The Relationship Between TGD and GRT

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Abstract

In this chapter the recent view about TGD as Poincare invariant theory of gravitation is discussed. Radically new views about ontology were necessary before it was possible to see what had been there all the time. Zero energy ontology states that all physical states have vanishing net quantum numbers. The hierarchy of dark matter identified as macroscopic quantum phases labelled by arbitrarily large values of Planck constant is second aspect of the new ontology.

1. The fate of Equivalence Principle

There seems to be a fundamental obstacles against the existence of a Poincare invariant theory of gravitation related to the notions of inertial and gravitational energy.

a) The conservation laws of inertial energy and momentum assigned to the fundamental action would be exact in this kind of a theory. Gravitational four-momentum can be assigned to the curvature scalar as Noether currents and is thus completely well-defined unlike in GRT. Equivalence Principle requires that inertial and gravitational four-momenta are identical. This is satisfied if curvature scalar defines the fundamental action principle crucial for the definition of quantum TGD. Curvature scalar as a fundamental action is however non-physical and had to be replaced with so called Kähler action.

b) One can question Equivalence Principle because the conservation of gravitational four-momentum seems to fail in cosmological scales.

c) For the extremals of Kähler action the Noether currents associated with curvature scalar are well-defined but non-conserved. Also for vacuum extremals satisfying Einstein's equations gravitational energy momentum is not conserved and non-conservation becomes large for small values of cosmic time. This looks fine but the problem is whether the failure of Equivalence Principle is so serious that it leads to conflict with experimental facts.

It turns out that Equivalence Principle can hold true for elementary particles having so called CP_2 type extremals as space-time correlates and for hadrons having string like objects as space-time correlates. This is more or less enough to have consistency with experimental facts. Equivalence Principle fails for vacuum extremals representing Robertson-Walker cosmologies and for all vacuum extremals representing solutions of Einstein's equations. The failure is very dramatic for string like objects that I have used to call cosmic strings. These failures can be however understood in zero energy ontology.

2. The problem of cosmological constant

A further implication of dark matter hierarchy is that astrophysical systems correspond to stationary states analogous to atoms and do not participate to cosmic expansion in a continuous manner but via discrete quantum phase transitions in which gravitational Planck constant increases. By quantum criticality of these phase transitions critical cosmologies are excellent candidates for the modelling of these transitions. Imbeddable critical cosmologies are unique apart from a parameter determining their duration and represent accelerating cosmic expansion so that there is no need to introduce cosmological constant.

It indeed turns out possible to understand these critical phases in terms of quantum phase transition increasing the size of large modelled in terms of "big" cosmic strings with negative gravitational mass whose repulsive gravitation drives "galactic" cosmic strings with positive gravitational mass to the boundaries of the void. In this framework cosmological constant like parameter does not characterize the density of dark energy but that of dark matter identifiable as quantum phases with large Planck constant.

A further problem is that the naive estimate for the cosmological constant is predicted to be by a factor 10^{120} larger than its value deduced from the accelerated expansion of the Universe. In TGD framework the resolution of the problem comes naturally from the fact that large voids are quantum systems which follow the cosmic expansion only during the quantum critical phases.

p-Adic fractality predicting that cosmological constant is reduced by a power of 2 in phase transitions occurring at times $T(k) \propto 2^{k/2}$, which correspond to p-adic time scales. These phase transitions would naturally correspond to quantum phase transitions increasing the size

of the large voids during which critical cosmology predicting accelerated expansion naturally applies. On the average $\Lambda(k)$ behaves as $1/a^2$, where a is the light-cone proper time. This predicts correctly the order of magnitude for observed value of Λ.

3. Topics of the chapter

The topics discussed in the chapter are following.

a) The relationship between TGD and GRT is discussed applying recent views about the relationship of inertial and gravitational masses, the zero energy ontology, and dark matter hierarchy. One of the basic outcomes is the TGD based understanding of cosmological constant as characterized of dark matter density.

b) The notion of many-sheeted space time interpreted as a hierarchy of smoothed out space-times produced by Nature itself rather than only renormalization group theorist is discussed. The dynamics of what might be called gravitational charges is discussed the basic idea being that the structure of Einstein's tensor automatically implies that metric carries information about sources of the gravitational field without any assumption about variational principle.

c) The theory is applied to the vacuum extremal embeddings of Reissner-Nordström and Schwartschild metric.

d) A model for the final state of a star, which indicates that Z^0 force, presumably created by dark matter, might have an important role in the dynamics of the compact objects. During year 2003, more than decade after the formulation of the model, the discovery of the connection between supernovas and gamma ray bursts provided strong support for the predicted axial magnetic and Z^0 magnetic flux tube structures predicted by the model for the final state of a rotating star. Two years later the interpretation of the predicted long range weak forces as being caused by dark matter emerged.

