Water molecules in Orion have a similar deuterium-to-hydrogen ratio that in the solar system. That likely means our water is billions of years older than the sun. The finding is analogous with the finding that some stars and galaxies are older than the Universe.

A possible TGD based explanation for the observation that water at Earth is older than the Sun could be based on zero energy ontology (ZEO) forming the basis of the TGD based quantum measurement theory solving the basic paradox of quantum measurement theory.

1. In ZEO, the arrow of geometric time changes in the ordinary state function reduction, which means that systems live forth and back in geometric time. By this forth and back motion, the evolutionary age of the system is different from the temporal distance from its moment of birth. This explains the existence of stars and galaxies older than the Universe and could also explain why the water at Earth is older than the Sun.

2. In the TGD based quantum biology water is a living system in the sense that it is characterized by a large value of effective Planck constant (second basic difference from standard quantum theory) implying long quantum coherence scales. This makes the geometric duration of a life in a given time direction long and therefore increases the evolutionary age of water. In living matter, Pollack effect occurs at physiological temperatures and means a formation of phase of water with effective stoic

3. The evolutionary age for water on Earth could be longer than for water in the Sun since the environment is different. Earthly environment makes the phase transitions producing the fourth phase of water discovered by Pollack [I12, L9, I24, I20] and discussed from the TGD point of view in [L9]. It has effective stoichiometry $H_{1.5}O$ and has properties suggesting the change of the arrow of time. These phase transitions occur at the physiological temperature range.

   At physiological temperatures the phase transitions changing the arrow of time could take more often and the life cycle with a given arrow of time would last longer. This is so because the magnetic body of water, carrying dark protons, makes it a macroscopic quantum system. The periods with a reversed arrow of time have been much longer (larger h_{eff} is the essential reason). Therefore the water on Earth could be older in the evolutionary sense.

There is however an objection against the ZEO based explanation.

1. The TGD view of the formation of planetary systems predicts that planets are formed in explosions throwing matter from the Sun. The water on Earth should therefore originate from the Sun or from the protostar Sun.

2. There is indeed evidence against the idea that water on Earth originates from melted meteorites: they are now known to be extremely dry. This leaves non-melted meteorites, chondrites, as one particular option (https://rb.gy/wwob8l).

3. There is also evidence for water in the Sun from Nasa (https://rb.gy/wc9vl7)! There is even a proposal that the water on Earth might have arrived from the Sun (see https://rb.gy/t1yaz8)!

   The idea about the presence of water in the Sun looks insane in the standard physics framework but in the TGD Universe the water molecules could reside at the monopole flux tubes of the magnetic body of the Sun.

How can the water on Earth be older than the Sun if it originates from the Sun? The simplest answer is that also the water in the Sun is much older than the Sun.

1. This is possible in the TGD view of the formation of astrophysical systems [L136, L137], in particular stellar cores [L82, L10, L94] and would conform with the findings, which led to the proposal that water to solar system has migrated from say Orion. Now this is not needed.

2. First the analog of "cold fusion" would have led to the formation of protostar at much lower temperature but already produced dark analogs of nuclei as dark proton sequences, which would have spontaneously transformed to ordinary nuclei and liberated essentially all nuclear binding energy. This would have led to the formation of water molecules already before the ordinary nuclear fusion started. This prestellar history would be universal and the same in the protostar Orion and in the protostar Sun. For this option, ZEO is not necessary and it would conform with the findings. Of course, the water in living matter could be evolutionarily much older than the water elsewhere in the solar system.

The mystery of the "radius wall" for planets as a starting for the Bohr model of planetary system

Over 5,200 exoplanets have been confirmed hitherto. Exoplanets have posed several challenges for the existing models of the formation of planets (https://rb.gy/hfwutz).

1. An expected finding is that giant exoplanets can have very small orbital radii. In some cases with orbital periods that last just a few days. The proposed explanation is that these planets have migrated to the vicinity of their stars.

2. The second mystery is that there is a mysterious size gap in the scale of exoplanets. Transit observations first by NASA's Kepler Space Telescope and now by TESS, the Transiting Exoplanet Survey Satellite, have found a puzzling absence of planets with radii between 1.4 and 2.4 times that of Earth. Astronomers call this the "radius valley" and although it seems to be telling us something fundamental about the nature, formation and evolution of planets, scientists have yet to ascertain what that something is. What comes in mind is quantization of orbit radii.

Helium could make up almost half the mass of the atmosphere of giant exoplanets that have migrated close to their star. A team led by PhD student Isaac Malsky of the University of Michigan and Leslie Rogers of the University of Chicago proposes a new approach to the radius valley problem [E215]. Perhaps it could signal an increasing abundance of helium gas in the atmosphere of planets 2.4 times larger than Earth. Planets of this scale are often described as mini-Neptunes, and if they have a rocky core, it's deep beneath a thick atmosphere. But why the abundance of helium gas would be higher?

Does Sun have a solid surface?

There are indications for the presence of elements other than water near the surface of the Sun. The findings discussed by Moshina [E213] suggested already about 17 years ago that the photosphere has a rigid conductive layer. This layer could also contain water.

One of my first speculative applications of the evolving TGD view of dark matter (roughly 15 years ago) and of the TGD based interpretation of the Nottale's formula [E87] was the proposal that could be interpreted as a TGD counterpart for a Bohr orbit, not as an orbit but a spherical layer [K111, K93].

At that time I had no ideas about number theoretic interpretation of the dark matter hierarchy nor a general view of the formation of astrophysical objects in terms of a transformation of dark energy of cosmic strings to dark matter at monopole flux tubes in turn transforming to the ordinary matter [L136].

The recent view of the formation of planets and their moons and rings indeed allows spherical layers having as representative Oort clouds; torus-like flux tubes having as representative the rings of Jupiter; and ordinary planets.

1. They would be formed in a phase transition in which the gravitationally dark matter associated with a bubble formed by monopole flux tubes transforms to ordinary matter and can be also localized to lower dimensional structure. The analog of localization in state function reduction in astrophysical scale taking place in measurement would be in question. For instance, the formation of a planet would correspond to a measurement of a momentum direction and radial distance for a delocalized state described approximately by the analog of hydrogen atom wave-function.

2. The Nottale model predicts that the inner planets Mercury, Venus and Earth correspond to Bohr orbits with $n = 3, 4, 5$. What about $n = 1$ and $n = 2$ orbits? For Earth one has $n = 5$ and from the radius of Earth orbit, which is $AU = 1.5 \times 10^8$ km by definition, the radius of $n = 1$ orbit given by gravitational Bohr radius a_{gr} and is $a_{gr} = AU/25 \simeq 6.0 \times 10^6$ km. The radius of the photosphere is $R = 6.96 \times 10^6$ km giving $a_{gr}/R \simeq .87$. $n = 1$ Bohr orbit or Bohr shell with radius $R_1 = a_{gr}$ would be just below the photosphere. $n = 2$ Bohr orbit would correspond to the radius $R_2 = 2.4 \times 10^7$ km. Is there any evidence for a spherical layer or a ring, at this distance?

3. If the mass of the layer of thickness ΔR is the same as that of Mercury ($.055 \times M_E$) with radius $R_M = .38 \times R_E$ and the density of the layer is the same as that of Earth, one obtains the estimate $\Delta R = (R_M/R_1)^2 R_M/3 \sim$ 3.2 m. The layer would be extremely thin. If the mass is Earth's mass, ΔR increases by the factor $.38^3$, roughly by two orders of magnitude.

Is there any empirical evidence for the proposed view?

1. There was already 15 years ago evidence that there is a solid surface with radius of $n = 1$ Bohr orbit. Recently new satellites have begun to provide information about what lurks beneath the photosphere. The pictures produced by Lockheed Martin's Trace Satellite and YOHKOH, TRACE and SOHO satellite programs are publicly available on the web. The SERTS program for the spectral analysis suggests a new picture challenging the simple gas sphere picture [E213].

   The visual inspection of the pictures combined with spectral analysis has led Michael Moshina to suggest that the Sun has a solid, conductive spherical surface layer consisting of calcium ferrite. The article of [E213] provides impressive pictures, which in my humble non-specialist opinion support this view. Of course, I have not worked personally with the analysis of these pictures so that I do not have the competence to decide how compelling the conclusions of Moshina are. In any case, I think that his web article deserves a summary.

2. Before the SERTS people were familiar with hydrogen, helium, and calcium emissions from the Sun. The careful analysis of the SERTS spectrum however suggests the presence of a layer or layers containing ferrite and other heavy metals. Besides ferrite, SERTS found silicon, magnesium, manganese, chromium, aluminum, and neon in solar emissions. Also elevated levels of sulphur and nickel were observed during more active cycles of the Sun. In

the gas sphere model these elements are expected to be present only in minor amounts. As many as 57 different types of emissions from 10 different kinds of elements had to be considered to construct a picture about the surface of the Sun.

3. Moshina has visually analyzed the pictures constructed from the surface of the Sun using light at wavelengths corresponding to three lines of ferrite ions (171, 195, 284 Angstroms). On the basis of his analysis he concludes that the spectrum originates from rigid and fixed surface structures, which can survive for days. A further analysis shows that these rigid structures rotate uniformly.

   The existence of a rigid structure idealizable as a spherical shell in the first approximation could by previous observation be interpreted as a spherical shell corresponding to $n = 1$ Bohr orbit of a planet not yet formed. This structure would already contain the germs of iron core and of crust containing Silicon, Ca and other elements.

Standard physics does not favor the existence of this kind of layer.

1. The solids become typically liquid at the temperature of about 5800 K prevailing in the photosphere (`https://rb.gy/rgvhpg`). Ordinary iron and also ordinary iron topologically condensed at dark space-time sheets, becomes liquid at temperature 1811 K at atmospheric pressure. Using for the photospheric pressure p_{ph}, the ideal gas approximation $p_{ph} = n_{ph}T_{ph}$, the values of photospheric temperature $T_{ph} \sim 5800$ K and density $\rho_{ph} \sim 10^{-2}\rho_{atm}$, and idealizing photosphere as a plasma of hydrogen ions and atmosphere as a gas of O_2 molecules, one obtains $n_{ph} \sim .32 n_{atm}$ giving $p_{ph} \sim 6.4 p_{atm}$.

   This suggests that calcium ferrite cannot be solid at temperatures of order 5800 K prevailing in the photosphere (the material with highest known melting temperature is graphite with melting temperature of 3984 K at atmospheric pressure). Thus it would seem that dark calcium ferrite at the surface of the Sun cannot be just ordinary calcium ferrite at dark space-time sheets. A more reasonable option is that there is new physics allowing to have a low temperature at the layer.

2. There is also a problem with the existence of water in the photosphere. The bond energy is 4.4 eV per bond so that the total bond energy is 8.8 eV. The peak energy of blackbody radiation is given by $E_{peak} = 2.4 \times 10^{-4} T/K$ eV and 8.8 eV is below the thermal energy of order 12.1 eV associated with the photospheric temperature $T = 5,500$ K so that water molecules are not be stable at these temperatures.

The following speculative explanation for the solid surface is an updating of the earlier proposal [K111, K93].

1. In the model of the solar cycle in terms of monopole flux tubes, the flux loops at the surface have inner and outer parts. The inner parts are always parallel to the solar surface and reside below it. Outer parts form flux loops extending outside the photosphere. With a 11 year cycle, the long monopole loops return to thin parallelepiped configuration, which splits to short monopole flux loops by reconnections, which then reorganize to flux tubes with opposite polarity. Could these monopole flux loops be accompanied by a solid surface of ordinary matter with the radius of $n = 1$ Bohr orbit.

   The interior portion of the gravitational monopole flux loops would carry dark matter with $\hbar_{gr} = GMm/\beta_0$, $\beta_0 \simeq 2^{-11}$ and corresponding gravitational Compton length $\Lambda_{gr} = GM/\beta_0 \simeq 6 \times 10^3$ km, which happens to be in a good approximation the radius of Earth.

2. Could the monopole flux tubes shield the ordinary matter at the layer from the effects of the radiation arriving from the solar interior in the same way as they would shield the biosphere from the cosmic radiation and solar wind? Could the radiation from the solar interior be caught by monopole flux tubes and leave the Sun as a solar wind?

3. If there are stable water molecules in this layer, its temperature should be rather low. If the water is in liquid or solid phase, the temperature must be of the order of the temperature at Earth. This inspires a crazy question: could the monopole flux tubes carrying gravitational

dark matter allow even chemical life inside this layer [L121, L119]? How low the temperature of dark matter at the flux tubes can be and is it possible to estimate it using the existing data?

4. The cyclotron energies of dark particles are proportional to $\hbar_{eff} = \hbar_{gr}$. Could this allow us to transform the arriving high temperature radiation from the solar interior to a low temperature radiation at the monopole flux tubes from which it could leak out as solar wind? Could even the radiation from the solar interior arrive along radial gravitational U-shaped monopole flux loops and have a low temperature? If so, the magnetic body of the solar interior would be an astrophysically quantum coherent system and very different from what we believe it to be.

The above posed questions of course sound totally crazy in the standard physics framework but we really have only the standard physics based view of what happens in the Sun. Quantum gravitational coherence in astrophysical scales might change our views completely.

Could TGD view of quantum gravitation allow nuclear life?

The prevailing dogma is that life is always chemical. The above considerations force us to challenge this dogma. Just for fun, one can therefore play with the thought that fractality of the TGD Universe could allow life at temperatures prevailing in the solar interior.

This life should be based on nuclear physics instead of chemistry. The realization of the genetic code [L127, L103] in the TGD framework relies on dark proton (or possibly nucleon) sequences. According to the TGD based view of nuclear physics [L2], the ordinary nuclei also correspond to sequences of nucleons at monopole flux tubes, which form a kind of nuclear spaghetti. Therefore the realization of also nuclear genetic code could rely on nucleon sequences. The chemical realization of the genetic code could be seen as the next step in evolution.

1. Gravitational magnetic body carrying gravitationally dark matter and consisting of the mopole flux tubes would still be the controller. The average magnetic field at the surface of the Sun is indeed about $2B_E \simeq 1$ Gauss. Just for definiteness, one could assume that the scale for the strength of the monopole magnetic field is twice that for the monopole flux tubes at the surface of Earth that is $2B_{E,mono} \simeq 4B_E/5 \simeq .4$ Gauss.

2. The scale of cyclotron energies for $\hbar_{gr} = GMm/\beta_0$, where $\beta_0 \simeq 2^{-11}$ is assumed in Nottale's model, would be scaled up from that at the surface of Earth by the factor $x = (M_S/M_E) \times (\beta_{0,E}/\beta 0, S) \times (B_S/B_E)$. For $\beta_{0,E} \simeq 1$ prevailing in the Earth's magnetosphere, this would give $x \simeq 2.5 \times 10^9$.

   For the energy 1 eV of a photon in biophoton wavelength range one the energy $E = h_{eff}f$ would scale up to 2.4 GeV, which corresponds to more than 2 proton masses! This looks non-sensible.

3. However, in the outer magnetosphere of Earth where $\hbar_{gr,S}$ is expected to prevail, the values of B_E are in the range 1-10 nTesla, which means that the scale of the magnetic field (and also monopole flux) is reduced by about 5×10^{-5}. This would reduce the dark cyclotron energy ratio to $x = 1.25 \times 10^5$. 1 eV energy would be scaled to the range of .1-1.0 MeV, which corresponds to nuclear binding energy scale.

4. For $\beta_{0,S} = 2^{-11}$ the lowest solar Bohr orbit has a radius slightly larger than the radius of the photosphere, so that it cannot correspond to the matter in the interior of the Sun.

   For $\beta_{0,core} = 1$, the lowest Bohr radius would be $r_B = 4\pi GM/\beta_{0,core} = 6\pi$ km, which makes 2π solar Scwartschild radii. The value of x would be $x = 5 \times 10^5 B_{core}/B_E$, and for $B_{core}/B_E = 1$ the biophoton energy scale of 1 eV would scale up to .5 MeV, which corresponds to the mass of electron and to the nuclear binding energy scale.

Maybe nuclear life at the solar core and even in the outer magnetosphere of Earth might be considered.

Summarizing the model for the formation of planets

The foregoing considerations suggest a simple model for the evolution of the parameters β_0 and k assumed to characterize planet-star pairs during the expansion.

1. β_0 was reduced to $\beta/5$ at distance when it became impossible to realize circular Bohr orbits for $\beta_0 \simeq 2^{-11}$ anymore. The radius of the planet was increased by a factor 5 and transformed an Earth-like planet to a giant planet.

2. The radii of Jupiter and Saturn would have been roughly $2r_E$ before this and the radii of Uranus and Neptune would have been roughly r_E. Mercurius and Mars would have had a radius not far from $r_E/2$. p-Adic length scale hypothesis is suggestive.

3. The increase of k is consistent with the Expanding Earth model involving the increase of Earth radius by a factor $k = 2$.

   Expanding Earth model [L131] and the fact that Λ_{gr} is roughly $r_E/2 \sim r_{Mars}$ suggests an even simpler model. Outer planets have suffered the transition $\beta_0 \rightarrow \beta_0/5$. Jupiter and Saturn with a radius about $20\Lambda_{gr}$ have also suffered two scalings $k = 1 \rightarrow 2 \rightarrow 4$. The remaining planets except Mars and Mercury have suffered the scaling $k = 1 \rightarrow 2$. In the simplest model, the solar proto planet would have a radius roughly that of Mars and Mercury.

The localization of the dark mass should have a classical space-time counterpart at the level of the space-time surface. It should be also consistent with the Newtonian view of gravitation in which gravitational flux as an analog of electric flux is conserved. Also consistency with stringy description of gravitation based on $3 \rightarrow 4$ holography is desirable. This raises the question whether flux tubes carrying Kähler electric flux are possible and whether one can construct candidates for them as simultaneous extremals of Kähler action and volume action.

1. Assume that the solar - and also other gravitational fluxes can be associated with monopole flux tubes which have 2-D M^4 projection as a string world sheet. If these flux tubes are defined so that the CP_2 projection as a homologically non-trivial 2-surface depends on time, Kähler electric field is generated and the flux tube has conserved Kähler electric charge Q_K.

2. The simplest guess for the flux tube carrying Kähler electric field is that the homologically trivial sphere as CP_2 projection rotates, not in 1-D sense but in 2-D sense meaning that at a given point of the string world sheet $X^2 \subset M^4$ it is obtained by a local color rotation of S^2 at standard position in CP_2.

   A natural interpretation of Q_K would be as a counterpart of gravitational flux. Note that this requires that Kähler electric charges have the same sign. This picture conforms with the finding that space-time surfaces with stationary, spherically symmetric induced metric with non-vanishing gravitational mass have at least some non-vanishing gauge charges. For monopole flux tubes Kähler electric charge is non-vanishing. If the flux tubes are U-shaped, the Kähler electric flux must vanish.

   The M^4 projections of the flux tubes would be counterparts of strings mediating gravitational interaction in AdS/CFT duality and mediate gravitational interaction and with Newtonian view.

3. How to describe the formation of the planets or smaller structures in this picture? One can regard the radial flux tubes from the Sun as analogs of particles and introduce for them a wave function in the orientational degrees of freedom, say as spherical harmonics with defined angular momentum.

   The magnetic bubble would correspond to a flux tube structure tangential to say 2-D sphere around the Sun and attached to the radial flux tube structure by wormhole contacts. This structure carries matter as dark particles (fermions).

   A nearly complete collective localization in the orientational degrees of freedom would correspond to a state function reduction involving the reorganization of the gravitational flux tubes to a radial bundle with a definite orientation forcing the tangential flux tube tangle to reduce in size so that it corresponds to the magnetic body of say, planet. This would give rise to the planet after the transformation of dark matter to ordinary matter. Also a localization to a torus-like structure is possible and gives rise to a ring-like structure.

The reduction of quantum coherence to a smaller scale would give rise to smaller structures such as formation of flux tube bundles assignable to mini-planets and even smaller structures as in the case of the Kuiper belt and Oort cloud.

What can one say of the flux tubes carrying Kähler electric field?

1. I have proposed this kind of extremals in the model of honeybee dance [K47], which was inspired by the work of topologist Barbara Shipman [?], who proposed that honeybee dance reflects the color symmetry of strong interactions. In the standard model this proposal does not make sense but is natural in the TGD framework.

   The local color rotation $s^k \rightarrow g^k(s^l)$ is an isometry of CP_2 and maps the Kähler form $J_{kl}ds^k \wedge ds^l$ and line element of $ds^2 = s_{kl}ds^k ds^l$ of the Kähler metric invariant. Using coordinates x^μ for X^2 and s^k for S^2, the induced Kähler form has the following structure

   - S^2 part is the same as for the standard S^2, that is $J_{kl} \rightarrow \partial_k g^r J_{rs}(g^{-1}(s))\partial_l g^s = J_{kl}(s)$. The same formula holds true for the CP_2 contribution to the induced metric.
   - X^2 part is of the form

     $$J_{\mu\nu} = g_\mu^{\ k}(g^{-1}Jg^{-1})_{kl}(s)g_\nu^{\ l} \equiv (\partial_\mu g g^{-1})J(g^{-1}\partial_\nu g) \ . \tag{10.4.1}$$

     The formula resembles the gauge transformation formula.

     Here the shorthand notations

     Here the shorthand notations

     $$g_\mu^{\ k} = \partial_\mu g^k(s) \ , \quad g_l^k(s) = \partial_l g^k \ , \quad (g^{-1}g)_l^k = \delta_l^k \tag{10.4.2}$$

     have been used.
   - The mixed $X^2 - S^2$ components are

     $$J_{\mu l} = g_\mu^{\ k}(g^{-1}J)_{kl}(s) \ . \tag{10.4.3}$$

     For the CP_2 contribution to the induced metric similar formulas hold true.

2. The induced Kähler electric field has both X^2 - and S^2 component and X^2 component defines the K "ahler charge assignable to transversal section S^2 as an electric flux. What is nice is that, although one does not have electric-magnetic duality, the Kähler electric field is very closely related to the Kähler magnetic field. Whether the solution ansatz works without additional conditions on the local color rotation has not been proven.

What could one say about the possible additional conditions on the locally color rotating object?

1. The model for the massless extremals (MEs) [K78] assumes that the space-time surface is locally representable as a map $M^4 \rightarrow CP_2$ such that the CP_2 coordinates are arbitrary functions of coordinates $u = k\cdot m$ and $v = \epsilon\cdot m$. k is light-like wave vector and ϵ a polarization vector orthogonal to it. This motivates the term "massless extremal".

2. If this representation is global, one expects that the space-time surface has a boundary assignable to E^2 so that a tube-like structure is obtained. Boundary conditions guaranteeing that isometry charges do not flow out of the boundary must be satisfied. In particular, the boundary must be light-like. These conditions are discussed in detail in [L125].

3. The color rotating objects could correspond to a situation in which the color rotation depends on light-like coordinate u only and the solution is such that the map of a region of E^2 to CP_2 to CP_2 is 2-valued and has S^2 as an image. Besides S^2, also more general complex 2-submanifolds of CP_2 can be considered.

4. The key difference between MEs and massless fields of gauge theories is that MEs are characterized by a non-vanishing light-like Kähler current [K9]. This must have deep physical implications.

   One has Kähler electric charge defined by the standard formula. Kähler electric flux orthogonal to the transversal cross section of ME and has light-like direction instead of space-like direction. One can also calculate the charge also for a section with time-like normal. Could this make it possible for the flux tubes to have Kähler electric flux as analog of gravitational flux? This picture would be consistent with both the Newtonian picture of gravitation mediated by the gravitational flux and the field theory picture of gravitation mediated by massless particles represented by MEs.

One can consider several generalizations of the solution ansatz motivated by physical intuition but not really proven.

1. The surface could define a many-sheeted covering of M^4. The conditions for the surface could be formulated as conditions stating that 4 functions of coordinates u, v and CP_2 coordinates vanish.

2. The "polarization coordinate" v could depend on the linear coordinates of E^2 non-linearly. For instance, it could correspond to a radial coordinate of E^2. The polarization would not be linear anymore.

   A possible restriction on v is that v is a real part of complex analytic function. The surface would possess a 4-D analog of holomorphy in the sense that complex CP_2 coordinates are analytic functions of a complex coordinate w of E^2 and hypercomplex coordinate of M^2. Also the coordinate u could be replaced with a "real" part of a hyper-analytic function of M^4 depending on a light-like coordinate u but this does not seem to change the situation in any way. This is a highly attractive 4-D generalization of the holomorphy of string world sheets.

3. One can even consider the possibility that the decomposition $M^4 = M^2 \times E^2$ to longitudinal and transversal spaces could be local so that also the light-like direction would be local. The condition would be that the distribution of the tangent spaces of M^2 and E^2 are integrable and defines a 4-surface having slicings to mutually orthogonal 2-D string world sheets and partonic 2-surfaces. This would correspond to what I have christened as Hamilton-Jacobi structure [K9].

   Physically this would mean the replacement of M^2 as a planar analog of a string world sheet with a curved string world sheet in M^4. The partonic 2-surface could in turn be interpreted as a many-valued image of a complex 2-surface of CP_2 in the local E^2.

In the recent situation, the simplest form of MEs motivates the question that the local color rotation of S^2 or of a more general complex 2-manifold $Y^2 \subset CP_2$ depends on the light-like coordinate $u = k \cdot m$ only. The induced Kähler gauge potential depends on u only so that the M^2 part of the Kähler electric field would vanish.

The Kähler electric flux would be parallel to E^2 (or the image of S^2 in M^4) and Kähler electric charge as electric flux could be (but need not be) non-vanishing. This flux would not however be in the direction of the flux tube so that it cannot correspond to gravitational flux.

Since Kähler electric flux would be very closely related to Kähler magnetic flux, an electric analog of the homological Kähler magnetic charge would make sense. This could topologically quantize the Kähler electric charge and also electric charge classically? In the case of CP_2 type extremals, the self-duality of CP_2 Kähler form indeed implies this. One would have electric-magnetic duality proposed to hold true in TGD.

10.4.4 A model for the formation of Kuiper belt and Oort clouds

The former planet Pluto (`https://rb.gy/elxw5g`) is the largest object in the Kuiper belt, which has a torus-like shape. The radius of Pluto is 1,191 km to be compared with $\Lambda_{gr} = 3,000$ and to the radius 2,439 km of Mercury.

The assumption that Pluto is a planet of solar origin requires $\beta_0 \to 3\beta_0$ for the Pluto-Sun pair at the time when Pluto originated if β_0 has remained unchanged during its evolution. This does not conform with the proposed model.

Could the Kuiper belt (`https://rb.gy/4qjg0c`), which is composed of mini-planets be analogous to a planetary ring, and be the oldest structure emanating from the Sun by the proposed mechanism? The total mass of Kuiper belt is recently about 10 per cent of the mass of Earth but there are reasons to believe that the original material has been 7 to 10 Earth masses so that Kuiper belt could be perhaps seen as a failed Jupiter sized giant planet for which the transformation of dark matter to ordinary matter did not lead to a single planet but to a large number of smaller objects.

The standard view of the formation of astrophysical structures is very different from the TGD view and the standard model should have anomalies if the TGD view is nearer to truth.

1. One example of such anomaly is described in the article "A dense ring of the trans-Neptunian object Quaoar outside its Roche limit" by Morgado et al [E185] (`https://rb.gy/zkfwqd`). The miniplanet known as Quaoar is an object half of the size of Pluto. The radius of the ring is 7 times the radius of Quaoar. The Roche limit is however 2.5 radii.

   Roche limit involves the assumption that the satellite is held together only by gravitational forces. that the satellite is held together only by gravitational forces. The gravitational tidal forces pull apart a satellite rotating too near to a planet so that it forms a ring. Therefore the formation of stable satellites is not possible within Roche radius. Conversely, a pre-existing ring can eventually condense to a satellite if its radius is larger than the Roche limit.

2. Also Saturn has two rings, which violate the Roche limit (`https://rb.gy/gsowu8`). The E ring of Saturn, which - unlike smaller rings - consists of micron and submicron sized particles, violates the Roche limit. The particles of E ring to accumulate to Moons that orbit with the ring. Also the Phoebe ring associated with Saturn's moon Phoebe violates the Roche limit.

Could the TGD view explain the violations of the Roche limit?

1. The TGD based idea that planets and Moons are formed by a gravitational condensation of the ordinary matter produced by dark matter at a torus like ring accompanied by monopole flux tube is supported by the behavior of the rings of Saturn, which tend to condense to associated Moons.

2. Could the presence of a circular monopole flux tube slow down the condensation process and make the ring rather stable? I have considered the possibility that the planetary orbits are accompanied by monopole flux tubes defining kinds of planetary paths. Could one identify some signatures of these paths? Do they still contain dark matter?

3. Planetary radii are consistent with the Roche limit. The matter in the Kuiper belt did not condensed to a single Jupiter-sized planet but to miniplanets. This could be interpreted in terms of the ongoing condensation process, which started as the Kuiper belt was formed as an expanding ring of matter accompanied by a monopole flux tube. Could the presence of a monopole flux tube slow down the condensation process? How does the Kuiper belt differ from planets?

   Suppose that the emission of Kuiper belt from the Sun involved a collective localization from a Bose-Einstein condensate-like state of dark particles to an analog of momentum eigenstate so that a planet rotating around the Sun was formed. Why did the localization for the Kuiper belt not occur to a wave function localized to a point rotating around Bohr orbit but to a set of points associated with the Bohr orbit?

Was the quantum coherence scale reduced by a reduction of $\hbar_{gr} \rightarrow \hbar_{eff} > \hbar$, which was followed by $\hbar_{eff} \rightarrow \hbar$ in the transformation of dark matter to ordinary matter. The tubular Bose-Einstein condensate formed in the tubular localization would have decomposed in the transition $\hbar_{gr} \rightarrow \hbar_{eff} > h$ to smaller regions before the transition $h_{eff} \rightarrow h$, which created miniplanets along the flux tube instead of a single planet.

4. Oort cloud (`https://rb.gy/71fmlm`) is a spherical layer of icy objects surrounding the Sun and likely occupies space at a distance between about 2,000 and 100,000 astronomical units (AU) from the Sun. The estimated total mass of the Oort cloud is 1.9 Earth masses (`https://rb.gy/hhvgsr`). Suppose that Oort cloud corresponds to a spherical shell emitted by the Sun. No localization to a tubular Bose-Einstein condensate would have occurred but the process $\hbar_{gr} \rightarrow \hbar_{eff} \rightarrow \hbar$ occurred directly so that a spherical cloud was created.

10.4.5 Heliosphere has oblique and rippled structures

It has been found that heliosphere contains oblique and rippled structures [**?**] (see this).

Here is the abstract of the article.

Past analysis has shown that the heliosphere structure can be deduced from correlations between long-scale solar wind pressure evolution and energetic neutral atom emissions. However, this required spatial and temporal averaging that smoothed out small or dynamic features of the heliosphere. In late 2014, the solar wind dynamic pressure increased by roughly 50% over a period of 6months, causing a time and directional-dependent rise in around 2–6keV energetic neutral atom fluxes from the heliosphere observed by the Interstellar Boundary Explorer.

Here, we use the 2014 pressure enhancement to provide a simultaneous derivation of the three-dimensional heliospheric termination shock (HTS) and heliopause (HP) distances at high resolution from Interstellar Boundary Explorer measurements.

The analysis reveals rippled HTS and HP surfaces that are oblique with respect to the local interstellar medium upwind direction, with significant asymmetries in the heliosphere structure compared to steady-state heliosphere models. We estimate that the heliosphere boundaries contain roughly tenastronomical unit-sized spatial variations, with slightly larger variations on the HTS surface than the HP and a large-scale, southwards-directed obliquity of the surfaces in the meridional plane. Comparisons of the derived HTS and HP distances with Voyager observations indicate substantial differences in the heliosphere boundaries in the northern versus southern hemispheres and their motion over time.

What makes the findings so interesting from the TGD point of view, is that heliosphere boundaries contain roughly 10 AU sized spatial variations. These variations are oblique with respect to the direction of the galactic wind. What comes first in mind in the TGD framework is that these could correspond to a icosahedral lattice-like structure with 12 vertices and 20 triangular faces (note that spherical geometry allows only Platonic solids as regular tessellations as analogs of condensed matter lattices). The appearance of AU in this context would be seen as an accident in standard physics but in TGD the situation is different.

If astrophysical quantum coherence is accepted then AU expressible in Nottale's model as $AU = \hbar_{gr}(M_S, m)/m = GM_S/\beta_0^2 = r_S/2\beta_0$, $\beta_0 \simeq 2^{-11}/5$. AU defines the Bohr radius as the radius of the Earth's orbit for the gravitational Planck constant $_{gr}(M, m) = GMm/\beta_0$ assignable to the pair formed by Sun with mass M and particle with mass m in the case of the outer planets in Nottale's model. Therefore it defines a fundamental quantum length and might appear elsewhere in the solar system. For instance, the gravitational Compton radius of the Sun is one half of the Earth's radius.

One can compare the situation with atomic lattices where atomic Bohr radius defines a natural scale. The mutual distances of the ripples at the heliosphere are about 10AU. The value of atomic Bohr radius is about .5 Angstrom in the atomic situation. By scaling by a factor 10, this would predict that the distances of atoms would be about 5 A: for atomic lattices this gives the order of magnitude for the lattice constant (see `https://periodictable.com/Properties/A/LatticeConstants.html`).

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Chapter 11

Magnetic Bubbles in TGD Universe: Part II

11.1 Introduction

The finding that motivated these comments was the finding of what was so-called solar heartbeat [E138] (`https://rb.gy/7gaa78`). Two kinds of quasiperiodic pulsations (QPPs) with periodicities 10-20 s and 30-60 s of microwave emissions during solar flares. These periods are correlated and probably have the same underlying reason. A kind of solar heartbeat is in question. It might be assignable with the reconnection process for the solar magnetic field. The notion of magnetic reconnection is however poorly understood in the standard physics framework: the estimates for the reconnection rate are by 13-15 orders of magnitude too small.

The TGD framework leads to a new view of space-time as a 4-D surface in $H = M^4 \times CP_2$ and also of electromagnetic and other fields. In particular, fields are replaced by topological field quanta identifiable as space-time quanta. One ends up with the notion of a field body, in particular that of a magnetic body (MB) consisting of monopole flux tubes not possible in Maxwell's electrodynamics and flux tubes with boundaries serving as counterparts of Maxwellian magnetic fields.

Could periodic reconnections of closed flux tubes with the shape of a very flat square caused by the transverse oscillations of the flux tubes occurring during solar flares induce the periodic reconnections of flux tubes? Microwave frequencies for dark charged matter at the flux tubes could be due to cyclotron transitions.

What could be the origin of the periodicities of transversal oscillations? I have earlier discussed [L70] the 26 second rhythm of Earth [L70] analogous to alpha rhythm. Intriguingly, this period is between the mentioned periods. Could the Earth's alpha rhythm and solar heartbeat relate to each other? This might be considered in the TGD framework if the rhythms are associated with gravitational monopole flux tubes emerging from the Sun and connecting the gravitational magnetic bodies of Earth and Sun to a single quantum coherent entity.

This finding inspired the attempt to understand solar flares in the TGD framework.

11.1.1 Basic problems of the existing models of solar flares

The models for the solar flares (`https://rb.gy/yw5jpd`) have several problems.

1. The source of the flare's energy is believed to be magnetic but what is the basic mechanism? How the magnetic energy is transformed to the kinetic energy of particles? How accelerations to energies in GeV range and beyond are possible? In the standard framework extreme accelerations would be required.

2. Reconnection of magnetic field lines is believed to be the basic mechanism but the predicted rate of reconnections is by 13-14 orders of magnitude too small. There might be something fundamentally wrong with the notion of reconnection.

3. There are also inconsistencies regarding the total number of accelerated particles. Sometimes this number is larger than the total number in the coronal loop. Where could the additional particles come from?

4. It is not possible to forecast flares.

11.1.2 The notion of reconnection is questionable

The Maxwellian notion of reconnection can be challenged. Field lines rather than flux tubes which reconnect. Note however that the notion of flux tubes is used in the phenomenology of MHD.

The rate of reconnections based on the Maxwellian picture assumes that the reconnection rate is proportional to the electric field associated with the separatrix at which the reconnection of field lines occurs. The actual reconnection rate for solar flares is by 13-14 orders higher than predicted so that something is badly wrong. The fact that conductivity can vary in huge limits suggests that charges for which conductivity is very high or even superconducting matter might be present.

Could the TGD view of reconnection help? Monopole flux tubes or flux tubes with boundaries as counterparts of Maxwellian magnetic fields carrying currents as dark matter in the TGD sense might provide a more realistic approach and the rate of connection could be estimated from classical dynamics for preferred extremals.

11.1.3 Is the Maxwellian view of currents and plasma correct?

When the conductivity of charge carriers is effectively infinite, Maxwellian MHD currents are frozen to flux lines. In the TGD framework, the Maxwellian flux tubes having boundaries could carry ordinary ohmic currents. Could dark particles at monopole flux tubes flow like supra current with vanishing resistance? At least these currents could correspond to currents frozen to field lines.

The absence of dissipation for the dark matter at the monopole flux tubes could explain the presence of ultra-energetic particles and the strange finding that solar flare can involve more particles than contained by the flare. The reconnection process gives rise to a pair of U-shaped flux tubes, which are highly curved. Could the dark particles leak out from the flux tubes in the reconnection process and transform to ordinary particles. There would be no gigantic acceleration since the dark particles would already have very high energies.

What about the TGD counterpart of plasma? Does the plasma correspond to the ordinary electrons at flux tubes with boundary or to the dark electrons at the gravitational monopole flux tubes? A possible TGD view of quark gluon plasma [L134] is that sea partons reside at the MB of hadrons and are dark in the TGD sense. Could the dark current carriers be analogous to sea partons? Could ordinary charge carriers with ohmic resistance serve as the analogs of valence quarks?

The answers to these questions requires a TGD based formulation of the basic concepts of plasma physics and magnetohydrodynamics (MHD) of the Sun.

1. MHD (`https://rb.gy/kv09cj`) and plasma physics (`https://rb.gy/g6wxyl`) must be reconsidered in [L109] in terms of the TGD based view of electromagnetic fields.

2. The new geometric view of magnetic fields forces a reconsideration of the notions of solar magnetic field and related notion of Parker spiral, coronal loops `https://rb.gy/gedbk2`), current sheets (`https://rb.gy/8yw1r8`) and `https://rb.gy/n0cyoe`).

3. The dynamics of the solar magnetic field involves several notions, which must be reformulated in the TGD framework. Sunspot cycle (`https://rb.gy/cvu4av`) and `https://rb.gy/rigawy`) must be understood in the TGD framework. Solar activity is maximum is assignable to the polar reversal of the solar magnetic field. There are many poorly understood phenomena related to the polar reversal such as solar flares (`https://rb.gy/yw5jpd`) and magnetic reconnections (`https://rb.gy/sbktub`) about which TGD could provide insights. Magnetic reconnection is an especially poorly understood notion: in the standard model the rate for their formation is 13-14 orders of magnitude too low.

The recent advances in the TGD based understanding of the formation of astrophysical structures in various scales [L136] lead to a general vision, which inspires the attempt to understand the structure of the solar magnetic field and its dynamics involving solar cycle, solar flares, reconnections and reversal of the solar magnetic field. By fractality, the general vision leads to a concrete model for the solar cycle and strongly suggests a concrete analogy of the solar cycle with the basic rhythms appearing in biological systems and the identification of the counterparts of anabolism and catabolism at the fundamental level.

The general picture also leads to a model for the reversals of the Earth's magnetic field and to interesting speculations concerning their connection with the evolutionary leaps. In zero energy ontology, the reversal involves the decay and re-organization of the magnetic body in zero energy ontology. The decay is analogous to the decay of the biological body after death and induces it. This interpretation provides an understanding of the so-called Tukdam phenomenon.

11.2 A TGD inspired model for solar flares

In the sequel a TGD based view of the reversal of the solar magnetic field is discussed. Besides the new view of space-time and electromagnetic fields, the proposal involves in a crucial manner zero energy ontology (ZEO) [L84, ?, L133].

11.2.1 The motivating finding

The finding that motivated these comments was the finding of what was called solar heartbeat [E138] (`https://rb.gy/7gaa78`). Two kinds of quasiperiodic pulsations (QPPs) with periodicities 10-20 s and 30-60 s of microwave emissions during solar flares. These periods are correlated and probably have the same underlying reason. A kind of solar heartbeat is in question. It might be assignable with the reconnection process for the solar magnetic field. The notion of magnetic reconnection is however poorly understood in the standard physics framework: the estimates for the reconnection rate are by 13-15 orders of magnitude too small.

The TGD framework leads to a new view of space-time as a 4-D surface in $H = M^4 \times CP_2$ and also of electromagnetic and other fields. In particular, fields are replaced by topological field quanta identifiable as space-time quanta. One ends up with the notion of a field body, in particular that of a magnetic body (MB) consisting of monopole flux tubes not possible in Maxwell's electrodynamics and flux tubes with boundaries serving as counterparts of Maxwellian magnetic fields.

Could periodic reconnections of closed flux tubes with the shape of a very flat square caused by the transverse oscillations of the flux tubes occurring during solar flares induce the periodic reconnections of flux tubes? Microwave frequencies for dark charged matter at the flux tubes could be due to cyclotron transitions.

What could be the origin of the periodicities of transversal oscillations? I have earlier discussed the 26 second rhythm of Earth analogous to alpha rhythm [L70]. Intriguingly, this period is between the mentioned periods. Could the Earth's alpha rhythm and solar heartbeat relate to each other? This might be considered in the TGD framework if the rhythms are associated with gravitational monopole flux tubes emerging from the Sun and connecting the gravitational magnetic bodies of Earth and Sun to a single quantum coherent entity.

This finding inspired the attempt to understand solar flares in the TGD framework.

11.2.2 Basic problems of the existing models of solar flares

The models for the solar flares (`https://rb.gy/yw5jpd`) have several problems.

1. The source of the flare's energy is believed to be magnetic but what is the basic mechanism? How the magnetic energy is transformed to the kinetic energy of particles? How accelerations to energies in GeV range and beyond are possible? In the standard framework extreme accelerations would be required.

2. Reconnection of magnetic field lines is believed to be the basic mechanism but the predicted rate of reconnections is by 13-14 orders of magnitude too small. There might be something fundamentally wrong with the notion of reconnection.

3. There are also inconsistencies regarding the total number of accelerated particles. Sometimes this number is larger than the total number in the coronal loop. Where could the additional particles come from?

4. It is not possible to forecast flares.

The notion of reconnection is questionable

The Maxwellian notion of reconnection can be challenged. Field lines rather than flux tubes which reconnect. Note however that the notion of flux tubes is used in the phenomenology of MHD.

The rate of reconnections based on the Maxwellian picture assumes that the reconnection rate is proportional to the electric field associated with the separatrix at which the reconnection of field lines occurs. The actual reconnection rate for solar flares is by 13-14 orders higher than predicted so that something is badly wrong. The fact that conductivity can vary in huge limits suggests that charges for which conductivity is very high or even superconducting matter might be present.

Could the TGD view of reconnection help? Monopole flux tubes or flux tubes with boundaries as counterparts of Maxwellian magnetic fields carrying currents as dark matter in the TGD sense might provide a more realistic approach and the rate of connection could be estimated from classical dynamics for preferred extremals.

Is the Maxwellian view of currents and plasma correct?

When the conductivity of charge carriers is effectively infinite, Maxwellian MHD currents are frozen to flux lines. In the TGD framework, the Maxwellian flux tubes having boundaries could carry ordinary ohmic currents. Could dark particles at monopole flux tubes flow like supra current with vanishing resistance? At least these currents could correspond to currents frozen to field lines.

The absence of dissipation for the dark matter at the monopole flux tubes could explain the presence of ultra-energetic particles and the strange finding that solar flare can involve more particles than contained by the flare. The reconnection process gives rise to a pair of U-shaped flux tubes, which are highly curved. Could the dark particles leak out from the flux tubes in the reconnection process and transform to ordinary particles. There would be no gigantic acceleration since the dark particles would already have very high energies.

What about the TGD counterpart of plasma? Does the plasma correspond to the ordinary electrons at flux tubes with boundary or to the dark electrons at the gravitational monopole flux tubes? A possible TGD view of quark gluon plasma [L134] is that sea partons reside at the MB of hadrons and are dark in the TGD sense. Could the dark current carriers be analogous to sea partons? Could ordinary charge carriers with ohmic resistance serve as the analogs of valence quarks?

The answers to these questions requires a TGD based formulation of the basic concepts of plasma physics and magnetohydrodynamics (MHD) of the Sun.

1. MHD (`https://rb.gy/kv09cj`) and plasma physics (`https://rb.gy/g6wxyl`) must be reconsidered in [L109] in terms of the TGD based view of electromagnetic fields.

2. The new geometric view of magnetic fields forces a reconsideration of the notions of solar magnetic field and related notion of Parker spiral, coronal loops `https://rb.gy/gedbk2`), current sheets (`https://rb.gy/8yw1r8`) and `https://rb.gy/n0cyoe`).

3. The dynamics of the solar magnetic field involves several notions, which must be reformulated in the TGD framework. Sunspot cycle (`https://rb.gy/cvu4av`) and `https://rb.gy/rigawy`) must be understood in the TGD framework. Solar activity is maximum is assignable to the polar reversal of the solar magnetic field. There are many poorly understood phenomena related to the polar reversal such as solar flares (`https://rb.gy/yw5jpd`) and magnetic reconnections (`https://rb.gy/sbktub`) about which TGD could provide insights. Magnetic reconnection is an especially poorly understood notion: in the standard model the rate for their formation is 13-14 orders of magnitude too low.

11.2.3 A TGD based view of the polarity reversal of the solar magnetic field

In the sequel a TGD based view of the reversal of the solar magnetic field is discussed. Besides the new view of space-time and electromagnetic fields, the proposal involves in a crucial manner zero energy ontology (ZEO) [L84, **?**, L133].

TGD counterpart of the Maxwellian magnetic field

Flux tubes carrying magnetic fields replace the flux lines of the Maxwellian theory. TGD predicts two kinds of flux tubes: monopole flux tubes with closed cross section and Maxwellian flux tubes with boundary. There is an analogy with the fields H and M of Maxwell's theory.

The Maxwellian part of the magnetic field could correspond to magnetization M having as the TGD counterpart flux tubes with boundary carrying currents generating the fields in the interior of the flux tube. The field H of Maxwell's theory could correspond to monopole flux tubes and could induce magnetization M as Maxwellian part of the magnetic field. Monopole flux tubes and Maxwellian flux tubes could correspond to parallel space-time sheets.

The monopole flux part of the magnetic field differs in several respects from the Maxwellian part.

1. The magnetic fields at monopole flux tubes require no current to maintain the magnetic field. The presence of monopole flux tubes allows us to understand the existence of magnetic fields in cosmic scales and also the maintenance of the magnetic field of Earth [L13].

2. Monopole flux tubes would carry charged dark matter characterized by effective Planck constant $h_{eff} = nh_0$. Especially interesting flux tubes are gravitational flux tubes with gravitational Planck constant $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0$, where $\beta_0 = v_0/c < 1$ is velocity parameter, and M is large mass of say Sun or Earth and m corresponds to small mass such as electron mass. This notion was introduced first by Nottale [E87].

   The freezing of the charge carriers to the flux lines would have a concrete interpretation. The freezing could occur also for the Maxwellian flux tubes and charge carriers would be at the boundaries of the flux tubes. The large value of h_{eff} implies large scale quantum coherence and the monopole flux part of the MB would naturally serve as a "boss" controlling the dynamics at the lower levels of hierarchy. This motivates the interpretation as counterpart for the field H.

3. Maxwellian parts of the magnetic fields could be generated by currents at the boundaries of the flux tubes if conductivity is very large. The flux tubes would be analogous to current wires. Magnetization M could correspond to the flux tubes with boundary, which carry the currents inducing the magnetic field in the interior. Magnetization would occur for the charged particles at the boundaries of these flux tubes.

4. The thickening of dark flux tubes is a phase transition liberating magnetic and volume energy and also dark matter if part of it transforms to ordinary matter in the process. Extreme accelerations would not be required since the dark particles forming quantum coherent phases at the flux tubes would have very high energies due to the very low dissipation. This could explain the huge production of energy and anomalously high particle energies.

5. For the topological counterpart of the reconnection process, field lines are replaced by flux tubes. When a closed flux tube has the shape of a very narrow rectangle, it is critical against reconnection, which could involve the chance of h_{eff}. The dark charge carriers leaked out of the flux tubes would have the ordinary value $h_{eff} = h$ of the effective Planck constant.

A model for the reconnection

There was an interesting article in Quanta Magazine about the reconnections of the magnetic fields for astrophysical objects (`rb.gy/npoc0`). Two kinds of reconnections have been observed. The slow ones for which the Maxwellian electrodynamics provides a satisfactory description and the fast ones, which are not understood.

Fast reconnections liberate magnetic energy powering solar flares and solar wind, high-energy particles ejected by exploding stars, and the glow of jets from black holes. The popular article told about a theory of Yi-Shin Liu et al (`rebrand.ly/6uv3jb3`) claimed to allow the understanding of the fast reconnections in the Maxwellian framework. The model assumes that reconnection is induced by a generation of electric fields for instance by different velocities of protons and electrons moving along the flux lines.

Personally I am a little bit skeptical. There are many other enigmas related to magnetic fields in cosmic scales. Particular, the existence and stability of magnetic fields in astrophysical scales is a mystery in the Maxwellian framework. Also these problems should be solved.

In the TGD Universe, the flux lines are replaced with flux tubes which can be seen as bundles of flux lines assignable to 3-D surfaces in $M^4_2 having 4-D space-time surfaces as orbits. Reconnection of flux lines is replaced$ $space as 3-surface so that topological reactions for 3-surfaces are in question: this conforms with "Topological GeometroD$

Intriguingly, TGD allows two kinds of flux tubes.

1. Flux tubes with a disk as cross section and having a boundary correspond to the Maxwellian situation. Cross section can be also closed but if the flux vanishes, the flux tube is not stable against splitting.

   The Maxwellian flux tubes with open cross section require currents to create the magnetic field. Currents tend however to dissipate so that the Maxwellian flux tubes and corresponding magnetic fields are not stable. This leads to a problem in understanding why magnetic fields in astrophysical scales are so stable.

2. The monopole flux tubes which have closed 2-surface (say) spheres as a cross section are not possible in Minkowski space and carry conserved monopole fluxes.

Monopole flux tube have several properties which make them very attractive, not only astrophysically and biologically but in all scales, for instance from the perspective of particle physics.

1. Monopole flux tubes are stable against splitting. U-shaped monopole flux tubes can however split by reconnection which means emission of a closed flux tube. This occurs for instance in solar wind at the night-side of the Earth.

2. Monopole flux tubes form tube networks having physical objects in various scales as nodes. They occur in all scales, including astrophysical and biological scales.

3. The tell-tale signature of the monopole flux fields is that no current is needed to create them. Monopole flux tubes explain the existence of magnetic fields in cosmic scales which would not have been even created since the currents needed to create them are random.

   For instance, Earth's magnetic field is the sum of these two contributions and monopole flux is estimated to be 2/5 of the entire flux. Monopole contribution would be stable and explain why the Earth's magnetic field has not decayed long ago. The monopole part of the Earth's magnetic field plays a key role in TGD inspired quantum biology based on the notion of dark matter as phases of ordinary matter with an effective Planck constant residing at the magnetic body of the system.

4. Monopole flux tubes are the key building bricks of all astrophysical structures in the TGD Universe, in particular solar magnetic fields, and are actually directly visible. Dark matter and energy would be associated with cosmic strings (not those of gauge theories), which have 2-D string world sheet as cross section and 2-D complex manifold of $CP_2, say sphere, as a CP_2 projection. They create at$

The reconnections of the monopole flux tubes would be natural candidates for a fast reconnection for which the Maxwellian model was proposed. Do the TGD view and the Maxwellian view exclude each other or could they be parts of the same story?

The reconnection of a U-shaped flux tube for which parallel portions carry opposite currents requires a pinch of the flux tube so that flux tube portions can touch each other. Ampere's law states that current wires carrying parallel currents attract each other. Could it explain the pinch? One can imagine two mechanisms.

1. The current along the U-shaped flux tube is conserved unless there is a temporary accumulation of electric charge. The absence of charge accumulation implies that the net currents along parallel portions are opposite and repel each other. However, if charge accumulation takes place, the currents can become locally parallel and this could cause the attraction and pinch. The interesting question is what could cause the local charge accumulation.

2. One can also consider a geometric mechanism in which the second portion of the U-shaped flux tubes turns temporarily backwards and the portion in which current runs parallel to the current in the unaffected portion comes near to it so that an attractive force causing the pinch is generated and U-shaped flux tube pair emits a closed flux tube.

3. In the TGD framework, quantum tunneling in macroscopic length scales as a pair of "big" state function reductions (BSFRs) reversing the arrow of time temporarily is suggestive. Suppose that in the initial situation there are two U-shaped flux tubes associated with the two molecules and currents are steady and conserved except during the reconnection period.

   Reconnection of the two U-shaped flux loops would give rise to a pair of monopole flux tubes of opposite magnetic fluxes connecting the two objects, say biomolecules. In this conformation parallel currents flow along the flux tubes. It is assume that the charges at the different flux tubes form Cooper pairs.

   Supra current induces an accumulation of net charges of opposite sign at the ends of the flux tube pair. Supra current cannot however flow forever. Charge saturation occurs and the supra current goes to zero. In this situation reconnection back to U-shaped flux loops can take place. This state is not superconducting since individual charges at the flux tubes flow in opposite directions and cannot form Cooper pairs. Therefore the splitting of Cooper pairs and reconnection would occur simultaneously. BSFR would correspond to a phase transition between super-conducting and non-superconducting states. This phase transition would be a basic mechanism of bio-catalysis.

TGD based model for the solar magnetic field

What can one guess about the structure of the MB consisting of monopole flux tubes (and possibly also sheets)?

1. Only the Maxwellian magnetic field at QFT limit obtained by replacing many-sheeted space-time with a slightly curved Einsteinian space-time surface with 4-D M^4 is directly accessible to the experiments. These fields are known only in the region outside the solar surface. This leaves a lot of freedom.

   A guideline comes from the notion of magnetic bubble [L135] playing a key role in the TGD inspired model for the formation of astrophysical structures as explosive processes. Magnetic bubbles consist of monopole flux tubes at a 2-D surface, such as a sphere. By fractality, one expects that the model should work also in the case of solar flares, which also involve explosions.

2. The magnetic bubble with $\hbar_{eff} = \hbar_{gr}$ a spaghetti of monopole flux tubes with a shape of 2-D closed surface. It would be emitted in an explosive process liberating dark matter and energy. Dark matter would be transformed to ordinary matter and liberate energy.

   A good guess is that the solar surface carries this kind of spherical layer consisting of closed monopole flux loops. The inner parts of monopole flux loops would be along the solar surface and fixed with it. The outer parts of the flux loops would extend to outer space and bound the shape of a moon crescent. This shape would be an outcome of centrifugal force which would be compensated by the force due to string tension.

3. The rotation of the outer parts of the flux tubes is not rigid body motion with a constant angular velocity. The motion is slower than rigid body rotation and this gives rise to a differential rotation in which the angular velocity at the equator is smallest. This affects the shape of the flux tube so that it becomes spiral-like. The lag is largest at the equator.

   String tension of the flux tube opposes this motion and eventually the situation becomes critical for the reconnections when the flux tube portions carrying opposite fluxes and located near the equator are close enough. This reconnection process is associated with the formation of solar spots. This leads to a transformation of the outer part of the flux tube so that it becomes parallel to the solar surface.

By freezing, the spiral structure for the current sheet should conform with the structure of the magnetic field in the Maxwellian picture obtained at the QFT limit. In TGD, the assumption that currents flow along monopole flux tubes implies this if the Maxwellian flux tubes are parallel to the monopole flux tubes. In this case the freezing would occur for the entire magnetic field.

A general view of the solar flare as a reconnection process

1. In TGD the reconnection is replaced with a topological reconnection for monopole flux tubes and their Maxwellian counterparts.

2. Reconnection at the equatorial current sheet eventually occurs for twisted flux tubes and the outer part of the flux tube decays by emitting small flux loops. Solar flares would accompany this process. Huge magnetic and volume energies could be liberated if the flux tubes are thickened in the phase transition. Twisted flux loops are transformed by the emission of loops to non-twisted dipole loops with strands parallel to the solar surface.

   In this process charged dark particles with very high energies leak out from the flux tubes. No acceleration mechanism is needed. This mechanism could also explain cosmic rays with ultrahigh energies without a need for acceleration mechanisms. Monopole flux tubes can also carry electric fields parallel to them and this could accelerate the charged particles to very high energies since dissipation is absent or very small due to the large value of $\hbar_{gr}$.

3. This picture allows us to also understand the presence of the current sheet. It would be associated with the Maxwellian part of the magnetic field at equator where the fluxes of neighboring portions of the flux tube are opposite and reconnections occur.

   The Maxwellian flux tubes could be parallel to the monopole flux tubes and the current sheet would be associated with them if Maxwell's equations hold true approximately as they would at the QFT limit of the TGD. This limit is obtained by replacing the sheets of the many-sheeted space-time with single metrically deformed region of M^4 such that gravitational field *resp.* gauge potentials are identified as sums of deviations of induce metric from M^4 metric *resp.* induce gauge potentials.

How the reconnection process could lead to a reversal of the polarity

How the reconnection process could lead to the reversal of the polarity.

1. The flip of the polarity of the solar magnetic field occurs when the activity of the Sun is maximum. The direction of the magnetic flux at the long rectangular monopole flux tubes must change.

   Conserved monopole flux however prevents this. One option is that the rectangular flux tube rotates along its axis by π and permutes inner and outer parts of the flux tube. This cannot be excluded but does not seem plausible since the inner part of the flux tube is fixed.

   The second option is that the closed flux tubes split by a reconnection process into pieces and the short flux loops should flip and by reconnections fuse back to long flux loops with an opposite direction of magnetic flux.

2. The question how the monopole flux tubes carrying opposite fluxes could be generated from the short flux tubes produced by the decay process, looks very difficult to answer in the framework of standard quantum physics. Second law forbids this process.

   Could zero energy ontology (ZEO) come to rescue? In ZEO both arrows of time are possible and the arrow of time is changed in ordinary ("big) state function reduction (BSFR) [L84, **?**, L133].

One has quantum gravitational coherence at the level of gravitational flux tubes. Could BSFR and therefore a time reversal take place at the level of gravitational MB? Could the reconnection of small loops to a long loop in the opposite direction of time somehow correspond to a decay process with a reversed thermodynamic arrow of time. Note that the change of the thermodynamic arrow of time should not be confused with time reflection T as a geometric symmetry.

3. What happens to the magnetic field B when the thermodynamic arrow of time changes? The Maxwellian part of B changes its sign since it is a curl of vector potential A, having as its source the 3-D current j, which behaves like velocity and changes its sign.

   The monopole flux part of B does *not* have j as source and for string-like objects $X^2 \times Y^2 \subset M^4 \times CP_2$ monopole flux changes sign only if the change of the thermodynamic arrow of time involves a complex conjugation in CP_2. It seems that also the induced electric field associated with the deformation of a string-like object changes its sign too in complex conjugation. This means that the charges change sign and therefore also currents. Nothing would happen to B.

   If no complex conjugation occurs for CP_2, monopole fluxes are not affected. However, the minimization of the magnetic interaction energy between long Maxwellian flux loops and short monopole flux loops could force the monopole flux loops to flip. The roles of H and M in the magnetization would be permuted: M would change the direction of H.

4. Could Lazarus effect have an interpretation as a BSFR so that no new CD would be generated? The consistency with the earlier view would require that the arrow of time changes in BSFR but that the moment of the geometric time identified as a correlate of subjective time assigned with the decay process corresponds to the M^4 time coordinate for the intersection of the half-cones. If the sub-CDs of CD located in either half-cone of CD co-move with it in its expansion by discrete scalings so that the M^4 time associated with their mid points flows, this picture is consistent with that discussed in [?, L133].

   Or could Lazarus effect mean a creation of a new CD as an embedding space correlate for a perceptive field of a conscious entity, self [L142, L133]? Ordinary birth could serve as an example of a generation of a new CD.

In the ZEO based interpretation as a BSFR, the interpretation of this process would be as an analog of biological death followed by reincarnation with an opposite arrow of time.

1. In ZEO, the monopole flux tube pair, which has split into short segments, would be the "corpse" of both the previous gravitational MB and the new MB with an opposite arrow of time. The corpse could be seen as the outcome of two aging processes proceeding with opposite arrows of time from geometric future and past and meeting at the moment of the reconnection process, which corresponds to quantum criticality.

2. The outsider would see the death and decay process of the gravitational MB and its miraculous reincarnation to MB with opposite magnetic fluxes. This "Lazarus effect" would be something new as compared to the earlier applications of ZEO. The sunspot cycle could be perhaps seen as an analog of the sleep-wakeup cycle.

3. This picture is very general and living matter provides especially interesting applications since the decay process for the monopole magnetic flux tubes in biological death should induce the decay process of the biochemical structures. Metabolism has two sides: anabolism is the generation of organic molecules carrying metabolic energy taking place in photosynthesis and in the reconstruction of organic molecules from simpler building bricks produced by catabolism liberating metabolic energy and occurring in digestion. Could the anabolism and catabolism be time reversals of each other and reduce to catabolism of monopole flux loops with opposite arrows of thermodynamic time?

11.3 Possible applications to the polarity reversal of Earth's magnetic field and to biology

The proposed picture might apply also to the model for the flip of the Earth's magnetic field discussed in [L13]? Magnetic poles wander and this could be understood as a rigid body motion of MB. The polarity flip takes place rather rapidly and could occur BSFR and involve the magnetic catabolism and anabolism of the monopole flux loops. Since the monopole magnetic fields play a central role in the TGD inspired quantum biology, the possible disastrous consequences of this transition challenge the TGD inspired quantum biology.

11.3.1 Do the reversals of the Earth's magnetic field induce evolutionary leaps?

I received from Zakaria Ameziane a highly interesting question related to the TGD inspired theory of consciousness and quantum biology, in particular self hierarchy and the notion of quantum jump according to TGD, and the role of the Earth's magnetic field in quantum biology. The question went roughly as follows.

”There is an interesting hypothesis which demonstrates that the DMT, by its affinity with UV-B rays, could be produced significantly, endogenously when the electromagnetic fields are reversed. If this hypothesis would prove to be true, could it trigger a new quantum jump?”

The question involve a link to a discussion in DMT Quest discussion group (DMT Quest is an organization, which supports DMT research) in Twitter (`https://rb.gy/sijxt9`). The link is warmly recommended. The discussion was related to the the so-called Stoned Ape Theory of evolution claims that that the transition from Homo erectus to Homo sapiens and the cognitive revolution was caused by the addition of psilocybin mushrooms, specifically the mushroom Psilocybe cubensis, into the human diet around 100,000 years ago. One can also consider alternative forms of this idea.

From the discussion one can pick up the following facts.

1. DMT is often assigned with pineal gland, ”third eye” and the seat of the soul, according to Descartes but according to recent views it is present in the entire brain (see ¡A HREF=”https://rb.gy/yftalo”¿this¡/A¿). DMT (I have discussed DMT from the TGD point of view in [L33, L100]) is reported to induce a growth of neurons (`https://rb.gy/zx7zsh`).

   By its affinity with UV-B rays, DMT could be produced significantly endogenously as magnetic field reversal occurs and the shield provided by the Earth's magnetic field against UV rays is temporarily lost.

2. The latest magnetic reversal occurred 40,000 years ago in the so-called Laschamp event (`https://rb.gy/i35kqa`). Interestingly, Neanderthals disappeared at this time.

3. 40,000 years also corresponds to a time when a large change in the shape of human brain took place [J4] (`https://rb.gy/hcg8ii`). The following excerpt is from the abstract of the article.

   ”.... Our data show that, 300,000 years ago, brain size in early H. sapiens already fell within the range of present-day humans.

   Brain shape, however, evolved gradually within the H. sapiens lineage, reaching present-day human variation between about 100,000 and 35,000 years ago. This process started only after other key features of craniofacial morphology appeared modern and paralleled the emergence of behavioral modernity as seen from the archeological record.

   Our findings are consistent with important genetic changes affecting early brain development within the H. sapiens lineage since the origin of the species and before the transition to the Later Stone Age and the Upper Paleolithic that mark full behavioral modernity.”

4. Relatively recent research indicates that changes in the geomagnetic field of the earth causes genetic and metabolic changes in plants indicating the potential to be a driver of evolution [I7] (`https://rb.gy/mxhq2z`).

These observations inspire the question whether the magnetic reversal could have induced not only a significant growth of neurons in human brains but also an evolutionary jump?

1. Could this effect have occurred at the level of genes, at the level of epigenesis or both? The amazing findings of Levin [I18, I19, I23, I17], discussed from the TGD point of view in [L142], suggest that besides genes, also electromagnetic field patterns assignable to cell groups (not only neuron groups), determine the outcome of morphogenesis via epigenesis and that modifications of these patterns during the embryo stage can dramatically modify the outcome of morphogenesis without any change at the level of genes. What is remarkable is that these changes are inherited.

2. Could the magnetic reversal have induced an inheritable change of the shape and the electromagnetic structure of the brains of developing embryos? Could the increased amount of DMT during the reversal be behind this change? If only a permanent epigenetic change is in question, it might be induced by DMT.

The following summarizes roughly my reply to the question by Zakaria Ameziane. The reply describes first very briefly what self hierarchy and quantum jumps mean inthe TGD framework.

1. Selves can fuse to larger selves by entangling stably. This could occur in both "small" and "big" statefunction reductions (SFRs). In a pair of BSFRs (BSFRs change the arrow of time) and a TGD counterpart of quantum tunnelling takes place this kind of fusion could occur. This would mean an extension of consciousness. Perhaps this happens as the person gradually wakes up. Also the fusion of say visual fields to single visual field could occur in this way. Right and left brain, or rather their magnetic bodies, could also fuse in this way.

2. DMT is assigned with pineal gland, I would tend to see its presence as a prerequisite for a connection to a rather high level of hierarchy of selves, magnetic body corresponding to a rather long length and time scales.

Concerning the finding that something dramatic took place in the evolution of the human brain about 40,000 years ago when also magnetic reversal took place. Catastrophes induce quantum criticality in long scales which in turn could induce evolutionary jumps.

1. I have just developed a model for the change of the magnetic polarity [L135]: the change of the polarity would be associated both in the case of Sun and Earth to a BSFR changing the arrow of time. This process would be like death followed by reincarnation with the opposite arrow of time at the level of the magnetic body (MB). The sequences of reversals would define the analog of a sleep-wakeup cycle on a large scale.

2. BSFR corresponds to quantum criticality: the monopole flux loops of the magnetic body of Earth decay into pieces, change direction and fuse again as required by the magnetic reversal. MB is the boss and this universal mechanism would also induce biological decay after death and re-organization of molecules to a living organism. It would also be behind catabolism and anabolism at molecular level.

3. During the period of BSFR associated with the reversal, the UV radiation from outer space can enter the Earth's surface and induce large genetic and also other kinds of biological changes. A BSFR at the level of MB of Earth inducing the magnetic reversal could have induced a cascade of BSFRs at shorter scales possibly inducing dramatic evolutionary changes.

   In the TGD Universe, the genes do not dictate everything. Also electromagnetic field patterns at the cellular level, both for neurons and ordinary cells, are in a central role in dictating the development of embryos, as Levin's findings demonstrate. Their change would involve epigenetic change [L142]. This point was already discussed.

4. For instance, these BSFRS inducing large changes at the MB of the brain could have increased the probability of the fusion of MBs of say left and right hemispheres to a larger unit, the MB of the entire brain. This would have induced a stronger interaction of right and left hemispheres. The period of time in an entangled, "whole-brainy" state would have significantly increased.

This might relate to the hypothesis that bicamerality in which right and left hemispheres behaved like independent selves (schizophrenics and young children might be bicamerals) transformed to modern consciousness in which the brain hemisphere tends to behave like a single coherent entity.

5. There is evidence that the magnetic field of Earth is changing right now (https://rb.gy/penzen). Could this mean that polarity reversal of the Earth's magnetic field might happen in the not so distant future. An interesting question is what this could mean for our species.

6. The magnetic bodies of Sun and Earth interact and in TGD framework both MBs play a key role in the quantum biology [L121, L119] based on gravitational quantum coherence prevailing in astrophysical scales.

   An interesting question is whether the solar 11+11 year "sleep-awake" cycle of the solar MB could induce periodicies in human behavior, say in social structures. Maybe statisticians could have something to say about this.

11.3.2 Tukdam and TGD

The following considerations were inspired by a TV document (https://rb.gy/abt8za) about a strange phenomenon known as Tukdam. What happens is that in Tukdam state the person is physically dead but is believed to be in a continued meditation. There is no EEG, the heart does not beat, and there is no normal metabolism. What is strange is that the decomposition processes do not start. The condition can last up to a couple of weeks. Similar longer-lasting ones have been reported: a yogi can be buried underground for months in an oxygen-free state and then wake up.

Tukdam phenomenon challenges neuroscience's view of the brain as the seat of consciousness. According to reports there could be awareness and a sensory experience consisting of different light sensations. The Tibetan Book of the Dead describes these experiences. Near-death experiences have many similar features.

In the body in Tukdam, the area of the heart is reported to feel warmer to the touch than the rest of the body, but the thermometer does not detect this difference. This would indicate that the body receives metabolic energy at the cellular level from some other source than in the normal metabolism, and that living matter can detect what measuring devices based on the recent knowledge provided by modern physics cannot detect.

Where could this energy come from? If one wants to answer this, one must also ask what happens in death and what is consciousness and what is life.

1. Dark energy and matter are the two basic puzzles of recent day physics. In the TGD approach, dark matter is identified as phases of ordinary matter, for which the effective Planck constant h_{eff} is much larger than normally. In particular, the Planck constant $h_{eff} = h_{br}$ characterizing gravitational flux tubes can be very large and makes quantum coherence possible even on astrophysical scales. Large Planck constants would be associated with the dark matter magnetic body, which would be the TGD counterpart to the magnetic field of Maxwell's theory, but would differ from it in many respects. As a quantum coherent unit, this magnetic body would control the ordinary biological body and induce its coherence. The classical energy of a magnetic body, consisting of volume energy and magnetic energy, would be dark energy.

2. In the TGD Universe dominated by zero energy ontology, consciousness is a universal phenomenon and present on all scales, from elementary particles to the level of the cosmos. Even galaxies, stars and planets would be conscious beings. Also life and death would be universal phenomena. Likewise, the biological decomposition process associated with death would correspond to the universal decomposition process, which would essentially correspond to the decomposition of magnetic monopole flux tubes (magnetic catabolism), which would induce the catabolism of the breakdown of biomolecules. Its time-reversed version would be magnetic anabolism and induce the building of bio-structures such as molecules.

3. The reversal of the Sun's magnetic field would correspond to magnetic catabolism as the breakdown of long monopole flux tubes into very short parts. It would be followed by

magnetic anabolism as their re-fusion into long flux tubes. The solar cycle would correspond to the sleep-wake cycle, or more precisely: a series of lives in different directions of time. Death would only be a change of time's arrow, nothing final.

4. The fundamental metabolic processes would be basically magnetic anabolism and catabolism induced by "big" state function reductions changing the arrow of time and inducing the biological anabolism and catabolism. Death would mean reincarnation with the opposite arrow of time.

In Tukdam, the biological body would be dead, but the magnetic body would still be alive and prevent the biological decay from starting. The disintegration of the magnetic body as a reconnection process splitting monopole flux tubes to pieces in the way described above would start in Tukdam much later than normally, and initiate the disintegration of the biological body. The contents of the conscious experience in Tukdam, light sensations and deep peace, would come from the magnetic body. The dead biological body would not provide contribution from sensory input, motor activity, and cognition.

11.4 Summary and outlook

This article was inspired by a single puzzling astrophysical observation but was extended by further similar observations. The discussion of these findings allowed us to develop a TGD based vision about the generation of astrophysical structures to a much more detailed level. This vision should apply also to other interactions.

The foregoing discussion suggests that the dynamics of gravitational fields could reduce to the dynamics of flux tubes subject to the conservation of total Kähler electric fluxes, which have a definite sign.

The topological dynamics would be essentially re-organization of the network formed by electric flux quanta as nodes of the network connected to each other by flux tubes, which can also carry Kähler electric flux. Twistor lift of TGD and M^8-H duality [L91, L92] led to a rather similar picture for the scattering amplitudes [L116, L117] in terms of fundamental fermions.

This generalizes also to the dynamics of gauge fields. Flux tubes can be characterized by the value of h_{eff} characterizing a given interaction, and the notion of gravitational Planck constant generalizes to all interactions. The key physical idea is that Nature is theoretician friendly: if quantum coherence is to be preserved, a phase transition replacing the ordinary Planck constant $\hbar$ with $\hbar_{eff}$ must take place, when the interaction strength $Q_1Q_2/4\pi\hbar$ becomes too large for the perturbation series to converge. The alternative option is that the system decomposes to coherent subunits such that the perturbation series converges for them. This means a reduction of quantum coherence scale.

The understanding of atomic and molecular physics at the space-time level has been a longstanding challenge of TGD.

1. I have proposed that $h_{eff}>h$ for the valence bonds as flux tubes could allow us to gain insights about the periodic table [L148]. Monopole flux tubes can also carry ordinary electric fluxes and this would allow us to understand the recent empirical findings about chemical bonds as carriers of electric flux [L107]. TGD also suggests a flux tube model for hydrogen bonds. Also a generalization of hydrogen and valence bonds involving quantum gravitation in the TGD sense [L119] can be considered so that quantum gravitation would define an essential part of biochemistry.

2. What about atoms in TGD Universe? The proposed description for the gravitational interaction at the level planetary system in terms of flux tubes could generalize almost as such to a description of electromagnetic interactions at the atomic level. The U-shaped flux tube pairs with opposite magnetic charges and carrying electromagnetic flux besides monopole magnetic flux would emanate from protons and connect them to electrons. For a pair of opposite charged particles, the U-shaped flux tubes would be closed. For ions the flux tube pair would continue outside the atom. The flux tubes of a given atom could also form flux tube bundles. Also linking and knotting are possible for the flux tubes so that the capacity for topological quantum computation emerges.

3. A powerful restriction comes from the condition that monopole flux tubes must be closed. The proposal is that they are U-shaped and form pairs of flux tubes connecting two systems. This does not require that the Kähler electric charges of the members are opposite. For gravitational flux tube pairs they are of the same sign. For gauge interactions they are of the same sign but the sign can vary.

There are many topics related to flux tubes, which are not considered in this article.

1. TGD predicts homologically non-trivial flux tubes: in the simplest situation $X^4 = X^2 \times S^2$, the CP_2 projection S^2 is a homologically trivial geodesic sphere. If they are allowed by the preferred extremal property, they would serve as natural correlates for the Maxwellian magnetic fields. One cannot exclude flux tubes with light-like boundaries, and they would be even more natural counterparts for Maxwellian fluxes.

   In the standard terminology of condensed matter physics [L109], they would correspond to the magnetization M, whereas the monopole part of the measured magnetic field, which needs no currents as its sources, would correspond to the magnetizing "external" field H, which can be said to control M (and possibly containing $h_{eff} = h$ phases). The presence of monopole fluzes allows us to understand the puzzle posed by the fact the magnetic field of Earth is non-vanishing although dissipation of currents implies the decay of the Maxwellian part.

2. Interesting questions relate to the many-sheeted space-time. Monopole fluxes can flow between two space-time sheets through wormhole contacts. Elementary particles have wormhole contacts as building bricks [L110] [K68, K69]. Can one separate this level from the levels just discussed. For instance, can one consider closed flux loops travelling through several sheets in long length scales as the hierarchy of Planck constants would suggest.

Chapter 12

LIGO and TGD

12.1 Introduction

The recent detection of gravitational radiation by LIGO [E174] (see the posting of Lubos at http://tinyurl.com/z6mruqk and the article http://tinyurl.com/ja2uraj) can be seen as birth of gravito-astronomy. The existence of gravitational waves is however an old theoretical idea: already Poincare proposed their existence at the time when Einstein was starting the decade lasting work to develop GRT (see http://tinyurl.com/jdbg4k2).

Gravitational radiation has not been observed hitherto. This could be also seen as indicating that gravitational radiation is not quite what it is believed to be and its detection fails for this reason. This has been my motivation for considering the TGD inspired possibility that part or even all of gravitational radiation could consist of dark gravitons [K79]. Their detection would be different from that for ordinary gravitons and this might explain why they have not been detected although they are present (Hulse-Taylor binary).

In this respect the LIGO experiment provided extremely valuable information: the classical detection of gravitational waves - as opposed to quantum detection of gravitons - does not seem to differ from that predicted by GRT. On the other hand, TGD suggests that the gravitational radiation between massive objects is mediated along flux tubes characterized by dark gravitational Planck constant $\hbar_{gr} = GMm/v_0$ identifiable as $\hbar_{eff} = n \times \hbar$ [K93, K79]. This allows to develop in more detail TGD view about the classical detection of dark gravitons.

A further finding was that there was an emission of gamma rays [E118] .4 seconds after the merger. The proposal that dark gravitons arrive along dark magnetic flux tubes inspires the question whether these gamma rays were actually dark cyclotron radiation in extremely weak magnetic field associated with these flux tubes. There was also something anomalous involved. The mass scale of the merging blackholes deduced from the time evolution for so called chirp mass was 30 solar masses and roughly twice too large as compared to the upper bound from GRT based models (see http://tinyurl.com/zehmcao).

12.2 Some history and observations

The evolution of the theory of gravitational radiation involves strange twists as also the evolution of the experimental side.

12.2.1 Development of theory of gravitational radiation

A brief summary about the development of theory of gravitational radiation is useful.

1. After having found the final formulation of GRT around 1916 after ten years hard work Einstein found solutions representing gravitational radiation by linearizing the field equations. The solutions are very similar in form to the radiation solutions of Maxwell's equations. The interpretation as gravitational radiation looks completely obvious in the light of after wisdom but the existence of gravitational radiation was regarded even by theoreticians far

from obvious until 1957. Einstein himself wrote a paper claiming that gravitons might not exist after all: fortunately the peer review rejected it (see `http://tinyurl.com/ho857g8`)!

2. During 1916 Schwartschild published an exact solution of field equations representing a non-rotating black hole. At 1960 Kerr published an exact solution representing rotating blackhole. This gives an idea about how difficult the mathematics involved is.

3. After 1970 the notion of quasinormal mode was developed. Quasinormal modes are like normal modes and characterized by frequencies. Dissipation is however taken into account and this makes the frequencies complex. In the picture representing the gravitational radiation detected by LIGO, the damping is clearly visible after the maximum intensity is reached. These modes represent radiation, which can be thought of as incoming radiation totally reflected at horizon. These modes are needed to describe gravitational radiation after the blackhole is formed.

4. After 1990 post-Newtonian methods and numerical relativity developed and extensive calculations became possible allowing also precise treatment of the merger of two blackholes to single one.

I do not have experience in numerics nor in findings solutions to field equations of GRT. General Coordinate Invariance is extremely powerful symmetry but it also makes difficult the physical interpretation of solutions and finding of them. One must guess the coordinates in which everything is simple and here symmetries are of crucial importance. This is why I have been so enthusiastic about sub-manifold gravity: M^4 factor of embedding space provides preferred coordinates and physical interpretation becomes straightforward. In TGD framework the construction of extremals - mostly during the period 1980-1990 - was surprisingly easy thanks to the existence of the preferred coordinates. In TGD framework also conservations laws are exact and geodesic motion can be interpreted in terms of analog of Newton's equations at embedding level: at this level gravitation is a genuine force and post-Newtonian approximation can be justified in TGD framework.

12.2.2 Evolution of the experimental side

1. The first indirect proof for gravitational radiation was Hulse-Taylor binary pulsar (see `http://tinyurl.com/hmjuse9`). The observed increase of the rotation period could be understood as resulting from the loss of rotational energy by gravitational radiation.

2. Around 1960 Weber suggests a detector based on mass resonance with resonance frequency 1960 Hz. Weber claimed of detecting gravitational radiation on daily basis but his observations could not be reproduced and were probably due to an error in computer program used in the data analysis.

3. At the same time interferometers as detectors were proposed. Interferometer has two arms and light travels along both arms arms, is reflected from mirror at the end, and returns back. The light signals from the two arms interfere at crossing. Gravitational radiation induces the oscillation of the distance between the ends of interferometer arm and this in turn induces an oscillating phase shift. Since the shifts associated with the two arms are in general different, a dynamical interference pattern is generated. Later laser interferometers emerged.

   One can also allow the laser light to move forth and back several times so that the phase shifts add and interference pattern becomes more pronounced. This requires that the time spent in moving forth and back is considerably shorter than the period of gravitational radiation. Even more importantly, this trick also allows to use arms much shorter than the wavelength of gravitational radiation: for 35 Hz defining the lower bound for frequency in LIGO experiment the wavelength is of the order of Earth radius!

4. One can also use several detectors positioned around the globe. If all detectors see the signal, there are good reasons to take it seriously. It becomes also possible to identity precisely the direction of the source. A global network of detectors can be constructed.

5. The fusion of two massive blackholes sufficiently near to Earth (now they were located at distance of about Gly!) is optimal for the detection since the total amount of radiation emitted is huge.

12.2.3 What was observed?

LIGO detected an event that lasted for about .2 seconds. The interpretation was as gravitational radiation and numerical simulations are consistent with this interpretation. During the event the frequency of gravitational radiation increased from 35 Hz to 250 Hz. Maximum intensity was reached at 150 Hz and correspond to the moment when the blackholes fuse together. The data about the evolution of frequency allows to deduce information about the source if post-Newtonian approximation is accepted and the final state is identified as Kerr blackhole.

1. The merging objects could be also neutron stars but the data combined with the numerical simulations force the interpretation as blackholes. The blackholes begin to spiral inwards and since energy is conserved (in post-Newtonian approximation), the kinetic energy increases because potential energy decreases. The relative rotational velocity for the fictive object having reduced mass increases. Since gravitational radiation is emitted at the rotational frequency and its harmonics, its frequency increases and the time development of frequency codes for the time development of the rotational velocity. This rising frequency is in audible range and known as chirp.

   In the recent situation the rotational frequency increases from 35 Hz to maximum of 150 Hz at which blackholes fuse together. After that a spherically symmetric blackhole is formed very rapidly and exponentially damped gravitational radiation is generated (quasinormal modes) as frequency increases to 250 Hz. A ball bouncing forth and back in gravitational field of Earth and losing energy might serve as a metaphor.

2. The time evolution of the frequency of radiation coded to the time evolution of interference pattern provides the data allowing to code the masses of the initial objects and of final state object using numerical relativity. So called chirp mass can be expressed in two ways: using the masses of fusing initial objects and the rotation frequency and its time derivative. This allows to estimate the masses of the fusing objects. They are 36 and 29 solar masses respectively. The sizes of these blackholes are obtained by scaling from the blackhole radius 3 km of Sun. The objects must be blackholes. For neutron stars the radii would be much larger and the fusion would occur at much lower rotation frequency.

3. Assuming that the rotating final state blackhole can be described as Kerr's blackhole, one can model the situation in post-Newtonian approximation and predict the mass of the final state blackhole. The mass of the final state blackhole would be 62 solar masses so that 3 solar masses would transform to gravitational radiation! The intensity of the gravitational radiation at peak was more than the entire radiation by stars int the observed Universe. The second law of blackhole thermodynamics holds true: the sum of mass squared for the initial state is smaller than the mass squared for the final state ($32^2 + 29^2 \leq 62^2$).

12.3 Are observations consistent with TGD predictions?

The general findings about masses of blackholes and their correlations with the frequency and about the net intensity of radiation are also predictions of TGD. The possibility of dark gravitons as large h_{eff} quanta however brings in possible new effects and might affect the detection. The consistency of the experimental findings with GRT based theory of detection process raises critical question: are dark gravitons there?

12.3.1 Some TGD background for LIGO observations

Some TGD background is in order before discussion of various findings from LIGO.

About the relationship between GRT and TGD

The proposal is that GRT plus standard model defines the QFT limit of TGD replacing many-sheeted space-time with slightly curved region of Minkowski space carrying gauge potentials defined as sums of the components of the induced spinor connection and the deviation of metric from flat metric as sum of similar deviations for space-time sheets [K111]. This picture follows from the assumption that the test particle touching the space-time sheets experience the sum of the classical fields associated with the sheets.

The open problems of GRT limit of TGD have been the origin of Newton's constant - CP_2 size is almost four orders of magnitude longer than Planck length.Amusingly, a dramatic progress occurred in this respect just during the week when LIGO results were published.

The belief has been that Planck length is genuine quantal scale not present in classical TGD. The progress in twistorial approach to classical TGD however demonstrated that this belief was wrong. The idea is to lift the dynamics of 6-D space-time surface to the dynamics of their 6-D twistor spaces obeying the analog of the variational principle defined by Kähler action. I had thought that this would be a passive reformulation but I was completely wrong [L20] [L20] (see `http://tinyurl.com/zjgmax6`).

1. The 6-D twistor space of the space-time surface is a fiber bundle having space-time as base space and sphere as fiber and assumed to be representable as a 6-surface in 12-D twistor space $T(M^4) \times T(CP_2)$. The lift of Kähler action to Kähler action requires that the twistor spaces $T(M^4)$ and $T(CP_2)$ have Kähler structure in generalized sense. These structures exist only for S^4, E^4 and its Minkowskian analog M^4 and CP_2 so that TGD is completely unique if one requires the existence of twistorial formulation. In the case of M^4 one has a hybrid of complex and hyper-complex structure.

2. The radii of the two spheres bring in new length scales. The radius in the case of CP_2 is essentially CP_2 radius R. In the case of M^4 the radius is very naturally Planck length so that the origin of Planck length is understood and it is purely classical notion whereas Planck mass and Newton's constant would be quantal notions.

3. The 6-D Kähler action must be made dimensionless by dividing with a constant with dimensions of length squared. The scale in question is actually the area of $S^2(M^4)$, not the inverse of cosmological constant as the first guess was. The reason is that this would predict extremely large Kähler coupling strength for the CP_2 part of Kähler action.

   There are however two contributions to Kähler action corresponding to $T(CP_2)$ and $T(M^4)$ and the corresponding Kähler coupling strengths - the already familiar α_K and the new $\alpha_K(M^4)$ - are independent. The value of $\alpha_K(M^4) \times 4\pi R(S^2(M^4)$ corresponds essentially to the inverse of cosmological constant and to a length scale which is of the order of the size of Universe in the recent cosmology. Both Kähler coupling strengths are analogous to critical temperature and are predicted to have a spectrum of values. According to the earlier proposal, $\alpha_K(M^4)$ would be proportional to p-adic prime $p \simeq 2^k$, k prime, so that in very early times cosmological constant indeed becomes extremely large. This has been the problem of GRT based view about gravitation. The prediction is that besides the volume term coming from $S^(M^4)$ there is also the analog of Kähler action associated with M^4 but is extremely small except in very early cosmology.

4. A further new element is that TGD predicts the possibility of large $h_{eff} = n \times h$ gravitons. One has $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where v_0 has dimensions of velocity and satisfies $v_0/c < 1$: the value of v_0/c is of order $.5 \times 10^{-3}$ for the 4 inner planets. h_{gr} seems to be absolutely essential for understanding how perturbative quantum gravitation emerges.

   What is nice is that the twistor lift of Kähler action suggests also a concrete explanation for $h_{eff}/h = n$. It would correspond to winding number for the map $S^2(X^4) \rightarrow S^2(M^4)$ and one would indeed have covering of space-time surface induced by the winding as assumed earlier. This covering would have the special property that the base base for each branch of covering would reduce to same 3-surface at the ends of the space-time surface at the light-like boundaries of causal diamond (CD) defining fundamental notion in zero energy ontology (ZEO).

Twistor approach thus shows that TGD is completely unique in twistor formulation, explains Planck length geometrically, predicts cosmological constant and assigns p-adic length scale hypothesis to the cosmic evolution of cosmological constant, and also suggests an improved understanding of the hierarchy of Planck constants.

Can one understand the detection of gravitational waves if gravitons are dark?

The problem of quantum gravity is that if the parameter $GMm/h = Mm/m_P^2$ associated with two masses characterizes the interaction strength and is larger than unity, perturbation theory fails to converge. If one can assume that there is no quantum coherence, the interactions can be reduced to those between elementary particles for which this parameter is below unity so that the problem would disappear. In TGD framework however fermionic strings mediate connecting partonic 2-surface mediate the interaction even between astrophysical objects and quantum coherence in astrophysical scales is unavoidable.

The proposal is that Nature has been theoretician friendly and arranged so that a phase transition transforming gravitons to dark gravitons takes place so that Planck constant is replaced with $\hbar_{gr} = GMm/v_0$. This implies that $v_0/c < 1$ becomes the expansion parameter and perturbation theory converges. Note that the notion of h_{gr} makes sense only of one has $Mm/m_P^2 > 1$. The notion generalizes also to other interactions and their perturbative description when the interaction strength is large. Plasmas are excellent candidates in this respect.

1. The notion of h_{gr} was proposed first by Nottale from quite different premises was that planetary orbits are analogous to Bohr orbits and that the situation is characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0$. This replaces the parameter $GMm/\hbar$ with v_0 as perturbative parameter and perturbation theory converges. h_{gr} would characterize the magnetic flux tubes connecting masses M and m along which gravitons mediating the interaction propagate.

   According to the model of Nottale [E87] for planetary orbits as Bohr orbits the entire mass of star behaves as dark mass from the point of view particles forming the planet. $\hbar_{gr}$ appears as in the quantization of angular momentum and if dark mass $M_D < M$ is assumed, the integer characterizing the angular momentum must be scaled up by M/M_D. In some sense all astrophysical objects would behave like quantum coherent systems and many-sheeted space-time suggests that the magnetic body of the system along which gravitons propagate is responsible for this kind of behavior.

2. The crucial observation is that h_{gr} depends on the product of interacting masses so that h_{gr} characterizes a pair of systems satisfying $Mm/m_P^2 > 1$ rather than either mass. If so, the gravitons at magnetic flux tubes mediating gravitational interaction between masses M and m are always dark and have $h_{gr} = h_{eff}$. One cannot say that the systems themselves are characterized by h_{gr}. Rather, only the magnetic bodies or parts of them can be characterized by h_{gr}. The magnetic bodies can be associated with mass pairs and also with self interactions of single massive object (as analog of dipole field).

3. The general vision is that ordinary particles and large h_{eff} particles can transform to each other at quantum criticality [?]. Above temperatures corresponding to critical temperature particle would be ordinary, in a finite temperature range both kind of particles would be present, and below the lower critical temperature the particles would be dark. High T_c super-conductivity would provide a school example about this.

One would expect that for pairs of quantum coherent objects satisfying $GMm/h > 1$, the graviton exchange is by dark gravitons. This could affect the model for the detection of gravitons.

1. The first thing to notice is that the detectors can evaluate the distance of the source only by using the GRT prediction for the power of radiation and observed intensity. If alternative theory predicts different power (say if in the recent case dark gravitons remain un-detected), the distance of the source deduced from the data is changed.

2. Since Planck constant does not appear in classical physics, one might argue that the classical detection does not distinguish between dark and ordinary gravitons. Gravitons corresponds

classically to radiation with same frequency but amplitude scaled up by $\sqrt{n}$. One would obtain for $h_{gr} > 1$ a sequence of pulses with large amplitude length oscillations rather than continuous oscillation as in GRT. The average intensity would be same as for classical gravitational radiation.

Interferometers detect gravitational radiation classically as distance oscillations and the finding of LIGO suggests that all of the radiation is detected. Irrespective of the value of h_{eff} all gravitons couple to the geometry of the measuring space-time sheets. This looks very sensible in the geometric picture for this coupling. A more quantitative statement would be that dark and ordinary gravitons do not differ for detection times longer than the oscillation period. This would be the case now.

The detection is based on laser light which goes forth and back along arm. The total phase shift between beams associated with the two arms matters and is a sum over the shifts associated with pulses. The quantization to bunches should be smoothed out by this summation process and the outcome is same as in GRT since average intensity must be same irrespective of the value of h_{gr}. Since all detection methods use interferometers there would be no difference in the detection of gravitons from other sources.

3. The quantum detection h_{eff} gravitons - as opposed to classical detection - is expected to differ from that of ordinary gravitons. Dark gravitons can be regarded as bunches of n ordinary gravitons and thus is n times higher energy. Genuine quantum measurement would correspond to an absorption of this kind of giant graviton. Since the signal must be "visible" dark gravitons must transform to ordinary gravitons with same energy in the detection. For 35 Hz graviton the energy would have been $GMm/v_0\hbar$ times the energy or ordinary graviton with the same frequency. This would give energy of $19(c/v_0)$ MeV: one would have gravitational gamma rays. The detection system should be quantum critical. The transformation of dark gravitons with frequency scale done by $1/n$ and energy increased correspondingly would serve as a signature for darkness.

   Living systems in TGD Universe are quantum critical and bio-photons are interpreted as dark photons with energies in visible and UV range but frequencies in EEG range and even below [K80]. It can happen that only part of dark graviton radiation is detected and it can remain completely undetected if the detecting system is not critical. One can also consider the possibility that dark gravitons first decay to a bunch of n ordinary gravitons. Now however the detection of individual gravitons is impossible in practice.

It is interesting to look what one obtains if one assumes that the collapse occurs to the gravitational Compton radius $r_{gr} = \hbar_{gr}/M$ of the resulting blackhole. Using $\hbar_{gr} = GMm/v_0$ (I have used erratic formula $h_{gr} = GMm/v_0$ in some texts), the value of this radius is $r_{gr} = GM/v_0$ ($c = 1$). The post-Newtonian parameter $v = (GM\pi f)^{1/3}$ interpreted as relative velocity in in the article equals to $v \simeq .62$. $v_0 = v$ gives $r_{gr}/r_s = .5/.62 < 1$ (note that f is gravitational wave frequency which is twice the orbital frequency). The intuitive expectation is that $v_0 = 1/2$ defines upper limit for v_0. For this value one would have $r_s = r_{gr}$ and the outcome would be essentially the same as for ordinary blackhole collapse.

12.3.2 A gamma ray pulse was detected .4 seconds after the merger

The Fermi Gamma-ray Burst Monitor detected 0.4 seconds after the merger a pulse of gamma rays with red shifted energies about 50 keV [E118] (see the posting of Lubos at `http://tinyurl.com/huyny49` and the article from Fermi Gamma Ray Burst Monitor at `http://tinyurl.com/zpmx3rm`). At the peak of gravitational pulse the gamma ray power would have been about one millionth of the gravitational radiation. Since the gamma ray bursts are not detected too often (1 per day), it is rather plausible that the pulse comes from the same source as the gravitational radiation. The simplest model for blackholes does not suggest this but it is not difficult to develop more complex models involving magnetic fields.

Could this observation be seen as evidence for the assumption that dark gravitons are associated with magnetic flux tubes?

1. The radiation would be dark cyclotron gravitation generated at the magnetic flux tubes carrying the dark gravitational radiation at cyclotron frequency $f_c = qB/m$ and its harmonics (q denotes the charge of charge carrier and B the intensity of the magnetic field and its harmonics and with energy $E = h_{eff}eB/m$.

2. If $\hbar_{eff} = \hbar_{gr} = GMm/v_0$ holds true, one has $E = GMeB/v_0$ so that all particles with same charge respond at the same the same frequency irrespective of their mass: this could be seen as a magnetic analog of Equivalence Principle. The energy 50 keV corresponds to frequency $f \sim 5 \times 10^{18}$ Hz. For scaling purposes it is good to remember that the cyclotron frequency of electron in magnetic field $B_{end} = .2$ Gauss (value of endogenous dark magnetic field in TGD inspired quantum biology) is $f_c = .6$ Mhz.

   From this the magnetic field needed to give 50 keV energy as cyclotron energy would be $B_o = (f/f_c)B_{end} = .4$ GT corresponds to electrons with ordinary value of Planck constant the strength of magnetic field. If one takes the redshift of order $v/c \sim .1$ for cosmic recession velocity at distance of Gly one would obtain magnetic field of order 4 GT. Magnetic fields of with strength of this order of magnitude have been assigned with neutron stars.

3. On the other hand, if this energy corresponds to $\hbar_{gr} = GMm_ec/v_0$ one has $B = (h/h_{gr})B_o = (v_0m_P^2/Mm_e) \times B_o \sim (v_0/c) \times 10^{-11}$ T $(c = 1)$. This magnetic field is rather weak (fT is the bound for detectability) and can correspond only to a magnetic field at flux tube near Earth. Interstellar magnetic fields between arms of Milky way are of the order of 5×10^{-10} T and are presumably weaker in the intergalactic space.

4. Note that the energy of gamma rays is by order or magnitude or two lower than that for dark gravitons. This suggests that the annihilation of dark gamma rays could not have produced dark gravitons by gravitational coupling bilinear in collinear photons.

One can of course forget the chains of mundane realism and ask whether the cyclotron radiation coming from distant sources has its high energy due to large value of h_{gr} rather than due to the large value of magnetic field at source. The presence of magnetic fields would reflects itself also via classical dynamics (that is frequency). In the recent case the cyclotron period would be of order $(.03/v_0)$ Gy, which is of the same order of magnitude as the time scale defined by the distance to the merger.

In the case of Sun the prediction for energy of cyclotron photons would be $E = [v_0(Sun)/v_0] \times [M(Sun)/M(BH)] \times 50$ keV $\sim [v_0(Sun)/v_0]$ keV. From $v_0(Sun)/c \simeq 2^{-11}$ one obtains $E = (c/v_0) \times .5$ eV $\geq .5$ eV. Dark photons in living matter are proposed to correspond to $h_{gr} = h_{eff}$ and are proposed to transform to bio-photons with energies in visible and UV range [K80].

Good dialectic would ask next whether both views about the gamma rays are actually correct. The "visible" cyclotron radiation with standard value of Planck constant at gamma ray energies would be created in the ultra strong magnetic field of blackhole, would be transformed to dark gamma rays with the same energy, and travel to Earth along the flux tubes. In TGD Universe the transformation ordinary photons to dark photons would occur in living matter routinely. One can of course ask whether this transformation takes place only at quantum criticality and whether the quantum critical period corresponds to the merger of blackholes.

The time lag was .4 second and the merger event lasted .2 seconds. Many-sheeted space-time provides one possible explanation. If the gamma rays were ordinary photons so that dark gravitons would have travelled along different flux tubes, one can ask whether the propagation velocities differed by $\Delta c/c \sim 10^{-17}$. In the case of SN1987A neutrino and gamma ray pulses arrived at different times and neutrinos arrived as two different pulses [K98] so that this kind of effect is not excluded. Since the light-like geodesics of the space-time surface are in general not light-like geodesics of the embedding space signals moving with light velocity along space-time sheet do not move with maximal signal velocity in embedding space and the time taken to travel from A to B depends on space-time sheet. Could the later arrival time reflect slightly different signal velocities for photons and gravitons?

Could one imagine a function for the gamma ray pulse possibly explaining also why it came considerably later than gravitons (0.4 seconds after the merger which lasted 2. seconds)? This function might relate to the transfer of surplus angular momentum from the system.

1. The merging blackholes were reported to have opposite spins. Opposite directions of spins would make the merger easier since local velocities at the point of contact are in same direction. The opposite directions spins suggest an analogy with two vortices generated from water and this suggests that their precedessors were born inside same star. There is also relative orbital angular momentum forming part of the spin of the final state blackhole, which was modelled as a Kerr blackhole. Since the spins of blackholes were opposite, the main challenge is to understand the transition to the situation in all matter has same direction of spin. The local spin directions must have changed by some mechanism taking away spin.

2. Magnetic analogs blackholes seem to be needed. They would be analogs of magnetars, which are pulsars with very strong magnetic fields. Magnetic fields are needed to carry out angular momentum from the matter as blackhole is formed. Same should apply now. Outgoing matter spirals along the helical jets (and carries away the spin which is liberated as the rotating matter in two spinning blackholes slows down to rest and the orbital angular momentum becomes the total spin.

3. If cyclotron adiation left .4 later, it would be naturally assignable to the liberation of temporarily stored surplus angular momentum which blackhole could not carry stably. This cyclotron radiation could have carried out the surplus angular momentum. Amusingly, it could be also seen as a dark analog of Hawking radiation.

Here one must be ready to update the beliefs about what black hole like objects are. About their interiors empirical data tell of course nothing.

1. The exteriors could contain magnetic fields and must do so in TGD Universe. Kerr-Newman solution represents a rotating magnetic blackhole solution of Einstein-Maxwell theory (see Appendix). It carries quadrupole magnetic field so that one can say that "blackhole has no hair theorem" stating that blackhole is completely characterized by conserved charges associated with long range interactions: mass, angular momentum and electric charge fails for Kerr-Newman solution. The solution is is however unphysical containing closed time-like curves: the space-like ring singularity of Kerr solution is transformed to infinitely long time-like curve when charge is introduced. In TGD framework this solution seems very implausible even at GRT limit of the theory since closed time-like geodesics are impossible for space-time surfaces. What is required is analog of blackhole with magnetic monopole charge or dipole moment and to my best knowledge no such solutions are known for Einstein-Maxwell theory.

2. No hair theorem has been challenged quite recently by Hawking (for TGD inspired commentary [L15] see `http://tinyurl.com/yby3r3ec`). This suggest the possibility that higher multiple moments characterize blackhole like entities. An extension of $U(1)$ gauge symmetries allowing gauge transformations, which become constant in radial direction at large distances but depend on angle degrees of freedom, is in question. In TGD framework the situation is analogous but much more general and super-symplectic and other symmetries with conformal structure extend the various conformal symmetries and allow to understand also the hierarchy of Planck constants in terms of a fractal hierarchy of symmetry breakins to sub-algebra isomorphic with the full algebra of symmetries in question [**?**].

3. There exist also experimental data challenging the no-hair theorem. The supermassive blackhole like entity near the galactic center is known to have a magnetic field (see `http://tinyurl.com/hazseka`) and thus magnetic moment if the magnetic field is assignable to the blackhole itself rather than matter surrounding it.

Be as it may, any model should explain why the cyclotron radiation pulse came .4 seconds later than gravitaton pulse rather than at the same time. Compared to .2 seconds for blackhole formation this is quite a long time.

1. Suppose that blackhole like objects have - as any gravitating astrophysical object in TGD Universe must have - a magnetic body making possible the transfer of gravitons and carrying classical gravitational fields. Suppose that radial monopole flux tubes carrying gravitons can carry also BE condensates for which charged particles have varying mass m. $\hbar_{gr} =$

$GMm/v_0 = \hbar_{eff} = n \times \hbar$ implies that particles with different masses reside at their own flux tubes like books in book shelves - something very important in TGD inspired quantum biology [K80].

One might argue that $\hbar_{gr}$ serves as a very large spin unit and makes the storage very effective but here one must be very cautious: spin fractionization suggested by the covering property of space-time sheets could scale down the spin unit to $\hbar/n$. I do not really understand this issue well enough. In any case, already the spontaneously magnetized BE condensate with relative angular momentum of Cooper makes at pairs of helical flux tubes possible effective angular momentum storage.

2. The spontaneously magnetized dark Bose-Einstein condensate would consist of charged bosons - say charged fermion pairs with members located at parallel flux tubes as in the TGD inspired model of hight T_c superconductor with spin $S = 1$ Cooper pairs. This BE condensate would be ideal for the temporary storage of surplus spin and relative angular momentum of members of pairs at parallel helical flux tubes. Orbital angular momentum assignable to the flux tubes twisted by the rotation is much more effective storage mechanism than dark magnetization since orbital angular momentum has typically much larger values spin. This angular momentum would have been radiated away as a gamma ray pulse in a quantum phase transition.

   The first possibility is that this phase transition is to a state without dark spontaneous magnetization. A more promising possibility is that the transition corresponds (also) to a reconnection of flux tubes leading to un-knotting of the flux tubes and liberation of energy and angular momentum as gamma ray pulse. In TGD framework the twisting and braiding of the magnetic monopole flux tubes induced by the rotation of the blackhole like entity store the surplus rotational energy and angular momentum of merging blackholes to magnetic body liberated as the magnetic flux tubes reconnect leading to the unk-knotting the braid. In Sun the solar spot cycle with a period of 11 years corresponds to this kind of periodic braiding and un-braiding by re-connections.

3. In TGD framework there are reasons to ask whether the magnetic field associated with blackhole consists of flux tubes carrying essentially radial monopole flux. If electric charge is involved as the fact that all metrics behaving like Schwartschild metric asymptotically carry arbitrarily small but non-vanishing gauge charge(s), it could be transferred along same flux tubes with self dual Kähler form giving rise to self-dual U(1) gauge field. Also the charged matter in the accretion disk around blackhole could generate magnetic field. Since no currents are needed to generate monopole magnetic field, the accretion disk would be un-necessary.

   Note that at elementary particle the magnetic flux tubes at partonic 2-surfaces satisfies self-duality condition as a boundary condition. Since the flux lines are closed, the simplest elementary particle like entity must involve two wormhole contacts with Euclidian signature of metric through which the magnetic flux flows between space-time sheets with Minkowskian signature flows. Also astrophysical objects could be connected by monopole flux tubes mediating gravitational interaction. If the flux is self-dual, it must be small since the electric charges involve are small albeit predicted to be non-vanishing in TGD framework.

4. Penrose process (see `http://tinyurl.com/ybovomcb`) allows a transfer of energy from rotating Kerr blackhole (see Appendix). This is due to the very special properties of ergosphere (see Appendix), whose boundaries are defined by the condition $g_{tt} = 0$. Blandford-Znajek process [B44] (see `http://tinyurl.com/zlwgwzc`) allows a transfer of energy and angular momentum with the mediation of magnetic field and it has been proposed that this mechanism entangling the flux lines could serve as a mechanism of energy and angular momentum transfer quasars. In this case the magnetic field is external magnetic field rather than inherent to blackhole. Recall that Kerr-Newman solution corresponds to magnetic quadrupole with monopolar $1/r^2$ radial dependence and cannot describe the situation in which magnetic field is dipole or even monopole type.

   In TGD framework the decay of cosmic strings to particles analogous to the decay of inflaton vacuum energy to particles would generate beams in the direction of string like object. This mechanism for quasar would predict that quasars can apparently disappear as the string and thus beam changes its direction and ceases to be directed to Earth. Quite recently, this kind of mysterious disappearance of quasar has been seen (see `http://tinyurl.com/zgbuolt`).

5. One could criticize the assumption that monopolar Kähler magnetic flux tubes mediate the gravitational field. One can in fact consider an alternative. The twistor lift of the Kähler action [L20] describes the dynamics of twistor spaces of space-time surfaces as 6- surfaces in the product of the 6-D twistor spaces of M^4 and CP_2, and dimensionally reduces to Kähler action involving the analog of cosmological term and possibly also the M^4 analog of Kähler action. This approach explains Planck length as the radius of the 2-sphere associated as fiber with M^4 twistor space. The extremely small value of cosmological constant in the recent cosmology reduces to the extremely large value of Kähler coupling strength associated with M^4 twistor part reducing to a volume term coming from S^2 part of Kähler form and possibly also M^4 analog of Kähler action.

   Cosmological constant would be analogous to critical temperature and has a spectrum coming as inverse square of p-adic length scale and its sign is predicted correctly. One must assign to M^4 twistor space a self-dual Kähler form and its M^4 projection could (but need not) appear also in the dimensionally reduced Kähler action. The Kähler form for a causal diamond would be naturally radial self-dual monopole field - I have considered this possibly earlier but gave it up. One can ask whether the magnetic monopole flux assigned with flux tubes could correspond to M^4 part of Kähler form or whether the two induced Kähler forms could have same flux tubes.

Clearly, LIGO could mean also a new era in the theory of gravitation. The basic problem of GRT description of blackholes relates to the classical conservation laws and it becomes especially acute in the non-stationary situation represented by a merger. Post-Newtonian approximation is more than a calculational tool since it brings in conservation laws from Newtonian mechanics and fixes the coordinate system used to that assignable to empty Minkowski space. Further observations about blackhole mergers might force to ask whether Post-Newtonian approximation actually feeds in the idea that space-time is surface in embedding space. If the mergers are accompanied by gamma ray bursts as a rule, one is forced to challenge the notion of blackhole and GRT itself.

12.3.3 Does GW150914 force to modify the views about formation of binary blackhole systems?

The considerations below were inspired by a popular article (see `http://tinyurl.com/hhvejqf`) related to the discovery of gravitational radiation in the formation of blackhole from two unexpectedly massive blackholes.

LIGO has hitherto detected two events in which the formation of blackhole as fusion of two blackholes has generated a detectable burst of gravitational radiation. The expected masses for the stars of the binary are typically around 10 solar masses. The later event involve a pair with masses of 8 and 14 solar masses marginally consistent with the expectation. The first event GW150914 involves masses of about 30 solar masses. This looks like a problem since blackhole formation is believed to be preceded via a formation of a red super giant and supernova and in this events star loses a large fraction of its mass.

The standard story evolution of binary to a pair of blackholes would go as follows.

1. In the beginning the stars involved have masses in the range 10-30 solar masses. The first star runs out of the hydrogen fuel in its core and starts to burn hydrogen around the helium core. In this step it puffs up much of the hydrogen at its surface layers forming a red supergiant. The nuclear fusion proceeds in the core until iron core is formed and fusion cannot continue anymore. The first star collapses to a super nova and a lot of mass is thrown out (conservation of momentum forces this).

2. Second star sucks much of the hydrogen after the formation of red supergiant. The core of the first star eventually collapses into a black hole. The stars gradually end end up close to each other. As the second star turns into a supergiant it engulfs its companion inside a common hydrogen envelope. The stars end up even closer to each other and the envelope is lost into space. Eventually the core of also second star collapses into a black hole. The

two black holes finally merge together. The model predicts that due to the mass losses the masses of companions of the binary are not much higher than 10 solar masses. This is the problem.

Selma de Mink (see `http://tinyurl.com/zgdhr97`) has proposed a new kind of story about the formation of blackholes from the stars of a binary.

1. The story begins with two very massive stars rotating around each other extremely rapidly and so close together than they become tidally locked. They are like tango dancers. Both dancers would spin around their own axis in the same direction as they spin with respect to each other. This spinning would stir the stars and make them homogenous. Nuclear fusion would continue in the entire volume of the star rather in the core only. Stars would never run out of fuel and throw away they hydrogen layers. Therefore the resulting blackhole would be much more massive. This story would apply only to binaries.

2. The simulations of the homogenous model however have difficulties with more conventional binaries such as the blackhole of the second LIGO signal. Second problem is that the blackholes forming GW150914 have very low spins if any. The proposed explanation would in terms of dance metaphor.

   Strong magnetic fields are present forcing the matter to flow near to the magnetic poles. The effect would be similar to that when figure skater stretches her arms to increase the moment of inertia in spin direction so that the spinning rate slows down by angular momentum conservation. This requires that the direction of the dipole differs from the axis of rotation considerably. Otherwise the spinning rate increases since moment of inertia is reduced: this is how the dancer develops the pirouette. The naïve expectation is that the directions of the magnetic and rotation axis are near to each other.

What kind of story would TGD suggest?

1. The additional actor in this story is dark matter identified as large $h_{eff} = h_{gr}$ phases with $\hbar_{gr} = GMm/v_0$, where $v_0/c <$ has dimensions of velocity: ($c = 1$ is assumed for convenience) [K93, K79]. M is the large mass and m a small mass, say mass of elementary particle. The parameter v_0 could be proportional to a typical rotational velocity in the system with universal coefficient.

   The crucial point is that the gravitational Compton length $\Lambda_{gr} = \hbar_{gr}/m = GM/v_0$ of the particle does not depend on its mass and for $v_0 < c/2$ is larger than Schwartschild radius $r_S = 2GM$. For $v_0 > c/2$ the dark particles can reside inside blackhole.

2. Could dark matter be involved with the formation of very massive blackholes in TGD framework? In particular, could the transformation of dark matter to ordinary matter devoured by the blackhole or ending as such to blackhole as such help to explain the large mass of GW150914?

   I have written already earlier about a related problem. If dark matter were sucked by blackholes the amount of dark matter should be much smaller in the recent Universe and it would look very different. TGD inspired proposal is that the dark matter is dark in TGD sense and has large value of Planck constant $h_{eff} = n \times h = h_{gr}$ implying that the dark Compton length for particle with mass m is given by $\Lambda = \hbar_{gr}/m = GM/v_0 = r_S/2v_0$. Λ_{gr} is larger than the value of blackhole horizon radius for $v_0/c < 1/2$ so that the dark matter remains outside the blackhole unless it suffers a phase transition to ordinary matter.

   For $v_0/c > 1/2$ dark matter can be regarded as being inside blackhole or having transformed to ordinary matter. Also the ordinary matter inside r_S could transform to dark matter. For $v_0/c = 1/2$ for which $\Lambda = r_S$ holds true and one might say that dark matter resides at the surface of the blackhole.

3. What could happen in blackhole binaries? Could the phase transition of dark matter to ordinary matter take place or could dark matter reside inside blackhole for $v_0/c \geq 1/2$? This would suggest large spin at the surface of blackhole. Note that the angular momenta of dark

matter - possibly at the surface of blackhole - and ordinary matter in the interior could cancel each other.

The GRT based model GW150914 has a parameter with dimensions of velocity very near to c and the earlier argument leads to the proposal that it approaches its maximal value meaning that Λ approaches $r_S/2$. Already $\Lambda = r_S$ allows to regard dark matter as part of blackhole: dark matter would reside at the surface of blackhole. The additional dark matter contribution could explain the large mass of GW150914 without giving up the standard view about how stars evolve.

4. Do blackholes of the binary dance now? If the gravitational Compton length $\Lambda_{gr} = GM/v_0$ of dark matter particles are so large that the other blackhole is contained within the sphere of radius Λ_{gr}, one might expect that they form single quantum system. This would favor v_0/c considerably smaller than $v_0/c = 1/2$. Tidal locking could take place for the ordinary matter favoring parallel spins. For dark matter antiparallel spins would be favored by vortex analogy (hydrodynamical vortices with opposite spins are attracted).

The more one thinks about the situation, the clearer it becomes that angular momentum transfer is the key problem. The following two mechanisms come in mind in TGD framework.

1. Could magnetic fields explain the low spin of the components of GW150914? In TGD based model for blackhole formation magnetic fields are in a key role. Quite generally, gravitational interactions would be mediated by gravitons propagating along magnetic flux tubes. Sunspot phenomenon in Sun involves twisting of the flux tubes of the magnetic field and with 11 year period reconnections of flux tubes resolve the twisting: this involves loss of angular momentum. Something similar is expected now: dark photons, gravitons, and possibly also other parts at magnetic flux tubes take part of the angular momentum of a rotating blackhole (or star). The gamma ray pulse observed by Fermi telescope assigned to GW150914 could be associated with this un-twisting sending angular momentum of twisted flux tubes out of the system. This process could transfer the spin of the star out of the system and produce a slowly spinning blackhole. Same process could have taken place for the component blackholes and explain why their spins are so small.

2. The development of ideas about the formation of galaxies and stars tangles of long cosmic strings [L69, L93, L82] occurred after writing of the first paragraph allow to formulate the problem in a more general manner. In standard framework it is difficult to understand how very massive blackholes are possible at all. During the formation of blackhole the radius decreases and the star should throw out a lot of angular momentum to avoid too high spinning velocity in the collapse. This can be achieved by throwing out mass but this makes heavy blackholes impossible.

3. Can TGD provide a solution of this problem? Suppose that both galaxies and stars are tangles along long cosmic strings locally thickened to monopole flux tubes carrying dark matter and energy in TGD sense Long flux tube would provide new degrees of freedom. Could the angular momentum of collapsing star consisting of ordinary matter be transferred from the star to the cosmic string/flux tube without large loss of stellar mass.

   Suppose that one has instead of single monopole flux tube a pair of flux tubes (flux tubes would combine to form a closed flux tube) forming a rotating helical structure. This structure could store the angular momentum to its rotation. Also the radiation and particles travelling around these helical flux tubes could take away part of the angular momentum but flux tubes themselves as TGD counterparts of galactic dark matter could do the main job. Heavy blackholes would be a direct signature for energy and angular mmentum transfer between ordinary matter and galactic dark matter in TGD sense.

12.3.4 Gravitational Waves from Black Hole Megamergers Are Weaker Than Predicted

Few months after LIGO results there was an interesting popular article in Scientific American with title "Gravitational Waves from Black Hole Megamergers Are Weaker Than Predicted" (see http://tinyurl.com/j7ckmdw). The article told about the failure to find support for the effects of gravitational waves from the fusion of supermassive blackholes. The fusions of supermassive blackholes generate gravitational radiation. These collisions would be scaled up versions of the LIGO event.

Supermassive blackholes in galactic centers are by statistical arguments expected to fuse in the collisions of galaxies so often that the generated gravitational radiation produces a detectable hum. This should produce a background hum which should be seen as a jitter for the arrival times of photons of radiation from pulsars. This jitter is same for all pulsars and therefore is expected to be detectable as kind of "hum" defined by gravitational radiation at low frequencies. The frequencies happen to be audible frequencies. For the past decade, scientists with the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) collaboration tried to detect this constant "hum" of low-frequency gravitational waves [E81] (see http://tinyurl.com/y98gbagh). The outcome is negative and one should explain why this is the case.

I do not know how much evidence there exists for nearby collisions of galaxies in which fusion of galactic supermassive blackholes really take place. What would TGD suggest? For year ago I would have considered an explanation in terms of dark gravitons with lower detection rate but after the revision of the model for the detection of gravitational waves forced by LIGO discovery the following explanation looks more plausible.

1. In TGD Universe galaxies could be like pearls in necklace carrying dark magnetic energy identifiable as dark matter. This explains galactic rotation curves correctly $1/\rho$ force in plane orthogonal to the long cosmic string (in TGD sense) defining the necklace gives constant velocity spectrum plus free motion along string: this prediction distinguishes TGD from the competing models. Halo is not spherical since stars are in free motion along cosmic string. The galactic dark matter is identified as dark energy in turn identifiable as magnetic energy of long cosmic string. There is a considerable evidence for these necklaces and this model is one of the oldest parts of TGD inspired astrophysics and cosmology [K31, K94].

2. Galaxies as vehicles moving along cosmic highways defined by long cosmic strings is more dynamical metaphor than pearls in necklace and better in recent context. The dominating interaction would be the gravitational interaction keeping the galaxy at highway and might make fusion of galactic blackholes a rare process.

This model allows to consider the possibility that the fusions of galactic super-massive blackholes are much rarer than expected in the standard model.

1. The gravitational interaction between galaxies at separate highways passing near each other would be secondary interaction and galaxies would pass each other without anything dramatic occurring.

2. If the highways intersect each other the galaxies could collide with each other if the timing is correct but this would be a rare event. This is like two vehicles arriving a crossing simultaneously. In fact, I wrote for a couple of years ago about the possibility that Milky Way could have resulted as the intersection of two cosmic highways (or as a result of cosmic traffic accident).

3. If the galaxies are moving in opposite directions along the *same* highway, the situation changes and a fusion of galactic nuclei in head on collision is unavoidable. It is difficult to say how often this kind of events occur: it could occur that galaxies have after sufficiently many collisions "learned" to move in the same direction and define analog of hydrodynamical flow. A cosmic flow has been observed in "too" long scales and could correspond to a coherent flow along cosmic string.

12.3.5 Third gravitational wave detection by LIGO collaboration

The news about third gravitational wave detection managed to direct the attention of at least some of us from the doings of Donald J. Trump. Also New York Times (see http://tinyurl.com/y7xc9xap) told about the gravitational wave detection by LIGO, the Laser Interferometer Gravitational-Wave Observatory. Gravitational waves are estimated to be created by a black-hole merger at distance of 3 billion light years. The results are published in article "Observation of a 50-Solar-Mass Binary Black Hole Coalescence at Redshift 0.2" in Phys Rev Lett [E173] (see http://tinyurl.com/ybpqla3v).

Two black holes with masses $19 \times M(Sun)$ and $31 \times M(Sun)$ merged to single blackhole hole of with mass of $49 \times M(Sun)$ meaning that roughly one solar mass was transformed to gravitational radiation. During the the climax of the merger, they were emitting more energy in the form of gravitational waves than all the stars in the observable universe.

The colliding blackholes were very massive in all three events. There should be some explanation for this. An explanation considered in the article is that the stars giving rise to blackholes were rather primitive containing light elements and this would have allowed large masses. The transformation to blackholes could have occurred directly without the intervening supernova phase. There is indeed quite recent finding (see http://tinyurl.com/y9odpqs2) showing a disappearance of very heavy star with 25 solar masses suggesting that direct blackhole formation without super-nova explosion is possible for heavy stars.

It is interesting to take a fresh look to these blackhole like entities in TGD framework. This however requires brief summary about the formation of galaxies and stars in TGD Universe [L30, L47].

1. The simplest possibility allowed by TGD [L47] is that galaxies as pearls in necklace are knots (or spagettilike substructures) in long cosmic strings. This does not exclude the original identification as closed strings around long cosmic string. These loops must be however knotted. Galactic super-blackhole could correspond to a self-intersection of the long cosmic string. This view is forced by the experimental finding that for mini spirals, there is volume with radius containing essentially constant density of dark matter. The radius of this volume is 2-3 times larger than the volume containing most stars of the galaxy. This region would contain a galactic knot.

   The important conclusion is that stars would be subknots of these galactic knots as indeed proposed earlier. Part of the magnetic energy would decay to ordinary matter giving rise to visible part of start as the cosmic string thickens. This conforms with the finding that the region in which dark matter density seems to be constant has size few times larger than the region containing the stars (size scale is few kpc).

2. The light beams from supernovas would most naturally arrive along the flux tubes being bound to helical orbits rotating around them. Primordial cosmic string as stars, galaxies, linear structures of galaxies, even elementary particles, hadrons, nuclei, and biomolecules: all these structures would be magnetic flux tubes possibly knotted and linked. The space-time of GRT as a small deformation of M^4 would have emerged from cosmic string dominated phase via the TGD counterpart of inflationary period. The signatures of the primordial cosmic string dominated period would be directly visible in all scales! We would be seeing the incredibly simple truth but our theories would prevent us to become aware about what we are seeing!

The crucial question concerns the dark matter fraction of the star.

1. The fraction depends on the thickness of the deformed cosmic string having originally 1-D projection $E^3 \subset M^4$. If Kähler magnetic energy dominates, the energy per length for a thickened flux tube is proportional to $1/S$, S the area of M^4 projection and thus decreases rapidly with thickening. The thickness of the flux tube would be in minimum about CP_2 size scale of 10^4 Planck lengths. If S is large enough, the contribution of cosmic string to the mass of the star is smaller than that of visible matter created in the thickening.

2. What about very primitive stars - say those associated with LIGO mergers. The proportion of visible matter in star should gradually increase as flux tube thickens. Could the detected blackhole fusion correspond to a fusion of dark matter stars rather than that of Einsteinian blackholes? If the radius of the objects satisfies $r_S = 2GM$, the blackhole like entities are in question also in TGD. The space-time sheet assigable to blachhole according to TGD has however two horizons. The first horizon would be a counterpart of the usual Schwartschild horizons. At second horizon the signature of the induced metric would become Euclidian -

this is possible only in TGD. Cosmic string would topologically condense at this space-time sheet.

3. Could most of matter be dark even in the case of Sun? What can we really say about the portion of the ordinary matter inside Sun? The total rate of nuclear fusion in the solar core depends on the density of ordinary matter and one can argue that existing model does not allow a considerable reduction of the portion of ordinary matter.

   There is however also another option - dark fusion - which would be at work in TGD based model of cold fusion [K25] (low energy nuclear reactions (LENR) is less misleading term) and also in TGD inspired biology (there is evidence for bio-fusion) as Pollack effect [L9], in which part of protons go to dark phase at magnetic flux tubes to form dark nuclear strings creating negatively charged exclusion zone). Dark fusion would give rise to dark proton sequences at magnetic flux tubes decaying by dark beta emission to beta stable nuclei and later to ordinary nuclei and releasing nuclear binding energy.

   Dark fusion could explain the generation of elements heavier than iron not possible in stellar cores [K25]. Standard model assumes that they are formed in supernova explosions by so called r-process but empirical data do not support this hypothesis. In TGD Universe dark fusion could occur outside stellar interiors.

4. But if heavier elements are formed via dark fusion, why the same could not be true for the lighter elements? The TGD based model of atomic nuclei represents nucleus as a string like object or several of them possibly linked and knotted. Thickened cosmic strings again! Nucleons would be connected by meson like bonds with quark and antiquark at their ends.

   This raises a heretic question: could also ordinary nuclear fusion rely on similar mechanism? Standard nuclear physics relies on potential models approximating nucleons with point like particles: this is of course the only thing that nuclear physicists of past could imagine as children of their time. Should the entire nuclear physics be formulated in terms of many-sheeted space-time concept and flux tubes? I have proposed this kind of formulation long time ago [K97, L2]. What would distinguish between ordinary and dark fusion would be the value of $h_{eff} = n \times h$.

5. Months after writing the above comments I analyzed the books by Steven Krivit about the history of "cold fusion". It is now clear that genuine cold fusion cannot in question. The TGD interpretation is in terms of what I call dark nucleosynthesis (DNS) [L31] [K25]. DNS would explain both the energy production and production of various isotopes in "cold fusion". DNS could also be the precedessor of the ordinary nucleosynthesis, serving as a kind of warmup band. This unavoidably leads to the idea that "cold fusion" alone could have led to a formation of stars containing relatively light elements and thus able to have rather large masses: very old stars could be this kind of stars. DNS could even give rise to metal corres of planets and Fe core of Earth could have emerged in this manner.

After this prelude it is possible to speculate about blackholes in the spirit of TGD .

1. Also the interiors of blackholes would contain dark knots and have magnetic structure. This predicts unexpected features such as magnetic moments not possible for GRT blackholes. Also the matter inside blackhole would be dark (the TGD based explanation for Fermi bubbles assumes this [L47]). Already the model for the first LIGO event explained the unexpected gamma ray bursts in terms of the twisting of rotating flux tubes as effect analogous to what causes sunspots: twisting and finally reconnection.

2. One must also ask whether LIGO blackholes are actually dark stars with very small amount of ordinary matter. If the radius is indeed equal to Schwarschild radius $r_S = 2GM$ and mass is really what it is estimated to be rather than being systematically smaller, then the interpretation as TGD counterparts of blackholes makes sense. If mass is considerably smaller, the radius would be correspondingly large, and one would not have genuine blackhole. I do not however take this option too seriously.

3. What about collisions of blackholes? Could they correspond to two knots moving along same string in opposite directions and colliding? Or two cosmic strings intersecting and forming a cosmic crossroad with second blackhole in the crossing? Or self-intersection of single cosmic string? In any case, cosmic traffic accident would be in question.

   The second LIGO event gave hints that the spin directions of the colliding blackholes were not the same. This does not conform with the assumption that binary blackhole system was in question. Since the spin direction would be naturally that of long cosmic string, this suggests that the traffic accident in cosmic cross road defined by intersection or self-intersection created the merger. Note that intersections tend to occur (think of moving strings in 3-D space) and could be stablized by gravitational attraction: two string world sheet at 4-D space-time surface have stable intersections just like strings in plane unless they reconnect.

12.3.6 Some comments about GW170817

The observation of GW170817 [E142] (see http://tinyurl.com/ybv9xo6m) was one of the events of the year in physics. Both gravitational waves and electromagnetic radiation from the collision of two neutron stars fusing to single object were detected. The event occurred at a distance of order 130 Mly (size scale of large voids). The event was a treasure trove of information.

The first piece of information relates to the question about the synthesis of elements heavier than Fe. It is quite generally assumed that the heavier elements are generated in so called r-process involving creation of neutrons fusing with nuclei. One option is that the r-process accompanies supernova explosions but SN1987A did not provide support for this hypothesis: the characteristic em radiation accompanying r-process was not detected. GW170817 generated also em radiation, so called kilonova (see http://tinyurl.com/ycagjeau), and the em radiation accompanying r-process was reported. Therefore this kind of collisions would generate at least part of the heavier elements. In TGD framework also so called dark nucleosynthesis occurring outside stellar interiors and explaining so called nuclear transmutations, which are now rather well-established phenomenon, would also contribute to he generation of heavier elements (and also the lighter ones) [L31] (see http://tinyurl.com/y7u5v7j4).

Second important piece of information was that in GW170817 both gravitational waves and gamma ray signal were detected, and the difference between the arrival times was about 1.7 seconds: gamma rays arrived slightly after the gravitational ones. From this the difference between effective propagation velocities between gravitational and em waves is extremely small.

Note that similar difference between neutrino signal and gamma ray signal was measured for SN1987A. Even gamma rays arrived at two separate pulses from SN1987A. In this case the delay was longer and a possible TGD explanation is that the signals arrived along different space-time sheets (one can certainly tailor also other explanations).

1. In the recent case it would seem and gravitons and photons arrived along the same space-time sheet (magnetic flux tubes) or at least that the difference for effective light velocity was extremely small if the sheets were different. Perhaps this is the case for all exactly massless particles. In the case of SN1987A neutrino burst was observed 3 hours after gamma ray burst.

2. From the distance of about .17 MLy one can estimate $\Delta c/c$. If $\Delta c/c$ has the same value for GW17081, the neutrino burst for it should have arrived after 2846 hours making 118 days (day=24 hours). This would explain why neutrinos were not detected in the case of GW170817. The explanation has been that the direction was such that neutrino pulse was to weak to be detected in that direction. If colleagues were mature enough to take TGD seriously, they would be eagerly waiting for the arrival of the neutrino pulse!

Second implication relates to so called modified gravity theories. These theories claim that dark matter and dark energy are not real (for instance MOND suggesting a more or less ad hoc modification of gravitation at very small accelerations and Verlinde's model, which has received a lot of attention recently). Certain class of these models predict a breaking of Equivalence Principle. Gravitons would couple only to the metric created by ordinary matter as predicted by GRT whereas ordinary matter would couple to that created by dark and ordinary matter as predicted by GRT.

Although this kind of models look hopelessly ad hoc (at least to me), they have right to be shown wrong and GW170817 did this (see http://tinyurl.com/ycm3gnn4). The point is that the coupling to dark matter besides ordinary matter implies that gamma rays experience additional delay and arrive later than gravitons coupling only to the ordinary matter. This causes what is called Shapiro delay of about 1000 days much longer than the observed 1.7 seconds. Thus these models are definitely excluded. I do not know what this means for the original MOND and for Verlinde's model.

There is an amazing variety of MOND like models there to be killed and another article about what GW170817 managed to do can be found (see http://tinyurl.com/ybg6mxc4). Theoretical physics is drowning to a flood of ad hoc models: this is true also in particle physics where great narratives have been dead for four decades now. GW170817 looks therefore like a godly intervention similar to what happened with Babel's tower.

There is a popular article titled "Seeing One Example Of Merging Neutron Stars Raises Five Incredible Question" (see http://tinyurl.com/ybuzdb4o) telling that GW100817 seems to be very badly behaving guy challenging the GRT based models for the collisions of neutron stars. Something very fishy seems to be going on and this might be the change for TGD to challenge GRT based models.

1. The naïve estimate for the rate of these events is 10 times higher than estimated (suggesting that colliding objects were connected by flux tube somewhat like biomolecules making them possible to find each other in the molecular soup).

2. The mass ejected from the object was much larger than predicted. The signal in UV and optical parts of the spectrum should have lasted about one day. It lasted for two days before getting dimmer.

3. The final state should have been blackhole or magnetar collapsing rapidly into blackhole. It was however supermassive neutron star with mass about 2.74 solar masses. The upper limit is about 2.5 solar masses for non-rotating neutron star so that the outcome should have been a blackhole without any ejecta!

   TGD view about blackholes differs from that of GRT. The core region of all stars (actually all physical objects including elementary particles) involves a space-time sheet for which the signature of the induced metric is Euclidian. The signature changes at light-like 3-surface somewhat analogous to blackhole horizon. For blackhole like entities there is also Schwartschild horizong above this horizon. Could this model provide a better model for the outcome of the fusion.

4. Why gamma ray bursts were so strong and in so many directions instead of cone of angular width about 10-15 degrees? Although gamma ray burst was about 30 degrees from the line of sight, it was seen.

   Heavier elements cannot be produced by fusion in stellar interiors since the process requires energy. r-process in the fusions of neutron stars has been proposed as the mechanism, and the radiation spectrum from GW170817 is consistent with this proposal. The so called dark nucleosynthesis proposed in TGD framework to explain nuclear transmutations (or "cold fusion" or low energy nuclear reactions (LENR)) [L31]. This mechanism would produce more energy than ordinary nuclear fusion: when dark proton sequence (dark nucleus) transforms to ordinary nucleus almost entire nuclear binding energy is liberated. Could the mechanism producing the heavier elements be dark nuclear fusion also in the fusion of neutron stars. This would have also produced more energy than expected.

12.3.7 LIGO: no evidence for cosmic strings

LIGO has reported [E80] (see http://tinyurl.com/ydy89shr) that it has not found any evidence for so called cosmic strings, which are a basic prediction of GUTs. It is becoming painfully clear that GUTs have led the entire theoretical physics to a wrong track. Regrettably, we have spent for more than four decades at this wrong track now. Also superstring models and M-theory assume GUT as their limit at long length scales so that this finding should finally wake up even the most sleepy colleagues.

As Peter W*it (for some reason Lubos wants to write "o":s as "*":s in this context) tells in N*t Even Wr*ng (see `http://tinyurl.com/glet7y5`), cosmic strings have been one of so called qualitative predictions of many variants of superstring theory. This is true but since Lubos is one of the few remaining superstring fans, Woit's blog post made him very irritated (see `http://tinyurl.com/yaecfr2n`) .

What about TGD? Do I have reasons to get irrirated? Cosmic strings appear also in TGD but are very different objects than those of GUTs. They differ also from those of superstrings theories, where they can appear at the GUT limit or as very long fundamental strings.

Cosmic strings in GUTs and superstring theories

What mainstream cosmic strings are?

1. In GUTs cosmic strings are 1-D defects associated with singular gauge field configurations. There is a phase, which grows by a multiple of 2π as one goes around the defect line. One has essentially vortex line locally. At the singularity the modulus of field variable associated with the phase must vanish.

   Here comes in the fundamental difference between gauge fields in GUTs and in TGD where they are induced and QFT limit of TGD does not allow either GUT cosmic strings, GUT monopoles, nor instantons implying strong CP breaking plaguing QCD.

2. In superstring theories one also has these defects almost unavoidably if one believes that some kind of GUT defines the long length scale limit of superstring theories. Superstring theories also suggests that fundamental strings somehow give rise to very long fundamental cosmic strings: I cannot say anything about the details of the proposed mechanism.

The dynamics of string like objects is almost universal.

1. The first parameter is string tension μ predicted by GUTs. There are strong bounds on μ in terms of $1/G$. The upper bound $\mu G \simeq 10^{-7}$ emerges from the fact that cosmic strings have not been found yet. The string tension of TGD cosmic strings satisfies this condition: the order of magnitude for the ratio is determined by the ratio $l_P^2/R^2 = 2^{-24} \sim .6 \times 10^{-7}$, where l_P is Planck length scale and R is radius of CP_2 geodesic circle. The tension of cosmic strings involves also Kähler coupling strength.

2. Second parameter characterizes the dynamics of string networks and is reconnection probability p for strings. It would be $p \sim 10^{-1}$ for strings with topological origin (GUT strings) and $p \sim 10^{-3}$ for possibly existing long superstrings. Using these parameters one can build dynamical models and perform numerical simulations. In LIGO article several models are discussed together with their predictions.

Reconnections lead to a generation of oscillating string loops and these would generate gravitational radiation at harmonics of the frequency, which is essentially the inverse of the length of the string. In particular, the kinks and cusps (string moves with light-velocity locally) propagating along these strings would generate gravitational radiation. Concerning the evolution of the string network the ratio of l/a, where a is cosmic time identifiable as the proper-time coordinate of light-cone, is essential.

1. One expects that kinks and cusps correspond to delta function singularities in energy momentum tensor serving as sources of gravitational radiation. In cusps the determinant of 2-D induced metric vanishes and the energy momentum tensor proportional to 2-D contravariant metric diverges like $1/det(g)$. This seems to produce a singularity.

2. Energy momentum tensor serving as the source of gravitational radiation seems to be however only discontinuous at kinks. naïvely one might think that the ordinary divergence of energy momentum tensor having delta function singularity tells how much energy momentum goes out from string as gravitational radiation. My guess is that one must add to the action an additional term corresponding to the discontinuity and depending on Christoffel symbols at

the discontinuity to describe the curvature singularity. This term would serve as a source of gravitational radiation.

This term is essentially the second fundamental form for the embedding of the singularity as a 3-surfaces and its trace would define the interaction term just as the naïve picture would lead to expect. The interpretation of this term is essentially as the analog of acceleration and accelerating particle indeed creates radiation, also gravitational radiation. As a matter fact, this kind of term must be also added in 2-D case to the curvature scalar to get correctly Gauss-Bonnet law for polygons having corners.

Do TGD cosmic strings produce gravitational radiation?

The cosmic strings in TGD sense are different from those in the sense of GUTs and superstring theories. To discuss the question what TGD cosmic strings are and whether they radiate one must say something general about the dynamics of space-time surfaces in TGD.

1. There are two kinds of space-time surfaces in TGD Universe

There are two kinds of space-time surfaces in TGD Universe. These two kinds fo space-time surfaces appear at the boths sides of $M^8 - H$ duality: here one has $H = M^4 \times CP_2$. In the following I stay at the H-side of the duality.

There is a rather precise analogy with the vision about what happens in particle reactions. External particles decouple from interactions and interactions take place in interaction regions, where interactions are in some sense coupled on. This is realized for the preferred extremals of the action determining space-time surfaces in rather precise sense. The twistor lift of TGD predicts that the action is sum of Kähler action and volume term analogous to cosmological term.

1. The preferred exremals can be minimal surfaces in which case field equations are satisfied separately for Kähler action and volume term: the two interactions effectively decouple. The dynamics reduces to holomorphy conditions and coupling constants disappear completely from it. This corresponds to the universal dynamics of quantum criticality.

   The minimal 4-surfaces are direct 4-D analogs of geodesic lines, free particles. Also cosmic strings are surfaces or this kind and presumably also the magneti flux tubes. In Zero Energy Ontology (ZEO) these surfaces represent external particles entering or leaving causal diamond (CD). Free particles do not emit any kind of radiation and this would be indeed realized now.

2. Inside CDs Kähler action and volume term do not decouple and there is genuine interaction between them. One does not have minimal surfaces anymore and coupling constants appear in the dynamics. In this region the emission of radiation and also of gravitational radiation is possible.

2. Cosmic strings in TGD sense

Also TGD predicts what I call cosmic strings.

1. Ideal cosmic strings a la TGD string like objects, space-time surfaces. They are not singular densities of matter in 4-D space-time which would be small deformation of Minkowski metric. Rather, they are 4-D surfaces havng 2-D string world sheets as M^4 projection. String world sheet and string like object are minimal surfaces and should emit no radiation.

   Remark: Since M^4 projection is not 4-D GRT limit does not make sense for cosmic strings and the GRT based calculation for gravitational radiation does not apply in TGD framework.

2. Cosmic strings dominate the dynamics in very early universe. In reasonable approximation one could speak about gas of cosmic strings in M^4 - or strictly speaking in $M^4 \times CP_2$. The transition to radiation dominated era is the TGD counterpart for inflationary period: the space-time in GRT sense emerges as space-time sheets having 4-D M^4 projection. Stringlike objects topologically condense at 4-D space-time sheets. Also their M^4 projection becomes 4-D and begins to thicken during cosmic evolution so that magnetic field strength starts to weaken.

Cosmic strings can carry Kähler magnetic monopole flux explaining the mysterious long ranged magnetic fields in cosmological scales. Reconnection and formation of closed loops is possible. Many-sheetedness is an important aspect: there are flux tubes within flux tubes.

Cosmic strings/magnetic flux tubes play a key role in the formation of galaxies and larger (and even smaller) structures. Galaxies are along cosmic strings like pearls along necklace: the simplest model assumes that pearls are knots along cosmic strings (note the amusing analogy with DNA having coding regions as nucleosomes along it). Flux tubes and their reconnections play also key role in TGD inspired quantum biology.

3. Does TGD survive the findings of LIGO?

The question of the title reduces to the question whether the cosmic strings in TGD sense emit gravitational radiation.

1. If cosmic strings are idealizable as minimal surfaces and therefore as stationary states outside CDs they do not produce any kind of radiation. Radiation and gravitational radiation can emerge only in space-time regions, where there is a coupling between Kähler action and volume term. In particular, the purely internal dynamics of ideal cosmic strings cannot produce gravitational radiation.

   There is also the question about whether kinks and cusps are possible for preferred extremals satisfying extremely tight symmetry conditions realizing strong form of holography. If not, they are not expected at QFT limit either. In fact, kinks seem impossible whereas the orbits of wormhole throats represent analogs of cusps to be discussed below.

2. One can of course argue that topologically condensed thickened cosmic strings actually interact and ought to be described as something inside CD. In any case, there is a coupling between Kähler degrees of freedom and geometry of string and this means that GRT based model cannot apply.

   One can ask whether GRT based calculation for the emission of gravitational radiation makes sense for thickened cosmic strings having 4-D M^4 projection. This requires going to the GRT-QFT limit involving the approximation of the many-sheeted space-time with GRT space-time: this means replacing sheets with single sheet and identifying deviation of the metric from M^4 metric and gauge potentials with sums of the corresponding induced quantities.

   In topological condensation 4-D wormhole contacts with Euclidian signature of the induced metric are generated, and the 3-D boundaries between Euclidian and Minkowskian space-time regions defining the boundaries of wormhole contacts have light-like metric and are completely analogous to cusps of cosmic strings. These surfaces would serve as sources of radiation at GRT limit. However, in TGD framework wormhole contacts are identified as basic building bricks of elementary particles so that the emission of gravitational radiation would be due to elementary particles at space-time sheets carrying magnetic fields! If kinks are absent as preferred extremal property suggests, one can say that cosmic strings do not radiate in GRT sense in TGD.

3. The role of cosmic strings/magnetic flux tubes in the generation of gravitational radiation would be different. On basis of findings of LIGO, the observed rate for the collisions of blackholes and neutron stars is suspiciously high. How do they find each other more often than expected? This would be the case if these objects are associated with cosmic strings and propagate along them. Cosmic strings indeed have radial gravitational field giving rise to constant velocity spectrum whereas the motion along string is free motion.

   Also stars could be located along cosmic string forming a knot-like structure of long cosmic string containing galaxies as knots. Knot would define the core region of galaxy with approximately constant mass density difficult to explain in the halo model predicting a peak in the density of dark matter. Also stars could be knots but in shorter length scale. In molecular biology flux tubes connecting biomolecules to form a network would make it possible biomolecules to find each other in the molecular crowd.

12.3.8 LIGO challenges the views about formation of neutron stars and their collisions

The observation of gravitational radiation by LIGO allowing interpretation as fusion of two neutron stars has challenged the views about neutrons stars and star formation: see the popular article in Quanta Magazine (`http://tinyurl.com/tqwnrne`) about the work of Enrico Ramirez-Ruiz and colleagues [E242] (`https://arxiv.org/abs/2001.04502`). Single neutron star collision with exceptional characteristics as such is not enough for revolution. One can however ask what it could mean if this event is not a rare statistical fluctuation but business as usual.

1. The pair has too high total mass: only 10 per cent of stars are estimated to be massive enough to make so massive neutron stars. Something in the models for star formation might be badly wrong.

2. Also the models for the formation of neutron star pairs are unable to explain why the abundance of so massive pairs would be so high as LIGO would predict. There could be something wrong also in the models for the collisions of stellar objects.

TGD provides several new physics elements to the possible model.

1. Galaxies, stars, even planets are tangles in cosmic strings carrying dark energy and (also galactic) dark matter and thickened to monopole flux tubes not possible in standard gauge theories. This leads to a general model of stars and of final states of stars as flux tube tangles as spaghettis filling the volume and thus maximally dense. One obtains nice quantitative predictions plus a generalization of the notion of blackhole like entity (BHE) so that all final states of stars are BHEs: BHEs would be characterizized by the quantized thickness of the flux tube in question.

   Also a TGD based modification of the view about nuclear fusion required by a 10 year old nuclear physics anomaly and "cold fusion" is involved solving a long list of nuclear physics related anomalies (`http://tinyurl.com/tkkyyd2`).

2. Collision of stellar objects producing blackholes can occur much more often than expected. Suppose one has two long flux tube portions going very near to each other: they could be portions of the same closed flux tube or of two separate flux tubes. The situation would be this for instance in galactic nuclei of spiral galaxies (`http://tinyurl.com/sg9c4sd`).

   The colliding stellar objects correspond to flux tube tangles moving along them. Since the stellar objects are forced to move along these cosmic highways, their collisions as cosmic traffic accidents become much more frequent than for randomly moving objects in ordinary cosmology. The cosmic highways force them to come near to each other at crossings and gravitational attraction strengthens this tendency.

   Situation would be analogous in bio-chemistry: bio-catalysis would involve flux tubes connecting reactants and the reduction of effective Planck constants would reduce flux tube length and bring the reactants together and liberating the energy to overcome the potential wall making reaction extremely slow in ordinary chemistry.

   Already the high rate of collisions might allow to understand why the first collision of neutron stars observed by LIGO was that for unexpectedly high total mass.

This model does not yet answer the question why so heavy neutron stars are possible at all. Also the fusion of "too heavy" blackholes has been observed by LIGO [L24] (`http://tinyurl.com/y79yqw6q`). Thus the blackhole formation from a neutron star pair with unexpectedly high combined mass supports the expecation that "too" heavy stars are a rule rather than exception.

1. The problem is that during the formation of blackhole or neutron the radius of the star decreases and the star should throw out a lot of angular momentum to avoid too high spinning velocity in the collapse. This can be achieved by throwing out mass but this makes heavy blackholes and neutron stars impossible.

2. Can TGD provide a solution of this problem? Suppose that both galaxies and stars are tangles along long cosmic strings locally thickened to monopole flux tubes carrying dark matter and energy in TGD sense Long flux tube would provide new degrees of freedom. Could the angular momentum of collapsing star consisting of ordinary matter be transferred from the star to the cosmic string/flux tube without large loss of stellar mass.

   Suppose that one has single monopole flux tube or a pair of monopole flux tubes as analog of DNA double strand (flux tubes would combine to form a closed flux tube) forming a rotating helical structure. This structure could store the angular momentum to its rotation. Also the radiation and particles travelling around these helical flux tubes could take away part of the angular momentum but flux tubes themselves as TGD counterparts of galactic dark matter could do the main job. Heavy blackholes would be a direct signature for energy and angular mmentum transfer between ordinary matter and galactic dark matter in TGD sense.

12.4 Appendix: Some details about rotating and charged blackholes

Kerr blackhole is rotating and Kerr-Newman blackhole possess also charge so that it could describe blackhole with magnetic field generated by the rotating charge. Schwartschild-Nordström blackhole allows embedding to $H = M^4 \times CP_2$ but the dimension of $M^4 \times CP_2$ is probably too low to allow embedding of rotating blackholes and certainly the Kerr-Newman blackhole is non-imbeddable. Kerr metrics could however make sense as GRT approximation to a description of rotating and charged system in terms of many-sheeted space-time.

I received from Ulla a link to slides explaining rather clearly the basic facts about rotating blackholes (see `http://tinyurl.com/qzukqhs`): unfortunately there is a mistake in the formula for the line element of Kerr metric. Also Wikipedia article (see `http://tinyurl.com/ya9dnt6t`) gives a nice summary about Kerr-Newman metric [B16, B46]. Another further link was to an article explaining Blandford-Znajek process possibly allowing to extract energy and angular momentum from a rotating blackhole in external magnetic field (see `http://tinyurl.com/zlwgwzc`).

This motivated to collect facts about Kerr-Newman blackholes from TGD view point.

1. Kerr and Kerr-Newman blackholes are easier to represent in Boyer-Lindqist coordinate system related to spherical coordinates in very simple manner:

$$x = \rho sin(\theta)cos(\phi) \ , \quad y = \rho sin(\theta)sin(\phi) \ , \quad z = rcos(\theta) \ , \quad \rho = \sqrt{a^2+r^2} \ . \tag{12.4.1}$$

   One can say that there is a hole of radius $asin(\theta)$. Parameter $a = J/M$ defines the maximal radius of the hole.

2. Kerr-Newman metric(signature $(1, -1, -1, -1)$) is given by

$$ds^2 = -(\frac{dr^2}{\Delta} + d\theta^2)\rho^2 + (dt - asin^2\theta d\phi)^2\frac{\Delta}{\rho^2} - (r^2+a^2)d\phi - adt)^2\frac{sin^2(\theta)}{\rho^2} \ , \tag{12.4.2}$$

   where various auxiliary variables and parameters are defined as

$$\begin{array}{lll} \rho^2 = r^2 + a^2cos^2(\theta) \ , & \Delta = r^2 - r_sr + a^2 + r_Q^2 \ , & \\ r_S = 2GM \ , & a = \frac{J}{M} \ , & r_Q^2 = Q^2G \ . \end{array} \tag{12.4.3}$$

   For $Q = 0$ one obtains Kerr metric and for $(J = 0, Q = 0)$ one obtains Kerr metric and for $J = 0$ Scwartschild metric.

Kerr-Newman metric has more complex singularities than Scwartschild metric. The singularities come from $\rho^2 = 0$ and $\Delta = 0$ as is easy to see by inspecting the metric.

1. The first singularity correspond to vanishing of Δ and gives

$$r_\pm = \frac{1}{2}(r_S^2 \pm \sqrt{r_S^2 - a^2 - r_Q^2}) \ .$$

If r is replaced with ρ these spheres look like ellipsoids. The larger ellipsoid is within Schwartschild radius. The condition that $r_\pm$ is real implies

$$J^2 + GM^2Q^2 \leq G^2M^4 \ . \tag{12.4.4}$$

For $Q = 0$ this gives

$$J \leq GM^2 \ . \tag{12.4.5}$$

There is a possibly interesting connection with the notion of gravitational Planck constant. It is defined originally for flux tubes connecting systems with masses M and m as $\hbar_{gr} = GMm/v_0$, $v_0/c < 1$ but could be defined also for the flux tubes of dipole field associated with mass M as $\hbar_{gr} = GM^2/2\pi v_0$. This would give $J \leq 2\pi(v_0/c)\hbar_{gr}$. If dark dark spin is quantized as usual: $J = j\hbar_{gr}$, $j = 1, 1/2, 1, ...$ this would give $2\pi(v_0/c)$ giving $j \leq 6$ and $v_0/c \geq 1/4\pi$. One must take this with extreme caution since there is evidence that fractionization of quantum numbers takes place for large $h_{eff} = n$: in this case one cannot regard h_{gr} as unit of angular momentum.

2. Second singularity correspond to $\rho^2 = 0$ for which $r = 0$ and $\theta = \pi/2$ holds: one obtains what looks like a ring at equator. For Kerr metric this is indeed a circle with circumference $2\pi a$ as the inspection of line-element show ($g_{\phi\phi} \to a^2$).

3. For Kerr-Newman metric $g_{\phi\phi}$ changes sign and becomes infinite so that the angle coordinate becomes time like coordinate. The circumference of the circle would be infinite. One has closed time-like geodesic of infinite length and more of them with finite length in the immediate vicinity of the ring. This physically very strange and even more strange from TGD view point if one thinks of possible (even approximate) embeddings into H. This is what one obtains for the line elements given in Wikipedia anda lso in [B46]`http://tinyurl.com/y7r2gdvn`. Since the form depending on Δ appears in two references (in second article Newman himself is second author!), it seems that it must be correct.

4. The condition $g_{tt} = 0$ defines the boundaries of ergosphere as

$$r_{es,\pm} = \frac{1}{2}(r_S \pm \sqrt{r_S^2 - a^2cos^2(\theta)}) \ . \tag{12.4.6}$$

The larger ellipsoid defining the outer boundary of the ergosphere contains the horizons and and has r_S as the maximal value of radius. For Kerr metric he lower boundary corresponds to smaller ellipsoid for Kerr metric and contains the ring singularity.

Inside ergosphere only space-like geodesics are possible so that everything - also test particles - moves with superluminal velocity. One can perhaps say that this space-time region is geodesically Euclidian. Also the hypothesis that Equivalence Principle in the sense that one can describe the local physics using QFT in Minkowski space fails since massive and massless on mass-shell states do not exist: this is an important objection against the idea that blackhole horizon has no physical significance because the curvature is small. The geodesics are light-like at the surface of ergosphere. These observations support the TGD proposal that blackhole interior has actually Euclidian signature of (induced) metric in TGD framework and horizon is the light-like surface at which the signature changes and the dimension of the tangent degenerates $D = 3$. This conforms also with the strong form of holography stating these light-like surfaces can be regarded as carriers of various quantum numbers.

Even outside the ergosphere non-vanishing of $g_{t\phi}$ induces so called frame dragging: one can say that blackhole forces the surrounding space-time to rotate with it. For instance, test particle rotating in opposite direction eventually turns to rotate in the same direction as blackhole.

Could Kerr-Newman metric represent a blackhole with magnetic field as the non-vanishing charge and rotation suggests?

1. From Wikipedia article one finds the explicit expression for the gauge potential and there is indeed magnetic field represent. $J_{\theta\phi}$ approaches asymptotically to $sin(\theta)cos(\theta)$, which corresponds to quadrupole rather than monopole: on the other hand, the radial dependence is $1/r^2$ rather than $1/r^4$ so that the behaviour looks weird. Locally the flux is constant so that in TGD framework one could consider the possibility that the flux is mediated along flux tubes, which return back with the direction of flux and angular density of flux tubes depending on θ. The very strange behavior at ring singularity however suggests that this solution is not interesting even at the GRT limit of TGD.

2. Penrose process allows a transfer of energy from rotating blackhole. This is due to the very special properties of ergosphere, whose boundaries are defined by the condition $g_{tt} = 0$. Blandford-Znajek process [B44] (see `http://tinyurl.com/zlwgwzc`) allows a transfer of energy and angular momentum with the mediation of magnetic field and it has been proposed that this mechanism entangling the flux lines could serve as a mechanism of energy and angular momentum transfer quasars. In this case the magnetic field is external magnetic field rather than inherent to blackhole.

   In TGD framework the decay of cosmic strings to particles analogous to the decay of inflaton vacuum energy to particles would generate beams in the direction of string like object. This mechanism for quasar would predict that quasars can apparently disappear as the string and thus beam changes its direction and ceases to be directed to Earth. Quite recently, this kind of mysterious disappearance of quasar has been seen.

Chapter 13

TGD View about Quasars

The work of Rudolph Schild and his colleagues Darryl Letier and Stanley Robertson (among others) suggests that quasars are not supermassive blackholes but something else - MECOs, magnetic eternally collapsing objects having no horizon and possessing magnetic moment. Schild et al argue that the same applies to galactic blackhole candidates and active galactic nuclei, perhaps even to ordinary blackholes as Abhas Mitra, the developer of the notion of MECO proposes.

In the sequel TGD inspired view about quasars relying on the general model for how galaxies are generated as the energy of thickened cosmic strings decays to ordinary matter is proposed. Quasars would not be be blackhole like objects but would serve as an analog of the decay of inflaton field producing the galactic matter. The energy of the string like object would replace galactic dark matter and automatically predict a flat velocity spectrum.

TGD is assumed to have standard model and GRT as QFT limit in long length scales. Could MECOs provide this limit? It seems that the answer is negative: MECOs represent still collapsing objects. The energy of inflaton field is replaced with the sum of the magnetic energy of cosmic string and positive volume energy, which both decrease as the thickness of flux tube increases. The liberated energy transforms to ordinary particles and their dark variants in TGD sense. Time reversal of blackhole would be more appropriate interpretation. One can of course ask, whether the blackhole candidates in galactic nuclei are time reversals of quasars in TGD sense.

The writing of the article led also to a considerable understanding of two key aspects of TGD. The understanding of twistor lift and p-adic evolution of cosmological constant improved considerably. Also the understanding of gravitational Planck constant and the notion of space-time as a covering space became much more detailed in turn allowing much more refined view about the anatomy of magnetic body.

13.1 Introduction

The work of Rudolph Schild and his colleagues Darryl Letier and Stanley Robertson (among others) suggests that quasars are not supermassive blackholes but something else [E244] (see `http://tinyurl.com/y9uyzjlp`)- MECOs, magnetic eternally collapsing objects. There is a popular article about the claim (see `http://tinyurl.com/ydcurslo`). Schild *et al* argue that the same applies to galactic blackhole candidates and active galactic nuclei, perhaps even to ordinary blackholes as Abhas Mitra, the developer of the notion of MECO proposes.

13.1.1 Could quasars be MECOs rather than supermassive blackholes?

The basic claim of Schild *et al* is that quasars are not blackholes but eternally collapsing magnetic objects. This claim is based on long lasting study of quasar Q0957+561.

Methods

Before the publication of their article [E244] authors studied single quasar - Q0957+561 at distance of about billion light years for more than two decades. They also speak of Q0957+561 A,B referring to the two images of this quasar produced by gravitational lensing made possible by the fact that there happens to be a galaxy between us and Q0957+561. This lucky co-incidence has made possible to deduce detailed information about the structure and dynamics of the quasar. Besides galactic lense effect there is micro-lensing caused by the start of galaxy moving between the quasar and galaxy and leading to a variation of the measured luminosity - flickering.

The information about the quasar's structure and dynamics is deduced from the time dependence of the spectrum of the galaxy at various frequencies. Autocorrelation functions provide information about the dynamics of quasar and turn to have a period of about 10 days independent of frequencies. This period must be related to the dynamics and geometry of the quasar and the distance travelled by light in this time must define a basic scale of the quasar.

The repetitions of almost similar temporal patters - features - suggest an interpretation in terms of signal generated in quasar and then reflected as it encounters second part of quasar. Also fluorescence would generate secondary radiation. The time lapse gives direct information about the size and the shape of the structure. Combined with theoretical considerations this this gives a rather detailed view about the geometry and dynamics of the quasar. The fluctuations of the luminosity provide also information.

Findings and interpretation as MECOs

The quasars would indeed differ from blackholes. Quasars would have magnetic moment unlike ordinary blackholes but lack event horizon. Quasars would have relatively complex geometric structure and dynamics. Authors describe their findings in terms of Schild-Vakulik structure (see `http://tinyurl.com/y92m2tah`) with the following anatomy.

1. A central object analogous to blackhole in that the radius is essentially Schwartschild radius r_S (or gravitational radius R_g as authors prefer to call it). The mass of this object is estimated to be $M \sim 3.6 \times 10^9 M_{sun}$. The corresponding Schwartschild radius r_S is by scaling from that of Sun equal to $r_{S,Sun} \simeq 3$ km equal to $r_S = 1.1 \times 10^{10}$ km. Note that the mass of the proposed supermassive black hole in the core of Milky Way is about 4.1 million solar masses and 3 orders of magnitude smaller. Could this mean that that quasar center loses its mass in the process and generates in this way the galaxy so that a kind of time reversal of blackhole would be in question? Note that the mass of the visible part of Milky Way itself is of order 10^{12} solar masses.

2. An empty disk around the central object would be caused by magnetic propellor effect: the radial Lorentz force overcoming gravitational attraction would sweep charged particles from the disk. This effect is possibly inside magnetosphere, where magnetic pressure dominates over the ordinary pressure. Lorentz force would dominate over the gravitational force. An objection against this proposal (see `http://tinyurl.com/ycwd2nho`) is that the gas in this region could be filled with very hot, tenuous gas, which would not radiate much.

3. An inner luminous ring at the inner boundary of the accretion disk having radius $R \sim 74R_g$ would be the luminous object producing the radiation. Instead of r_S authors talk about gravitational radius R_g of the central object, which would be slightly larger than Schwartschild radius. The inner radius would be about $(3.9 \pm .16) \times 10^{11}$ km. The diameter d characterizing the thickness of the inner ring is estimated to be about $d = 5.4 \times 10^9$ km. Note that d is roughly one half of r_S.

   The radius of the disk defines the size of the magnetosphere of the object. Few per cent fluctuation in the luminosity with variance increasing linearly with time has been observed - the radiation from accretion disk would increase like t^2 or t^3 depending on whether it is optically thick or thin. This observation has motivated the assignment of the luminosity to the ring.

   The fluctuations must be generated by some events. The proposed interpretation is that the flow of the matter to the central object causes these events. Second possibility is that the fluctuations are associated with outwards mass flow from the central object colliding with the accretion disk.

4. In the accretion disk gravitation and pressure dominate over magnetic forces and there is a competition between pressure and gravitation. This structure is also associated also with ordinary blackholes. The mass flow could be outwards in the disk.

5. The outer ring as boundary of the accretion disk is called Elvis structure: the name derives from Martin Elvis, who has also studied the structure of quasars [E211] (see `http://tinyurl.com/yd5j9uno`). In the abstract of the article it is stated that a funnel shaped thin shell creates various structures in the inner regions of quasar. The identification of this structure would be in terms of the base of the funnel from which the matter flows out. Funnel has opening angle about 60 degrees. The outflow leads to ask whether the net flow of matter matter from the quasar is outwards rather than inwards. There are also illustrations of the 3-D structure of quasars (see `http://tinyurl.com/y755gc4a`).

   The size R_e of and the vertical location H_e of the Elvis structure above disk are estimated to be $R_e = 2 \times 10^{12}$ km and $H_e = 5 \times 10^{11}$ km. The radial width of UV-luminous Elvis structure would be $\Delta R_e = 4 \times 10^{11}$ km .

   There is also a structure emitting radio waves. Its size R_r and vertical location H_r are estimated to be $R_r = 2 \times 10^{11}$ km and $H_r = 9 \times 10^{11}$ km .

6. The strength of the magnetic field B at the gravitational radius $R_g \simeq r_S$ of the central object is estimated on basis if MECO to be $2.5 \times 10^9 \sqrt{7M_{Sun}/M} \simeq 4.4 \times 10^4$ Tesla. The dependence of the magnetic field on distance far from the dipole core is $(R_g/R)^3$. The estimate for the observed magnetic field strength extrapolated to $R = R_g$ is given in Table 2 and equals to .77 Tesla being much smaller than 4.4×10^4 Tesla. The latter field correspond to a magnetic field obtained from MECO solution for stellar object by scaling.

The authors propose that a solution of field equations of general relativity found by Abhas Mitra, called (M)ECO ((magnetic) eternally collapsing object) [E58] could provide a model for the empirical findings about the structure and dynamics of the quasars. The original proposal of Mitra is that (M)ECOs could replace blackholes.

Mitra's general argument against blackholes is that the formation of ordinary blackholes is not possible since the collapsing matter should move with superluminal velocity. There are however objections against this argument (see `http://tinyurl.com/ycwd2nho`). (M)ECOs would be free of horizons and represent eternal collapse: at Eddington limit the radiation pressure inside the object would halt the collapse. (M)ECOs can have hair, in particular magnetic moment.

13.1.2 TGD view

In the sequel TGD inspired view about quasars relying on the general model for how galaxies are generated as the energy of thickened cosmic strings decays to ordinary matter is proposed. Quasars would not be be blackhole like objects but would serve as an analog of the decay of inflaton field producing the galactic matter. The energy of the string like object would replace galactic dark matter and automatically predict a flat velocity spectrum.

TGD is assumed to have standard model and GRT as QFT limit in long length scales. Could MECOs provide this limit? It seems that the answer is negative: MECOs represent still collapsing objects. The energy of inflaton field is replaced with the sum of the magnetic energy of cosmic string and positive volume energy (essentially magnetic energy from 6-D perspective), which both decrease as the thickness of flux tube increases. The liberated energy transforms to ordinary particles and their dark variants in TGD sense. Time reversal of blackhole would be more appropriate interpretation. One can of course ask, whether the blackhole candidates in galactic nuclei are time reversals of quasars in TGD sense.

I am not specialist so that I must concentrate on just what I see the most essential aspects and considerations rely crucially on the general TGD inspired vision about formation of galaxies. Furthermore, quasar dynamics is not a mere straightforward application of TGD but has proceeded through highs and lows - almost moments of total despair! The understanding of the twistor lift of TGD, of cosmological constant, of hierarchy of Planck constants and the notion of gravitational Planck constant are far from complete, and the information coming from the quasar dynamics has provided a valuable input allowing to solve some key puzzles involved.

13.2 Background about TGD

To develop TGD view about quasars, one must first summarize general vision about the formation of galaxies in TGD Universe. The starting point is the twistor lift of TGD and cosmic strings and their deformations as basic dynamical objects. A further key notion is the hierarchy of Planck constant predicted by adelic physics [L41, L42]. The notion of gravitational Planck constant is still only partially understood and this work forced to develop a more precise view allowing to overcome various objections.

All applications make me aware of some poorly understood aspects of TGD and quasar model was not an exception. It forced to clarify some details related to twistor lift and answer what covering space property and the notion gravitational Planck constant do really mean in TGD. Also the details related to the understanding of cosmological constant emerging from twistor lift of TGD naturally have been clarified considerably.

13.2.1 General vision

Consider first the general vision about galaxy formation in TGD Universe.

1. In TGD Universe quasars would represent the analog of the decay of inflaton field to matter [L52]. Galaxies associated with long cosmic string would be like pearls in necklace [L56]. The long string like object - magnetic flux tube - would have what I have called knots or tangles along it. The gravitational force created by the long string would automatically explain the flat velocity spectrum of distant stars and galactic dark matter would correspond to the energy assignable to this long string like object: there would be no halo.

   That galaxies are assignable to long linear structures have been known for decades [E272] but for some reason this message has not been taken by the theoreticians believing in dark matter halo. The number of conflicts of the halo model with empirical facts has increased steadily and it now seems that dark matter halo is empirically excluded.

   The galactic tangle would contain stars and even planets as sub-tangles. The topology of the flux tube structure would be analogous to the field line topology of magnetic field field, in reasonable approximation a dipole field in the case of quasar. Knotting and linking would be possible.

2. The dynamics of the flux tubes structures relies on the twistor lift of TGD [K106, L43, L22] predicting that the dimensional reduction of 6-D Kähler action defining twistor structure at space-time surface as twistor structure induced from that of $H = M^4 \times CP_2$ and having the crucial Kähler structure only for this choice of H. Space-time surfaces correspond to the base-spaces of their 6-D twistor spaces as induced twistor structures with S^2 fiber. 8-D twistor structure solves one of the basic problems of ordinary twistor approach due to the condition that particles must be massless. Now particles must be massless in 8-D sense and can therefore be massive in 4-D sense.

   The dimensionally reduced action contains besides 4-D Kähler action also a volume term analogous to cosmological constant term. The interpretation of field equations is as a 4-D generalization of equations of motion for point-like particle with Kähler charge natural since particles are indeed replaced with 3-surfaces in TGD.

   Cosmic strings identifiable as 4-surfaces having string world sheets as M^4 projection and complex 2-surface Y^2 as CP_2 projection belong to the basic extremals [K9, K14]. These surfaces are unstable against thickening of 2-D M^4 projection to 4-dimensional one and one can speak of flux tubes.

   There are two kinds of flux tubes: those for with Y^2 carries homological charge having interpretation as magnetic charge so that these flux tubes carry monopole flux and those for which Y^2 has vanishing homological charge. The flux tubes of first kind are of special interest as far as formation of galaxies is considered. Whatever happens to this flux tubes, the quantized magnetic flux - homology charge - is conserved.

3. The flux tubes of the tangle like structures along the long cosmic string would increase in thickness so that by flux conservation they would liberate magnetic energy as ordinary

particles and their dark variants since magnetic energy density per length behaves like $1/S$, S cross-sectional area. On the other hand, the volume energy proportional to S increases and there is some flux tube radius at which the energy is minimum and expansion cannot continue anymore. This process would eventually give rise to the formation of the galaxy.

If cosmological constant depends on p-adic length scale like $1/L^2(k)$, one has hierarchy of limiting radii for flux tubes. Interestingly, for the cosmological constant in cosmological scales the flux tube radius deduced from the density of volume energy is about 1 mm, a biological scale, which means connection between cosmology and biology.

Remark: The volume energy is indeed positive since it is magnetic energy associated with twistor sphere S^2 for dimensionally reduced 6-D Kähler action.

13.2.2 Twistor lift of TGD

Twistor lift of TGD led to a dramatic progress in the understanding of TGD but also created problems with previous interpretation. The new element was that Kähler action as analog of Maxwell action was replaced with dimensionally reduced 6-D Kähler action decomposing to 4-D Kähler action and volume term having interpretation in terms of cosmological constant.

One can of course ask whether the resulting induced twistor structure is acceptable. Certainly it is not equivalent with the standard twistor structure. In particular, the condition $J^2 = -g$ is lost. In the case of induced Kähler form at X^4 this condition is also lost. For spinor structure the induction guarantees the existence and uniqueness of the spinor structure, and the same applies also to the induced twistor structure being together with the unique properties of twistor spaces of M^4 and CP_2 the key motivation for the notion.

There are some potential problems related to the definition of Kähler function. The most natural identification is as 6-D dimensionally reduced Kähler action.

1. WCW metric must be Euclidian - that positive definite. Since it is defined in terms of second partial derivatives of the Kähler function with respect to complex WCW coordinates and their conjugates, the preferred extremals must be completely stable to guarantee that this quadratic form is positive definite. This condition excludes extremals for which this is not the case. There are also other identifications for the preferred extremal property and stability condition would is a obvious additional condition. Note that at quantum criticality the quadratic form would have some vanishing eigenvalues representing zero modes of the WCW metric.

2. Vacuum functional of WCW is exponent of Kähler function identified as negative of Kähler action for a preferred extremal. The potential problem is that Kähler action contains both electric and magnetic parts and electric part can be negative. For the negative sign of Kähler action the action must remain bounded, otherwise vacuum functional would have arbitrarily large values. This favours the presence of magnetic fields for the preferred extremals and magnetic flux tubes are indeed the basic entities of TGD based physics.

3. One can ask whether the sign of Kähler action for preferred extremals is same as the overall sign of the diagonalized Kähler metric: this would exclude extremals dominated by Kähler electric part of action or at least force the electric part be so small that WCW metric has the same overall signature everywhere.

If one accepts the proposal that the preferred extremals are minimal surfaces (the known extremals are), extremal property is satisfied for both 4-D Kähler action and volume term separately except at finite set of singular points at which there is transfer of conserved charges between the two degrees of freedom. In this principle this would allow the identification of Kähler function as either 4-D Kähler function or 4-D volume term (actually magnetic S^2 part of 6-D Kähler action). This option looks however rather ad hoc.

13.2.3 Is the cosmological constant really understood?

The interpretation of the coefficient of the volume term as cosmological constant has been a long-standing interpretational issue and caused many moments of despair during years. The intuitive picture has been that cosmological constant obeys p-adic length scale scale evolution meaning that Λ would behave like $1/L_p^2 = 1/p \simeq 1/2^k$ [L22].

This would solve the problems due to the huge value of Λ predicted in GRT approach: the smoothed out behavior of Λ would be $\Lambda \propto 1/a^2$, a light-cone proper time defining cosmic time, and the recent value of Λ - or rather, its value in length scale corresponding to the size scale of the observed Universe - would be extremely small. In the very early Universe - in very short length scales - Λ would be large.

A simple solution of the problem would be the p-adic length scale evolution of Λ as $\Lambda \propto 1/p$, $p \simeq 2^k$. The flux tubes would thicken until the string tension as energy density would reach stable minimum. After this a phase transition reducing the cosmological constant would allow further thickening of the flux tubes. Cosmological expansion would take place as this kind of phase transitions (for a mundane application of this picture see [L55]).

This would solve the basic problem of cosmology, which is understanding why cosmological constant manages to be so small at early times. Time evolution would be replaced with length scale evolution and cosmological constant would be indeed huge in very short scales but its recent value would be extremely small.

I have however not really understood how this evolution could be realized! Twistor lift seems to allow only a very slow (logarithmic) p-adic length scale evolution of Λ [L62]. Is there any cure to this problem?

1. The magnetic energy decreases with the area S of flux tube as $1/S \propto 1/p \simeq 1/2^k$, where $\sqrt{p}$ defines the transversal length scale of the flux tube. Volume energy (magnetic energy associated with the twistor sphere) is positive and increases like S. The sum of these has minimum for certain radius of flux tube determined by the value of Λ. Flux tubes with quantized flux would have thickness determined by the length scale defined by the density of dark energy: $L \sim \rho_{vac}^{-1/4}$, $\rho_{dark} = \Lambda/8\pi G$. $\rho_{vac} \sim 10^{-47}$ GeV^4 (see http://tinyurl.com/k4bwlzu) would give $L \sim 1$ mm, which would could be interpreted as a biological length scale (maybe even neuronal length scale).

2. But can Λ be very small? In the simplest picture based on dimensionally reduced 6-D Kähler action this term is not small in comparison with the Kähler action! If the twistor spheres of M^4 and CP_2 give the same contribution to the induced Kähler form at twistor sphere of X^4, this term has maximal possible value!

   The original discussions in [K106, L22] treated the volume term and Kähler term in the dimensionally reduced action as independent terms and Λ was chosen freely. This is however not the case since the coefficients of both terms are proportional to $(1/\alpha_K^2)S(S^2)$, where $S(S^2)$ is the area of the twistor sphere of 6-D induced twistor bundle having space-time surface as base space. This are is same for the twistor spaces of M^4 and CP_2 if CP_2 size defines the only fundamental length scale. I did not even recognize this mistake.

The proposed fast p-adic length scale evolution of the cosmological constant would have extremely beautiful consequences. Could the original intuitive picture be wrong, or could the desired p-adic length scale evolution for Λ be possible after all? Could non-trivial dynamics for dimensional reduction somehow give it? To see what can happen one must look in more detail the induction of twistor structure.

1. The induction of the twistor structure by dimensional reduction involves the identification of the twistor spheres S^2 of the geometric twistor spaces $T(M^4) = M^4 \times S^2(M^4)$ and of T_{CP_2} having $S^2(CP_2)$ as fiber space. What this means that one can take the coordinates of say $S^2(M^4)$ as coordinates and embedding map maps $S^2(M^4)$ to $S^2(CP_2)$. The twistor spheres $S^2(M^4)$ and $S^2(CP_2)$ have in the minimal scenario same radius $R(CP_2)$ (radius of the geodesic sphere of CP_2. The identification map is unique apart from $SO(3)$ rotation R of either twistor sphere possibly combined with reflection P. Could one consider the possibility that R is not trivial and that the induced Kähler forms could almost cancel each other?

2. The induced Kähler form is sum of the Kähler forms induced from $S^2(M^4)$ and $S^2(CP_2)$ and since Kähler forms are same apart from a rotation in the common S^2 coordinates, one has $J_{ind} = J + RP(J)$, where R denotes a rotation and P denotes reflection. Without reflection

one cannot get arbitrary small induced Kähler form as sum of the two contributions. For mere reflection one has $J_{ind} = 0$.

Remark: It seems that one can do with reflection if the Kähler forms of the twistor spheres are of opposite sign in standard spherical coordinates. This would mean that they have have opposite orientation.