The recent progress in understanding of hadronic mass calculations has led to the identification of so called super-canonical bosons and their super-counterparts as basic building blocks of hadrons. This notion leads also to a microscopic description of neutron stars and black-holes in terms of highly entangled string like objects in Hagedorn temperature and in very precise sense analogous to gigantic hadrons.

e) There is experimental evidence for gravimagnetic fields in rotating superconductors which are by 20 orders of magnitudes stronger than predicted by general relativity. A TGD based explanation of these observations is discussed.

1 Introduction

In this chapter the recent view about TGD as Poincare invariant theory of gravitation is discussed. It must be admitted that the development of the proper interpretation of the theory has been rather slow and involved rather weird twists motivated by conformist attitudes. Typically these attempts have brought into theory ad hoc identifications of say gravitational four-momentum although theory itself has from very beginning provided completely general formulas.

Perhaps the real problem has been that radically new views about ontology were necessary before it was possible to see what had been there all the time. Zero energy ontology states that all physical states have vanishing net quantum numbers. The hierarchy of dark matter identified as macroscopic quantum phases labelled by arbitrarily large values of Planck constant is second aspect of the new ontology.

1.1 The fate of Equivalence Principle

The motivation for TGD as a Poincare invariant theory of gravitation was that the notion of four-momentum is poorly defined in curved space-time since corresponding Noether currents do not exist. There however seems to be a fundamental obstacles against the existence of a Poincare invariant theory of gravitation related to the notions of inertial and gravitational energy.

1. The conservation laws of inertial energy and momentum assigned to the fundamental action would be exact in this kind of a theory. Gravitational four-momentum can be assigned to the curvature scalar as Noether currents and is thus completely well-defined unlike in GRT. Equivalence Principle requires that inertial and gravitational four-momenta are identical. This is satisfied if curvature scalar defines the fundamental action principle crucial for the definition of quantum TGD. Curvature scalar as a fundamental action is however non-physical and had to be replaced with so called Kähler action.

2. One can question Equivalence Principle because the conservation of gravitational four-momentum seems to fail in cosmological scales. It must be however emphasized that here zero energy ontology implying that the notions of inertial and four-momenta are length scale dependent concepts could change the situation.

3. For the extremals of Kähler action the Noether currents associated with curvature scalar are well-defined but non-conserved. Also for vacuum extremals satisfying Einstein's equations gravitational energy momentum is not conserved and non-conservation becomes large for small values of cosmic time. This looks fine but the problem is whether the failure of Equivalence Principle is so serious that it leads to conflict with experimental facts.

The failure of Equivalence Principle was something which I could not take seriously and I ended up with a long series of ad hoc constructs trying to save Equivalence Principle instead of trying to characterize the failure, to find out whether it has catastrophic consequences, and to relate it to the recent problems of cosmology, in particular the necessity to postulate somewhat mysterious dark energy characterized by cosmological constant. The irony was that all this was possible since TGD allows to define both inertial and gravitational four-momenta and generalized gravitational charges assignable to isometries of $M^4 \times CP_2$ precisely.

It indeed turns out that Equivalence Principle can hold true for elementary particles having so called CP_2 type extremals as space-time correlates and for hadrons having string like objects as space-time correlates. This is more or less enough to have consistency with experimental facts. Equivalence Principle fails for vacuum extremals representing Robertson-Walker cosmologies and for all vacuum extremals representing solutions of Einstein's equations. The failure is very dramatic for string like objects that I have used to call cosmic strings. These failures can be however understood in zero energy ontology.

1.2 Zero energy ontology

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 [C1, D3] indeed leads naturally to zero energy ontology 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 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.

The concept of negative potential energy is completely standard notion in physics. Perhaps so standard that physicists have begun to regard it as understood. The precise physical origin of the negative potential energy is however complete mystery, and one is forced to take the potential energy as a purely phenomenological concept deriving from quantum theory as an effective description.