One can choose the rotation to act on (y,z)-plane as $(y,z) \rightarrow (cy + sz, -sz + cy)$, where s and c denote the cosines of the rotation angle. A small value of cosmological constant is obtained for small value of s. Reflection P can be chosen to correspond to $z \rightarrow -z$. Using coordinates $(u = cos(\Theta), \Phi)$ for $S^2(M^4)$ and (v, Ψ) for $S^2(CP_2)$ and by writing the reflection followed by rotation explicitly in coordinates (x,y,z) one finds $v = -cu - s\sqrt{1-u^2}sin(\Phi)$, $\Psi = arctan[(su/\sqrt{1-u^2}cos(\Phi) + ctan(\Phi)]$. In the lowest order in s one has $v = -u - s\sqrt{1-u^2}sin(\Phi)$, $\Psi = \Phi + scos(\Phi)(u/\sqrt{1-u^2})$.

3. Kähler form J^{ind} is sum of unrotated part $J(M^4) = du \wedge d\Phi$ and $J(CP_2) = dv \wedge d\Psi$. $J(CP_2)$ equals to the determinant $\partial(v,\Psi)/\partial(u,\Phi)$. A suitable spectrum for s could reproduce the proposal $\Lambda \propto 2^{-k}$ for Λ. The S^2 part of 6-D Kähler action equals to $(J^{ind}_{\theta\phi})^2/\sqrt{g_2}$ and in the lowest order proportional to s^2. For small values of s the integral of Kähler action for S^2 over S^2 is proportional to s^2.

   One can write the S^2 part of the dimensionally reduced action as $S(S^2) = s^2F^2(s)$. Very near to the poles the integrand has $1/[sin(\Theta) + O(s)]$ singularity and this gives rise to a logarithmic dependence of F on s and one can write: $F = F(s, log(s))$. In the lowest order one has $s \simeq 2^{-k/2}$, and in improved approximation one obtains a recursion formula $s_n(S^2,k) = 2^{-k/2}/F(s_{n-1}, \log(s_{n-1})$ giving renormalization group evolution with k replaced by anomalous dimension $k_{n,a} = k + 2log[F(s_{n-1}, log(s_{n-1})]$ differing logarithmically from k.

4. The sum $J^{ind} = J + RP(J)$ defining the induced Kähler form in $S^2(X^4)$ is covariantly constant since both terms are covariantly constant by the rotational covariance of J.

5. The embeddings of $S^2(X^4)$ as twistor sphere of space-time surface to both spheres are holomorphic since rotations are represented as holomorphic transformations. Also reflection as $z \rightarrow 1/z$ is holomorphic. This in turn implies that the second fundamental form in complex coordinates is a tensor having only components of type $(1,1)$ and $(-1,-1)$ whereas metric and energy momentum tensor have only components of type $(1,-1)$ and $(-1,1)$. Therefore all contractions appearing in field equations vanish identically and $S^2(X^4)$ is minimal surface and Kähler current in $S^2(X^4)$ vanishes since it involves components of the trace of second fundamental form. Field equations are indeed satisfied.

6. The solution of field equations becomes a family of space-time surfaces parameterized by the values of the cosmological constant Λ as function of S^2 coordinates satisfying $\Lambda/8\pi G = \rho_{vac} = J \wedge (*J)(S^2)$. In long length scales the variation range of Λ would become arbitrary small.

7. If the minimal surface equations solve separately field equations for the volume term and Kähler action everywhere apart from a discrete set of singular points, the cosmological constant affects the space-time dynamics only at these points. The physical interpretation of these points is as seats of fundamental fermions at partonic 2-surface at the ends of light-like 3-surfaces defining their orbits (induced metric changes signature at these 3-surfaces). Fermion orbits would be boundaries of fermionic string world sheets.

   One would have family of solutions of field equations but particular value of Λ would make itself visible only at the level of elementary fermions by affecting the values of coupling constants. p-Adic coupling constant evolution would be induced by the p-adic coupling constant evolution for the relative rotations R combined with reflection for the two twistor spheres. Therefore twistor lift would not be mere manner to reproduce cosmological term but determine the dynamics at the level of coupling constant evolution.

8. What is nice that also $\Lambda = 0$ option is possible. This would correspond to the variant of TGD involving only Kähler action regarded as TGD before the emergence of twistor lift. Therefore the nice results about cosmology [K94] obtained at this limit would not be lost.

13.2.4 Does p-adic coupling constant evolution reduce to that for cosmological constant?

One of the chronic problems if TGD has been the understanding of what coupling constant evolution could be defined in TGD.

Basic notions and ideas

Consider first the basic notions and ideas.

1. The notion of quantum criticality is certainly central. The continuous coupling constant evolution having no counterpart in the p-adic sectors of adele would contain as a sub-evolution discrete p-adic coupling constant evolution such that the discrete values of coupling constants allowing interpretation also in p-adic number fields are fixed points of coupling constant evolution.

   Quantum criticality is realized also in terms of zero modes, which by definition do not contribute to WCW metric. Zero modes are like control parameters of a potential function in catastrophe theory. Potential function is extremum with respect to behavior variables replaced now by WCW degrees of freedom. The graph for preferred extremals as surface in the space of zero modes is like the surface describing the catastrophe. For given zero modes there are several preferred extremals and the catastrophe corresponds to the regions of zero mode space, where some branches of co-incide. The degeneration of roots of polynomials is a concrete realization for this.

   Quantum criticality would also mean that coupling parameters effectively disappear from field equations. For minimal surfaces (generalization of massless field equation allowing conformal invariance characterizing criticality) this happens since they are separately extremals of Kähler action and of volume term.

   Quantum criticality is accompanied by conformal invariance in the case of 2-D systems and in TGD this symmetry extends to its 4-D analogas isometries of WCW.

2. In the case of 4-D Kähler action the natural hypothesis was that coupling constant evolution should reduce to that of Kähler coupling strength $1/\alpha_K$ inducing the evolution of other coupling parameters. Also in the case of the twistor lift $1/\alpha_K$ could have similar role. One can however ask whether the value of the 6-D Kähler action for the twistor sphere $S^2(X^4)$ defining cosmological constant could define additional parameter replacing cutoff length scale as the evolution parameter of renormalization group.

3. The hierarchy of adeles should define a hierarchy of values of coupling strengths so that the discrete coupling constant evolution could reduce to the hierarchy of extensions of rationals and be expressible in terms of parameters characterizing them.

4. I have also considered number theoretical existence conditions as a possible manner to fix the values of coupling parameters. The condition that the exponent of Kähler function should exist also for the p-adic sectors of the adele is what comes in mind as a constraint but it seems that this condition is quite too strong.

   If the functional integral is given by perturbations around single maximum of Kähler function, the exponent vanishes from the expression for the scattering amplitudes due to the presence of normalization factor. There indeed should exist only single maximum by the Euclidian signature of the WCW Kähler metric for given values of zero modes (several extrema would mean extrema with non-trivial signature) and the parameters fixing the topology of 3-surfaces at the ends of preferred extremal inside CD. This formulation as counterpart also in terms of the analog of micro-canonical ensemble (allowing only states with the same energy) allowing only discrete sum over extremals with the same Kähler action [L61].

5. I have also considered more or less ad hoc guesses for the evolution of Kähler coupling strength such as reduction of the discrete values of $1/\alpha_K$ to the spectrum of zeros of Riemann zeta or actually of its fermionic counterpart [L12]. These proposals are however highly ad hoc.

Could the area of twistor sphere replace cutoff length?

As I started once again to consider coupling constant evolution I realized that the basic problem has been the lack of explicit formula defining what coupling constant evolution really is.

1. In quantum field theories (QFTs) the presence of infinities forces the introduction of momentum cutoff. The hypothesis that scattering amplitudes do not depend on momentum cutoff forces the evolution of coupling constants. TGD is not plagued by the divergence problems of QFTs. This is fine but implies that there has been no obvious manner to define what coupling constant evolution as a continuous process making sense in the real sector of adelic physics could mean!

2. Cosmological constant is usually experienced as a terrible head ache but it could provide the helping hand now. Could the cutoff length scale be replaced with the value of the length scale defined by the cosmological constant defined by the S^2 part of 6-D Kähler action? This parameter would depend on the details of the induced twistor structure. It was shown above that if the moduli space for induced twistor structures corresponds to rotations of S^2 possibly combined with the reflection, the parameter for coupling constant restricted to that to $SO(2)$ subgroup of $SO(3)$ could be taken to be taken $s = sin(\epsilon)$.

3. RG invariance would state that the 6-D Kähler action is stationary with respect to variations with respect to s. The variation with respect to s would involve several contributions. Besides the variation of $1/\alpha_K(s)$ and the variation of the $S(^2)$ part of 6-D Kähler action defining the cosmological constant, there would be variation coming from the variations of 4-D Kähler action plus 4-D volume term . This variation vanishes by field equations. As matter of fact, the variations of 4-D Kähler action and volume term vanish separately except at discrete set of singular points at which there is energy transfer between these terms. This condition is one manner to state quantum criticality stating that field equations involved no coupling parameters.

   One obtains explicit RG equation for α_K and Λ having the standard form involving logarithmic derivatives. The form of the equation would be

$$\frac{dlog(\alpha_K)}{ds} = -\frac{S(S^2)}{S_K(X^4) + S(S^2)} \frac{dlog(S(S^2))}{ds} \quad . \tag{13.2.1}$$

   It should be noticed that the choices of the parameter s in the evolution equation is arbitrary so that the identification $s = sin(\epsilon)$ is not necessary.

   The equation contains the ratio $S(S^2)/(S_K(X^4) + S(S^2))$ of actions as a parameter. This does not conform with idea of micro-locality. One can however argue that this conforms with the generalization of point like particle to 3-D surface. For preferred extremal the action is indeed determined by the 3 surfaces at its ends at the boundaries of CD. This implies that the construction of quantum theory requires the solution of classical theory.

   In particular, the 4-D classical theory is necessary for the construction of scattering amplitudes, and one cannot reduce TGD to string theory although strong form of holography states that the data about quantum states can be assigned with 2-D surfaces. Even more: $M^8 - H$ correspondence implies that the data determining quantum states can be assigned with discrete set of points defining cognitive representations for given adel This set of points depends on the preferred extremal!

4. How to identify quantum critical values of α_K? At these points one should have $dlog(\alpha_K)/ds = 0$. This implies $dlog(S(S^2)/ds = 0$, which in turn implies $dlog(\alpha_K)/ds = 0$ unless one has $S_K(X^4) + S(S^2) = 0$. This condition would make exponent of 6-D Kähler action trivial and the continuation to the p-adic sectors of adele would be trivial. I have considered also this possibility [L62].

   The critical values of coupling constant evolution would correspond to the critical values of S and therefore of cosmological constant. The basic nuisance of theoretical physics would determine the coupling constant evolution completely! Critical values are in principle possible. Both the numerator $J^2_{u\Phi}$ and the numerator $1/\sqrt{det(g)}$ increase with ϵ. If the rate for the variation of these quantities with s vary it is possible to have a situation in which the one has

$$\frac{dlog(J^2_{u\Phi})}{ds} = -\frac{dlog(\sqrt{det(g)})}{ds} \quad . \tag{13.2.2}$$

5. One can make highly non-trivial conclusions about the evolution at general level. For the extremals with vanishing action and for which α_K is critical (vanishing derivate), also the second derivative of $d^2S(S^2)/ds^2 =$ holds true at the critical point. The QFT analogs of these points are points at which beta function develops higher order zero. The tip of cusp catastrophe is second analogy.

   The points at which that the action has minimum are also interesting. For magnetic flux tubes for which one has $S_K(X^4) \propto 1/S$ and $S_{vol} \propto S$ in good approximation, one has $S_K(X^4) = S_{vol}$ at minimum (say for the flux tubes with radius about 1 mm for the cosmological constant in cosmological scales). One can write

$$\frac{dlog(\alpha_K)}{ds} = -\frac{1}{2}\frac{dlog(S(S^2))}{ds} \quad , \tag{13.2.3}$$

   and solve the equation explicitly:

$$\frac{\alpha_{K,0}}{\alpha_K} = \frac{S(S^2)}{S(S^2)_0})^x \quad , \quad x = 1/2 \quad . \tag{13.2.4}$$

   A more general situation would correspond to a model with $x \neq 1/2$: the deviation from $x = 1/2$ could be interpreted as anomalous dimension. This allows to deduce numerically a formula for the value spectrum of $\alpha_{K,0}/\alpha_K$ apart from the initial values.

6. One should demonstrate that the critical values of s are such that the continuation to p-adic sectors of the adele makes sense. For preferred extremals cosmological constant appears as a parameter in field equations but does not affect the field equations expect at the singular points. Singular points play the same role as the poles of analytic function or point charges in electrodynamics inducing long range correlations. Therefore the extremals depend on parameter s and the dependence should be such that the continuation to the p-adic sectors is possible.

   A naïve guess is that the values of s are rational numbers. Above the proposal $s = 2^{-k/2}$ motivated by p-adic length scale hypothesis was considered but also $s = p^{-k/2}$ can be considered. These guesses might be however wrong, the most important point is that there is that one can indeed calculate $\alpha_K(s)$ and identify its critical values.

7. What about scattering amplitudes and evolution of various coupling parameters? If the exponent of action disappears from scattering amplitudes, the continuation of scattering amplitudes is simple. This seems to be the only reasonable option. In the adelic approach [L41] amplitudes are determined by data at a discrete set of points of space-time surface (defining what I call cognitive representation) for which the points have M^8 coordinates belong to the extension of rationals defining the adele.

   Each point of $S^2(X^4)$ corresponds to a slightly different X^4 so that the singular points depend on the parameter s, which induces dependence of scattering amplitudes on s. Since coupling constants are identified in terms of scattering amplitudes, this induces coupling constant evolution having discrete coupling constant evolution as sub-evolution.

Could the critical values of α_K correspond to the zeros of Riemann Zeta?

Number theoretical intuitions strongly suggests that the critical values of $1/\alpha_K$ could somehow correspond to zeros of Riemann Zeta. Riemann zeta is indeed known to be involved with critical systems.

The naïvest ad hoc hypothesis is that the values of $1/\alpha_K$ are actually proportional to the non-trivial zeros $s = 1/2 + iy$ of zeta [L12]. A hypothesis more in line with QFT thinking is that they correspond to the imaginary parts of the roots of zeta. In TGD framework however complex values of α_K are possible and highly suggestive. In any case, one can test the hypothesis that the values of $1/\alpha_K$ are proportional to the zeros of ζ at critical line. Problems indeed emerge.

1. The complexity of the zeros and the non-constancy of their phase implies that the RG equation can hold only for the imaginary part of $s = 1/2 + it$ and therefore only for the imaginary part of the action. This suggests that $1/\alpha_K$ is proportional to y. If $1/\alpha_K$ is complex, RG equation implies that its phase RG invariant since the real and imaginary parts would obey the same RG equation.

2. The second - and much deeper - problem is that one has no reason for why $dlog(\alpha_K)/ds$ should vanish at zeros: one should have $dy/ds = 0$ at zeros but since one can choose instead of parameter s any coordinate as evolution parameter, one can choose $s = y$ so that one has $dy/ds = 1$ and criticality condition cannot hold true. Hence it seems that this proposal is unrealistic although it worked qualitatively at numerical level.

It seems that it is better to proceed in a playful spirit by asking whether one could realize quantum criticality in terms of of the property of being zero of zeta.

1. The very fact that zero of zeta is in question should somehow guarantee quantum criticality. Zeros of ζ define the critical points of the complex analytic function defined by the integral

$$X(s_0, s) = \int_{C_{s_0\rightarrow s}} \zeta(s)ds \ , \tag{13.2.5}$$

where $C_{s_0\rightarrow s}$ is any curve connecting zeros of ζ, a is complex valued constant. Here s does not refer to $s = sin(\epsilon)$ introduced above but to complex coordinate s of Riemann sphere.

By analyticity the integral does not depend on the curve C connecting the initial and final points and the derivative $dS_c/ds = \zeta(s)$ vanishes at the endpoints if they correspond to zeros of ζ so that would have criticality. The value of the integral for a closed contour containing the pole $s = 1$ of ζ is non-vanishing so that the integral has two values depending on which side of the pole C goes.

2. The first guess is that one can define S_c as complex analytic function $F(X)$ having interpretation as analytic continuation of the S^2 part of action identified as $Re(S_c)$:

$$\begin{aligned} S_c(S^2) &= F(X(s, s_0)) \ , & X(s, s_0) &= \textstyle\int_{C_{s_0\rightarrow s}} \zeta(s)ds \ , \\ S(S^2) &= Re(S_c) = Re(F(X)) \ , & & \\ \zeta(s) &= 0 \ , & Re(s_0) &= 1/2 \ . \end{aligned} \tag{13.2.6}$$

$S_c(S^2) = F(X)$ would be a complexified version of the Kähler action for S^2. s_0 must be at critical line but it is not quite clear whether one should require $\zeta(s_0) = 0$.

The real valued function $S(S^2)$ would be thus extended to an analytic function $S_c = F(X)$ such that the $S(S^2) = Re(S_c)$ would depend only on the end points of the integration path $C_{s_0\rightarrow s}$. This is geometrically natural. Different integration paths at Riemann sphere would correspond to paths in the moduli space $SO(3)$, whose action defines paths in S^2 and are indeed allowed as most general deformations. Therefore the twistor sphere could be identified Riemann sphere at which Riemann zeta is defined. The critical line and real axis would correspond to particular one parameter sub-groups of $SO(3)$ or to more general one parameter subgroups.

One would have

$$\frac{\alpha_{K,0}}{\alpha_K} = (\frac{S_c}{S_0})^{1/2} \quad . \tag{13.2.7}$$

The imaginary part of $1/\alpha_K$ (and in some sense also of the action $S_c(S^2)$) would determined by analyticity somewhat like the real parts of the scattering amplitudes are determined by the discontinuities of their imaginary parts.

3. What constraints can one pose on F? F must be such that the value range for $F(X)$ is in the value range of $S(S^2)$. The lower limit for $S(S^2)$ is $S(S^2) = 0$ corresponding to $J_{u\Phi} \to 0$.

   The upper limit corresponds to the maximum of $S(S^2)$. If the one Kähler forms of M^4 and S^2 have same sign, the maximum is $2 \times A$, where $A = 4\pi$ is the area of unit sphere. This is however not the physical case.

   If the Kähler forms of M^4 and S^2 have opposite signs or if one has RP option, the maximum, call it S_{max}, is smaller. Symmetry considerations strongly suggest that the upper limit corresponds to a rotation of 2π in say (y,z) plane ($s = sin(\epsilon) = 1$ using the previous notation).

   For $s \to s_0$ the value of S_c approaches zero: this limit must correspond to $S(S^2) = 0$ and $J_{u\Phi} \to 0$. For $Im(s) \to \pm\infty$ along the critical line, the behavior of $Re(\zeta)$ (see http://tinyurl.com/y7b88gvg) strongly suggests that $|X| \to \infty$. This requires that F is an analytic function, which approaches to a finite value at the limit $|X| \to \infty$. Perhaps the simplest elementary function satisfying the saturation constraints is

$$F(X) = S_{max} tanh(-iX) \quad . \tag{13.2.8}$$

   One has $tanh(x+iy) \to \pm 1$ for $y \to \pm\infty$ implying $F(X) \to \pm S_{max}$ at these limits. More explicitly , one has $tanh(-i/2-y) = [-1+exp(-4y)-2exp(-2y)(cos(1)-1)]/[1+exp(-4y)-2exp(-2y)(cos(1)-1)]$. Since one has $tanh(-i/2+0) = 1-1/cos(1) < 0$ and $tanh(-i/2+\infty) = 1$, one must have some finite value $y = y_0 > 0$ for which one has

$$tanh(-\frac{i}{2} + y_0) = 0 \quad . \tag{13.2.9}$$

   The smallest possible lower bound s_0 for the integral defining X would naturally to $s_0 = 1/2 - iy_0$ and would be below the real axis.

4. The interpretation of $S(S^2)$ as a positive definite action requires that the sign of $S(S^2) = Re(F)$ for a given choice of $s_0 = 1/2 + iy_0$ and for a propertly sign of $y - y_0$ at critical line should remain positive. One should show that the sign of $S = a\int Re(\zeta)(s = 1/2+it)dt$ is same for all zeros of ζ. The graph representing the real and imaginary parts of Riemann zeta along critical line $s = 1/2 + it$ (see http://tinyurl.com/y7b88gvg) shows that both the real and imaginary part oscillate and increase in amplitude. For the first zeros real part stays in good approximation positive but the amplitude for the negative part increase be gradually. This suggests that S identified as integral of real part oscillates but preserves its sign and gradually increases as required.

   A priori there is no reason to exclude the trivial zeros of ζ at $s = -2n$, $n = 1, 2, ...$

1. The natural guess is that the function $F(X)$ is same as for the critical line. The integral defining X would be along real axis and therefore real as also $1/\alpha_K$ provided the sign of S_c is positive: for negative sign for S_c not allowed by the geometric interpretation the square root would give imaginary unit. The graph of the Riemann Zeta at real axis (real) is given in MathWorld Wolfram (see http://tinyurl.com/55qjmj).

2. The functional equation

$$\zeta(1-s) = \zeta(s)\frac{\Gamma(s/2)}{\Gamma((1-s)/2)} \tag{13.2.10}$$

allows to deduce information about the behavior of ζ at negative real axis. $\Gamma((1-s)/2)$ is negative along negative real axis (for $Re(s) \leq 1$ actually) and poles at $n+1/2$. Its negative maxima approach to zero for large negative values of $Re(s)$ (see http://tinyurl.com/clxv4pz) whereas $\zeta(s)$ approaches value one for large positive values of s (see http://tinyurl.com/y7b88gvg). A cautious guess is that the sign of $\zeta(s)$ for $s \leq 1$ remains negative. If the integral defining the area is defined as integral contour directed from $s<0$ to a point s_0 near origin, S_c has positive sign and has a geometric interpretation.

3. The formula for $1/\alpha_K$ would read as $\alpha_{K,0}/\alpha_K(s=-2n) = (S_c/S_0)^{1/2}$ so that α_K would remain real. This integration path could be interpreted as a rotation around z-axis leaving invariant the Kähler form J of $S^2(X^4)$ and therefore also $S = Re(S_c)$. $Im(S_c) = 0$ indeed holds true. For the non-trivial zeros this is not the case and $S = Re(S_c)$ is not invariant.

4. One can wonder whether one could distinguish between Minkowskian and Euclidian and regions in the sense that in Minkowskian regions $1/\alpha_K$ correspond to the non-trivial zeros and in Euclidian regions to trivial zeros along negative real axis. The interpretation as different kind of phases might be appropriate.

What is nice that the hypothesis about equivalence of the geometry based and number theoretic approaches can be killed by just calculating the integral S as function of parameter s. The identification of the parameter s appearing in the RG equations is no unique. The identification of the Riemann sphere and twistor sphere could even allow identify the parameter t as imaginary coordinate in complex coordinates in $SO(3)$ rotations around z-axis act as phase multiplication and in which metric has the standard form.

Some guesses to be shown to be wrong

The following argument suggests a connection between p-adic length scale hypothesis and evolution of cosmological constant but must be taken as an ad hoc guess: the above formula is enough to predict the evolution.

1. p-Adicization is possible only under very special conditions [L41], and suggests that anomalous dimension involving logarithms should vanish for $s = 2^{-k/2}$ corresponding to preferred p-adic length scales associated with $p \simeq 2^k$. Quantum criticality in turn requires that discrete p-adic coupling constant evolution allows the values of coupling parameters, which are fixed points of RG group so that radiative corrections should vanish for them. Also anomalous dimensions Δk should vanish.

2. Could one have $\Delta k_{n,a} = 0$ for $s = 2^{-k/2}$, perhaps for even values $k = 2k_1$? If so, the ratio c/s would satisfy $c/s = 2^{k_1} - 1$ at these points and Mersenne primes as values of c/s would be obtained as a special case. Could the preferred p-adic primes correspond to a prime near to but not larger than $c/s = 2^{k_1} - 1$ as p-adic length scale hypothesis states? This suggest that we are on correct track but the hypothesis could be too strong.

3. The condition $\Delta d = 0$ should correspond to the vanishing of dS/ds. Geometrically this would mean that $S(s)$ curve is above (below) $S(s) = xs^2$ and touches it at points $s = x2^{-k}$, which would be minima (maxima). Intermediate extrema above or below $S = xs^2$ would be maxima (minima).

13.2.5 What does one really mean with gravitational Planck constant?

There are important questions related to the QFT-GRT limit of TGD.

What does one mean with space-time as covering space?

The central idea is that space-time corresponds to n-fold covering for $h_{eff} = n \times h_0$. It is not however quite clear what this statement does mean.

1. How the many-sheeted space-time corresponds to the space-time of QFT and GRT? QFT-GRT limit of TGD is defined by identifying the gauge potentials as sums of induced gauge potentials over the space-time sheets. Magnetic field is sum over its values for different space-time sheets. For single sheet the field would be extremely small in the present case as will be found.

2. A central notion associated with the hierarchy of effective Planck constants $h_{eff}/h_0 = n$ giving as a special case $\hbar_{gr} = GMm/v_0$ assigned to the flux tubes mediating gravitational interactions. The most general view is that the space-time itself can be regarded as n-sheeted covering space. A more restricted view is that space-time surface can be regarded as n-sheeted covering of M^4. But why not n-sheeted covering of CP_2? And why not having $n = n_1 \times n_2$ such that one has n_1-sheeted covering of CP_2 and n_2-sheeted covering of M^4 as I indeed proposed for more than decade ago [K81] but gave up this notion later and consider only coverings of M^4? There is indeed nothing preventing the more general coverings.

3. $n = n_1 \times n_2$ covering can be illustrated for an electric engineer by considering a coil in very thin 3 dimensional slab having thickness L. The small vertical direction would serve and as analog of CP_2. The remaining 2 large dimensions would serve as analog for M^4. One could try to construct a coil with n loops in the vertical direction direction but for very large n one would encounter problems since loops would overlap because the thickness of the wire would be larger than available room L/n. There would be some maximum value of n, call it n_{max}.

   One could overcome this limit by using the decomposition $n = n_1 \times n_2$ existing if n is prime. In this case one could decompose the coil into n_1 parallel coils in plane having $n_2 \geq n_{max}$ loops in the vertical direction. This provided n_2 is small enough to avoid problems due to finite thickness of the coil. For n prime this does not work but one can of also select n_2 to be maximal and allow the last coil to have less than n_2 loops.

   An interesting possibility is that preferred extremal property implies the decomposition $n_{gr} = n_1 \times n_2$ with nearly maximal value of n_2, which can vary in some limits. Of course, one of the n_2-coverings of M^4 could be in-complete in the case that n_{gr} is prime or not divisible by nearly maximal value of n_2. We do not live in ideal Universe, and one can even imagine that the copies of M^4 covering are not exact copies but that n_2 can vary.

4. In the case of $M^4 \times CP_2$ space-time sheet would replace single loop of the coil, and the procedure would be very similar. A highly interesting question is whether preferred extremal property favours the option in which one has as analog of n_1 coils n_1 full copies of n_2-fold coverings of M^4 at different positions in M^4 and thus defining an n_1 covering of CP_2 in M^4 direction. These positions of copies need not be close to each other but one could still have quantum coherence and this would be essential in TGD inspired quantum biology [L53].

   Number theoretic vision [L41, L42] suggests that the sheets could be related by discrete isometries of CP_2 possibly representing the action of Galois group of the extension of rationals defining the adele and since the group is finite sub-group of CP_2, the number of sheets would be finite.

   The finite sub-groups of $SU(3)$ are analogous to the finite sub-groups of $SU(2)$ and if they action is genuinely 3-D they correspond to the symmetries of Platonic solids (tetrahedron,cube,octahedron, icosahedron, dodecahedron). Otherwise one obtains symmetries of polygons and the order of group can be arbitrary large. Similar phenomenon is expected now. In fact the values of n_2 could be quantized in terms of dimensions of discrete coset spaces associated with discrete sub-groups of $SU(3)$. This would give rise to a large variation of n_2

and could perhaps explain the large variation of G identified as $G = R^2(CP_2)/n_2$ suggested by the fountain effect of superfluidity [L59].

5. There are indeed two kinds of values of n: the small values $n = h_{em}/h_0 = n_{em}$ assigned with flux tubes mediating em interaction and appearing already in condensed matter physics [L38, L54, L23] and large values $n = h_{gr}/h_0 = n_{gr}$ associated with gravitational flux tubes. The small values of n would be naturally associated with coverings of CP_2. The large values $n_{gr} = n_1 \times n_2$ would correspond n_1-fold coverings of CP_2 consisting of complete n_2-fold coverings of M^4. Note that in this picture one can formally define constants $\hbar(M^4) = n_1\hbar_0$ and $\hbar(CP_2) = n_2\hbar_0$ as proposed in [K81] for more than decade ago.

Planck length as CP_2 radius and identification of gravitational constant G

There is also a puzzle related to the identification of gravitational Planck constant. In TGD framework the only theoretically reasonable identification of Planck length is as CP_2 length $R(CP_2)$, which is roughly $10^{3.5}$ times longer than Planck length [L59]. Otherwise one must introduce the usual Planck length as separate fundamental length. The proposal was that gravitational constant would be defined as $G = R^2(CP_2)/\hbar_{gr}$, $\hbar_{gr} \simeq 10^7\hbar$. The G indeed varies in un-expectedly wide limits and the fountain effect of superfluidity suggests that the variation can be surprisingly large.

There are however problems.

1. Arbitrary small values of $G = R^2(CP_2)/\hbar_{gr}$ are possible for the values of $\hbar_{gr}$ appearing in the applications: the values of order $n_{gr} \sim 10^{13}$ are encountered in the biological applications. The value range of G is however experimentally rather limited. Something clearly goes wrong with the proposed formula.

2. Schwartschild radius $r_S = 2GM = 2R^2(CP_2)M/\hbar_{gr}$ would decrease with $\hbar_{gr}$. One would expect just the opposite since fundamental quantal length scales should scale like $\hbar_{gr}$.

3. What about Nottale formula [E87] $\hbar_{gr} = GMm/v_0$? Should one require self-consistency and substitute $G = R^2(CP_2)/\hbar_{gr}$ to it to obtain $\hbar_{gr} = \sqrt{R^2(CP_2)Mm/v_0}$. This formula leads to physically un-acceptable predictions, and I have used in all applications $G = G_N$ corresponding to $n_{gr} \sim 10^7$ as the ratio of squares of CP_2 length and ordinary Planck length.

Could one interpret the almost constancy of G by assuming that it corresponds to $\hbar(CP_2) = n_2\hbar_0$, $n_2 \simeq 10^7$ and nearly maximal except possibly in some special situations? For $n_{gr} = n_1 \times n_2$ the covering corresponding to $\hbar_{gr}$ would be n_1-fold covering of CP_2 formed from n_1 n_2-fold coverings of M^4. For l $n_{gr} = n_1 \times n_2$ the covering would decompose to n_1 disjoint M^4 coverings and this would also guarantee that the definition of r_S remains the standard one since only the number of M^4 coverings increases.

If n_2 corresponds to the order of finite subgroup G of $SU(3)$ or number of elements in a coset space G/H of G (itself sub-group for normal sub-group H), one would have very limited number of values of n_2, and it might be possible to understand the fountain effect of superfluidity [L59] from the symmetries of CP_2, which would take a role similar to the symmetries associated with Platonic solids. In fact, the smaller value of G in fountain effect would suggest that n_2 in this case is larger than for G_N so that n_2 for G_N would not be maximal.

13.3 TGD view about quasars

TGD based model for quasar does not identify it as a blackhole like entity digesting matter around it but identified it as source of matter and energy resulting in the decay of the magnetic field of the flux time representing thickened cosmic string liberating also gravitational energy since the volume energy is indeed negative for a positive sign of volume action.

13.3.1 Overall view about the model

Consider now the basic picture about quasars and galaxies provided by TGD.

1. The authors still believe in restricted blackhole paradigm and assume that this structure "digests" matter from surroundings. The unit would have mass $10^{-3}M_{Sun}$ or $10^{-5}M_{Sun}$ - depending on estimate. Here TGD based view differs: the quasar need not digest matter around it but to feed it to the surroundings!

   The cleaning of charged matter from the inner disk would achieved if the total current vanishes so that the rotation velocities are opposite for charges with opposite sign and the directions of the Lorentz force are same, outwards or inwards both. The horizonal ring like structure would be a closed magnetic flux tube along which charged particles would rotate in the field created by the flux tubes of dipole field.

   The matter would flow into the central object if the Lorentz force is opposite: this is the case if the rotation velocities are opposite. Time reversal of this object analogous to blackhole would be in question and quasar could perhaps be seen as time reversed blackhole like entity analogous to time reversal of MECO. Note that in TGD time reversal symmetry T (and CP) are slightly broken. TGD predicts time reversals of the conscious entities assignable to cosmologies (and sub-cosmologies in Russian doll cosmology of TGD) and for them things would happen in opposite time direction fin the standard time frame [L52]: this cosmology is in some aspects analogous to the cosmology proposed by Penrose.

2. TGD based model leads to the proposal that the cylindrical magnetic dipole in the central region could (but certainly need not) be many-sheeted structure - n_1-sheeted covering of CP_2 consisting of disjoint flux tubes and n_2-sheeted covering of M^4 Minkowski space with $n_2 \simeq 10^7$ assigned with the Newtonian value G_N of G identified as $G_N = R^2(CP_2)/n_2\hbar$. This entity would be completely analogous to what I call magnetic body distinguishing between Maxwell's theory TGD (in many-sheeted space-time any system has field identity - field body - in the sense that its fields are associated with different space-time sheets than those of other systems).

   Magnetic body would serve as intentional agent in living systems and would be characterized by a large value of gravitational Planck constant (the notion is originally due to Nottale [E87]) $\hbar_{gr} = GMm(CP_2)/v_0 = (n_{gr}/6) \times \hbar$, $\hbar = 6 \times \hbar_0$. n_{gr} characterizes in adelic TGD [L42, L40] the algebraic complexity as dimension of extension of rationals.

   In the case of quasar M would be the mass of the central blackhole like object - about 3.6×10^9 solar masses as also the candidate for the galactic blackhole in Milky Way. $m(CP_2)$ is CP_2 mass about $10^{-3.5}$ Planck masses and would take the role of Planck mass. G would be identified as $G = R^2(CP_2)/\hbar_2$ rather than $R^2(CP_2)/\hbar_{gr}$ as in [L59], where it was assumed that $n_1 = 1$ so that one indeed had $n_{gr} = n_2$. n_{gr} would have a spectrum realized as a discrete scaling invariance in M^4 such that scaling acts also in G. It remains to be shown that the modification of the formula $G = R^2(CP_2)/\hbar_{gr}$ to $G = R^2(CP_2)/\hbar_2$ preserves the argued scaling invariance in M^4. The interpretation $v_0 < c$ is discussed in [L50].

   It was already discussed how one can understand the approximate constancy of G in this framework. In the simplest situation the coverings involved is $n_{gr} = n_1 \times n_2$ covering such that there is n_1-fold covering of CP_2 correspond to disjoint flux tubes in M^4 and n_2-fold M^4 covering associated with each flux tube. $n_2 \simeq 10^7$ would predict that gravitational constant $G = R^2/\hbar$ is near to its Newtonian value G_N.

3. The algebraic complexity of the galactic magnetic body identified as the cylindrical dipole part of the dipole field represented as flux tubes would be huge. The return flux outside the dipole would consist of simpler structures having smaller number of sheets and fusing to the dipole structure at the galactic nucleus. The flux tubes could wander to rather large distances and the stars would correspond to looped sub-tangles with flux tube structure mimicking the topology of field lines of dipole field.

   n_{gr} plays the role of IQ in TGD based model of living matter as governed by magnetic body. This forces to consider the possibility that quasars and galaxies are living organisms - much above us in hierarchy - having stars, planets,.... , us,... as sub-systems, sub-selves representing their mental images. One can say that the galactic dipole would represent the brain of galaxy. It is needless to say that this would completely revolutionize our world view.

We would not be desperate cosmic loners anymore but children of the Universe living and conscious in all scales.

Is there any empirical support for this speculative picture? There is evidence that galactic day as opposed to solar is period for precognitive events studied by people taking seriously "paranormal" phenomena which they prefer to call remote mental interactions [K17]. The reason would be that galactic magnetic field and therefore galactic magnetic body with strength of order nanoTesla is involved.

13.3.2 Estimate for the strength of the poloidal component B_θ of the magnetic field just below r_S

The estimate for the strength of the poloidal component of the magnetic field deduced from MECO solution just below $R_g \simeq r_S$ is $2.5 \times 10^9 \sqrt{7M_{Sun}/M} \simeq 4.4 \times 10^4$ Tesla. Could one say something about this field in TGD framework.

1. Flux quantization in the dipole core where the return flux of looping long cosmic string enters repeatedly to the dipole region and has the same direction would be integer multiple of unit flux assignable in the simplest case also to the long cosmic string: also this flux is quantized as integer multiples of a basic flux and predicts that the velocity is quantized as $\sqrt{n}$ if the contribution of volume term to the string tension is negligible. This is indeed expected due the smallness of Λ. Note that the long cosmic string makes the looping and after than continues.

   As already described one would have naturally $n_2 \sim 10^7$-fold covering of M^4 for the Newtonian value of G. Therefore one would have n_{gr}/n_2 disjoint flux tubes forming quantum coherent unit, the magnetic body of the quasar.

2. The Nottale proposal for the gravitational Plack constant $\hbar_{gr} = \hbar_{eff} = n_{gr}\hbar_0$, $\hbar = 6h_0$ suggest that the dipole has unit flux but with unit $\hbar_{gr} = GMm(CP_2)/v_0$, $m_{CP_2} = \hbar/R(CP_2)$. In the most original form of the hypothesis the second mass m was any mass but one can argue that since h_{gr} cannot be smaller than h, one must assume that m must have $m(CP_2)$ as lower bound. This leads also to other problems if m is too small. The interpretation in terms of quantum coherent structures with mass coming as multiple of $m(CP_2)$ is discussed in [L53].

3. This allows to estimate the value of the magnetic field from $eBS = n_{gr}\hbar_0 = n_{gr}\hbar/6$. Substituting the estimate $R_{CP_2} = 10^{3.5}l_P \simeq 5.1 \times 10^{-32}$ m, $r_S = 10^{10}$ km. Assume first that one has $n_2 = 1$ - no covering over M^4 so that one has disjoint flux tubes. A monopole flux through a closed surface is in question and there is no boundary and the area should be replaced with area of a topological sphere, which is the CP_2 geodesic sphere deformed in M^4 direction and having area $S = 4\pi R^2$ rather than $S = \pi R^2$ for a disk like cross section of flux tube. Spherical deformation is of course idealized assumption and the area could larger if the sphere is not spherical.

   $$eB = \frac{GMm(CP_2)\hbar}{8v_0\pi r_S^2} = \frac{1}{8\pi v_0}\frac{\hbar}{X} \ ,$$
   $$X = R(CP_2)r_S \simeq 10^{-18} \ m^2 \ . \tag{13.3.1}$$

   This gives for the magnetic length $l_B = \sqrt{\hbar/eB}$ and magnetic field B the expressions

   $$l_B = \sqrt{\frac{\hbar}{eB}} = \sqrt{8\pi v_0 \times X} \simeq \sqrt{\pi v_0} \ nm \ ,$$
   $$\frac{B}{Tesla} = (\frac{l_B}{26 \ nm})^{-2} = \frac{26^2}{8\pi\beta_0} \ . \tag{13.3.2}$$

   The smallest value is obtained at the limit $\beta = v_0/c = 1$ and equals $B_{min} = 26.9$ Tesla.

4. From the conclusions section of the article one learns that the the poloidal component of the magnetic field just below radius $R_g \simeq r_S$ is estimated to be about $B \sim \sqrt{7M_{Sun}/M}10^{13}$ Gauss giving $B \sim 4.4\times10^4$ Tesla. This gives $v_0 \simeq 6\times10^{-4}$. This is quite near to the estimate $v_0 = 2^{-11} \simeq 4.9 \times 10^{-4}$ obtained from the Bohr orbit model for the inner planet orbits in solar system [K93, ?].

   This estimate was for $n_2 = 1$ but this is very special situation. For $n_2 = 10^7$ the value of the magnetic field for single sheet one would have $B \to B/n_2 \simeq 44$ Gauss. This option is the realistic one in the proposed framework. For $n_2 = n_{gr}$ corresponding to single flux tube with this number of sheets over M^4 $B \to B/n_{gr}$ which is extremely weak field.

   The effective value $B_{eff} \sim 4.4 \times 10^4$ of the magnetic field would correspond to the sum of n_{gr} copies of this field over all sheets of all tubes. If one has quantum coherence, this field value appears in the formula for cyclotron energies and this formula is crucial in biological applications allowing to have cyclotron energies in visible and UV range for dark photons with cyclotron frequency in EEG range.

13.3.3 Intelligent blackholes?

I received from Nikolina Benedikovic an interesting link to Leonard Susskinds's interview (see `http://tinyurl.com/yco7pd55` and for arousing my curiosity. In the link one learns that Leonard Susskind has admitted that superstrings do not provide a theory of everything. This is actually not a mind blowing surprise since very few can claim that the news about the death of superstring theory would be premature. Congratulations in any case to Susskind: for a celebrated super string guru it requires courage to change one's mind publicly. I will not discuss in the following the tragic fate of superstrings. Life must continue despite the death of superstring theory and there are much more interesting ideas to consider.

Susskind is promoting an idea about growing blackholes increasing their volume as they swallow matter around them (see `http://tinyurl.com/ybw78hpn`). The idea is that the volume of the blackhole measures the complexity of the blackhole and from this its not long way to the idea that information - may be conscious information (I must admit that I cannot imagine any other kind of information) - is in question.

Some quantum information theorists find this idea attractive. Quantum information theoretic ideas find a natural place also in TGD. Magnetic flux tubes would naturally serving as space-time correlates for entanglement (the p-adic variants of entanglement entropy can be negative and would serve as measures of conscious information) and this leads to the idea about tensor networks formed by the flux tubes [L21] (see `http://tinyurl.com/y9lmfrbz`). So called strong form of holography states that 2-D objects - string world sheets and partonic 2-surfaces as sub-manifolds of space-time surfaces carry the information about space-time surface and quantum states. $M^8 - M^4 \times CP_2$ correspondence [L34] would realize quantum information theoretic ideas at even deeper level and would mean that discrete finite set of data would code for the given space-time surface as preferred extremal.

In TGD Universe long cosmic strings thickened to flux tubes would be key players in the formation of galaxies and would contain galaxies as tangles along them. These tangles would contain sub-tangles having interpretation as stars and even planets could be such tangles.

In the proposed model quasars need not be blackholes in GRT sense but have structure including magnetic moment (blackhole has no hair), an empty disk around it created by the magnetic propeller effect caused by radial Lorentz force, a luminous ring and accretion disk, and so called Elvis structure involving outwards flow of matter. One could call them quasi- blackholes - I will later explain why.

1. Matter would not fall in blackhole but magnetic and volume energy in the interior would transform to ordinary matter and mean thickening of the flux tubes forming a configuration analogous to flow lines of dipole magnetic fields by looping. Think of formation of dipole field by going around flux line replaced by flux tube, returning and continuing along another flux line/tube.

2. The dipole part of the structure would be cylindrical volume in which flux tubes would form structure consisting analogous to a coil in which one makes $n_2 \simeq 10^7$ $(G_N = R^2/n_2 h_0)$

windings in CP_2 direction and continues in different position in M^4 and repeats the same. This is like having a collection of coils in M^4 but each in CP_2 direction. This collection of coils would fill the dipole cylinder having the case of quasar studied a radius smaller than the Schwartshild radius $r_S \simeq 5 \times 10^9$ km but with the same order of magnitude. The wire from given coil would continue as a field line of the magnetic dipole field and return back at opposite end of dipole cylinder and return along it to opposite pole. The total number of loops in the collection of n_1 dipole coils with n_2 windings in CP_2 direction is $n_1 \times n_2$.

3. What is unexpected that although the volume contribution to action assignable to cosmological constant is positive as it must be, the energy is negative (I have checked this many times but cannot find mistake)! Could the expansion of flux tubes liberating ordinary and dark matter particles (in TGD sense) as analog of the decay of inflaton field continue without limit? At certain flux tube radius the total energy becomes zero - this corresponds roughly to a biological length scale about 1 mm for the value of cosmological constant in the length scale of the observed universe. Could the string tension become negative so that ordinary matter could be created without limit? It is quite possible that preferred extremal property prevents negative values of string tension but I have not found a good argument for this.

   Remark: Note that the twistor lift of TGD allows to consider entire hierarchy of cosmological constants behaving like $1/L(k)^2$, where $L(k)$ is p-adic length scale corresponding to $p \simeq 2^k$.

4. Cosmological expansion would naturally relate to the thickening of the flux tubes, and one can also consider the possibility that the long cosmic string gets more and more looped (dipole field gets more and more loops) so that the quasi-blackhole would increase in size by swallowing more and more of long cosmic string spaghetti to the dipole region and transforming it to the loops of dipole magnetic field.

5. The quasar (and also galactic blackhole candidates and active galactic nuclei) would be extremely intelligent fellows with number theoretical intelligence quotient (number of sheets of the space-time surfaces as covering) about

$$\frac{h_{eff}}{h} = \frac{n}{6} = \frac{n_1 \times n_2}{6} \geq \frac{GMm(CP_2)}{v_0} \times \hbar = \frac{r_S}{R(CP_2)} \times \frac{1}{2\beta_0} \ ,$$

   where one has $\beta_0 = v_0/c$, where v_0 is roughly of the order $10^{-3}c$ is a parameter with dimensions of velocity, r_S is Schwartshild radius of quasi-blackhole of order 5×10^9 km, and $R(CP_2)$ is CP_2 radius of order 10^{-32} meters. If this blackhole like structure is indeed cosmic string eater, its complexity and conscious intelligence increases and it would represent the brains of the galaxy as a living organism. This picture clearly resembles the vision of Susskind about blackholes.

6. This cosmic spaghetti eater has also a time reversed version for which the magnetic propellor effect is in opposite spatial direction: mass consisting of ordinary particles flows to the interior. Could this object be the TGD counterpart of blackhole? Or could one see both these objects as e blackholes dual to each other (maybe as analogs of white holes and blackholes)? The quasar like blackhole would eat cosmic string and its time reversal would swallow from its environment the particle like matter that its time reversed precedessor generated. Could one speak of breathing? Inwards breath and outwards breath would be time reversals of each other. This brings in mind the TGD inspired living cosmology based on zero energy ontology (ZEO) [L52] as analog of Penrose's cyclic cosmology, which dies and re-incarnates with opposite arrow of time again and again.

A natural question is whether also the ordinary blackholes are quasi-blackholes of either kind. In the fractal Universe of TGD this would look extremely natural.

1. How to understand the fusion of blackholes (or neutron stars, I will however talk only about blackholes in the sequel) to bigger blackhole observed by LIGO if quasi-blackholes are in question? Suppose that the blackholes indeed represent dipole light tangles in cosmic string. If they are associated with the same cosmic string, they collisions would be much more probable than one might expect. One can imagine two extreme cases for the motion of the blackholes. There are two options.

(a) Tangles plus matter move along string like along highway. The collision would be essentially head on collision.

(b) Tangles plus matter around them move like almost free particles and string follows: this would however still help the blackholes to find each either. The observed collisions can be modelled as a formation of gravitational bound state in which the blackholes rotate around each other first.

The latter option seems to be more natural.

2. Do the observed black-hole like entities correspond to quasar like objects or their time reversals (more like ordinary blackholes). The unexpectedly large masses would suggests that they have not yet lost their mass by thickening as stars usually so that they are analogs of quasars. These objects would be cosmic string eaters and this would also favour the collisions of blackhole like entities associated with the same cosmic string.

3. This picture would provide a possible explanation for the evidence for gravitational echoes and evidence for magnetic fields in the case of blackholes formed in the fusion of blackholes in LIGO [L24] (see `http://tinyurl.com/y79yqw6q`). The echoes would result from the repeated reflection of the radiation from the inner blackhole like region and from the ring bounding the accretion disk.

   Note that I have earlier proposed a model of ordinary blackholes in which there would be Schwartschild radius but at some radius below it the space-time surface would become Euclidian. In the recent case the Euclidian regions would be however associated only with wormhole contacts with Euclidian signature of metric bounded by light-like orb its of partonic 2-surfaces and might have sizes of order Compton length scaled up by the value of h_{eff}/h for dark variants of particle and therefore rather small as compared to blackhole radius.

4. The latest news tells that 28 August 2019 LIGO observed two gravitational waves with a time lapse of 21 minutes in the same direction (see `http://tinyurl.com/yxpblf4p`). The events are christened as S190828j and S190828l. This suggests that the signals coule originate from same event. Gravitational lense effect could be one explanation.

   TGD suggests an alternative explanation based on the notion of gravitational flux tubes. Magnetic flux tubes, in particular gravitational flux ones, form loops. The later signal could have spent 21 minutes by rotating around this kind of loop. This rotation can occur several times but the intensity of signal is expected to diminish exponentially if only a constant fraction remains in loop at each turn.

   This sticking of radiation inside magnetic loops predicting echo like phenomenon is a general prediction of TGD and I have considered the possible occurrence of this phenomenon for cosmic gamma rays arriving in solar solar system in a model for solar cycle [L83] (see `http://tinyurl.com/y2nltfpz`.

   This kind of repetition of the signal has been observed already earlier for gravitational waves and has been dubbed "blackhole echoes" (see `http://tinyurl.com/yahxk2ca`this) but in a time scale of .1 seconds (fundamental bio-rhythm by the way). I have considered possible TGD based explanations of blackhole echoes in [L24] (see `http://tinyurl.com/y79yqw6q`) and [K79] (see `http://tinyurl.com/yy5f6wll`).

   The two time scales differ by four orders of magnitude but one cannot exclude same explanation. With light velocity Earth sized loop would correspond to a time lapse of about .1 seconds. Light travels in 21 minutes over a distance of 378 million kilometers to be compared with astronomical unit AU = 150 million kilometers defining the distance of Earth from Sun. Therefore loops in the scale of Earth's orbit around Sun could be involved and perhaps associated with the magnetic body of the collapsed system. .1 seconds defining the time scale for the blackhole echoes in turn corresponds to a circumference of order Earth circumference.

13.4 Appendix: Explicit formulas for the evolution of cosmological constant

What is needed is induced Kähler form $J(S^2(X^4)) \equiv J$ at the twistor sphere $S^2(X^4) \equiv S^2$ associated with space-time surface. $J(S^2(X^4))$ is sum of Kähler forms induced from the twistor spheres $S^2(M^4)$ and $S^2(CP_2)$.

$$J(S^2(X^4) \equiv J = P[J(S^2(M^4)) + J(S^2(CP_2))] \ , \tag{13.4.1}$$

where P is projection taking tensor quantity T_{kl} in $S^2(M^4) \times S^2(CP_2)$ to its projection in $S^2(X^4)$. Using coordinates y^k for $S^2(M^4)$ or $S^(CP_2)$ and x^μ forS^2, P is defined as

$$P : T_{kl} \to T_{\mu\nu} = T_{kl}\frac{\partial y^k}{\partial x^\mu}\frac{\partial y^l}{\partial x^\nu} \ . \tag{13.4.2}$$

For the induced metric $g(S^2(X^4)) \equiv g$ one has completely analogous formula

$$g = P[g(J(S^2(M^4)) + g(S^2(CP_2))] \ . \tag{13.4.3}$$

The expression for the coefficient K of the volume part of the dimensionally reduced 6-D Kähler action density is proportional to

$$L(S^2) = J^{\mu\nu}J_{\mu\nu}\sqrt{det(g)} \ . \tag{13.4.4}$$

(Note that $J_{\mu\nu}$ refers to S^2 part 6-D Kähler action). This quantity reduces to

$$L(S^2) = (\epsilon^{\mu\nu}J_{\mu\nu})^2\frac{1}{\sqrt{det(g)}} \ . \tag{13.4.5}$$

where $\epsilon^{\mu\nu}$ is antisymmetric tensor density with numerical values +,-1. The volume part of the action is obtained as an integral of K over S^2:

$$S(S^2) = \int_{S^2} L(S^2) = \int_{-1}^{1} du \int_0^{2\pi} d\Phi \frac{J^2_{u\Phi}}{\sqrt{det(g)}} \ . \tag{13.4.6}$$

$(u, \Phi) \equiv (cos(\Theta, \Phi)$ are standard spherical coordinates of S^2) varying in the ranges $[-1, 1]$ and $[0, 2\pi]$.

This the quantity that one must estimate.

13.4.1 General form for the embedding of twistor sphere

The embedding of $S^2(X^4) \equiv S^2$ to $S^2(M^4) \times S^2(CP_2)$ must be known. Dimensional reduction requires that the embeddings to $S^2(M^4)$ and $S^2(CP_2)$ are isometries. They can differ by a rotation possibly accompanied by reflection

One has

$$(u(S^2(M^4)), \Phi(S^2(M^4)) = (u(S^2(X^4), \Phi(S^2(X^4)) \equiv (u, \Phi) \ ,$$

$$\left[u(S^2(CP_2)), \Phi(S^2(CP_2))\right] \equiv (v, \Psi) = RP(u, \Phi)$$

where RP denotes reflection P following by rotation R acting linearly on linear coordinates (x,y,z) of unit sphere S^2). Note that one uses same coordinates for $S^2(M^4)$ and $S^2(X^4)$. From this action one can calculate the action on coordinates u and Φ by using the definite of spherical coordinates.

The Kähler forms of $S^2(M^4)$ resp. $S^2(CP_2)$ in the coordinates $(u = cos(\Theta), \Phi)$ resp.(v, Ψ) are given by $J_{u\Phi} = \epsilon = \pm 1$ resp. $J_{v\Psi} = \epsilon = \pm 1$. The signs for $S^2(M^4)$ and $S^2(CP_2)$ are same or opposite. In order to obtain small cosmological constant one must assume either

1. $\epsilon = -1$ in which case the reflection P is absent from the above formula (RP $\rightarrow$ R).
2. $\epsilon = 1$ in which case P is present. P can be represented as reflection $(x, y, z) \rightarrow (x, y, -z)$ or equivalently $(u, \Phi) \rightarrow (-u, \Phi)$.

Rotation R can represented as a rotation in (y,z)-plane by angle ϕ which must be small to get small value of cosmological constant. When the rotation R is trivial, the sum of induced Kähler forms vanishes and cosmological constant is vanishing.

13.4.2 Induced Kähler form

One must calculate the component $J_{u\Phi}(S^2(X^4)) \equiv J_{u\Phi}$ of the induced Kähler form and the metric determinant $det(g)$) using the induction formula expressing them as sums of projections of M^4 and CP_2 contributions and the expressions of the components of $S^2(CP_2)$ contributions in the coordinates for $S^2(M^4)$. This amounts to the calculation of partial derivatives of the transformation R (or RP) relating the coordinates (u, Φ) of $S^2(M^4)$ and to the coordinates (v, Ψ) of $S^2(CP_2)$.

In coordinates (u, Φ) one has $J_{u\Phi}(M^4) = \pm 1$ and similar expression holds for $J(v\Psi)S^2(CP_2)$. One has

$$J_{u\Phi} = 1 + \frac{\partial(v, \Psi)}{\partial(u, \Phi)} \quad . \tag{13.4.7}$$

where right-hand side contains the Jacobian determinant defined by the partial derivatives given by

$$\frac{\partial(v,\Psi)}{\partial(u,\Phi)} = \frac{\partial v}{\partial u}\frac{\partial \Psi}{\partial \Phi} - \frac{\partial v}{\partial \Phi}\frac{\partial \Psi}{\partial u} \quad . \tag{13.4.8}$$

13.4.3 Induced metric

The components of the induced metric can be deduced from the line element

$$ds^2(S^2(X^4) \equiv ds^2 = P[ds^2(S^2(M^4)) + ds^2(S^2(CP_2))] \quad .$$

where P denotes projection. One has

$$P(ds^2(S^2(M^4))) = ds^2(S^2(M^4)) = \frac{du^2}{1-u^2} + (1-u^2)d\Phi^2 \quad .$$

and

$$P[ds^2(S^2(CP_2))] = P[\frac{(dv)^2}{1-v^2} + (1-v^2)d\Psi^2] \quad ,$$

One can express the differentials $(dv, d\Psi)$ in terms of $(du, d\Phi)$ once the relative rotation is known and one obtains

$$P[ds^2(S^2(CP_2))] = \frac{1}{1-v^2}[\frac{\partial v}{\partial u}du + \frac{\partial v}{\partial \Phi}d\Phi]^2 + (1-v^2)[\frac{\partial \Psi}{\partial u}du + \frac{\partial \Psi}{\partial \Phi}d\Phi]^2 \quad .$$

This gives

$$\begin{aligned} & P[ds^2(S^2(CP_2))] \\ & = [(\tfrac{\partial v}{\partial u})^2\tfrac{1}{1-v^2} + (1-v^2)(\tfrac{\partial \Psi}{\partial u})^2]du^2 \\ & +[(\tfrac{\partial v}{\partial \Phi})^2\tfrac{1}{1-v^2} + (\tfrac{\partial \Psi}{\partial \Phi})^2 1-v^2]d\Phi^2 \\ & +2[\tfrac{\partial v}{\partial u}\tfrac{\partial v}{\partial \Phi}\tfrac{1}{(1-v^2)} + \tfrac{\partial \Psi}{\partial u}\tfrac{\partial \Psi}{\partial \Phi}(1-v^2)]dud\Phi \quad . \end{aligned}$$

From these formulas one can pick up the components of the induced metric $g(S^2(X^4)) \equiv g$ as

$$\begin{aligned} g_{uu} &= \frac{1}{1-u^2} + (\frac{\partial v}{\partial u})^2 \frac{1}{1-v^2} + (1-v^2)(\frac{\partial \Psi}{\partial u})^2] \ , \\ g_{\Phi\Phi} &= 1-u^2 + (\frac{\partial v}{\partial \Phi})^2 \frac{1}{1-v^2} + (\frac{\partial \Psi}{\partial \Phi})^2(1-v^2) \\ g_{u\Phi} &= g_{\Phi u} = \frac{\partial v}{\partial u}\frac{\partial v}{\partial \Phi}\frac{1}{(1-v^2)} + \frac{\partial \Psi}{\partial u}\frac{\partial \Psi}{\partial \Phi}(1-v^2) \ . \end{aligned} \tag{13.4.9}$$

The metric determinant $det(g)$ appearing in the integral defining cosmological constant is given by

$$det(g) = g_{uu}g_{\Phi\Phi} - g_{u\Phi}^2 \ . \tag{13.4.10}$$

13.4.4 Coordinates (v,Ψ) in terms of (u,Φ)

To obtain the expression determining the value of cosmological constant one must calculate explicit formulas for (v,Ψ) as functions of (u,Φ) and for partial derivations of (v,Ψ) with respect to (u,Φ).

Let us restrict the consideration to the RP option.

1. P corresponds to $z \rightarrow -z$ and to

$$u \rightarrow -u \ . \tag{13.4.11}$$

2. The rotation R $(x,y,z) \rightarrow (x',y',z')$ corresponds to

$$x' = x, \quad y' = sz + cy = su + c\sqrt{1-u^2}sin(\Phi) \ , \quad z' = v = cu - s\sqrt{1-u^2}sin(\Phi) \tag{13.4.12}$$

Here one has $(s,c) \equiv (sin(\epsilon), cos(\epsilon)$, where ϵ is rotation angle, which is extremely small for the value of cosmological constant in cosmological scales.

From these formulas one can pick v and $\Psi = arctan(y'/x)$ as

$$v = cu - s\sqrt{1-u^2}sin(\Phi) \quad \Psi = arctan[\frac{su}{\sqrt{1-u^2}}cos(\Phi) + tan(\Phi)] \ . \tag{13.4.13}$$

3. RP corresponds to

$$v = -cu - s\sqrt{1-u^2}sin(\Phi) \quad \Psi = arctan[-\frac{su}{\sqrt{1-u^2}}cos(\Phi) + tan(\Phi)] \ . \tag{13.4.14}$$

13.4.5 Various partial derivatives

Various partial derivates are given by

$$\begin{aligned} \frac{\partial v}{\partial u} &= -1 + s\frac{u}{\sqrt{1-u^2}}sin(\Phi) \ , \\ \frac{\partial v}{\partial \Phi} &= -s\frac{u}{\sqrt{1-u^2}}cos(\Phi) \ , \\ \frac{\partial \Psi}{\partial \Phi} &= (-s\frac{u}{\sqrt{1-u^2}}sin(\Phi) + c)\frac{1}{X} \ , \\ \frac{\partial \Psi}{\partial u} &= \frac{scos(\Phi)(1+u-u^2)}{(1-u^2)^{3/2}}\frac{1}{X} \ , \\ X &= cos^2(\Phi) + [-s\frac{u}{\sqrt{1-u^2}} + csin(\Phi)]^2 \ . \end{aligned} \tag{13.4.15}$$

Using these expressions one can calculate the Kähler and metric and the expression for the integral giving average value of cosmological constant. Note that the field equations contain S^2 coordinates as external parameters so that each point of S^2 corresponds to a slightly different space-time surface.

13.4.6 Calculation of the evolution of cosmological constant

One must calculate numerically the dependence of the action integral S over S^2 as function of the parameter $s = sin(\epsilon))$. One should also find the extrema of S as function of s.

Especially interesting values are very small values of s since for the cosmological constant becomes small. For small values of s the integrand (see Eq. 13.4.6) becomes very large near poles having the behaviour $1/\sqrt{g} = 1/(sin(\Theta) + O(s))$ coming from $\sqrt{g}$ approaching that for the standard metric of S^2. The integrand remains finite for $s \neq 0$ but this behavior spoils the analytic dependence of integral on s so that one cannot do perturbation theory around $s = 0$. The expected outcome is a logarithmic dependence on s.

In the numerical calculation one must decompose the integral over S^2 to three parts.

1. There are parts coming from the small disks D^2 surrounding the poles: these give identical contributions by symmetry. One must have criterion for the radius of the disk and the natural assumption is that the disk radius is of order s.

2. Besides this one has a contribution from S^2 with disks removed and this is the regular part to which standard numerical procedures apply.

One must be careful with the expressions involving trigonometric functions which give rise to infinite if one applies the formulas in straightforward manner. These infinities are not real and cancel, when one casts the formulas in appropriate form inside the disks.

1. The limit $u \to \pm 1$ at poles involves this kind of dangerous quantities. The expression for the determinant appearing in $J_{u\Phi}$ remains however finite and $J^2_{u\phi}$ vanishes like s^2 at this limit. Also the metric determinant $1/\sqrt{g}$ remains finite expect at $s = 0$.

2. Also the expression for the quantity X in $\Psi = arctan(X)$ contains a term proportional to $1/cos(\Phi)$ approaching infinity for $\Phi \to \pi/2, 3\pi/2$. The value of $\Psi = arc(tan(X)$ remains however finite and equal to $\pm\Phi$ at this limit depending on on the sign of us.

Concerning practical calculation, the relevant formulas are given in Eqs. 13.4.5, 13.4.6, 13.4.7, 13.4.8, 13.4.9, 13.4.10, and 13.4.15.

The calculation would allow to test/kill the key conjectures already discussed.

1. There indeed exist extrema satisfying $dS(S^2)/ds = 0$.

2. These extrema are in one-one correspondence with the zeros of zeta.

There are also much more specific conjctures to be killed.

1. These extrema correspond to $s = sin(\epsilon) = 2{-}k$ or more generally $s = p^{-k}$. This conjecture is inspired by p-adic length scale hypothesis but since the choice of evolution parameter is to high extent free, the conjecture is perhaps too spesific.

2. For certain integer values of integer k the integral $S(S^2)$ of Eq. 13.4.6 is of form $S(S^2) = xs^2$ for $s = 2^{-k}$, where x is a universal numerical constant.

   This would realize the idea that p-adic length scales realized as scales associated with cosmological constant correspond to fixed points of renormalization group evolution implying that radiative corrections otherwise present cancel. In particular, the deviation from $s = 2^{-d/2}$ would mean anomalous dimension replacing $s = 2^{-d/2}$ with $s^{-(d+\Delta d)/2}$ for $d = k$ the anomalies dimension Δd would vanish.

   The condition $\Delta d = 0$ should be equivalent with the vanishing of the dS/ds. Geometrically this means that $S(s)$ curve is above (below) $S(s) = xs^2$ and touches it at points $s = x2^{-k}$, which would be minima (maxima). Intermediate extrema above or below $S = xs^2$ would be maxima (minima).

Chapter 14

Solar Metallicity Problem from TGD Perspective

14.1 Introduction

For ten years ago it was though that Sun isa well-understood system but more precise computations demonstrated a problem. The metallicities deduced from spectroscopic data deviate strongly from those deduced from helio-seismology and solar neutrino data as described in the Annual Review of Astronomy and Astrophysics by Martin Asplund *et al* [E66] (see `http://tinyurl.com/y4bmbjzg`), who were pioneers modelling solar surface as 3-D structure rather than idealizing it with 2-D structure.

Calculations of metallicities and their comparison with the helio-seismological results are discussed in [E247] (`http://tinyurl.com/yyxw9bpn`). The abundances used are determined from meteorites and these estimates are more accurate and are consistent with the values determined by Asplund *et al* and used also to extrapolate the metallicities in core.

1. The metallicity of Sun deduced from spectroscopy by Asplund *et al* would be 1.3 per cent whereas the older model and also helio-seismology give 1.8 per cent metallicity. Is the metallicity indeed 1.3 per cent using standard model to extrapolate the spectroscopic data at surface? Or is it 1.8 per cent deeper in the interior in which case the extrapolation used to deduce metallicity in the interior would not be realistic?

2. There are also other discrepancies. The height of convective zone at which radiative energy transfer is replaced with convection is given by $R_{CZ} = .724R$. The predicted He abundance at surface is $Y_{surf} = .231$. These values are in conflict with $R_{CZ} = .713R$ and $Y_{surf} = .248$ deduced from helio-seismological data. Also density and sound velocity profiles deviate from those deduced from the helio-seismological data. The earlier model approximating solar surface as 2-D structure is in excellent accordance with the helio-seismological data.

14.1.1 Is there something wrong with the standard solar model?

I received interesting links to a couple of popular articles (see `http://tinyurl.com/y4zxmdqz` and `http://tinyurl.com/y52clelq`) suggesting that the physics of solar core, where nuclear fusion is assumed to take place, might not be quite what it is believed to be. Here is the abstract of the first popular article:

Analysis of sound and light transmission from solar surface using a new 3-D model instead of the standard 2-D standard model suggests that the chemical composition of the Sun is far different from what has been assumed. There appears to be significantly less elements heavier than hydrogen than had been estimated using obsolete models that use calculations assuming completely flat surface for the Sun. Sun's missing metals means that there is a large mass, several billion megatons, of material that is unaccounted for. One possibility that has been suggested is that the Sun's core may be comprised dark matter - a source of mass that exerts gravitational force and does not interact in the same way that ordinary matter does.

The popular article talks about 1500 Earth masses of missing matter particles heavier than hydrogen and helium so that the amount of missing mass would be about $M_D \sim 8 \times times 10^{27}$ kg, perhaps dark matter. Solar mass is about $M(Sun) = 2 \times 10^{30}$ kg. The fraction M_D/M would be $M_D/M \sim 4 \times 10^{-3}$. This missing mass is obtained if the metallicities deduced from the spectroscopy are indeed correct.

Just to check that there are no mis-understandings, one can estimate the missing mass in core by using the fact that in the core (see `http://tinyurl.com/nrcojr2`) has about 34 per cent of solar mass and the reduction of metallicity 1.3 per cent deduced from the earlier value 1.8 per cent is .5 per cent. This gives the estimate $M_D/M \simeq 1.7 \times 10^{-3}$, which is roughly 1/2 of the estimate.

The metallicity deduced from spectroscopy is 1.3 per cent, and helio-seismology gives metallicity of 1.8 per cent. Who is right: spectroscopists or helio-seismologists? Or could both be right: could the very notion of metallicity used by them be actually different?

1. The first option is that spectroscopists are right and that there is some form of matter in the core not behaving like ordinary matter and has different opacity and acoustic resonances. The higher the metallicity, the higher the opacity since metals absorb light. The exotic state of of matter should have higher opacity and absorb light more effectively so that it would give too high metallicity in standard model for the core.

   If so, the amount of elements heavier than Helium could be what 3-D spectroscopy predicts. There is some empirical support for this expectation from the opacity measurements for Fe at temperatures and pressures expected to prevail in solar core by Jim Bailey working at Sandia National Laboratories in New Mexico (see `http://tinyurl.com/y5fp4fhk` and `http://tinyurl.com/yxqtpe34`).

   The model introduced by Vincent *et al* [E257] discussed in popular article (see `http://tinyurl.com/y68p4lqb`) assumes the missing matter to be dark matter with rather exotic and implausible-to-me properties. If I have understood correctly, the model of Vincent *et al* claims that if the abundances in the interior are indeed lower if there is a dark mass about $M_D \sim 10^{27}$ kg in the core of the Sun giving $M_D/M \sim 2^{-11}$.

2. Second option would be that helio-seismology gives a correct estimate for the metallicity and that that the extrapolation of the spectroscopic data obtained from the surface layer of Sun to interior is somehow wrong. Also this brings also in mind some new physics: what comes in mind in TGD framework is many-sheeted space-time and magnetic flux tube structures with non-standard value of effective Planck constant $h_{eff} = nh_0$.

3. The third option is that both spectroscopists and helio-seismologists are right and that metallicity means different thing for them. TGD based model for cold fusion on the vision about dark matter as hierarchy of $h_{eff} = nh_0$ phases predicts the possibility of dark nuclei. Spectroscopists measure only the abundance of ordinary dark matter but helio-seismologists measure also the contribution of dark nuclei present in core and perhaps also in convective zone to metallicity.

14.1.2 More precise statement of the problem

Consider now a more precise statement of the metallicity/abundance problem. This problem can be seen a problem of the entire astrophysics since the model of Sun is extrapolated to deduce the structure other stars from the spectroscopic data. Estimates for the metallicity and abundances of elements heavier than He in Sun can can be deduced in several way.

1. One can deduce metallicity by spectroscopy based on emission and absorption lines at solar surface and here the work of Martin Asplund and his group developing 3-D models for the atmosphere of Sun (photosphere,chromosphere, and solar corona) has been of utmost importance and deduce that the metallicity should be 1.3 per cent. This model also gives for the thickness of the convection zone a value smaller than older approach approximating the surface with 2-D structure.

2. Metallicity can be deduced also from helio-seismology by studying the oscillations of Sun allowing to deduce information about the inner structure of Sun. This gives metallicity of about 1.8 per cent consistent with the earlier 2-D model. For instance, it was found that the light from the Sun suggests that it had about 20 to 25 per cent less C, N, and O than thought previously. These findings contradict the data from helio-seismology which can deduce precise information about the abundances of elements heavier than helium since they affect the sound wave propagation within the star.

   Earlier 2-D model however agrees with helio-seismological data. Ironically, a more precise model for the solar atmosphere leads to a conflict with other data. Could the approximation of solar surface as 2-D structure be better than 3-D description for some reason: in TGD framework one can ask whether the notion of many-sheeted space-time - in particular p-adic length scale hypothesis) suggesting layered structure - could somehow relate to this. This does not look plausible.

3. Metallicities can be also deduced very accurately from meteorites and these abundances are in good accordance with the the 3-D model and are used in the comparison. This gives support for the model of Asplund but means that meteoritic abundances would be lower than those expected in the solar interior on basis of standard solar model.

4. A further approach is based on solar neutrinos (see `http://tinyurl.com/yy5ewynp`). This approach gives a result consistent with 1.8 per cent. The model of solar neutrinos is very sensitive to metallicity.

It seems that without new physics one has a paradox.

14.1.3 Possible approaches to the problem

One should explain the conflict between the two determinations of metallicities. The first option would be that the spectroscopic determinations give correct result. The optical and acoustic properties of the matter in the core could however differ from those assumed in standard model. Due to unexpectedly high opacity of the core the metallicity determined from standard helio-seismology would be too high. Also acoustic characteristic should be different. The many-sheeted space-time of TGD and the notion of magnetic body could provide concrete ideas in this respect.

Second possibility is that there is a new physics mechanism increasing the rate of production of nuclei as one goes deeper. Even more, the produced nuclei could exist in some exotic states not possible outside solar interior. If a production mechanism involving some new physics exists, one can wonder whether it could allow to understand the nuclear abundances outside stars in the framework of standard model.

1. Standard model has already a problem with elements heavier than Fe. The generation of elements heavier than Fe in stellar interiors is not possible, and one proposal has been that they are generated in supernovas but this model has not received empirical support (see `http://tinyurl.com/y74rh5rw`).

2. If the abundances of elements heavier than He are small in solar core, then also the elements lighter than Fe could pose a problem. Super-nova explosions should scatter elements lighter than Fe to interstellar space and their amount in interstellar space could be smaller than predicted by the standard model. Could the fusion of these elements take place also outside core or even in interstellar space?

TGD based model of “cold fusion” relies on the notion of dark nucleus [L31]. Could also dark nuclei be possible inside Sun and contribute also to metallicity? The paradox would dis-solve due to the different notion of metallicity used outside Sun and in the interior of Sun. TGD based view about quantum tunnelling essential for the modelling of solar fusion indeed predicts that both ordinary and dark nuclei are in kinetic equilibrium inside solar core at least.

The model proposed by Aaron Vincent

Could the dark matter model proposed by Aaron Vincent *et al* [E257] (see `http://tinyurl.com/y68p4lqb` and `http://tinyurl.com/yy5ewynp` relate to ZEO based model? The weird looking assumption of the model is that the dark particles in question would have higher probability of having collisions with larger energy and momentum transfer than those with small energy transfer. In the hot solar core these dark particles would get heated and then propagate to cooler parts of Sun and in interactions with would provide very effectively their energy to ordinary.

I must admit that I do not really understand the argument leading to the increase of the metallicity as one goes deeper into the sun. One might however think that this energy feed raises the temperature faster towards core than standard model predicts so that also the metallicities should increase faster.

How TGD could cure the problem?

TGD based new nuclear physics suggests both spectroscopists and helio-seismologists are right.

1. Solar core and also convective zone could contain dark nuclear matter explaining the missing mass. The amount of dark nuclei would be fraction of order 4×10^{-2} of the ordinary matter. TGD based model for the formation of galaxies, stars and planets involves magnetic flux tubes carrying dark energy and possibly also dark matter as key elements, and the dark matter might be assigned to a dark nuclear flux tubes going through the solar core.

   The dark nuclei at the magnetic body would affect the model for the propagation of light and sound in the solar core and also outside it. For instance, photons could be transformed to dark photons at flux tubes an this would increase opacity. Also sound waves would interact with dark nuclei since the acoustic oscillations could be transformed to oscillations of magnetic fields tubes (dark Alfwen waves) and oscillations of dark nuclei.

2. TGD based models of "cold fusion" [L31] and of Pollack effect [L9] [L9] led to a proposal of what I call dark nuclear physics. Dark nuclear physics explaining "cold fusion" in TGD framework could play a central role even in the pre-stellar evolution and in nuclear fusion in stars. As will be found, this suggests a new way to see tunnelling crucial for nuclear fusion inside stars and even in laboratory.

   Tunnelling is not allowed in TGD since classical physics is exact part of quantum TGD, and would be replaced by a generation of dark nuclei with $h_{eff} = nh_0$ by state function reduction and having lower nuclear binding energy scale making possible to overcome Coulomb wall so that nuclear fusion would be possible without tunnelling.

   The most conservative expectation is that this model for tunnelling reproduces the nuclear physics of ordinary nuclear matter in good approximation. What is however new is that the dark nuclei are present as new exotic states of nuclei, and must be taken in the modelling of sound waves and photons. Therefore helio-seismology and solar neutrinos would allow to deduce the total metallicity as sum over ordinary and dark metallicity whereas spectroscopy and meteorite determinations would provide only the ordinary metallicity since the attention is paid only to ordinary nuclei as outcomes of reactions.

The vision about galaxies and stars

The view about the role of new nuclear physics predicted by TGD in the model of solar interior [L82] gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles. One ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges naturally since flux tubes are universal objects in TGD Universe and could be also inspired by the fashion of dualizing everything to blackholes.

The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature. The second thermodynamics is assignable to the gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low.

The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense. This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In zero energy ontology (ZEO) quasars and galactic blackholes can be seen as time reversals of each other.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years. Also "too" fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

14.2 Could solar metallicity problem reflect the presence of dark matter in solar core?

Dark matter identified as $h_{eff} = nh_0$ phases has become key player in TGD inspired new physics being now a crucial element of TGD based view about living matter. Dark nuclear fusion is proposed to provide the new physics allowing to understand "cold fusion" [L31]. In the following it will be found that dark matter in TGD associated with solar core could provide an elegant solution also to the solar metallicity problem.

In TGD classical physics is an exact part of quantum physics. The tunnelling phenomenon essential for nuclear physics based model of solar nuclear fusion would correspond in TGD to a state function reduction creating a phase consisting of dark nuclei which can fuse without tunnelling due to the reduction of the binding energy scale. State function reduction to ordinary phase would lead to the final state of the reaction. In ZEO "big" (ordinary) state function reduction (BSFR) would reverse the arrow of time so that if tunnelling phenomenon is assignable to BFSR rather than "small" state function reductions (SFSRs) as TGD counterparts of "weak" measurements, ZEO would make possible nuclear fusion. The recent findings of Minev *et al* [L68] provide support for ZEO [L68].

The missing nuclear matter inside the core would be dark variants of nuclei associated with dark flux tubes. This would explain the conflict between the metallicities deduced from spectroscopic and meteoritic data on one hand and those deduced from helio-seismic data on the other hand. The reason would be that sound waves and photons in the core would couple to both ordinary and dark matter so that helio-seismology would give metallicities as sums of ordinary and dark metallicities. Using the estimate for the thickness of the dark flux tube coming from the TGD based model of "cold fusion", one can estimate the length of dark flux tube inside solar core and it turns out to fill about 30 per cent of its volume, which is rather near to the maximal allow value and implies that dark nuclear strings must be taken into account.

One can relate the model also to the model for the formation of galaxies, stars, and planets [L43, L46, L30, L63] as tangles assignable to cosmic strings thickened to flux tubes implying the decay of their Kähler magnetic energy to ordinary matter in analogy with the decay of inflaton field and nice quantitative estimates follow. Also a connection with twistor lift of TGD predicting hierarchy of cosmological constants emerges and the radius of solar core turns out to corresponds to the value of cosmological constant implied by the amount of missing matter identified as dark matter at flux tubes.

14.2.1 Could "cold fusion" come in rescue?

TGD based on the model of "cold fusion" [L31] predicting that all elements can be produced by what I call dark fusion outside stellar cores could come in rescue.

1. Standard model has what I tend to see as a potential problem related to the temperature in the solar core. naïvely the nuclear fusion in stellar temperatures around 1.5×10^3 eV is not possible since nuclear binding energy scale is above MeV. Quantum tunneling is however

believed to make it possible to overcome the Coulomb wall. The main argument against "cold fusion" is that the colliding nuclei cannot overcome the Coulomb wall at room temperatures. TGD provides a mechanism allowing to overcome the problem [L31]. Could this mechanism be at work also in ordinary nuclear fusion in stars and make it possible outside stellar core?

2. The model relies on the notion of dark nuclei as dark nuclear strings [L2], flux tubes containing sequences of dark protons and neutrons and having non-standard value of effective Planck constant $h_{eff} = nh_0$. Also ordinary nuclei would be nuclear strings but for their dark variants the binding energies would scale like inverse of size scale and thus like $1/h_{eff}$. The binding energy scale would therefore be lower for dark nuclei and they could be formed at lower temperatures.

3. This suggests a model for pre-stellar evolution in which dark nuclei would be formed first. Their transformation to dark nuclei with smaller h_{eff}, even ordinary nuclei with $h_{eff} = h$, would liberate energy and cause heating making possible the fusion of dark nuclei with various values of h_{eff}. Eventually the temperature would reach the value making formation of ordinary nuclei possible. Heavier elements could be generated also outside stellar cores. Also now the mechanism would be formation of dark nuclei, possibly fusing to form heavier nuclei, and decaying to ordinary nuclei.

4. Dark nuclear physics would be present also at low temperatures. For instance, in Pollack effect [L9] [L9] dark nuclei could be formed at room temperature by irradiation of water in presence of gel. The transformation of dark nuclei to ordinary nuclei could explains the reported bio-fusion [C3, C17]. The dark nuclei would give rise to a realization of genetic codons in terms of linear dark proton triplets [L18]. Chemical codons would be kind of secondary representation.

In "cold fusion" [L31] dark nuclei would be formed in the similar manner and they could transform to ordinary nuclei liberating essentially entire nuclear binding energy. Could the ridiculed "cold fusion" provide a possible mechanism generating not only only the elements heavier Fe but all elements heavier than He outside stellar cores in the case that core consists of dark matter - and perhaps also in interstellar space? One can however counter argue.

1. Ordinary nuclear physics provides a well-tested description of fusion reactions in laboratory and the model based on "cold fusion" in TGD sense should be consistent with the standard model for cold fusion. In stellar core the temperature is however not much higher than $T \sim 1.5 \times 10^3$ eV. Tunnelling effect should be involved in an essential manner. These models are phenomenological potential models. What the TGD description of tunnelling could be?

   In TGD framework all quantum processes should have exact classical space-time correlates as space-time surfaces analogous to Bohr orbits, preferred extremals. Quantum state would be superposition of these. The first new elements would be the description of nuclear dynamics in terms of space-time surfaces obeying classical dynamics.

   By definition, tunnelling represents a process impossible classically. Could the TG counterpart of tunnelling involve a state function reduction creating a superposition of space-time surfaces for which tunnelling is replaced by a process possible classically? Could the tunnelling involve the formation of dark intermediate state with much smaller nuclear binding energy scale and its decay to the final state containing the fused nuclei?

2. What could the creation and decay of this dark intermediate state mean? If it corresponds to ordinary state function reduction, it means in zero energy ontology (ZEO) reverse the arrow of time. The recent strange findings of Minev *et al* [L68] about state function reduction in atomic systems provide rather strong support for ZEO based quantum measurement theory [L68], whose main justification is that it solves the basic paradox of quantum measurement theory.

   The time reversed zero energy state would be a superposition of preferred extremals starting from final dark nucleon state and going to geometric past and decay to state consisting of ordinary nucleons in accordance with the generalized second law.

   During subsequent time evolution by SSFRs as analogs of "weak" measurements nuclear fusion would occur easily due to the small binding energy.

After that second BSFR replacing the arrow of time with original one would occur and induce the decay of dark nuclei to ordinary nuclei including the fusion products. This process could take place also in "cold fusion". This description might make sense since also ordinary nuclei are in TGD framework string like entities [L2].

3. One must be however cautious here. One cannot exclude the possibility that also SSFRs increasing the value of h_{eff} could give rise to tunnelling but to me the proposed model looks more attractive.

   (a) ZEO based quantum measurement theory [L44] combined with $M^8 - H$ duality ($H = M^4 \times CP_2$) [L34] and number theoretic vision [L76, L75] leads to the view that preferred extremals in M^8 consists of a sequence of 4-D pieces glued together at preferred values of M^4 time $t = r_n$, which correspond to the roots of a polynomial with rational coefficients determining the extension of rationals characterizing the adele in adelic physics which can be seen as a fusion of real physics of sensory experience and various p-adic physics of cognition [L41, L42].

   This polynomial would determine octonionic polynomial as its analytic continuation in turn defining 4-D space-time surface in M^8 as an algebraic surface identified as a root of its "real" or "imaginary" part in quaternionic sense. The roots $t = r_n$ would correspond to special 6-D brane like solutions of the polynomial having topology and metric of 6-sphere S^6 and intersecting M^4 along the 3-ball $t = r_n, r < r_n$ defining a "special moment in the life of self" in TGD inspired theory of consciousness [L75].

   This surface would be mapped by $M^8 - H$ duality to a preferred extremal in H, which is minimal surface having string world sheets and partonic 2-surfaces as singularities. At the 2-D singularities 4-D quaternionic tangent or normal space in M^8 would degenerate to 2-D space.

   (b) One can say that incoming and outgoing space-time surfaces representing particles are glued together along their ends at these hyperplanes of M^4. These time values would naturally correspond to the time values at which SFRSs take place. SSFRs correspond to quantum measurements that commute with the observables, whose eigenstates the states the passive boundary of CD are. Time would be one of the observables measured in SSFR and involve temporal localization for the position of the active boundary of CD determining the size of CD.

4. The most conservative picture is that the existing nuclear physics deduced from laboratory experiments provides a faithful phenomenological description of nuclear physics of ordinary nuclei. However, if this picture is correct, nuclear fusion might occur also in the convective zone with dark fusion as intermediate step. One expects that the rate is very sensitive to the temperature and becomes very small near the surface of Sun. Dark fusion could increase the temperature and this could reduce the thickness of the convective zone deduced from the model of Asplund *et al* [E66, E247].

Could this model solve the metallicity problem?

1. In spectroscopic determinations only ordinary matter becomes visible. Also spectroscopic determinations detect only the ordinary matter. On the other hand, the intermediate states with non-standard value of Planck constant would be however real rather than virtual states. Therefore dark nuclear matter should be taken into account in the models the propagation of sound waves and photons in solar interior.

2. For sound wave propagation the time scale of propagation is much longer than the time scale assignable to the dark nuclei. This is the case also for photons with energies below the scale of dark nuclear energies if they have same value of h_{eff} and are thus dark. This would suggest that the density of dark nuclei contributes to the total density of nuclei deducible from the opacity, sound velocity, and density as parameters. The solar abundance problem would be thus provide direct evidence for dark matter in TGD sense.

3. Dark nuclei would correspond to magnetic flux tubes carrying dark nucleon sequences and the mass fraction of dark nuclei would correspond to the fraction of missing matter estimated to be 1500 Earth masses giving $M_D/M/ \sim 4 \times 10^{-3}$. The ratio of the dark metallicity to ordinary metallicity would be about 5/13 from the metallicities 1.3 per cent *resp.* 1.8 per cent deduced from spectroscopy *resp.* helio-seismology.

14.2.2 Evidence for the tunnelling of electrons in nanoscales

The proposed model would mean that dynamical tunnelling could have in TGD framework different description. Is there any empirical evidence for this prediction? There is a popular article in Phys.org describing a highly interesting finding (`https://tinyurl.com/ybkewpga`) made by condensed matter physicist Doug Natelson and his colleagues at Rice and the University of Colorado Boulder. Light emission associated with the tunnelling of electrons through a nano-scaled potential barrier between Gold electrodes has been observed. The intensity of emission is larger by factor 10,000 than predicted and this suggests new physics.

By definition tunnelling means that electrons get through the potential barrier without getting energy - classical picture would require this. Now it however seems that electron receives energy and the higher the barrier the larger energy is needed. Should one challenge the notion of tunnelling? Could it have a classical counterpart?

In TGD framework all quantum phenomena should have classical counterparts, also tunnelling. Therefore the tunnelling electron would somehow get energy to get over the potential barrier classically. I the case of nuclear reactions this energy would come from the

1. In zero energy ontology (ZEO) [L84] (`https://tinyurl.com/wd7sszo`) solving the basic problem of quantum measurement theory quantum states are superpositions of deterministic classical time evolutions, preferred extremals. Classical physics is exact part of quantum theory. The key prediction is that in ordinary, "big", state function reductions (BSFRs) the arrow of time is changed. In small SFRs (SSFRs) - analogs of weak measurements - this does not happen. ZEO leads to a theory of self-organization in which energy feed to self-organizing system corresponds to dissipation for time reversed state associated with dissipating system.

2. In ZEO tunnelling [L82] (`https://tinyurl.com/yyjy5e2r`) could mean that electrons make a BSFR reversing the arrow of time. In time reversed state they dissipate in reverse time direction: in standard time direction of observer they receive energy in standard time direction allowing them to get over the potential barrier. In the second BSFR establishing the original arrow of time they would liberate the energy and the higher the barrier, the larger the liberated energy and the brighter the light emission.

   The tunnelling in this sense would be already self-organization phenomenon involving BSFR. This dynamical tunnelling does not exclude the analog of wave-mechanical tunnelling as a non-dynamical process. The dynamical tunnelling could actually lead to asymptotic states in which particle is at both sides of the forbidden region or even in forbidden region but with extraction of classical energy from environment so high that this is not forbidden anymore.

14.2.3 Could Sun contain dark magnetic flux tubes carrying dark matter?

The proposal of metallicity problem proposed above relies on dark matter in TGD sense - that is as $h_{eff} = nh_0$ phases. TGD predicts however also galactic dark matter assignable to long cosmic strings which thicken to magnetic flux tubes during cosmic evolution. These objects carry dark energy as magnetic and volume energy and it might be that one should dark about galactic dark energy. They can carry also dark matter in TGD sense. In any case, they would produce ordinary matter and its dark variants as $h_{eff} = n \times h_0$ phases in the thickening process reducing string tension somewhat like the decay of inflaton field produces ordinary matter.

Galactic dark matter in TGD

Consider first the model for galactic dark matter in TGD

1. TGD explains galactic dark matter as being associated with long cosmic strings, which form tangles at which the cosmic string thickens to flux tube and part of its Kähler magnetic energy transforms to ordinary particles and creates the ordinary matter associated with galaxy (this might included also $h_{eff} = nh_0$ phases which also behave like dark matter whereas galactic dark matter could correspond to dark energy alone). The thickening however generates volume energy and the process must stop.

   A phase transition reducing the value of thel ength scale dependent cosmological constant proportional to the inverse square of p-adic length scale $L_p \propto \sqrt{p}$, $p \simeq 2^k$ [K72], and thus reducing the contribution of volume energy however initiates the expansion again. Accelerating cosmological expansion and inflationary cosmology would represent examples of these accelerating periods. This gives a sequence of expansion period first accelerating and then decelerating. The values of cosmological constant and string tension come in some powers of 2. $T_{tube} = 2^{-k}T_{max}$, $k > 0$ some integer. In this picture cosmological expansion would mean generation of space-time sheets with larger size scales and smaller cosmological constant but also the space-time sheets with smaller cosmological constant would be present unlike in standard cosmology.

2. This model assigns galactic dark matter with long cosmic strings and automatically predicts flat velocity spectrum with velocity proportional to $\sqrt{T_{tube}G}$, T_{tube} string tension. It also explains the old observation that galaxies form long linear structures.

   Here one must stop and ask what string tension does mean. T_{tube} has been taken to mean classical string tension determined by the Kähler magnetic energy and volume energy. What about the contribution of dark matter inside flux tube and consisting at fundamental level of quarks? Should one count it separately? Or does quantum classical correspondence (QCC) imply that the classical contribution is equal to the quantum contribution? QCC as basic principle of TGD indeed suggests that the latter option is correct. But does this mean that dark matter and dark energy in TGD sense should be regarded as equivalent?

3. The fractality of TGD Universe suggests that stars and even planets are sub-tangles of the tangles associated with galaxies. Even the TGD counterparts of galactic magnetic fields as flux tube structures could be understood as tangles resembling field line structures of dipole magnetic field. This could apply to stars and even planets. Stars and planets emerge at later stages of cosmic evolution so that one would have $T_{tube} << T_{max}$. One would have fractal structure: tangles along tangles along ...

Could solar core contain dark matter as dark nuclear strings at magnetic flux tubes?

The proposed explanation assumes that dark nuclear strings assignable to magnetic flux tubes define the intermediate states providing the TGD counterpart of quantum tunnelling impossible in TGD The flux tubes would be generated by the thickening of cosmic strings during cosmic evolution and it is interesting to look whether this picture conforms with this model.

1. The expression for string tension T_{max} for cosmic string as an object of form $X^4 = X^2 \times S^2 \subset M^4 \times CP_2$, where X^2 is minimal surface and S^2 is homologically non-trivial geodesic sphere, is deduced in [K93] and is given by

   $$T_{max} = \frac{1}{8\alpha_K R^2_{CP_2}} \quad .$$

   Here one assumes that only Kähler action contributes. The volume contribution is expected to be of same order of magnitude and of the same sign since in twistor lift volume contribution is also essentially magnetic energy. For $\alpha_K = 1/137$ and $R^2_{CP_2} \sim 10^7 G$ one would obtain $T_{max} \sim 10^{-6}/G$.

   p-Adic length scale hypothesis suggests that the thickening reduces T_{tube} by powers of 2 in equilibria in which magnetic energy does not transform to particles anymore. Note that the decay of magnetic energy to particles is analog for the decay of inflaton field in inflationary cosmology.

2. To get an idea about the value of reduced string tension T_{tube}, one can estimate the mass of a straight string portion with length of solar diameter $D(Sun) = 2R(Sun) = 1.4 \times 10^6$ km going through the Sun and having string tension $T_{tube} = T_{max}$. Solar mass $M(Sun)$ corresponds to a blackhole with Schwartschild radius $R_S \sim 3$ km. Solar diameter corresponds $D(Sun) = 2R(Sun) \sim .46 \times 10^6 \times R_S$.

   For $T_{max} \sim 10^{-6}/G$ and for $D(Sun) = 2R(Sun)$ the mass of straight string portion the mass would be about $2.3M(Sun)$. This option would suggest that a portion of long string with length of solar diameter of Sun and having solar mass has thickened to a flux tube forming a tangle filling the entire Sun and perhaps also the Kähler magnetic flux tubes assignable to the solar magnetic field.

3. If only the solar mass has been produced by the transformation of the dark energy of cosmic string to particles and dark flux tubes, the string tension should be corrected to $T_{max}/2.3$ to give just the solar mass. The mass for the portion contained in the core would be $M(Core) \sim 8 \times 10^{-3}M(Sun)$, which is roughly twice the estimated missing mass if it is 1500 Earth's masses mentioned in the popular article would correspond to a fraction of 4.5×10^{-3} of solar mass. My own estimate gave roughly twice this value, which happens to co-incide with the above value. Is this a mere co-incidence?

4. The discrepancy could be resolved by assuming that the flux tube has formed a tangle extending outside Sun. Roughly half of the flux tube mass should go to the tangle outside Sun. The general proposal indeed is that the tangle represents also the Kähler magnetic field of Sun. It could even give rise to the planetary tangles.

One can imagine two extreme options.

1. The thickness of the flux tube would be very small in the core for $T_{tube} = T_{max}/4$. For T_{tube} not much smaller than $T_{max}/4$ it would take negligibly small volume and could not have strong effects on opacity, acoustic properties, and nuclear fusion by the proposed counterpart of tunnelling. This option seems to be excluded.

2. If the flux tube is strongly thickened and has thus small T_{tube} it must be much be considerably longer than core diameter and thus form a spaghetti like structure filling a considerable portion of the volume of core. Filling fraction must be however smaller than 1. This could increase opacity and modify acoustic properties, and most importantly make possible nuclear fusion. The thickened flux tube would serve as seat of dark nuclei and give rise to dark nuclear strings. This option is favored by the proposed solution of the abundance problem.

Consider now a more detailed estimate.

1. The model for "cold fusion" [L31] suggests that at least in this case the flux tube thickness corresponds to electronic Compton to which one can assign Mersenne prime $M_{127} = 2^{127} - 1$. A good guess is that this is the case also in nuclear core.

   One would have $L_e \simeq \sqrt{5}L(127) = 2.4 \times 10^{-12}$ meters assignable to electrons essentially equal to the electron Compton length about 10^{-12} meters. The p-adic length scale assignable to proton and neutron corresponds to $L(107)$ and if this scale characterizes also the nuclear strings, the scaling of the nuclear flux tube thickness would be roughly by a factor $\sqrt{5} \times 2^k$, $k = (127 - 107)/2 = 2^{10}$, giving roughly the scaling factor 2^{11}.

   The ratio of the flux tube thickness to the thickness of cosmic string given by $R_(CP_2) \simeq 10^{3.5}L_{Pl}$, where L_{Pl} is Planck length, would be roughly the ratio $L_e/R_{CP_2} \sim 4.7 \times 10^{19}$. The string tension of cosmic strings would be reduced by a factor of order $L_e^2/R_{CP_2}^2 \sim .45 \times 10^{-39}$. The reduction of string tension from the estimate for T_{max} to L_e^2 would give 10 times larger estimate $L_e^2 T_{max} \sim 4.5 \times 10^{-39}$.

2. If nuclear binding energy scales like inverse of p-adic length scale $L(k)$, the nuclear binding energy scale would be reduced roughly by the ratio L_p/L_e of Compton length scales of proton and electron scaling roughly by a factor $m_e/m_p \sim 2^{-11}$ from the maximal value about 7 MeV to 3.5 keV. The temperature of the solar core corresponds to thermal energy larger than 1.5 keV. Thus the "cold fusion" inspired estimate for the flux tube thickness seems to make sense.

3. The condition that string tension is $T_{tube} \sim 1/L_e^2$ and the dark mass is about $M_D \sim 4 \times 10^{-3} M(Sun)$ gives and estimate for the length L_{tube} of the flux tube inside solar core from the equation

$$T_{tube} L_{tube} \sim \frac{L_{tube}}{L_e^2} \sim M_D \sim 4 \times 10^{-3} M(Sun) \sim T_{max} R(core) \ . \tag{14.2.1}$$

This gives for L_{tube} the estimate

$$L_{tube} = L_e^2 T_{max} R(core) \tag{14.2.2}$$

giving

$$\frac{L_{tube}}{R(core)} = L_e^2 T_{max} \sim 2.2 \times 10^{39} \tag{14.2.3}$$

using the earlier estimate.

4. Does this make sense? In other words, is the volume fraction filled by the flux tube smaller than one? The fractional volume taken by the flux tube of transversal area $S \sim \pi L_e^2$ would be

$$\frac{V_{tube}}{V_{core}} \sim \frac{3}{4} \frac{L_{tube} L_e^2}{R(core)^3} = \frac{3}{4} L_e^2 T_{max} \frac{L_e^2}{R(core)^2} \sim .3 \tag{14.2.4}$$

for $R(core) = 1.4 \times 10^5$ km. 30 per cent of volume would be filled by flux tube so that dark nuclear physics would be important and could explain the missing mass. This estimate is rough but suggests that the model might work.

One can look the situation from the viewpoint of twistor lift predicting a hierarchy of cosmological constants depending on the p-adic length scale [L43, L64, L62, L88, L89].

1. The value of the cosmological constant in cosmic scales would correspond to an effective volume energy density proportional to $1/GL_{p_H}^2$ with $L_{p_H} \sim 10^9$ ly H refers to "horizon". The effective volume energy density could be expressed at GRT limit as proportional to $1/L_{p(small)}^4$. One has $L_{p(small)} \sim L_{neuron} \sim 10^{-4}$ m, the size scale of large neuron, which suggests a connection between cosmology and quantum biology. $1/L_{neuron}^2$ defines order of magnitude for string tension of the flux tubes involved and having thickness of order $1/L_{neuron}^2$.

2. In the case of nuclear flux tubes in solar core the dark energy density in scale of large neuron would be larger by fact L_{neuron}^4/L_e^4 by a factor of order 10^{-32}. The scale L_{p_H} defining scale of horizon would be reduced by factor of order 10^{-16} from its cosmological value $L_{p_H} \sim 10^9$ ly to $L_{p_H} \sim 2.5 \times 10^8$ m to be compared with the radius $R(core) \sim 1.4 \times 10^8$ meters of the solar core. In many-sheeted cosmology nuclear core could be seen as scaled down cosmology.

To sum up, these estimates are rough and involve numerical factors but it seems to me that the model survives the simplest quantitative tests.

Is there a relation to the model of solar dark matter inspired by Nottale's proposal?

One can look the situation also in the TGD based model of solar dark matter [K93, K11] [L50, L49] inspired Nottale's proposal [E87] that planetary orbits could be interpreted as Bohr orbits. In TGD framework the Bohr orbits could be assigned with dark matter accompanying ordinary planetary matter perhaps assignable as distributions with the flux tubes along orbits.

First a couple of general comments about the TGD variant of the generalization of the model of Nottale to TGD framework.

1. What is new that the perturbative expansion for scattering amplitudes would be in powers of the gravitational analog of fine structure constant equal to $GMm/\hbar_{gr}(M,m) = v_0/c < 1$ and is expected to converge. This would make possible quantal perturbation theory for $GMm >> 1$.

2. Since the orbital radii do not depend at all on M (by Equivalence Principle dictating the form of h_{gr}) one can imagine decomposing m as $m = \sum m_i$. One indeed expects that gravitational flux tubes with a spectrum of $h_{eff} = h_{gr}$ is involved.

3. Can one assume that flux tube connects masses M and m forming its ends or does m correspond to space-time sheet having wormhole contacts with the gravitational flux tubes rather than serving as the end of flux tube? For the first option one would have decomposition to $M = \sum M_i$ to dark parts M_i and $m = \sum m_i$ with $\hbar_{gr} = GM_im/v_0(M_i, m_i)$ at corresponding flux tubes connecting them to masses m at orbit with given radius. One would have partitioning of M and m to interacting pairs. There would be no gravitational interaction between M_i and m_j for $i \neq j$, and this does not conform with the universality of gravitational interaction.

   Note that would differentiate between gauge interactions and gravitational interactions. For the gauge of gauge interactions one could say that the flux tube as wormhole throats as its ends and there would be screening. Note however that flux tubes carrying monopole must be closed, and could be 2-sheeted with return flux going to a parallel sheet through wormhole contact and returning along it.

Consider now the possible relationship with the proposal that solar core carries dark matter.

1. $v_0 = 2^{-11}c$ appears as a velocity type parameter in the Bohr orbit model for planetary system proposed first by Nottale and later developed in TGD further [K93, K79, K11] [L50, L49]. The value of the gravitational Planck constant $h_{eff} = nh_0$ for the dark flux tubes mediating gravitational interaction between large mass M and small mass m would be $\hbar_{eff} = \hbar_{gr} = GMm/v_0$. M would be solar mass. By Equivalence Principle m can the mass of the planet or of any particle composing it. $v_0/c \simeq 2^{-11}$ is the value required for the 4 inner planets.

2. The article mentions also the value of $M_D/M \sim 2^{-11}$ for the fraction of dark matter in the solar core. One would have $M_D/M = v_0/c$: is this mere accident? Notice however the value $M_D/M \sim 4\times 2^{-11}$ is from $M_D = 1500$ Earth masses and my own estimate $M_D/M \sim 2\times 2^{-11}$. I

   If one takes these estimates seriously, it would seem that the value of v_0/c in the core is larger than outside Sun. In this case flux tubes are longer and since flux tube length as quantal length is expected to increase with h_{gr}, one expects that h_{gr} is larger. Indeed, for the outer planets the Nottale model requires $v_0 \rightarrow v_0/5$.

What about galaxies?

I have proposed that this general vision applies also to the formation of spiral galaxies. This can be tested in the case of Milky Way at order of magnitude level.

1. The mass $M(gal)$ of the Milky way is estimated to be in the range $[.8, 4.5] \times 10^{12} M(Sun)$. For a string with maximal string tension this would correspond to a direct string portion with length $L(gal) = M(gal)/R(Sun) = M(gal)/M(Sun)$. In fact, this stringy mass formula is known to hold for quite a many astrophysical objects as I learned decades ago in a particle

physics conference - in good old times times particle physics conferences allowed non-main-stream talks during the last conference day. This gives the estimate $L(gal) \in [.6, 3.3] \times 10^5$ ly. The radius R_{gal} of galaxy is estimated to be in the range $[.75, 1.0] \times 10^5$ ly. The length of string within galactic radius would satisfy $L_{gal} = [.8, 3.3] R_{gal}$. The estimate excludes the lower bound. For the upper bound the one has $L_{gal} \sim 3.3 \times R_{gal}$.

The thickness of the Milky Way is about 2×10^3 ly which suggests that the portion of long string making galaxy is soaked up to the galactic plane [L63].

The supermassive blackhole in the galactic center is estimated to have mass $M(BH) = 4 \times 10^6 \times M(Sun)$. By scaling this would correspond to a straight cosmic string portion with length $L_{BH} \sim .1$ ly. The size of the galactic blackhole (see `http://tinyurl.com/od3spdu`) is $R_{S,BH} \sim 4.4 \times 10^{-5}$ ly giving $R_{S,BH}/L_{gal} \sim 4.4 \times 10^{-4}$. One has $T_{max} \sim 10^{-6}/G$ and blackhole corresponds effectively to a string with tension $T_G \sim 1/2G$ and length $R_{S,BH}$ so that the ratio would be $R_{S,BH}/L_{gal} \sim 2G/T_{max} \sim 2 \times 10^{-6}$. The straight string with length L_{BH} would have been compressed to a volume of Schwartchild radius $R_{B,S} \sim 2^{-11} L_{BH}$.

2. Could the spiral structure of spiral galaxies involving several spiral correspond to a rotating cosmic string thickened to a flux tube? The original model for the spiral structure as a cosmic string at rest in in Robertson-Walker coordinates and seemingly rotating in linear Minkowski coordinates failed [K31] since it predicted too weak spiralling. The observed spiral structure could however corresponds to a thickened dark flux tube with lower string tension and longer length.

   If so the length of the original spiral should be about $L_{gal} = 3.3 \times R_{gal}$. Perhaps the primordial configuration of the dark flux tube could be modelled as a cosmic string solution at rest in Robertson-Walker coordinates, which then thickened and gained length becoming more spiral.

3. For elliptic galaxies (see `http://tinyurl.com/ayyvg9n`) the sizes vary in the range $3 \times 10^3 - 7 \times 10^5$ ly (roughly 2 orders of magnitude) and masses in the range $[10^5, 10^{13}]$ ly (8 orders of magnitude!) so that linear relationship between size and mass is excluded. The length $L(gal)$ of the original straight string would be in the range $[10^{-8}, 7.4 \times 10^5]$ ly giving $L_{gal} \in [.3 \times 10^{-6}, 1.0] \times R_{gal}$. Thus elliptical cannot correspond to cosmic strings. At the upper limit elliptic galaxy could correspond to straight cosmic string and the visible matter would not come from the decay of the cosmic string. This estimate conforms with the earlier proposal that only spiral galaxies correspond to cosmic strings.

14.3 Some anomalies of astrophysics from TGD point of view

In the following some anomalous findings of astrophysics are discussed from TGD point of view.

14.3.1 Youthful Oldies

I received very interesting link (see `http://tinyurl.com/ryg2g3l`) to findings challenging the standard beliefs about the formation of stars and at the same time nuclear physics and providing support for the proposed picture about nuclear fusion [E102].

The standard story about formation of stars goes as follows. Nuclear fusion at the cores of stars produced the elements. In the first stars only light elements were formed and spewed out in supernova explosion to get gathered to the stars of next generation able to produce heavier elements. The elements heavier than Fe were not produced in stellar interiors since this was not energetically possible. One would expect that in very early Universe in which only few generations of stars had been present, the interstellar clouds would contain only light elements.

This story can be compared to empirical facts by observing quasars emitting light with huge intensity coming from cosmic gas clouds. The light from quasars reveals their chemical composition via absorption lines. The researches (Eduardo Banados, Michael Rauch and Tom Cooper) were able to identify 13 billion year old cosmic clouds formed 850 million years after

Big Bang and study their spectroscopy. The work is published in The Astrophysical Journal (see `http://tinyurl.com/qkk26dv`).

The surprising finding was that the abundances of elements look very modern, they are very much like those in the cosmic clouds formed several billion years later. The conclusion is that the first generation of stars formed more quickly than believed and were already expired before the formation of the cosmic clouds so that the clouds would consist of chemical products of much later star generations even before the galaxies were in place.

To me this interpretation does not look convincing. For me these findings represent a further challenge for nuclear physics as we believe it to be. Let us list some shortcoming of the standard nuclear physics first.

1. The formation of elements heavier than Fe is still poorly understood. No evidence for the R-process in supernovae was found in the case of SN1987A. There is no generally accepted model for the production of elements heavier than Fe.

2. Even worse, nuclear fusion inside solar stars thought to be thoroughly understood, has a 10 year old anomaly [E66, E247]. The abundances of elements are higher in the interior than they should be (see `http://tinyurl.com/yyjy5e2r`). This is really serious anomaly and challenges the foundations of nuclear physics - in particular the idealization of nucleons with point like particles and use of potential models and the notion of tunnelling which is central for understanding nuclear fusion [L82].

3. There is also "cold fusion" or LENR, which is a fact but still not admitted by the mainstream [L31, L10, L67] (see `http://tinyurl.com/y7u5v7j4`) and `http://tinyurl.com/tqgwmz7`). The essential aspects are production of heat energy and transmutations.

4. The observed abundances of Li, Be, and B cannot be explained in terms of production in Big Bang, stellar interiors or in supernovas. It is not that the abundances were too low: they are quite too high. The amount of ^{6}Li and ^{7}Li produced in big bang nucleosynthesis (BBNC, see `http://tinyurl.com/qczc8ty`) have been found empirically to be near the correct values in the early Universe and the amount of Li approaches to constant for low-metallicity stars (first star generations) although the amount of ^{7}Li is too small by a factor of 1/3 at least (see `http://tinyurl.com/vwcfujb`).

   Li is however unstable in the stellar cores and is destroyed there since Li cannot survive in the high temperature of solar core and there is no manner to create it since the intermediate isotopes giving rise to them by decay are very short lived. Same applies to Be and B. The problem is that the amounts of Li, Be, and B in the recent Universe are too high. This is of course highly desirable from the point of view of living systems.

   The official explanation discussed is based on the notion of spallation (see `http://tinyurl.com/smgmvgf`). The collisions of very energetic cosmic rays with heavy nuclei would induce their decay to smaller ones and produce Li, Be, and B. There are many uncertainties involved so that taking this mechanism seriously remains a matter of belief. TGD proposal is "cold fusion" outside stellar interiors as a produced of Li, Be, and B. This mechanism might also relate to the ^{7}Li puzzle.

TGD based model of "cold fusion" leads also to a modification of standard view about what happens ordinary nuclear fusion.

1. The tunnelling is central element in ordinary nuclear fusion and is replaced by a new mechanism involving in an essential manner the geometrodynamics of space-time as a surface in $M^4 \times CP_2$ and new view about quantum theory and dark matter residing at monopole magnetic flux tubes. The mechanism of "cold fusion" relies on the formation of dark protons sequences at magnetic flux tubes giving rise to dark nuclei with much smaller nuclear binding energy. These decay spontaneously to ordinary nuclei and liberate almost all nuclear binding energy leading to the heating and transmutations.

2. Besides ordinary nuclei also their dark variants as phases having effective Planck constant $h_{eff} = n \times h_0$ are present in solar interior and contribute to the abundances deduced from helioseismic data.

3. The view about pre-stellar evolution changes. "Cold fusion" in near to the surface region of star precedes ordinary fusion and serves as "warmup band" heating the matter to temperatures of ordinary nuclear fusion.

   "Cold fusion" as induced by dark fusion becomes an important contributor to the production of also heavier elements formed already before the hot fusion in the solar core has started. This mechanism works also outside stars and the elemental abundances could be almost universal having very little to do with the nuclear physics in the stellar interior.

The basic prediction is that the spectroscopic signatures for the star would not depend much on the generation of the star. Therefore also the spectroscopy of cosmic clouds would be almost independent of their age.

14.3.2 Helium problem and CNO problem: two anomalies explained by dark fusion

Helium problem [E234] (http://tinyurl.com/r3xqebt) means that there are stars with very low Helium content in the very early Universe. The predicted content is 3 times higher. This suggests that the view about Big Bang Nucleosynthesis (BBN) is not quite correct. If the BBN abundance is one third from the accepted, there must be an additional mechanism producing He and it cannot be stellar fusion.

The popular article "*Astronomers detect very unusual chemical composition in ancient star's atmosphere*" (http://tinyurl.com/rhsqk8g tells about unexpectedly high C, N, and O contents in the atmosphere of one of the oldest and most elementally depleted stars known - a "primitive star" scientists call J0815+4729 representing. For a more technical representation see the original article [E96] (http://tinyurl.com/u3rrnn9). This finding obviously challenges the views about stellar nuclear fusion since the star in question is very young star and the element abundances should be near to those produced in BBN. Note however that the elemental abundances are associated with atmosphere of the star. Could there be a variant of fusion process taking place outside the stellar cores?

TGD predicts new nuclear physics, which could explain these anomalies. I have already earlier considered explanation of various anomalies [L74] (http://tinyurl.com/slyo8p3). These two anomalies are only additional items in a long list.

"Cold fusion" researchers, originally labelled as swindlers and crackpots, are nowadays regarded respectable scientists. Genuine cold fusion not allowed by standard nuclear physics is not in question and "low energy nuclear reactions" (LENR) is a politically more correct expression. "Nuclear transmutation" is also a term used.

In TGD framework "cold fusion" is replaced by dark fusion involving generation of dark proton strings (some protons can transform to neutrons) having interpretation as dark nuclei [L31, L10] (http://tinyurl.com/y7u5v7j4 and http://tinyurl.com/y2v3qn6a). They would have non-standard value $h_{eff} = n \times h_0$ of effective Planck constant and would be formed of protons directly because of thei large Compton length. Dark nuclei can transform to ordinary nuclei. This would give rise to "cold fusion".

2. Dark fusion would precede ordinary nuclear fusion occurring in the cores of stars and contribute to the nuclear abundances and modify the predictions of bigbang fusion and stellar fusion and explain a long list of astrophysics anomalies. Also the theory of ordinary hot fusion would be changed and solve the 10 year old anomaly related to metallic abundances identified by Asplund *et al* [E66, E247] [L82]. The fusion reactions could occur via a creation of dark nuclei - rather than via tunnelling - and the dark nuclei would read and reaction products would tranform back to ordinary nuclei.

3. The model change the view about the prestellar period of stars. "Cold fusion" in TGD sense would serve as a "warm-up band" and the energy liberated as dark nuclei generated from protons transform to ordinary nuclei would transform to ordinary nuclei and gradually heat the matter so that ordinary nuclear physics enters in the game and stellar core is born. The dark fusion generates nuclei with all nuclear weights.

How could understand the two anomalies in terms of dark fusion? Consider first the Helium content of the early Universe.

1. Light elements D, T, He, Be would have been produced during by Big Bang Nucleosynthesis (BBN) during first few minutes (http://tinyurl.com/qczc8ty and http://tinyurl.com/vr7ctaq). The production ceased as the temperature became too low for nuclear reactions to occur. Nuclear reactions started again in the stellar cores and according to the prevailing wisdom produced the heavier elements.

   The relative abundance of Helium (which cannot be produced in stellar interiors), estimated to be about 25 per cent, would be determined by BBN. He abundance depends on the density protons and the exact value of Hubble constant determining the expansion rate. It is possible to vary these parameters so that the observed value of He abundance (difficult to observe, for instance for Sun it is not known) is taken as the input.

2. Giving up entire Big Bang theory (BB) is not a plausible idea. One can modify the parameters of BB to obtain a lower amount of Helium. This however requires an additional fusion mechanism, which must have been at work outside stellar cores and produced higher He content outside stars after BB.

   The contribution of dark fusion tends to increase the abundances determined by BBN. The amount of Helium produced in BBN should be considerably lower than believed and Helium poor stars would provide a better upper bound for He produced in BB. The amount of He would increase at least by a factor 3 by the production during pre-stellar periods by dark fusion. This implies that the density fraction of baryonic matter - few per cent in standard picture - would have been even lower. This does not seem to be a problem.

Dark fusion outside stellar interiors could also explain the anomalously high CNO content in the atmospheres of stars as being due to the prestellar period and have nothing to do with the physics in the stellar cores. Exceptionally high C, N, and O abundances would be produced by dark fusion outside stellar interiors - such as stellar atmospheres - and relate to the warm-up period.

What is intriguing C, N, and O playing a central role in biology are involved. There is evidence for bio-fusion [C3, C17] - not taken seriously by the mainstream - and since Pollack effect [L9] generating dark nuclei at room temperature in presence of say solar radiation, is central in TGD based quantum biology, dark fusion producing ordinary nuclei in living matter is predicted [L31].

14.3.3 Basic organic molecules emerge much earlier than they should

Nikolina Benedikovic gave a link to an interesting popular article (https://tinyurl.com/y7eqzjqz) about the appearance of pre-biotic molecules in stellar nurseries at time when star formation had not yet begun. The article told about the work work of astrophysicists Yancy Shirley and Samantha Scibelli [E239] (https://arxiv.org/abs/2002.02469) published in Astrophysical Journal with the title "*Prevalence of Complex Organic Molecules in Starless and Prestellar Cores within the Taurus Molecular Cloud*" .

The stellar nursery studied consisted of 31 starless cores scattered throughout a star-forming region in Taurus molecular cloud located about 440 ly from Earth. The molecules studied were methanol (CH_3O-H) and acetaldehyde (CH_3CH=O). These molecules serving as building bricks for chemical life were found to be much more ubiquitous than expected and present hundreds of thousands of years before star formation actually began.

The molecular evolution producing complex organic molecules requires the analog of metabolic energy feed: the temperature should be quite high - measured using molecular binding energies as scale - about few eV typically. The existing theories assume that proto-stars - stars in the process of formation produced the heating necessary for the formation of these molecules. But in regions without proto-stars the temperature of gas has been quite to provide the heating. Where did the energy needed for local heating come from?

TGD based view about "cold fusion" - which during last years has been getting rid of the label of pseudoscience - is that it is induced by what I call dark nuclear fusion possible at low temperatures [K25] (https://tinyurl.com/yd336epx). Dark matter corresponds in TGD Universe to ordinary particles but with non-standard value of Planck constant (or cautiously effective Planck constant) $h_{eff} = nh_0$ larger than $h = 6h_0$ [L23, L54, L96].

Dark nuclei formed as dark proton sequences at magnetic flux tubes with protons having distance about electron Compton length and scaled down nuclear binding energy in eV scale would have formed at temperatures of order eV or even lower. They would have spontaneously decayed to ordinary nuclei liberating energy of order nuclear binding energy, which is in MeV scale. The dark nuclei can actually occur in several scales but could transform sequentially to ordinary nuclei. The liberated nuclear binding energy would have heated the gas locally. This kind of regions would have served as pre-stellar objects leading to protostars and eventually stellar cores as ordinary nuclear reactions would have started.

TGD predicts that alsoordinary nuclear reactions are initiated by phase transitions generating dark nuclei as intermediate states: this would be the counterpart for quantum tunneling assumed to take place in ordinary nuclear reactions and allow them to already occur at collision energies about 1/100 lower than classical considerations would allow (see for instance [L82, L94] (https://tinyurl.com/yyjy5e2r, https://tinyurl.com/s8gzrf).

14.3.4 Hyperon problem of neutron star physics

Hyperon problem (https://cutt.ly/NQWZKvZ) is a mystery related to the physics of neutron stars. In neutron star neutrons temperature is zero in good approximation and Fermi statistics implies that the all states characterized by momentum and spin are filled up to maximum energy, known as Fermi energy E_F identifiable as a chemical potential determined by the number density of fermions.

The increase of density inside a neutron star increases the total Fermi energy. Above a critical Fermi temperature possible in the core of the neutron star, the transformation of neutrons to hyperons which are baryons with some strange quarks becomes possible. λ hyperon with mass about 10 percent higher than neutron mass becomes possible. In a thermo-dynamical equilibrium the chemical potentials of hyperons and neutrons are identical. Note that chemical potentials are in a good approximation Fermi energies at zero temperature.

If part of neutrons transform to hyperons, the total energy decreases since the Fermi energy scales like 1/mass. One therefore expects the presence of hyperons in the cores of neutron stars, where the density and therefore also Fermi energy is high enough. The problem is that the maximal mass for known stars is above the maximal mass expected if hyperon fraction is present. Hyperon cores seem to be absent.

If further neutrons are added part of them transforms to hyperons and eventually all particles transform to neutrons and one can even think of the doomsday option that all matter transforms to hyperon stars.

Can one imagine any manner to prevent the formation of the hyperon core? Could the Fermi energy in the core remain below the needed critical Fermi energy by some new physics mechanism.

1. Apart from numerical constants, the Fermi energy for effectively n-D system is given by $E_F = \hbar;^2 k_F^2/2$, where k_F is some power $(N/V_n)^{2/n}$ of number density, where V_n refers to volume, area, or length for $n = 3, 2, 1$. Since zero temperature approximation is good, Fermi energy depends only on the density.

2. Could one think that part of neutrons transforms to dark neutrons in the transformation $h_{eff} \rightarrow kh_{eff}$ such that neither mass, energy, and Fermi energy are not affected but that wavelength is scaled up as also the volume. For an effectively 3-D system, dark neutrons would occupy a volume which is scaled up by factor k^3.

3. The Fermi energies as chemical potentials for both ordinary neutrons and their dark variants could remain the same in thermal equilibrium and remain below the critical value so that the transformation to hyperons would not take place? The condition that Fermi energies are the same implies that the numbers of ordinary and dark neutrons are the same. This would reduce individual Fermi energies by a factor $1/2^{2/3}$ but is only a temporary solution.

   One can however introduce phases with M different values of h_{eff} and in this case the reduction of Fermi energies is $1/M^{2/3}$.

4. Fermi statistics might however pose a problem. The second quantization of the induced spinor fields at the space-time surface is induced by the second quantization of free spinor fields in the embedding space $M^4 \times CP_2$. Could the CP_2 degrees of freedom give additional degrees of freedom realized as many-sheeted structures allowing to avoid the problems with Fermi statistics?

14.4 Conclusions

First a general comment about nuclear physics, which applies with appropriate modifications also to the evolution of theoretical particle physics (or lack of it) after the emergence of standard model followed by GUTS and superstring models.

1. One can see the standard nuclear physics as a tragic Odysseia due to the stubborn sticking to the naïve length scale reductionism. All began with the modelling of nucleons as point like particles inspired by the successes of atomic physics. It turned out that the model for nucleons as point like particles failed and we still do not understand low energy nuclear physics. The wave-mechanical potential models and QFT models assuming the notion of point-like nucleon led to an inflation of nuclear models each of them explaining some aspects of nuclei but a real theory is still missing.

2. Dark nuclear physics was originally suggested in TGD framework to explain "cold fusion" and later conjectured to allow the understanding of pre-stellar evolution as a step-wise process leading to the gradual heating of matter leading to nuclear fusion. The model relies on nuclear strings and their dark variants as dark nuclear matter. In this article it is argued that this picture leads to a realistic model of nuclear fusion and of stellar core and perhaps entire stellar interior as a dark spaghetti like structure. Ironically, "cold fusion" researchers regarded for decades as the pariahs of physics community, would show the path to follow.

The proposed model involves several new deep ideas inspired by the fusion of general TGD based visions about nuclear physics on one hand and about the formation of galaxies, stars, and planets on the other hand. Behind both visions is the notion about fractal hierarchy of flux tubes formed from cosmic strings by gradual thickening during the cosmic evolution. A further important piece is ZEO based view about quantum state and quantum measurement forcing to modify ordinary quantum mechanical description.

1. The idea is that Sun and its Kähler magnetic field form a sub-tangle of the galactic tangle associated with a long cosmic string and extending outside Sun, and perhaps including also planets as sub-tangles. This can be made more precise by assuming that total mass of the straight cosmic string portion involved equals to the total mass of the system considered. The estimate from the diameter of Sun suggests that the total mass is few times the solar mass. This model connects closely with the problem of cosmological constant solved by the twistor lift of TGD and solar physics can be associated with one particular value of length scale dependent cosmological constant: also this idea forced by TGD is revolutionary.

2. Quantum classical correspondence stating that quantum states are superpositions of Bohr orbit like preferred extremals challenges the idea about tunnelling as an essential element of nuclear physics. The first option is that BSFR - identified as ordinary $\rightarrow$ dark phase transition increasing the value of h_{eff} and involving time reversal followed by its reversal - allows wave-mechanical tunnelling as an approximate description. An alternative realization encouraged by M^8-H duality would be as SSFR involving no time reversal but discontinuity at the level of space-time development involving TGD counterparts of branes. This option resonates with the idea about sequence of SRFFs as TGD counterpart of a unitary time evolution suggested by the wave mechanical model. In any case, both TGD view about dark matter and ZEO would become part of nuclear physics, and mean giving up standard ontology and standard wave mechanics as a description of nuclei.

   It would not be surprising if similar view about tunnelling could apply also to particle reactions and I have proposed that dark variants of nuclei of M_{89} hadron physics as scaled variant of ordinary M_{107} hadron physics have made themselves visible via the observed (but neglected) bumps with masses obtained by scaling up the masses of ordinary mesons by factor 512 [K68]. Tunnelling would be now from ordinary hadron physics to dark M_{89} hadron physics.

3. When one has paradox, one knows that something is wrong with the basic conceptualization. The presence of dark variants of nuclei makes itself directly visible via the conflict between metallicities deduced from spectroscopy and meteorite abundances and those derived from helio-seismology and solar neutrino physics. Besides ordinary nuclei also their dark variants would present and contribute to metallicity in the solar interior.

Chapter 15

Comparing Electric Universe hypothesis and TGD

15.1 Introduction

I have encountered the notion of Electric Universe (EU) several times during the years. Rational Wiki (see `http://tinyurl.com/y847jn6w`) describes EU as pseudoscience claiming that the formation and evolution can be better explaining by electricity and magnetism than by gravity alone as the standard belief goes. Aether is also reported to be part of the theory and have elements from mythology.

One must be however very cautious with these kind of highly negatively emotional articles pretending to represent balanced and objective scientific statements. The words crank and crackpot appeared quite too often in them, and when the entire article is collection of emotionally negative associations about people behind EU than the contents of EU itself, one knows that this is not science.

I have become during last 42 years very familiar with people calling themselves "skeptics" and therefore I decided to to take a more analytic approach and concentrate on "than in terms of gravitation alone". This tells the reductionistic motivations of the author. Author has decided cosmology and astrophysics can be described in terms of gravitation only: the proposal that electromagnetism could be involved, is pseudoscience. The article is only part of battle between different world vires. It is already now clear that one day "gravitation alone" hypothesis will be regarded comparable to the aether hypothesis.

15.1.1 Could we learn something from EU and the work of SAFIRE team

What EU (see `http://tinyurl.com/y847jn6w`) really claims. There is of course no unique EU but collection of models. Rather, it claims that electromagnetism, in particular plasmas, are central for the understanding of galaxies and astrophysical objects, in particular nuclear fusion. The Electric Sun model (see `http://tinyurl.com/y2mm8cjg`) assumes that astrophysical objects derive their main sources of their power electrically. That gravitation would not be needed at all is only an extremist claim. To me the claim that nuclear physics is not needed, looks unrealistic.

The lucky instance, is that the experimental work of SAFIRE team (see `http://tinyurl.com/y2ae9tar` and `http://tinyurl.com/y2ae9tar`) to be discussed in the sequel concentrates only on question whether nuclear fusion can be achieve in plasma system and the conclusion is that nuclear transmutations occur. This does not mean that nuclear physics is not needed. What it however implies that the recent view about nuclear physics is wrong also also the phenomenon dubbed as "cold fusion" or "low energy nuclear reactions" (LENR) has demonstrated [L31, L26, L10]. Nuclear physics of solar core has been also plagued by a very serious anomaly for 10 years now [L82].

Could we take a less emotional approach and look whether we could learn something - open-mindedness if not anything else - from the people labelled with "EU"? I had luck: I received two extremely interesting links from Wes Johnson to videos describing purely empirical and experimental physics. Nothing about mythology, aether, or anything like that but two highly inspiring videos allowing to see what science as a process of discovery is. This is something totally different from what I have seen SUSY and superstring theoreticians doing last four decades. It is about what is there in the real world, concrete numbers and correlations, discovery of physical anomalies. Something different from infertile games with braney worlds, multiverses, blackholes, etc. and endless production of hype.

It was clear from beginning that these videos provide further applications for the TGD view about cosmology and formation of galaxies and smaller stellar objects.

15.1.2 TGD view about classical fields

TGD does not assume aether but neither does it assume that gravitation alone is enough for understanding cosmology and astrophysics. In TGD both gravitation and long range electromagnetic fields are in crucial role. Nuclear physics is part of TGD but TGD view from it differs in some crucial aspects.

TGD leads to a new view about classical fields differing from the views of standard model and General Relativity (GRT).

1. The notion of field is generalized by induction procedure. All classical fields are expressible in terms of 8 coordinates of 8-D embedding space $H = M^4 \times CP_2$ and their gradients. General coordinate invariance reduces their number to 4 effectively. This means enormous reduction in local field like degrees of freedom. The extreme complexity of many-sheeted space-time compensates for this reduction and space-time is topologically complex in all scales.

   This does not reduce gravitation to electromagnetism as EU claims: rather both gravitation, electromagnetism and actually electroweak and color interactions are reduced to the geometry of space-time surface via the notion of the induced gauge field and metric. The induction of spinor structure does the same for spinor fields.

2. Standard model and GRT emerge at QFT limit when space-time sheets are replaced with single region of M^4 made slightly curved. The replacement of many-sheeted space-time with Einsteinian space-time however means enormous loss of information. In particular, the information about magnetic flux tubes is completely lost. This loss of information makes description of systems like living matter extremely difficult.

3. In primordial cosmology Einsteinian picture does not work even as approximation. At this limit space-time surfaces can be idealized by what I call cosmic strings having 2-D M^4 projection and behaving like strings for most practical purposes. Ironically, string like objects are present in all scales in TGD, not only something in Planck length scale. The tragedy of superstring models is easy to see: people had so enormous hurry to guarantee the call from Stocholm that they did not have time to realize that strings must be generalized to 3-D objects having interpretation as both particles and 3-space - depending on the scale.

15.1.3 Cosmic strings thickening to flux tubes as basic element of TGD based cosmology and astrophysics

Cosmic strings carrying monopole fluxes bring a lot of new elements to cosmology and astrophysics and solve the numerous problems of "gravitation only" approach.

1. These cosmic strings, in particular those carrying monopole flux possible due to the non-trivial topology of CP_2 thicken gradually to flux tubes, which are central element of TGD view about formation of various structures, in particular galaxies, stars, planets, and even smaller objects.

   They are present in all scales: also in quantum biology, biochemistry, chemistry, molecular physics, atomic physics, nuclear physics, hadron physics. In all scales new phenomena are predicted and it has been fascinating to realize that the experimental physics is producing anomalies in all these branches of physics and really stunning to realize that theoretical physicists could not be less interested.

Also in cosmology and astrophysics they are crucial and without them one cannot understand cosmological constant, the notion of dark matter and energy, the formations mechanisms of galaxies, stellar object, stars, and even smaller objects. "Gravitation alone" is not enough.

2. The twistor lift of TGD predicts that cosmological constant depends on p-adic length scale and become extremely small in cosmological scales but very large in short scales. This solves the basic problem of cosmology due to the gigantic value of cosmological constant also due its wrong sign which eventually killed string models.

   During cosmological evolution phase transitions reducing the value of cosmological constant occur leading to an accelerated expansion since volume energy is reduced. This sequences of jerks replaces smooth cosmological expansion of standard cosmology and solves the mystery due to the fact that astrophysical objects co-expand but do not seem to expand themselves. Smooth cosmic expansion is replaced with a sequence of jerks involving accelerating and slowing down periods.

   The reason is that magnetic contribution to string tension is reduced in thickening but volume energy increases so that one has acceleration followed by slowing down leading to a stationary situation. This expansion transforms the energy of flux tube identifiable as dark energy/dark matter to ordinary matter and is counterpart for inflation but occurring in all scales.

3. The model for galaxies as tangles along long cosmic strings predicts that the thickening of flux tube in the tangle generates ordinary matter. This explains the flat velocity spectrum of stars around galaxies as being due to the gravitational field of long string, and also the galaxies apparently without dark matter as galaxies formed around short circular cosmic strings. The model allows to solve the accumulating anomalies of halo model based on dark matter identified as some exotic particles.

4. The local jerks have counterpart even at the level of Earth and the TGD inspired Expanding Earth model predicting that in Cambrian Explosion the radius of Earth increased very rapidly by a factor of 2 can be regarded as this kind of jerk [L55]. This leads also to an explanation of Cambrian Explosion and a model for the evolution of prebiotic life as occurring in underground oceans shielded from cosmic rays and meteoric bombardment and preventing the oxygen from leaking to outer space. The splitting of core of Earth to inner core and rotating outer core generated ordinary magnetic field making possible atmosphere.

5. TGD suggests also that dark matter identifiable as $h_{eff} = n \times h_0$ phases and dark energy identifiable as magnetic and volume energy of flux tubes are by quantum classical correspondence (QCC) one and same thing basically. More formally, QCC implies that the eigenvalues for fermionic representations of Cartan algebra generators as Noether charges - observables - are same as the values for classical Noether charges. In particular, energy, momentum and angular momentum.

From this picture it is clear that in TGD Universe both gravitation and electromagnetism - or more generally the physics of induced electroweak and color fields is crucial for understand the formation of astrophysical objects.

15.1.4 The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L22].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = 8\pi^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as$\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L22] . For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L63].

Consider now some representative examples to see whether this picture can be connected to empirical reality.

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see `http://tinyurl.com/k4bwlzu`). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.

2. If the large scale R is solar radius about 7×10^8 m, the short scale $r \sim 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to Mersenne prime $M_{127} = 2^{127} - 1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L26, L31]: this requires $h_{eff} \sim 2^{12}$!

   Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

   The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L82] (see `http://tinyurl.com/y38m54ud`) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion". The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.

3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113} = (1 + i)^{113} - 1$ defining nuclear size scale of $r \sim 10^{-14}$ m, one has $R \sim 10$ km, the radius of a typical neutron star (see `http://tinyurl.com/y5ukv2wt`) having a typical mass of 1.4 solar masses.

   A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?

4. Short scale $r \sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see `http://tinyurl.com/y3n78tjs`)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

15.1.5 TGD view about craters of Moon and findings of SAFIRE team

This article is a commentary of the mentioned two videos from TGD point of view.

1. The first video told about craters of Moon and I learned that existing theories, about which I found representations in Wikipedia too, are full of anomalies. I could not find anything

obviously pseudoscientific in the representations apart. Since I have a habit to concentrate on content than social clues, I realized only later that the killer label EU assigned with these both videos.

It was immediately clear that TGD based model for "cold fusion", another branch of evolving science labelled as pseudoscience but already now led to a developing technology, can be scaled up to describe the formation of craters.

2. Second video was about experiments done by SAFIRE team. They forget theoretical prejudices and just try to look whether Sun can be created in laboratory. Sun would be spherical electrode with positive charge surrounded by similar electrode with opposite charge and there would be strong electric field between them. The video told about the discoveries made also by "cold fusion" people: transmutations producing elements with higher isotope number are found to occur. Do transmutations occur everywhere and is nuclear fusion in solar core only one part of the story? This is the question that also TGD raises.

It must be emphasized, that these videos represent only two examples of the continual stream of anomalies having immediate explanation in TGD framework. Some time ago I had learned that even the cherished nuclear physics has had a very serious anomaly for a decade [L82]: the model of cold fusion [L31] [K25] based on TGD view about dark matter and the notion of monopole magnetic flux tube generalizes to a model of nuclear reactions and of Sun itself explaining this anomaly too. Only few weeks ago I had learned that the magnetic field of Mars behaves very weirdly: popular article used the word "magnetic madness" [L71]. Some days ago I learned about evidence that Earth's surface 600 million years was without details such as rivers and lakes: this fits with the Expanding Earth hypothesis [L55]. I learned also fascinating and strange facts about earthquakes and volcanic eruptions providing an applications for zero energy ontology based view about state function reduction in macroscopic length scales [L73].

15.2 What created the craters of Moon and other celestial bodies?

I received from Wes Johnson a link to to a Youtube video of Space News: Electric Universe titled "*Our Lightning-Scarred Moon-The Evidence Grows*" (see `http://tinyurl.com/y3bsgevu`). Very briefly: the basic message is that in case of Moon the basic theories for the formation of craters assuming impacts and volcanism as mechanisms are challenged by a large number of anomalies. It is also claimed that the theory assuming electric discharges - lightnings- as a cause is consistent with the data.

The video was highly interesting and I listened it through several times and the following is my attempt to summarize what I learned and how the model based on electric lightnings can be formulated in TGD framework. Actually a generalization of a model formulated for what happens in "cold fusion" as dark nuclei transform to ordinary ones, is in question. The formation of craters could involve "cold fusion" and a kind of nuclear explosion.

15.2.1 Standard view about the formation of craters

Consider first what mainstream science says about the formation of craters. Impacts and volcanism would be the basic mechanisms. Most of craters would be however due to impacts.

1. According to Wikipedia article (see `http://tinyurl.com/7vnrysd`), the cratering records of very old surfaces, such as Mercury, the Moon, and the southern highlands of Mars, record a period of intense early bombardment in the inner Solar System around 3.9 billion years ago. This is actually hypothesis known as late bombardment hypothesis.

2. The Wikipedia article about craters in Moon (see `http://tinyurl.com/y2ja9qjg`) states that most craters in Moon are impact craters. The number of craters in Moon and Mars is many orders of magnitude larger than that of impact craters in Earth. A natural explanation is that geological processes have destroyed the craters and very few from time before 500 million years are known (happens to be the time of Cambrian explosion [L55] (see `http://tinyurl.com/yc4rgkco`) about which I have talked a lot).

15.2.2 Anomalies of the standard model

The video argues that the properties of craters of Moon are not consistent with either hypothesis.

1. The sizes of craters can be enormous. Moon has a gigantic crater which has radius of 25000 km and is 390 km deep. It is one of the largest craters in solar system. Impact theory predicts that there should be material bursted from the mantle to the surface. The material is shocked and melded and there is no material from mantle as volcanic hypothesis would require (data are from Apollo mission).

2. Why Moon should be so heavily cratered? The hypothesis that so called late heavy bombardment (see `http://tinyurl.com/y6hx2q3b`) period 4.5-3.8 Gy ago lasting for 20 -200 million years gave rise to the impacts producing the craters. Asteroids have been assumed to have caused the impacts. The video mentions an article claiming that asteroids are not probable cause. The modified hypothesis is that remnants from the formation of planetary system caused the impacts.

3. The craters are highly circular and can form sequences. There are also smaller craters at the rims of the craters bringing in mind fractal structure: vortices containing vortices containing....

4. Also very long rilles very different from lava tubes at Earth are found and often start from the circular craters. Rilles have sequences of craters within them. The rilles can be very long, much longer than at Earth: the longest rille is 185 km long. Just the opposite should be the case, since the heat loss in very thin atmosphere should be faster than at Earth with insulating atmosphere so that the rilles should be shorter. There is no rubble at the bottom of rilles as at Earth. The rilles can be directed uphill rather than downhill as in hydrodynamic and lava flows. Rilles also disappear instantaneously. The rilles dwindle suddenly, which does not support the idea that lava flow caused their formation by "eating" the surface material. Rather this, suggest a sheet like structure entering the surface as giving rise to the rille. In the case of the highly circular craters a tube like structure meeting the surface orthogonally suggests itself.

5. Also glass spheres and chondrules and minerals formed at very high temperatures are found in craters. Amusingly, crop circles [K35, K36] (see `http://tinyurl.com/y32n3qwc` and `http://tinyurl.com/y4mawmqh`) involve also glass spheres and the model that propose for their formation decades ago would be the same as the model to be discussed for the formation of craters.

6. The near side of Moon less cratered than far side. There are even hexagonal craters. At Mars there is hemisphere dichotomy with southern hemisphere containing more craters.

15.2.3 Electric discharge model

Consider the model based on electric discharges argued to be consistent with all data.

1. Immanuel Velikovsky proposed that cosmic lightnings between planets and Moons created the craters of Moon Mainstream has labelled Velikovski as pseudoscientist. Carl Sagan has written a rather civilized critic (see `http://tinyurl.com/yxfzae93`) of Velikovski's ideas concentrating on content rather than direct personal insults. On basis of his vision Velikovski predicted remanent magnetism in lunar rocks. Nowadays the magnetic field is very weak. This remanent magnetism has been observed.

2. The crucial discovery by Brian J. Ford was that the electric discharges in lab applied also in industrial processes produce structures very similar to those observed in Moon. The ratio of sizes of largest to smallest craters is the same in Moon and in Mars. In particular, the craters produced in electric discharges are extremely circular. The document claims the electric discharge hypothesis is consistent with all findings about craters in Moon.

3. R. Juergens studied the rilles appearing in many scales and starting typically from the craters. They were originally called cracks and proposed to be formed by a flow of water or lava across surfaces or beneath the ground. Juergens found however that high energy electric discharge is favoured as a model. Lava and water cannot explain the features of rilles already listed like craters along rilles whereas electric discharges reproduce these features.

15.2.4 TGD based model

If the arguments of the document are true, the proposal must be taken very seriously. It seems incredible that mainstream could neglect so serious anomalies but I have seen this to happen in particle physics for decades. So: suppose that one take the claims seriously. What could be TGD explanation?

1. Monopole magnetic flux tubes carrying dark matter - perhaps dark nuclei as dark proton sequences is of course what comes first in mind. The flux tubes carrying the dark nuclei as dark cosmic rays could be associated with solar wind and are proposed to form a part of a bigger network allowing cosmic rays to propagate between galaxies, stars and smaller astrophysical objects. This would be a cosmic analog of blood circulation [L82, L73] (see `http://tinyurl.com/yyjy5e2r` and `http://tinyurl.com/y23qczau`).

   Flux tubes have flux tubes within flux tubes that mathematical connection between incompressible liquid flow and magnetic field would allow to understanding the various structures as analogs of hydrodynamic tubules having vortices within vortices fractal structure.

2. In the collision with ground the dark nucleus formed by dark nucleon sequence nucleons would transform to ordinary nucleons and liberate practically all nuclear binding energy [K25] [L31] (see `http://tinyurl.com/y7u5v7j4` and `http://tinyurl.com/y2v3qn6a`) . The event would be like a nuclear explosion and this could explain why the effect is so large. This would be "cold fusion" event in macro scale. "Cold fusion" is known to involve formation of craters in micro scale and it would interesting to see whether the situation are scaled versions of each other.

   Also flux sheets are possible and the long rilles could correspond to these. Flux tubes inside flux tubes and inside flux sheets are possible and could give rise to fractal craters. This explanation would mean that also electric discharges in laboratory give rise to nuclear transmutations producing heavier elements as happens also in "cold fusion". This predictions could be tested in lab.

3. From Wikipedia article (see `http://tinyurl.com/7vnrysd`) one learns that ores often accompany craters and an interesting question is whether the craters formed in this manner give rise to ores.

4. What one can say about these monopole flux tubes carrying the dark nuclei to Moon. Most naturally they would be dark flux tubes associated with solar wind bringing cosmic rays. Earth does not have this kind of craters and the number of impact craters is small. The simplest explanation is that geological and atmospheric processes have caused the erosion of these structures. This is proposed as an explanation for the very small number of impact craters in Earth (190), whereas their number in Moon, some planets and their moons is much larger due to the absence of atmosphere.

   It is also possible that reconnections of solar flux tubes with the flux tubes of dark magnetic field associated with the Moon (planet or its moon) is involved and leads to the event! Also the flux tubes of dark magnetic fields of planets and Moon (moons of planets) could take place.

One can test the hypothesis is consistent with the TGD inspired version of Expanding Earth model [L55] (see `http://tinyurl.com/yc4rgkco`).

1. The model assumes that Earth had radius, which is half of the recent value before Cambrian explosion and same as the recent radius of Mars. Then came geologically fast expansion (jerk in sequence of fast expansions reducing the value of length scale dependent cosmological

constant replacing smooth cosmic expansion in TGD Universe) and the life that had evolved in underground oceans below Earth's surface bursted to the surface and oceans were formed.

2. The assumption that the situation at Earth was the same as in Mars before the expansion [L71] (see `http://tinyurl.com/yxzye6xu`), would explain the finding that the surface of Earth seems to have lost various details like rivers and lakes about 600 million years ago preceding Cambrian explosion about 512 million years ago.

   If the surface of Earth was like the surface of Mars now it would have been full of craters formed by electrical discharges due to the solar wind. This does not kill the model. The presence of erosion due to the emergence of atmosphere and biosphere would explain the absence of these craters at the surface of recent Earth. At the bottom of oceans formed in the expansions they would be automatically absent. Inside tectonic plates signatures of their presence might be found.

3. The recent Earth is shielded by van Allen belts. If the van Allen belts consisted of dark flux tubes, they should have been present also before expansion and shielded Earth from cosmic rays and solar wind by guiding it to the Earth's interior. This would have brought ions and dark photons into the underground oceans and made possible the evolution of multicellular life capable of photosynthesis.

15.2.5 Strange glass spheres in the Moon

According to the Eurekalert article (`https://cutt.ly/3CWde6M`), translucent glass globules have been found on the Moon in a study led by Dr. Zhiyong Xiao (Planetary Environmental and Astrobiological Research Laboratory, School of Atmospheric Sciences, Sun Yat-sen University), who is a core scientific team member of the first in-situ lunar mission to the Moon, Chang'E-4.

1. The team examined images taken by the panorama camera onboard the Yutu-2 rover, and discovered several translucent spherical and dumbbell-shaped glassy globules (see the images in `https://cutt.ly/3CWde6M`). Perching on the surface regolith, the globules are transparent to translucent, and they exhibit a light brownish color. Such centimeter-sized translucent glass globules are not found on the Moon before and their presence was unexpected.

2. This kind of glassy globules were found also by Apollo astronauts and their size was also below 1 cm but they were mostly opaque and clast rich, which means that the glass crystals are accompanied by some other material . The sizes of tektites found at the surface of Earth, believed to be produced in terrestrial impact events, are opaque and have sizes ranging from micrometers (microtektites) to a few centimeters. They are believed to be produced in impact events creating craters.

There is an alternative theory explaining the formation of craters in planets and Moons related to the notion of the Electric Universe (see `http://tinyurl.com/y3bsgevu`). Electric Universe in its extreme nothing-but-version claims that electromagnetism determines everything even in astrophysical scales and that one can forget gravitation, whereas the standard view is that gravitation determines everything.

In the TGD framework, both gravitation and the analog of electromagnetism are key players in astrophysics. In particular, the Kähler magnetic flux tubes carrying monopole flux are predicted to be key players in all scales from biology to the formation of galaxies and stars. This explains anomalies such as the existence of magnetic fields in cosmic scales and also the stability of the Earth's magnetic field.

1. The craters, and also glass spheres, could be due to strong electric currents flowing between planets rather than due to the collisions of meteors and meteorites. Lightning strikes could cause these strong currents. Volcanic lightning is indeed known to cause the formation of glass spheres (see `https://cutt.ly/wCWsKSM`). I have discussed both the standard view and the lightning theory for the formation of craters from the TGD point of view [L67].

2. If the electric currents arrive orthogonally to the surface of the planet, this theory explains various anomalies such as the fact that craters are disk-like. For collisions of meteors one

would expect all elliptic shapes depending on the arrival angle. This theory could also explain the glass balls.

3. In the TGD framework, these currents could consist of very high energy dark matter particles (dark in the TGD sense, and thus having $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0 \geq\geq \hbar$, $\beta_0 = v_0/c \leq 1$, arriving along monopole flux tubes of Kähler magnetic field to the surface and liberating energy as they transform to ordinary particles. This would generate a high temperature, which would melt the quartz and produce the glass spheres and dumb-bell like objects. The large value of h_{eff} at flux tubes implies a very low rate of dissipation, which would explain the association of relativistic electrons and gamma rays with lightnings. In the atmosphere, they would rapidly lose their energy.

4. The gravitational Compton length associated with particles of mass m is given by $\Lambda_{gr} = \hbar_{gr}/m = GM/\beta_0 = r_s/2\beta_0$ and does not depend on the mass of dark particle (Equivalence Principle). If M is the Earth's mass M_E, one has $\Lambda_{gr} > .45$ cm. Intriguingly, this is the size scale of the glass spheres found on the Moon and of tektonites found on the Earth.

   Moon mass is 1.2 percent of M_E so that the size scale would be above 45 μm, the size scale of a cell, for the gravitational flux tubes assignable to the Moon. The size scale of one centimeter would suggest that the monopole flux tubes of the Earth's magnetic field extends at least to the Moon, whose distance from Earth is about 30 Earth radii.

   Interestingly, the size scale of snowflakes is also this and the explanation could be based one gravitational quantum coherence predicted to be possible in arbitrarily long scales [L121, L119].

The same mechanism could explain the reported and published finding of glass spheres around crop circles [H7, H5, H4, H1, H6, H11, H3] available at `https://cutt.ly/CCWvMFR`.

1. I have discussed crop circles from the TGD point of view [K35, K36]. The high temperature explains boiling, which has occurred for the crops (like for a tomato in a microwave oven) would make possible the formation of crop circle. Meteoric iron has been found in the glass balls and could have arrived along magnetic flux tubes and originate from a meteorite arriving in the atmosphere.

2. In TGD, the magnetic bodies (MBs) consisting of momopole flux tubes and sheets with a very large value of h_{eff} equal to h_{gr} would be intelligent entities controlling various biosystems. Quite generally, h_{eff} would serve as a measure of algebraic complexity and the level of intelligence in TGD based view of consciousness and cognition based on number theory [L42, L41].

   Even crop fields would have MB. The charged meteoric iron could have ended up in the monopole flux tubes of the MB of the crop field, accelerated in the electric field parallel to flux tubes, and ended up to the surface of Earth and made the MB visible as a crop circle. An alternative idea is that the crop circles are purposefully manufactured by a higher intelligence using this mechanism. Crop circles could be analogous to neural representations but in crop fields instead of brains. The large value of h_{gr} for flux tubes is the same as for living matter in general and could explain why crop fields can have aspects, which bring to mind the brain. The conscious intelligence would however reside at the level of MBs.

   These flux tubes would connect astrophysical objects, even galactic blackhole-like objects to distant stars and make the Universe a kind of neural network.

15.2.6 Why do meteors always land in craters?

Why do meteors always land in craters? I encountered this innocent layman question on Face Book and from the TGD perspective it looked brilliant. I did a web search and found this question at some pages accompanied by strong emotional responses in style "craters are of course made by meteorites, you idiot!".

This is of course true and one must formulate the question more precisely. One must characterize meteor crater by size. Suppose that smaller craters assigned to meteors indeed have a tendency to appear inside larger craters. One would have a fractal like structure.

What is known about the size destribition of meteor craters and its correlation with the distribution of their locations? Is the fractal structure only an illusion: is it easier to spot the crateres if they are inside craters? Or is this tendency real? I do not know for certain but I can make what-if... questions.

I have proposed a model for the craters created in meteor collisions based on the TGD view of the magnetic body of a planet, say Earth [L67].

1. The model was inspired by an anomaly: the meteor craters seem to favor meteor orbits orthogonal to the surface of the planet so that the craters tend to look like circular disks rather than ellipsoids.

2. The craters assigned with meteor collisions could be created by matter, which arrives along magnetic flux tubes roughly perpendicular to the surface of the planet. Part of the material of the meteor could end up as dark, possibly charged, matter at the magnetic flux tubes or bundle of tubes. Since the friction and electric resistance of the dark matter inside the flux tube are much smaller than for ordinary matter, dark particles could achieve very high energies before collision with Earth. This would also explain the gamma rays and ultrahigh energy electrons associated with lightning.

3. If the magnetic flux tube bundles form rather stable structures with fractal flux tubes inside flux tubes inside ... inside flux tubes, which emanate from larger craters, the meteors or the material created in their decay could tend to land in craters. This hypothesis should be testable. For instance, could lightnings have tendency to be associated with craters?

One exotic application of the idea relates to the observation that the craters in the Moon are accompanied by glass spheres [L67]. Also the crop circles, which any real academic physicist of course regards as pseudoscience, involve glass spheres suggesting very high temperatures created somehow [K35, K36].

15.3 The findings of SAFIRE team as support for dark nucleosynthesis

I got from West Johnson a highly interesting link to a video providing a representation about the experimental work done in SAFIRE project (see `http://tinyurl.com/y548t9qk` . The motivation is so called Electric Universe model, which I see as unrealistic but the work itself was purely experimental. The mainstream claim, which can be found in Wikipedia is that these scientists are crackpots. To my best understanding this claim is simply an intentional lie. This conclusion is not difficult to make on basis of what I have been experienced during these four decades of TGD. The world view is changing: the old memes defending themselves against new memes desperately and the end justifies the means.

One must of course be extremely cautious. Nuclear transmutations are in air, so to say. This is because mainstream nuclear physics has had for a decade profound anomaly associated with solar nuclear synthesis: the abundances deduced in solar interior differ from those deduce from spectroscopy and meteorites [L82] (see `http://tinyurl.com/yyjy5e2r`). It is difficult to believe that TGD would be totally unknown in physics community although there is politically motivated total silence about TGD leading to even comic manifestations. When it begins to look plausible that certain theory might provide a breakthrough at the level of entire world view, it might lead to over-reactions. However, Electric Universe seems to be the theoretical background of SAFIRE project and it is very different vision as compared to TGD.

15.3.1 What SAFIRE team is studying?

What SAFIRE group is doing?

1. SAFIRE team is studying plasma (see `http://tinyurl.com/yxkw334n`). They are not doing it in garage, a big laboratory is in question, and the researchers have academic credentials.

2. One has two electrodes - positively charge inner spherical electrode and outer negatively charged spherical anode. This gives rise to a strong electric field. Various gases are in the atmosphere, in particular hydrogen: (see `http://tinyurl.com/y4cxohp3` for the Youtube video). Electric discharge is created and electric currents run in the voltage. The situation is like in electrolysis. The temperatures is rather low: around 100 degrees Celsius.

   Note that in cold fusion experiments one has a situation in which hydrogen atoms are absorbed in the cathode. Plasma is created in this kind of situation and one looks what happens by measuring all kinds of observables. One can study what happens at the surface of the anode, one can study the plasma atmosphere say by measuring the voltage and doing optic spectroscopy.

15.3.2 What SAFIRE team observed?

SAFIRE team observed several phenomena challenging the existing views about plasmas.

Occurrence of nuclear transmutations

For me the most interesting topic of the talk (see `http://tinyurl.com/y4cxohp3` for the Youtube video) were nuclear transmutations. "Cold fusion" model based on magnetic flux tubes containing dark matter as $h_{eff} = n/timesh_0$ phases predicts just what has been observed. It was really amazing to see direct experimental verification of the most radical predictions of TGD: things are going really fast now.

1. One of the basic predictions of TGD are nuclear transmutations. They observe nuclear transmutations at low temperatures than believed and production of energy. Essentially this is observed also by "cold fusion" experimentalists [?]see `http://tinyurl.com/y7u5v7j4`) and `http://tinyurl.com/y2v3qn6a`).

2. Energy production was claimed. The ratio of the output power to input power seemed to me incredible. Dark nuclear fusion predicts in optimal situation very large COP but in the "cold fusion" experiments the COP is of order 2-3 typically. If I understood correctly, it was now something like 10 or even more. Maybe I misunderstood.

3. The experimentalists do not know the mechanism involved and there is no such mechanism in standard model Universe. In TGD Universe it would be the formation of dark proton sequences - dark nuclei - transforming to ordinary nuclei and liberating essentially nuclear binding energy. In fact, also ordinary nuclear reactions would also proceed by the formation of dark nuclei as intermediate states: this replaces tunnelling phenomenon as mechanism in TGD Universe [?]see `http://tinyurl.com/yyjy5e2r`). A long list of elements produced in transmutations was claimed: C, O in the second row; Na, Mg, (Al,Si), P, S, Cl in the third row; K, Ca, Ti, Zn in the fourth row; Sn in the fifth row; Ba in sixth row; and La in the eigth row of the periodic table. Al and Si are not certain since they could have contamined.

4. It was also claimed that SAFIRE produces by transmutations just those non-organic atoms that are observed in interstellar space. If true, this would support the TGD based proposal that part of elements is formed in interstellar space besides solar cores. If both are involved, the abundances from both should be very similar. If nuclear transmutations involve only the production of dark proton sequences transforming to ordinary nuclei whereas ordinary nucleosynthesis in Sun would involve also the fusions of ordinary nuclei by generating dark nuclei as intermediate states, it is is not clear whether this is the case.

5. The flux tubes carry also electric fields parallel to them in average sense and charges along them can accelerate to high energies. Second point is that dissipation is very slow due to the large value of h_{eff}: this brings a completely new element into the picture. The dark protons and ions at flux tubes can accelerate to very high energies. This would explain for instance the production of very high energy electrons in lightnings: would they accelerate to

unexpectedly high energies in the electric field of Earth prevailing also inside flux tubes. By the way, I am still not sure whether gravitational flux tubes can be regarded as monopole flux tubes.

The phenomena at the surface

Consider first the phenomena observed at the surface of anode. Highly interesting were the pictures about the microscopic structures involved. They brought in mind the craters on the surface of Moon (see http://tinyurl.com/y6yqtdj7). The mechanism would be the same - TGD Universe is fractal.

The balls of size in micron scale formed by elements were one very interesting detail that should be understood. Some kind of micro-crystallization happening in cooling of liquid or vapour phase of elements fromed by dark fusion mechanism could be in question. In the talk this is suggested to be very much analogous to gravitational phenomenon. The propolals relies on the EU hypothesis that gravitation reduces to electromagnetism and the belief that plasma phenomena are purely electromagnetic. Note that micron scale corresponds to biological length scale.

Was the transformation to ordinary nuclei quantum coherent process as I have proposed on basis of large h_{eff} and occurred for a bundle of flux tubes simultaneously? - these bundles are actually part of the h_{eff} hypothesis. The motivation was the observation of Holmlid [L26] that even kaons with masses in 500 MeV range were produced! The production of so large energy quanta is not possible without large scale quantum coherence since nuclear binding energies are in MeV range. h_{eff} is proportional the number of flux tubes in bundle [L59] (see http://tinyurl.com/yy88v35d) .

The formation of double plasma layers

The formation of self-organized double plasma layers in the atmosphere around anode formed from double layers was also reported. The layers have opposite charges at their boundaries. Double layers represent a standard phenomenon in plasma physics (see http://tinyurl.com/y52s3a32.

1. The thickness of the double layer is of order 10 Debye lengths $\lambda_D = 1/k_D$,

$$k_D^2 = (4\pi)^2\alpha q^2 n\lambda_{th} \qquad \lambda_{th} = \frac{n\hbar}{T} \ . \tag{15.3.1}$$

   n is the density of screening ions, q their charge using e a unit, and $\alpha = 4\pi e^2/\hbar \simeq 1/137$ is fine structure constant (I have used units with $((c = 1, k_B = 1))$. λ_{th} is thermal Compton length telling the distance below which macroscopic quantum phenomena are possible.

2. Debye length is the distance over which charge is screened in plasma in the units used. λ_D is few centimeters in the ionosphere, few tens of meters in the interplanetary medium, and tens of kilometers in the intergalactic medium. Note that the formula is purely classical in the sense that $\hbar$ disappears from it.

3. In the layer the electric field is strong that outside it because of the polarization. The temperature T inside double layer is higher than outside it because of acceleration and dissipation of charges in the electric field. These double layers bring in mind cell membranes and polarization over cell membrane. Also a negatively charged layer very near to the positively charged anode has been observed.

4. So called dark mode was mentioned and the behaviour of electric voltage as function of distance for dark mode and glow mode with visible atmosphere were compared. If I understood correctly, the plasma becomes invisible in dark mode. What could this mean in TGD Universe? Could a phase transition transforming ordinary photons to dark photons be in question? Or is the rate for the transformation of dark photons to ordinary photons for some reason much slower in the dark mode? Could this rate be proportional to h_{eff} and could dark mode have larger h_{eff}.

15.3.3 TGD based model for the findings

In the following the basic building bricks of TGD based model are described and then a model for the formation of the spherical crystals is considered.

Some applications of the TGD view about dark matter as starting point

It is good to start with the basic building bricks provided by existing applications of the vision about dark matter as phases of ordinary matter labelled by the hierarchy of Planck constants

1. Nottale [E87] [K93, K79, K11] was the first to propose the expression $h_{eff} = nh_0 = \hbar_{gr} = GM_Dm/v_0$ for the gravitational Planck constant assignable to gravitational flux tubes. Here M_D is some large dark mass. v_0 is a parameter with dimensions of velocity: for the 4 inner planets of Sun $\beta_0 = v_0/c \simeq 2^{-11}$ gives a satisfactory estimate for their radii as radii of Bohr orbits.

   $\hbar_{gr}$ must be used when its value is larger than $\hbar$: one motivation is that Nature itself guarantees the convergence of the perturbation series by making a phase transition increasing the effective value of Planck constant. This transition can be interpreted as a change of the space-time topology: one can say that it becomes n-sheeted structure. A more detailed view is that one has $n = n_1n_2$, where n_1 is the number of sheets over CP_2 and n_2 over M^4. Sheets over CP_2 would correspond to parallel flux tubes.

   For gravitation the parameter $GMm/\hbar_{gr} = \beta_0$ appearing in perturbation series is smaller than 1. The integer n has concreate topological interpretation in terms of space-time topology [L59] (see `http://tinyurl.com/yy88v35d`) . This formula has rather obvious generalization to the electromagnetic case.

   How to identify the large dark mass M_D? $M_D = M_E$ is the naïve first guess. On the other hand, the application to the fountain phenomenon in super-fluid in turn suggests $M_D \sim 10^{-4}M_E$.

2. In accordance with Equivalence Principle the gravitational Compton length $\lambda_{gr} = GM_D/v_0 = 2r_s/\beta_0$ does not depend on m at all and also cyclotron energy $E_c = \hbar_{gr}ZeB/m$ is independent of m. In TGD inspired quantum biology this would guarantee that the cyclotron energies of all charged particle generate same molecular transitions in UV and visible range.

   $\lambda_{gr} = 2r_S(M)/v_0$ looks like a natural parameter for the size scale (radius) of the layers and corresponds to the same scales as the system itself (say anode). For $M_D = M_E$ one would have $r_s(M_E) \sim 1$ mm. $v_0 = 2^{-11}$ (true for Sun and inner planet flux tubes) would give $\lambda_{gr} \sim 4$ m. For $M_D \sim 10^{-4}M_E$ suggested by the model of fountain effect of super-fluidity one would have $\lambda_{gr} \sim r_S$. Could the value of M_D be determined by the condition $\lambda_{gr} = r_S(M)$? This is however not the case for Sun.

   If this picture makes sense, quantum gravitation could be central element of plasma phenomena regarded usually purely electromagnetic in contrast to EU hypothesis stating just the opposite. Later it will be found that quantum gravitation could be essentials also for phenomena like crystallization.

3. The model for the quantal effects of ELF radiation on vertebrate brain involves the assumption about the presence of "endogenous" magnetic field $B_{end} \sim 2B_E/5$, $B_E = .5 \times 10^{-4}$ Gauss is the nominal value of the Earth's magnetic field strength. Is B_{end} is associated with the gravitational flux tubes or with monopole flux tubes and can gravitational flux tubes be monopole flux tubes. I cannot answer this question definitively. In any case, since the magnetic field should consist of monopole flux tubes and those assignable to the ordinary magnetic field, B_{end} can correspond to the monopole fluxes.

   Dark ions are not only an essential element of the effects of ELF em fields on vertebrate brain but of entire TGD inspired quantum biology [K85, K86]. What makes ion dark and how do they relate to the dark variants of atoms/ions explaining Pollack effect and "cold fusion"? The vision has been that dark atoms/ions differ from ordinary atoms/ions in that their magnetic body has dark part with non-standard value of h_{eff}. The value of Planck constant should be large: perhaps the gravitational part of the magnetic body is dark having Planck constant $h_{eff} = h_{gr}$.

4. Also the thermal Compton length $\lambda_{th} = \hbar_{gr}/T$ is expected to be relevant and is very large for large values of h_{gr}. For instance, at room temperature one has $T \sim 10^{-2}$ eV and $\lambda_{th} \simeq 10^{-4}$ m. Bio-applications suggest that EEG frequencies - say $f = 10$ Hz - correspond to energies $E = h_{gr}f$ above thermal energy of 10^{-2} eV and having $\lambda \sim 10^{12}$ Hz giving $\hbar_{gr}/h \geq 10^{11}$. This would correspond to $\lambda_{th} \sim 10^7$ m which is of the order of the Earth's radius. This length scales could correspond to the size scale of gravitonic Bose-Einstein condensate. Note that the effective value of fine structure constant is scaled down to keep so that the Debye length is unaffected.

"Cold fusion" and Pollack effect represent situations in which the value of h_{eff} is not so large and might be assignable to flux tubes mediating electromagnetic interactions.

1. The dark protons in "cold fusion" have essentially the same Compton length as electrons from the findings of Holmlid [L26, L31], which would suggest that analogs of hydrogen atoms are formed as neutral bound states of dark protons and ordinary electrons. This generalizes: further scaling of h_{eff} for protons can be accompanied by similar scaling for electrons to guarantee local charge neutrality. Similar local neutralization mechanisn applies to dark DNA identified as dark protons sequences and ordinary DNA [L48].

   For "cold fusion" h_{eff} would be about $m_p/m_e \sim 2^{11}$ and much smaller than h_{gr}. Therefore the flux tubes assignable to the dark atom cannot be gravitational flux tubes although dark atom flux tube can reside inside gravitational flux tube. One would have two kinds of flux tubes: do they correspond to the monopole flux tubes and non-monopole flux tubes predicted by TGD and which is which?

   The binding energy of dark nuclei is scaled down by $1/h_{eff}$. The proposal is that this is due to the lengthening of the flux tubes of the magnetic body of nucleons mediating nuclear interactions. Nuclei would look like plants: the nucleus would be like the seed or root and magnetic body would correspond to the visible part of the plant. Parts of magnetic body could become dark by the change of h_{eff} from the standard value.

2. Dark nuclei formed in Pollack effect [L9] [L9] would be dark proton sequences but with a value of h_{eff} differing from that in cold fusion. If also weak interactions become dark, their rate is comparable to that for em interactions below the scaled up weak length scale h_{eff}/M_W and one can say that electroweak symmetry breaking is absent. Could the dark proton sequences transform to dark nuclei by dark weak decays $p \rightarrow n + e^+ + \nu_e$. Could the resulting stable dark nuclei correspond to stable ordinary nuclei?

Thermodynamical anomalies as apparent breaking of second law and causal anomalies due to the change of the arrow of thermodynamical time are predicted by ZEO based view about macroscopic quantum jumps requiring also large value of h_{eff}, and might be observable in the system studied.

A model for the formation of spherical micro-crystals

TGD encourages to consider the possibility that all self-organization process are basically quantal [L79] and even more, involve the increase of the effective Planck constant $h_{eff} = n \times h_0$ requiring energy feed. If the interpretation of transmutations in terms dark nuclear fusion is correct, the energy needed would come from this. Self-organization would be associated with the long range quantum coherence at dark magnetic flux tubes in turn forcing non-quantal long range coherence of the ordinary matter realized now as a double layer.

Concerning the values of h_{eff} the situation is far from understood. The values of h_{eff} label the flux tubes mediating various interactions and one can talk about gravitational Planck constant h_{gr} and electromagnetic Planck constant h_{em}. The TGD based model for "cold fusion" leads to a concrete identification of Planck constant involved, and one might call it nuclear Planck constant or assign it with dark color interactions. Flux tubes can be also classified according to whether they carry monopole flux or not. Therefore the applications involve guesswork.

1. The formulas for the Debye length and thermal Compton length give some idea about the self-organization process involved. Debye length is purely classical notion having no dependence on Planck constant and characterizes ordinary matter: this scale defines naturally the thickness of the layers. If dark matter and ordinary matter are in thermal equilibrium, the value of thermal Compton length is scaled up by $\hbar_{eff}/\hbar$ for which the estimate is $\hbar_{eff}/\hbar = n/6$ [L23]. Dark thermal Compton length $\lambda_T = \hbar_{eff}/T$ would define one quantum scale.

2. EU theory assumes that electromagnetism is enough to understand the situation. In TGD however quantum gravitation plays key role in living matter and perhaps also in self-organization in long length scales. This motivates the notion of gravitational Planck constant $h_{eff} = h_{gr}$ assignable to the flux tubes mediating gravitational interactions (it is not clear whether they are monopole flux tubes carrying net magnetic flux or not) - to be distinguished from the flux tubes mediating em interaction and having much smaller value of h_{eff}. One can also talk about h_{em}, h_{weak} and h_{strong}.

3. TGD predicts also scaled up Compton lengths of dark variants of particles proportional to h_{eff}. In particular, dark gravitational Compton length associated with gravitational Planck constant $h_{gr} = h_{eff}$ having no dependence on particle mass is predicted.

The talk claims that the formation of balls with radius about few microns - biological scale - looks like a gravitational phenomenon: the idea would be that gravitation reduces to plasma physics. In TGD framework the claim is that gravitation is involved with plasma physics thought to be a purely electromagnetic phenomenon.

Spherical micro-crystals are quite general phenomenon and the natural guess is that the balls are micro-crystals. This would suggests that crystallization in general could involve quantum gravitation in an essential manner.

1. The thermal Compton length λ_{th} for the ordinary value of Planck constant is of order 10^{-5} m at room temperature: not far from the size scale of the balls. This is a possible clue but will not be followed in the sequel. The thickness of the flux tubes for B_{end} is few microns. This inspires some guesses concerning the formation of the balls having also radius of this order of magnitude.

2. Suppose that the balls are formed from dark atoms as they transform to ordinary atoms. What dark atoms could be? Pollack effect suggests that dark protons rather than dark hydrogen atoms reside at flux tubes. Dark proton sequence could be accompanied by a neutralizing sequence of ordinary electrons. If this is the case, one can talk about dark atoms.

   Could the dark atoms in this sense with $h_{eff} \leq\leq h_{gr}$ reside at the gravitational flux tubes with $B = B_{end}$ having $h_{eff} = h_{gr}$ and make a phase transition to ordinary atoms condensing to form spherical micro-crystals with size scale of the thickness of the gravitational flux tube? h_{gr} is proportional to the mass of the atom so that given ball characterized by h_{gr} would consist of single type of atom and one would indeed obtain mono-crystals.

3. Quasicrystals cannot be formed by crystal growth as realized by Penrose, who suggested that the formation takes place by macroscopic quantum transition. This kind of transitions are a general TGD based prediction and one of the latest applications is to earthquakes and volcanic eruptions [L73] involving in an essential manner zero energy ontology predicting the observed causal anomaly.

   Could the formation of all crystals quite generally involve quantum gravitation and identifiable as a macroscopic quantum jump and involve the proposed selection mechanism putting atoms with different mass numbers to different flux tubes like books with different topics in library as I have suggested earlier? Note this would make living matter a well-organized library instead of random soup of biomolecules.

15.3.4 How stars and planets could have formed?

In the second part of a talk a proposal for how stars and planets are formed was discussed.

1. It was essentially TGD view except that they did not talk about monopole flux tubes and tangles along them: the natural possibility is that tangles have structure analogous to that of flux lines of dipole magnetic field.

2. One of the basic conjectures of TGD is that stellar interiors are not the only places, where elements are produced. They could be produced by "cold fusion" everywhere and the craters would provide direct evidence for this. The dark currents going along flux tubes to the interior of planets and smaller objects coming from Sun along flux tube network could be in crucial role and give rise to dark nuclear fusion.

3. Electromagnetic fields in long length scales are essential for the formation of the planets and their chemistry. But I do not see purely electric universe as a realistic option. Gravitational fields are also central and the role of gravitational Planck constant assignable to gravitational flux tubes having huge values is in key role in TGD. But also "gravitation alone" approach has failed. What makes electromagnetic fields equally important is the existence of monopole magnetic flux tubes and the hierarchy of Planck constants.

Chapter 16

Cosmic string model for the formation of galaxies and stars

16.1 Introduction

The view about the role of new nuclear physics predicted by TGD in the model of solar interior [L82] gives excellent guidelines for attempts to develop a more detailed understanding about TGD counterparts of blackholes as volume filling flux tube tangles.

16.1.1 Brief description of the model for for the formation of galaxies and stars

TGD based cosmology predicts that the primordial cosmology was dominated by cosmic strings identified as 4-surfaces having 2-D M^4 projection in $H = M^4xCP_2$. CP_2 projection is a complex surface of CP_2. The dimension of M^4 projection is unstable against perturbations and during cosmological evolution the M^4 projection thickens. This leads to a model for the formation of galaxies as tangles along cosmic strings in turn containing stars and even planets as sub-tangles.

1. Twistor lift of TGD [L22] predicts that cosmological constant at the level of space-time surface (to be distinguished from that associated with GRT limit of TGD) is length scale dependent. This solves the basic problem caused by the huge value of cosmological constant in the very early Universe. In zero energy ontology length scale dependent Λ having spectrum coming in some negative powers of 2 characterizes the space-time sheets assignable to individual system and the corresponding causal diamond (CD) and is determined by its p-adic length scale.

   For instance, Sun has its own cosmological constant predicted by the model solving the puzzle due to larger abundances obtained in solar-seismological determinations than in spectroscopic and meteoritic determinations. Dark nuclear states of nuclei inside solar core contribute also to the nuclear abundances [L82].

2. The energy of flux tubes consists of Kähler magnetic energy and volume energy. Quantum classical correspondence strongly suggests that this energy is identifiable as dark matter even for minimal value of h_{eff}.

3. Phase transitions reducing the value of cosmological constant are possible. Cosmic strings (or rather their M^4 projections) start to thicken and lose magnetic energy by transforming to ordinary matter. This is analogous to the decay of the inflaton field to matter. This generates Einsteinin space-time with space-time surfaces having large and increasing 4-D M^4 projection. Flux tubes and cosmic strings are however still present.

   The expansion of flux tubes in phase transitions reducing Λ gives rise to a jerk-wise accelerated expansion at the level of astrophysical objects. For given phase transition the accelerated expansion eventually stops since the expansion increases volume energy. The expansion periods however repeat being induced by phase transitions reducing length scale dependent quantized cosmological constant Λ associated with the volume action coming as powers of 2 and making flux tubes unstable against thickening and transformation of magnetic energy to ordinary matter. The recent accelerated expansion corresponds to this kind of period being thus analogous to inflation and is predicted to stop since volume energy increases. The expansion rate is predicted to oscillate so that the expansion takes place as jerks and there is evidence for this [E233] (see (http://tinyurl.com/oqcn2hp) discussed from TGD point of view in [K66].

4. In particular, the TGD counterpart of inflation would have led from cosmic string dominated primordial cosmology in which Einsteinian space-time does not make sense to a radiation dominated phase in which Einsteinian space-time makes sense. Expanding Earth model [L55] allowing to understand Cambrian Explosion is one application of TGD based quantum cosmology.

16.1.2 The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L22].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = (8\pi)^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as $\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L22] . For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L63].

Evidence for the anisotropy of the acceleration of cosmic expansion has been reported (see http://tinyurl.com/rx4224f). Thanks to Wes Johnson for the link. Anisotropy of cosmic acceleration would fit with the hierarchy of scale dependent cosmological constants predicting a fractal hierarchy of cosmologies within cosmologies down to particle physics length scales and even below. The phase transitions reducing the value of Λ for given causal diamond would induce accelerated inflation like period as the magnetic energy of flux tubes decays to ordinary particles. This would give a fractal hierachy of accelerations in various scales.

Consider now some representative examples to see whether this picture can be connected to empirical reality.

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see http://tinyurl.com/k4bwlzu). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.

2. If the large scale R is solar radius about 7×10^8 m, the short scale $r \simeq 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to

Mersenne prime $M_{127} = 2^{127} - 1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L26, L31]: this requires $h_{eff} \sim 2^{12}$!

Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L82] (see `http://tinyurl.com/y38m54ud`) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion". The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.

3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$ defining nuclear size scale of $r \sim 10^{-14}$ m, one has $R \sim 10$ km, the radius of a typical neutron star (see `http://tinyurl.com/y5ukv2wt`) having a typical mass of 1.4 solar masses.

   A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?

4. Short scale $r \sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see `http://tinyurl.com/y3n78tjs`)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

Starting from this picture, one ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars. The idea about ordinary stars as blackhole like objects emerges naturally since flux tubes are universal objects in TGD Universe and could be also inspired by the fashion of dualizing everything to blackholes.

The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature. The second thermodynamics is assignable to the gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low.

The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense. This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In zero energy ontology (ZEO) quasars and galactic blackholes can be seen as time reversals of each other.

The cosmological time anomalies such as stars older than the Universe can be understood. In ZEO the time evolution for the zero energy states associated with causal diamonds (CDs) by sequences of small state function reductions (weak measurements) gives rise to conscious entity, self. Self dies and re-incarnates with an opposite arrow of time in big (ordinary) state function reduction reversing the arrow of time. These reincarnations define kind of universal Karma's cycle. If the Karma's cycle leaves the sizes of CDs bounded and their position in M^4 unaffected, quantum dynamics reduces to a local dynamics inside CDs defining sub-cosmologies. In particular, the age distributions and properties of stars depend only weakly on the value of cosmic time - stars older than the Universe become possible in standard view about time.

The flux tube picture about galaxies and larger structures is discussed with application to some anomalies strongly suggesting the presence of coherence in scales of even billion light years.

Also "too" fast spinning galaxies are discussed. The local galaxy supercluster Laniakea is discussed in the flux tube picture as a flux tube tangle in scale of .5 Gly.

16.2 Blackholes, quasars, and galactic blackholes

I have discussed a model of quasars in [L63] (see `http://tinyurl.com/y2jbru4k`) . The model is inspired by the notion of MECO and proposes that quasar has a core region analogous to black hole in the sense that the radius is apart from numerical factor near unit $r_S = 2GM$. This comes from mere dimensional analysis.

16.2.1 Blackholes in TGD framework

In TGD the metric of blackhole exterior makes sense and also part of interior is embeddable but there is not much point to consider TGD counterpart of blackhole interior, which represents failure of GRT as a theory of gravitation: the applicability of GRT ends at r_S. The following picture is an attempt to combine ideas about hierarchy of Planck constant and from the model of solar interior [L82] deriving from the 10 year old nuclear physics anomaly [E66, E247].

1. The TGD counterpart of blackhole would be maximally dense spaghetti formed from monopole flux tube. Stars would not be so dense spaghettis. A still open challenge is to formulate precise conditions giving the condition $r_S = 2GM$. The fact that condition is "stringy" with $T = 1/2G$ taking formally the role of string tension encourages the spaghetti idea with length of cosmic string/flux tube proportional to r_S.

2. The maximal string tension allowed by TGD is determined by CP_2 radius and estimate for Kähler coupling strength as $1/\alpha_K \simeq 1/137$ and is roughly $T_{max} \sim 10^{-7.5}/G$ suggesting that in blackhole about $10^{7.5}$ parallel flux tubes with maximal string tension and with length of about r_S give rise to blackhole like entity. Kind of dipole core consisting of monopole flux tubes formed by these flux tubes comes in mind. The flux tubes could close to short flux tubes or flux tubes could continue like flux lines of dipole magnetic field and thicken so that the energy density would be reduced.

3. This picture conforms with the proposal that the integer n appearing in effective Planck constant $h_{eff} = n \times h_0$ can be decomposed to a product $n = m \times r$ associated to space-time surface which is m-fold covering of CP_2 and r-fold covering of M^4. For $r = 1$ m-fold covering property could be interpreted as a coherent structure consisting of m almost similar regions projecting to M^4: one could say that one has field theory in CP_2 with m-valued fields represented by M^4 coordinates. For $r = 1$ each region would correspond to r-valued field in CP_2.

   This suggests that Newton's constant corresponds apart from numerical factors $1/G = m\hbar/R^2$, where R is CP_2 radius (the radius of geodesic circle). This gives $m \sim 10^{7.5}$ for gravitational flux tubes. The deviations of m from this value would have interpretation in term of observed deviations of gravitational constant from its nominal value. In the fountain effect of super-fluidity the deviation could be quite large [**?**].

   Smaller values of h_{eff} are assigned in the applications of TGD with the flux tubes mediating other than gravitational interactions, which are screened and should have shorter scale of quantum coherence. Could one identify corresponding Planck constant in terms of the factor r of m: $h_{eff} = r\hbar_0$? TGD leads also to the notion of gravitational Planck constant $\hbar_{gr} = GMm/v_0$ assigned to the flux tubes mediating gravitational interactions - presumably these flux tubes do not carry monopole flux.

4. Length scale dependent cosmological constant should characterize also blackholes and the natural first guess is that the radius of the blackhole corresponds to the scaled defined by the value of cosmological constant. This allows to estimate the thickness of the flux tube by a scaling argument. The cosmological constant of Universe corresponds to length scale $L = 1/\sqrt{\Lambda} \sim 10^{26}$ m and the density ρ of dark energy corresponds to length scale $r = \rho^{-1/4} \sim 10^{-4}$ m. One has $r = (8\pi r)^{1/4}\sqrt{Ll_P}$ giving the scaling law $(r/r_1) = (L/L_1)^{1/2}$. By taking

$L_1 = r_s(Sun) = 3$ km one obtains $r_1 = .7 \times 10^{-15}$ m rather near to proton Compton length 1.3×10^{-15} m and even nearer to proton charge radius $.87 \times \times 10^{-15}$ m. This suggests that the nuclei arrange into flux tubes with thickness of order proton size, kind of giant nucleus. Neutron star would be already analogous structure but the flux tubes tangled would not be so dense.

Denoting the number of protons by N, the length of flux tube would be $L_1 \simeq Nl_p \equiv xr_S$ (l_p denotes proton Compton length) and the mass would be Nm_p. This would give x as $x = (l_p/l_{Pl})^2 \sim 10^{38}$. Note that the ratio of the volume filled by the flux tube to the M^4 volume V_S defined by r_S is

$$\frac{V_{tube}}{V_S} = \frac{3}{8}(\frac{l_P}{l_{Pl}})^2 \times (\frac{l_p}{r_S})^2 \sim 10(\frac{r_S(Sun)}{r_S})^2 \ . \tag{16.2.1}$$

The condition $V_{tube}/V_S < 1$ gives a lower bound to the Schwartschild radius of the object and therefore also to its mass: $r_S > \sqrt{10} r_S(Sun)$ and $M > \sqrt{10} M(Sun)$. The lower bound means that the flux tube fills the entire M^4 volume of blackhole. Blackhole would be a volume filling flux tube with maximal mass density of protons (or rather, neutrons -) per length unit and therefore a natural endpoint of stellar evolution. The known lower limit for the mass of stellar blackhole is few stellar masses (see `http://tinyurl.com/ycd4w4m4`) so that the estimate makes sense.

5. An objection against this picture are very low mass stars with masses below $.5M(Sun)$ (see `http://tinyurl.com/ceoo6sj`) not allowed for $k \geq 107$. They are formed in the burning of hydrogen and the time to reach white dwarf state is longer than the age of the universe. Could one give up the condition that flux tube volume is not larger than the volume of the star. Could one have dark matter in the sense of n_2-sheeted covering over M^4 increasing the flux tube volume by factor n_2.

6. This picture does not exclude star like structure realized in terms of analogs of protons for scaled up variants of hadron physics M_{89} hadron physics would have mass scale scaled up by a factor 512 with respect to standard hadron physcs characterized by Mersenne prime M_{107}. The mass scale would correspond to LHC energy scale and there is evidence for a handful of bumps having interpretation as M_{89} mesons. It is of course quite possible that M_{89} baryons are unstable against transforming to M_{107} baryons.

7. The model for star [L82] inspired by the 10 year old nuclear physics anomaly led to the picture that protons form at least in the core dark proton sequences associated with the flux tube and that the scaled up Compton length of proton is rather near to the Compton length of electron: there would be zooming up of proton by a factor about $2^{11} \sim m_p/m_e$. The formation of blackhole would mean reduction of h_{eff} by factor about 2^{-11} making dark protons and neutrons ordinary.

16.2.2 Can one see also stars as blackhole like entities?

The assignment of blackholes to almost any physical objects is very fashionable, and the universality of the flux tube structures encourages to ask whether the stellar evolution to blackhole as flux tube tangle could involve discrete steps involving blackhole like entities but with larger Planck constant and with larger radius of flux tube.

1. Could one regard stellar objects as blackholes labelled by various values of Planck constant h_{eff}? Note that h_{eff} is determined essentially as the dimension n of the extension of rationals [L34, L40]. The possible p-adic length scales would correspond to the ramified primes of the extension. p-Adic length scale hypothesis selects preferred length scales as $p \simeq 2^k$, with prime values of k preferred. Mersennes and Gaussian Mersennes would be in favoured nearest to powers of 2.

The most general hypothesis is that all values of k in the range $[127, 107]$ are allowed: this would give half-octaves spectrum for p-adc length scales. If only odd values of k are allowed, one obtains octave spectrum.

2. The counterpart of Schwartchild radius would be $r_S(k) = (L(k)/L(107))^2 r_S$ corresponding to the scaling of maximal string tension proportional to $1/G$ by $L(107)/L(k)^2$, where k is consistent with p-adic length scale hypothesis.

   The flux tube area would be scaled up to $L(k)^2 = 2^{k-107}L(107)^2$, and the constant $x \equiv x(107)$ would scale to $x(k) = 2^{k-107}x$. Scaling guarantees that condition $V(tube)/V_S$ does not change at all so that the same lower bound to mass is obtained. Note that the argument do not give upper bound on the mass of star and this conforms with the surprisingly large masses participating in the fusion of blackholes producing gravitational radiation detected at LIGO.

3. The favoured p-adic length scales between p-adic length scale L_{107} assignable to black hole and $L(127)$ corresponding to electron Compton length assignable to solar interior are the p-adic length scale $L(113) = 8L(127)$ assignable to nuclei, and the length scale $L(109)$, which corresponds to p near prime power of two.

   (a) For $k = 109$ (assignable to deuteron) the value of the mass would be scaled by factor 4 to a lower about 12 km to be compared with the typical radius of neutron star about 10 km. The masses of neutron stars around about 1.4 solar masses, which is rather near to the lower bound derived for blackholes. Neutron star could be seen the last phase transition in the sequence of p-adic phase transition leading to the formation of blackhole.

   (b) Could $k = 113$ phase precede neutron stars and perhaps appear as an intermediate step in supernova? Assuming that the flux tubes consist of nucleons (rather than nuclei), one would have $r_S(113) = 64r_S$ giving in the case of Sun $r_S(113) = 192$ km.

   (c) For $k = 127$ the p-adic scaling from $k = 107$ would give Schwartschild radius $r_S(127) \sim 2^{20}r_S$. For Sun this would give $r_S(127) = 3 \times 10^9$ m is roughly by factor 4 larger than the radius of the solar photosphere radius 7×10^8 meters. $k = 125$ gives a correct result. This suggests that $k = 127$ corresponds to the minimal value of temperature for ordinary fusion and corresponds to the value of dark nuclear binding energy at magnetic flux tubes.

   The evolution of stars increases the fraction of heavier elements created by hot fusion and also temperatures are higher for stars of later generations. This would suggest that the value of k is gradually reduced in stellar evolution and temperature increases as $T \propto 2^{(127-k)/2}$. Sun would be in the second or third step as far the evolution of temperature is considered. Note that the lower bound on radius of star allows also larger radii so that the allowance of smaller values of k does not lead to problems.

16.2.3 Magnetars in TGD framework

There is an interesting popular article about magnetars in Quanta Magazine (`http://tinyurl.com/uh5r3az`). The article tells about the latest findings of Zhou and Vink and colleagues [E170] (`http://tinyurl.com/s24dq23`) giving hints about the mechanism generating the huge magnetic fields of magnetars.

Neutron stars have surface magnetic field of order 10^8 Tesla. Magnetars have surface magnetic field stronger by a factor 1000 - of order 10^{11} Tesla. The mechanism giving rise to so strong magnetic fields at the surface of neutron star is poorly understood. Dynamo mechanism is the first option. The rapidly rotating currents at the surface of neutron star would generate the magnetic field. Second model assumes that some stars simply have strong magnetic fields and the strength of these magnetic fields can vary even by factor of order 1000. Magnetars and neutron stars would inherit these magnetic fields. The model should also explain why some stars should have so strong magnetic fields - what is the mechanism generating them. In Maxwellian world currents would be needed in any case and some kind of dynamo model suggests itself.

Dynamo model requires very rapid rotation with rotation frequency measured using millisecond as a natural unit. The fast rotation rate predicts that magnetars are produced in more energetic explosions than neutron stars. The empirical findings however support the view that there is no difference between supernovas producing magnetars and neutron stars. Therefore it would seem that the model assuming inherited magnetic fields is favored.

What says TGD? TGD view about magnetic fields differs from Maxwellian view and this allows to understand the huge magnetic without dynamo mechanism and could give a justification for the inheritance model.

1. TGD predicts that magnetic field decomposes to topological field quanta - flux tubes and sheets - magnetic flux tubes carry quantized magnetic flux. Flux tubes can have as cross section either open disk (or disk with holes) or closed surface not possible in Minkowskian space-time. The cross section can be sphere or sphere with handles.

2. If the cross section is disk a current at its boundaries is needed to create the flux. If the cross section is closed surface, no current is needed and magnetic flux is stable against dissipation and flux tube itself is stable against pinching by flux conservation. These monopole fluxes could explain the fact that there are magnetic fields in cosmological scales not possible in Maxwellian theory since the currents should be random in cosmological scales.

   This also solves the maintenance problem of the Earth's magnetic field. Its monopole part would stable and 2/5 of the entire magnetic field $B_E = .5$ Gauss from TGD based model of quantum biology involving endogenous magnetic field $B_{end} = .2$ Gauss identifiable in terms of monopole flux.

The model for the formation of astrophysical objects in various scales such as galaxies and stars and even planets and also for quantum biology relies crucially on monopole fluxes.

1. The proposal made in [L69] is that stars correspond tangles formed to long monopole flux tube. Reconnection could of course give rise to closed short flux tubes and one would have kind of spaghetti.

   The interior of Sun would contain flux tubes containing dark nuclei as nucleon sequences and one ends up to a modification of the model of nuclear fusion based on the excitation of dark nuclei [L82]. The model solvs a 10 year old anomaly of nuclear physics of solar core [E66, E247]. From the TGD based model of "cold fusion" one obtains the estimate that the flux tube radius is of order electron Compton length, and thus about $h_{eff}/h_0 \simeq m_p/m_e \sim 2000$ times longer than proton Compton length. This has been assumed also in the model of stars discussed in [L69].

2. The final states of stars could correspond to a volume filling spaghettis of flux tube analogous to blackhole. They would be characterized by the radius of the flux tube, which would naturally correspond to a p-adic length scale $L(k) \propto 2^{k/2}$: one could speak of various kinds of blackhole like entities (BHEs). There radius of the flux tube would be scaled up by the value of effective Planck constant $h_{eff} = n \times h_0$ so that one would have $n \propto 2^{k/2}$ in good approximation.

3. The p-adic length scales $L(k)$, with k prime are good candidates for p-adic lengths scales. Most interesting candidates correspond to Mersenne primes and Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$. Ordinary blackhole could correspond to a flux tube with radius of order Compton of proton corresponding to the p-adic length scale $L(107)$.

   For neutron star the first guess would be as the p-adic length scale $L(127)$ of electron from the model of Sun. $L(113)$ assignable to nuclei and corresponding to Gaussian Mersenne is also a good candidate for magnetar's p-adic length scale. $L(109)$ assigned to deuteron would correspond to an object very near to blackhole corresponding to $L(107)$ [L69]. Also the surface and interior of BHE would carry enormous monopole fluxes 32 times stronger than for magnetars.

   The are just guesses but bringing in quantized monopole fluxes together with p-adic length scale hypothesis allows to develop a quantitative picture.

Consider first the flux quantization hypothesis more precisely.

1. The observation that to the vision about monopole magnetic fields and hierarchy of Planck constants now derivable from adelic physics was that the irradiation of vertebrate brain by ELF frequencies induces physiological and behavioral effects which look like quantal. As if cyclotron transitions in endogenous magnetic field $B_{end} = 2B_E/5 \simeq 0.2$ Gauss would have been in question. The energies of photons involved are however ridiculously small and cannot have any effects. The proposal was that the effective value of Planck constant is quantized: $h_{eff} = nh_0$ and can have very large values in living matter. The energies $E = h_{eff}f$ of photons could thus be over thermal threshold and have effects. The matter with non-standard value of h_{eff} would correspond to dark matter.

2. One can make the picture more quantitative by considering the quantization of flux. The radius r of a flux tube carrying unit magnetic flux is known as magnetic length $r^2 = \Phi_0/e\pi B$, where Φ_0 corresponds to minimal quantized flux $\Phi_0 = BS = B\pi r^2 = n \times \hbar/eB$ for flux tube having disk D^2 as cross section. If B_{end} is ordinary Maxwellian flux one obtains for $B_{end} = 0.2$ Gauss $r = 5.8$ μm which is rather near to $L(169) = 5 \times 10^{-6}$ μm Cell membrane length scale $L(151) = 10$ nm corresponds to the scaling $B_{end} \rightarrow 2^{18}B_{end} \simeq 5$ Tesla and 1 Tesla corresponds to the magnetic length $r = 2.23 \times L(151)$.

   One can argue that one must have quantization of flux as multiples of h_{eff}. The geometric interpretation is that $\hbar_{eff} = n\hbar_0$ corresponds to n-sheeted structure (Galois covering) and the above quantization gives flux for a single sheet. The total flux as sum of these fluxes is indeed proportional to $\hbar_{eff}$.

3. For monopole flux tubes disk D^2 is replaced with sphere S^2 and the area $S = \pi \times r^2$ in magnetic flux is replaced with $S = 4\pi r^2$. This means scaling $r \rightarrow r/2$ for the magnetic length. The p-adic length scale becomes $L(167)$, which corresponds to Gaussian Mersenne is indeed the scale that might have hoped whereas the ordinary flux quantization giving $L(169)$ was a disappointment. This gives a solution to a longstanding puzzle why $L(169)$ instead of $L(167)$ and additional support for monopole flux tubes in living matter. As a matter of fact, there are four Gaussian Mersennes corresponding to $k \in \{151, 157, 163, 167\}$ giving rise to 4 p-adic length scales in the range [10 nm, 2.5 μm] in the biologically most important length scale range. This is a number theoretic miracle.

It is useful to list some numbers for monopole flux by using the scaling $\propto 1/L^2(k) \propto 2^{-k/2}$ to get a quantitative grasp about the situation for magnetars and other final states of stars.

1. For monopole flux $L(151)$ corresponds to $2^{16}B_{end}(k = 167) \simeq 1.28$ Tesla. For ordinary flux it corresponds to 2.56 Tesla. A good mnemonic is that Tesla corresponds to $r = 1.13 \times L(151)$.

2. For neutron star one has $B \sim 10^8$ Tesla. For monopole flux this would correspond for ordinary flux magnetic length $r \simeq 1.13$ pm roughly $2.8L_e$, where $L_e = .4$ pm is electron Compton length. Note that the corresponding p-adic length scales is $L(127) = 2.5$ pm $\simeq 2.2r$ so that also interpretation in terms of $L(125)$ can be considered. For non-monopole flux one would have roughly $r = 2.26$ pm. Neutron star would be formed when all flux tubes become dark flux tubes and perhaps form single connected volume filling structure.

3. For magnetar one has magnetic field about $B = 10^{11}$ Tesla roughly 1000 times stronger than for neutron star. For monopole flux this would give $r = 30$ fm to be compared with the nuclear p-adic length scale $L(113) = 20$ fm. Could the p-adic length scale $L(109) = 2L(107) = 5$ fm correspond to a state rather near to blackhole? $L(109)$ would would have 16 times stronger surface magnetic field $B \simeq .45 \times 10^{12}$ Tesla than magnetar. For the TGD counterpart of ordinary blackhole having $k = 107$ the surface magnetic field $B \simeq 1.8 \times 10^{12}$ Tesla would be 32 times stronger than for magnetar.

All these estimates are order of magnitude estimates and p-adic lengths scale hypothesis only says something about scales.

16.2.4 What about blackhole thermodynamics?

Blackhole thermodynamics is part of the standard blackhole paradigm? What is the fate of this part of theoretical physics in light of the proposed model?

TGD view about blackholes

Consider first the natural picture implied the vision about blackhole as space-filling flux tube tangle.

1. The flux tubes are deformations of cosmic strings characterized by cosmological constant which increases in the sequence of increasing the temperature of stellar core. The vibrational degrees of freedom are excited and characterized by a temperature. The large number of these degrees of freedom suggests the existence of maximal temperature known as Hagedorn temperature at which heat capacity approaches to infinity value so that the pumping of energy does not increase temperature anymore.

   The straightforward dimensionally motivated guess for the Hagedorn temperature is suggested by p-adic length scale hypothesis as $T = x\hbar/L(k)$, where x is a numerical factor. For blackholes as $k = 107$ objects this would give temperature of order 224 MeV for $x = 1$. Hadron physics giving experimentally evidence for Hagedorn temperature about $T = 140$ MeV near to pion mass and near to the scale determined by Λ_{QCD}, which would be naturally relate to the hadronic value of the cosmological constant Λ.

   The actual temperature could of course be lower than Hagedorn temperature and it is natural to imagine that blackhole cools down. The Hagedorn temperature and also actual temperature would increase in the phase transition $k \rightarrow k-1$ increasing the value of $\Lambda(k)$ by a factor of 2.

2. The overall view about the situation would be that the thermal excitations of cosmic string die out by emissions assignable perhaps to black hole jets and also going to the cosmic string until a state function reduction decreasing the value of k occurs and the process repeats itself.

   The naïve idea is that this process eventually leads to ideal cosmic string having Hagedorn temperature $T = \hbar/R$ and possible existing at very low temperature: this would conform with the idea that the process is the time reversal of the evolution leading from cosmic strings to astrophysical objects as tangles of flux tube. This would at least require a phase transition replacing M_{107} hadron physics with M_{89} hadron physics and this with subsequent hadron physics. One must of course consider also all values of k as possible options as in the case of the evolution of star. The hadron physics assignable to Mersenne primes and their Gaussian counterparts could only be especially stable against a phase transition increasing $\Lambda(k)$.

Quantitative support for the model of blackhole-like object as flux tube spaghetti

The TGD based model for blackhole-like object is as monopole flux tube spaghetti [L69] containing one proton per proton Compton length and filling the entire volume. There is no need to emphasize that the models means giving up the standard view of blackhole-like objects.

Consider now the estimation of the total mass of the flux tube spaghetti.

1. Assuming additivity and neglecting self-gravitation, the total mass in units of m_p is M/m_p (here $m_p \simeq m_n$ is proton mass, the star would consist of neutrons).

2. Self gravitation for a spherically symmetric mass constant distribution inside sphere of radius R and given as $\rho = M/Vol(R)$ created by the flux tube spaghetti gives to the stationary metric contribution $\Delta g_{tt} = -\Phi_{gr}$, where one has

$$\Phi_{gr}(r) = 2G\frac{2M(r)}{r} = \frac{8\pi}{3}\frac{GM}{Vol(R)}r^2 = 2GM\frac{r^2}{R^3} \quad .$$

   The gravitational potential energy of the mass distribution is in Newtonian appproximation given by

$$E_{gr} = -\int \rho(r)\Phi_{gr}(r)dV = -\frac{6GM^2}{5R} \quad .$$

For $R = r_S = 2GM$ this gives

$$E_{gr} = -\frac{6GM^2}{10GM} = -\frac{3}{5}M \quad .$$

Therefore the observed mass M_{obs} using m_p as a unit is given

$$M_{obs} = \frac{E_{tot}}{m} = \frac{2}{5}\frac{M}{m_p} \quad .$$

3. Suppose that the flux radius of thickness R contains a single proton per length zR so that one proton fills the volume $\pi * zR^3$. Suppose R corresponds to the proton Compton length $L_p = h/m_p$.

   Assume that $h_{eff} \neq h$ is possible so that L_p is scaled by $y = h_{eff}/h$. One would have

$$L_p(h_{eff}) = yL_p \quad .$$

4. The total mass M using m_p as unit and neglecting gravitational potential energy is given by the ratio of the volume V of the blackhole regarded as region of Minkowski space to the volume V_p taken by a single proton:

$$\frac{M}{m_p} = \frac{V}{V_p} = \frac{4}{3zy^3}(\frac{r_S}{L_p})^3 \quad .$$

   Taking into account gravitational potential energy, one obtains

$$\frac{M_{obs}}{m} = \frac{2}{5}\frac{V}{V_p} = \frac{8}{15zy^3}(\frac{r_S}{L_p})^3 \quad .$$

One can test the model for the Sun. One has $M_S = 2 \times 10^{30}$ kg and $r_S = 3$ km. Proton has mass $m_p = 1.6 \times 10^{-27}$ kg and Compton length $L_p = 1.3 \times 10^{-15}$ m. Substituting the values to the above formula, one obtains $(y,z) = (1,.992) \simeq (1,1)$. In the above formula M_{obs}/m on r.h.s decreases slightly in $m_p \rightarrow m_n$ and $1/L_p^3$ also increases on t l.h.s in $m_p \rightarrow m_n$. The changes of l.h.s and r.h.s are proportional to $-\epsilon \times l.h.s$ and $3\epsilon \times r.h.s$, where one has $\epsilon = (m_n - mp)/m_p \simeq .1.811 \times 10^{-3}$. This requires $\Delta(1/z) \simeq -4\epsilon(1/z)$ so that $z = .992$ is replaced with $z_{new} = (1+4\epsilon)z \simeq .9992$, which deviates from unity by -8×10^{-4}.

The conclusion is that the simple flux tube model for $h_{eff} = h$ and neutron taking a volume of Compton length, which is definitely different from the general relatistic model, is surprisingly realistic.

What happens to blackhole thermodynamics in TGD?

Blackhole thermodynamics (see `http://tinyurl.com/y7pvj23x`) has produced admirable amounts of literature during years. What is the fate of the blackhole thermodynamics in this framework? It turns out that the dark counterpart of of Hawking radiation makes sense if one accepts the notion of gravitational Planck constant assigned to gravitational flux tube and depending on masses assignable to the flux tube. The condition that dark Hawking radiation and flux tubes at Hagedorn temperature are in thermal radiation implying $T_{B,dark} = T_H$. The emerging prediction T_H is consistent with the value of the hadronic Hagedorn temperature.

1. In standard blackhole thermodynamics the blackhole temperature T_B identifiable identifiable as the temperature of Hawking radiation (see `http://tinyurl.com/md6mmvg`) is essentially the surface gravity at horizon and equal to $T_B = \kappa/2\pi = \hbar/4\pi r_S$ is analogous to Hagedorn temperature as far as dimensional analysis is considered. One could think of assigning T_B

to the radial pulsations of blackhole like object but it is very difficult to understand how the thermal isolation between stringy degrees of freedom and radial oscillation degrees of freedom could be possible.

2. The ratio $T_B/T_H \sim L_p/4\pi r_S$ would be extremely small for ordinary value of Planck constant. Situation however changes if one has

$$T_B = \frac{\hbar_{eff}}{4\pi r_S} \quad , \tag{16.2.2}$$

with $\hbar_{eff} = n\hbar_0 = \hbar_{gr}$, where $\hbar_{gr}$ is gravitational Planck constant.

The gravitational Planck constant $\hbar_{gr}$ was originally introduced by Nottale [E87] [K93, K79] assignable to gravitational flux tube (presumably non-monopole flux tube) connecting dark mass M_D and mass m (M and m touch the flux tubes but do not define its ends as assumed originally) is given by

$$\hbar_{gr} = \frac{GM_D m}{v_0} \quad , \tag{16.2.3}$$

where $v_0 < c$ is velocity parameter. For the Bohr orbit model of the 4 inner planets Nottale assumes $M_D = M(Sun)$ and $\beta_0 = v_0/c \simeq 2^{-11}$. For blackholes one expects that one has $\beta_0 < 1$ is not too far from $\beta_0 = 1$.

The identification of M_D is not quite clear. I have considered the problem how v_0 and M_D are determined in [L50, L49] [K11]. For the inner planets of Sun one would have $\beta_0 \sim 2^{-11} \sim m_e/m_p$. Note that the size of dark proton would be that of electron, and one could perhaps interpret $1/\beta_0$ as the $h_{eff}/\hbar$ assignable to dark protons in Sun. This would solve the long standing problem about identification of β_0.

3. One would obtain for the Hawking temperature $T_{B,D}$ of dark Hawking radiation with $h_{eff} = h_{gr}$

$$T_{B,D} = \frac{\hbar_{gr}}{\hbar} T_B = \frac{1}{8\pi\beta_0} \times \frac{M_D}{M} \times m \quad . \tag{16.2.4}$$

For $k = 107$ blackhole one obtains

$$\frac{T_{B,D}}{T_H} = \frac{\hbar_{gr}}{\hbar} \times T_B \times \frac{L(107)}{x\hbar} = \frac{1}{8\pi\beta_0(107)} \times \frac{M_D}{M} \times \frac{L(107)m}{x\hbar} \quad . \tag{16.2.5}$$

For $m = m_p$ this gives

$$\frac{T_{B,D}}{T_H} = \frac{\hbar_{gr}}{\hbar} T_B \times \frac{L(107)}{x\hbar} = \frac{1}{8\pi x\beta_0(107)} \times \frac{M_D}{M} \times \frac{m_p}{224\ MeV} \quad . \tag{16.2.6}$$

The order of magnitude of thermal energy is determined by m_p. The thermal energy of dark Hawking photon would depend on m only and would be gigantic as compared to that of ordinary Hawking photon.

4. Thermal equilibrium between flux tubes and dark Hawking radiation looks very natural physically. This would give

$$\frac{T_{B,D}}{T_H} = 1 \quad (16.2.7)$$

giving the constraint

$$\frac{\hbar_{gr}}{\hbar} T_B \times \frac{L(107)}{x\hbar} = \frac{1}{8\pi x\beta_0} \times \frac{M_D}{M} \frac{m_p}{224\ MeV} = 1\ . \quad (16.2.8)$$

on the parameters. For $M/M_D = 1$ this would give $x\beta_0 \simeq 1/6.0$ conforming with the expectation that β_0 is not far from its upper limit.

5. If ordinary stars are regarded as blackholes in the proposed sense, one can assign dark Hawking radiation also with them. The temperature is scaled down by $L(107)/L(k)$ and for Sun this would give factor of $L(107)/L(125) = 2^{-9}$ if one requires that $r_S(k)$ corresponds to solar radius. This would give

$$T_B(dark, k) \to \frac{\hbar_{gr}}{\hbar} \times \frac{L(107)}{L(k)} T_B = \frac{2^{(k-107)/2}}{8\pi\beta_0} \times \frac{M_D}{M} \times m\ . \quad (16.2.9)$$

For $k = 125$ and $M_D = M$ this would give $T_B(dark, 125) = m/2\pi$.

The condition $T_{B,D} = T_H$ for $k = 125$ would require scaling of $\beta_0(107)$ to $\beta(125) = 2^{-9}\beta_0(107) \simeq 2^{-11}$. This would give $\beta_0(107) \simeq 1/4$ in turn giving $x \simeq .66$ implying $T_H \simeq 149$ MeV. The replacement of $m_p = 1$ GeV with correct value $m_p = .94$ GeV improves the valueThis value is consistent with the value of hadronic Hagedorn temperature so that there is remarkable internal consistency involved although a detailed understanding is lacking.

6. The flux of ordinary Hawking thermal radiation is $T_B^4/\hbar^3$. The flux of dark Hawking photons would be $T_{B,dark}^4/\hbar_{gr}^3 = (\hbar_{gr}/\hbar)T_B^4$ and therefore extremely low also now also. In principle however the huge energies of the dark Hawking quanta might make them detectable. I have already earlier proposed that $T_B(h_{gr})$ could be assigned with gravitational flux tubes so that thermal radiation from blackhole would make sense as dark thermal radiation having much higher energies.

   One can however imagine a radical re-interpretation. BHE is not the thermal object emitting thermal radiation but BHE plus gravitational flux tubes are the object carrying thermal radiation at temperature $T_H = T_B$. For this option dark Hawking radiation could play fundamental role in quantum biology as will be found.

7. What about the analog of blackhole entropy given by

$$S_B = \frac{A}{4G} = \pi \frac{l_{Pl}^2}{T_B^2}\ , \quad (16.2.10)$$

where $A = 4\pi r_S^2$ is blackhole surface area. This corresponds intuitively to the holography inspired idea that horizon decomposes to bits with area of order l_P^2?

   The flux tube picture does not support this view. One however ask whether the volume filling property of flux tube could effectively freeze the vibrational degrees of flux tubes. Or whether these degrees of freedom are thermally frozen for ideal blackhole. If so, only the ends of he flux tubes at the surface or their turning points (in case that they are turn back) can oscillate radially. This would give an entropy proportiona+l to the area of the surface but using flux tube transversal area as a unit. This would give apart from numerical constant

$$S_B = \frac{A}{4L(k)^2} \quad . \tag{16.2.11}$$

Constraint from $\hbar_{gr}/\hbar > 1$

When mass m can interact quantum gravitationally and are thus allowed in h_{gr} for given M_D?

1. The notion of h_{gr} makes sense only for $h_{gr} > h$. If one has $h_{gr} < h$ assume $h_{gr} = h$. An alternative would be $h_{gr} =\!\!\rightarrow h_0 = h/6$ for $h_{gr} < h_0$. This would given $GM_Dm/v_0 > \hbar_{min}$ ($\hbar_{min} = \hbar$ or $\hbar/6$) leading

$$m > \frac{\beta_0\hbar}{2r_S(M_D)} \times \frac{\hbar_{min}}{\hbar} \quad . \tag{16.2.12}$$

   This condition is satisfied in the case of stellar blackholes for all elementary particles.

2. One can strengthen this condition so that it would satisfied also for gravitational interactions of two particles with the same mass ($M_D = m$). This would give

$$\frac{m}{m_{Pl}} > \sqrt{\beta_0} \quad . \tag{16.2.13}$$

   For $\beta_0 = 1$ this would give $m = m_{Pl}$, which corresponds to a mass scale of a large neuron and to size scale 10^{-4} m. $\beta_0(125) = 2^{-11}$ gives mass scale of cell and size scale about 10^{-5} meters. $\beta_0(127) \simeq 2^{-12}$ corresponding to minimum temperature making hot fusion possible gives length scale about 10^{-6} m of cell nucleus. A possible interpretation is that the structure in cellular length scale have quantum gravitational interaction via gravitational flux tubes. Biological length scales would be raised in special position from the point of view of quantum gravitation.

3. Also interactions of structures smaller than the size of cell nucleus with structures with size larger the size of cell nucleus are possible. By writing the above condition as $(m/m_{Pl})(M_D/m_{pl}) > \beta_0$, one sees that from a given solution to the condition one obtains solutions by scaling $m \rightarrow xm$ and $M_D \rightarrow M_D/x$. For $\beta_0(127) \simeq 2^{-11}$ corresponding to the scale of cell nucleus the atomic length scale 10^{-10} m and length scale 10^{-4} m of large neuron would correspond to each other as "mirror" length scales. There would be no quantum gravitational interactions between structures smaller than cell nucleus. There would be master-slave relationship: the smaller the scale of slave, the larger the scale of the master.

Quantum biology and dark Hawking radiation

The scaling formula $\beta_0(k) \propto 1/L(k)$ with flux tube thickness scale given by $L(k)$ allows to estimate $\beta_0(k)$. In this manner one obtains also biologically interesting length scales. An interesting question is whether the scales for the velocities of Ca waves (see `http://tinyurl.com/qs3j5cp`) and nerve pulse conduction velocity could relate to v_0.

1. The tube thickness about 10^{-4} m, which corresponds to ordinary cosmological constant being in this sense maximal corresponds to the p-adic length scale $k = 171$. The scaling of $\beta_0 \propto 1/L(k)$ gives $v_0(171) \sim 4.7$ μm/s In eggs the velocity of Ca waves varies in the range 5-14 μm/s, which roughly corresponds to range $k \in \{171, 170, 169, 168\}$.

In other cells Ca wave velocity varies in the range 15-40 μm/s. $k = 165$ corresponds to 37.7 μm/s near the upper bound 40 μm/s. The lower bound corresponds to $k = 168$. $k = 167$, which corresponds to the larges Gaussian Mersenne in the series assignable to $k \in \{151, 157, 163, 167\}$ the velocity is 75 μm/s.

2. For $k = 127$ gives $v_0 \sim 75$ m/s. $k = 131$ corresponds to $v_0 = 18$ m/s. These velocities could correspond to conduction velocities for nerve pulses in accordance with the view that the smaller the slave, the larger the master.

I have already earlier considered that dark Hawking radiation could have important role in living matter. The Hawking/Hagedorn temperature assuming $x = 1/6.0$ $k = L(171)$ has peak energy 38 meV to be compared with the membrane potential varying in the range 40-80 meV. Room temperature corresponds to 34 meV. For $k = 163$ defining Gaussian Mersenne one would have peak energy about .6 eV: the nominal value of metabolic energy quantum is .5 eV. $k = 167$ corresponds to .15 eV and 8.6 μm - cell size. Even dark photons proposed to give bio-photons when transforming to ordinary photons could be seen as dark Hawking radiation: Gaussian Mersenne $k = 157$ corresponds to 4.8 eV in UV. Could CMB having peak energy of .66 meV and peak wavelength of 1 mm correspond to Hawking radiation associated with $k = 183$? Interestingly, cortex contains 1 mm size structures. To sum up, these considerations suggest that biological length scales defined by flux tube thickness and cosmological length scales defined by cosmological constant are related.

16.2.5 Zero energy ontology and stellar and galactic evolution

Zero energy ontology (ZEO) replaces ordinary ontology in TGD based view about quantum states and quantum jump [L84].

1. In ZEO zero energy states are superpositions of space-time surfaces inside causal diamond (CD) identified as preferred extremals of the basic action principle of TGD. CD is cartesian product of causal diamond cd of M^4 and of CP_2. The preferred extremals analogous to Bohr orbits have boundaries - ends of space-time - at the light-like boundaries of CD. There is a fractal hierarchy of CDs and given CD is an embedding space correlate for a conscious entity - self - consciousness is universal.

2. Zero energy states can be seen as superpositions of state pairs with members assigned to the opposite boundaries of CD. ZEO predicts that in ordinary or "big" state function reductions (BSFRs) the arrow of time of system changes and remains unaffected in "small" state functions (SSFRs), which are TGD counterpart for "weak" measurements and associated with a sequence of unitary evolution for the state assignable to the active boundary CD, which also shifts farther from the passive boundary. Passive boundary is unaffected as also members of state pairs at it.

3. Subjective time is identified as a sequence of SSFRs and correlates strongly with clock time identifiable as the distance between the tips of CD and increasing in statistical sense during the sequences of SSFRs.

4. BSFR corresponds to state function reduction at active boundary of CD which becomes passive. This forces the state at passive boundary to change. Passive boundary becomes active. BSFR means the death of self and reincarnation with an opposite arrow of time. Thus the notion of life cycle is universal and life can be lieved in both directions.

5. What happens to CD in long run? There are two options.

   (a) The original assumption was that the location of formerly passive boundary is not changed. This would mean that the size of CD would increase steadily and the outcome would be eventually cosmology: this sounds counter-intuitive. Classically energy and other Poincare charges are conserved for single preferred extremal could fail in BSFRs due to the fact that zero energy states cannot be energy eigenstates.

(b) The alternative view suggested strongly $M^8 - H$ duality [L34] is that the size of CD is reduced in BSFR so that the new active boundary can be rather near to the new passive boundary. One could say that the reincarnated self experiences childhood. In this case the size of CD can remain finite and its location in M^8 more or less fixed. One can say that the self associated with the CD is in a kind of Karma's cycle living its life again and again. Since the extension of rationals can change in BSFR and since the number of extensions larger than given extension is infinitely larger than those smaller than it, the dimension of extension identifiable in terms of effective Planck constant increases. Since $n = h_{eff}/h_0$ serves as a kind of IQ, one can say that the system becomes more intelligent.

Cosmic redshift but no expansion of receding objects: one further piece of evidence for TGD cosmology

"Universe is Not Expanding After All, Controversial Study Suggests" was the title of very interesting Science News article (see http://tinyurl.com/o6vyb9g) telling about study, which forces to challenge Big Bang cosmology. The title of course involved the typical exaggeration.

The idea behind the study was simple. If Universe expands and also astrophysical objects - such as stars and galaxies - participate the expansion, they should increase in size. The observation was that this does not happen! One however observes the cosmic redshift so that it is too early to start to bury Big Bang cosmology. This finding is however a strong objection against the strongest version of expanding Universe. That objects like stars do not participate the expansion was actually known already when I developed TGD inspired cosmology for quarter century ago, and the question is whether GRT based cosmology can model this fact naturally or not.

The finding supports TGD cosmology based on many-sheeted space-time. Individual space-time sheets do not expand continuously. They can however expand in jerk-wise manner via quantum phase transitions increasing the p-adic prime characterizing space-time sheet of object by say factor two of increasing the value of $h_{eff} = n \times h$ for it. This phase transition could change the properties of the object dramatically. If the object and suddenly expanded variant of it are not regarded as states of the same object, one would conclude that astrophysical objects do not expand but only comove. The sudden expansions should be observable and happen also for Eart. I have proposed a TGD variant of Expanding Earth hypothesis along these lines [**?**]

Stars as reincarnating conscious entities

One can apply ZEO to the evolution of stars. The basic story (see http://tinyurl.com/ceoo6sj) is that the star is formed from he interstellar gas cloud, evolves and eventually collapses to a white dwarf, degenerate carbon-oxygen core, supernova or even blackhole if the mass of the remnant resulting in explosion throwing outer layers of the star away is in the range of 3-4 solar masses. Only very massive stars end up to supernovas. The type of the star depends on the abundances of various elements in the interstellar gas from which they formed and believed to contain heavier elements produced by earlier supernovas.

There are however several anomalies challenging the standard story. There are stars older than Universe (see http://tinyurl.com/s698l86). There is also evidence that the abundances of heavier elements in the early cosmology are essentially the same as for modern stars [E102] (see http://tinyurl.com/qkk26dv). TGD based explanation is discussed in [L82].

Karma's cycle option for the stellar evolution could explain these anomalies.

1. Stars would be selves in Karma's cycle with their magnetic bodies reincarnating with a reversed arrow of time in a collapse to blackhole/white hole like entity (BHE/WHE) - depending on the arrow of time. This would follow by a stellar evolution leading to an asymptotic state BHE/WHE corresponding to maximum size of CD followed by a collapse to BHE or WHE. Also ordinary stars would correspond to BHEs/WHEs characterized by p-adic length scale $L(k)$ longer than $L(107)$ assignable to GRT blackholes. In standard time direction WHE would look like blackhole evaporation.

2. This would allow stars older than the Universe and suggests also universal abundances. Note however that the abundances would strongly depend on the abundances of the interstellar

gas and matter produced by the magnetic energy of flux tube. "Cold fusion" as dark fusion could produce elements heavier than Fe and light elements Li, Be, B, whose abundances for fusion in stellar core is predicted to be much much smaller than the observed abundances in the case of old stars. The lifetimes of stars depend on their type. Also a universal age distribution of stars in stellar clusters not depending appreciably on cosmic time is highly suggestive. I remember of even writing about this. Unfortunately I could not find the article.

To put it more generally, the hierarchy of CDs implies that the Universe decomposes effectively to sub-Universes behaving to some degree independently. The view about Karma's cycles provides a more precise formulation of the pre-ZEO idea that systems are artists building themselves as 4-D sculptures. In particular, this applies to mental images in TGD based view about brain.

1. One could perhaps say that also quantum non-determinism has classical correlates. CDs would be the units for which time-reversing BSFRs are possible. Also SSFRs affecting CDs could have classical space-time correlates. M^8-H duality [L34] predicts that the time evolution for space-time surface inside CDs decomposes to a sequence of deterministic evolutions glued together along M^4 time $t=r_n$ hyperplanes of M^4 defining special moments in the life of self at which the new larger CD receives a new root $t=r_n$. The non-deterministic discontinuity could be localized to the 2-D vertices represented by partonic 2-surfaces at which the ends of light-like partonic orbits meet.

2. The M^4 hyperplanes $t=r_n$ correspond to the roots of a real polynomial with rational coefficients defining the space-time surfaces at the level of M^8 as roots for the real or imaginary part in quaternionic sense for the octonionic continuation of the polynomial. These moments of time could correspond to SSFRs.

3. The finite classical non-determinism is in accordance with the classical non-determinism predicted at the limit of infinitely large CD and vanishing cosmological constant at which classical action reduces to Kähler action having a huge vacuum degeneracy due to the fact than any space-time surface having Lagrangian manifold (vanishing induced Kähler form) as CP_2 projection is a vacuum extremal. The interpretation of this degeneracy interpreted in terms of 4-D spin glass degeneracy would be that at the limit of infinitely large CD the extension of rationals approaches to algebraic numbers and the roots $t=r_n$ becomes dense and the dynamics becomes non-deterministic for vacuum extremals and implies non-determinism for non-vacuum extremals.

No time dilation for the periods of processes of quasars

There are strange findings about the time dilation of quasar dynamics challenging the standard cosmology [E203]. One expects that the farther the object is the slower its dynamics looks as seen from Earth. Lorentz invariance implies red shift for frequencies and in time domain this means the stretching of time intervals so that the evolution of distant objects should look the slower the longer their distance from the observer is. In the case of supernovae this seems to be the case. What was studied now were quasars at distances of 6 and 10 billion years and the time span of the study was 28 years [E222]. Their light was red shifted by different amounts as one might expect but their evolution went on exactly the same rhythm. This looks really strange.

In GRT the redshift violates conservation of four-momentum. In TGD cosmic redshift reduces to the fact that the tangent spaces of the space-time surface for target and receiver differ by a Lorentz boost. Redshift does not mean non-conservation of four-momentum but only that the reference frames are different for target and observer. The size for the space-time sheets assignable to the systems considere must be large, of the order of the size scale L defined by the size of the recent cosmology to which one assigns the Hubble constant. In the flux tube picture this means that the flux tubes have length of order L but thickness would be about $R=10^{-4}$ meters - the size scale of large neuron. Photons arrive along flux tubes connecting distant systems. Note that CMB corresponds to 10 times longer peak wavelength.

I have already earlier discussed this time anomaly [K66] but what I have written is just the statement of the problem and and some speculations about its solution in terms of ZEO.

A valuable hint is that the time anomaly appears for quasars- very heavy objects - but not for supernovae - much lighter objects. This suggests that the redshift depends on the masses of the objects considered.

1. One considers an approximately periodic process. It is quite possible that this process is not classical deterministic process at space-time level but that one has sequence of SSFRs (weak measurements) or even BSFRs for a subsystem of the target. These processes replace quantum superposition of space-time surfaces inside CD with a new one and SSFR also increases its size in statistical sense. A natural Lorentz invariant "clock time" for the target is the distance between the tips of CD - light-cone proper time. Both M^4 linear coordinates and light-cone Robertson-Walker coordinates are natural coordinates for space-time sheets with 4-D M^4 projection.

   "Clock time" must be mapped to M^4 linear time for some space-time sheet. The Minkowski coordinates for the CD are determined only modulo Lorentz boost leaving the light-like boundary of CD invariant. In general the M^4 coordinates of the target and observer are related by a Lorentz boost and this gives rise to cosmological redshift and also gravitational reshift.

2. The information about SSFR or BSFR at the target must be communicated to the observer so that the space-time sheets in question must be connected by flux tubes carrying the photons. CD must contain both systems and naturally has cosmological size given by L so that flux tubes have thickness about R. The M^4 time coordinate must be common to both systems. The natural system to consider is center of mass system (cm) in which the sum of the momenta of two systems vanishes.

Did cosmology have any "Dark Ages"?

A further potential time anomaly of the recent cosmology relates to the "Dark Ages" of the Universe. Between the decoupling of CMB radiation from matter and the formation of stars there should have been a "Dark Ages" during which there was only neutral hydrogen. Star formation generated radiation at energies high enough to ionize hydrogen and the ionized interstellar gas started to produce radiation.

The 21 cm line of neutral hydrogen serves as a signature of neutral hydrogen. This line is redshifted and from the lower bound for the redshift one can deduce the time when "Dark Ages" ended. The popular article tells (see `http://tinyurl.com/wzegzxk`) that the recent study using Murchison Widefield Array (MWA) radio telescope by Jonathan Pober and collaborators gave an unexpected result. Only a new lower upper bound for this redshift emerged: the upper bound corresponds to about 2 meters [E155] (see `http://tinyurl.com/qttq3gl`). The conclusion of the experimenters is optimistic: soon the upper bound for the redshift should be brought to light.

In TGD based view about cosmology and astrophysics [L69] (`http://tinyurl.com/tkkyyd2`) one can formulate two questions.

1. One can ask whether there were any "Dark Ages" at all!

2. An alternative question is whether the "Dark Ages" in distant geometric past are prevailing anymore! This would be like asking whether the Hitler of thirties is the Hitler we know anymore. The point is that in TGD framework one must distinguish between subjective time and geometric time and this leads to some rather dramatic modifications of the prevailing view about time. The following arguments encourage a positive answer to the first question and negative answer to the second question.

The following arguments encourage positive answer to the first question and negative answer to the second question.

The answer to the first question relies of TGD based view about nuclear physics solving anomalies of standard nuclear physics and leading to a new view about stellar evolution.

1. In TGD framework the formation of stars could have preceded by a pre-stellar period during which dark fusion giving rise to dark proton sequences - dark nuclei - at monopole flux tubes

happened: this is Pollack effect in biology. This would have been "cold fusion" period in the stellar evolution and would have occurred spontaneously at low temperatures. It would have already produced abundances, which are not far from modern ones and one of the recent surprises is that the abundances at very early period are already near to modern ones.

2. The model predicts also the possibility of neutral states for which electrons are at flux tubes parallel to dark proton flux tubes and have the same scaled up size (due to non-standard value of $h_{eff} = nh_0$, which is smaller by factor about 1/2000) as dark protons. In solar interior dark protons would have Compton size of electron so that h_{eff} for them would be about 2000 times higher $H = M^4 \times CP_2$ than h. Also smaller and larger value of h_{eff} are possible. For blackholes the protons at flux tubes would be ordinary: $h_{eff} = h$.

3. The transformation of dark nuclei having much smaller binding energy would have liberated nuclear binding energy and the resulting photons having energy up to gamma ray energies would have ionized the neutral hydrogen.

Zero energy ontology (ZEO) leads to a negative answer to the question whether "Dark Ages" still prevail in distant past.

1. In ZEO Universe consists at the level of embedding space $H = M^4 \times CP_2$ of a fractal hierarchy of $CD = cd \times CP_2$, where cd is causal diamond of M^4.*CDshaveinterpretationasahierarchyofsub− cosmologies.EachCDdefinesacorrelateforaconsciousentityandincreasesinsizeineach\small" statefunctic passive−asalsomembersofstatepairsatitdefiningzeroenergystates.Theactiveboundaryrecedesfartherawa*

2. In a "big" (ordinary) state function reduction (BSFR) the roles of boundaries of CD change. Active becomes passive and vice versa. The arrow of time changes. Self dies and reincarnates with opposite arrow of time. The simplest possibility is that the size of CD can decrease in BSFR meaning that the formerly passive boundary becomes much nearer to active. In this case CD begins to grow from a small size: self has "childhood". In this case it can happen that self never reaches a size larger than some upper bound and lives again and its life. Each life is more evolved since the extension of rationals involved with space-time surface increases in statistical sense in BSFR. This is nothing but Karma's cycle but in all scales.

3. At the level of stars this would mean that star could undergo evolution as Karma's cycle also in cosmological remote past as an object located at fixed point of H. The abundances would be more or less the same as for modern stars. This would explain the mystery of stars older than the Universe and solve also other time anomalies of the standard cosmology. This explanation is consistent with the first one and actually the first one is needed to explain abundances of nuclei heavier than Fe and the light nuclei Li, B, Be much higher than predicted by standard model. Thus both questions would have positive answer.

Observation of a time reversal of blackhole like object?

A very strange object behaving like time reversal of blackhole has been observed (`http://tinyurl.com/umzxaoe`). The blackhole in question is super-massive and in the middle of galaxy cluster. Usually blackhole eat the surrounding matter and also prevent the formation of stars since they are powerful emitters of gamma rays - this is not in accordance with the naïve view about blackholes. The weird blackhole does not emit gamma rays and the environment around it cools and this makes possible star formation. Instead of eating the surrounding matter it should feed matter to surroundings making possible the star formation.

The most obvious TGD identification of the mystery object relies on zero energy ontology allowing both arrow of time. The arrow of time chances in ordinary state function reduction - the "big" one as opposed to "small" one corresponding to weak measurement. This predicts time reversed blackhole like objects (BHEs) analogous to white holes: white hole like objects (WHEs).

WHEs could appear in the very early states of the galactic evolution. They could feed the magnetic energy of monopole flux tubes to environment transformed to ordinary matter in turn forming galaxies. As a matter of fact, monopole flux tubes portions emanating it much lines of magnetic field would be formed and their local thickening and formation of tangles would give rise to stars.

If the time reversal idea is taken very seriously WHEs should suck gamma rays from environment inducing cooling making the star formation easier. This would be dissipation in non-standard direction of time identifiable as the basic metabolic mechanism associated with all kinds of self-organization process: quantum coherence at the level of magnetic body would be essential and induce long range coherence of ordinary matter as forced coherence.

WHE could be also created in BSFR for a BHE.

Do quasars and galactic blackholes relate by time reversal in ZEO?

This picture combined with zero energy ontology (ZEO) based view about ordinary state functions changing the arrow of time and occurring even in astrophysical scales leads to a tentative view about quasars and galactic blackholes as time reversals of each other.

1. Quasars could be seen as analogs of white holes feeding the mass of cosmic string out to build the galactic tangle and part of the mass of thickening tangle would transform to ordinary matter. They would initiate the formation of galaxy meaning emergence of increasing values of h_{eff} in the hierarchy of Planck constant. Cosmic string would basically feed the mass and energy liberated in the decay of magnetic energy at cosmic strings thickening to flux tubes to ordinary matter and serving in the role of metabolic energy driving self-organization.

2. Galactic blackholes could be perhaps indeed analogs of blackholes as time reversals of quasars - "big" (ordinary) state function reduction would transform quasar as white hole to a galactic blackhole. Now the system would be drawing back the mass from the surroundings to the flux tube and maybe cosmic string. The process could be like breathing. In zero energy ontology breathing could indeed involve a sequence of states and their time reversals.

This raises also the question whether the evolution of stars could be seen as a time reverse for the formation of blackholes: kind of growth followed by a decay perhaps since the values of Planck constant h_{eff} would be reduced. The climax of his evolution would correspond to maximal values of h_{eff}. The evolution of life would be certainly this kind of climax.

An objection against the notion of dark energy

Nikolina Benedikovic gave a link to a popular article (`http://tinyurl.com/ydo2sna9`) describing a finding challenging the notion of dark energy. This finding made by a team of astronomers working at Yonsei University (Seoul, South Korea) is very interesting since twistor lift of TGD predicts length scale dependent cosmological constant.

Let us collect the basic facts first.

1. Standard candle property (`http://tinyurl.com/pn9goe2`) is essential assumption leading to dark energy hypothesis. It states that the distance corrected luminosity of SN Ia supernovae does not evolve with redshift that it is it depends only on distance.

2. Observation: The luminosity of SN Ia supernova correlates significantly with the population age of the host galaxy. The luminosity thus depends on the environment provided by the host galaxy.

   According to the article:

   > The team has performed very high quality spectroscopic observations to cover most of the reported nearby early-type host galaxies of SN Ia, from which they obtained the most direct and reliable measurements of population ages for these host galaxies. They find a significant correlation between SN luminosity and stellar population age at a 99.5 percent confidence level. As such, this is the most direct and stringent test ever made for the luminosity evolution of SN Ia. Since SN progenitors in host galaxies are getting younger with redshift (look-back time), this result inevitably indicates a serious systematic bias with redshift in SN cosmology. Taken at face values, the luminosity evolution of SN is significant enough to question the very existence of dark energy. When the luminosity evolution of SN is properly taken into account, the team found that the evidence for the existence of dark energy simply goes away (see Figure 1).

3. This is in conflict with the standard candle property if the population age of the host galaxy decreases with distance. This is obvious in standard cosmology. But is this true in TGD Universe obeying zero energy ontology (ZEO)?

In ZEO [L84] (http://tinyurl.com/yfjtmoq6) the situation might be different. ZEO provides a quantum measurement theory solving the basic paradox of standard quantum measurement theory and leads to a theory of consciousness.

1. The first prediction is that geometric time and experienced time identified as sequence of "small" state function reductions (SSFRs as counterparts of weak measurements) are not same. This is of course an empirical fact - thermodynamical time is irreversible unlike geometric time, etc... but in standard ontology these times are identified.

2. In small state function reductions (SSFRs) as counterparts of weak measurements) arrow of time does not change and their sequence defines self as conscious entity. In big (ordinary) state function reductions (BSFRs) the system "dies" and reincarnates with opposite arrow of time. The experiments of Minev *et all* provide direct support for ZEO in atomic systems [L68] (http://tinyurl.com/yjbpoy3q). Libet's findings support this in neuroscience [J1].

3. Assume that the size of the causal diamond (CD) decreases in "reincarnation" that is self experiences "childhood". If so the size of CD can remain bounded. Irrespective of this assumption the temporal center of mass position of CD in embedding space $H = M^4 \times CP_2$ remains the same during the sequence of reincarnations.

   Most importantly: the steady motion towards future assumed in standard ontology with single arrow of time is replaced with forth-and-back motion in time with constant cm position of CD in H.

4. ZEO explains several time anomalies such stars older than the universe and the observation that the nuclear abundances of very distance stars seem to have nearly their modern values supporting the view that the population age of galaxy does not depend significantly on distance [L69](hhttp://tinyurl.com/ydlogkb4) .

   In particular, the age distribution for the populations of galaxies would not depend significantly on distance - standard candle hypothesis would be saved!

16.2.6 Objections against GRT blackholes

The basic theoretical objection against blackholes was due to Einstein himself. The collapse of matter to single point is simply impossible. This objection has been however forgotten since doing calculations is much more pleasant activity than hard thinking, and an enormous literature have been produced based on this idealization. There is no doubt that blackhole like entities (BHEs) with about Schwartschild radius exist, but general relativity does not allow to say anything about the situation inside possibly existing horizon.

Badly behaving blackholes

There is an excellent video (thanks to Howard Lipman for a link) challenging the standard view about blackholes. In the sequel list some arguments that I remember.

TGD was born as a solution to the fundamental difficulty of GRT due to the loss of classical conservation laws. In TGD framework BHEs correspond to *volume filling* flux tube tangles. Also galactic BHEs would correspond to a volume filling flux tube tangles.

In TGD framework also stars could be seen as BHEs having the flux tube thickness characterized by p-adic length scale as an additional parameter. GRT blackholes correspond to flux tube thickness about proton Compton length. For instance, Sun can be seen as a BHE and the size is predicted correctly [L69](see http://tinyurl.com/tkkyyd2) .

The model for BHEs makes large number of correct predictions.

1. The minimal radii/masses of GRT blackholes and neutron stars are predicted correctly.

2. Ordinary blackhole thermodynamics is replaced with the thermodynamics associated with monopole flux tubes carrying galactic dark mass characterized by Hagedorn temperature and the thermodynamics gravitational flux tubes characterized by Hawking temperature but for gravitational Planck constant h_{gr} so that it is gigantic as compared to the ordinary Hawking temperature.

   In thermal equilibrium these temperatures are same and this predicts hadronic string tension correctly.

Consider now the empirical objections against BH paradigm in light of TGD picture.

1. The observations by ALMA telescope show that stars can be formed surprisingly near to galactic BHEs (see `http://tinyurl.com/ry746pg`). For instance, 11 young stars just forming have been found at distance of 3 ly from galactic BHE of Milky Way. This is impossible since the intense tidal forces and UV and X ray radiation should make impossible the condensation of stars from gas clouds.

   TGD explanation: Galaxies are formed as tangles on long thickened cosmic string responsible for galactic dark matter as dark energy. Same mechanism give rise to stars as sub-tangles generating at least part of the ordinary matter as decay of the magnetic energy of the flux tube as it thickens. Ordinary matter already present could concentrate around the tangle.

   One learns from the discussion in the above link that star formation involves bipolar flow consisting two jets in opposite directions believed to take care of angular momentum conservation: the star formed is thought to be formed from a rotating gas cloud (rotation would be around flux tube) having much larger angular momentum and part of must be carried out by jets naturally parallel to the flux tube. Also this gives support for the view that stars are tangles along flux tube. There are also hundreds of massive and much older stars in the vicinity of galactic BHE.

   Note that in TGD also these stars could be seen as BHEs but with different p-adic length scale characterizing the thickened flux tube. The reason why galactic BHE does not swallow these objects could be that they are bound states around flux tube (or even cosmic string outside the star), which is rather rigid by its string tension.

   "Non-hungry" BHEs are found.

   TGD explanation: In zero energy ontology to which quantum TGD relies, one must distinguish between BHEs and their time reversals, white hole like objects (WHEs), analogous to white holes. WHEs would not be "hungry" but feed matter into environment. The counterparts or jets would flow into WHE and matter would flow out from WHE.

3. The standard theoretical belief is that in a dense star cluster only single blackhole can exist. If there are several blackholes, they start to rotate around each other and fuse to a larger blackhole. A case with two blackholes have been however observed.

   TGD explanation: A possible explanation is that the objets are WHEs and their behavior is time reversal of BHEs.

4. The velocities of particles in the jets associated with a galactic BHEs are near light velocity and require extremely high energies and thus strong magnetic fields. No strong magnetic field has been however observed.

   TGD explanation: In TGD Maxwellian magnetic fields are replaced with flux tubes carrying quantized monopole flux not possible in Maxwellian world. Their existence allows to understand the presence of magnetic fields in even cosmological scales, the maintenance problem of Earth's magnetic field, and the recent findings about the magnetic field of Mars [L71]. Ordinary magnetic fields correspond to vanishing total flux and are indeed weak: it is these magnetic fields outside the jet which would have been measured. Galaxies are tangles in monopole flux tube and this is the carrier of very strong magnetic field associated with jets parallel to the flux tube.

5. Very distant galactic blackholes with distances in scale of million light years have radio jets in the same direction. This is very difficult to understand in the standard view about cosmology.

   TGD explanation: The galactic BHEs would be associated with the same long cosmic string forming galaxies as tangles.

Too heavy blackhole in Milky Way

The standard model for blackhole formation predicts an upper bound on the mass of blackhole depending also on environment since the available amount of matter in environment is bounded. In the case of Milky Way the bound is about 20 solar masses. Now however a blackhole like entity (BHE) with mass about 70 solar masses has been discovered (see `http://tinyurl.com/w7xlb78`). I am grateful for Wes Johnson for the link. Also the masses of BHEs producing the gravitational radiation in their fusion have been also unexpectedly high, which suggets that standard view about BHEs is not quite correct.

The proposed model for BHEs as a volume filling flux tube gives correct lower bounds for masses of neutron star and TGD counterpart of blackhole but does not give upper bound for the mass. For time reversed BHEs - analogs of white holes (WHEs) possibly identifiable as quasars - the mass of WHE comes from a tangling long cosmic string and there is no obvious upper bound. Even galactic BHEs could correspond to WHEs, which have made quantum jump to BHEs at the level of magnetic body: in this state the flux tube forming counter the magnetic field is fed back from environment. A breathing spaghetti would be in question.

In standard model the mechanism for the formation of blackhole is different since there is no flux tube giving the dominant dark energy/dark matter contribution to the mass. Therefore the upper bound for mass - if there exists such - is expected to increase. In TGD framework the dominant contribution would come from the monopole flux tubes giving rise TGD counterpart of magnetic field which extends at least over the region containing stars assumed to correspond sub-tangles of the galactic flux tangle. Intuitively it seems clear that the upper bound is higher than in GRT. If the spaghetti straightens - the tangled flux tube would untangle- one could have upper bound.

The simplest model predicts that only the flux tube mass contributes to the mass of BHE. The mass of the ordinary matter going to BHE would transform back to dark energy/mass of the flux tube. The process would be time reversal of the process making sense in zero energy ontology [L84] in which the magnetic energy of flux tube transforms to ordinary matter: time reversal for the TGD counterpart of inflation.

16.3 A model for the formation of galaxies

I have proposed a general vision about galaxy formation as formation of tangles on cosmic strings carrying monopole flux. The strings can be long and also short. In the case of long string the model explains flat velocity spectrum of distant stars automatically. For closed short strings the velocity spectrum is not flat. There is however no detailed model for the galaxy formation. In particular, the complex structure of spiral galaxies is poorly understood. Even the question whether there is single long cosmic string orthogonal to the galactic plane or cosmic string parallel to the spiral structure in galactic plane - as proposed decades ago in the original model [K31, K94] - or both has remained open. In the sequel I make an attempt to collect the essential facts about elliptic and spiral galaxies and consider a qualitative model for the galaxy formation consistent with these facts. The goal is rather modest: just to develop an internally consistent view about the evolution of galaxies.

1. The simplest model for elliptic galaxy is as a closed string possibly reconnected as a loop from long string or as a tangle of a cosmic string having topology analogous to that of field lines of dipole magnetic field. Quasar would have preceded the formation of the tangle in which string would have thickened to flux tube and dark energy would have transformed to ordinary matter [E58] [L63]. Quasars would be time reversal of galactic blackhole like entity (GBHE).

2. In the case of spiral galaxies the existence of vast polar structures (VPOS) in the plane orthogonal to the galactic plane of spiral galaxy (http://tinyurl.com/k553545) strongly suggest [L47] that two cosmic strings are involved and that the spiral structure believed to correspond to a standing wave analogous to traffic jam is associated with dark matter of a long cosmic string. This model conforms with the fact that the stars of spiral galaxies are older than those of elliptic galaxies except inside the bulge.

   The asymmetry between the two planes suggests that the spiral arms are formed when an elliptic galaxy identified as a tangle of a long string $S_{||}$ formed via a quasar stage [L63] in the galactic plane has collided with a cosmic string $S_{\perp}$ orthogonal to the galactic plane. These collisions are unavoidable for non-parallel strings and gravitational attraction causes the needed relative motion.

   The differential rotation of portion of $S_{||}$ around $S_{\perp}$ would have deformed $S_{||}$ to a spiral shape. $S_{||}$ would have also generated the visible spiral arm pair in the transformation of dark energy to ordinary matter. Galactic bulge would correspond to the elliptic galaxy and galactic blackhole like entity (GBHE) would have formed from the matter in bulge: this conforms with the fact that elliptic galaxies have always galactic blackhole. The galactic bar could be analogous to the dipole of dipole magnetic field. In principle also the string orthogonal to the galactic plane could produce ordinary matter by thickening.

One open question relates to the fact that TGD predicts two kinds of cosmic strings with closed transverse cross section and having vanishing induced Kähler field or non-vanishing induced Kähler form carrying monopole flux. The latter are stable against splitting by the conservation of the monopole flux and have no counterpart in Maxwellian electrodynamics [L66]. The monopole flux tubes could correspond to the cosmic strings giving rise to galaxies, stars, and even planets as tangles. Non-monopole flux tubes might serve as gravitational flux tubes mediating gravitational interactions. Presumably both kinds of flux tubes are involved but their precise roles are not well-understood.

16.3.1 Some basic facts about galaxies

In the following I collect basic facts about galaxies.

Elliptic galaxies

The following facts about elliptic galaxies (http://tinyurl.com/ayyvg9n) are relevant for what follows.

1. 10-15 per cent of all galaxies are elliptic. The stars of elliptic galaxies are old and older than those of spiral galaxies outside the bulge.

2. The size of elliptic galaxies is typically 1-2 pc and therefore more than by order of magnitude smaller than that of spiral galaxies. Elliptic galaxies are essentially 3-D structures without sub-structures, and the central bulge of spiral galaxies resembles elliptical galaxy. There is no preferred galactic plane. Large enough elliptic galaxies have supermassive blackhole-like entity (BHE) at their center. Elliptic galaxies are populated by globular clusters. The motions of stars in elliptic galaxies are mostly radial.

3. Whether elliptic galaxies contain dark matter is not clear and the non-existence of dark matter cannot be excluded for elliptic galaxies (http://tinyurl.com/s2wrd26).

Basic structures for spiral galaxies

Most galaxies 85-90 per cent of galaxies are spiral galaxies. Spiral galaxies are highly structured.

Consider first the visible structure taking Milky Way as a representative example (also so called mini-spirals exist [L47]).

1. Stellar disk of spiral galaxy (http://tinyurl.com/vx2hams) has radius $R_D = 23 - 30$ kpc. In the case of Milky Way one can distinguish 3 different disks. The young thin disk contains

young stars and has thickness of .1 kpc, which is also the size scale of globular clusters. The old thin disk has thickness of .325 pc. The thick disk has a thickness of 1.5 kpc. This gives some hints about the formation of the Milky Way.

2. Milky Way has 4 spiral arms. The arms begin from the ends of galactic bar with length 1-5 kpc. The interpretation of arms is as standing waves. Traffic jam is used analogy for arms: the stars rotating around the center of galaxy would slow down at the arm. The question is what causes the jam. For the second arm pair the number of stars is larger than for the second pair.

3. Spiral galaxies do not have bulge always (`http://tinyurl.com/tb7ca72` and `http://tinyurl.com/uv79o9x`). The bulge can contain also spiral sub-bulge in the galactic plane. The bulge is few kpc thick. Galactic blackhole (like entity) is present only if bulge is present and has in the case of Milky Way size scale of 10^4 ls (10^{-4} pc).

4. Vast polar structure - VPOS (`http://tinyurl.com/k553545`) is a disk in the plane orthogonal to the galactic plane containing satellites, which are dwarf galaxies and globular clusters and streams of stars and gas. The disk has radius 250 kpc considerably larger than stellar disk in galactic plane. Its thickness is 50-60 kpc whereas the components of galactic disk have much smaller thickness.

5. There are also stellar nebulae containing hydrogen and acting as stellar nurseries.

6. Cold dark matter scenario (`http://tinyurl.com/zv6wg4s`) leads to the conclusion that galaxy involves dense dark core radius 2-3 times that of stellar disk and having constant density and behaving like rigid body in good approximation. Dark matter halo predicts that the density is peaked and this leads to core-cusp problem [E266]. The dark matter core could relate to the VPOS having the same thickness. Inside the core region rotation velocity should be constant if dark matter dominates.

Milky Way has a pair of Fermi bubbles located symmetrically at the opposite sides of the galactic plane and touching it. The diameter of bubble is 7.7 kpc. By the way, Earth is at the boundary of Fermi bubble (`http://tinyurl.com/r9f8nee`). The bubbles expand at velocity $v = 3.2 \times 10^{-3}c$. It is believed that the bubbles are a remnant of a very energetic event occurred for millions of years ago in the galactic center. The bubbles would not be a dynamical phenomenon rather than a morphological feature.

16.3.2 TGD based model

In the sequel the TGD inspired cosmology and model for the formation of galaxies is first briefly summarized, and after that a possible qualitative model for the formation of galaxies is discussed.

TGD inspired view about cosmology

TGD based model to be discussed relies on the general vision about cosmology.

1. Einsteinian space-time corresponds to space-time surfaces with 4-D M^4 projection. The many-sheetedness of space-time surface is lost at the QFT-GRT limit replacing the sheets with single region of M^4, whose metric is slightly deformed. The sums of the induced gauge potentials *resp.* deviations of the metric from M^4 metric define gauge fields of the standard model *resp.* metric of GRT space-time. This approximation fails for cosmic strings.

2. Cosmic strings come in two different varieties having closed transversal cross section as 2-D CP_2 projection and string world sheet as M^4 projection. The 2-D cross section can carry non-trivial monopole type Kähler flux or vanishing Kähler flux but non-vanishing electroweak gauge fields. Neither flux tube needs current to create the magnetic field since cross section is closed.

   In primordial cosmology cosmic strings of both types dominate. The cosmic strings are unstable against thickening of M^4 projection and during the analog of inflationary period meaning transition to a radiation dominated cosmology the M^4 projection becomes 4-D and Einsteinian space-time becomes a reasonable approximation in long length scales.

Cosmic strings and thin flux tubes are however present also during Einsteinian period and cannot be completely neglected. For instance, monopole flux tubes explain the existence of magnetic fields in cosmic scales and also solve the maintenance problem of Earth's magnetic field [L13]. There are many open questions. For instance, it is not clear whether the flux tubes mediating gravitational interaction have nearly vanishing induced Kähler form and vanishing Kähler magnetic flux. It is assumed that long cosmic strings having galaxies as tangles carry monopole flux but even this assumption can be challenged.

3. Twistor lift of TGD plays a central role in the scenario. It predicts that the dimensionally reduced 6-D Kähler action for the 12-D product of twistor spaces of M^4 and CP_2 decomposes to a sum of 4-D Kähler action and volume term having cosmological constant Λ as a coefficient. Dimensional reduction is required by the induction of the twistor structure to the space-time surface as S^2 bundle.

   Λ has spectrum and is proportional to the inverse square of the p-adic length scale assumed to satisfy p-adic length scale hypothesis $p \simeq 2^k$: one can write $\Lambda = \Lambda(k)$. Thus any astrophysical system (say galaxy,star, or planet) as space-time sheet inside causal diamond (CD) is characterized by $\Lambda(k)$. This solves the basic problem due to the huge size of cosmological constant since cosmological constant goes to zero in long length scales. This also predicts the thickness of flux tubes. For "cosmological" cosmological constant the thickness is that of large neuron.

4. The thickness of the flux tube remains piecewise constant in cosmic evolution and increases in phase transitions reducing the value of $\Lambda(k)$. The simplest assumption is that the phase transitions are induced by the expansion of the larger space-time sheet at which the subsystem is glued by CP_2 sized wormhole contacts. In the formation of blackholes these phase transition would take place in opposite direction leading to contraction. For instance, in stars the thickness of flux tubes would be larger than in blackhole like entities (BHEs) defined by the volume filling flux tubes with thickness of proton Compton length [L69].

   For cosmic strings and primordial flux tubes the thickness would be presumably smaller and protons could be replaced with those of hadron physics characterized by a Mersenne prime smaller than M_{107} characterizing ordinary hadron physics. M_{89} is the Mersenne labelling the fractal copy of hadron physics in LHC energy scale and there are indications for the mesons of M_{89} hadron physics at LHC [K68, K69].

TGD based model for the formation of galaxies

In TGD framework the presence of VPOS (`http://tinyurl.com/k553545`) [L47] suggests the presence of long cosmic string $S_\perp$ orthogonal to the galactic plane containing dark matter and energy and at least one cosmic string $S_{||}$ thickened to flux tube parallel to the galactic plane. Single $S_{||}$ would suggest two spiral arms but there are four. Also the existence of 3 disks suggest that there are actually 2 flux tubes $S_{||,i}$, $i = 1, 2$, which would collided with $S_\perp$. Could gravitational force between cosmic strings have caused the formation of spiral structures and could visible galactic matter be generated from the thickening of these flux tubes?

One should also understand the flat velocity spectrum of distant stars. $S_\perp$ creates such a spectrum. Also $S_{||}$ creates such as spectrum for objects rotating in VPOS plane. Same is approximately true for the stars rotating in galactic plane since the dark mass of string plus its decay products within ball of given radius R (distance from the galactic center) is expected to be proportional to R. As a matter fact, the original proposal [K31, K94] was that there is only string in the galactic plane and corresponds to the spiral structure.

One should understand the morphologies of elliptic and spiral galaxies and how they were formed.

1. Elliptic galaxies are simple and older than spiral galaxies. A good guess is that they represent the primordial galaxies and are formed as tangles along cosmic strings thickening locally to flux tubes and producing the ordinary matter as dark energy and dark matter of string

transforms to ordinary matter. Quasars as time reversals of blackholes would represent the primordial stages of elliptic galaxies [L63]. That there are also small elliptic galaxies without GBHE supports the view that time reversal is in question.

2. Spiral galaxies with much complex morphology would be an outcome of dynamical processes involving collisions. The bulge of the spiral galaxy resembles elliptic galaxy, which gives hints about the dynamics involved with the formation of the spiral galaxy.

   The presence of VPOS and strong asymmetry between the VPOS plane orthogonal to the galactic plane strongly suggests a collision of elliptic galaxy assignable to cosmic string $S_{||}$ with some object The simplest identification of this object is as $S_{||}$, which has remained mostly dark but shows itself as a preferred direction for galactic jets. Indeed, two strings not parallel to each other and moving with respect to each other are doomed to intersect and intersection would give rise to spiral galaxy. The relative motion would be caused by the gravitational attraction of the strings.

3. Spiral morphology should be understood. Why 4 spiral arms? Why a pair of dense spiral arms with members connected by galactic bar to connected structure? Why the pair of less dense spiral arms forming similar connected structure? Are the pairs separate structures or parts of the same structure and could bulge show the existence of sub-structure consistent with the fusion of two elliptic bulges. Could the existence the 3 disks with different ages and thicknesses relate to the existence of 3 strings?

   Could the VPOS cosmic string(s) $S_{||}$ ($S_{||,i}$) in the galactic plane have rotated differentially with respect to the cosmic string $S_\perp$ orthogonal to the galactic plane and given rise to a pair of spiral arms. Are 2 parallel strings $S_{II,1}$ and $S_{||,2}$ in galactic plane needed to explain both pairs of spiral arms.

   One must understand the asymmetry between $S_\perp$ and $S_{||,i}$. Did $S_{||,i}$ contain a tangle giving rise to elliptic galaxy by the transformation of dark matter to ordinary matter. Did the elliptic galaxy become the bulge of the spiral galaxy? Did $S_\perp$ collide $S_{||,i}$. Did $S_{||,i}$ start differential rotation around the long string and give rise to spiral structure with two arms connected by the bar?

   The gravitational attraction between $S_\perp$ and $S_{||,i}$ should have increased the probability of the collisions - 85-90 per cent of galaxies are spiral galaxies. Gravitational attraction could have made possible also the second collision in which the less dense pair of arms emerged and gave rise to the thin disk.

4. One should understand galactic bar. Bar brings in mind is dipole creating dipole magnetic field. Could one have the analog of dipole field with monopole flux tubes needing not current to generate it and perhaps assignable to $S_{||,i}$. Could dark flux tubes associated with $S_{||,i}$ give rise to flux tube structures with topology resembling that of dipole magnetic field?

   Remark: The dipole nature for dark monopole flux structure is somewhat ad hoc assumption since there would be no current as source. There are also flux tubes carrying vanishing total flux and correspond to thickening of flux tubes. A possible interpretation would be as flux tubes mediating gravitational interaction and characterized by very large value of $h_{eff} = h_{gr} = GMm/v_0$ [E87] [K93, K11] [L50]. The dipole like flux tube structure could correspond to these flux tubes.

5. What about galactic blackhole, which in TGD would correspond to galactic black-hole like entity (GBHE) identifiable as volume filling flux tube structure [L69]. TGD actually suggests a hierarchy of BHEs classifiable by the thickness of the volume filling flux tube and ordinary stellar blackholes would correspond to flux tubes for which proton Compton length would define the thickness. An important empirical input comes from the fact that GBHE is present only if also the galactic bulge is present, and that elliptic galaxies have GBHE as a rule. This also supports the view that GBHE is formed after the formation of elliptic galaxy which could take place via a formation of quasar in which dark matter transforms to ordinary matter in a process which is time reversal for the formation of blackhole: white hole like entity (WHE) might be appropriate term in the case of quasar [L63].

6. The presence of old thick disk, thin disk, and young thin disk suggest interpretation as bulge (elliptic galaxy), younger portion of the same string $S_{||,1}$ decaying to ordinary matter and leaving the string, and possibly portion of $S_{||,2}$ suffering similar decay. This interpretation would suggest that the dwarf galaxies and globular clusters in VPOS have been there from the beginning and are not generated from $S_{||,i}$.

7. How satellites - dwarf galaxies and globular clusters - are formed? Are they basically bound states of closed strings with VPOS string. Have they reconnected from VPOS string as separate loops? Did reconnections of this VPOS string produce dwarf galaxies or were they there from beginning as satellites. Note that the number of stars about one thousandth from that for galaxies and globular clusters have size scale .1 kPc.

The core-cusp problem of cold dark matter model [E266] gives guidelines for the model building. The existence of dark core (DC) with approximately constant density with radius 2-3 times that of stellar disk is suggestive: it should have density peaked at center instead of constant density: this leads to the halo-cusp problem.

1. TGD suggests that the dark matter of astrophysical objects have as asymptotic states volume filling flux tube spaghettis [L69] (`http://tinyurl.com/tkkyyd2`). The size R of the spaghetti correlates with the thickness r of the flux tube. Dark matter dense core associated with strings should form a spaghetti with size $R \sim 90$ kpc few times the size of the stellar disk. GBH would be spaghetti with radius about $R_{GBH} \sim 10^{-4}$ pc with flux tube thickness given by proton Compton wavelength $L_p \sim 10^{-15}$ m.

   By scaling the thickness L_p of flux tube of GBH by factor $R/R_{GBH} \sim 10^9$ one obtains dark flux tube radius about $r \sim 10^{-6}$ m - the size scale of cell nucleus by the way. Recall that flux tube thickness 10^{-4} m corresponding the size scale of large neutron is assignable with "cosmological" cosmological constant Λ. Note that $\Lambda(k)$ is length scale dependent in TGD and characterizes the system's causal diamond as "sub-cosmology".

2. There are several open questions. Either $S_{||,i}$ or $S_{\perp}$ could give rise DC. Which of them? $S_{\perp}$ makes itself visible only via the presence of galactic jets and as structures along which galaxies form linear structures. Why so passive role? Does dense core correspond to a flux tube tangle possibly having the topological structure of field lines of a dipole magnetic field? Can the flux tube structure be disjoint from the long string - perhaps formed in reconnection?

16.3.3 Support for the proposed model of galaxies

In the following some empirical support for the proposed model is discussed.

Evidence for 3 different temperatures at galactic halo

The model for Milky Way suggests the presence of 3 cosmic strings thickened to flux tubes. Galactic disk has indeed 3 components with different thickness. There is support for the presence of 3 components also in the Milky Way halo [E158] (`http://tinyurl.com/ssxl3ux`, thanks to Wes Johnson for the link) as gas at different temperatures, and perhaps assignable to 3 different cosmic strings.

The information was gained by studying X rays from a blazar, very active energetic core of a distant galaxy emitting intense beams of light. The blazar was at distance of 5 billion light years. The light passed through the galactic halo and the temperature of the halo was determined from the properties of light received at Earth.

The halo was expected to have single temperature in the range between $10^4 - 10^6$ K. It was however found to contain 3 components at different temperatures, and the hottest component had temperature about 10^7 K. The unexpectedly high temperature is proposed to be due to the winds emanating from the disc of stars of MW. It was also found that the halo contains besides hydrogen also significant amounts of heavier elements suggesting that the halo has received material created by certain stars during their lifetime and final stages.

In TGD framework "cold fusion" [L31] outside stellar interiors could have generated at least part of the heavier elements. "Cold fusion" proceeds by a formation of dark nuclei identifiable as dark nucleon sequences at magnetic flux tubes with $h_{eff}/h \simeq m_p/m_e \sim 2000$ and having radius of electron Compton length. Nuclear binding energy is scaled down by a factor of about 1/2000 to keV range. Dark nuclei would have transformed to ordinary nuclei liberating practically all nuclear binding energy outside stellar nuclei. This process would serve as a kind of warm-up band in the pre-stellar evolution leading eventually to the ordinary fusion [L31, L82, L69].

Evidence for the presence of monopole flux tubes

Monopole flux is the key property of flux tubes proposed to be behind various astrophysical structures. Is there any direct evidence for this? Evidence has emerged for the existence of giant clouds with size about 100 AU in the vicinity of the supermassive GBHE of Milky Way [E117] (`http://tinyurl.com/sukomc6` and `http://tinyurl.com/tz2hta5`). These objects - called G objects - look like gas clouds but behave like stars. G objects stretch longer when nearer to GBHE but get their original shape when farther away. One would expect that they are torn apart by the enormous tidal forces created by GBHE.

The identification could be as visible matter assignable to a spaghetti like structure formed by monopole like flux tube, which could have also produced the visible matter in the thickening of the flux tube. By flux conservation the monopole flux prevents the flux tubes from splitting even in the huge gravitational field of supermassive GBHE. Without monopole flux tubes to which visible matter is gravitationally bound the structure would be torn to pieces. In Maxwellian world monopole flux tubes are not possible. In biology the behavior of gels (the contents of an egg is the basic example) could be based on monopole flux tubes connecting the cells together.

Cosmic strings and angular momentum problem of General Relativity

Vladimir Nechitailo took contact and asked for comments about his World-Universe model (WUM) (`http://tinyurl.com/vm2k7hb`). In the following my reaction to the claim

"The angular momentum problem is one of the most critical problems in BBM. Standard Cosmology cannot explain how Galaxies and Extra Solar systems obtained their substantial orbital and rotational angular momenta, and why the orbital momentum of Jupiter is considerably larger than the rotational momentum of the Sun. WUM is the only cosmological model in existence that is consistent with the Law of Conservation of Angular Momentum. "

appearing in the abstract of his article.

I cannot quite agree with this statement.

I have not explicitly considered the problem of large angular momenta in TGD. I do not think that the problem is non-conservation - note however that general relativity has problem with classical conservation laws which led to the idea about space-times as surfaces in $M^4 \times S$.

The challenge is to explain naturally the large angular momenta, which obey the analog of stringy mass formula: mass squared proportional to angular momentum. In TGD framework monopole flux tubes made possible by the homology of CP_2 lead to a picture in which cosmic strings with huge string tension carrying magnetic and volume energy thicken to flux tubes, and in this process lose magnetic energy transform to ordinary matter.

Cosmic strings [K31, K94, K66] explain dark matter and energy: galaxies are associated as tangles to long cosmic strings and the gravitational field of long cosmic string explains the flat velocity spectrum of distant stars [L30, L47, L69] (`http://tinyurl.com/tkkyyd2`. The rotation of the galactic matter around the long cosmic string explains the large angular momenta. For halo models one does not obtain this prediction. Large angular momenta are of course associated also to distant stars with constant velocity.

WUM as primordial period of cosmology is in TGD replaced with cosmic strings as non-Einsteinian 4-D space-times surfaces with with 2-D M^4 projection and complex manifold of CP_2 as CP_2 projection would dominate the primordial cosmology transforming to radiation dominated cosmology by the thickening of M^4 projection of cosmic string to 4-D [K66, L30]. This period would be the analog of inflation in TGD but without inflaton fields. Dark matter would correspond to $h_{eff} = n \times h_0$ phases at flux tubes present in all scales - even biological and also hadronic scales - as remnants of the primordial period.

Too young to be so heavy

The model should also allow to understand quasars and in [L63] (http://tinyurl.com/y2jbru4k) I considered a model of quasars as precedessors of galaxies. And additional support for the proposed picture came from a rather thought provoking article (http://tinyurl.com/sz9n72n) telling about a particular quasar identified as a super-massive blackhole with mass $.780M(Sun)$ ($M(Sun)$ is solar mass). Quite generally quasar masses vary in the range $10^8 - 10^9$ $M(Sun)$. Galactic blackholes have mass in the range $10^5 - 10^9$ $M(Sun)$. Milky Way blackhole has much smaller mass about $4 \times 10^6 M(Sun)$ (http://tinyurl.com/7wtza99).

Remark: I prefer to talk about blackhole like entities (BHEs): the TGD view about BHEs see is described in [L69] (http://tinyurl.com/tkkyyd2).

1. The first question considered by the researches is what burned away the neutral fog around the BHE: it is known that re-ionization (http://tinyurl.com/y8xodylx) must have burned away the fog ending the "dark ages" during which the Universe was transparent but there were no sources of light, which we could see (cosmic redhsift). Dark ages ended when re-ionization took place by light burning away the fog - perhaps light coming from dwarf galaxies and high energy photons from quasars did this. Despite re-onization the light could propagate since the density of matter absorbing it was so low.

2. There is also second deep problem: quasar - if indeed BHE - is too massive quite too early. This problem is met for all quasars - the age of the universe is measures using 1 billion years as a natural time unit for the observed quasars. If the galactic blackholes were former quasars, their masses should be larger than for quasars. The mass of Milky Way BHE is however of order $10^6 M(Sun)$ and much smaller than for quasars.

   From the list of blackholes (http://tinyurl.com/s3e223q) one gets an idea about the masses of galactic BHEs. Typically masses are considerably lower than quasar masses. There is however lenticular (between elliptic and spiral galaxy having disk but not spiral structure) galaxy NGC 1277 with galactic blackhole with mass about $1.7 \times 10^{10} M(Sun)$.

   The smaller mass scale makes it is difficult to believe that galactic blackholes could be former quasars. One can also ask whether very old lenticular galaxies, which posses neither spiral structure but have galactic plane could be formed from quasars and whether the central object could be quasar.

These problems challenge the interpretation of quasars as BHEs and TGD suggests an interpretation of all quasars as time reversals of BHEs - whitehole like entities (WHEs). Zero energy ontology (ZEO) of TGD indeed allows time reversed states and the arrow of time changes in ordinary, "big" state function reductions (BSFRs), which in TGD Universe can occur even in astrophysical scales so that even BHEs could be time reversals of WHEs. BSFRs would occur routinely in living matter, and self-organization as a process in apparent conflict with second law could be based on time reversal at magnetic body (MB) carrying dark matter as $h_{eff} = n \times h_0$ phases. Self-organization would be based on dissipation with reversed arrow of time at MB and violate standard arrow of time. In accordance with experimental facts, it would require energy feed since the creation of states with non-standard value of h_{eff} requires energy feed.

ZEO allows to imagine two solutions to the problem of "too-young-to- be-so-heavy" problem.

1. Quasars could be WHEs [L63] (http://tinyurl.com/y2jbru4k) and they would feed matter to environment rather that eating it (there was not much to eat yet!). The dark energy and matter of a tangled of cosmic string would transform to ordinary matter eventually creating the visible galaxy as the tangle thickens to magnetic flux tube and loses its energy. The precedessors of quasars would be generated during inflationary period as tangles of cosmic strings of primordial cosmology started to thicken and Einsteinian space-time with 4-D M^4 projection in $H = M^4 \times CP_2$ was created. Before this it was 2-D string world sheet. The fog, presumably hydrogen around the quasar formed from cosmic string energy, was formed from the energy of cosmic string.

   The huge energy emission by quasars could accompany a reduction of length scale dependent cosmological constant leading to the emission of volume energy whose density is proportional to cosmological constant.

2. One can also imagine that quasars were indeed BHEs which got their mass from the material produced by the decaying cosmic strings before stars were even formed. This would be less radical option than the first one and require that BHEs of galactic nuclei started to form much later than quasars and have therefore much smaller masses. They are however present in all elliptic galaxies except dwarfs. Elliptic galaxies are rather old and could have perhaps formed as self-intersections of the flux tube tangle giving rise to the elliptic galaxy.

Surprises from Milky Way

The continual feed of unexpected observations has forced a critical re-evaluation of what we really know about galaxies and their formation. The standard wisdom that they are due a condensation of matter under gravitational attraction is challenged.

Even the Milky Way is yielding one surprise after another. It is amusing to witness how empirical findings are gradually leaving TGD as the only viable option. The surprise that inspired these comments, came from Science Alert (`https://cutt.ly/KQPo8ZV`). The article tells at layman level about the findings reported in an article accepted to The Astrophysical Journal Letters [E141] (`https://cutt.ly/MQPpq4V`).

The discovery of the largest gas filament in our Galaxy, or a new spiral arm?

Cattail is a gigantic structure with a length which can be as much as 16,300 light-years, discovered in the Milky Way. It is a filament which does not seem to be analogous to a spiral arm since it does not follow the warping of the galactic disk which is thought to be an outcome of some ancient collision. In the TGD framework this structure would be associated with a cosmic string, which has in some places thickened to a flux tube and generated ordinary matter in this process.

Also the spiral arms might be accompanied by cosmic strings. In any case, there would be a long cosmic string orthogonal to the galactic plane (jets are parallel to it quite generally) having galaxies along it and generated by the thickening of the cosmic string generating blackhole-like entities as active galactic nuclei.

Just yesterday I learned that the Milky Way also offers other surprises (`https://cutt.ly/pQPpyJo`). One of them is that the galactic disk contains old stars that should not be there but in the outskirts of the galaxy which is the place for oldies whereas younger stars live active life in the galactic disk. This if one assumes that the usual view about the formation of galaxies is correct. This applies also to the weird filaments mentioned above.

In the TGD Universe, galaxies are not formed by a condensation of gas but by a process replacing inflaton decay with a process in which cosmic strings thicken and their string tension - energy density - is reduced [L63, L69, L111]. The liberated energy forms the ordinary matter giving rise to the galaxy. This solves the dark matter problem: strings define dark matter and energy and no halo is needed to produce a flat velocity spectrum of distant stars. The collisions of cosmic strings are unavoidable in 3-D space and could have induced the thickening process creating the active galactic nuclei (quasars).

This process would be opposite to what is believed to occur in the standard model. What comes to mind is that the oldies in the disk are formed from a cosmic string portion in the galactic plane. The tangle of the cosmic string can indeed extend in the galactic plane over long distances and there can also be cosmic strings (associated with galactic spiral arms?) in the galactic plane, which would have almost intersected a cosmic string orthogonal to the plane inducing the formation of the Milky Way.

16.4 Anomalies related to galactic dynamics

Wes Johnson sent also two links related to the long range correlation between the dynamics of quasars and galaxies. The first result was about correlations of quasar spins in billion light-year scale. Second result was about coherence between the galactic spin and motions of surrounding galaxies at least up to 6 Mly. The explanation of both findings is in terms of cosmic strings thickened to flux tubes, which are the basic element in the TGD based model for the formation of quasars and galaxies. Third anomaly relates to “too” fast spinning galaxies.

16.4.1 Correlated galactic spins in billion light-year scale

The first link is to a popular article "*Alignment of quasar polarizations with large-scale structures*" (see http://tinyurl.com/rcoam7g) telling about alignment of quasar polarization with large scale structure in scale of Gly, which is a really huge scale. This suggests that the quasar spin axes are aligned with a linear structure connecting the quasars.

The correlations between spin directions of quasars over distances of billion light-years have been observed. These correlations have been observed earlier over much shorter distances for quasars/galaxies along the well-known linear structures. This suggests that the linear structures are much longer than previously thought.

This is what I have been preaching for decades. There would exist a fractal tensor network of cosmic string/monopole flux tubes over entire cosmos having local flux tube tangles as nodes. Networks inside networks inside.... The flux tubes would carry dark matter in TGD sense making possible quantum coherence in arbitrarily long length scales.

1. TGD predicts a fractal hierarchy of flux tubes formed from cosmic strings: 4-D surfaces in $M^4 \times CP_2$ having 2-D strings world sheet as M^4 projection.

2. Galaxies reside along linear structures which would correspond to what I call cosmic strings: galaxies would be tangles along these strings thickened locally to monopole flux tubes: part of their magnetic energy would have transformed partially to matter and formed the visible part of galaxy. Volume energy would correspond to length scale dependent cosmological constant. They would explain also flat velocity spectra associated with spiral galaxies. There would be no dark matter halo.

   Cosmic strings and their monopole flux tube portions would be remnant from cosmic string dominated period, which transformed to GRT type cosmology via an inflation type period as cosmic strings thickened to flux tubes. These strings containing the galaxies as tangles would form a network correlating the dynamics of individual galaxies and making possible correlations and synchrony even over distances of about 1 billion ly.

3. The correlations between spin directions of galaxies is what has been been could be inherited from past when the galaxies along strings were much closer to each other. Angular momentum conservation would take care that correlation are preserved.

4. Macroscopic quantum coherence even in cosmological scales is however possible by hierarchy of Planck constants explaining dark matter as $h_{eff} = n \times h_0$ phases of ordinary matter. We could be seeing quantum coherence of dark matter inducing ordinary coherence of matter in cosmic scales.

Remark: I have asked whether all self-organization phenomena involving energy feed (needed to increase h_{eff} responsible for quantal long range correlations at dark level) could be induced by dark matter at magnetic flux tubes [L79]. A further interesting question is whether self-organization is dissipation in reversed time direction so that also it would be due to second law but in generalized sense required by ZEO.

16.4.2 Mysterious coherence in several-megaparsec scales between galaxy rotation and neighbor motion

Second link was to article "*Mysterious Coherence in Several-megaparsec Scales between Galaxy Rotation and Neighbor Motion*" by Lee *et al* (see http://tinyurl.com/sbmcn6g). The article states that there is a "mysterious" coherence between the rotational direction of galaxy and the average motion of its nearest neighbours within 6 MPc, possibly even up to 11 MPc. This coherence cannot result from collisions with nearby galaxies like coherence below 1 MPc and is proposed to originate from the collective motion of a structure containing the galaxies affecting the directions of angular momenta of galaxies: the coherence would be induced from that of the collective motion.

In TGD framework the natural identification for the collective structure would be as a long monopole flux tube containing the galaxies or at least a subset of them as tangles. There could be of course several monopole flux tubes in the sample studied. It was indeed found that the coherence was especially strong when neighbors of the galaxy at center were restricted to red galaxies. Red galaxies could correspond to the same flux tube. Alternatively, the collective motion affects them less than other galaxies as the article suggests.

16.4.3 Galaxies spinning "too" fast

The anomalous findings relating to cosmology and astronomy are proliferating I am grateful for Wes Johnson for a flow of links. This particular link (see `http://tinyurl.com/qv2vpw3`) gives pictures provided by NASA about spiral galaxies spinning "too" fast. The problem is that centrifugal acceleration destabilizes the system spinning too fast. This suggests that the structure of galaxy is not what our models involving ordinary matter and dark matter halo are somehow wrong. TGD suggests an improved view allowing to understand also "too" fast spinning rates.

Suppose that galaxies are tangles along monopole cosmic string such that string has thickened to flux tube. Monopole cosmic string would be rotating. These monopole tangles would serve as TGD counterparts for the magnetic field of galaxy which has no Maxwellian counterpart. No currents are needed for their maintenance.

1. Monopole flux tube has closed cross section, which is non-contractible 2-surface, pinch is impossible. In other words, the conservation of monopole flux prevents its splitting so that centrifugal acceleration cannot break the flux tube even at the highest spinning velocities. Only radial deformation increasing the size is possible.

2. Ordinary matter - generated as the magnetic energy of the flux tubes has transformed to ordinary matter in process analogous to inflation - in turn is gravitationally bound with the flux tube so that the galaxy manages to keep also the ordinary matter.

16.4.4 Galaxy, which existed 1 billion years after Big Bang

Galaxy GN-z11 (see `http://tinyurl.com/tg7sscu`) existed 1 billion years after the Big Bang and gave rise to stars with a rate much faster than Milky Way. There should have been any stars giving rise to the galaxies by the usual mechanism of gravitational condensation.

TGD explanation is simple. Galaxies formed as tangles to long cosmic string, which thickened and liberated part of its magnetic energy to ordinary matter, which formed the stars of the galaxy as local tangles inside tangle. The formation of stars was faster because local cosmological constant was larger and the rate for the transformation of magnetic energy to ordinary matter was higher. The periods of star formation should correspond to the phase transitions decreasing the local cosmological constant.

Also in younger galaxies the star formation is highest near the galactic blackhole, even at distances smaller than 3 ly, where it should not happen at all. The mechanism would be the same. For the flux tubes extending farther from galactic center the local cosmogical constant is smaller and the rate for the formation of stars is slower.

16.4.5 Support for TGD view about galactic dark matter

Cosmology an also other fields of physics with one exception - particle physics - produces fascinating results on daily basis. It is really a pity that particle physicists living in the jail of their reductionistic world view cannot pay any attention to these discoveries and continue moaning that there is no data so that it impossible to go beyond standard model. Bad philosophy can kill entire field of science. Having replaced Planck length scale reductionism by fractality I can enjoy swimming in the flood of anomalies.

One of the surprises was a popular article about a detection of dark matter lumps [E131] (`http://tinyurl.com/vjvhyud`) by Hubble telescope. The discovery is based on gravitational lense effect. The popular article tells about light coming distant quasars - distance is about 10 million light years. At the path of light coming to Earth there is foreground galaxy - distance is about 2 million light years. They are reported to give rise to four separate images of the galaxy by lense effect.

I am however wondering why one observes four images of each quasar by foreground galaxy. My naïve expectation would be a ring if dark matter halo gives rise to the lensing. If so the finding would represent an anomaly. It is also stated that the number of images depends on how many different dark matter particles there exists. I must admit that I do not understand.

What says TGD?

1. If galaxies are associated with long cosmic strings as tangles as in TGD Universe, flat velocity spectrum is automatically predicted without any other assumptions and velocity spectrum determines string tension [L63, L69]. (http://tgdtheory.fi/public_html/articles/meco.pdf and http://tgdtheory.fi/public_html/articles/galaxystars.pdf).

2. Long cosmic string would give rise to two separate images in lensing effect rather than ring as halo would do. Two long foreground cosmic strings with different directions - say being nearly orthogonal - would give rise to four images.

3. The two cosmic strings could be assigned with fusion of two galaxies associated with separate cosmic strings. One can consider the possibility that visible galaxies are formed as two cosmic strings collide: this would give rise to instability initiating the thickening of the 2-D M^4 projection of cosmic string and formation of tangles associated with both cosmic strings. Magnetic energy would be liberated and transform to ordinary matter giving rise to the visible matter of galaxy. For instance, could the 4 spiral arms of Milky way could relate to the second cosmic string in the plane of Milky way tangled around the second cosmic string orthogonal to the plane of Milky Way?

   One can consider also a situation in which there is no foreground galaxy but just two cosmic strings and this might provide a test for TGD view.

16.5 Cosmic spinning filaments that are too long

The inspiration for writing this article came from a highly interesting popular article (https://cutt.ly/inMODTT) providing new information about the cosmic filaments (thanks to Jebin Larosh for the link). The popular article tells about the article published in Nature [E165] (https://cutt.ly/HnMOGcP) and telling about the work of a team led by Noam Libeskind.

16.5.1 Findings

What has been studied is a long filament with length of order 10^8 ly characterizing the sizes of large cosmic voids. The filament consists of galaxies and the surprising finding is that besides moving along the filament, the galaxies associated with the filaments spin around the filament axis.

This finding suggests a network of filaments of length of order 10^8 ly and thickness of order 10^6 ly intersecting at nodes formed by large galaxy clusters. The larger the masses at the ends of the filament are, the larger the spin is.

How angular momentum is generated is the problem. The problem is quite general and is shared by both Newtonian and General Relativistic Universes. The natural assumption is that angular momentum vanishes in the original situation. Angular momentum conservation requires a generation of compensating angular momentum. This should happen in the case of all rotating structures. Already the case of galaxies is problematic but if the length scale of the structure is 10^8 ly, the situation becomes really difficult.

Gravitationally bound states have as a rule angular momentum preventing gravitational collapse but how the angular momentum is generated in a process believed to be a concentration of a homogeneous matter density to astrophysical objects? The basic problem is that the Newtonian description relies on scalar potential so that the field lines of the Newtonian gravitational field are never closed. It is difficult to imagine mechanisms for the generation of angular momentum by rotation. In the GRT based description gravi-magnetic fields, which are rotational, emerge but they are extremely weak. The proposal is that tidal forces could generate angular momentum but the generation of angular momentum remains poorly understood.

16.5.2 TGD view about the angular momentum generation

Could one understand the recent finding, and more generally, the generation of angular momentum, in the TGD framework? What raises hope is that in the TGD framework Kähler magnetic fields, whose flux tubes can be regarded as space-time quanta, are key players of dynamics in all scales besides gravitation.

Cosmic strings as carriers of dark matter and energy

The basic difference between GRT and TGD are cosmic strings and flux tubes resulting from their thickening. Cosmic strings are preferred extremals which are space-time surfaces with 2-D string world sheet as M^4 projection and complex surface of CP_2 as CP_2 projection.

1. The presence of the long filaments is one of the many pieces of support for the fractal web of cosmic strings thickened to flux tubes predicted by TGD. The scale is the scale of large voids 10^8 ly forming a kind of honeycomb like structure. The density of matter would be fractal in the TGD Universe [L63, L69] (`http://tgdtheory.fi/public_html/articles/meco.pdf` and `http://tgdtheory.fi/public_html/articles/galaxystars.pdf`).

2. Long cosmic string has a gravitational potential proportional to $1/\rho$, ρ the transverse distance. This predicts a flat velocity spectrum for the stars rotating around the galaxy. No dark matter halo is needed. The model contains only a single parameter, string tension, and also this can be understood in terms of the energy density of the cosmic string. The motion along the string is essentially free motion which allows to distinguish the model from the halo model. In fact, the article [E165] reports linear motion along the filament.

   Amusingly, the same day that I learned about the spinning filaments, I learned about a new evidence for the absence of the galactic halo from a popular article (`https://cutt.ly/MnMOI7F` telling about the article by Shen *et al* [E159] (`https://cutt.ly/HnMOPNA`).

Compensating angular moment as angular momentum of dark matter at cosmic string

Consider now the problem of how the compensating angular momentum is generated as visible matter starts to rotate.

In the TGD framework the picture is just the opposite.

1. The basic assumption of the Newtonian and GRT based models for the generation of angular momentum is that all astrophysical objects are formed by a condensation of matter along perturbations of the mass density. The flow of mass occurs from long scales to short scales.

2. Cosmic strings are the basic objects present already in primordial cosmology [K94, K66, K31]. Long cosmic strings form tangles along them in a local thickening, which gives rise to flux tubes [L63, L69, L82]. This involves the decay of dark energy and matter at cosmic string to ordinary matter around them as the string tension is reduced in a phase transition decreasing the coefficient of the volume term present in the action besides Kähler action as predicted by twistor lift of TGD [L43, L64]. This parameter corresponds to length scale dependent cosmological constant Λ.

   Λ depends on p-adic length scale $L_p \propto \sqrt{p}$, $p \simeq 2^k$ and satisfies $\Lambda(k) \propto 1/L^2(k)^2$. $\Lambda(k)$ approaches zero in long p-adic length scales characterizing the transversal size of flux tubes. This solves the cosmological constant problem. The thickness $d \sim L(k)$ of the flux tube, which is rather small, determines the string tension. To $L(k)$ there is associated a long p-adic length scale which is of order size of observed cosmology if $d \sim L(k)$ is of order of 10^{-4} meters, which happens to be the size of a large neuron.

3. The phase transitions reducing Λ reduce string tension are analogous to the decay of the inflaton field vacuum energy to ordinary matter. Now inflaton field vacuum energy is replaced with the dark energy and matter associated with the thickening cosmic string. Each phase transition is accompanied by an accelerated expansion. The period known as inflation in stanaard cosmology is the first phase transition of this kind. The recent accelerated expansion would correspond to a particular period of this kind and will eventually slow down.

What could happen in the decay of the energy of a flux tube tangle of a cosmic string to visible matter?

1. The visible matter resulting in the decay of the cosmic string must start to rotate around the cosmic string since otherwise it would fall back to the cosmic string like matter into a blackhole. The cosmic string must somehow generate a spin compensating the angular momentum of the visible matter.

2. One should understand angular momentum conservation. Generation of visible matter with angular momentum is possible only if the dark cosmic string is helical or becomes (increasingly) helical in the phase transitions. The angular momentum would be accompanied by the longitudinal motion along the string: this motion has been observed for the filaments [E165]
.

   The helical structure could be present from the beginning or be generated during the decay of energy of the cosmic string leading to the local thickenings to flux tube giving rise to galaxies as tangles along a long cosmic string. Also the dark matter and energy at the cosmic string already have angular momentum so that the dark matter that transforms to visible matter would inherit this angular momentum.

   The reported correlation between the masses at the ends of the filament and the spin of the filament [E165] could be understood if the masses at the ends are formed from the dark energy and mass of the filament having angular momentum. The amount of spin and mass at the ends would be the larger, the longer the decay process has lasted.

3. The identification of the galaxies as tangles along long cosmic strings explains the flatness of the galactic velocity spectrum. Galaxy rotates and also now the angular momentum conservation is the problem. The simplest solution is that the cosmic string portions between the tangles generate the angular momentum opposite to that of the visible matter.

   This would happen not only for the portions of cosmic string between galaxies but also those between stars in the galactic tangle. Stars would be flux tube spaghettis and the angular momentum of the star would be compensated by the angular momentum associated with the helical cosmic string continuing outside the star and connecting it to other stars.

The illustration of the popular article brings in mind a DNA double strand and inspires a consideration of an alternative, perhaps unnecessarily complex, model.

1. Suppose one has a double helix of cosmic strings, call them Alice and Bob. Two stellar objects can form a gravitationally stable state only if relative rotation is present. This would be true also for a cosmic double strand to prevent gravitational collapse in 2-D sense.

2. Alice could remain a cosmic string and thus dark so that we would not see it. Bob would thicken to a flux tube and produce ordinary matter as galaxies as ordinary matter realized tangles along it. The matter would inherit the angular momentum the dark matter and energy producing it already has. The string tension of Bob would be reduced in this process. Of course, both Alice and Bob could have tangles along them. The experiments however support the view that spin direction is the same along the filament.

3. If the helical pair of cosmic strings is actually a closed loop in which the second strand is a piece of the same string, the motion of matter along strands is automatically in opposite directions and spins are opposite. The rotational motion as a stabilizer of a gravitationally bound state is transformed to a helical motion. The problem is however why only the other strand decays to ordinary matter (in the case of ordinary DNA there is an analogous problem due to the passivity of the second strand).

Is quantum gravitation cosmic scales involved?

There is an interesting connection to atomic physics suggesting that quantum effects are associated with gravitationally bound dark matter even in astrophysical scales.

1. The basic problem was that the electron should radiate its energy and fall into the atomic nucleus. The Bohr model of the atom solved the problem and non-radiating stationary states prevented the infrared catastrophe. Also in the gravitational case something similar is expected to happen for gravitational interaction.

2. The Bohr model of solar system [K93, K11], originally introduced by Nottale [E87], relies on the notion of gravitational Planck constant $hbar_{gr} = GMm/\beta_0$ predicts angular momentum quantization [L62, L106].

3. Angular momentum quantization as multiples of $\hbar_{gr}$ could occur also for the matter rotating around the cosmic string. In the case of the filament, the mass M could be replaced with the mass of the cosmic string (or possibly several of parallel cosmic strings) and m could correspond to the mass of a galaxy rotating around it. The velocity parameter $\beta_0 = v_0/c$ has a spectrum of values [L106] proposed to come as inverse integers.

16.6 A solution of two galactic anomalies in the TGD framework

Two anomalies related to the physics of galaxies are discussed. The first strange finding is that the initial mass function of galaxies depends on distance from the observer [E161]. The newest anomaly of cold dark matter models is that the stars of the satellite galaxies of bigger galaxies tend to rotate around the host galaxy in planar orbits rather than along random orbits as halo models predict.

16.6.1 Can the initial mass function of galaxies really depend on distance from the observer?

In learned about new very interesting findings related to distant galaxies from a popular article "*New discovery about distant galaxies: Stars are heavier than we thought*" (see `https://cutt.ly/UJdEG2G`. The article tells of the work done by astrophysicists in Niels Bohr Institute, Denmark by A. Sneppen et al.

The article "*Implications of a Temperature-dependent Initial Mass Function. I. Photometric Template Fitting*" [E161] provides a technical description of the work (`https://cutt.ly/SJdEZik`). The abstract of the article gives an overall view of the findings.

> *A universal stellar initial mass function (IMF) should not be expected from theoretical models of star formation, but little conclusive observational evidence for a variable IMF has been uncovered. In this paper, a parameterization of the IMF is introduced into photometric template fitting of the COSMOS2015 catalog. The resulting best-fit templates suggest systematic variations in the IMF, with most galaxies exhibiting top-heavier stellar populations than in the Milky Way. At fixed redshift, only a small range of IMFs are found, with the typical IMF becoming progressively top-heavier with increasing redshift. Additionally, subpopulations of ULIRGs, quiescent and star-forming galaxies are compared with predictions of stellar population feedback and show clear qualitative similarities to the evolution of dust temperatures.*

Here is how I understand the basic notions and reported findings appearing in the article.

1. Initial mass function IMF used in the modelling of the galaxies is the key notion. IMF would be the initial distribution of stellar masses as galaxy started to evolve. The ages of galaxies between 10-13.6 billion years so that they formed very early. It would be very natural to assume that IMF is universal and same for all galaxies, and this has been indeed done. The candidate for a universal IMF has been determined from the data related to Milky Way and its satellites. There are however several candidates for the galactic IMF.

2. The finding of the group is that IMF is not universal and tends to concentrate towards higher masses for distant and therefore younger galaxies. The proposed IMF is parametrized by using a temperature like parameter T_{IMF}, interpretable as the temperature when the galaxy was formed.

   Here I however encounter a problem in my attempts to understand. I find it difficult to comprehend why T_{IMF}, a parameter that should characterize a galaxy, should depend on the distance of this galaxy from us. This looks nonsensical. Perhaps IMF is not what "initial mass function" suggests. What does one mean with "initial"? Or maybe some very interesting new physics related to the notion of time and aging of the stars is lurking there!

3. High mass stars have a short lifetime and end up to Supernovae unless the star formation creates new ones. Because stellar mass is dominated by low-mass stars, the inferred stellar masses and star formation rates (SFRs) are highly sensitive to the ratio of high-mass to low-mass stars in the IMF. The inferred extinction, metallicity, and other properties depend on the assumed IMF.

   In the standard model, star formation is sensitive to the pressure-gravitation balance. The IMF should be sensitive to all variables that can affect it. Article mentions central gravitational potential, existing stellar mass, star formation history, supernova rate, cosmic-ray density and galactic magnetic fields, metallicity, dust density and composition, AGN activity, and the environment and merger history.

   All of these are known to vary both between different galaxies at fixed redshift and across different redshifts. According to the authors, it should be expected that the IMF is not universal but rather differs between galaxies and between different epochs for the same galaxy. In particular, the IMF should depend upon the gas temperature of star-forming clouds, with higher-temperature regions producing higher average stellar masses. Because observations of dust even at moderate redshifts find an increase in temperature toward higher redshifts.

4. Authors notice that already in the case of the Milky Way there are several candidates for IMB and that typical stellar mass and star formation rate (SFR) are highly sensitive to IMF. There are also significant degeneracies between the IMF and extinction, metallicity, star formation history, and the age of the stellar population, which makes it very difficult to determine the entire shape of IMF.

5. The group performs a fit to a temperature dependent family of IMFs having initial temperature T_{IMF} as a parameter. What is nice is that for a given redshift, this is found to give only a few candidates for the IMF. The very distant galaxies would be top-heavier (stellar mass would be concentrated towards higher masses) and the fraction of heavier stars would be higher.

The proposal of the authors can be criticized. There is no doubt that the dependence of IMF on the galaxy is a fact but its dependence on the distance of the galaxy from us is in a glaring conflict with the standard view about time evolution, in particular with the basic assumption of the standard ontology stating that our geometric past is fixed.

Initial mass function (IMF) would be the initial distribution of stellar masses as the galaxy started to evolve about 10-13.6 billion years ago. It would be very natural to assume that the IMF is universal and the same for all galaxies, and this has indeed been done. The candidate for a universal IMF has been determined from the data related to the Milky Way and its satellites. There are several candidates for the galactic IMF. It has been however found that the IMF depends on the distance of the galaxy from Earth and that the IMFs tend to concentrate on larger stellar masses. The dependence of MF on this distance is in conflict with the standard view about time assuming that the geometric past is fixed.

Zero energy ontology (ZEO) [L84, L108, L118] [K119] defines the ontology behind TGD based quantum measurement theory and solves the basic paradox of quantum measurement theory. Second key element is the predicted hierarchy of effective Planck constants [L41] labeling phase of ordinary matter behaving like dark matter.

ZEO suggests a solution to the paradox created by the findings. TGD Universe is quantum coherent also in astrophysical scales and "big" state function reductions (BSFRs) reversing the arrow of time opposite to that for the environment occur for stars making them blackholes. This is the case also in GRT for Kerr-Newman rotating blackholes. Also quasars as white holes transform in BSFR to galactic blackholes with an arrow of time opposite to that for a distant environment. ZEO implies that the geometric past and thus the IMF of the galaxy changes in the sequence of BSFRs. A simple argument based on the fact that massive stars are shorter-lived shows that the IMF for large distances from Earth indeed is concentrated on larger stellar masses.

16.6.2 The satellite plane anomaly of the cold dark matter model

The anomalies of the halo models of galactic matter have been steadily accumulating during years. For instance, it has been found that satellite galaxies of larger galaxies tend to move in planes [E217] whereas the ΛCDM predicts that the orbits are more or less random. Quite generally, ΛCDM fails on short scales.

The TGD based solution of the satellite galaxy problem relies on the TGD view about galactic dark matter: dark energy and dark matter reside at long cosmic strings, which can form tangles at which the flux tubes thicken and liberate energy forming the ordinary galactic matter. The orbits of the stars around the cosmic string are helical orbits in a plane orthogonal to the string and, as a special case, planar orbits. The velocity curve is flat without further assumptions. The preferred planes could correspond to planar minimal surfaces with 3-D E^3 projection.

16.6.3 TGD based explanation for the dependence of IMF on distance

What could be the TGD based interpretation of the strange findings? Could the cosmic string model for the formation of galaxies and stars [L63, L69, L111] predict the time evolution of the galactic mass distribution by assuming a universal IMF? The paradoxical finding challenges the standard view about time: could zero energy ontology (ZEO) [L84, L108, L118] implying radical revision of this notion, be involved in an essential manner?

Cosmic string model for the formation of astrophysical objects

Consider first the cosmic string model for the formation of galaxies, stars, planets and and also smaller objects [**?**]

1. Cosmic strings would be the fundamental objects. Their string tension is determined by CP_2 length scale determining their energy density identifiable as dark energy and Kähler magnetic energy. Also ordinary and dark particles in the TGD sense can contribute to the density of energy. Galaxies are assumed to be tangles of a long cosmic string at which the cosmic string has thickened to a monopole flux tube with reduced string tension. The flat velocity spectrum of stars rotating around the cosmic string is flat and the value of the velocity is dictated by the string tension. Therefore galactic dark matter as a halo is replaced with the energy density of the long cosmic string containing galaxies as its tangles: this explains the linear structure formed by galaxies.

2. The energy of the cosmic strings would have been liberated as ordinary matter: this is completely analogous to the formation of ordinary matter in the decay of the inflaton field in inflation models. The seeds of stars can be identified as sub-tangles of galactic flux tubes analogous to spaghettis. This hierarchy of tangles inside tangeles inside... tangles continues to short length scales, even biomolecules, atomic nuclei, and hadrons would be this kind of tangles. The already existing ordinary matter could condense around these seeds.

   The conservative guess is that this analog of inflation was significant only during the very early stages of star formation when no stars existed yet and only the transformation of dark energy to ordinary matter could give rise to stars.

   The flux tube tangle would thicken and generate stellar objects as subtangles. The farther the star is, the younger the galaxy is. Massive stars as supernovas die soon and the mass function shifts to lighter stellar masses.

3. New massive stars are not formed after the galactic cosmic string tangle and galactic blackhole-like entity reaches a maximal size: one could say that the galaxy dies. After this star formation could happen as a condensation process around tangles serving as seeds as in the standard model and would give rise to stars, planets, and even smaller objects. The development of the flux tube containing the tangles would determine galactic evolution.

4. Note that a quasar identified as a galactic blackhole-like object would be there from the beginning and feed mass to its environment. In the spirit of ZEO, I have proposed that it is the TGD analog of white hole and a time reversed version of a blackhole-like object. Instead

of sucking matter inside it it would spew matter outside, essentially energy of cosmic string, out which gives rise to the galactic matter.

BSFR means death in a universal sense and in a well-defined sense, a blackhole is a dead object. Could blackhole be a time reversal of a white hole as quasar. BSFR changes the arrow of time and the radiation produced by blackhole would travel to the geometric past: nothing would come out from the perspective of the observer in the future! This what ordinary blackholes indeed look like. Could blackhole-like entities have an arrow of time, which is opposite to that of the environment? As a matter of fact, this would not be new! Also in GRT, Kerr-Newman solutions representing rotating blackholes have an arrow of time opposite to that of a distant environment [B46]. I have discussed Kerr-Newman blackholes in the appendix of [L24].

Both galactic blackholes and stellar blackholes would be dead and time reversed quasars and "live" in a reversed time direction. Also ordinary blackholes would "live" in the opposite direction of time.

The interpretation of IMF and T_{IMF} in the TGD framework

What could be the interpretation of the IMF in the TGD framework? Does the parameter T_{IMF} appear naturally? Since the formation of galaxies and stars would be a process analogous to inflation, it would seem that the gravitational condensation around seeds defined by the flux tube tangles dominates except in very early times. Hence it would seem that the interpretation in terms of IMF which depends on T_{IMF} must make sense in the TGD framework. This is not possible without a new view about time provided by zero energy ontology (ZEO).

1. Zero energy ontology (ZEO) [L84, L108, L118] suggests a radical interpretation for the dependence of IMF on the distance of the galaxy from us. In ZEO, the stars of the galaxy evolve by state function reductions (SFRs) occurring in stellar and even longer scales. This is due to the hierarchy of effective Planck constants predicted by number theoretical vision of TGD involving the notion of M^8-H duality [L91, L92]) and adelic physics [L41]. ZEO predicts that both "big" and "small" SFRs (BSFRs and SSFRs) are possible.

2. In the BSFR, the arrow of geometric time changes and BSFRS can change even in astrophysical scales. This could explain the observation of stars which are older than the Universe [L69]. A given star would make BSFRs and in this manner evolve forth and back in the geometric time and become physically older but the center of mass time coordinate for the causal diamond (CD) of the star would not shift to the geometric future so that aging as it is usually understood would not take place.

   The size L of the CD is expected to increase in the process and could define as its inverse a parameter analogous to $T_{IMF}=\hbar_{eff}/L$.

3. The stellar BSFRs could explain the nonsensical looking dependence of the IMF on the distance of the galaxy from us. These stars of these very old galaxies would experienced would have made a large number of BSFRs. By universal evolution [L41] they would be at a high evolutionary stage and can be said to be represent old stars, stars older than the Universe. Star would have transformed to a blackhole and back to a white hole serving as a seed for the formation of a new star. The massive stars would have disappeared as supernovas and the mass distribution of these stars defining the IMF would shift towards lighter masses. Also the temperature would decrease for these stars determining IMF, which would imply the paradoxical looking decrease of T_{IMF} with the increasing cosmic distance.

16.6.4 TGD based explanation of the satellite plane anomaly of the cold dark matter model

The satellite galaxies of larger galaxies tend to move in a plane around the host as described in the review article [E217] whereas the ΛCDM predicts that the orbits are more or less random. The article gives illustrations showing the concentration around the planes for the Milky Way, Andromeda, and Centaurian. The plane of satellites is approximately orthogonal to the plane of the host galaxy in all cases.

Quite generally, ΛCDM fails on short scales. The success in long scales is understandable in the TGD framework since the approximation of the mass density of cosmic strings by a continuous mass density is good in long scales.

Why planar orbits are preferred?

TGD predicts [L63, L69, L111] a fractal network of very massive long cosmic strings which can locally thicken to flux tubes: this thickening involves transformation of dark energy and possible dark matter of cosmic string to ordinary matter giving rise to galaxies and other structures. Also stars would have thickened flux tube tangles inside themselves. The model finds support from the observation that galaxies form long strings as found decades ago (Zeldowich was one of the discoverers [E272]).

The TGD based model predicts the formation of planes in which objects in various scales move. The prediction is fractal: this applies to planets around stars, stars around galaxies, satellite galaxies around larger galaxies,....

This model explains the satellite plane anomaly and also the earlier anomalies if the galaxies are associated with the long "cosmic strings" predicted by TGD [K31]. They create a strong gravitational potential giving rise to a radial force in the plane orthogonal to the cosmic string. The motion along the string is free whereas the planar motion is rotation. The velocity spectrum is flat as required by the flatness of the galactic velocity spectrum. In the simplest model cosmic string is the carrier of galactic dark matter and dark energy. No dark matter halo and no exotic dark matter particles are needed.

Helical orbits are the most general orbits. If a concentration of matter occurs to a plane, it tends to catch objects moving freely in the direction of string to its vertical gravitational field and planar sheets such planetary systems, spiral galaxies, and the planar systems formed by satellite galaxies can form.

The first guess is that the satellite galaxies move in the plane of the host galaxy. The plane is however approximately orthogonal to the plane of the host in the 3 cases illustrated in [E217].

1. I have proposed that the intersections of nearly orthogonal cosmic strings could induce the thickening to flux tubes and transformation of the dark energy of flux tubes to ordinary matter starting to rotate in the planes defined by the intersecting cosmic string.

2. These intersections are unavoidable for strings like objects in 4-D space-time and would occur at discrete points. In the collision of cosmic strings, these points would define the nucleus of the host galaxy, say the Milky Way. The satellite galaxies would be assignable to the plane defined by the second colliding cosmic string, which would take the role of stars in the plane of the host galaxy.

   The colling cosmic strings would be in a very asymmetric position. Why this asymmetry? Could the satellites correspond to circular pieces of cosmic string generated in the collision by reconnections (note the analogy with reconnections of magnetic flux tubes of solar wind occurring during auroras) and generating the matter of the satellite.

   Why only the second cosmic string would have satellites around it? For two separate cosmic strings it is difficult to understand why reconnection would form loops. This process is natural for the two antiparallel strands of a closed U-shaped loop. Cosmic strings indeed form loops.

This model involves two strings. One can also consider a single cosmic string.

1. Cosmic strings are closed in a large enough scale, and the model for quantum biology encourages to consider U-shaped cosmic strings for which the parallel string portions carry opposite magnetic fluxes and can naturally reconnect. The flux tube could self-reconnect and generate loops, possibly assignable to the satellite galaxies. The reconnection process would be fundamental in TGD inspired quantum biology (see for instance [L122]).

2. In the reconnection of the strands carrying opposite magnetic flux would form a section S orthogonal to the long part L of the U-shaped string. Could one assign the host galaxy with L and the satellite galaxies to S? L and S would define nearly orthogonal planes and the satellite galaxies could form around loops created from L by a repeated reconnection and they would rotate around the host in the plane defined by S.

Evidence for the failure of the dark halo model has been steadily accumulating during years. The popular article "New Discovery Indicates an Alternative Gravity Theory" published in SciTechDaily (`https://cutt.ly/dBVUBUn`) tells of the most recent discovery challenging the halo model. The dwarf galaxies of one of Earth's closest galaxy clusters do not behave as the halo model predicts.

Elena Asencio, a Ph.D. student at the University of Bonn was the lead author of the article *"The distribution and morphologies of Fornax Cluster dwarf galaxies suggest they lack dark matter* published in Monthly Notices of the Royal Astronomical Society [E100] (`https://cutt.ly/wNPRLI5`).

The following gives the abstract of the article in shortened form.

Due to their low surface brightness, dwarf galaxies are particularly susceptible to tidal forces. The expected degree of disturbance depends on the assumed gravity law and whether they have a dominant dark halo. This makes dwarf galaxies useful for testing different gravity models.

1. Tidal susceptibility η (half-mass radius divided by theoretical tidal radius) is the basic notion. Below a certain critical value η_{destr}, tidal forces destroy the dwarf galaxy.

2. The properties of dwarf galaxies in the Fornax Cluster were compared with those predicted by the Lambda cold dark matter (ΛCDM) standard model of cosmology and Milgromian dynamics (MOND). A test particle simulation of the Fornax system was constructed. The Markov Chain Monte Carlo (MCMC) method was used to fit this to the FDS distribution of η, the fraction of dwarfs that visually appear disturbed as a function of η, and the distribution of projected separation from the cluster centre.

3. It was possible to constrain the η value at which dwarfs should get destroyed by tides. Accounting for an r'-band surface brightness limit of 27.8 magnitudes per square arcsec, the required stability threshold is $\eta_{destr} = 0.25 + 0.07 - 0.03$ in ΛCDM. This value is in tension with previous N-body dwarf galaxy simulations, which indicate that $\eta_{destr} \sim 1$.

4. The MOND N-body simulations indicated $\eta_{destr} = 1.70 \pm 0.30$, which agreed well with the MCMC analysis of the FDS. The conclusion was that the observed deformations of dwarf galaxies in the Fornax Cluster and the lack of low surface brightness dwarfs towards its centre are incompatible with ΛCDM expectations but well consistent with MOND. In accordance with findings, the observed half mass radii tend to be larger in MOND than in ΛCDM dynamics.

The dwarfs are more sensitive to the effects of the tidal forces in the MOND dynamics than in ΛCDM dynamics because the dark matter halo surrounding the dwarf galaxy and acting like a mattress, would shield it from the tidal forces. The observed tidal forces are too large to be consistent with the presence of the dark matter halo.

In the TGD framework [L63, L69, L111], the dark matter halo is replaced with a long cosmic string whose energy density giving rise to dark energy explains also the flat velocity spectrum of galaxies. There is no shielding.

Is there something that could define galactic planes?

One can wonder whether there is something, which serves as a seed for the concentration of stars around a selected plane, perhaps associated with the boundary of a cell of the honeycomb structure. The collision of two cosmic strings would naturally define two planes of this kind. In the case of a single U-shaped closed string, which looks a more promising option, there is no obvious identification of the plane orthogonal to this object.

1. In the TGD Universe, space-time is a 4-surface in $H = M^4 \times CP_2$ and also membrane like entities are predicted as 4-D minimal surfaces of H having lower-D singularities analogous to the frames of a soap film minimal surface property (and simultaneous extermality with respect to Kähler action) fail but the field equations for the entire action involving volume term and Kähler action are satisfied at the singularities.

2. One can also consider 3-D singularities, which form a tessellation of H^3 at a given moment of cosmic time a and assign it with the honeycomb of large voids. The frame would be a tessellation. The quantization of cosmic redshifts in a given direction, discussed from the TGD viewpoint in [K94], could be seen as evidence for cosmic tessellations having astrophysical objects at their nodes.

   The boundaries of the large cosmic voids form a honeycomb structure and could correspond to a tessellation of H^3. The long U-shaped cosmic strings would be associated with the boundaries of the cells of the honeycomb and perhaps even form a 2-D lattice like structure.

   TGD suggests [L63, L69, L111] a fractal network of very massive long cosmic strings which can locally thicken to flux tubes: this thickening involves transformation of dark energy and possible dark matter of cosmic string to ordinary matter giving rise to galaxies and other structures. Also stars would have thickened flux tube tangles inside themselves. The model finds support from the observation that galaxies form long strings as found decades ago (Zeldowich was one of the discoverers [E272]).

3. The objects $M^1 \times X^2 \times S^1$, where M^1 is time axis, X^2 is a piece of plane of E^2, and S^1 is a geodesic sphere of CP_2, define very simple minimal surfaces carrying no induced Kähler field. The objects X^2
   $timesS^1$ could accompany the boundaries of the honeycomb cells. Universe could be populated by these membrane-like objects. Cell membrane is one important example.

4. Planar or approximately planar objects orthogonal to the cosmic string could tend to gather the matter flowing along helical orbits along the cosmic string. These planes would accompany planetary, galactic, etc... planes and the honeycomb structure could be also seen as a fractal analog of a multicellular structure.

5. Warped planes represent slightly more complex minimal surfaces with 3-D M^4 projection (a thin metal foil or sheet of paper gets warped) for which the plane is deformed but still flat minimal surface. I am not sure whether the "warping" [E56] (`https://cutt.ly/dHoeZKw`) of the outer regions of galactic planes, which has received attention recently (`https://cutt.ly/pHorgcD` and) but has been detected already 1956, is really really warping that is vertical deformation, which depends only single coordinate varying along a straight line (a 2-D plane wave of membrane).

16.7 Can the initial stellar mass distribution of galaxy really depend on its distance from Earth?

In learned about new very interesting findings related to distant galaxies from a popular article "*New discovery about distant galaxies: Stars are heavier than we thought*" (see `https://cutt.ly/UJdEG2G`. The article tells of the work done by astrophysicists in Niels Bohr Institute, Denmark by A. Sneppen et al.

The article "*Implications of a Temperature-dependent Initial Mass Function. I. Photometric Template Fitting*" [E161] provides a technical description of the work (`https://cutt.ly/SJdEZik`). The abstract of the article gives an overall view of the findings.

> *A universal stellar initial mass function (IMF) should not be expected from theoretical models of star formation, but little conclusive observational evidence for a variable IMF has been uncovered. In this paper, a parameterization of the IMF is introduced into photometric template fitting of the COSMOS2015 catalog. The resulting best-fit templates suggest systematic variations in the IMF, with most galaxies exhibiting top-heavier stellar populations than in the Milky Way. At fixed redshift, only a small range*

of IMFs are found, with the typical IMF becoming progressively top-heavier with increasing redshift. Additionally, subpopulations of ULIRGs, quiescent and star-forming galaxies are compared with predictions of stellar population feedback and show clear qualitative similarities to the evolution of dust temperatures.

Here is how I understand the basic notions and reported findings appearing in the article.

1. Initial mass function IMF used in the modelling of the galaxies is the key notion. IMF would be the initial distribution of stellar masses as galaxy started to evolve. The ages of galaxies between 10-13.6 billion years so that they formed very early. It would be very natural to assume that IMF is universal and same for all galaxies, and this has been indeed done. The candidate for a universal IMF has been determined from the data related to Milky Way and its satellites. There are however several candidates for the galactic IMF.

2. The finding of the group is that IMF is not universal and tends to concentrate towards higher masses for distant and therefore younger galaxies. The proposed IMF is parametrized by using a temperature like parameter T_{IMF}, interpretable as the temperature when the galaxy was formed.

   Here I however encounter a problem in my attempts to understand. I find it difficult to comprehend why T_{IMF}, a parameter that should characterize a galaxy, should depend on the distance of this galaxy from us. This looks nonsensical. Perhaps IMF is not what "initial mass function" suggests. What does one mean with "initial"? Or maybe some very interesting new physics related to the notion of time and aging of the stars is lurking there!

3. High mass stars have a short lifetime and end up to Supernovae unless the star formation creates new ones. Because stellar mass is dominated by low-mass stars, the inferred stellar masses and star formation rates (SFRs) are highly sensitive to the ratio of high-mass to low-mass stars in the IMF. The inferred extinction, metallicity, and other properties depend on the assumed IMF.

   In the standard model, star formation is sensitive to the pressure-gravitation balance. The IMF should be sensitive to all variables that can affect it. Article mentions central gravitational potential, existing stellar mass, star formation history, supernova rate, cosmic-ray density and galactic magnetic fields, metallicity, dust density and composition, AGN activity, and the environment and merger history.

   All of these are known to vary both between different galaxies at fixed redshift and across different redshifts. According to the authors, it should be expected that the IMF is not universal but rather differs between galaxies and between different epochs for the same galaxy. In particular, the IMF should depend upon the gas temperature of star-forming clouds, with higher-temperature regions producing higher average stellar masses. Because observations of dust even at moderate redshifts find an increase in temperature toward higher redshifts.

4. Authors notice that already in the case of the Milky Way there are several candidates for IMB and that typical stellar mass and star formation rate (SFR) are highly sensitive to IMF. There are also significant degeneracies between the IMF and extinction, metallicity, star formation history, and the age of the stellar population, which makes it very difficult to determine the entire shape of IMF.

5. The group performs a fit to a temperature dependent family of IMFs having initial temperature T_{IMF} as a parameter. What is nice is that for a given redshift, this is found to give only a few candidates for the IMF. The very distant galaxies would be top-heavier (stellar mass would be concentrated towards higher masses) and the fraction of heavier stars would be higher.

The proposal of the authors can be criticized. There is no doubt that the dependence of IMF on the galaxy is a fact but its dependence on the distance of the galaxy from us is in a glaring conflict with the standard view about time evolution, in particular with the basic assumption of the standard ontology stating that our geometric past is fixed.

Initial mass function (IMF) would be the initial distribution of stellar masses as the galaxy started to evolve about 10-13.6 billion years ago. It would be very natural to assume that the IMF is universal and the same for all galaxies, and this has indeed been done. The candidate for a universal IMF has been determined from the data related to the Milky Way and its satellites. There are several candidates for the galactic IMF. It has been however found that the IMF depends on the distance of the galaxy from Earth and that the IMFs tend to concentrate on larger stellar masses. The dependence of MF on this distance is in conflict with the standard view about time assuming that the geometric past is fixed.

Zero energy ontology (ZEO) [L84, L108, L118] [K119] defines the ontology behind TGD based quantum measurement theory and solves the basic paradox of quantum measurement theory. Second key element is the predicted hierarchy of effective Planck constants [L41] labeling phase of ordinary matter behaving like dark matter.

ZEO suggests a solution to the paradox created by the findings. TGD Universe is quantum coherent also in astrophysical scales and "big" state function reductions (BSFRs) reversing the arrow of time opposite to that for the environment occur for stars making them blackholes. This is the case also in GRT for Kerr-Newman rotating blackholes. Also quasars as white holes transform in BSFR to galactic blackholes with an arrow of time opposite to that for a distant environment. ZEO implies that the geometric past and thus the IMF of the galaxy changes in the sequence of BSFRs. A simple argument based on the fact that massive stars are shorter-lived shows that the IMF for large distances from Earth indeed is concentrated on larger stellar masses.

16.7.1 TGD based explanation for the dependence of IMF on distance

What could be the TGD based interpretation of the strange findings? Could the cosmic string model for the formation of galaxies and stars [L63, L69, L111] predict the time evolution of the galactic mass distribution by assuming a universal IMF? The paradoxical finding challenges the standard view about time: could zero energy ontology (ZEO) [L84, L108, L118] implying radical revision of this notion, be involved in an essential manner?

Cosmic string model for the formation of astrophysical objects

Consider first the cosmic string model for the formation of galaxies, stars, planets and and also smaller objects [**?**]

1. Cosmic strings would be the fundamental objects. Their string tension is determined by CP_2 length scale determining their energy density identifiable as dark energy and Kähler magnetic energy. Also ordinary and dark particles in the TGD sense can contribute to the density of energy. Galaxies are assumed to be tangles of a long cosmic string at which the cosmic string has thickened to a monopole flux tube with reduced string tension. The flat velocity spectrum of stars rotating around the cosmic string is flat and the value of the velocity is dictated by the string tension. Therefore galactic dark matter as a halo is replaced with the energy density of the long cosmic string containing galaxies as its tangles: this explains the linear structure formed by galaxies.

2. The energy of the cosmic strings would have been liberated as ordinary matter: this is completely analogous to the formation of ordinary matter in the decay of the inflaton field in inflation models. The seeds of stars can be identified as sub-tangles of galactic flux tubes analogous to spaghettis. This hierarchy of tangles inside tangeles inside... tangles continues to short length scales, even biomolecules, atomic nuclei, and hadrons would be this kind of tangles. The already existing ordinary matter could condense around these seeds.

   The conservative guess is that this analog of inflation was significant only during the very early stages of star formation when no stars existed yet and only the transformation of dark energy to ordinary matter could give rise to stars.

   The flux tube tangle would thicken and generate stellar objects as subtangles. The farther the star is, the younger the galaxy is. Massive stars as supernovas die soon and the mass function shifts to lighter stellar masses.

3. New massive stars are not formed after the galactic cosmic string tangle and galactic blackhole-like entity reaches a maximal size: one could say that the galaxy dies. After this star formation could happen as a condensation process around tangles serving as seeds as in the standard model and would give rise to stars, planets, and even smaller objects. The development of the flux tube containing the tangles would determine galactic evolution.

4. Note that a quasar identified as a galactic blackhole-like object would be there from the beginning and feed mass to its environment. In the spirit of ZEO, I have proposed that it is the TGD analog of white hole and a time reversed version of a blackhole-like object. Instead of sucking matter inside it it would spew matter outside, essentially energy of cosmic string, out which gives rise to the galactic matter.

   BSFR means death in a universal sense and in a well-defined sense, a blackhole is a dead object. Could blackhole be a time reversal of a white hole as quasar. BSFR changes the arrow of time and the radiation produced by blackhole would travel to the geometric past: nothing would come out from the perspective of the observer in the future! This what ordinary blackholes indeed look like. Could blackhole-like entities have an arrow of time, which is opposite to that of the environment? As a matter of fact, this would not be new! Also in GRT, Kerr-Newman solutions representing rotating blackholes have an arrow of time opposite to that of a distant environment [B46]. I have discussed Kerr-Newman blackholes in the appendix of [L24].

   Both galactic blackholes and stellar blackholes would be dead and time reversed quasars and "live" in a reversed time direction. Also ordinary blackholes would live in the opposite direction of time.

The interpretation of IMF and T_{IMF} in the TGD framework

What could be the interpretation of the IMF in the TGD framework? Does the parameter T_{IMF} appear naturally? Since the formation of galaxies and stars would be a process analogous to inflation, it would seem that the gravitational condensation around seeds defined by the flux tube tangles dominates except in very early times. Hence it would seem that the interpretation in terms of IMF which depends on T_{IMF} must make sense in the TGD framework. This is not possible without a new view about time provided by zero energy ontology (ZEO).

1. Zero energy ontology (ZEO) [L84, L108, L118] suggests a radical interpretation for the dependence of IMF on the distance of the galaxy from us. In ZEO, the stars of the galaxy evolve by state function reductions (SFRs) occurring in stellar and even longer scales. This is due to the hierarchy of effective Planck constants predicted by number theoretical vision of TGD involving the notion of $M^8 - H$ duality [L91, L92]) and adelic physics [L41]. ZEO predicts that both "big" and "small" SFRs (BSFRs and SSFRs) are possible.

2. In the BSFR, the arrow of geometric time changes and BSFRS can change even in astrophysical scales. This could explain the observation of stars which are older than the Universe [L69]. A given star would make BSFRs and in this manner evolve forth and back in the geometric time and become physically older but the center of mass time coordinate for the causal diamond (CD) of the star would not shift to the geometric future so that aging as it is usually understood would not take place.

   The size L of the CD is expected to increase in the process and could define as its inverse a parameter analogous to $T_{IMF} = \hbar_{eff}/L$.

3. The stellar BSFRs could explain the nonsensical looking dependence of the IMF on the distance of the galaxy from us. These stars of these very old galaxies would experienced would have made a large number of BSFRs. By universal evolution [L41] they would be at a high evolutionary stage and can be said to be repret old stars, stars older than the Universe. Star would have transformed to a blackhole and back to a white hole serving as a seed for the formation of a new star. The massive stars would have disappeared as supernovas and the mass distribution of these stars defining the IMF would shift towards lighter masses. Also the temperature would decrease for these stars determining IMF, which would imply the paradoxical looking decrease of T_{IMF} with the increasing cosmic distance.

The newest anomaly of the cold dark matter model (ΛCDM) is discussed popular article "Space Has Invisible Walls Created by Mysterious 'Symmetrons,' Scientists Propose" (`https://cutt.ly/mHorkqG`). It has been found that satellite galaxies of larger galaxies tend to move in planes whereas the ΛCDM predicts that the orbits are more or less random. Quite generally, ΛCDM fails in short scales. The proposed model is involves traditional kind of new physics: a new exotic particle and symmetry breaking producing galactic plane domain walls.

TGD predicts [L63, L69, L111] a fractal network of very massive long cosmic strings which can locally thicken to flux tubes: this thickening involves transformation of dark energy and possible dark matter of cosmic string to ordinary matter giving rise to galaxies and other structures. Also stars would have thickened flux tube tangles inside themselves. The model finds supports from the observation that galaxies form long strings as found decades ago (Zeldowich was one of the discoverers [E272]).

The TGD based model predicts the formation of planes in which objects in various scales move. The prediction is fractal: this applies to planets around stars, stars around galaxies, satellite galaxies arond larger galaxies,....

This model explains the newest anomaly and also the earlier anomalies if the galaxies are associated with the long "cosmic strings" predicted by TGD [K31]. They create a strong gravitational potential giving rise to a radial force in the plane orthogonal to the cosmic string. The motion along the string is free whereas the planar motion is rotation. The velocity spectrum is flat as required by the flatness of the galactic velocity spectrum. In the simplest model cosmic string is the carrier of galactic dark matter and dark energy. No dark matter halo and no exotic dark matter particles are needed.

Helical orbits are the most general orbits. If a concentration of matter occurs to a plane, it tends to catch objects moving freely in the direction of string to its vertical gravitational field and planar sheets such planetary systems, spiral galaxies, and the planar systems formed by satellite galaxies can form.

One can of course wonder whether there is something which serves as a seed for the concentration of stars around particular plane. In TGD, space-time is a 4-surface in $H = M^4 \times CP_2$ and also membrane like entities are predicted as 4-D minimal surfaces in H. For instance, objects $M^1 \times X^2 \times S^1$ are predicted, where M^1 is time axis, X^2 is a piece of plane of E^2, and S^1 is a geodesic sphere of CP$_2$.$Universecouldbepopulatedbythesemembrane-likeobjects.Cellmembraneisoneimportantexample.Theseplan$

Warped planes represent slightly more complex solutions (a thin metal foil or sheet of paper gets warped) for which the plane is deformed but still flat minimal surface. I am not sure whether the "warping" (`https://cutt.ly/dHoeZKw`) of the outer regions of galactic planes, which has received attention recently (`https://cutt.ly/pHorgcD` and) but has been detected already 1956, is really really warping that is vertical deformation, which depends only single coordinate varying along a straight line (a 2-D plane wave of membrane).

16.8 Local super-cluster Laniakea as flux tube structure

In the following I try to concretize the ideas about monopole flux tube network as a basic structure behind formation of astrophysical structures by discussing the supercluster Laniakea in this framework (the idea came from the question of Wes Johnson about how I understand Laniakea in TGD framework). There are two excellent videos about Laniakea (see `https://www.youtube.com/watch?v=rENyyRwxpHo` and `http://tinyurl.com/ufvw6v5`).

Consider first the structure of Laniakea.

1. Wikipedia contains a nice article about Laniakea (see `http://tinyurl.com/zfphldm`). Laniakea is a local supercluster containing also Milky Way so that it is own home supercluster. Local supercluster is defined as a basin of a local flow of galaxies directed to the center of the super-cluster.

   There is a video giving view about the structure and dynamics of Laniakea is warmly recommended (see `https://vimeo.com/104910552`). Laniakea contains about 10^5 galaxies, decomposes to four smaller super-cluster like entities and contains about 500 galaxy clusters.

2. The general picture supports the idea about fractal spaghetti formed by monopole flux tube or several of them. The presence of four smaller super-cluster type entities suggests quadrupole

field as a rough starting point as one tries to gues the analog as field line topology. The first very naïve guess is that the tangle defining the supercluster represents roughly the topology of quadrupole magnetic field in the first approximation: there would be pair of dipoles. One cannot of course fix the number of cosmic strings.

The simplest starting point hypothesis is that there is just single closed cosmic string forming a structure analogous to that of quadrupole magnetic field. Reconnection can split smaller closed cosmic string from a closed cosmic string and this could correspond to a decay of galaxy to smaller galaxies. Therefore single cosmic string is certainly an approximation.

Remark: Recall that cosmic strings are closed and one can have for instance helical structures: say two closed cosmic strings analogous to DNA double strands or single closed single having strands as pieces of it.

Remark: Also non-monopole flux tubes are involved and the proposal is that gravitational interactions are mediated along these flux tubes emanating radially from the source. The flux for them is vanishing and there is no current needed to create the field. These flux tubes are not topologically stable against splitting.

3. Cosmic strings are assumed to form a fractal hierarchy and that in TGD inspired biology cosmic strings thickened to monopole flux tubes are behind various linear biomolecules organized around them as ordinary matter. This leads to ask whether DNA double strand and the organization of DNA double strands to chromosomes might be more general phenomenon. Chromosomes consist of 4 strands, which allows to ask whether something similar happens even at the level of superclusters and that the topology of quadrupole field is involved.

   Interestingly, also Milky Way consists of four arms assignable spiral density waves for ordinary matter so that it is not clear whether the arms can be assigned with four poles of quadrupole. Fermi spheres are a peculiarity Milky Way possibly possibly related to a quadrupole structure of monopole flux tube topology suggesting two cosmic strings meeting at the nucleus of galaxy. There is evidence that Milky Way could be seen as being formed in a kind of cosmic collision. I have asked whether this is due to a cosmic highway accident at crossroad at which two cosmic string are pass by very near to each other is in question. This could make sense if tangle as a quadrupole corresponds to two dipoles.

Consider next the dynamics of Laniakea. Reader can build his/her own views with the help of the beautiful videos (see `https://www.youtube.com/watch?v=rENyyRwxpHo` and `http://tinyurl.com/ufvw6v5`) demonstrating the velocity flow of visible parts of galaxies, which would be associated with tangles moving along cosmic strings.

1. Wikipedia mentions that Laniakea is not gravitationally bound. Also this suggests that the galaxies associated with it are tangles of one or more cosmic strings. The dynamics would correspond to s motion in gravitational field with constraint forcing the galaxy to move along the cosmic string.

2. The motion of galactic tangles and that of ordinary matter formed from it along cosmic string is free in absence of external forces: this distinguishes TGD from halo model having a spherical symmetry. This would mean rather lose binding but strong correlation produced by the cosmic string. Most galaxy motions are directed inward towards Great Attractor: this would have explanation in terms of gravitational attraction. A good guess is that motion are along flux tube/cosmic string.

Chapter 17

Could solar system be modelled as a miniature version of spiral galaxy?

17.1 Introduction

The fractality of the TGD Universe motivates a model for planetary systems as miniature version of the model of spiral galaxy discussed in [L93]. The first two key elements are many-sheeted space-time, the notion of magnetic flux tubes - both monopole flux tubes and gravitational flux tubes without monopole flux - and the identification of dark matter as phases of ordinary matter labelled by effective Planck constant $h_{eff} = n \times h_0$ ($h = 6h_0$ is a good guess [L23, L54]). Also the TGD generalization of Nottale's model for planetary system as analog of Bohr atom characterized by large gravitational Planck constant h_{gr} identified as h_{eff} is in a key role [L50, L49] [K93, K79, K11].

A further key aspect is the prediction of twistor lift of TGD [L43] [?] that cosmological constant is length scale dependent and characterizes various systems in all scales. The phase transitions reducing the cosmological constant lead to expansion of space-time sheet and define a sequence of jerks replacing smooth cosmic expansion for astrophysical objects expected in standard cosmology but not observed.

TGD provides a model for "cold fusion" based on dark fusion [L31, L10] and suggests the possibility of fusion outside stellar cores perhaps serving as "warm-up band" for hot fusion during pre-stellar evolution. Also a new view about nuclear fusion in stellar interiors is suggestive [L82].

I did not originally end up with the model to be discussed from general theoretical considerations.

1. The first empirical input were the problems related to the collision - and accretion models for the formation of planets - TGD allows to consider the replacement of these models with quantal model involving the dark nuclear fusion in planetary cores.

2. The discovery of "too" heavy blackholes and neutron stars by LIGO [L24] suggesting that TGD view about the formation of also planets could provide understanding about the role of angular momentum.

3. There are also problems related to the understanding of the entire planetary system: the dramatic difference between terrestrial and giant planets is not really understood.

The problematic aspects of the Bohr orbit model together with the poorly understood differences between terrestrial and giant planets lead to a proposal that phase transition increasing the $\hbar_{gr}$ by factor 5 and accompanying a transition reducing the length scale dependent cosmological constant Λ could have scaled up the orbital radii of former inner planets. The transition could have also scaled up the radii of the former inner planets so that they became giant planets.

17.2 Some observations challenging the standard picture about the formation of planets and stars

It is best to start from observations and observations problematic from the standard model point of view are the best.

17.2.1 Two observations about planetary formation

The following apparently mutually conflicting observations help to develop the TGD based model.

A surprising observation about the formation of Earth

The popular article published in Phys Org (http://tinyurl.com/uj95y59) tells about observations of he group led by Associate Professes Martin Schiller [E245] suggests that the formation of the Earth's core took place in time which is about 1/1000 times shorter than the estimate 2.4 Gy for the existence of the Earth meaning that the formation time was about 2.5 My. The traditional theory assuming that Earth was formed by random collisions of increasingly larger planetary bodies predicts that the formation took 3-10 times longer time.

The evidence comes from the dust of single meteorite CI (C is for carbocaneous chondrite and I to the place where the collision with Earth occurred) covering the entire Earth. The group found that this dust determines the Fe abundance a the surface of Earth and corresponds to that in solar Corona . In the standard view about the formation of Earth this makes sense only if the iron at the surface of Earth had already sinked into the core. Therefore the age of the CI obtained by radioactive dating gives an estimate for the formation time of the core. This excludes the model for the formation based on planetesimal collisions predicting 3-10 times longer age. The authors propose a model of formation based on the accretion of cosmic dust consisting of milli-meter size objects.

Conflicting observations about the formation time for Mars

There are conflicting observations about the formation of Mars [E216].

1. From isotope ratios for tungsten one can conclude that the formation of Martian core took place in 2-4 My. This conforms with the above estimate for the formation time of Earth coming from CI meteor.

2. A popular article (http://tinyurl.com/wunpj85) published in Phys Org tells that about the proposal of a research group led by Dr. Simone Marchi published in Science Advances [E216] that formation time for long is longer than this - about 20 My years. There are a handful of meteorites at Earth thought to have emerged from Mars. The abundances of iron-philic ("iron loving") elements vary in a wide range. This suggests that the surface of Mars is heterogeneous and has a marble-cake like appearance that would have resulted in collisions of large planetesimals making even about 10 per cent of the mass of Mars. These collisions would have affected the isotope ratios for tungsten and the actual formation time would be about 20 My.

The two proposals are in conflict unless the formation mechanisms of Mars and Earth differ somehow. Could the formation mechanisms and formation times for the core be the same as in the case of Earth, and could formation of the core of Mars have followed by collisions with large planetesimals giving rise to to the surface layers? Jupiter is the planet next to Mars: Jupiter is a giant planet. Giant planets differ from terrestrial planets (Mercury, Venus, Earth, Mars), which are rocky and metallic and have no or very few Moons unlike giant planets (Jupiter has 79 Moons). Could the large planetesimals accompanying Jupiter have bombarded Mars and caused the different surface structure?

17.2.2 LIGO challenges the views about formation of neutron stars and their collisions

The observation of gravitational radiation by LIGO allowing interpretation as fusion of two neutron stars has challenged the views about neutrons stars and star formation: see the popular article in Quanta Magazine (`http://tinyurl.com/tqwnrne`) about the work of Enrico Ramirez-Ruiz and colleagues [E242] (`https://arxiv.org/abs/2001.04502`). Single neutron star collision with exceptional characteristics as such is not enough for revolution. One can however ask what it could mean if this event is not a rare statistical fluctuation but business as usual.

1. The pair has too high total mass: only 10 per cent of stars are estimated to be massive enough to make so massive neutron stars. Something in the models for star formation might be badly wrong.

2. Also the models for the formation of neutron star pairs are unable to explain why the abundance of so massive pairs would be so high as LIGO would predict. There could be something wrong also in the models for the collisions of stellar objects.

TGD provides several new physics elements to the possible model.

1. Galaxies, stars, even planets are tangles in cosmic strings carrying dark energy and (also galactic) dark matter and thickened to monopole flux tubes not possible in standard gauge theories. This leads to a general model of stars and of final states of stars as flux tube tangles as spaghettis filling the volume and thus maximally dense. One obtains nice quantitative predictions plus a generalization of the notion of blackhole like entity (BHE) so that all final states of stars are BHEs: BHEs would be characterizized by the quantized thickness of the flux tube in question.

   Also a TGD based modification of the view about nuclear fusion required by a 10 year old nuclear physics anomaly and "cold fusion" is involved solving a long list of nuclear physics related anomalies (`http://tinyurl.com/tkkyyd2`).

2. Collision of stellar objects producing blackholes can occur much more often than expected. Suppose one has two long flux tube portions going very near to each other: they could be portions of the same closed flux tube or of two separate flux tubes. The situation would be this for instance in galactic nuclei of spiral galaxies (`http://tinyurl.com/sg9c4sd`).

   The colliding stellar objects correspond to flux tube tangles moving along them. Since the stellar objects are forced to move along these cosmic highways, their collisions as cosmic traffic accidents become much more frequent than for randomly moving objects in ordinary cosmology. The cosmic highways force them to come near to each other at crossings and gravitational attraction strengthens this tendency.

   Situation would be analogous in bio-chemistry: bio-catalysis would involve flux tubes connecting reactants and the reduction of effective Planck constants would reduce flux tube length and bring the reactants together and liberating the energy to overcome the potential wall making reaction extremely slow in ordinary chemistry.

   Already the high rate of collisions might allow to understand why the first collision of neutron stars observed by LIGO was that for unexpectedly high total mass.

This model does not yet answer the question why so heavy neutron stars are possible at all. Also the fusion of "too heavy" blackholes has been observed by LIGO [L24] (`http://tinyurl.com/y79yqw6q`). Thus the blackhole formation from a neutron star pair with unexpectedly high combined mass supports the expecation that "too" heavy stars are a rule rather than exception.

1. The problem is that during the formation of blackhole or neutron the radius of the star decreases and the star should throw out a lot of angular momentum to avoid too high spinning velocity in the collapse. This can be achieved by throwing out mass but this makes heavy blackholes and neutron stars impossible.

2. Can TGD provide a solution of this problem? Suppose that both galaxies and stars are tangles along long cosmic strings locally thickened to monopole flux tubes carrying dark matter and energy in TGD sense Long flux tube would provide new degrees of freedom. Could the angular momentum of collapsing star consisting of ordinary matter be transferred from the star to the cosmic string/flux tube without large loss of stellar mass.

   Suppose that one has single monopole flux tube or a pair of monopole flux tubes as analog of DNA double strand (flux tubes would combine to form a closed flux tube) forming a rotating helical structure. This structure could store the angular momentum to its rotation. Also the radiation and particles travelling around these helical flux tubes could take away part of the angular momentum but flux tubes themselves as TGD counterparts of galactic dark matter could do the main job. Heavy blackholes would be a direct signature for energy and angular mmentum transfer between ordinary matter and galactic dark matter in TGD sense.

17.3 Could one model planetary system as a miniature of spiral galaxy?

In the sequel a model for the formation of planetary systems based on the idea that they are miniature forms of spiral galaxies is considered. The motivations for the proposal come from several sources.

17.3.1 Could one generalize the model for the formation of spiral galaxies to that for planetary systems?

TGD based general model [L63, L47, L65, L69, L93] for the formation of galaxies, stars, and planets relies on the notion of many-sheeted space-tme and the idea that they are tangles in long cosmic strings [K31, K94, K66] thickened to flux tubes carrying monopole flux - possible only in TGD but not in Maxwellian electrodynamics. The model explains the flat velocity spectrum of distant stars of galaxy leading to the notion of galactic dark matter in terms of long range cylindrically symmetric gravitational field created by cosmic string possibly thickened to flux tube. String tension decreasing with the thickness of the flux tube parameterizes the model.

1. The model for planetary system should not only provide a model and a mechanism for the emergence of single planet [L82] but also explain also the holistic characteristics of the planetary system.

   The TGD based model for spiral galaxies [L93] assumes two nearly orthogonal colliding flux tubes - one flux tube vertical to the galactic plane and second flux tube with spiral shape. What is so nice is that the collisions of moving flux tubes analogous to reconnections of strings are topologically unavoidable.

   The fractality of TGD Universe raises the question whether planetary system could be a miniature version of a spiral galaxy.

2. Vertical flux tube would be long flux tube orthogonal to the galactic plane and the four rocky and metallic terrestrial planets would be assignable to it. The 4 giant planets would have formed as tangles of a spiral flux tube in the plane of solar system. Giant planets as tangles of planar flux tube would have entered solar system, reconnected as closed flux tube structures from it, and started to rotate around Sun.

   The Grand Tack Hypothesis stating that Jupiter has arrived in solar system (`http://tinyurl.com/cmhrtc3` has some resemblances with this picture. Grand Tack Hypothesis (`http://tinyurl.com/yx3sjl42` states that planets also terrestrial ones were formed when Jupiter came to solar system along spiral orbit. The predicted formation time scale for Earth is however inconsistent with the measured terrestrial composition, which suggests that terrestrial and non-terrestrial planets are different in some aspect.

3. The heterogenous surface structure distinguishing between Mars and Earth suggests (`http://tinyurl.com/uqrxz63`) that the formation of Martian core was followed by a period during

which large planetesimals collided with proto-Mars. Giant planet Jupiter near Mars would be natural source of them. Also this supports the model of solar system as a miniature spiral galaxy. Note that this does not require that Jupiter arrived to the solar system from outside.

4. One can deduce an upper bound for the string tension of the flux tubes involved from the condition that the cylindrically symmetric gravitational fields of the flux tubes do not have any observable effect on the dependence of the velocities of planets on their planetary orbital radii so that Kepler's low $v^2 = GM/R$ for planetary orbit must hold true in excellent approximation. String tension T of the flux tube provides additional contribution for the motion in the plane of string as $v^2 = GM/R + TG$ so that one must have $T \leq\leq M/R$.

   One can parameterize the string tension as $T = xT_{max}$, where $T_{max} \simeq 10^{-5}/G$ is the string tension of cosmic string with thickness given by the radius $R(CP_2) \simeq 10^{-30}$ of CP_2. This leads to the condition $x \leq\leq GM/R = r_S/2R$, where r_S is the Schwartshild radius of Sun. For Neptune one has $R = 4.5 \times 10^9$ km, which together with $r_S(Sun) = 3$ km gives $x \leq\leq 3 \times 10^{-10}$. Since T is inversely proportional to the square of flux tube radius r, one obtains $r \geq\geq 10^5 R(CP_2)$. The flux tube thickness for the flux tube in solar interior is about electron Compton length so that the condition looks trivial.

The basic objection against the models of both spiral galaxy and planetary system is the asymmetry between the two flux tubes involved. The vertical flux tube would be more cosmic string like and would have no other tangles near Sun but could have them at much larger distances as other stars of galaxy. The planar flux tube would have several tangles in the vicinity of Sun, which have reconnected off the long flux tube and formed planets rotating around Sun. This would suggest that the flux tube thickness is larger and the length scale dependent cosmological constant smaller for the flux tube in the planetary plane (for the flux tube in the galactic plane). Why this difference? Could small string tension increase the probability of re-connection?

The requirement that the long range gravitational field created by long flux tube has negligible effects in solar system requires only that the flux tube thickness is larger than the minimal thickness about CP_2 length by a factor much larger than 10^5. The flux tubes in solar interior estimated to have thickness about electron Compton radius so that the condition is trivial for the flux tubes in the core of Sun and presumably also in the planetary plane.

17.3.2 Nottale's model for planetary system as a guideline

Nottale proposed [E87] that astrophysical systems could be regarded effectively as quantum systems in the sense that a system consisting of two masses M and m is characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0$, where $\beta_0 = v_0/c$ is a velocity parameter having the value $\beta_0 =\simeq 2^{-11}$ in solar system.

1. h_{gr} is not fundamental constant in the usual sense since it depends on M and m. In TGD framework [K93, K79, K11] [L50, L49] the proposal is that all systems are characterized by effective Planck constant $h_{eff} = nh_0$, $h = 6h_0$. h_{eff} would characterize dark matter at flux tubes. For gravitational flux tubes one would have $h_{eff} = h_{gr}$ assignable to the gravitons at the flux tube. The flux tube could be either monopole flux tube or carryig vanishing magnetic flux: the latter optio is more plausible. Monopole flux tubes would in turn be crucial for the formation galaxies, stars, planets, and actully objects down to elementary particle scales.

   The actual Planck constant would be h_0 but for space-time surfaces representing n_1-fold covering of M^4 and n_2-fold covering of CP_2 there $n = n_1 \times n_2$ sheets related by Galois group for the extension of rationals defining the hierarchy level in adelic physics [L41, L42] acting as symmetries and there are n identical contributions to the action so that one has effectively $h_{eff} = nh_0$. Ordinary Planck constant would correspond to 6-fold covering perhaps providing a geometric representation for half-odd integer spin and 3-value color of quarks.

2. A more general formulation of the Nottale's hypothesis would be in terms of zero energy ontology (ZEO). $h_{eff} = h_{gr}$ having rather large values would characterized gravitational flux tubes mediating gravitational interaction $n = h_{gr}/h_0$ would be very large and mean that gravitational interaction has very high evolutionary level - much higher than other

interactions. This would relate not only to the long range but also non-screened character of gravitational interaction.

Gravitational flux tubes would be algebraically very complex and essential for living systems. In ZEO one could assign the values of h_{eff} and thus also of h_{gr} the flux tubes of 3-surfaces assignable to the light-like boundaries of causal diamond (CD) define as an intersection of future- and past-directed light-cones.

Remark: The original formulation stated that flux tubes have M and m as their ends. A more precise formulation however forces to assume that M and m have topological sum contacts with the gravitational flux tubes.

3. If the value of h_{gr} becomes smaller than $\hbar_0$, one must assume that $h_{gr} = h_0$. The $Mm/m_{Pl}^2 \geq v_0\hbar_0$ poses a low bound for the product of the masses. For identical masses one has $M \geq \sqrt{v_0/6}M_{Pl}$ so that one has critical mass.

4. One can also construct a relativistic variant of Nottale's proposal by replacing Mm with the inner product $P_1 \cdot P_2$ of the 4-momenta of the two system.

A model of planetary system as analog of Bohr atom

Consider now a detailed model for planetary system as an analog of Bohr atom.

1. The central object with mass M in the formulate would correspond to dark matter whereas the small mass m by Equivalence Principle could correspond to even single elementary particle. How entire Sun can look like consisting of dark matter? This is the basic objection against the proposal.

2. The orbital radii R are same independently what the value of the mass m is. There is seems be an asymmetry. In fact, doing the little calculation for the circular Bohr orbits using angular momentum quantization $L = \mu v \times R = n\hbar$ and central force condition $\mu v^2/R = GMm/R^2$, one finds $v = v_0/n$ and $R = n^2G(M + m)/v_0^2$. Binding energies are give by $E = (v_0^2/4\pi n^2)/[G(M+m)]$ v depends on v_0 only and R E depend only on the Scwartschild radius for mass $M_{tot} = M + m$ and depends on $M + m$ only so that there is a complete symmetry.

3. R is same for given M_{tot} so that one can consider a wave function in the space of mass pairs (M, m) with fixed total mass M_{tot} this would mean very large variation in the masses of the gravitationally bound systems.

   The quantization condition $\hbar_{gr}/\hbar_0 = N$ gives the condition

$$\Delta[(r_s(M_{tot}) - r_s(m))] = v_0\frac{\hbar_0}{m} = v_0L_c(m) \tag{17.3.1}$$

4. One can have a discrete wave function in the space of (M, m) pairs with discretization step proportional to the ordinary Compton length $L_c(m)$. Gravitational Compton length equals to $L_{gr,tot} = G(M + m)/v_0$ and one can write

$$\Delta[(L_{gr}(M_{tot}) - L_{gr}(m))] = L_c(m) \ . \tag{17.3.2}$$

   Also the formula obtained by replacing m with M holds true.Gravitational Compton lengths M and m would have Compton lengths of m and M as unit.

5. One could even consider variation of R since v does not depend on R. This would give a quantum superposition of single particle orbits with varying radius $R \propto M + m$. One could consider many-particle system with particles with varying masses treated independently and giving rise to a representation of non-point-like orbiting object.

One can make the model relativistic by the replacements

$$\begin{aligned} \mu &\rightarrow \frac{P_1 \cdot P_2}{|P_1 + P_2|} \ , \\ \hbar_{gr} &\rightarrow \frac{Gp_1 \cdot P_2}{v_0} \end{aligned} \tag{17.3.3}$$

for the reduced mass μ and $\hbar_{gr}$. As a consequence, $M+m$ is replaced by $|P_1+P_2|$ in the expressions for relativity velocity v, binding energy E, and orbital radius R.

For $|P_1+P_2| = constant$, the quantization condition for $\hbar_{gr} = n\hbar_0$ implies $(G/v_0)\Delta(P_1 \cdot P_2) = 2n$, which in turn gives $(G/v_0)\Delta(P_1 - P_2)^2 = -n$ (note that $(P_1 - P_2)^2$ can be negative in Minkowski metric). One has

$$\frac{\Delta(P_1 - P_2)^2}{m_{Pl}^2} = -2n\beta_0 \ . \tag{17.3.4}$$

This gives a quantization rule for the relative momenta appearing in the wave function in terms of Planck mass. The rule is reminiscent of stringy mass mass formula.

Problems of the Bohr orbit model for the planetary system

The model of planetary orbits as Bohr orbits proposed originally by Nottale [E87] leads to a rough quantum model of dark matter as a part of the solar system in TGD framework. This model is certainly only a rough approximation. There are however objections.

1. What looks highly unsatisfactory is that the model treats inner and outer planets differently. The value of the gravitational Planck constant $\hbar_{gr} = GMm/v_0$ characterizing the gravitational flux tubes to which Sun and planet are attached by topological sum to by factor 5 smaller for outer planets (includes Mars) $v_{0,in} = 5v_{0,out}$. Could this problem disappear if the colliding terrestrial and non-terrestrial planetary systems are assignable to vertical and plane flux tubes with different values of $\hbar_{gr}$?

2. Second unsatisfactory feature of the model is that the principal quantum numbers for the 4 inner planets are $n = 3, 4, 5, 6$ rather than $n = 1, 2, 3, 4$ as the atomic physics based intuition would suggest. Could the gravitational attraction of Jupiter and/or the presence of monopole flux tubes have induced quantum jumps of the 4 inner planets to larger orbits? It turns that classically the gravitational modification of orbital radii due to the presence of Jupiter is very small so that gravitationally induced transitions do not look plausible.

3. Furthermore, in the case of Mars $v_{0,in}$ should change to $v_{0,out} = v_{0,in}/5$. This suggests a phase transition reducing v_0 and scaling all planetary orbital radii by factor 25. Could this transition accompany a phase transition reducing the value cosmological constant predicted by twistor lift of TGD [L43], and required by the condition that also astrophysical objects participate cosmic expansion occurring as jerks analogous to quantum transitions. Could this transition also scale up the sizes of the former inner planets to that for outer giant planets? TGD inspired Expanding Earth model assumes similar phase transition increasing the radius of Earth by factor 2 in Cambrian Explosion [L55].

17.3.3 Two models for why terrestrial and giant planets are so different

One can consider two models for why terrestrial and giant planets are so different.

Could the approach of Jupiter have induced planetary quantum transitions ?

One can try to estimate the effect of Jupiter's approach on the orbit of Mercury and other terrestrial planets perturbatively assuming Newtonian mechanics and forgetting flux tubes and possible angular momentum exchanges between stars and helical flux tubes as also the Bohr orbitology.

1. Since the orbital radii are much smaller one can assume that angular momentum is conserved and that the orbit stays approximately circular and the radii are changed only slightly.
2. One can apply the condition stating that the sum of gravitational forces of Sun and Jupiter and centrifugal force cancel each other and angular momentum conservation in the transition $R \rightarrow R_1 = R + \Delta R, v_1 \rightarrow v_1 + \Delta v$:

$$\begin{aligned} \frac{v^2}{R_1} - \frac{GM_S}{R_1^2} + \frac{GM_J}{(R_J - R_1)^2} &= 0 \ . \\ vR &= v_1 R_1 \ . \end{aligned} \tag{17.3.5}$$

Jupiter's mass $M_J \simeq x_J M_S$, $x_J = 10^{-3}$, is small and in the first order approximation treating the presence of Jupiter as a small perturbation.

3. A little calculation gives

$$\frac{\Delta R}{R} \simeq -\frac{1}{2\beta_{0,i}^2} x_J \frac{R_S}{R_J} \frac{R}{R_J} \ . \tag{17.3.6}$$

Contrary to the intuitive expectations, the radius decreases and rotation velocity increases if one assumes angular momentum conservation. In the case of Mercury one has $\Delta R/R \simeq -2 \times 10^{-6}$. The change is very small also for other planets. The orbital velocities of planes vary in rather small range and $v/c = x \times 10^{-3}$,where x is near unity. In particular, the nearness of Jupiter to Mars should not have had dramatic effects and the small effect would have had even wrong sign.

It seems that in quantum situation gravitation cannot induced quantum transitions since the changes of orbit radii should be large.

Could non-gravitational interactions induce transitions increasing orbital radii?

One can challenge the assumption that only classical gravitation is involved. Could the perturbation caused by the planar flux tube intersecting the vertical flux tube cause large quantum effects near the Sun and affect dramatically the orbit of Mercury? Could the nearness of Jupiter have caused large quantum effect on Mars and even the reduction of $v_{0,in}$ by factor 1/5: this could be seen as a rough quantum analog for Grand Tack Hypothesis? Could the presence of monopole flux tubes induce non-inertial interactions at the level of dark matter affecting most strongly light masses.

The first option is that quantum transitions between the state atom like planetary system increased the radii of the Bohr orbits and thus the principal quantum number n for the Bohr orbits of the 4 inner planets. One can also ask whether the nearness of Mars to Jupiter could have also changed the value of v_0 for Mars - here and this of course raises the question whether this happened for all orbits and whether a phase transition increasing length scale dependent cosmological constant was in question. One can consider 3 options.

1. Classical considerations involving only gravitational interaction would favor a small effect and $n = (3, 4, 5, 6)$ in the initial situation for terrestrial planets. Only the orbit of Mars would be affected and the fractional change of radius would be

$$\frac{\Delta R}{R} = (\frac{n_f \beta_{0,i})}{n_{0,i}\beta_{0,i}})^2 - 1) = \frac{16}{9} \ .$$

If Mars has in initial state $n = 10$, radius, remains unaffected. The transition cannot be induced by gravitation. The missing orbits with $n = 1, 2$ are an aesthetic problem taking into account that exoplanets can have very small orbital radii.

2. The assumption $n_1 = (1,2,3,4)$ and $v_{0,i} = 2^{-11}$) for terrestrial planets in the initial situation is aesthetically attractive. In the final situation one has $n_f = (3,4,5,6)$ for inner planets and $n_f = 2$ and $\beta_{0,f} = \beta_{0,i}/5$ for Mars. The radii of (Mercury, Venus, Earth, Mars, Jupiter) are $(.4,.7,1.0,1.5,5.2)$ AU. The changes of the radii proportional to Δn^2 relate like $8:12:17:84$. This is in qualitative accordance with the fact that the gravitational force caused by Jupiter increases with the distance from Sun.

   The scalings of the radii would be

$$\frac{R_f}{R_i} = (\frac{n_f v_{i,0}}{n_i v_{0,f}})^2 \ ,$$

   and given by $(9,4,25/9,25/4)$. It is not quite clear to me whether relative or linear scale should be used asa measure for the size of the effects. For inner planets the relative change in the radius is largest for Mercury: neither the largest distance from Jupiter nor Equivalence Principle favour this.

   If also non-gravitational forces possibly assignable to monopole flux tube connections between Jupiter and other planets are important, the mass of the planet matters. The masses of Mercury, Venus, Earth, and Mars are $0.055, 0.82, 1.0, 0.12)M_E$. Mercury's mass is the smallest one.

3. A more conservative option is $n = (2,3,4,5)$ for terrestrial planets in the initial situation. The changes of the radii would relate like $5:13:16:75$. The scalings of radii would be given by $(9/4,16/9,25/16,25/4)$. For inner planets the relative change of the radius of Mercury is still largest. For both options the relative change for the radius of Mars is largest and conforms with the nearness of the Jupiter.

Neither of these options looks attractive. In particular, there is no proposal for a physical mechanism causing the quantum transition.

Did a phase transition $\beta_{0,in} \rightarrow \beta_{0,out} = \beta_{0,in}/5$ generate giant planets from Earth-like planets

The twistor lift of TGD [L43] predicts that cosmological constant Λ is length scale dependent and every space-time sheet is characterized by "personal" Λ, which determines the thickness of the monopole flux tubes assignable to the magnetic body (MB) of the system. Λ scales like $1/L^2(k)$, and approaches zero in p-adic scales $L(k)$ characterizing space-time sheets. This solves the problem related to the huge value of cosmological constant and also predicts correctly its sign.

Cosmological expansion takes for all space-time sheets. Not continuously but as jerks, phase transitions in which Λ for the system decreases and the magnetic flux tubes thicken. This provides also a justification for the Expanding Earth model [L55] in which the radius of Earth is scaled up by factor 2 during Cambrian explosion in rather short time scale and having rather dramatic implications for geology, climate, and biology.

These observations together with the discovery of exoplanets - in particular, hot Jupiters - orbiting very near their Suns, inspire the question why Sun does not have planets very near to its surface, and allows to imagine very different origin of giant planets as resulting in a phase transition decreasing Λ and β_0 for the planet system and providing at the same time explanation for why the values of β_0 differ for inner and outer planets.

1. Phase transitions increasing the length scale dependent cosmological constant Λ and the size scale the size of of the system - presumably by some power of $r = \beta_{0,i}/\beta_{0,f}$. For the atomic model of solar system, second power of r would be in question. This phase transition would also involve increase of $n = h_{eff}/\hbar_0 = h_{gr}/\hbar_0$ having interpretation as dimension for extension of rationals by factor factor 5 so that an evolutionary step increasing algebraic complexity would be in question.

2. All planets would have had initially the same value of $\beta_0 \simeq 2{-}11$ as inner planets have now. Proto variants of Earth, Mars, Jupiter, Saturn, Uranus, and Neptune had had $n = (1,2,3,4,5,6)$. The phase transition $\beta_0 \rightarrow \beta_0/5$ accompanying the change of the scaled

dependent cosmological constant scaled up their orbital radii by factor 25. The orbital radius of proto-Earth in ground state, proto-Jupiter, and proto-Neptune would have been $AU/25 = .04AU \simeq 8.6R_S$, R_S solar radius, $(3/5)^2AU \simeq .08AU$, and $(6/5)^2AU \sim 7AU/5$.

3. Gas giants proto-Jupiter with $n = 3$ and proto-Saturn with $n = 4$ are problematic since these values would correspond also to Mercury and Venus. Could Mercury and Venus be remnants from proto-Jupiter and proto-Saturn at different space-time sheets, which did not follow the expansion. This kind of remnant cannot be planetary core since all planets have it. Earth has also inner and "inner-inner" cores. Could Mercury and Venus be either of these structures, which did no follow the former pro-planet in the expansion or where formed later? Maybe they did correspond to different space-time sheet.

4. Why didn't Earth and Mars with $n = 1$ and $n = 2$ leave any remnants: does this relate somehow to terrestriality? Interestingly, without this phase transition biological life in solar system would not have been possible. Note also that the Earth would have been the lowest orbital, which could explain its special role. If the orbitals correspond to wave functions then Earth would correspond to a unique state having non-vanishing dark matter wave function down to the solar interior - this would be true also now.

5. Why the outer planets have radii are by an order of magnitude larger than the radii of inner planets (`http://tinyurl.com/sowh6cn`)? Could the expansion have scaled up - not only the planetary plane but also - the radii of the planets by a power of v_0 as the reduction of the scale dependent Λ would suggest. This would have reduced the density of proto-planet and the densities of giant planets are indeed considerably lower than those of terrestrial planets. Accretion of matter would have increased the mass of the giant planets. It would be nice to understand whether and how the phase transition could lead to the formation of moons and rings of giant planets.

   Note that the presence of Jupiter like exoplanets very near to their host stars however suggests that giant planets were giants already during their proto-stage.

17.3.4 The problem of angular momentum balance

Angular momentum balance is poorly understood in the models for the formation of stars. If there is no angular momentum in the initial situation the question is where the compensating angular momentum of the star resides. As already explained, LIGO has observed "too" heavy neutron stars and blackholes in the sense that standard model for stellar evolution does not allow them: the star must throw away must to keep its rotation velocity small enough. In TGD picture the angular momentum would be transferred to the orthogonal flux helical flux tube (or pair of them) to which the system is associated as a tangle.

The spins of the terrestrial planets and even their angular momenta for the motion around Sun could be compensated by the spin of the local helical cosmic string portion assignable to them. The planetary angular momenta for the rotation around Sun could be also compensated by the helical spin of the long vertical cosmic string going through Sun. If the solar tangle intersects the planet, the "personal" flux tube is part of solar flux tube tangle. The angular momentum transfer would be made possible by gravitational or monopole flux tubes: and the latter would lead to effect breaking Equivalence Principle. This could apply also to the non-terrestrial planets.

17.3.5 Could dark fusion be responsible for the formation of planetary cores?

As already described, the formation time of Earth is according to the latest findings considerably shorter than the model based on collisions of planetesimals of increasing size predicts (`http://tinyurl.com/uj95y59`). The accretion of milli-meter sized objects is suggested as a formation mechanism.

TGD does not exclude accretion mechanism - as at least part of the formation mechanism - but the formation of planet seed giving rise to the core as a tangle of cosmic string is highly attractive option. The dark fusion outside stellar core [L10, L31, L82] provides a mechanism of "cold fusion" and could provide a "warmup band" for ordinary fusion in stellar core and also the seed for the solar core. This mechanism could provide also the iron core of the stellar object as a seed for planet so that sinking of iron from the surface to the core would not be needed. The explanation for why CI determines the abundance of iron at the surface of Earth's would be that the density of the iron at the surface of Earth has been always much lower than believed.

It is not clear whether also ordinary fusion could have been initiated, and led to the formation of the planetary iron core. Note that TGD based vision about nuclear physics [L82] the tunnelling in ordinary fusion could take place via the formation of intermediate dark nuclei as "on-mass-shell states". This would be in accordance with quantum-classical correspondence. The structures above core could have formed by accretion.

Chapter 18

TGD View of the Engine Powering Jets from Active Galactic Nuclei

18.1 Introduction

This work was inspired by a Quanta Magazine article "Physicists Identify the Engine Powering blackhole Energy Beams" (`https://cutt.ly/dQtDK7Q`) telling about an empirical support for the model of Blandford and Znajek (BZ model in the sequel) [E231] for the central engine providing energy for jets from active galactic nuclei (AGNs). In the BZ model (`https://cutt.ly/9QtDOkK`) AGN is identified as a blackhole and the Penrose process would provide the energy of the jets emerging from the blackhole. The energy would come basically from the blackhole mass. The empirical support is found by studying the supermassive blackhole associated with a galaxy known as Messier 87 (M87).

The basic problem is the identification of the central engine of the active galactic nuclei (AGNs) (`https://cutt.ly/eQtFyib`) providing the huge energy feed to the the jets.

18.1.1 Typical properties of active galactic nuclei

The power emitted by active galactic nuclei (AGNs) is typically of the order of 10^{38} W corresponding to a transformation of a mass of 10^{22} kg per second to energy. The typical radius of the AGN is $R \simeq 2$ AU for the active region.

One must distinguish between magnetic fields associated with the interior of the central objects, the region near its surface, and the jet region with the scale of visible jets about 10^5 ly. According to the estimate of [E160] (`https://cutt.ly/DQtFzD3`), the magnetic field is about 10 Gauss in the jet region. About $10^6 - 10^7$ Gauss near horizon. Also near-horizon magnetic fields in the range $10^8 - 10^{11}$ Tesla have been proposed for some AGNs.

Quasars are examples of AGNs and also M87 central region idenfied as a blackhole is such. In this case the mass is $6.5 \times 10^9 M_{Sun}$ and Scwartschild radius is about 2×10^{10} km $= 1.3 \times 10^3$ AU. For M87 central object the magnetic field in the jet region is that of refrigerator magnet and about 100 Gauss. For Sagittarius A has a in the center of the Milky Way the radius of the central object .4 AU.

One can pose some general conditions on the central engine serving as the energy source for the jets. The time scale Δt for the luminosity fluctuations in the power should satisfy $\Delta t < R$. For M87 one has $\Delta t \leq 10^4$ s. The gravitational force is assumed to be balanced by the radiation pressure of the outward radiation.

Consider now the observations about the M87 blackhole-like entity (`https://cutt.ly/dQtDK7Q`).

1. The mass of the M87 black-hole-like entity is about $6.5 \times 10^9 M_{Sun}$.

2. There are two 5,000 ly long white hot plasma jets travelling in opposite time directions with emitted power of 3×10^{36} W. They have blobs at their ends. Synchrotron radiation is emitted at radio wavelengths in the magnetic field, which according to the popular article has the

strength of a refrigerator magnet, so that one would have $B \sim 100$ Gauss. Both the intensity of B and the size of the emitting region contribute to the intensity of the energy flow.

3. There are two alternatives for the BZ process that have been developed and explored in hundreds of computer simulations in recent decades. They have acronyms MAD and SANE.

   For the SANE option B is weak: charged matter dominates over B. For the MAD option B is strong, has a spiral structure and acts as a "boss" of the matter. The tight spiral structure forms a sleeve around the jet preventing charges from entering the central object. This inspires a critical question: doesn't the object look more like a whitehole.

   The strongly polarized light in the Event Horizon Telescope's new photo suggests strong magnetic fields, and supports the MAD version. B has a strength of about 100 Gauss, that is 200 times the strength of the Earth's magnetic field with the nominal value $B_E \simeq .5$ Gauss. The polarization pattern for the radio waves is found to be stripy and the polarization in a plane locally: this allows us to conclude that the magnetic field is indeed helical and non-random.

18.1.2 Central engine as a Penrose process?

In the BZ model, the central object is assumed to be a blackhole and Penrose process would provide the energy feed to the jets of length about 5000 ly. Note that the Milky Way is about 1,0000 ly thick.

1. The blackhole is surrounded by an accretion disk from which the matter ends down to the BH.

2. Kerr solution of Einstein-Maxwell field equations [B16, B46] (`https://cutt.ly/sQuKXth`) involving magnetic field is the starting point. Matter falling into the Kerr blackhole rotates and the magnetic field lines are twisted to helical shape. By Faraday law, an electric field along field lines is generated by the rotation of the flux lines. Electrons and positrons created in the annihilation photons emitted as the particles fall to the region near the blachole, start to flow along the field lines of the electric field in opposite directions and generate the jets.

3. The model assumes that the electromagnetic field is force free so that it does not dissipate and Lorentz force vanishes. At a single particle level this implies the condition $E+qv\times B=0$. Vanishing dissipation requires $v\cdot E=0$. This helical structure would be in the direction of the jet.

4. The basic question has been whether it is accretion disk or magnetic field that controls the dynamics. The first option, known as SANE, corresponds to weak and incoherent magnetic fields. The second option, known as MAD, corresponds to strong and coherent magnetic fields.

5. MAD is favoured by the recent observations. Magnetic field would form a sleeve around the jet and the synchrotron radiation pressure would prevent matter from falling into the blackhole. Matter can only occasionally leak to blackhole.

   One can however wonder whether it makes sense to talk about blackhole anymore! Doesn't this look more like white hole as a time reversal of blackhole feeding energy and matter to the environment?

18.1.3 TGD inspired view of the central engine

In the TGD framework the model of the central engine as a Penrose process is replaced by the following picture. The key concepts are following:

1. Space-time is identified as a 4-D minimal surface in $H = M^4 \times CP_2$ [L114] or as an algebraic surface in complexified M^8 having octonionic interpretation [L91, L92, L104]. These descriptions are related by $M^8 - H$ duality analogous to momentum-position duality, which does not generalize from wave mechanics to quantum field theory (QFT). Therefore the points or M^8 are 8-momenta.

The classical dissipation is absent for the generalized Beltrami fields and the proposal [L114] is that minimal surfaces (apart form singularities defining dynamically generated frame for space-time surfaces as analog of a soap film) define locally generalized Beltrami fields.

2. Zero energy ontology (ZEO) [L84, L108, L105] predicts that time reversal occurs in the TGD counterparts of ordinary state function reductions ("big" SFRs) but not in "small" SFRs (SSFRs).

3. The hierarchy of effective Planck constants predicts a hierarchy of phases of ordinary matter labelled by the values of effective Planck constant $h_{eff} = nh_0$. The phases with different values of h_{eff} behave in many respects like dark matter with respect to each other. The findings of Randell Mills suggest $\hbar/\hbar_0 = 6$ [L23] but also larger values for this ratio can be considered [L106]. In [L106] it is proposed that the $\hbar_0/\hbar$ is equal to the ratio l_P/R of Planck length l_P to CP_2 radius R.

   As a special case, one obtains gravitational Planck constant satisfying $h_{eff} = h_{gr} = GMm/\beta_0$, where $\beta_0 = v_0/c$ and $\beta_0 < c$ has dimensions of velocity, as a generalization of Nottale's hypothesis [E87]. The gravitational Compton length $\lambda_{gr} = \hbar_{gr}/m = GM/\beta_0$ does not depend on m and is equal to Schwartschild radius r_s for $\beta_0 = 1/2$. Also the cyclotron energy spectrum $E_c = nGMqB/\beta_0$ is independent of the mass of the charged particle.

   The hierarchy of Planck constants, the notion of $\hbar_{gr}$, and coupling constant evolution are discussed in detail in [L106].

Consider now the key elements of the model.

1. TGD leads to a general model for the formation of galaxies, stars, planets,... in terms of cosmic strings thickening to flux tubes [L63, L69, L82]. The energy of the flux tube, which consists of a volume energy and Kähler magnetic energy, is transformed to ordinary matter as the string tension is reduced in a sequence of phase transitions reducing the length scale dependent cosmological constant Λ.

   This process is analogous to the decay of an inflaton field to matter. The model (there are actually several basic variants of it) explains the flat velocity spectra associated with the spiral galaxies. For the first option, a long cosmic string normal to the galactic plane causes the gravitational field explaining the flat velocity spectrum of spiral galaxies. For galaxies formed around closed flux loops the velocity spectrum is not flat. There is no dark matter halo although it is possible that the galactic plane contains cosmic strings parallel to the plane.

2. ZEO (ZEO) [L84, L108, L105], which predicts that the TGD counterparts of ordinary state function reductions (SFRs) involve time reversal, is involved in an essential way. TGD predicts both blackhole-like objects (BH) and whitehole-like objects (WH) as the time reversals of BHs. The seed of the galaxy, active galactic nucleus (AGN), involves WH. Quasars are cases of AGNs as WHs [L63, L69].

3. In the TGD framework, the Kerr blackhole [B16, B46] is replaced with a whitehole-like object (WH). Kerr blackhole indeed has an opposite arrow of time reversal as the distant environment. The WH is time reversal of BH and feeds matter and energy to the environment. This serves as an analog of the Penrose process in the TGD based model.

4. The TGD analog for the rotation of spacetime and the twisting of the magnetic field lines near the Kerr blackhole is very concrete. Space-time is a 4-surface and the flux tubes carrying monopole flux are pieces of 3-space as a 3-surface. They quite concretely rotate and get twisted in the process. Analogous process occurs in the Sun with a period of 11 years ending as reconnections untwist the flux tubes.

5. WH would correspond to a tangle of a long cosmic string in the direction of the jet thickened to a flux tube but still carrying an extremely strong magnetic field. The helical magnetic field in the exterior of the jet would not represent return flux of this field as one might first think. There is a current ring associated with the equator of Earth, which carries a parallel magnetic field analogous to the helical magnetic field.

The magnetic field in the exterior of WH is associated with a space-time surface, which is many-sheeted with respect to CP_2 rather than M^4 so that either CP_2 or cosmic string world sheet $M^2 \times S^2 \subset M^4 \times CP_2$) would serve as the arena of physics rather than M^4, which is quantum coherent flux tube bundle analogous to BE-condensate. M^4 coordinates as functions of CP_2 or $M^2 \times CP_2$ coordinates would be many-valued rather than vice versa. This picture is very natural if one accepts $M^8 - H$ duality [L91, L92, L104].

Cosmic strings dominate during the primordial cosmology in TGD Universe, and the analog of the inflationary period corresponds to the transition to a phase in which the Einsteinian space-time with M^4 as the arena of physics is a good approximation. Hence the $M^2 \times CP_2$ option looks more plausible.

6. The force-free em fields appearing in the BZ model [E231] correspond to space-time surfaces as minimal surfaces realizing a 4-D generalization [K85, K86, K10] of 3-D Beltrami fields [B11, B41, B29, B32], which do not not dissipate classically [K9]. The interpretation of the non-dissipating Kähler currents is as classical correlates for supracurrents [L98]. The prediction is that charged particles flow without dissipation that is as supra currents: not only Cooper pairs but also charged fermions. Also the analogs of laser beams of dark photons are expected.

7. The hierarchy of Planck constants [L62] [L106] is an important piece of the picture emerging from adelic physics [L42, L41]. From $\hbar_{gr} = GMm/\beta_0$ realizing Equivalence Principle, the gravitational Compton length $\lambda_{gr} = r_s/2\beta_0$ is universal and equals to r_S for $\beta_0 \equiv \beta_0 = 1/2$.

   All astrophysical objects are predicted to be quantum coherent in the scale of $\lambda_{gr} = r_s/2\beta_0$ at least. The quantum coherence would be at the level of magnetic body (MB) [L82, L69]. WH/BH as a thickened flux tube tangle would not have large h_{eff} but would be accompanied by a large scale quantum object.

   The astroscopic quantum coherence would be associated with the helical magnetic field surrounding the long cosmic string having BH or WH as a tangle.

8. Also the cyclotron energy spectrum is universal and does not depend on the mass of the charged particles so that all charged particles rather than only electrons are expected to form supracurrents. Dark matter would flow along flux tubes and form the dark core of the jet, perhaps extending over cosmic distances to other galaxies identified as tangles of the one and the same cosmic string.

   Stars and even planets would be parts of this fractal network. Dark cyclotron states have huge energies for $h_{eff} = h_{gr}$ serving also as a measure for algebraic complexity and, in the TGD inspired theory of consciousness, also for intelligence and scale of quantum coherence. The analogy with a cosmic nervous system is obvious.

9. The decay of quantum coherent states to ordinary states takes place by the loss of quantum coherence in which $h_{eff} = h_{gr}$ is reduced. This would create the visible jets and blobs at their ends. For M87, which is elliptical for which the velocity spectrum is not flat, the flux tubes would be closed in a relatively short scale. Their length scale could be that of the jets in the case of ellipticals. The thickening of the cosmic string at the core leads to the reduction of mass of WH and gives rise to the flow of mass and energy to the environment. One could see this process as a time reversal for the generation of BH and perhaps also as an analogy for the evaporation of BH.

10. $M^8 - H$ duality [L91, L92, L104] and adelic physics [L41] help to understand the decoherence process geometrically. The reduction of h_{eff} and thus of the length scale of quantum coherence, allows a number theoretic description at the level of M^8. An irreducible polynomial, which depends on parameters, reduces to a product of polynomials for some critical values of the parameters. This gives rise to a set of disjoint space-time surfaces, which are not correlated. This means decoherence. This includes as a special case the description of catastrophic changes in catastrophe theory of Thom [**?**]. The maximal decoherence produces a product of first order polynomials with rational roots.

    At the level of H this corresponds to a decay of coherent flux tube bundle to disjoint uncorrelated flux tubes.

18.2 TGD based model for the formation of galaxies and other astrophysical structures

TGD leads to a rather detailed picture about the formation of galaxies and other basic astrophysical structures [L63, L69, L82].

18.2.1 Brief description of the model for for the formation of galaxies and stars

TGD based cosmology predicts that the primordial cosmology was dominated by cosmic strings identified as 4-surfaces having 2-D M^4 projection in $H = M^4 \times CP_2$. CP_2 projection is a complex surface of CP_2. The dimension of M^4 projection is unstable against perturbations and during cosmological evolution the M^4 projection thickens. This leads to a model for the formation of galaxies as tangles along cosmic strings in turn containing stars and even planets as sub-tangles [L69, L63, L82].

1. Twistor lift of TGD [L22] predicts that cosmological constant Λ at the level of space-time surface (to be distinguished from that associated with GRT limit of TGD) is length scale dependent. This solves the basic problem caused by the huge value of cosmological constant in the very early Universe. In ZEO length scale dependent Λ having spectrum coming as some negative powers of 2 characterizes the space-time sheets assignable to individual system and the corresponding causal diamond (CD) and is determined by its p-adic length scale.

   For instance, Sun has its own cosmological constant predicted by the model solving the puzzle due to larger abundances obtained in solar-seismological determinations than in spectroscopic and meteoritic determinations. Dark nuclear states of nuclei inside solar core contribute also to the nuclear abundances [L82].

2. The energy of flux tubes consists of Kähler magnetic energy and volume energy. Quantum classical correspondence strongly suggests that this energy is identifiable as dark matter even for minimal value of h_{eff}.

3. Phase transitions reducing the value of cosmological constant are possible. Cosmic strings (or rather their M^4 projections) start to thicken and lose magnetic energy by transforming to ordinary matter. This is analogous to the decay of the inflaton field to matter. This generates Einsteinin space-time with space-time surfaces having large and increasing 4-D M^4 projection. Flux tubes and cosmic strings are however still present.

   The expansion of flux tubes in phase transitions reducing Λ gives rise to a jerk-wise accelerated expansion at the level of astrophysical objects. For given phase transition the accelerated expansion eventually stops since the expansion increases volume energy. The expansion periods however repeat being induced by phase transitions reducing length scale dependent quantized cosmological constant Λ associated with the volume action coming as powers of 2 and making flux tubes unstable against thickening and transformation of magnetic energy to ordinary matter.

   The recent accelerated expansion corresponds to this kind of period being thus analogous to inflation and is predicted to stop since volume energy increases. The expansion rate is predicted to oscillate so that the expansion takes place as jerks and there is evidence for this [E233] (see (`http://tinyurl.com/oqcn2hp`) discussed from TGD point of view in [K66].

4. In particular, the TGD counterpart of inflation would have led from cosmic string dominated primordial cosmology in which Einsteinian space-time does not make sense to a radiation dominated phase in which Einsteinian space-time makes sense. Expanding Earth model [L55, L113], which allows to understand Cambrian Explosion is one application of TGD based quantum cosmology.

18.2.2 The notion of length scale dependent cosmological constant

TGD predicts that cosmological constant Λ characterizing space-time sheets is length scale dependent and depends on p-adic length scale. Furthermore, expansion would be fractal and occur in jerks. This is the picture that twistor lift of TGD leads to [L22].

Quite generally, cosmological constant defines itself a length scale $R = 1/\Lambda^{1/2}$. $r = (8\pi)^{1/4}\sqrt{Rl_P}$ - essentially the geometric mean of cosmological and Planck length - defines second much shorter length scale r. The density of dark energy assignable to flux tubes in TGD framework is given as $\rho = 1/r^4$.

In TGD framework these scales corresponds two p-adic length scales coming as half octaves. This predicts a discrete spectrum for the length scale dependent cosmological constant Λ [L22, L43, L64] . For instance, one can assign to ..., galaxies, stars, planets, etc... a value of cosmological constant. This makes sense in many-sheeted space-time but not in standard cosmology.

Cosmic expansion is replaced with a sequence of fast jerks reducing the value of cosmological constant by some power of 2 so that the size of the system increases correspondingly. The jerk involves a phase transition reducing Λ by some negative power of 2 inducing an accelerating period during which flux tube thickness increases and magnetic energy transforms to ordinary matter. Thickening however increases volume energy so that the expansion eventually halts. Also the opposite process could occur and could correspond to a "big" state function reduction (BSFR) in which the arrow of time changes.

An interesting question is whether the formation of neutron stars and super-novas could involve BSFR so that these collapse phenomena would be kind of local Big Bangs but in opposite time direction. One can also ask whether blackhole evaporation could have as TGD analog BSFR meaning return to original time direction by a local Big Bang. TGD analogs of blackholes are discussed in [L63].

Evidence for the anisotropy of the acceleration of cosmic expansion has been reported (see `http://tinyurl.com/rx4224f`). Anisotropy of cosmic acceleration would fit with the hierarchy of scale dependent cosmological constants predicting a fractal hierarchy of cosmologies within cosmologies down to particle physics length scales and even below. The phase transitions reducing the value of Λ for given causal diamond would induce accelerated inflation like period as the magnetic energy of flux tubes decays to ordinary particles. This would give a fractal hierachy of accelerations in various scales.

18.2.3 Some examples

Consider now some representative examples to see whether this picture can be connected to empirical reality [L69].

1. Cosmological constant in the length scale of recent cosmology corresponds to $R \sim 10^{26}$ m (see `http://tinyurl.com/k4bwlzu`). The corresponding shorter scale $r = (8\pi)^{1/4}\sqrt{Rl_P}$ is identified essentially as the geometric mean of R and Planck length l_P and equals to $r \sim 4 \times 10^{-4}$ m: the size scale of large neuron. This is very probably not an accident: this scale would correspond to the thickness of monopole flux tubes.

2. If the large scale R is solar radius about 7×10^8 m, the short scale $r \simeq 10^{12}$ m is about electron Compton length, which corresponds to p-adic length scale $L(127)$ assignable to Mersenne prime $M_{127} = 2^{127} - 1$. This is also the size of dark proton explaining dark fusion deduced from Holmlid's findings [L26, L31]: this requires $h_{eff} \sim 2^{12}$!

   Remark: Dark proton sequences could be neutralized by a sequence of ordinary electrons locally. This could give rise to analogs of atoms with electrons being very densely packed along the flux tube.

   The prediction of the TGD based model explaining the 10 year old puzzle related to the fact that nuclear abundances in solar interior are larger than outside [L82] (`http://tinyurl.com/y38m54ud`) assumes that nuclear reactions in Sun occur through intermediate states which are dark nuclei. Hot fusion in the Sun would thus involve the same mechanism as "cold fusion" [L31, L94]. The view about cosmological constant and TGD view about nuclear fusion lead to the same prediction.

3. If the short scale is p-adic length $L(113)$ assignable to Gaussian Mersenne $M_{G,113} = (1+i)^{113} - 1$ defining nuclear size scale of $r \sim 10^{-14}$ m, one has $R \sim 10$ km, the radius of a typical neutron star (see `http://tinyurl.com/y5ukv2wt`) having a typical mass of 1.4 solar masses.

   A possible interpretation is as a minimum length of a flux tube containing sequence of nucleons or nuclei and giving rise to a tangle. Neutron would take volume of about nuclear size - size of the magnetic body of neutron? Could supernova explosions be regarded as phase transitions scaling the stellar Λ by a power of 2 by making it larger and reducing dramatically the radius of the star?

4. Short scale $r \sim 10^{-15}$ m corresponding to proton Compton length gives R about 100 m. Could this scale correspond to quark star (see `http://tinyurl.com/y3n78tjs`)? The known candidates for quark stars are smaller than neutron stars but have considerably larger radius measured in few kilometers. Weak length scale would give large radius of about 1 cm. The thickness of flux tube would be electroweak length scale.

Starting from this picture, one ends up to rather detailed picture making correct predictions about minimum radii of blackholes and neutron stars.

1. The idea about ordinary stars as blackhole-like objects in generalized sense emerges naturally since flux tubes are universal objects in TGD Universe and could be also inspired by the fashion of dualizing everything to blackholes.

2. The standard blackhole thermodynamics is replaced by two thermodynamics. The first thermodynamics is assignable to the flux tubes as string like entities having Hagedorn temperature T_H as maximal temperature.

   The second thermodynamics is assignable to the gravitational flux tubes characterized by the gravitational Planck constant h_{gr}: Hawking temperature T_B is scaled up by the ratio $\hbar_{gr}/\hbar$ to $T_{B,D}$ and is gigantic as compared to the ordinary Hawking temperature but the intensity of dark Hawking radiation is extremely low.

   The condition $T_H = T_{B,D}$ for thermodynamical equilibrium fixes the velocity parameter $\beta_0 = v_0/c$ appearing in the Nottale formula for $\hbar_{gr}$ and suggests $\beta_0 = 1/h_{eff}$ for the dark nuclei at flux tubes defining star as blackhole like entity in TGD sense.

   This also predicts the Hagedorn temperature of the counterpart of blackhole in GRT sense to to be hadronic Hagedorn temperature assignable to the flux tube containing dark nuclei as dark nucleon sequences so that there is a remarkable internal consistency. In ZEO (ZEO) quasars and active galactic nuclei can be seen as white-hole like objects (WHs) and time reversals of blackhole-like objects (BHs).

3. The cosmological time anomalies such as stars older than the Universe can be understood. In ZEO the time evolution for the zero energy states associated with causal diamonds (CDs) by sequences of small state function reductions (weak measurements) gives rise to conscious entity, self. Self dies and re-incarnates with an opposite arrow of time in big (ordinary) state function reduction reversing the arrow of time. These reincarnations define kind of universal Karma's cycle. If the Karma's cycle leaves the sizes of CDs bounded and their position in M^4 unaffected, quantum dynamics reduces to a local dynamics inside CDs defining sub-cosmologies. In particular, the age distributions and properties of stars depend only weakly on the value of cosmic time - stars older than the Universe become possible in standard view about time.

4. The flux tube picture about galaxies and larger structures explains the flat velocity spectrum of spiral galaxies if they correspond to tangles of long cosmic strings in which string thickens to flux tube. For elliptical galaxies the cosmic string would be relatively short that the velocity spectrum would not be flat. There would be no dark matter halo except possibly due to the presence of cosmic strings in galactic plane. Some anomalies strongly suggesting the presence of quantum coherence in scales of even billion light years. This could be due to the presence of long quantum coherent structures consisting of flux tube bundles.

5. The presence of dark matter in TGD sense having huge effective Planck constant $h_{eff} = h_{gr} = GMm/\beta_0$ provides a general solution of the well-known angular momentum problem. As the energy associated with thickening cosmic string is transformed to ordinary matter, it must start to rotate around the string to avoid falling back to the cosmic string. This is consistent with angular momentum conservation only if cosmic string generates an opposite angular momentum by developing a helical structure [L99] such that dark matter flows along string and rotates at the same time. This solves the well-known angular momentum of the GRT based models.

6. The general model suggests that at least quasars and perhaps all AGNs are actually white-hole like objects as time reversals of blackhole-like objects. The TGD counterpart of BZ model support this view.

18.2.4 Is James Webb telescope forcing a revolution in cosmology?

The first preliminary findings of the James Webb telescope, the successor of the Hubble telescope, are in conflict with the standard view of the formation of galaxies. The YouTube video (`https://cutt.ly/OZc4lV7`) "James Webb Found Galaxies That Sort of Break Modern Theories" gives a good summary of these findings. The findings are also summarized in an article in Nature [E265] (`https://cutt.ly/lZc4clq`) with the title "Four revelations from the Webb telescope about distant galaxies".

The official story

The official story of the formation of galaxies goes roughly as follows.

1. Around 3 minutes of cosmic time, the cosmic microwave background emerged as the first atoms formed and radiation decoupled from matter.

2. When the age of the Universe was more than about .1 billion years, the first stars were formed. They lived their life and exploded as supernovas and yielded interstellar hydrogen gas. Galaxies started to form. One can see this process as a gravitational condensation. What is essential is that this process went from long to short scales, just as the formation of stars in the earlier phase.

3. The model gives a stringent upper bound for the age of the galaxies. They should be younger than the oldest observed stars. This limit gives an upper bound for the distance of the galaxy, that is for its redshift.

The findings of James Webb telescope

The first, preliminary, observations of the James Webb telescope were galaxies with redshifts up to 16. Even redsshift extending to 20 have been speculated in arXiv papers. Redshift 16 would correspond to the age of 250 million years and redshift of 20 to the age of 200 million years. They are too far to fit into the official picture. To get some perspective, note that the estimate for the age of the Universe is 13.8 billion years.

The ages of these galaxies were few hundred million years and of the same order as the estimated ages of about 100 million years of the hypothetical population III stars (`https://cutt.ly/eZc4mr1`), which are thought to be the oldest stars but have not not (yet?) detected. The criterion for the age of the star is its metal content: the first stars should have contained only hydrogen and Helium and "metal" here means anything heavier than Helium.

The suggestive conclusion is that there was a significant population of star forming galaxies in the early universe. This challenges the standard view stating that stars came first and led to the formation of galaxies.

Scientific American has an article with title "JWST's First Glimpses of Early Galaxies Could Break Cosmology" (`https://cutt.ly/R0hqYLW`), which provide a nice summary of the first findings of the telescope. This gave an opportunity to sharpen the somewhat fuzzy view of how the findings of James Webb telescope relate to TGD.

What was found first, was a galaxy dubbed as "GLASS-z13". It was found by Rohan Naidu and led to an article published within a few days. The discovery of the GLASS-z13 was followed by a discovery by numerous even more distant galaxies. The very existence and the properties of these galaxies came as a total surprise.

1. From the redshift of about $z = 13$, the GLASS-z13 was dated back 300 million years after the big bang that is thought to have occured 13.8 billion years ago. According to the standard view of galaxy formation (so called Lambda CDM model involving dark matter as exotic particles), galaxies with such a large distance are not expected to even exist. According to the standard model, the formation of galaxies should have begun at the cosmic age of about 400 million years. The galaxy found by Naidu would have emerged more than 70 millions years too early.

2. The images of the galaxies from so early era were expected to be extremely dim. The galaxies discovered were however anomalously bright.

3. The large size of the galaxies came as a total surprise. The age of the galaxies increases with its age and the conclusion was that the galaxies had to be much more mature than the standard model for the formation of galaxies allows. This leads to a paradox since the first galaxies should be very young.

The TGD view of the formation of galaxies

TGD proposes an unofficial view of the formation of galaxies [L63, L69, L111].

1. In the very beginning the Universe was dominated by cosmic strings, which were space-time surfaces in $H = M^4 \times CP_2$ having 2-dimensional M^4 projection. They were not "Einsteinian" space-time surfaces with 4-D M^4 projection and have no counterpart in general relativity.

2. Cosmic strings were unstable against thickening of the M^4 projection to 4-D one. Phase transitions thickening the cosmic strings occurred and increased their thickness and reduced string tension so that part of their energy transformed to ordinary matter. This is the TGD counterpart for inflation.

   This process led to radiation dominated Universe and the local description of the Universe as an Einsteinian 4-surface became a good approximation and is used in standard cosmology based on the standard model as a QFT limit of TGD.

   At this moment the thickness of the thickened strings would be around 100 micrometers, which corresponds to a length scale around large neuron size. Water blob with this size has mass of order Planck mass. The connection with biology is suggestive [L119, L126, L90].

3. The liberated dark energy (and possible dark matter, dark in the TGD sense) assignable to cosmic strings produced quasars, which in the TGD framework are identified as time reversals of the ordinary galactic blackholes. They did not extract matter from the environment but feeded darl energy as matter to the environment as jets. Jets are observed and explained in terms of the magnetic field due to the rotation of the galaxy.

   The jets are somewhat problematic in the GRT based cosmology since the simplest, non-rotating Schwarzschild blackholes do not allow them. The rotating blackholes identifiable as Kerr-Newman blackholes [B16, B46] accompanied by magnetic fields, also have some interpretational problems. For instance, the arrow of time can be said to be different in the nearby and faraway regions and closed time-like geodesics are possible. In TGD, this could have an interpretation in terms of zero energy ontology (ZEO). The matter from the jets would have eventually led to the formation of atoms, stars, and galaxies.

4. What is essential is that the formation of galaxies proceeds from short to long scales rather than vice versa as in the standard cosmology. A second essential point is that the dark energy (and possible dark matter) concentrated at cosmic strings was added to the ordinary matter predicted by the standard model to be present in the radiation dominated cosmology. This led to the formation of galaxies. Therefore this picture is consistent with the standard story as far as the formation of atoms and emergence of CMB is considered.

The possibility considered in [L63, L69, L111] is that quasars are time reversed black-holes (this property can be formulated precisely in zero energy ontology (ZEO), which forms the basis of TGD based quantum measurement theory) [L84, L118] [K119]. Note that the time reversal property would hold true in long time scales at the magnetic body (MB) defined by the monopole flux tubes produced by the thickening of the cosmic strings. For ordinary matter, the scale for the time spent with a given arrow of time is very short but MB with a large gravitational Planck constant can force ordinary matter to effectively behave like its time reversed version.

There is indeed quite recent support for the proposal that quasars are time reversals of blackhole-like objects identified in the TGD framework as monopole flux tube tangles. The Hubble telescope detected a dwarf galaxy at a distance of 30 million light years for which the number of stars is about 10 per cent for that in the Milky Way [E246]. Its center contains a blackhole-like object (`https://cutt.ly/kZc77B1`), which did not extract matter from the environment but did just the opposite by jets, which gave rise to a formation of stars.

The observations challenging the basic dogma of blackhole physics are not new and during writing of the article [L111] I got the impression that one of the basic challenges is to explain why some blackholes do just the opposite of what they should do.

This picture leads to ask whether blackhole evaporation could have a counterpart in TGD. The "death" of blachole-like object (BHO) could mean a macroscopic "big" state function reduction (BSFR) in which the arrow of time changes. Since the time reversal occurs at the level of MB, one can observe the behavior of time reversed BHO at the new geometric past of the BHO and finds that BHO feeds matter to the environment and can produce stars. Biological death (and also falling asleep) would correspond to BSFR. Could the time reversed history for BHO correspond to the evaporation of the ordinary blackhole? Could an analog of the decay of a dead organism occur after the geometric time at which time reversal for BHO took place.

TGD based explanation for the three paradoxical findings

One can indeed understand the 3 paradoxical findings described in Scientific American article in the TGD view of galaxy formation.

1. According to the standard model, these galaxies were formed quite too early. The standard mechanism of formation is a gravitational condensation of stars and interstellar to form galaxies. Dark matter halo plays a key role in the process. The model is however plagued by several contradictions. As a matter of fact, empirical facts suggest that there is no dark halo. The MOND model explains many of the anomalies but is in conflict with the Equivalence Principle and in conflict with standard Newtonian gravitation. The TGD based model replaces dark matter halo with long cosmic strings carrying dark energy and possibly also dark matter. One does not lose either Equivalence Principle or Newtonian gravitation.

   The TGD based view of galaxy formation is diametrically opposite to the standard view, being analogous to the generation of ordinary matter via the decay of the inflation field in the inflationary cosmology. Ordinary matter would have been created by the decay of the energy of cosmic strings to ordinary matter as they formed tangles. This led to a thickening of cosmic strings to monopole flux tubes and to a reduction of string tension so that energy was liberated as ordinary matter. In particular, galactic dark matter and the flat velocity spectrum of distant stars find an elegant explanation.

   In this view galaxies started to emerge already during the TGD analogue of the inflationary period.

2. The high apparent luminosity of these galaxies is the second mystery. Are the galaxies indeed so luminous as they seem to be? Or could it be that the standard view of how light emitted by galaxies is distributed is somehow wrong?

   In the TGD framework, the space-time of general relativity is replaced with a fractal network of nodes defined by various structures including galaxies, stars, planets,... Monopole magnetic flux tubes connect the nodes and the light propages as beams of dark photons (in the TGD sense) along these flux tubes. A light beam travelling along a flux tube is not attenuated at all if the cross section of the flux tube stays constant. Therefore the intensity of the light beam is not reduced with distance. In GRT it would be reduced since there would be no splitting to beams. This would explain why the apparent luminosities of the galaxies are anomalously high.

3. The unexpectedly large size of the galaxies implies a long age if one believes in the standard view of galactic evolution. This paradox finds a solution in zero energy ontology (ZEO), which defines the ontology of quantum TGD. ZEO solves the basic paradox of quantum measurement theory and is forced by the holography implied in the TGD framework by 4-D general coordinate invariance.

   In ZEO, the arrow of time changes in ordinary quantum jumps ("big" state function reductions, BSFRs). The repeated change of the arrow of time in the sequence of BSFRs implies that the system can be said to live forth and back in geometric time. Aging does not correspond to "center of mass motion" in time direction but this forth and back motion. In the TGD inspired biology, BSFR is analogous to death or falling asleep.

   In "small" SFRs (SSFRs) the arrow of time is not changed and they are counterparts of weak measurements introduced by quantum opticians. They generalize the quantum measurements associated with the Zeno effect, in which a system is frozen and its state does not change. Now the sequence of SSFRs would define a conscious entity, self.

   In TGD, gravitational quantum coherence is possible in all scales and galaxies would be astrophysical quantum systems performing BSFRs. Even astrophysical objects such as galaxies would live forth and back in time. This would give rise to galaxies and stars older than the Universe if one tries to explain their age using the standard view of the relationship between experienced time and geometric time.

18.3 The findings of the James Webb telescope concerning very early Universe

The list of the discoveries of the James Webb telescope is rather impressive (`rb.gy/8gjh2`). There is also a popular article "12 amazing James Webb Space Telescope discoveries across the universe" (`rb.gy/rdj0c`). The list includes discoveries related to galaxies and globular star clusters in the very early universe, star formation, exoplanets, in particular hot Jupiters, protoplanets, and brown dwarfs.

The Youtube video (see `rb.gy/j52ux`) in LAB360 with the title "James Webb Telescope Detects more than 700 Galaxies at the Edge of Our Universe" summarizes some of the basic findings of the James Webb telescope concerning the very early Universe.

The preliminary paradoxical findings of the James Webb telescope have been affirmed and now there is much more detailed picture available about galaxies and stars in the very early Universe challenging the standard cosmology.

I have considered the findings of James Webb telescope from the TGD point of view in [L123, L111]). The TGD view of cosmology and astrophysics is discusse in articles [L63, L69, L111, L136, L137].

18.3.1 Summary of the findings of the James Webb telescope

The existence of more than 700 galaxies a few hundred million years after BB is in sharp conflict with the standard Big Bang Model although it is consistent with the cosmic expansion. Distance measurements indeed use cosmic redshift to deduce the distances of the galaxies. In any case, the James Webb telescope is profoundly shaking the foundations of cosmology. It seems that one can safely forget the standard story about the formation of stars and galaxies and also inflation as the generally accepted story of what happened before that.

In the standard picture, the epoch of reionization starts 1 billion years after the BB as the fog of gas is cleared by reionization so that photons can propagate. No signals hould arrive from the epoc preceding reionization. These 700 galaxies should not be there since they are too young, existing 370-500 million years after BB.

The mass of the galaxy serves as a measure for the age of the galaxy but 6 galaxies with age .5 Gy and 10 times bigger than the Milky Way have been found! This makes one wonder, what will be found when one goes farther back in time?

JW can see galaxies as extended objects with visible structures and this provides a lot of additional information about the composition of these too-early birds.

1. Complex organic molecules, found also in smoke/fog, were found [E227]: this is 1 billion years too early! These molecules, polycyclic aromatic hydrocarbons (PAHs) (`rb.gy/cx75l`), are big molecules, containing hundreds of atoms. What adds to the mystery, is that PAHs were found in regions where there are no stars or star formation but not in regions where stars are forming! PAH world hypothesis states that PAHs have played a key role in prebiotic life leading the emergence of RNAs (`rb.gy/z6vma`).

2. Also the locations of these molecules can be determined by JW in terms of their spectra. The distribution of the molecules is not uniform as one might expect. These galaxies can have the same mass as the Milky Way. The mass serves as a measure for the age of the galaxy but the age of these galaxies, according to standard cosmology, is only 10 percent of that of the Milky Way. This creates a paradox.

3. One particular galaxy, GN-z11 (`rb.gy/gx9fh`) is observed as it existed 13.3 Gy ago.

   (a) GN-z11 is found to contain an exceptionally high proportion of nitrogen and abundance of stars.

   (b) Birth of globular star clusters (`rb.gy/xezay`) have been found in GN-z11. This finding is especially paradoxical since they are regarded as very old objects! The compositions of O,N, Na, and Al vary inside globular clusters. These anomalies have been known for a long time `rb.gy/8rdew`). One however expects that the stars of the cluster should have the same origin and age in the early universe.

   (c) Also supermassive stars (`rb.gy/o0y36`), having masses of few hundred solar masses, have been found in globular clusters. Multiple globular clusters have been found.

18.3.2 What theoretical implications the discoveries might have?

The findings of the James Webb telescope could be fatal for the fashionable theories related to standard cosmology. Inflationary scenario is the predecessor of radiation dominated cosmology which was once thought to be understood and it is difficult to think that it could survive if the cosmic evolution at the later period differs dramatically from the expectations.

One of the possible victims of the mass extinction of theories is ΛCDM model of cold dark matter, which has been the guiding cosmology for decades. Professor Boylan-Kolchin's paper, "Stress testing ΛCDM with high-redshift galaxy candidates" published in Nature Astronomy [E208] (`https://www.nature.com/articles/s41550-023-01937-7`) discusses the constraint posed by the James Webb findings. The problem is that both the stellar and galactic masses are limited by the baryonic reservoir and the detected unexpectedly large number of massive stars and galaxies is at the very edge of these limits.

18.3.3 TGD explanation of the paradoxical findings of the James Webb telescope about very early Universe

What goes wrong with the standard cosmology? Could TGD inspired cosmology suggest an answer?

Zero energy ontology

Consider first zero energy ontology (ZEO) and the TGD view of dark matter. TGD suggests that the prevailing view about the notion of time is wrong. TGD forces a new ontology of quantum theory, which I call zero energy ontology (ZEO) [L84].

1. Causal diamond (CD) as a state-determined and dynamical quantization volume has two boundaries and zero energy states are in fermionic degrees of freedom superpositions of pairs of 3-D states asociated with these two.

2. Zero energy states corresponds also to superpositions of space-time surfaces connecting the two boundaries of CD. By the almost deterministic holography implied by the 4-D general coordinate invariance, the space-time analogs 4-D analogs of Bohr orbits of particles as 3-D surfaces. In ZEO, subjective time and geometric time are not the same thing but are strongly correlated. This new ontology solves the basic paradox of quantum measurement theory.

3. There are two kind of state functions reductions (SFRs): "Small" SFRs (SSFRs) corresponding to repeated measurements in Zeno effect and "big" SFRs (BSFRs) corresponding to ordinary SFRs. CD has two kind of boundaries; active and passive. In SSFRs, the active boundary and states at it change whereas the passive boundary and the states at it remain unaffected. This is the counterpart of the Zeno effect: the state changes slighty but the arrow of time is preserved. SSFRs also correspond to weak measurements in quantum optics.

   In BSFRs the arrow of time changes. BSFR occurs when the set of observables measured in SSFR a the active boundary of CD does not commute with those measured earlier at the passive boundary of CD. CD increases in size in a statistical sense during the sequence of SSFRs since the active boundary drifts farther from the passive one. This gives rise to the correlation of subjective time a sequence of SSFRs with geometric time a distance between the tips of CD.

Hierarchy of dark matters as $h_{eff} = nh_0$ phases of ordinary matter

TGD also predicts quantum coherence in arbitrarily long scales and gravitational quantum coherence corresponds to the longest, even astrophysical, coherence scales since gravitational interaction has infinite range and is unscreened [L119]. The gravitational Planck constant introduced by Nottale [E87] characterizes the monopole flux tubes connecting astrophysical objects. Along these flux dark gravitons mediating gravitational interaction and also other dark particles propagate. This has important implications in TGD inspired biology since the gravitational magnetic bodies of Sun, planets and perhaps even Moon become key plaryes in TGD inspired quantum biology.

TGD leads also to a view of dark energy identified as classical energy assignable to string like objects that I call cosmic strings. Their thickening to monopole flux tubes lead to vision about the formation of galaxies, stars and planets differing in many respects dramatically from the standard view [L63, L69, L111, L136, L137]. In particular, galactic dark matter would be associated with long cosmic strings formed as thickenings of the cosmic strings to monopole flux tubes.

The change of arrow of time in BSFR implies dramatic effects even in astrophysical scales. Even astrophysical objects can live forth and back in geometric time. The ageing in the physical sense occurs in both directions of geometric time so that the physical age is total time spent in this moving forth and back. Since the passive boundary is stationary, the physical ageing in ZEO is faster than ageing in the standard ontology.

TGD view of the anomalies

Consider now a slightly more detailed the explanation of the various anomalies.

1. Time anomalies

Consider first the time anomalies.

1. ZEO explains stars and galaxies older than the Universe.

2. ZEO also predicts the variation of the ages of galaxies and stars in the very early Universe. Since galaxies and stars can be born at different periods in this life forth and back in geometric time, they can have different ages in the sense of ZEO. This explains why the abundances of atoms associated with the stars of star clusters are found to vary. The life forth and back in time also explains the appearance of globular star clusters, which are very old and are not possible in standard cosmology.

2. PAHs in the very early Universe

What about PAHs, which appear in the regions where star formation does not occur and do not appear in the region containing stars?

1. The TGD view of nuclear physics, originally inspired by the findings about "cold fusion", and based on the notion of dark nuclei, identified scaled up analogs of ordinary nuclei, leads to a model of prestellar evolution based on dark fusion (explaining also "cold fusion" [L82, L31, L94]).

   "Dark" means that the nucleons of these nuclei have non-standard values of Planck constant $h_{eff} = nh_0$. In the number theoretic vision of TGD, integer n has interpretation as the dimension of extension of rationals associated with the polynomial with integer coefficients, which defines the space-time region [L91, L92, L138].

2. Dark fusion generates dark nuclei as sequences of dark protons at monopole flux tubes having size scale of electron Compton length. Their binding energy is much smaller than the binding energy of the ordinary nuclei. Dark nuclei can therefore transform to ordinary nuclei and liberate most of the nuclear binding energy in the process, this give rise to "cold fusion". The temperature of the dark fusion region increases in the process and eventually reaches the temperature at which ordinary nuclear fusion can start.

   Even chemistry and complex molecules can emerge before the ordinary nuclear fusion is ignited. This could explain the presence of PAHs, in particular their presence in regions, where there is no star formation or stars.

3. James Webb telescope has also found complex organic molecules, such as methanol and ethanol, in pre-stellar ice in the molecular cloud Chamaeleon I located 630 light year away (`rb.gy/d3q0s`). Contrary to expectations, this finding suggests that many star and planetary systems developing in Chamaeleon I contain molecules in a fairly advanced chemical state. This would indicate that the presence of precursors to prebiotic chemicals in planetary systems is a typical outcome of star formation rather than a peculiarity of our solar system.

   In the TGD framework, dark fusion could produce heavier elements before the ignition of the ordinary nuclear fusion and lead also to a development of complex chemistry [L31, L94]. This could resolve some mysteries related to the abundances of nuclei such as the origin of nuclei heavier than Fe and also the anomalous abundances of some lighter nuclei. Also objects like brown dwarfs (`rb.gy/41kp5`), called planets , which failed to become stars, could have emerged in this way. James Webb has also identified numerous protostars, which have not yet reached the ignition temperature (`rb.gy/6hsax`): they could be similar objects. TGD however suggests that planets could have formed by an explosion throwing out an outermost layer of the stellar magnetic body as a magnetic bubble consisting of monopole flux tubes carrying dark matter, which would then transform to ordinary matter in a process starting with dark fusion [L136, L137].

3. Why signals from the period preceding the reionization are possible at all?

One reason is that there was a reionization. TGD also allows us to consider the possibility that the signals arrive as dark photons along monopole flux tubes of a cosmic flux tube network acting as an analog of the nervous system. Also in the TGD based model of the brain, dark photon signals propagating between the central nervous system and magnetic body play a key role.

I have considered the findings of James Webb telescope from the TGD point of view in [L123, L111]). The TGD view of cosmology and astrophysics is discussed in various articles [L63, L69, L111, L136, L137].

18.3.4 About the identification of the Schrödinger galaxy

The latest mystery related created by the observations of James Webb telescope is so called Schrödinger galaxy [E149] (see this and this).

It has been found that the determination of the redshift $1+z = a_{now}/a_{emit}$ gives two possible space-time positions for the Schrödinger galaxy CEERS-1749 a_{now} *resp.* a_{emit} corresponds to the scale factor for the recent cosmology *resp.* cosmology when the radiation was emitted. Note that for not too large distances the recession velocity β satisfies the Hubble law $\beta = HD$. The nickname "Schrödinger galaxy" comes from the impression that the same galaxy could have existed in two different times in the same direction.

Accordingly, CHEERs allows two alternative identifications: either as an exceptionally luminous galaxy with $z \sim 17$ or as a galaxy with exceptionally low luminosity with $z \sim 5$. Both these identifications challenge the standard view about galaxy formation based on ΛCDM cosmology.

1. The first interpretation is that CHEERS is very luminous, much more luminous than the standard cosmology would suggest, and has the redshift $z \sim 17$, which corresponds to light with the age of 13.6 billion years. The Universe was at the moment of emission $t_{emit} = 220$ million years old.

   In the TGD framework, the puzzlingly high luminosity might be understood in terms of a cosmic web of monopole flux tubes guiding the radiation along the flux tubes. This would also make it possible to understand other similar galaxies with a high value of z but would not explain their very long evolutionary ages and sizes. Here the zero energy ontology (ZEO) of TGD could come in rescue [L143, L136, L137].

2. Another analysis suggest that the environment of the CHEERS contains galaxies with redshift $z \sim 5$. The mundane explanation would be that CHEERS is an exceptionally dusty/quenched galaxy with the redshift $z \sim 5$ for which light would be 12.5 billion years old.

   Could TGD explain the exceptionally low luminosity of $z \sim 5$ galaxy? Zero energy ontology (ZEO) and the TGD view of dark matter and energy predict that also galaxies should make "big" state function reductions (BSFRs) in astrophysical scales. In BSFRs the arrow of time changes so that the galaxy would become invisible since the classical signals from it would propagate to the geometric past. This might explain the passive periods of galaxies quite generally and the existence of galaxies older than the Universe. Could the $z \sim 5$ galaxy be in this passive phase with a reversed arrow of time so that the radiation from it would be exceptionally weak.

TGD seems to be consistent with both explanations. To make the situation even more confusing, one can ask whether two distinct galaxies at the same light of sight could be involved. This kind of assumption seems to be unnecessary but one can try to defend this question in the TGD framework.

1. In the TGD framework space-times are 4-surfaces in $M^4 \times CP_2$. A good approximation is as an Einsteinian 4-surface, which by definition has a 4-D M^4 projection. The scale factor a corresponds to the light-cone proper time assignable to the causal diamond CD with which the space-time surface is associated. a is a very convenient coordinate since it has a simple geometrical interpretation at the level of embedding space $M^4 \times CP_2$. The cosmic time t assignable to the space-time surface is expressible as $t(a)$.

2. Astrophysical objects, in particular galaxies, can form comoving tessellations (lattice-like structures) of the hyperbolic space H^3, which corresponds to $a = constant$, and thus $t(a)$ constant surfaces. The tessellation of H^3 is expanding with cosmic time a and the values of the hyperbolic angle η and spatial direction angles for the points of the tessellation do not depend on the value of a. The direction angles and hyperbolic angle for the points of the tessellation are quantized in analogy with the angles characterizing the points of a Platonic solid and this gives rise to a quantized redshift.

   A tessellation for stars making possible gravitational diffraction and therefore channelling and amplification of gravitational radiation in discrete directions, could explain the recently observed gravitational hum [L144],

   These tessellations could also explain the mysterious God's fingers [E176], discovered by Halton Arp, as sequences of identical look stars or galaxies of hyperbolic tessellations along the line of sight [L114, K94]. Maybe something similar is involved now.

This raises two questions.

1. Could two similar galaxies at the same line of sight be behind Schrödinger galaxy and correspond to the points of scaled versions of the tessellation of H^3 having therefore different

values of a and hyperbolic angle η? The spatial directions characterized by direction angle would be the same. Could one think that the tessellation consists of similar galaxies in the same way as lattices in condensed matter physics? The proposed explanation for the recently observed gravitational hum indeed assumes tessellation form by stars and most stars are very similar to our Sun [L144].

The obvious question is whether also the neighbours of the $z\sim 5$ galaxy belong to the scaled up tessellation. The scaling factor between these two tessellations would be $a_5/a_{17}=17/5$. Could it be that the resolution does allow to distinguish the neighbors of the $z\sim 17$ galaxy from each other so that they would be seen as a single galaxy with an exceptionally high luminosity? Or could it be that the $z\sim 5$ galaxy is in a passive phase with a reversed arrow of time and does not create any detectable signal so that the signal is due to $z\sim 17$ galaxy.

2. Could one even think that the values of hyperbolic angles are the same for the two galaxies in which case the $z\sim 5$ galaxy could correspond to $z\sim 17$ galaxy but in the passive phase with an opposite arrow of time? The ages of most galaxies are between 10 and 13.6 billion years so that this option deserves to be excluded. Could the hyperbolic tessellation explain why two similar galaxies could exist at the same line of sight in a 4-dimensional sense?

   This option is attractive but is actually easy to exclude. The light arriving from the galaxies propagates along light-like geodesics. Suppose that a light-like geodesic connects the observer to the $z\sim 17$ galaxy. The position of the $z\sim 5$ galaxy would be obtained by scaling the H^3 of the older galaxy by the ratio $a(young)/a(old)$. Geometrically it is rather obvious that the geodesic connecting it to the observer cannot be lightlike but becomes space-like. If one approximates space-time with M^4 this is completely obvious.

Consider now more precisely the conditions posed by the light-likeness of the geodesic representing the arriving photon.

1. Let us assume that the light from the distant galaxy moves along a light-like geodesic of X^4. The equation for the light-like geodesic line reads as $dt^2-a^2(t)sinh^2(\eta)d\eta^2=0$. From this one can solve $cosh(\eta)$ as

$$cosh(\eta)-1=2sinh^2(\eta/2)=\int_{t_{emit}}^{t_{now}} dt/a(t)) \quad .$$

2. It is convenient to look at what happens when the space-time surface X^4 is approximated with M^4. This gives $a=t$ and the differential equation can be solved:

$$sinh(\eta/2)=\sqrt{ln(\sqrt{\frac{a_{now}}{a_{emit}}})} \quad .$$

   The quantized value of η for the point of the tessellation fixes the ratio a_{now}/a_{emit} and therefore of a_{emit}. Already this is highly non-trivial. Since the functions appearing on both sides are monotonically increasing, only a single value of a_{emit} is possible for a given value of η. Therefore the strong option cannot be true as already the intuitive argument made clear.

3. During the matter dominated era lasting from $t_0=47,000$ years to $t_{end}=9.8$ billion years, the condition

$$a(t)=a_{end}(\frac{t}{t_{end}})^{2/3} \quad .$$

   After that standard model assumes de Sitter Universe with an accelerating expansion with

$$a(t)\propto a_{end}exp(H_0(t-t_{end}) \quad .$$

   Here one has $H_0=\sqrt{\Lambda/3}$, where Λ is cosmological constant and $H_0\simeq 70.88$ kms^{2}Mpc^{-1} is the Hubble constant. Hubble time corresponds to $t_H=H_0/c\simeq 13.79$ billion years.

Therefore the ratio t_{now}/t_H equals to 1 with percent accuracy. This gives $a(t) \simeq a_{end}exp((t-t_{end})/t_{now})$.

4. One obtains for the value of $sinh(\eta/2)$ the expression

$$sinh(\eta/2) = \sqrt{X_{md} + X_{dS}} \ \ , X_{md} = \frac{3}{4}t_{end}^{2/3}(t_{end}^{1/3} - t_{emit}^{1/3}) \ \ , X_{dS} \simeq \frac{1}{2}\frac{t_{now}}{a_{end}}(1 - exp[-1 + \frac{t_{end}}{t_{now}}]) \ \ .$$

A cautious TGD inspired conclusion is that TGD cannot select between $z \sim 17$ and $z \sim 5$ interpretations but that most naturally only one of them is realized. Certainly it is not possible to identify the two galaxies as time= constant snapshots of the same galaxy such that $z \sim 5$ galaxy has a reversed arrow of time and corresponds to the same point of an expanding tessellation of H^3. The identification of the galaxies as different points of an expanding tessellation with different quantized values of the hyperbolic angle η is not excluded but has no explanatory power. One could try to check whether the two galaxies can be identified as scaled variants of some hyperbolic tessellation having a different value of the η.

18.4 TGD counterpart of BZ model for central engine

The best manner to explain the TGD variant of BZ model inspired by the Penrose process is to start from the abstract of the original article [E231] (`https://cutt.ly/9QtDOkK`).

"It is shown that if the magnetic field and angular momentum of a Kerr blackhole are large enough, the vacuum surrounding the hole is unstable because any stray charged particles will be electrostatically accelerated and will radiate, with the radiation producing electron-positron pairs so freely that the electromagnetic field in the vicinity of the event horizon will become approximately force-free.

Equations governing stationary force-free electromagnetic fields in Kerr spacetime are derived, and it is found that energy and angular momentum can be extracted from a rotating blackhole by a purely electromagnetic mechanism.

The present concepts are applied to a model of an active galactic nucleus containing a massive blackhole surrounded by an accretion disk."

18.4.1 Beltrami field as the TGD counterpart of force-free field

1. Force free field corresponds in TGD to a generalized Beltrami field conjectured to define very general solutions of field equations [L98]. Beltrami fields are analogous to the solutions of Maxwell's equations in the sense that they are dissipation free. This corresponds to the vanishing of the Lorentz force giving $\rho E + j \times B = 0$ and vanishing dissipation giving $j \cdot E = 0$. Therefore the covariant divergence of the energy momentum tensor vanishes and it is plausible that Einstein's equations hold true at the field theory limit.

2. If Beltrami fields correspond to minimal surfaces and at the same time extremals of Kähler action (this requires what I call Hamilton-Jacobi structure as a generalization of ordinary complex structure), the analogs of massless field equations are satisfied as for Maxwell action.

3. The topologies of Beltrami fields are extremely composite and represent knotting and linking of field lines [B11, B41, B29, B32]. Helical flux tubes with electric fields parallel to the flux tubes are excellent candidates for Beltrami fields. Configurations of magnetic field, electric field and current such that all three are mutually orthogonal, are suggestive.

   Quantum classical coherence together with the absence of dissipation suggests that supracurrents proportional to j are present.

18.4.2 Whitehole-like object as the TGD counterpart of Kerr blackhole

Kerr blackhole is used as a model for a rotating blackhole with magnetic field [B16, B46] (https://cutt.ly/sQuKXth) has besides horizon an outer surface known as ergosphere. At ergosphere light-moving around light-like geodesics is stationary from the point of view of a very distant stationary observer.

In the TGD framework, Kerr blackhole is replaced with a white-hole like object (WH) as a time reversal of a blackhole-like object (BH). This is possible in ZEO (ZEO) [L84, L108]. WH is a portion of a tangle of a cosmic string, which has thickened to a flux tube. This reduces string tension as energy per unit length and the system emits energy as ordinary matter to the environment leading to the creation of the galaxy. The process is analogous to the decay of the inflaton field.

18.4.3 Are secondary objects with quantum coherence scale of order λ_{gr} possible?

All BHs and could be seen as gravitionally quantum coherent objects. For $\beta_0 = 1/2$ quantum gravitational coherence length is at least r_s. If $\beta_0 \leq 1/2$ holds true, r_S is the smallest possible quantum gravitational coherence length.

However, Nottale's hypothesis would assign quantum gravitational coherence length of at least $\lambda_{gr} = GME/v_0$ also to objects which are not BHs. As a matter of fact, TGD leads to a generalization of the notion of BH as a model for the final state of the star [L69].

The following intriguing observations inspire the question whether $r_s/2\beta_0$ could define the scale of quantum gravitational coherence also for the secondary objects associated with the astrophysical objects with mass M rather than only WHs and BHs.

1. For Sun λ_{gr} is rather near to the radius of Earth for $\beta_0 \simeq 2^{-11}$ for the 4 inner planets. Could this be interpreted in terms of quantum coherent structure formed by parallel flux tubes such that planets correspond to tangles associated with them?

2. The central engines of AGNs have typical size about 2AU, where AU is the distance of Earth from the Sun and size of the inner planetary system [L98]. For the blackhole in the center of Milky Way the radius is about .4 AU.

   Is this a mere coincidence or could the important size scales of stellar systems correspond at some level to quantum gravitionally coherent objects with gravitational Compton length determined by AGN? This could be the case if flux tube flux tube bundle from AGN with $h_{eff} = \hbar_{gr}(AGN)$ extends to the galactic plane and forms stellar systems as sub-tangles.

3. One could see the central engine as a provider of metabolic energy to the quantum coherent system formed by the flux tube bundle analogous to a laser beam. The energy feed is necessary to preserve the value of $\hbar_{gr}$ since it tends to be reduced spontaneously. For instance, flux tubes can separate from the bundles as tubes with $h_{eff} = h$. In the terminology of TGD inspired quantum biology, the flux tube bundle would be the magnetic body of the AGN.

18.4.4 The TGD counterpart of the Penrose process

A popular description of the Penrose process is as follows. Outside the Kerr blackhole a piece of mass split to two pieces. One piece falls to the blackhole and the other piece goes outside (one can imagine that a rocket accelerates outwards and the fuel from a rocket falls into the blackhole). The blackhole piece can be said to have negative energy. By energy conservation this means that one obtains energy from the blackhole. Also the angular momentum of WH is reduced.

One can say that the 3-space around Kerr blackhole is captured into a rotating motion. This applies also to magnetic fields so that the flux lines get twisted and helical patterns are generated. The matter associated with flux lines generates angular momentum.

1. In the TGD framework, the matter from WH forms gravitationally bound states and must rotate in order to avoid falling back to WH. Angular momentum conservation, which is exact in TGD and forces the twisting of the flux tubes so that linear motion forces rotational

motion and the system develops classical angular momentum. Also the charged particles flowing along the helical flux tube contribute to the angular momentum. For space-time surfaces, the notion of space-time being captured to rotation is very concretely realized.

2. Also electric field is generated along the helical flux tube to guarantee vanishing of the Lorentz force. In the recent case there is however no accelerated motion. Rather, the flow is dissipation free and gives rise to analog of a supracurrent and/or laser beam. The natural guess for the radius of the helix is as the Schwartschild radius. Quantum gravitational coherence would result from $\hbar_{gr} = GM/\beta_0$ at least in the scale defined by $\lambda_{gr} = r_s/2\beta_0$ equal to Schwartschild radius for $\beta_0 = v_0/c = 1/2$

The magnetic fields associated with the central object and jets

I have considered the identification of BH/WH as a volume filling tangle of a cosmic string thickened to a flux tube and having an ordinary value or relatively small value of $\hbar_{eff}$ much smaller than $\hbar_{gr}$ [L69, L82].

The flux tube outside BH/WH could form a flux tube bundle of parallel flux tubes having interpretation as manysheeted space-time with respect to CP_2 or more plausibly $M^2 \times S^2$, serving therefore as the arena of physics instead of M^4. The $\hbar_{gr}/h_0$ would correspond to parallel flux tubes forming a quantum coherent structure.

This helical quantum coherent flux tube structure would be parallel to cosmic string but could have much larger size that the jet length of order 5000 ly. Both would be closed. The tangles of the cosmic string could give give rise to other galaxies, stars, and even planets as suggested [L69, L82]. Cyclotron energy in the quantum coherent be however proportional to $\hbar_{gr}$.

In the case of spiral galaxies, this cosmic string would be very long and could connect galaxies: the recent findings suggest that the surrounding structure rotates. This leads to the proposal that the angular momentum of dark matter associated witht this structure compensates for that of ordinary matter [L99]: this would solve the well-known angular momentum problem of GRT based cosmology. For elliptical galaxies about which M87 is an example, the velocity spectrum is not flat and the flux tube bundles should close in a relatively short scale.

In the WH/BH region there would be much thinner volume filling flux tube - flux tube spaghetti with relatively small value of h_{eff}. The total flux for a single strand of tangle would be that for the cosmic string itself. There are analogous systems in biology. Proteins consist of parts, which are random coils, helical regions, and planar tangles. These geometries would be induced by the underlying flux tube parallel to the protein. In the recent case, the tangles would be 3-D and have cylindrical geometry in the simplest situation.

Consider now a more detailed model for the magnetic field of M87. The central region is expected to have very strong magnetic field whereas the surrounding region would have much weak magnetic field consisting of parallel flux tubes forming a quantum coherent structure with the length of quantum coherence larger than λ_{gr} identified as parallel space-time sheets but with respect to CP_2 rather than M^4.

Consider first the quantum coherent flux tube structure outside WH surrounding the jet like glove.

1. Suppose that the magnetic field (see the figure of `https://cutt.ly/dQtDK7Q`) external to the central region corresponds to that for a tangle formed by a cosmic string thickened to a flux tube. $\hbar_{gr}$ would be the number of the parallel flux tubes of the tangle. Many-sheetedness holds true with respect to CP_2 - one can say that CP_2 or $M^2 \times S^2$ serves as the arena of physics instead of M^4.

2. The estimate for the radius of the flux tube obtained by dividing the area πr_s^2 with $\hbar_{gr}/\hbar \simeq 10^{24}$ is of order 2 m so that the helical flux tube structure outside the central object cannot correspond to the observed stripy structure for the magnetic field seen in the polarization patterns. Could the observed stripes correspond to sub-bundles with $\hbar_{eff} \leq \hbar_{gr}$? Or could the quantized monopole flux for the flux tube proportional to the area of the flux tube be large?

3. A reasonable working hypothesis is that the strength of B outside the central region is not more than 100 Gauss in the recent case. Second working hypothesis is that the entire B outside WH is a monopole flux field.

   For $\beta_0 = 1/2$, the gravitational cyclotron energy is $E_{c,gr} \simeq 10^{10}$ GeV: this is by an order of magnitude smaller than the minimal energy scale of ultrahigh energy (UHE) cosmic rays, which is by definition larger than 10^{11} GeV. This supports $\beta_0 = 1/2$ as also the fact that λ_{gr} is equal to r_S, which is a good guess form the minimal value of λ_{gr}

   In the case of M87, quantum coherent emission - whatever it actually means - should take place in a region of size scale about r_s. The length of visible jets is about 5,000 ly Could this scale correspond to the length scale of the helical flux tube tangle in the vertical direction outside the central object?

According to the earlier model [L69] the central region corresponds to a volume filling monopole flux tube tangle formed from a cosmic string by thickening and having much narrower flux tubes and by flux conservation with much stronger field strength.

1. The field strength in the central region identified as WH could have considerably higher values. Active galactic nuclei (AGNs) (https://cutt.ly/DQtFhH3), which include quasars, emit jets and the emitted power is typically 10^{38} W to be compared with 3×10^{36} W for M87. The typical radius of the central region is $R \simeq 2$ AU for the active region and about 3 orders of magnitude larger than in the case of M87.

2. The estimate of [E160] (https://cutt.ly/DQtFzD3) gives a magnetic field $B \sim 10$ Gauss in the jet region whereas the field strength in the horizon is estimated to be in the range $10^6 - 10^7$ Gauss. Also near-horizon magnetic fields in the range $10^8 - 10^{11}$ Tesla have been proposed for AGNs.

One obtains a rough estimate for the radius r of the flux tube assuming that inside WH the tangle fills the volume.

1. Assume that the particles inside the flux tube are protons with $h_{eff} = h$ and with an average distance equal to the radius of the flux tube. The number N of protons is $N = V/v = (r_s/r)^3$ from which $r = (r_s^3/N)^{1/3}$. One can also express N as M/m_p so that one has $r = ((2G)^3M^2m_p)^{1/3} \propto M^{2/3}$ so that r increases with the mass of the central object. For M87 one obtains $r \simeq 10^{-12}$ m, which is of the order electron Compton length. This would suggest that the protons are dark with the value of $h_{eff}/h \simeq m_p/m_e \simeq 2^{11}$. The TGD based model for "cold fusion" leads to the value of h_{eff} [L31, L10, L94].

2. By flux conservation, a single unit of flux would correspond to a flux tube with radius equal to Compton length L_c of electron. If L_c equals to the magnetic length $L_B = \sqrt{\hbar/eB}$, one has from $L_B(Tesla) = 26nm$, that the $B \simeq 10^4$ Tesla. If the unit of quantization for magnetic flux is scaled up to $\hbar_{eff}$, the field strength is scaled by $mp_/m_e \simeq 2^{11}$ to 2×10^7 Tesla. This option is more natural.

To get some perspective, one can estimate r also for a blackhole with solar mass.

1. From the ratio $M(M87)/M_{Sun} \sim 6.5 \times 10^9$ one obtains that r for a blackhole with solar mass is roughly $.3 \times 10^{-6}$ times smaller than for M87 so that one would have $r \simeq .3 \times 10^{-18}$ m, which is by a factor $.2 \times 10^{-3}$ shorter than proton Compton length 1.3×10^{-15} m.

2. This suggests that the particles are not protons but particles with a higher mass $m = xm_p$. In this case the above estimate is scaled up $r \rightarrow x^{1/3}$. p-Adic length scale hypothesis, which is a central element of TGD, indeed predicts scaled up versions of hadron physics assignable to Mersenne primes and their Gaussian counterparts.

3. Ordinary hadron physics would correspond to Mersenne prime $M_{107} = 2^{107} - 1$ M_{89} defines a second candidate for hadron physics with mass scale scaled up by $2^{(107-89)/2} = 2^9$. This would scale up r by a factor $2^{9/3} = 2^3$ to 2.4×10^{-17} m to be compared with the Compton wavelength 2.6×10^{-18} m of M_{89} nucleon so that the interpretation of the flux tubes as

having ordinary value of h_{eff} seems to make sense. $\hbar$ would characterize the magnetic body of the BH like object. Note that the model discussed in [L69] led to a proposal that the particles at the flux tubes of BH are ordinary nucleons.

4. In this case the magnetic field strength of 2×10^7 Tesla would be scaled by factor 2^{18} to $.5 \times 10^{13}$ Tesla.

The identification of the energy source

Typical radius R of AGN is 2 AU which suggests that the size scale of AGN defines the size of the typical solar system as gravitational Compaton length λ_{gr}. Sagittarius A in the center of Milky way has radius .4 AU, which is the distance of Mercury from Sun. Could solar system be quantum coherent system with respect to Milky Way like Earth with respect to Sun?

One can start from the BZ model [E231] of the central object of M87 as a Kerr blackhole. In the TGD framework, blackhole *resp.* whitehole is replaced with a blackhole-like (BH) *resp.* whitehole-like object (WH). WH and BH are time reversals of each other [L63, L69, L82].

1. For BZ model, the matter falling into the blackhole would provide the "metabolic" energy feed to the jet and one would have a Penrose process. However, in general relativity the presence of the magnetic field requires Kerr blackhole. However, the arrow of time for Kerr solution is opposite to that of the environment at long distances, which suggests an interpretation as a whitehole having WH rather than BH as its TGD counterpart.

2. WH would have a time direction opposite to that of BH. The energy would come from dark energy and matter of cosmic string (or bundle of cosmic strings) thickening in standard time direction defined by the environment. WH as a quantum coherent object would receive this energy and emit it as jets in opposite directions along the flux tube carrying Beltrami field with electric component. The emission of the energy from thickening cosmic string is analogous to the decay of the inflaton field generating ordinary matter.

   This option looks more plausible and will be considered in the sequel.

In the case of M87 WH, one can estimate the rate of mass loss as the energy radiated as jets. The mass of M87, one would have $M(WH) = 6.5 \times 10^9 M_{Sun}$, $M_{Sun} = 2.2 \times 10^{57}$ J. The mass loss is $dM/dt = 3 \times 10^{36}$ J/s. This gives $dM/dt = -M/\tau$, $\tau = .7 \times 10^{14}$ y. The proportionality $\hbar_{gr} \propto M$ would mean that the rate for the reduction of quantum coherence scale and algebraic complexity defined as $\hbar_{gr}/dt/\hbar_{gr} = 1/\tau$ is slow. This process is analogous to blackhole evaporation as a time reversal for the formation of a blackhole.

One can consider three mechanisms for the energy emission creating a beam along cosmic string possibly thickened to flux tube also outside the WH.

1. The reduction of $\hbar_{gr}$ involves the splitting of the flux tubes from the quantum coherent flux tube bundle as they become ordinary flux tubes so that the number of dark flux tubes decreases. This splitting could give rise to a radiation associated with the jets. This includes synchrotron radiation in $B \sim 100$ Gauss. WH would lose energy as ordinary particles.

2. If the flux tube structure is of size of order of the length of jets about 5000 ly, the emission of closed flux tube bundles by reconnection could be second mechanism. This process would be analogous to the emission of closed flux tubes from the magnetic field of the solar wind. Also now $\hbar_{gr}$ should be reduced.

   The mysterious ultrahigh energy (UHE) cosmic rays could be produced in this process creating the analog of solar wind so that they could be seen as a support for the $\hbar_{gr}$ hypothesis. This process could be regarded as quantum coherent emission with the rate proportional N^2 rather than N, where $N = \hbar_{gr}/h_0$ is the number of flux tubes. The length $L \sim 5000$ ly could be interpreted as the size of the quantum coherent region and would be considerably larger than $\lambda_{gr} \sim 2 \times 10^{-3}$ ly.

3. Dark cyclotron particles and dark cyclotron photons could form an analog of laser beam as a quantum coherent flux tube structure extending to large distances although it forms a closed flux tube. This beam would be quantum analog of solar wind.

The dark particles could transform in the interactions with ordinary matter to dark particles with a smaller value of $h_{eff}/\hbar_0 = n$ identifiable as the number of flux tubes of the associated sub-bundle. Eventually the beam would decay to ordinary photons with energies which are multiples of E_c. The occurrence of this kind of process in atmosphere could explain the cosmic ray showers due to UHE cosmic rays.

18.4.5 Nottale's hypothesis and universal cyclotron energies

The non-relativistic approximation for cyclotron energies does not make sense in the recent case so that a relativistically invariant formula $\hbar_{gr} = GME/\beta_0$ [L106] is needed.

1. An approximate formula for cyclotron energy in thew relativistic case is obtained from the d'Alembertian equation

$$(E^2 - p_z^2 - m^2 - (p_T - qA)^2)\Psi = \Psi \quad . \tag{18.4.1}$$

The part depending on p_T and vector potential for a constant magnetic field gives the spectrum of non-relativistic harmonic oscillator $n\hbar_{gr}\omega_c$ Hamiltonian multiplied by $2m$. For a given value of n the are $2n+1$ angular momentum eigenstates states with spin in the range $|m| \leq n$. This gives for the energy eigenvalues

$$E_c^2 = m^2 + p_z^2 + n\hbar_{gr}\frac{qB}{m} = m^2 + p_z^2 + n\frac{GM}{\beta_0}qB \quad . \tag{18.4.2}$$

p_z satisfies is given by

$$p_z = k\frac{\hbar_{gr}}{L} = \frac{r_s}{L}\frac{m}{2\beta_0} \quad . \tag{18.4.3}$$

If the length L of the closed flux tube is of order 5000 ly, $p_z/m = (r_s/L)(1/2\beta_0)$ is very small one neglect p_z^2 and also m^2. This gives

$$E_c = n \times 2\frac{GM}{\beta_0} \quad . \tag{18.4.4}$$

The relativistic formula differs from the non-relativistic naive guess only by the factor 2.

2. $\beta_0 = 1/2$ gives $\lambda_{gr} = r_s$ and is therefore favored value in the vicinity of WH/BH. In the case of M87 WH with mass $M = 6.5 \times 19^9 M_{Sun}$ this gives the estimate $E_c = 10^{10}$ GeV, which corresponds to the highest energy for cosmic rays. Could these quanta propagate to Earth and interact with the nuclei of atmosphere to create cosmic ray showers with highest energies about 10^{11} GeV? Note that the proportionality to magnetic field B and $1/v_0$ allows to consider even higher energies.

Two simple models for cyclotron states in generalized Beltrami fields

To get some idea about the solutions of d'Alembertian for a generalized Beltrami field, consider a constant magnetic field at a straight flux tube parallel to the z-axis.

Assume that the constant velocity v corresponds to a rotation around the z-axis. Beltrami condition gives a constant electric field $E = v \times B$ in the radial direction with electric potential $\phi = qvB\rho$. Note that v corresponds to a parameter of Beltrami flow rather than being identified as a single particle operator $v = p_\phi/m = \partial_\phi/\rho m$.

The minimal substitution $p_\mu \rightarrow p_\mu - eA_\mu$ in the d'Alembertian gives

$$(E - qBv\rho)^2 - p_z^2 - m^2 - (p_T - qA)^2)\Psi = 0 \ . \tag{18.4.5}$$

One can write the equation in the form analogous to the non-relativistic Schrödinger equation:

$$\begin{aligned}(H_1 + H_2)\Psi &= \frac{1}{2m}(m^2 + p_z^2 - E^2)\Psi \ , \\ H_0 &= (p_T - qA)^2)\Psi \ , \\ H_1 &= \frac{(qBv)^2}{2m}\rho^2 - \frac{EqBv}{m}\rho \ .\end{aligned} \tag{18.4.6}$$

For $v \leq\leq c$, H_1 can be treated as a perturbation. For $H_0 = (p_T - qA)^2$, eigenstates of p_z, L_z and harmonic oscillator Hamiltonian can be solved exactly in the symmetric gauge $A = B\times\rho$, $\rho = (x, y)$. H_0 reduces to commuting harmonic oscillator Hamiltonians for energy and angular momentum L_z with operators x, ∂_x and y, ∂_y expressed as linear combinations of oscillator operators a^{dagger}, a and $b^\dagger, b$ which commute with each other (`https://cutt.ly/iQtFaPR`)

ρ^2-term in H_1 can be expressed as bilinear of these operators involving only terms formed from $a^\dagger$ and a *resp.* $b^\dagger$ and b. This term could be included in H_0 and one can hope that Bogoliubov transformation makes it possible to diagonalize the resulting Hamiltonian. ρ is a square root of ρ^2 and this produces problems. Since this term contains also c-number terms from the commutators $[a^{dagger}, a]$ and $[b^{dagger}, b]$, one can expand this term as a power series and treat it perturbatively. One can also use harmonic ordinary oscillator basis for H_0 and treat the situation perturbatively. Note that H_1 commutes with L_z so that one obtains degeneracy of states with respect to L_z also now.

If one had an ordinary gauge invariance, one could consider a gauge in which Kähler gauge potential A is of form $(A_x, A_y) = (0, Bx)$ (`https://cutt.ly/iQtFaPR`). This situation is of course interesting as such also in the TGD context and could provide a TGD based model for Hall effect.

For $v = (v_x, v_y, v_z)(0, v, 0)$, the electric part of the Kähler gauge potential is $\phi = vBx$. The effective Hamiltonian contains part $H_0 = (p_y - qBx)^2/2m$ and $H_1 = -(E - qvBx)^2/2m$. p_y commutes with both of them so that one can assume eigenstates of p_y. The sum $H_0 + H_1$ reduces to the following form:

$$H_0 + H_1 = \frac{k_1(x - x_0)^2}{2m} - \frac{k_1 x_0^2}{2} \ , \tag{18.4.7}$$

where one has

$$k_1 = \hbar^2\omega_1^2 \ , \quad \omega_1 = \sqrt{1 - v^2}\omega_c = \sqrt{1 - v^2}\frac{qB}{m} \ , \quad x_0 = \frac{Ev - p_y}{m}\frac{1}{\omega_1} \ . \tag{18.4.8}$$

The outcome is a harmonic oscillator Hamiltonian for cyclotron energy scale E_c scaled by factor $\sqrt{1 - v^2}$. The origin is shifted from $x = 0$ to $x_0 = (Ev - p_y)qB/m$. Besides this there is a constant term $-\sqrt{1 - v^2}(qB^2x_0^2/m)/2$.

For $p_y/E = v$ stating that the motion of particles occurs with velocity v, one has $x_0 = 0$ and no shift occurs for energy and the energy spectrum is only scaled by $\sqrt{1 - v^2}$ factor.

18.4.6 TGD view of jets

There are may questions to be answered.

What is the central engine causing the jets? How does it function? Where does the energy come from? One must also understand the transversal emission: otherwise the jets would be invisible.

BZ proposal is that he jets are naturally in the direction of flux tube along cosmic string of length about 5000 ly. Motion would be along helical orbits and transversal synchrotron radiation would make the jets visible.

There are also questions related to the TGD proposal.

1. Do the synctrotron states as such define the radiation of jet. Both charged dark particles and dark photons indeed have longitudinal momentum along the helix as required by the requirement that they carry angular momentum.

   Are also N-bosons and N-fermions, whose existence is proposed in the TGD based model of dark genetic codes [L148, L103] based on dark photons and dark protons, involved.

2. Could also quantum coherent cyclotron transitions give rise to dark photons with $h_{eff} = h_{gr}$ possibly also in directions transversal to the jet? Do all charged particles emit dark cyclotron radiation in synchrony or is this the case only for the charged particles with the same mass m as the fact that cyclotron frequencies depend on m suggests? Could the huge radiation power be due to quantum coherence: the radiation would be proportional to N^2 instead of N?

3. Could transversal synchrotron radiation with small value of h_{eff} take place for invidual flux tubes or sub-bundles forming a higher level flux tube? The value of $\hbar_{eff}$ would be smaller than $\hbar_{gr}$ for the sub-bundle. Could ordinary synchrotron radiation involve a separation of single flux tube from the condensate and reduction of $\hbar_{gr}$ to $\hbar$?

4. Could the helical flux tube loop also generate dark matter carrying closed flux tubes by reconnection just as occurs in the solar wind of the Sun? These flux tubes could carry cyclotron states and generate synchrotron radiation in transverse directions. This option is not plausible for long cosmic strings.

A model of jets based on Beltrami fields

The helical structure of the magnetic fields and the fact that the generalized Beltrami fields [B11, B41, B29, B32] could represent very general preferred extremals in the TGD framework suggest the following picture.

1. The helical structure of the magnetic field is forced by angular momentum conservation in the thickening of a cosmic string to a flux tube liberating energy as matter. Both the classical energy of the helical flux tubes and the motion of particles along the helical flux tube generates angular momentum compensating the angular of matter feeded into environment, which starts to avoid falling into WH.

2. Assume that longitudinal electric field is present inside flux tubes and induced by the rotation of the flux tube and that the classical em field is force-free and therefore a generalized Beltrami field. At single particle level this would mean that Lorenz force vanishes $E = v \times B$.

3. By quantum-classical correspondence, one expects non-dissipative supra current along the helical flux tube. There would be no dissipation by radiation in the ideal situation. One could have analogs of supra currents and laser beams along cosmic string in cosmic scales.

4. The analogs of supracurrents and laser beams would decay to dark particles with a smaller value of $h_{eff}/\hbar_0$ identifiable as the number of flux tubes of the associated sub-bundles. Eventually the beam would decay to ordinary photons. This kind of process occurring in atmosphere could explain ultra-high energy cosmic rays. This process could involve reconnection.

   The transversal synchrotron radiation could be created as $h_{eff} = h_{gr}$ for a particle decreases and photon with much smaller value of h_{eff} leaks out from the dark flux tube?

5. The quantum coherence along jet decreases gradually if its h_{eff} decreases. The WH associated defining a tangle of the cosmic string would however serve as a source of metabolic energy so that the value of $\hbar_{gr}$ would not be reduced. The situation would be very much like in TGD inspired biology except that the life in question would be in cosmological scales. The value of $\hbar_{gr}$ for AGNs would be huge as compared for that for Earth based life.

There is clearly an analog with the evaporation of blackholes and one can ask whether blackhole evaporation is induced by the change of the arrow of time for BH transforming it to WH.

How do the jets shine?

Jets shine, which means that photons and other particles are emitted in directions nearly parallel to the particle motion. One expects synchrotron radiation - possibly dark but with relatively small h_{eff}- in the plane orthogonal to the flux tube. According to the BZ proposal, particles rotating along the helical flux tubes in the direction of jet axis could emit the radiation as synchrotron radiation in directions roughly tangential to the helical orbit. How could this mechanism be realized in the TGD framework?

The synchrotron radiation could be seen as a leakage of particles from the helical flux tubes occurring directions near the tangential direction. This process could relate closely to the reduction of quantum coherence scale as flux tubes are separated in the quantum coherent flux tube bundle to a flux tube with ordinary value of Planck constant. For $\hbar_{gr}/\hbar \sim 8.1 \times 10^{24}$ (electron) and area πr_s^2 of the cylinder determined by $r_s \sim 19.5 \times 10^9$ km, the transversal area of single flux tube would be about 2.4π m^2. Cyclotron energy scale 5×10^{-7} eV corresponds to 2 meter wavelength for a radiowave photon.

One could also consider a splitting to quantum coherent sub-bundles of flux tubes with h_{eff} proportional to the number n of split flux tubes and cyclotron frequency scaled up accordingly.

UHE cosmic rays as a quantum gravitational effect?

The origin of ultra high energy (UHE) cosmic rays is poorly understood in the standard physics framework. The reader can consult a Wikipedia article about UHE cosmic rays (`https://cutt.ly/7QtFc7h`) and there is also Quanta Magazine article about the topic (`https://cutt.ly/ZQtFnff`).

Could the huge dark cyclotron energies for quantum gravitational cyclotron states make it possible to understand the origin of UHE cosmic rays? The following proposal is perhaps the simplest mechanism that one can imagine in TGD framework.

Assume that the monopole part $B_{end}(M87)$ of the magnetic field of M87 WH is equal to the magnetic field $B(M87) \sim 100$ Gauss: $B_{end}(M87) = B(M87)$.

For electron with $h_{eff} = h$ in $B_{end} = .2$ Gauss associated to Earth by the model for the findings of Blackman and others [J2] gives $E_c(e) = 4.96 \times 10^{-7}$ eV. For $B_{end}(M87) = B(M87) \simeq$ 100 Gauss $B_{end} = .2$ Gauss is scaled up by factor 500. $\hbar$ is scaled up by $\hbar_{gr}/\hbar \simeq 8.1 \times 10^{24}$. The relativistic formula $E_c(M87) = 2GMQB/\beta_0$ for the cyclotron energy scales gives for $\beta_0 = 1/2$ $E_c(M87) = 2(\hbar_{gr}/\hbar)(B_{end}) \simeq 10^{10}$ GeV . This is extremely high energy: note that 10^{10} GeV corresponds to the lower bound for UHE cosmic rays with energies of order 10^{11} GeV.

All charged particles have this energy scale independently of their mass. What could happen to dark photons emitted in cyclotron transitions and dark charged particles with energy about 10^{10} GeV if they are emitted from WH?

Is there any separate emission process or do the dark particles in cyclotron states travel along the direction of jet as an analog of laser beam?

1. If the laser beam option is realized, dark cyclotron photons and particles (this includes charged particles with large range of masses) could travel to Earth as such. The interaction with the atomosphere would make this dark cosmic ray observable. This process would involve reduction of $\hbar_{gr}$ to $\hbar$.

2. Is the direct transformation to single photon possible as in the case of the decay of dark photons to biophotons? This would conform with the interpretation as ordinary UHE cosmic ray - say proton.

3. TGD suggest also the decay to large number of photons with smaller values of h_{gr} and the flux tube bundle picture suggests that the sum of the integers n_i characterizing $h_{eff,i}$ and the number of flux tubes in the sub-bundle associated satisfies $\sum n_i \simeq \hbar_{gr}/\hbar_0$. For $n_i = 1$ the outcome would be a bunch of ordinary radiowave photons with $E_c \simeq 5 \times 10^{-7}$ eV. A natural expectation is that the decay process occurs as a cascade in which sub-bundles decay to smaller sub-bundles or transform to single ordinary photon with energy $n_i E_c$. Irrespective of the details of the decay process, the total energy of the cosmic ray show would correspond to $8.1 \times 10^{24} E_c$.

4. If the formula from the d'Alembertian is a good approximation, most of the energy of dark cyclotron particle parallel to the flux tube bundle, in particular the energy of photon, would be in transversal degrees of freedom in cyclotron motion at flux tube although the particle is by its huge energy massless in an excellent approximation.

   The synchrotron particles would propagate very slowly in the direction of the jet although the are massless: $p_z/E \leq\leq 1$. In fact, TGD based view about particle massivation relies on zitterbewung so that all particles are predicted to massless in short enough scales. This does not conform with the properties of MEs for which the longitudinal momentum is light-like although transversal degrees of freedom are present.

Steady state Universe or TGD Universe?

The title of the popular article "Universe is Not Expanding After All, Controversial Study Suggests" (`https://cutt.ly/0OnAjoy`) is quite provocative. The article tells about the findings of Lerner *et al* described in the article "UV surface brightness of galaxies from the local universe to z $\simeq$ 5" [E204] (`https://cutt.ly/6OnAvVT`).

Luminosity P is the total power of electromagnetic radiation emitted by the source per time. The total power $dP/d\Omega\Delta\Omega$ measured by an instrument spanning a solid angle $\Delta\Omega$ weakens as function of distance d like $1/d^2$. Bolometric surface brightness (SB) refers to the total radiation power per area at source and is $SB = d^2P/dSd\Omega$, that is $dP/d\Omega$ divided by the area S of the source.

The general relativity (GRT) based cosmology predicts that SB decreases as $(1+z)^{-4}$ and therefore very rapidly. One factor of $(1+z)^{-1}$ comes time dilation reducing the emission rate. Second $(1+z)^{-1}$ comes from the cosmic redshift. A factor of $(1+z)^{-2}$ comes from the fact that the apparent size as the area spanned by the source has decreased since the emission by cosmic expansion so that the apparent size is now by a factor $(1+z)^2$ larger at the moment of emission. If the cosmic redshift is caused by some other mechanism instead of expansion so that one has steady state cosmology, one has much weaker $(1+z)^{-1}$ dependence.

The findings of Lerner *et al* [E204] however suggest that SB for identical spiral galaxies defined as the emitted radiation power per area and solid angle depends only weakly on the distance of the source. In the Einsteinian Universe this favors steady state Universe. This is in conflict with the recent view of cosmology having a strong empirical support.

In the TGD Universe, galaxies are nodes of a network formed from cosmic strings thickened to flux tubes [L63, L69]. The article at "TGD view of the engine powering jets from active galactic nuclei" [L111] provides a model for how galactic jets would correspond to this kind of flux tube connections. The light from the galaxy from A to B travels only along the flux tubes connecting the source to the receiver. These flux tubes can stretch but the amount of light arriving B remains the same irrespective of distance. In the Einsteinian space-time this kind of channeling would not happen and the intensity would decrease like $1/d^2$.

This mechanism would give rise to a compensating factor $(1+z)^2$ so that the dependence of the BS on redshift would be $(1+z)^{-2}$, while the BS in the static Einsteinian Universe would be $(1+z)^{-1}$. For $z \simeq 5$, the TGD prediction for BS is by by a factor of 1/6 smaller than for static Universe whereas the GRT prediction is by a factor 1/196 smaller.

Chapter i

Appendix

A-1 Introduction

Originally this appendix was meant to be a purely technical summary of basic facts but in its recent form it tries to briefly summarize those basic visions about TGD which I dare to regarded stabilized. I have added illustrations making it easier to build mental images about what is involved and represented briefly the key arguments. This chapter is hoped to help the reader to get fast grasp about the concepts of TGD.

The basic properties of embedding space and related spaces are discussed and the relationship of CP_2 to the standard model is summarized. The basic vision is simple: the geometry of the embedding space $H = M^4 \times CP_2$ geometrizes standard model symmetries and quantum numbers. The assumption that space-time surfaces are basic objects, brings in dynamics as dynamics of 3-D surfaces based on the induced geometry. Second quantization of free spinor fields of H induces quantization at the level of H, which means a dramatic simplification.

The notions of induction of metric and spinor connection, and of spinor structure are discussed. Many-sheeted space-time and related notions such as topological field quantization and the relationship many-sheeted space-time to that of GRT space-time are discussed as well as the recent view about induced spinor fields and the emergence of fermionic strings. Also the relationship to string models is discussed briefly.

Various topics related to p-adic numbers are summarized with a brief definition of p-adic manifold and the idea about generalization of the number concept by gluing real and p-adic number fields to a larger book like structure analogous to adele [L42, L41]. In the recent view of quantum TGD [L128], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L91, L92] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L84] [K119] has become a central part of quantum TGD and leads to a TGD inspired theory of consciousness as a generalization of quantum measurement theory having quantum biology as an application. Also these aspects of TGD are briefly discussed.

A-2 Embedding space $M^4 \times CP_2$

Space-times are regarded as 4-surfaces in $H = M^4 \times CP_2$ the Cartesian product of empty Minkowski space - the space-time of special relativity - and compact 4-D space CP_2 with size scale of order 10^4 Planck lengths. One can say that embedding space is obtained by replacing each point m of empty Minkowski space with 4-D tiny CP_2. The space-time of general relativity is replaced by a 4-D surface in H which has very complex topology. The notion of many-sheeted space-time gives an idea about what is involved.

Fig. 1. Embedding space $H = M^4 \times CP_2$ as Cartesian product of Minkowski space M^4 and complex projective space CP_2. `http://tgdtheory.fi/appfigures/Hoo.jpg`

Denote by M^4_+ and M^4_- the future and past directed lightcones of M^4. Denote their intersection, which is not unique, by CD. In zero energy ontology (ZEO) [L84, L108] [K119] causal diamond (CD) is defined as cartesian product $CD \times CP_2$. Often I use CD to refer just to $CD \times CP_2$ since CP_2 factor is relevant from the point of view of ZEO.

Fig. 2. Future and past light-cones M^4_+ and M^4_-. Causal diamonds (CD) are defined as their intersections. `http://tgdtheory.fi/appfigures/futurepast.jpg`

Fig. 3. Causal diamond (CD) is highly analogous to Penrose diagram but simpler. `http://tgdtheory.fi/appfigures/penrose.jpg`

A rather recent discovery was that CP_2 is the only compact 4-manifold with Euclidian signature of metric allowing twistor space with Kähler structure. M^4 is in turn is the only 4-D space with Minkowskian signature of metric allowing twistor space with Kähler structure [**?**] so that $H = M^4 \times CP_2$ is twistorially unique.

One can loosely say that quantum states in a given sector of "world of classical worlds" (WCW) are superpositions of space-time surfaces inside CDs and that positive and negative energy parts of zero energy states are localized and past and future boundaries of CDs. CDs form a hierarchy. One can have CDs within CDs and CDs can also overlap. The size of CD is characterized by the proper time distance between its two tips. One can perform both translations and also Lorentz boosts of CD leaving either boundary invariant. Therefore one can assign to CDs a moduli space and speak about wave function in this moduli space.

In number theoretic approach it is natural to restrict the allowed Lorentz boosts to some discrete subgroup of Lorentz group and also the distances between the tips of CDs to multiples of CP_2 radius defined by the length of its geodesic. Therefore the moduli space of CDs discretizes. The quantization of cosmic recession velocities for which there are indications, could relate to this quantization.

A-2.1 Basic facts about CP_2

CP_2 as a four-manifold is very special. The following arguments demonstrate that it codes for the symmetries of standard models via its isometries and holonomies.

CP_2 as a manifold

CP_2, the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \ . \tag{A-2.1}$$

Here λ is any non-zero complex number. Note that CP_2 can be also regarded as the coset space $SU(3)/U(2)$. The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2. As j runs from 1 to 3 one obtains an atlas of three coordinate charts covering CP_2, the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homoeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2. Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^4".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, $i = 1, 2$ the coordinates of Eguchi and Freund [**?**] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it \ , \\ \xi^2 &= x + iy \ . \end{aligned} \tag{A-2.2}$$

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi+\Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= rexp(i\frac{(\Psi-\Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{A-2.3}$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second $b = 1$.

Fig. 4. CP_2 as manifold. `http://tgdtheory.fi/appfigures/cp2.jpg`

Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \rightarrow exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i\bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \quad \text{(A-2.4)}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \quad \text{(A-2.5)}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= log(F) \ , \\ F &= 1 + r^2 \ . \end{aligned} \quad \text{(A-2.6)}$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r, \phi) = (tan(\theta/2), \phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \quad \text{(A-2.7)}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ . \end{aligned} \quad \text{(A-2.8)}$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A \ , \quad \text{(A-2.9)}$$

are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , \quad e^1 = \tfrac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \tfrac{r\sigma_2}{\sqrt{F}} \ , \quad e^3 = \tfrac{r\sigma_3}{F} \ . \end{aligned} \quad \text{(A-2.10)}$$

The explicit representations of vierbein vectors are given by

$$
\begin{array}{llllll}
e^0 & = & \frac{dr}{F} \ , & e^1 & = & \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\
e^2 & = & \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 & = & \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ .
\end{array}
\tag{A-2.11}
$$

The explicit representation of the line element is given by the expression

$$
ds^2/R^2 = \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2) \ . \tag{A-2.12}
$$

From this expression one finds that at coordinate infinity $r = \infty$ line element reduces to $\frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2)$ of S^2 meaning that 3-sphere degenerates metrically to 2-sphere and one can say that CP_2 is obtained by adding to R^4 a 2-sphere at infinity.

The vierbein connection satisfying the defining relation

$$
de^A = -V^A_B \wedge e^B \ , \tag{A-2.13}
$$

is given by

$$
\begin{array}{llllll}
V_{01} & = & -\frac{e^1}{r} \ , & V_{23} & = & \frac{e^1}{r} \ , \\
V_{02} & = & -\frac{e^2}{r} \ , & V_{31} & = & \frac{e^2}{r} \ , \\
V_{03} & = & (r - \frac{1}{r})e^3 \ , & V_{12} & = & (2r + \frac{1}{r})e^3 \ .
\end{array}
\tag{A-2.14}
$$

The representation of the covariantly constant curvature tensor is given by

$$
\begin{array}{llllll}
R_{01} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\
R_{02} & = & e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} & = & -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\
R_{03} & = & 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} & = & 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ .
\end{array}
\tag{A-2.15}
$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$
J = -is_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.16}
$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$
J^k_{\ r} J^{rl} = -s^{kl} \ . \tag{A-2.17}
$$

The condition states that J and g give representations of real unit and imaginary units related by the formula $i^2 = -1$.

Kähler form is expressible locally in terms of Kähler gauge potential

$$
J = dB \ , \tag{A-2.18}
$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

$dJ = ddB = 0$ gives the topological half of Maxwell equations (vanishing of magnetic charges and Faraday's induction law) and self-duality $*J = J$ reduces the remaining equations to $dJ = 0$. Hence the Kähler form can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling).

The magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$\begin{aligned} B &= 2re^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2} dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F} sin\Theta d\Theta \wedge d\Phi \ . \end{aligned} \quad \text{(A-2.19)}$$

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1, 1).

Useful coordinates for CP_2 are the so called canonical (or symplectic or Darboux) coordinates in which the Kähler potential and Kähler form have very simple expressions

$$\begin{aligned} B &= \sum_{k=1,2} P_k dQ_k \ , \\ J &= \sum_{k=1,2} dP_k \wedge dQ_k \ . \end{aligned} \quad \text{(A-2.20)}$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$\begin{aligned} P_1 &= -\frac{1}{1+r^2} \ , \\ P_2 &= -\frac{r^2 cos\Theta}{2(1+r^2)} \ , \\ Q_1 &= \Psi \ , \\ Q_2 &= \Phi \ . \end{aligned} \quad \text{(A-2.21)}$$

Spinors In CP_2

CP_2 doesn't allow spinor structure in the conventional sense [?]. However, the coupling of the spinors to a half odd multiple of the Kähler potential leads to a respectable spinor structure. Because the delicacies associated with the spinor structure of CP_2 play a fundamental role in TGD, the arguments of Hawking are repeated here.

To see how the space can fail to have an ordinary spinor structure consider the parallel transport of the vierbein in a simply connected space M. The parallel propagation around a closed curve with a base point x leads to a rotated vierbein at x: $e^A = R^A_B e^B$ and one can associate to each closed path an element of $SO(4)$.

Consider now a one-parameter family of closed curves $\gamma(v) : v \in (0, 1)$ with the same base point x and $\gamma(0)$ and $\gamma(1)$ trivial paths. Clearly these paths define a sphere S^2 in M and the element $R^A_B(v)$ defines a closed path in $SO(4)$. When the sphere S^2 is contractible to a point e.g., homologically trivial, the path in $SO(4)$ is also contractible to a point and therefore represents a trivial element of the homotopy group $\Pi_1(SO(4)) = Z_2$.

For a homologically nontrivial 2-surface S^2 the associated path in $SO(4)$ can be homotopically nontrivial and therefore corresponds to a nonclosed path in the covering group Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallel propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2. Now, however this path corresponds to a lift of the corresponding $SO(4)$ path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the non-allowed -1-factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a $U(1)$ gauge potential this factor is given by the exponential

$exp(i2\Phi)$, where Φ is the magnetic flux through the surface. This factor has the value -1 provided the $U(1)$ potential carries half odd multiple of Dirac charge $1/2g$. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of $B/2$.

Geodesic sub-manifolds of CP_2

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the embedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h^k_α (understood as vectors of H) are covariantly constant quantities with respect to the covariant derivative taking into account that the tangent vectors are vectors both with respect to H and X^4.

In [?] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-2.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2.2 CP_2 geometry and Standard Model symmetries

Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [E194] and in particular that the right handed neutrinos decouple completely from the electro-weak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e = \pm 1$, CP_2-chirality l, r and M^4-chirality L, R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \tag{A-2.23}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \otimes \gamma_5$, $1 \otimes \gamma_5$ and $\gamma_5 \otimes 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electro-weak group: $SO(4)$ having as its covering group $SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \qquad \text{(A-2.24)}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{array}{llllll} V_{01} & = & -\frac{e^1}{r} \ , & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} \ , & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r - \frac{1}{r})e^3 \ , & V_{12} & = & (2r + \frac{1}{r})e^3 \ , \end{array} \qquad \text{(A-2.25)}$$

and

$$B = 2re^3 \ , \qquad \text{(A-2.26)}$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of $SO(4)$, one finds that the charged part of the spinor connection is given by

$$A_{ch} = 2V_{23} I_L^1 + 2V_{13} I_L^2 \ , \qquad \text{(A-2.27)}$$

where one have defined

$$\begin{aligned} I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{aligned} \qquad \text{(A-2.28)}$$

A_{ch} is clearly left handed so that one can perform the identification of the gauge potential as

$$W^\pm = \frac{2(e^1 \pm ie^2)}{r} \ , \qquad \text{(A-2.29)}$$

where $W^\pm$ denotes the charged intermediate vector boson.

The covariantly constant curvature tensor is given by

$$\begin{aligned} R_{01} &= -R_{23} = e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} &= -R_{31} = e^0 \wedge e^2 - e^3 \wedge e^1 \ , \\ R_{03} &= 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , \\ R_{12} &= 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{aligned} \qquad \text{(A-2.30)}$$

The charged part of the curvature tensor is left handed.

This is to be compared with the Weyl tensor, which defines a representation of quaternionic imaginary units.

$$\begin{array}{l} W_{03} = W_{12} \equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ W_{01} = W_{23} \equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ W_{02} = W_{31} \equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 \ . \end{array} \qquad \text{(A-2.31)}$$

The charged part of the Weyl tensor is right-handed and that the relative sign of the two terms in the curvature tensor and Weyl tensor are opposite.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$\begin{array}{rcl} X & = & re^3 \ , \\ Y & = & \frac{e^3}{r} \ , \end{array} \qquad \text{(A-2.32)}$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$\begin{array}{rcl} \bar{\gamma} & = & aX + bY \ , \\ \bar{Z}^0 & = & cX + dY \ , \end{array} \qquad \text{(A-2.33)}$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$\begin{array}{rcl} A_{nc} & = & [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\ & + & [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ . \end{array} \qquad \text{(A-2.34)}$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5 \Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c = -d \ . \qquad \text{(A-2.35)}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \qquad \text{(A-2.36)}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$\begin{array}{rcl} Q_{em} & = & \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} \ , \\ I_L^3 & = & \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ . \end{array} \qquad \text{(A-2.37)}$$

The fields γ and Z^0 are defined via the relations

$$\begin{aligned} \gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX+bY) \ , \\ Z^0 &= 4(a+b)\bar{Z}^0 = 4(X-Y) \ . \end{aligned} \tag{A-2.38}$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \tag{A-2.39}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of the Weinberg angle is a dynamical problem. The original approach was based on the assumption that it makes sense to talk about electroweak action defined at fundamental level and introduce a symmetry breaking by adding an additional term proportional to Kähler action. The recent view is that Kähler action plus volume term defines the fundamental action.

The Weinberg angle is completely fixed if one requires that the electroweak action contains no cross term of type γZ^0. This leads to a definite value for the Weinberg angle.

One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle. As a matter fact, color gauge action identifying color gauge field as proportional to $H^A J_{\alpha\beta}$ is proportional to Kähler action. A possible interpretation would be as a sum of electroweak and color gauge interactions.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) \ , \tag{A-2.40}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0\wedge e^3 + e^1\wedge e^2) \ , \\ R_{12} &= 2(e^0\wedge e^3 + 2e^1\wedge e^2) \ , \\ J &= 2(e^0\wedge e^3 + e^1\wedge e^2) \ , \end{aligned} \tag{A-2.41}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.42}$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{A-2.43}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \tag{A-2.44}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + fJ^{\alpha\beta}J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2}Tr(F^{\alpha\beta}F_{\alpha\beta}) \ , \end{aligned} \tag{A-2.45}$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$X = -\frac{K}{2g^2} + \frac{fp}{18} \ ,$$
$$K = Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ , \quad \text{(A-2.46)}$$

This parameter can be calculated by substituting the values of quark and lepton charges and weak isospins.

In the general case the value of the coefficient K is given by

$$K = \sum_i \left[-\frac{(18+2n_i^2)sin^2\theta_W}{9} \right] \ , \quad \text{(A-2.47)}$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18+n_i^2))} \ . \quad \text{(A-2.48)}$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \ . \quad \text{(A-2.49)}$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is not far from the typical value 9/24 of GUTs at high energies [B14]. The experimental value at the scale length scale of the electron can be deduced from the ratio of W and Z boson masses as $sin^2\theta_W = 1-(m_W/m_Z)^2 \simeq .22290$. This ratio and also the weak boson masses depend on the length scale.

If one interprets the additional term proportional to J as color action, one could perhaps interpret the value of Weinberg angle as expressing a connection between strong and weak coupling constant evolution. The limit $f \rightarrow 0$ should correspond to an infinite value of color coupling strength and at this limit one would have $sin^2\theta_W = \frac{9}{28}$ for $f/g^2 \rightarrow 0$. This does not make sense since the Weinberg angle is in the standard model much smaller in QCD scale Λ corresponding roughly to pion mass scale. The Weinberg angle is in principle predicted by the p-adic coupling constant evolution fixed by the number theoretical vision of TGD.

One could however have a sum of electroweak action, correction terms changing the value of Weinberg angle, and color action and coupling constant evolution could be understood in terms of the coupling parameters involved.

Electroweak symmetry breaking

One of the hardest challenges in the development of the TGD based view of weak symmetry breaking was the fact that classical field equations allow space-time surfaces with finite but arbitrarily large size. For a fixed space-time surface, the induced gauge fields, including classical weak fields, are long ranged. On the other hand, the large mass for weak bosons would require a short correlation length. How can one understand this together with the fact that a photon has a long correlation length?

In zero energy ontology quantum states are superpositions of space-time surfaces as analogs of almost unique Bohr orbits of particles identified as 3-D surfaces. For some reason the superposition should be such that the quantum averages of weak gauge boson fields vanish below the weak scale whereas the quantum average of electromagnetic fields is non-vanishing.

This is indeed the case.

1. The supersymplectic symmetries form isometries of the world of classical worlds (WCW) and they act in CP_2 degrees of freedom as symplectic transformations leaving the CP_2 symplectic form J invariant and therefore also its contribution to the electromagnetic field since this part is the same for all space-time surfaces in the superposition of space-time surfaces as a representation of supersymplectic isometry group (as a special case a representation of color group).

2. In TGD, color and electroweak symmetries acting as holonomies are not independent and for the $SU(2)_L$ part of induced spinor connection the symplectic transformations induces $SU(2)_L \times U(1)_R$ gauge transformation. This suggests that the quantum expectations of the induced weak fields over the space-time surfaces vanish above the quantum coherence scale. The averages of W and of the left handed part of Z^0 should therefore vanish.

3. $\langle Z^0 \rangle$ should vanish. For $U(1)_R$ part of Z^0, the action of gauge transformation is trivial in gauge theory. Now however the space-time surface changes under symplectic transformations and this could make the average of the right-handed part of Z^0 vanishing. The vanishing of the average of the axial part of the Z^0 is suggested by the partially conserved axial current hypothesis.

One can formulate this picture quantitatively.

1. The electromagnetic field [L140] contains, besides the induced Kähler form, also the induced curvature form R_{12}, which couples vectorially. Conserved vector current hypothesis suggests that the average of R_{12} is non-vanishing. One can express the neutral part of the induced gauge field in terms of induced spinor curvature and Kähler form J as

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) = J + 2e^0 \wedge e^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) = 3J - 2e^0 \wedge e^3 \quad , \end{aligned} \tag{A-2.50}$$

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} = 2(J + 2e^0 \wedge e^3) \qquad \text{(A-2.51)} \\ per. & \qquad \text{(A-2.52)} \end{aligned}$$

The condition $\langle Z^0 \rangle = 0$ gives $2\langle e^0 \wedge e^3 \rangle = -2J$ and this in turn gives $\langle R_{12} \rangle = 4J$. The average over γ would be

$$\langle \gamma \rangle = (3 - 4sin^2\theta_W)J \ .$$

For $sin^2\theta_W = 3/4 \ langle \gamma\rangle$ would vanish.

The quantum averages of classical weak fields quite generally vanish. What about correlation functions?

1. One expects that the correlators of classical weak fields as color invariants, and perhaps even symplectic invariants, are non-vanishing below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as hadron.

2. The intuitive picture is that in longer length scales one has disjoint 3-surfaces with a size scale of Compton length. If the states associated with two disjoint 3-surfaces are separately color invariant there are no correlations in color degrees of freedom and correlators reduce to the products of expectations of classical weak fields and vanish. This could also hold when the 3-surfaces are connected by flux tube bonds.

   Below the Compton length weak bosons would thus behave as correlated massless fields. The Compton lengths of weak bosons are proportional to the value of effective Planck constant h_{eff} and in living systems the Compton lengths are proposed to be even of the order of cell size. This would explain the mysterious chiral selection in living systems requiring large parity violation.

3. What about the averages and correlators of color gauge fields? Classical color gauge fields are proportional to the products of Hamiltonians of color isometries induced Kähler form and the expectations of color Hamiltonians give vanishing average above Compton length and therefore vanishing average. Correlators are non-vanishing below the hadron scale. Gluons do not propagate in long scales for the same reason as weak bosons. This is implied by color confinement, which has also classical description in the sense that 3-surfaces have necessarily a finite size.

   A large value of h_{eff} allows colored states even in biological scales below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as dark hadron.

Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:

1. Symmetries must be realized as purely geometric transformations.

2. Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [B15] .

The action of the reflection P on spinors of is given by

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0 \Psi \ . \tag{A-2.53}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \ , \\ \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \ . \end{aligned} \tag{A-2.54}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \Psi^{\dagger}\gamma^2\gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.55}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Induction procedure and many-sheeted space-time

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induction procedure for gauge fields and spinor connection

Induction procedure for gauge potentials and spinor structure is a standard procedure of bundle theory. If one has embedding of some manifold to the base space of a bundle, the bundle structure can be induced so that it has as a base space the imbedded manifold, whose points have as fiber the fiber if embedding space at their image points. In the recent case the embedding of space-time surface to embedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the embedding space to the space-time surface (see `http://tgdtheory.fi/appfigures/induct.jpg`).

Induction procedure makes sense also for the spinor fields of embedding space and one obtains geometrization of both electroweak gauge potentials and of spinors. The new element is induction of gamma matrices which gives their projections at space-time surface.

As a matter fact, the induced gamma matrices cannot appear in the counterpart of massless Dirac equation. To achieve super-symmetry, Dirac action must be replaced with Kähler-Dirac action for which gamma matrices are contractions of the canonical momentum currents of Kähler action with embedding space gamma matrices. Induced gamma matrices in Dirac action would correspond to 4-volume as action.

Fig. 9. Induction of spinor connection and metric as projection to the space-time surface. `http://tgdtheory.fi/appfigures/induct.jpg`.

A-3.2 Induced gauge fields for space-times for which CP$_2$ projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP$_2$ projection, only vacuum extremals and space-time surfaces for which CP$_2$ projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r = \infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP$_2$ projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \ .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

$Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP$_2$ projection color rotations and weak symmetries commute.

A-3.3 Many-sheeted space-time

TGD space-time is many-sheeted: in other words, there are in general several space-sheets which have projection to the same M^4 region. Second manner to say this is that CP_2 coordinates are many-valued functions of M^4 coordinates. The original physical interpretation of many-sheeted space-time time was not correct: it was assumed that single sheet corresponds to GRT space-time and this obviously leads to difficulties since the induced gauge fields are expressible in terms of only four embedding space coordinates.

Fig. 10. Illustration of many-sheeted space-time of TGD. `http://tgdtheory.fi/appfigures/manysheeted.jpg`

Superposition of effects instead of superposition of fields

The first objection against TGD is that superposition is not possible for induced gauge fields and induced metric. The resolution of the problem is that it is effects which need to superpose, not the fields.

Test particle topologically condenses simultaneously to all space-time sheets having a projection to same region of M^4 (that is touches them). The superposition of effects of fields at various space-time sheets replaces the superposition of fields.This is crucial for the understanding also how GRT space-time relates to TGD space-time, which is also in the appendix of this book).

Wormhole contacts

Wormhole contacts are key element of many-sheeted space-time. One does not expect them to be stable unless there is non-trivial Kähler magnetic flux flowing through then so that the throats look like Kähler magnetic monopoles.

Fig. 11. Wormhole contact. `http://tgdtheory.fi/appfigures/wormholecontact.jpg`

Since the flow lines of Kähler magnetic field must be closed this requires the presence of another wormhole contact so that one obtains closed monopole flux tube decomposing to two Minkowskian pieces at the two space-time sheets involved and two wormhole contacts with Euclidian signature of the induced metric. These objects are identified as space-time correlates of elementary particles and are clearly analogous to string like objects.

The relationship between the many-sheeted space-time of TGD and of GRT space-time

The space-time of general relativity is single-sheeted and there is no need to regard it as surface in H although the assumption about representability as vacuum extremal gives very powerful constraints in cosmology and astrophysics and might make sense in simple situations.

The space-time of GRT can be regarded as a long length scale approximation obtained by lumping together the sheets of the many-sheeted space-time to a region of M^4 and providing it with an effective metric obtained as sum of M^4 metric and deviations of the induced metrics of various space-time sheets from M^4 metric. Also induced gauge potentials sum up in the similar manner so that also the gauge fields of gauge theories would not be fundamental fields.

Fig. 12. The superposition of fields is replaced with the superposition of their effects in many-sheeted space-time. `http://tgdtheory.fi/appfigures/fieldsuperpose.jpg`

Space-time surfaces of TGD are considerably simpler objects that the space-times of general relativity and relate to GRT space-time like elementary particles to systems of condensed matter physics. Same can be said about fields since all fields are expressible in terms of embedding space coordinates and their gradients, and general coordinate invariance means that the number of bosonic field degrees is reduced locally to 4. TGD space-time can be said to be a microscopic description whereas GRT space-time a macroscopic description. In TGD complexity of space-time topology replaces the complexity due to large number of fields in quantum field theory.

Topological field quantization and the notion of magnetic body

Topological field quantization also TGD from Maxwell's theory. TGD predicts topological light rays ("massless extremals (MEs)") as space-time sheets carrying waves or arbitrary shape propagating with maximal signal velocity in single direction only and analogous to laser beams and carrying light-like gauge currents in the generi case. There are also magnetic flux quanta and electric flux quanta. The deformations of cosmic strings with 2-D string orbit as M^4 projection gives rise to magnetic flux tubes carrying monopole flux made possible by CP_2 topology allowing homological Kähler magnetic monopoles.

Fig. 13. Topological quantization for magnetic fields replaces magnetic fields with bundles of them defining flux tubes as topological field quanta. `http://tgdtheory.fi/appfigures/field.jpg`

The imbeddability condition for say magnetic field means that the region containing constant magnetic field splits into flux quanta, say tubes and sheets carrying constant magnetic field. Unless one assumes a separate boundary term in Kähler action, boundaries in the usual sense are forbidden except as ends of space-time surfaces at the boundaries of causal diamonds. One obtains typically pairs of sheets glued together along their boundaries giving rise to flux tubes with closed cross section possibly carrying monopole flux.

These kind of flux tubes might make possible magnetic fields in cosmic scales already during primordial period of cosmology since no currents are needed to generate these magnetic fields: cosmic string would be indeed this kind of objects and would dominated during the primordial period. Even superconductors and maybe even ferromagnets could involve this kind of monopole flux tubes.

A-3.4 Embedding space spinors and induced spinors

One can geometrize also fermionic degrees of freedom by inducing the spinor structure of $M^4 \times CP_2$.

CP_2 does not allow spinor structure in the ordinary sense but one can couple the opposite H-chiralities of H-spinors to an $n = 1$ ($n = 3$) integer multiple of Kähler gauge potential to obtain a respectable modified spinor structure. The em charges of resulting spinors are fractional (integer valued) and the interpretation as quarks (leptons) makes sense since the couplings to the induced spinor connection having interpretation in terms electro-weak gauge potential are identical to those assumed in standard model.

The notion of quark color differs from that of standard model.

1. Spinors do not couple to color gauge potential although the identification of color gauge potential as projection of $SU(3)$ Killing vector fields is possible. This coupling must emerge only at the effective gauge theory limit of TGD.

2. Spinor harmonics of embedding space correspond to triality $t = 1$ ($t = 0$) partial waves. The detailed correspondence between color and electroweak quantum numbers is however not correct as such and the interpretation of spinor harmonics of embedding space is as representations for ground states of super-conformal representations. The wormhole pairs associated with physical quarks and leptons must carry also neutrino pair to neutralize weak quantum numbers above the length scale of flux tube (weak scale or Compton length). The total color quantum numbers or these states must be those of standard model. For instance, the color quantum numbers of fundamental left-hand neutrino and lepton can compensate each other for the physical lepton. For fundamental quark-lepton pair they could sum up to those of physical quark.

The well-definedness of em charge is crucial condition.

1. Although the embedding space spinor connection carries W gauge potentials one can say that the embedding space spinor modes have well-defined em charge. One expects that this is true for induced spinor fields inside wormhole contacts with 4-D CP_2 projection and Euclidian signature of the induced metric.

2. The situation is not the same for the modes of induced spinor fields inside Minkowskian region and one must require that the CP_2 projection of the regions carrying induced spinor field is such that the induced W fields and above weak scale also the induced Z^0 fields vanish in order to avoid large parity breaking effects. This condition forces the CP_2 projection to be 2-dimensional. For a generic Minkowskian space-time region this is achieved only if the

spinor modes are localized at 2-D surfaces of space-time surface - string world sheets and possibly also partonic 2-surfaces.

3. Also the Kähler-Dirac gamma matrices appearing in the modified Dirac equation must vanish in the directions normal to the 2-D surface in order that Kähler-Dirac equation can be satisfied. This does not seem plausible for space-time regions with 4-D CP_2 projection.

4. One can thus say that strings emerge from TGD in Minkowskian space-time regions. In particular, elementary particles are accompanied by a pair of fermionic strings at the opposite space-time sheets and connecting wormhole contacts. Quite generally, fundamental fermions would propagate at the boundaries of string world sheets as massless particles and wormhole contacts would define the stringy vertices of generalized Feynman diagrams. One obtains geometrized diagrammatics, which brings looks like a combination of stringy and Feynman diagrammatics.

5. This is what happens in the the generic situation. Cosmic strings could serve as examples about surfaces with 2-D CP_2 projection and carrying only em fields and allowing delocalization of spinor modes to the entire space-time surfaces.

A-3.5 About induced gauge fields

In the following the induced gauge fields are studied for general space-time surface without assuming the preferred extremal property (Bohr orbit property). Therefore the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0, or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r,Θ,Ψ,Φ) for CP_2, the expression of Kähler form reads as

$$\begin{aligned} J &= \frac{r}{F^2}dr\wedge(d\Psi+cos(\Theta)d\Phi)+\frac{r^2}{2F}sin(\Theta)d\Theta\wedge d\Phi \ , \\ F &= 1+r^2 \ . \end{aligned} \tag{A-3.1}$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3+2p)\frac{r}{F^2}dr\wedge(d\Psi+cos(\Theta)d\Phi)+(3+p)\frac{r^2}{2F}sin(\Theta)d\Theta\wedge d\Phi \ , \\ p &= sin^2(\Theta_W) \ , \end{aligned} \tag{A-3.2}$$

where Θ_W denotes Weinberg angle.

1. The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi \ , \\ (3+2p)\frac{1}{r^2F}(d(r^2)/d\Theta)(k+cos(\Theta)) &+ (3+p)sin(\Theta)=0 \ , \end{aligned} \tag{A-3.3}$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$\begin{aligned} r &= \sqrt{\frac{X}{1-X}} \ , \\ X &= D\left[|\frac{k+u}{C}|\right]^{\epsilon} \ , \\ u &\equiv cos(\Theta) \ , \ C = k + cos(\Theta_0) \ , \ D = \frac{r_0^2}{1+r_0^2} \ , \ \epsilon = \frac{3+p}{3+2p} \ , \end{aligned} \tag{A-3.4}$$

where C and D are integration constants. $0 \leq X \leq 1$ is required by the reality of r. $r = 0$ would correspond to $X = 0$ giving $u = -k$ achieved only for $|k| \leq 1$ and $r = \infty$ to $X = 1$ giving $|u + k| = [(1 + r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$sign(u+k) \times [\frac{1+r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \leq k+1 \ ,$$

where $sign(x)$ denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$\begin{aligned} J &= -\frac{p}{3+2p} X du \wedge d\Phi \ , \\ Z^0 &= -\frac{6}{p} J \ . \end{aligned} \tag{A-3.5}$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

2. The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F} du \wedge d\Phi$ is useful.

3. The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$\begin{aligned} Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u} du \wedge d\Phi = (k+u) du \wedge d\Phi \ , \\ r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\ \gamma &= -\frac{p}{2} Z^0 \ . \end{aligned} \tag{A-3.6}$$

For a vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em,Z^0, or Kähler field is of practical value in the case of vacuum extremals and is given by

$$\begin{aligned} ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta}d\Theta^2 + s^{eff}_{\Phi\Phi}d\Phi^2] \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ , \end{aligned} \quad \text{(A-3.7)}$$

and is useful in the construction of vacuum embedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\begin{aligned} \Psi &= \omega_2 m^0 + k_2 m^3 + n_2\phi + \text{Fourier expansion} \ , \\ \Phi &= \omega_1 m^0 + k_1 m^3 + n_1\phi + \text{Fourier expansion} \ . \end{aligned} \quad \text{(A-3.8)}$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global embedding for, say a constant magnetic field. Although global embedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteeing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \ , \quad \text{(A-3.9)}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

A-4 The relationship of TGD to QFT and string models

The recent view of the relationship of TGD to QFT and string models has developed slowly during years and it seems that in a certain sense TGD means a return to roots: instead of QFT like description involving path integral one would have wave mechanics for 3-surfaces.

A-4.1 TGD as a generalization of wave mechanism obtained by replacing point-like particles with 3-surfaces

The first vision of TGD was as a generalization of quantum field theory (string models) obtained by replacing pointlike particles (strings) as fundamental objects with 3-surfaces.

The later work has revealed that TGD could be seen as a generalization of the wave mechanism based on the replacement of a point-like particle with 3-D surface. This is due to holography implied by general coordinate invariance. The definition of the metric of the "world of classical worlds" (WCW) must assign a unique or at least almost unique space-time surface to a given 3-surface. This 4-surface is analogous to Bohr orbit so that also Bohr orbitology becomes an exact part of quantum physics. The failure of strict determinism forces to replace 3-surfaces with 4-surfaces and this leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K53, K29, K89] [L110, L128].

Fig. 5. TGD replaces point-like particles with 3-surfaces. `http://tgdtheory.fi/appfigures/particletgd.jpg`

A-4.2 Extension of superconformal invariance

The fact that light-like 3-surfaces are effectively metrically 2-dimensional and thus possess generalization of 2-dimensional conformal symmetries with light-like radial coordinate defining the analog of second complex coordinate suggests that this generalization could work and extend the super-conformal symmetries to their 4-D analogs.

The boundary $\delta M^4_+ = S^2 \times R_+$- of 4-D light-cone M^4_+ is also metrically 2-dimensional and allows extended conformal invariance. Also the group of isometries of light-cone boundary and of light-like 3-surfaces is infinite-dimensional since the conformal scalings of S^2 can be compensated by S^2-local scaling of the light-like radial coordinate of R_+. These simple facts mean that 4-dimensional Minkowski space and 4-dimensional space-time surfaces are in a completely unique position as far as symmetries are considered.

In fact, this leads to a generalization of the Kac-Moody type symmetries of string models. $\delta M^4_+ \times CP_2$ allows huge supersymplectic symmetries for which the radial light-like coordinate of δM^4_+ plays the role of complex string coordinate in string models. These symmetries are assumed to act as isometries of WCW.

A-4.3 String-like objects and strings

String like objects obtained as deformations of cosmic strings $X^2 \times Y^2$, where X^2 is minimal surface in M^4 and Y^2 a holomorphic surface of CP_2 are fundamental extremals of Kähler action having string world sheet as M^4 projections. Cosmic strings dominate the primordial cosmology of the TGD Universe and the inflationary period corresponds to the transition to radiation dominated cosmology for which space-time sheets with 4-D M^4 projection dominate.

Also genuine string-like objects emerge from TGD. The conditions that the em charge of modes of induces spinor fields is well-defined requires in the generic case the localization of the modes at 2-D surfaces -string world sheets and possibly also partonic 2-surfaces. This in Minkowskian space-time regions.

Fig. 6. Well-definedness of em charge forces the localization of induced spinor modes to 2-D surfaces in generic situations in Minkowskian regions of space-time surface. `http://tgdtheory.fi/appfigures/fermistring.jpg`

A-4.4 TGD view of elementary particles

The TGD based view about elementary particles has two key aspects.

1. The space-time correlates of elementary particles are identified as pairs of wormhole contacts with Euclidean signature of metric and having 4-D CP_2 projection. Their throats behave effectively as Kähler magnetic monopoles so that wormhole throats must be connected by Kähler magnetic flux tubes with monopole flux so that closed flux tubes are obtained.

2. At the level of H Fermion number is carried by the modes of the induced spinor field. In space-time regions with Minkowski signature the modes are localized at string world sheets connecting the wormhole contacts.

Fig. 7. TGD view about elementary particles. a) Particle orbit corresponds to a 4-D generalization of a world line or b) with its light-like 3-D boundary (holography). c) Particle world lines have Euclidean signature of the induced metric. d) They can be identified as wormhole contacts. e) The throats of wormhole contacts carry effective Kähler magnetic charges so that wormhole contacts must appear as pairs in order to obtain closed flux tubes. f) Wormhole contacts are accompanied by fermionic strings connecting the throats at the same sheet: the strings do not extend inside the wormhole contacts. `http://tgdtheory.fi/appfigures/elparticletgd.jpg`

Particle interactions involve both stringy and QFT aspects.

1. The boundaries of string world sheets correspond to fundamental fermions. This gives rise to massless propagator lines in generalized Feynman diagrammatics. One can speak of "long" string connecting wormhole contacts and having a hadronic string as a physical counterpart. Long strings should be distinguished from wormhole contacts which due to their super-conformal invariance behave like "short" strings with length scale given by CP_2 size, which is 10^4 times longer than Planck scale characterizing strings in string models.

2. Wormhole contact defines basic stringy interaction vertex for fermion-fermion scattering. The propagator is essentially the inverse of the superconformal scaling generator L_0. Wormhole contacts containing fermion and antifermion at its opposite throats behave like virtual bosons so that one has BFF type vertices typically.

3. In topological sense one has 3-vertices serving as generalizations of 3-vertices of Feynman diagrams. In these vertices 4-D "lines" of generalized Feynman diagrams meet along their 3-D ends. One obtains also the analogs of stringy diagrams but stringy vertices do not have the usual interpretation in terms of particle decays but in terms of propagation of particles along two different routes.

Fig. 8. a) TGD analogs of Feynman and string diagrammatics at the level of space-time topology. b) The 4-D analogs of both string diagrams and QFT diagrams appear but the interpretation of the analogs stringy diagrams is different. `http://tgdtheory.fi/appfigures/tgdgraphs.jpg`

A-5 About the selection of the action defining the Kähler function of the "world of classical worlds" (WCW)

The proposal is that space-time surfaces correspond to preferred extremals of some action principle, being analogous to Bohr orbits, so that they are almost deterministic. The action for the preferred extremal would define the Kähler function of WCW [K53, K89].

How unique is the choice of the action defining WCW Kähler metric? The problem is that twistor lift strongly suggests the identification of the preferred extremals as 4-D surfaces having 4-D generalization of complex structure and that a large number of general coordinate invariant actions constructible in terms of the induced geometry have the same preferred extremals.

A-5.1 Could twistor lift fix the choice of the action uniquely?

The twistor lift of TGD [L43] [L110, L116, L117] generalizes the notion of induction to the level of twistor fields and leads to a proposal that the action is obtained by dimensional reduction of the action having as its preferred extremals the counterpart of twistor space of the space-time surface identified as 6-D surface in the product $T(M^4) \times T(CP_2)$ twistor spaces of $T(M^4)$ and

$T(CP_2)$ of M^4 and CP_2. Only M^4 and CP_2 allow a twistor space with Kähler structure [?] so that TGD would be unique. Dimensional reduction is forced by the condition that the 6-surface has S^2-bundle structure characterizing twistor spaces and the base space would be the space-time surface.

1. Dimensional reduction of 6-D Kähler action implies that at the space-time level the fundamental action can be identified as the sum of Kähler action and volume term (cosmological constant). Other choices of the action do not look natural in this picture although they would have the same preferred extremals.

2. Preferred extremals are proposed to correspond to minimal surfaces with singularities such that they are also extremals of 4-D Kähler action outside the singularities. The physical analogue are soap films spanned by frames and one can localize the violation of the strict determinism and of strict holography to the frames.

3. The preferred extremal property is realized as the holomorphicity characterizing string world sheets, which generalizes to the 4-D situation. This in turn implies that the preferred extremals are the same for any general coordinate invariant action defined on the induced gauge fields and induced metric apart from possible extremals with vanishing CP_2 Kähler action.

   For instance, 4-D Kähler action and Weyl action as the sum of the tensor squares of the components of the Weyl tensor of CP_2 representing quaternionic imaginary units constructed from the Weyl tensor of CP_2 as an analog of gauge field would have the same preferred extremals and only the definition of Kähler function and therefore Kähler metric of WCW would change. One can even consider the possibility that the volume term in the 4-D action could be assigned to the tensor square of the induced metric representing a quaternionic or octonionic real unit.

Action principle does not seem to be unique. On the other hand, the WCW Kähler form and metric should be unique since its existence requires maximal isometries.

Unique action is not the only way to achieve this. One cannot exclude the possibility that the Kähler gauge potential of WCW in the complex coordinates of WCW differs only by a complex gradient of a holomorphic function for different actions so that they would give the same Kähler form for WCW. This gradient is induced by a symplectic transformation of WCW inducing a U(1) gauge transformation. The Kähler metric is the same if the symplectic transformation is an isometry.

Symplectic transformations of WCW could give rise to inequivalent representations of the theory in terms of action at space-time level. Maybe the length scale dependent coupling parameters of an effective action could be interpreted in terms of a choice of WCW Kähler function, which maximally simplifies the computations at a given scale.

1. The 6-D analogues of electroweak action and color action reducing to Kähler action in 4-D case exist. The 6-D analog of Weyl action based on the tensor representation of quaternionic imaginary units does not however exist. One could however consider the possibility that only the base space of twistor space $T(M^4)$ and $T(CP_2)$ have quaternionic structure.

2. Kähler action has a huge vacuum degeneracy, which clearly distinguishes it from other actions. The presence of the volume term removes this degeneracy. However, for minimal surfaces having CP_2 projections, which are Lagrangian manifolds and therefore have a vanishing induced Kähler form, would be preferred extremals according to the proposed definition. For these 4-surfaces, the existence of the generalized complex structure is dubious.

   For the electroweak action, the terms corresponding to charged weak bosons eliminate these extremals and one could argue that electroweak action or its sum with the analogue of color action, also proportional Kähler action, defines the more plausible choice. Interestingly, also the neutral part of electroweak action is proportional to Kähler action.

Twistor lift strongly suggests that also M^4 has the analog of Kähler structure. M^8 must be complexified by adding a commuting imaginary unit i. In the E^8 subspace, the Kähler structure of E^4 is defined in the standard sense and it is proposed that this generalizes to M^4 allowing also generalization of the quaternionic structure. M^4 Kähler structure violates Lorentz invariance but could be realized at the level of moduli space of these structures.

The minimal possibility is that the M^4 Kähler form vanishes: one can have a different representation of the Kähler gauge potential for it obtained as generalization of symplectic transformations acting non-trivially in M^4. The recent picture about the second quantization of spinors of $M^4 \times CP_2$ assumes however non-trivial Kähler structure in M^4.

A-5.2 Two paradoxes

TGD view leads to two apparent paradoxes.

1. If the preferred extremals satisfy 4-D generalization of holomorphicity, a very large set of actions gives rise to the same preferred extremals unless there are some additional conditions restricting the number of preferred extremals for a given action.

2. WCW metric has an infinite number of zero modes, which appear as parameters of the metric but do not contribute to the line element. The induced Kähler form depends on these degrees of freedom. The existence of the Kähler metric requires maximal isometries, which suggests that the Kähler metric is uniquely fixed apart from a conformal scaling factor Ω depending on zero modes. This cannot be true: galaxy and elementary particle cannot correspond to the same Kähler metric.

Number theoretical vision and the hierarchy of inclusions of HFFs associated with supersymplectic algebra actings as isometries of WcW provide equivalent realizations of the measurement resolution. This solves these paradoxes and predicts that WCW decomposes into sectors for which Kähler metrics of WCW differ in a natural way.

The hierarchy subalgebras of supersymplectic algebra implies the decomposition of WCW into sectors with different actions

Supersymplectic algebra of $\delta M^4_+ \times CP_2$ is assumed to act as isometries of WCW [L128]. There are also other important algebras but these will not be discussed now.

1. The symplectic algebra A of $\delta M^4_+ \times CP_2$ has the structure of a conformal algebra in the sense that the radial conformal weights with non-negative real part, which is half integer, label the elements of the algebra have an interpretation as conformal weights.

   The super symplectic algebra A has an infinite hierarchy of sub-algebras [L128] such that the conformal weights of sub-algebras $A_{n(SS)}$ are integer multiples of the conformal weights of the entire algebra. The superconformal gauge conditions are weakened. Only the subalgebra $A_{n(SS)}$ and the commutator $[A_{n(SS)}, A]$ annihilate the physical states. Also the corresponding classical Noether charges vanish for allowed space-time surfaces.

   This weakening makes sense also for ordinary superconformal algebras and associated Kac-Moody algebras. This hierarchy can be interpreted as a hierarchy symmetry breakings, meaning that sub-algebra $A_{n(SS)}$ acts as genuine dynamical symmetries rather than mere gauge symmetries. It is natural to assume that the super-symplectic algebra A does not affect the coupling parameters of the action.

2. The generators of A correspond to the dynamical quantum degrees of freedom and leave the induced Kähler form invariant. They affect the induced space-time metric but this effect is gravitational and very small for Einsteinian space-time surfaces with 4-D M^4 projection.

   The number of dynamical degrees of freedom increases with $n(SS)$. Therefore WCW decomposes into sectors labelled by $n(SS)$ with different numbers of dynamical degrees of freedom so that their Kähler metrics cannot be equivalent and cannot be related by a symplectic isometry. They can correspond to different actions.

Number theoretic vision implies the decomposition of WCW into sectors with different actions

The number theoretical vision leads to the same conclusion as the hierarchy of HFFs. The number theoretic vision of TGD based on $M^8 - H$ duality [L128] predicts a hierarchy with levels labelled by the degrees $n(P)$ of rational polynomials P and corresponding extensions of rationals characterized by Galois groups and by ramified primes defining p-adic length scales.

These sequences allow us to imagine several discrete coupling constant evolutions realized at the level H in terms of action whose coupling parameters depend on the number theoretic parameters.

1. Coupling constant evolution with respect to $n(P)$

The first coupling constant evolution would be with respect to $n(P)$.

1. The coupling constants characterizing action could depend on the degree $n(P)$ of the polynomial defining the space-time region by $M^8 - H$ duality. The complexity of the space-time surface would increase with $n(P)$ and new degrees of freedom would emerge as the number of the rational coefficients of P.

2. This coupling constant evolution could naturally correspond to that assignable to the inclusion hierarchy of hyperfinite factors of type II_1 (HFFs). I have indeed proposed [L128] that the degree $n(P)$ equals to the number $n(braid)$ of braids assignable to HFF for which super symplectic algebra subalgebra $A_{n(SS)}$ with radial conformal weights coming as $n(SS)$-multiples of those of entire algebra A. One would have $n(P) = n(braid) = n(SS)$. The number of dynamical degrees of freedom increases with n which just as it increases with $n(P)$ and $n(SS)$.

3. The actions related to different values of $n(P) = n(braid) = n(SS)$ cannot define the same Kähler metric since the number of allowed space-time surfaces depends on $n(SS)$.

   WCW could decompose to sub-WCWs corresponding to different actions, a kind of theory space. These theories would not be equivalent. A possible interpretation would be as a hierarchy of effective field theories.

4. Hierarchies of composite polynomials define sequences of polynomials with increasing values of $n(P)$ such that the order of a polynomial at a given level is divided by those at the lower levels. The proposal is that the inclusion sequences of extensions are realized at quantum level as inclusion hierarchies of hyperfinite factors of type II_1.

   A given inclusion hierarchy corresponds to a sequence $n(SS)_i$ such that $n(SS)_i$ divides $n(SS)_{i+1}$. Therefore the degree of the composite polynomials increases very rapidly. The values of $n(SS)_i$ can be chosen to be primes and these primes correspond to the degrees of so called prime polynomials [L120] so that the decompositions correspond to prime factorizations of integers. The "densest" sequence of this kind would come in powers of 2 as $n(SS)_i = 2^i$. The corresponding p-adic length scales (assignable to maximal ramified primes for given $n(SS)_i$) are expected to increase roughly exponentially, say as 2^{r2^i}. $r = 1/2$ would give a subset of scales $2^{r/2}$ allowed by the p-adic length scale hypothesis. These transitions would be very rare.

   A theory corresponding to a given composite polynomial would contain as sub-theories the theories corresponding to lower polynomial composites. The evolution with respect to $n(SS)$ would correspond to a sequence of phase transitions in which the action genuinely changes. For instance, color confinement could be seen as an example of this phase transition.

5. A subset of p-adic primes allowed by the p-adic length scale hypothesis $p \simeq 2^k$ defining the proposed p-adic length scale hierarchy could relate to n_S changing phase transition. TGD suggests a hierarchy of hadron physics corresponding to a scale hierarchy defined by Mersenne primes and their Gaussian counterparts [K68, K69]). Each of them would be characterized by a confinement phase transition in which n_S and therefore also the action changes.

2. Coupling constant evolutions with respect to ramified primes for a given value of $n(P)$

For a given value of $n(P)$, one could have coupling constant sub-evolutions with respect to the set of ramified primes of P and dimensions $n = h_{eff}/h_0$ of algebraic extensions. The action would only change by U(1) gauge transformation induced by a symplectic isometry of WCW. Coupling parameters could change but the actions would be equivalent.

The choice of the action in an optimal manner in a given scale could be seen as a choice of the most appropriate effective field theory in which radiative corrections would be taken into account. One can interpret the possibility to use a single choice of coupling parameters in terms of quantum criticality.

The range of the p-adic length scales labelled by ramified primes and effective Planck constants h_{eff}/h_0 is finite for a given value of $n(SS)$.

The first coupling constant evolution of this kind corresponds to ramified primes defining p-adic length scales for given $n(SS)$.

1. Ramified primes are factors of the discriminant $D(P)$ of P, which is expressible as a product of non-vanishing root differents and reduces to a polynomial of the n coefficients of P. Ramified primes define p-adic length scales assignable to the particles in the amplitudes scattering amplitudes defined by zero energy states.

   P would represent the space-time surface defining an interaction region in $N-$-particle scattering. The N ramified primes dividing $D(P)$ would characterize the p-adic length scales assignable to these particles. If $D(P)$ reduces to a single ramified prime, one has elementary particle [L120], and the forward scattering amplitude corresponds to the propagator.

   This would give rise to a multi-scale p-adic length scale evolution of the amplitudes analogous to the ordinary continuous coupling constant evolution of n-point scattering amplitudes with respect to momentum scales of the particles. This kind of evolutions extend also to evolutions with respect to $n(SS)$.

2. According to [L120], physical constraints require that $n(P)$ and the maximum size of the ramified prime of P correlate.

   A given rational polynomial of degree $n(P)$ can be always transformed to a polynomial with integer coefficients. If the integer coefficients are smaller than $n(P)$, there is an upper bound for the ramified primes. This assumption also implies that finite fields become fundamental number fields in number theoretical vision [L120].

3. p-Adic length scale hypothesis [L129] in its basic form states that there exist preferred primes $p \simeq 2^k$ near some powers of 2. A more general hypothesis states that also primes near some powers of 3 possibly also other small primes are preferred physically. The challenge is to understand the origin of these preferred scales.

   For polynomials P with a given degree $n(P)$ for which discriminant $D(P)$ is prime, there exists a maximal ramified prime. Numerical calculations suggest that the upper bound depends exponentially on $n(P)$.

   Could these maximal ramified primes satisfy the p-adic length scale hypothesis or its generalization? The maximal prime defines a fixed point of coupling constant evolution in accordance with the earlier proposal. For instance, could one think that one has $p \simeq 2^k$, $k = n(SS)$? Each p-adic prime would correspond to a p-adic coupling constant sub-evolution representable in terms of symplectic isometries.

Also the dimension n of the algebraic extension associated with P, which is identified in terms of effective Planck constant $h_{eff}/h_0 = n$ labelling different phases of the ordinary matter behaving like dark matter, could give rise to coupling constant evolution for given $n(SS)$. The range of allowed values of n is finite. Note however that several polynomials of a given degree can correspond to the same dimension of extension.

Number theoretic discretization of WCW and maxima of WCW Kähler function

Number theoretic approach involves a unique discretization of space-time surface and also of WCW. The question is how the points of the discretized WCW correspond to the preferred extremals.

1. The exponents of Kähler function for the maxima of Kähler function, which correspond to the universal preferred extremals, appear in the scattering amplitudes. The number theoretical approach involves a unique discretization of space-time surfaces defining the WCW coordinates of the space-time surface regarded as a point of WCW.

   In [L128] it is assumed that these WCW points appearing in the number theoretical discretization correspond to the maxima of the Kähler function. The maxima would depend on the action and would differ for ghd maxima associated with different actions unless they are not related by symplectic WCW isometry.

2. The symplectic transformations of WCW acting as isometries are assumed to be induced by the symplectic transformations of $\delta M^4_+ \times CP_2$ [K53, K29]. As isometries they would naturally permute the maxima with each other.

A-6 Number theoretic vision of TGD

Physics as number theory vision is complementary to the physics as geometry vision and has developed gradually since 1993. Langlands program is the counterpart of this vision in mathematics [L124].

The notion of p-adic number fields emerged with the motivation coming from the observation that elementary particle mass scales and mass ratios could be understood in terms of the so-called p-adic length scale hypothesis [K72, K63, K26]. The fusion of the various p-adic physics leads to what I call adelic physics [L42, L41]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K32, K33, K34, K34].

Eventually this led to that the values of effective Planck constant could be identified as the dimension of an algebraic extension of rationals assignable to polynomials with rational coefficients. This led to the number theoretic vision in which so-called M^8-H duality [L91, L92] plays a key role. M^8 (actually a complexification of real M^8) is analogous to momentum space so that the duality generalizes momentum position duality for point-like particles. M^8 has an interpretation as complexified octonions.

The dynamics of 4-surfaces in M^8 is coded by polynomials with rational coefficients, whose roots define mass shells H^3 of $M^4 \subset M^8$. It has turned out that the polynomials satisfy stringent additional conditions and one can speak of number theoretic holography [L120, L124]. Also the ordinary 3→ 4 holography is needed to assign 4-surfaces with these 3-D mass shells. The number theoretic dynamics is based on the condition that the normal space of the 4-surface in M^8 is associative (quaternionic) and contains a commutative complex sub-space. This makes it possible to assign to this surface space-time surface in $H = M^4 \times CP_2$.

At the level of H the space-time surfaces are by holography preferred extremals and are assumed to be determined by the twistor lift of TGD [L43] giving rise to an action which is sum of the Kähler action and volume term. The preferred extremals would be minimal surfaces analogous to soap films spanned by frames. Outside frames they would be simultaneous extremals of the Kähler action, which requires a generalization of the holomorphy characterizing string world sheets.

In the following only p-adic numbers and hierarchy of Planck constants will be discussed.

A-6.1 p-Adic numbers and TGD

p-Adic number fields

p-Adic numbers (p is prime: 2, 3, 5, ...) can be regarded as a completion of the rational numbers using a norm, which is different from the ordinary norm of real numbers [?]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k\geq k_0} x(k)p^k,\ x(k) = 0,....,p-1\ . \quad \text{(A-6.1)}$$

The norm of a p-adic number is given by

$$|x| = p^{-k_0(x)} . \quad \text{(A-6.2)}$$

Here $k_0(x)$ is the lowest power in the expansion of the p-adic number. The norm differs drastically from the norm of the ordinary real numbers since it depends on the lowest pinary digit of the p-adic number only. Arbitrarily high powers in the expansion are possible since the norm of the p-adic number is finite also for numbers, which are infinite with respect to the ordinary norm. A convenient representation for p-adic numbers is in the form

$$x = p^{k_0}\varepsilon(x) , \quad \text{(A-6.3)}$$

where $\varepsilon(x) = k + ...$ with $0 < k < p$, is p-adic number with unit norm and analogous to the phase factor $exp(i\phi)$ of a complex number.

The distance function $d(x,y) = |x-y|_p$ defined by the p-adic norm possesses a very general property called ultra-metricity:

$$d(x,z) \leq max\{d(x,y), d(y,z)\} . \quad \text{(A-6.4)}$$

The properties of the distance function make it possible to decompose R_p into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \leq D . \quad \text{(A-6.5)}$$

This division of the metric space into classes has following properties:

1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.

2. Distances of points x and y inside single class are smaller than distances between different classes.

3. Classes form a hierarchical tree.

Notice that the concept of the ultra-metricity emerged in physics from the models for spin glasses and is believed to have also applications in biology [B31]. The emergence of p-adic topology as the topology of the effective space-time would make ultra-metricity property basic feature of physics.

Canonical correspondence between p-adic and real numbers

The basic challenge encountered by p-adic physicist is how to map the predictions of the p-adic physics to real numbers. p-Adic probabilities provide a basic example in this respect. Identification via common rationals and canonical identification and its variants have turned out to play a key role in this respect.

1. Basic form of the canonical identification

There exists a natural continuous map $I : R_p \to R_+$ from p-adic numbers to non-negative real numbers given by the "pinary" expansion of the real number for $x \in R$ and $y \in R_p$ this correspondence reads

$$\begin{aligned} y &= \sum_{k>N} y_k p^k \to x = \sum_{k<N} y_k p^{-k} , \\ y_k &\in \{0, 1, .., p-1\} . \end{aligned} \quad \text{(A-6.6)}$$

This map is continuous as one easily finds out. There is however a little difficulty associated with the definition of the inverse map since the pinary expansion like also decimal expansion is not unique (1 = 0.999...) for the real numbers x, which allow pinary expansion with finite number of pinary digits

$$
\begin{aligned}
x &= \sum_{k=N_0}^{N} x_k p^{-k} \ , \\
x &= \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1)p^{-N} + (p-1)p^{-N-1} \sum_{k=0,..} p^{-k} \ .
\end{aligned}
\tag{A-6.7}
$$

The p-adic images associated with these expansions are different

$$
\begin{aligned}
y_1 &= \sum_{k=N_0}^{N} x_k p^{k} \ , \\
y_2 &= \sum_{k=N_0}^{N-1} x_k p^{k} + (x_N - 1)p^{N} + (p-1)p^{N+1} \sum_{k=0,..} p^{k} \\
&= y_1 + (x_N - 1)p^N - p^{N+1} \ ,
\end{aligned}
\tag{A-6.8}
$$

so that the inverse map is either two-valued for p-adic numbers having expansion with finite pinary digits or single valued and discontinuous and non-surjective if one makes pinary expansion unique by choosing the one with finite pinary digits. The finite pinary digit expansion is a natural choice since in the numerical work one always must use a pinary cutoff on the real axis.

2. The topology induced by canonical identification

The topology induced by the canonical identification in the set of positive real numbers differs from the ordinary topology. The difference is easily understood by interpreting the p-adic norm as a norm in the set of the real numbers. The norm is constant in each interval $[p^k, p^{k+1})$ (see **Fig. A-6.1**) and is equal to the usual real norm at the points $x = p^k$: the usual linear norm is replaced with a piecewise constant norm. This means that p-adic topology is coarser than the usual real topology and the higher the value of p is, the coarser the resulting topology is above a given length scale. This hierarchical ordering of the p-adic topologies will be a central feature as far as the proposed applications of the p-adic numbers are considered.

Ordinary continuity implies p-adic continuity since the norm induced from the p-adic topology is rougher than the ordinary norm. p-Adic continuity implies ordinary continuity from right as is clear already from the properties of the p-adic norm (the graph of the norm is indeed continuous from right). This feature is one clear signature of the p-adic topology.

Fig. 14. The real norm induced by canonical identification from 2-adic norm. `http://tgdtheory.fi/appfigures/norm.png`

The linear structure of the p-adic numbers induces a corresponding structure in the set of the non-negative real numbers and p-adic linearity in general differs from the ordinary concept of linearity. For example, p-adic sum is equal to real sum only provided the summands have no common pinary digits. Furthermore, the condition $x +_p y < max\{x, y\}$ holds in general for the p-adic sum of the real numbers. p-Adic multiplication is equivalent with the ordinary multiplication only provided that either of the members of the product is power of p. Moreover one has $x \times_p y < x \times y$ in general. The p-Adic negative -1_p associated with p-adic unit 1 is given by $(-1)_p = \sum_k (p-1)p^k$ and defines p-adic negative for each real number x. An interesting possibility is that p-adic linearity might replace the ordinary linearity in some strongly nonlinear systems so these systems would look simple in the p-adic topology.

These results suggest that canonical identification is involved with some deeper mathematical structure. The following inequalities hold true:

$$(x+y)_R \leq x_R + y_R \ ,$$
$$|x|_p|y|_R \leq (xy)_R \leq x_R y_R \ , \tag{A-6.9}$$

where $|x|_p$ denotes p-adic norm. These inequalities can be generalized to the case of $(R_p)^n$ (a linear vector space over the p-adic numbers).

$$(x+y)_R \leq x_R + y_R \ ,$$
$$|\lambda|_p|y|_R \leq (\lambda y)_R \leq \lambda_R y_R \ , \tag{A-6.10}$$

where the norm of the vector $x \in T_p^n$ is defined in some manner. The case of Euclidian space suggests the definition

$$(x_R)^2 = (\sum_n x_n^2)_R \ . \tag{A-6.11}$$

These inequalities resemble those satisfied by the vector norm. The only difference is the failure of linearity in the sense that the norm of a scaled vector is not obtained by scaling the norm of the original vector. Ordinary situation prevails only if the scaling corresponds to a power of p.

These observations suggests that the concept of a normed space or Banach space might have a generalization and physically the generalization might apply to the description of some non-linear systems. The nonlinearity would be concentrated in the nonlinear behavior of the norm under scaling.

3. Modified form of the canonical identification

The original form of the canonical identification is continuous but does not respect symmetries even approximately. This led to a search of variants which would do better in this respect. The modification of the canonical identification applying to rationals only and given by

$$I_Q(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \tag{A-6.12}$$

is uniquely defined for rationals, maps rationals to rationals, has also a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$. It has turned out that it is this map which most naturally appears in the applications. The map is obviously continuous locally since p-adically small modifications of r and s mean small modifications of the real counterparts.

Canonical identification is in a key role in the successful predictions of the elementary particle masses. The predictions for the light elementary particle masses are within extreme accuracy same for I and I_Q but I_Q is theoretically preferred since the real probabilities obtained from p-adic ones by I_Q sum up to one in p-adic thermodynamics.

4. Generalization of number concept and notion of embedding space

TGD forces an extension of number concept: roughly a fusion of reals and various p-adic number fields along common rationals is in question. This induces a similar fusion of real and p-adic embedding spaces. Since finite p-adic numbers correspond always to non-negative reals n-dimensional space R^n must be covered by 2^n copies of the p-adic variant R_p^n of R^n each of which projects to a copy of R_+^n (four quadrants in the case of plane). The common points of p-adic and real embedding spaces are rational points and most p-adic points are at real infinity.

Real numbers and various algebraic extensions of p-adic number fields are thus glued together along common rationals and also numbers in algebraic extension of rationals whose number belong to the algebraic extension of p-adic numbers. This gives rise to a book like structure with rationals and various algebraic extensions of rationals taking the role of the back of the book. Note that Neper number is exceptional in the sense that it is algebraic number in p-adic number field Q_p satisfying $e^p \ mod \ p = 1$.

Fig. 15. Various number fields combine to form a book like structure. `http://tgdtheory.fi/appfigures/book.jpg`

For a given p-adic space-time sheet most points are literally infinite as real points and the projection to the real embedding space consists of a discrete set of rational points: the interpretation in terms of the unavoidable discreteness of the physical representations of cognition is natural. Purely local p-adic physics implies real p-adic fractality and thus long range correlations for the real space-time surfaces having enough common points with this projection.

p-Adic fractality means that M^4 projections for the rational points of space-time surface X^4 are related by a direct identification whereas CP_2 coordinates of X^4 at these points are related by I, I_Q or some of its variants implying long range correlates for CP_2 coordinates. Since only a discrete set of points are related in this manner, both real and p-adic field equations can be satisfied and there are no problems with symmetries. p-Adic effective topology is expected to be a good approximation only within some length scale range which means infrared and UV cutoffs. Also multi-p-fractality is possible.

The notion of p-adic manifold

The notion of p-adic manifold is needed in order to fuse real physics and various p-adic physics to a larger structure which suggests that real and p-adic number fields should be glued together along common rationals bringing in mind adeles. The notion is problematic because p-adic topology is totally disconnected implying that p-adic balls are either disjoint or nested so that ordinary definition of manifold using p-adic chart maps fails. A cure is suggested to be based on chart maps from p-adics to reals rather than to p-adics (see the appendix of the book)

The chart maps are interpreted as cognitive maps, "thought bubbles".

Fig. 16. The basic idea between p-adic manifold. `http://tgdtheory.fi/appfigures/padmanifold.jpg`

There are some problems.

1. Canonical identification does not respect symmetries since it does not commute with second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map arithmetic operations which requires pinary cutoff below which chart map takes rationals to rationals so that commutativity with arithmetics and symmetries is achieved in finite resolution: above the cutoff canonical identification is used

2. Canonical identification is continuous but does not map smooth p-adic surfaces to smooth real surfaces requiring second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map requiring completion of the image to smooth preferred extremal of Kähler action so that chart map is not unique in accordance with finite measurement resolution

3. Canonical identification violates general coordinate invariance of chart map: (cognition-induced symmetry breaking) minimized if p-adic manifold structure is induced from that for p-adic embedding space with chart maps to real embedding space and assuming preferred coordinates made possible by isometries of embedding space: one however obtains several inequivalent p-adic manifold structures depending on the choice of coordinates: these cognitive representations are not equivalent.

A-6.2 Hierarchy of Planck constants and dark matter hierarchy

Hierarchy of Planck constants was motivated by the "impossible" quantal effects of ELF em fields on vertebrate cyclotron energies $E = hf = \hbar \times eB/m$ are above thermal energy is possible only if $\hbar$ has value much larger than its standard value. Also Nottale's finding that planetary orbits migh be understood as Bohr orbits for a gigantic gravitational Planck constant.

Hierachy of Planck constant would mean that the values of Planck constant come as integer multiples of ordinary Planck constant: $h_{eff} = n \times h$. The particles at magnetic flux tubes characterized by h_{eff} would correspond to dark matter which would be invisible in the sense that only particle with same value of h_{eff} appear in the same vertex of Feynman diagram.

Hierarchy of Planck constants would be due to the non-determism of the Kähler action predicting huge vacuum degeneracy allowing all space-time surfaces which are sub-manfolds of any $M^4 \times Y^2$, where Y^2 is Lagrangian sub-manifold of CP_2. For agiven Y^2 one obtains new manifolds Y^2 by applying symplectic transformations of CP_2.

Non-determinism would mean that the 3-surface at the ends of causal diamond (CD) can be connected by several space-time surfaces carrying same conserved Kähler charges and having same values of Kähler action. Conformal symmetries defined by Kac-Moody algebra associated with the embedding space isometries could act as gauge transformations and respect the light-likeness property of partonic orbits at which the signature of the induced metric changes from Minkowskian to Euclidian (Minkowskianb space-time region transforms to wormhole contact say). The number of conformal equivalence classes of these surfaces could be finite number n and define discrete physical degree of freedom and one would have $h_{eff} = n \times h$. This degeneracy would mean "second quantization" for the sheets of n-furcation: not only one but several sheets can be realized.

This relates also to quantum criticality postulated to be the basic characteristics of the dynamics of quantum TGD. Quantum criticalities would correspond to an infinite fractal hierarchy of broken conformal symmetries defined by sub-algebras of conformal algebra with conformal weights coming as integer multiples of n. This leads also to connections with quantum criticality and hierarchy of broken conformal symmetries, p-adicity, and negentropic entanglement which by consistency with standard quantum measurement theory would be described in terms of density matrix proportional $n \times n$ identity matrix and being due to unitary entanglement coefficients (typical for quantum computing systems).

Formally the situation could be described by regarding space-time surfaces as surfaces in singular n-fold singular coverings of embedding space. A stronger assumption would be that they are expressible as as products of n_1 -fold covering of M^4 and n_2-fold covering of CP_2 meaning analogy with multi-sheeted Riemann surfaces and that M^4 coordinates are n_1-valued functions and CP_2 coordinates n_2 -valued functions of space-time coordinates for $n = n_1 \times n_2$. These singular coverings of embedding space form a book like structure with singularities of the coverings localizable at the boundaries of causal diamonds defining the back of the book like structure.

Fig. 17. Hierarchy of Planck constants. `http://tgdtheory.fi/appfigures/planckhierarchy.jpg`

A-6.3 $M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix **??**) has changed considerably towards the end 2021 [L110] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \rightarrow m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L110] of the M^8-H duality map takes mass shells $p^2 = m^2$ of $M^4 \subset M^8$ to cds with size $L(m) = \hbar_{eff}/m$ with a common center. The slicing by mass shells is mapped to a Russian doll like slicing by cds. Therefore would be no CDs in M^8 contrary to what I believed first.

Quantum classical correspondence (QCC) inspires the proposal that the point $p^k \in M^8$ is mapped to a geodesic line corresponding to momentum p^k starting from the common center of cds. Its intersection with the opposite boundary of cd with size $L(m)$ defines the image point. This is not yet quite enough to satisfy UP but the additional details [L110] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M^8_c$ (M^8 is complexified to M^8_c) as a "root" of its octonionic continuation [L91, L92]. E_n has an interpretation as energy, which can be complex. The original interpretation was as moment of time. For this interpretation, $M^8 - H$ duality would be a linear identification and these hyper planes would be mapped to hyperplanes in $M^4 \subset H$.

This motivated the term "very special moment in the life of self" for the image of the $E = E_n$ section of $X^4 \subset M^8$ [L75]. This notion does not make sense at the level M^8 anymore.

The modified $M^8 - H$ duality forces us to modify the original interpretation [L110]. The point $(E_n, p = 0)$ is mapped $(t_n = \hbar_{eff}/E_n, 0)$. The momenta (E_n, p) in $E = E_n$ plane are mapped to the boundary of cd and correspond to a continuous time interval at the boundary of CD: "very special moment" becomes a "very special time interval".

The quantum state however corresponds to a set of points corresponding to quark momenta, which belong to a cognitive representation and are therefore algebraic integers in the extension determined by the polynomial. These active points in E_n are mapped to a discrete set at the boundary of cd(m). A "very special moment" is replaced with a sequence of "very special moments".

So called Galois confinement [L97] forces the total momenta for bound states of quarks and antiquarks to be rational integers invariant under Galois group of extension of rationals determined by the polynomial P [L110]. These states correspond to states at boundaries of sub-CDs so that one obtains a hierarchy. Galois confinement provides a universal number theoretic mechanism for the formation of bound states.

A-7 Zero energy ontology (ZEO)

ZEO is implied by the holography forced in the TGD framework by general coordinate invariance.

A-7.1 Basic motivations and ideas of ZEO

The following gives a brief summary of ZEO [L84] [K119].

1. In ZEO quantum states are not 3-dimensional but superpositions of 4-dimensional deterministic time evolutions connecting ordinary initial 3-dimensional states. By holography they are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution. One can say that in the TGD framework general coordinate invariance implies holography and the slight failure of its determinism in turn forces ZEO.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced with a new superposition. Classical determinism of individual time evolution is not violated and this solves the basic paradox of quantum measurement theory. There are two kinds of quantum jumps: ordinary ("big") state function reductions (BSFRs) changing the arrow of time and "small" state function reductions (SSFRs) (weak measurements) preserving it and giving rise to the analog of Zeno effect [L84].

2. To avoid getting totally confused it is good to emphasize some aspects of ZEO.

   (a) ZEO does not mean that physical states in the usual 3-D sense as snapshots of time evolution would have zero energy state pairs defining zero energy states as initial and final states have same conserved quantities such as energy. Conservation implies that one can adopt the conventions that the values of conserved quantities are opposite for these states so that their sum vanishes: one can think that incoming and outgoing particles come from geometric past and future is the picture used in quantum field theories.

   (b) ZEO means two times: subjective time as sequence of quantum jumps and geometric time as space-time coordinate. These times are identifiable but are strongly correlated.

3. In BSFRs the arrow of time is changed and the time evolution in the final state occurs backwards with respect to the time of the external observer. BSFRs can occur in all scales since TGD predicts a hierarchy of effective Planck constants with arbitrarily large values. There is empirical support for BSFRs.

   (a) The findings of Minev et al [L68] in atomic scale can be explained by the same mechanism [L68]. In BSFR a final zero energy state as a superposition of classical deterministic time evolutions emerges and for an observer with a standard arrow of time looks like a superposition of deterministic smooth time evolutions leading to the final state. Interestingly, once this evolution has started, it cannot be stopped unless one changes the stimulus signal inducing the evolution in which case the process does not lead to anywhere: the interpretation would be that BSFR back to the initial state occurs!

(b) Libets' experiments about active aspects of consciousness [J1] can be understood. Subject person raises his finger and neural activity starts before the conscious decision to do so. In the physicalistic framework it is thought to lead to raising of the finger. The problem with the explanation is that the activity beginning .5 seconds earlier seems to be dissipation with a reversed arrow of time: from chaotic and disordered to ordered at around .15 seconds. ZEO explanation is that macroscopic quantum jump occurred and generated a signal proceeding backwards in time and generated neural activity and dissipated to randomness.

(c) Earthquakes involve a strange anomaly: they are preceded by ELF radiation. One would expect that they generate ELF radiation. The identification as BSFR would explain the anomaly [L73]. In biology the reversal of the arrow of time would occur routinely and be a central element of biological self-organization, in particular self-organized quantum criticality (see [L79, L147].

A-7.2 Some implications of ZEO

ZEO has profound implications for understanding self-organization and self-organized quantum criticality in terms of dissipation with non-standard arrow of time looking like generation of structures [L79, L147]. ZEO could also allow understanding of what planned actions - like realizing the experiment under consideration - could be.

1. Second law in the standard sense does not favor - perhaps even not allow - realization of planned actions. ZEO forces a generalization of thermodynamics: dissipation with a non-standard arrow of time for a subsystem would look like self-organization and planned action and its realization.

   Could most if not all planned action be like this - induced by BSFR in the geometric future and only apparently planned? There would be however the experience of planning and realizing induced by the signals from geometric future by a higher level in the hierarchy of conscious entities predicted by TGD! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than agents with completely free will.

2. The notion of magnetic body (MB) serving as a boss of ordinary matter would be central. MB carries dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n serving as a measure for algebraic complexity of extension of rationals as its dimension and defining a kind of universal IQ. There is a hierarchy of these phases and MBs labelled by extension of rationals and the value of n.

   MBs would form a hierarchy of bosses - a realization for master slave hierarchy. Ordinary matter would be at the bottom and its coherent behavior would be induced from quantum coherence at higher levels. BSFR for higher level MB would give rise to what looks like planned actions and experienced as planned action at the lower levels of hierarchy. One could speak of planned actions inducing a cascade of planned actions in shorter time scales and eventually proceeding to atomic level.

A-8 Some notions relevant to TGD inspired consciousness and quantum biology

Below some notions relevant to TGD inspired theory of consciousness and quantum biology.

A-8.1 The notion of magnetic body

Topological field quantization inspires the notion of field body about which magnetic body is especially important example and plays key role in TGD inspired quantum biology and consciousness theory. This is a crucial departure fromt the Maxwellian view. Magnetic body brings in third level to the description of living system as a system interacting strongly with environment. Magnetic body would serve as an intentional agent using biological body as a motor instrument and sensory receptor. EEG would communicated the information from biological body to magnetic body and Libet's findings from time delays of consciousness support this view.

The following pictures illustrate the notion of magnetic body and its dynamics relevant for quantum biology in TGD Universe.

Fig. 18. Magnetic body associated with dipole field. `http://tgdtheory.fi/appfigures/fluxquant.jpg`

Fig. 19. Illustration of the reconnection by magnetic flux loops. `http://tgdtheory.fi/appfigures/reconnect1.jpg`

Fig. 20. Illustration of the reconnection by flux tubes connecting pairs of molecules. `http://tgdtheory.fi/appfigures/reconect2.jpg`

Fig. 21. Flux tube dynamics. a) Reconnection making possible magnetic body to "recognize" the presence of another magnetic body, b) braiding, knotting and linking of flux tubes making possible topological quantum computation, c) contraction of flux tube in phase transition reducing the value of h_{eff} allowing two molecules to find each other in dense molecular soup. `http://tgdtheory.fi/appfigures/fluxtubedynamics.jpg`

A-8.2 Number theoretic entropy and negentropic entanglement

TGD inspired theory of consciousness relies heavily p-Adic norm allows an to define the notion of Shannon entropy for rational probabilities (and even those in algebraic extension of rationals) by replacing the argument of logarithm of probability with its p-adic norm. The resulting entropy can be negative and the interpretation is that number theoretic entanglement entropy defined by this formula for the p-adic prime minimizing its value serves as a measure for conscious information. This negentropy characterizes two-particle system and has nothing to do with the formal negative negentropy assignable to thermodynamic entropy characterizing single particle. Negentropy Maximization Principle (NMP) implies that number theoretic negentropy increases during evolution by quantum jumps. The condition that NMP is consistent with the standard quantum measurement theory requires that negentropic entanglement has a density matrix proportional to unit matrix so that in 2-particle case the entanglement matrix is unitary.

Fig. 22. Schrödinger cat is neither dead or alive. For negentropic entanglement this state would be stable. `http://tgdtheory.fi/appfigures/cat.jpg`

A-8.3 Life as something residing in the intersection of reality and p-adicities

In TGD inspired theory of consciousness p-adic space-time sheets correspond to space-time correlates for thoughts and intentions. The intersections of real and p-adic preferred extremals consist of points whose coordinates are rational or belong to some extension of rational numbers in preferred embedding space coordinates. They would correspond to the intersection of reality and various p-adicities representing the "mind stuff" of Descartes. There is temptation to assign life to the intersection of realities and p-adicities. The discretization of the chart map assigning to real space-time surface its p-adic counterpart would reflect finite cognitive resolution.

At the level of "world of classical worlds" (WCW) the intersection of reality and various p-adicities would correspond to space-time surfaces (or possibly partonic 2-surfaces) representable in terms of rational functions with polynomial coefficients with are rational or belong to algebraic extension of rationals.

The quantum jump replacing real space-time sheet with p-adic one (vice versa) would correspond to a buildup of cognitive representation (realization of intentional action).

Fig. 23. The quantum jump replacing real space-time surface with corresponding p-adic manifold can be interpreted as formation of though, cognitive representation. Its reversal would correspond to a transformation of intention to action. `http://tgdtheory.fi/appfigures/padictoreal.jpg`

A-8.4 Sharing of mental images

The 3-surfaces serving as correlates for sub-selves can topologically condense to disjoint large space-time sheets representing selves. These 3-surfaces can also have flux tube connections and this makes possible entanglement of sub-selves, which unentangled in the resolution defined by the size of sub-selves. The interpretation for this negentropic entanglement would be in terms of sharing of mental images. This would mean that contents of consciousness are not completely private as assumed in neuroscience.

Fig. 24. Sharing of mental images by entanglement of subselves made possible by flux tube connections between topologically condensed space-time sheets associated with mental images. `http://tgdtheory.fi/appfigures/sharing.jpg`

A-8.5 Time mirror mechanism

Zero energy ontology (ZEO) is crucial part of both TGD and TGD inspired consciousness and leads to the understanding of the relationship between geometric time and experience time and how the arrow of psychological time emerges. One of the basic predictions is the possibiity of negative energy signals propagating backwards in geometric time and having the property that entropy basically associated with subjective time grows in reversed direction of geometric time. Negative energy signals inspire time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig.** 24 in the appendix of this book) providing mechanisms of both memory recall, realization of intentational action initiating action already in geometric past, and remote metabolism. What happens that negative energy signal travels to past and is reflected as positive energy signal and returns to the sender. This process works also in the reverse time direction.

Fig. 25. Zero energy ontology allows time mirror mechanism as a mechanism of memory recall. Essentially "seeing" in time direction is in question. `http://tgdtheory.fi/appfigures/timemirror.jpg`

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