In TGD framework topological field quantization leads to the hypothesis that quantum concepts should have geometric counterparts and also potential energy should have precise correlate at the level of description based on topological field quanta. This indeed seems to be the case. As already explained, TGD allows space-time sheets to have both positive and negative time orientations. This in turn implies that also the sign of energy can be also negative. This suggests that the generation of negative energy space-time sheets representing virtual gravitons together with energy conservation makes possible the generation of huge gravitationally induced kinetic energies and gravitational collapse. In this process inertial energy would be conserved since instead, of positive energy gravitons, the inertial energy would go to the energy of matter.

This picture has direct correlate in quantum field theory where the exchange negative energy virtual bosons gives rise to the interaction potential. The gravitational red-shift of microwave background photons is the strongest support for the non-conservation of energy in General Relativity. In TGD it could have concrete explanation in terms of absorption of negative energy virtual gravitons by photons leading to gradual reduction of their energies. This explanation is consistent with the classical geometry based explanation of the red-shift based on the stretching of electromagnetic wave lengths. This explanation is also consistent with the intuition based on Feynman diagram description of gravitational acceleration in terms of graviton exchanges.

1.3 Dark matter hierarchy and hierarchy of Planck constants

The idea about hierarchy of Planck constants relying on generalization of the imbedding 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 [19] have space-time correlates [C8, C9]. There is a canonical hierarchy of Jones inclusions labelled by finite subgroups of SU(2)[18] This leads to a generalization of the imbedding 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 imbedding 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 axies. Entire configuration space is union over "books" corresponding to various choices of this sub-manifold.

The groups in question define in a natural manner 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 [C9]. 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 [C9]. 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 [C9, J1] and recently reported strange properties of graphene [45]. Also the tedrahedral and icosahedral symmetries of water molecule clusters could have similar interpretation [51, F9].

A further fascinating possibility is that the observed indications for Bohr orbit quantization of planetary orbits [52] could have interpretation in terms of gigantic Planck constant for underlying dark matter [D7] so that macroscopic and -temporal quantum coherence would be possible in astrophysical length scales manifesting itself in many manners: 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. Note that in the structure of chromosomes p-adic length scale $L(151) \simeq 10$ characterizes beads-on-string structure of DNA whereas the length scale $3L(151)$ appears in the coiling of this structure.

1.4 The problem of cosmological constant

A further implication of dark matter hierarchy is that astrophysical systems correspond to stationary states analogous to atoms and do not participate to cosmic expansion in a continuous manner but via discrete quantum phase transitions in which gravitational Planck constant increases. By quantum criticality of these phase transitions critical cosmologies are excellent candidates for the modelling of these transitions. Imbeddable critical cosmologies are unique apart from a parameter determining their duration and represent accelerating cosmic expansion so that there is no need to introduce cosmological constant.

It indeed turns out possible to understand these critical phases in terms of quantum phase transition increasing the size of large modelled in terms of "big" cosmic strings with negative gravitational mass whose repulsive gravitation drives "galactic" cosmic strings with positive gravitational mass to the boundaries of the void. In this framework cosmological constant like parameter does not characterize the density of dark energy but that of dark matter identifiable as quantum phases with large Planck constant.

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1.5 Topics of the chapter

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1. The relationship between TGD and GRT is discussed applying recent views about the relationship of inertial and gravitational masses, the zero energy ontology, and dark matter hierarchy. One of the basic outcomes is the TGD based understanding of cosmological constant as characterized of dark matter density.

2. The notion of many-sheeted space time interpreted as a hierarchy of smoothed out space-times produced by Nature itself rather than only renormalization group theorist is discussed. the basic idea being that the structure of Einstein's tensor automatically implies that metric carries information about sources of the gravitational field without any assumption about variational principle.

3. The theory is applied to the vacuum extremal embeddings of Reissner-Nordström and Schwartschild metric.

4. A model for the final state of a star, which indicates that Z^0 force, presumably created by dark matter, might have an important role in the dynamics of the compact objects. During year 2003, more than decade after the formulation of the model, the discovery of the connection between supernovas and gamma ray bursts [26] provided strong support for the predicted axial magnetic and Z^0 magnetic flux tube structures predicted by the model for the final state of a rotating star. Two years later the interpretation of the predicted long range weak forces as being caused by dark matter emerged.

The recent progress in understanding of hadronic mass calculations [F4] has led to the identification of so called super-canonical bosons and their super-counterparts as basic building blocks of hadrons. This notion leads also to a microscopic description of neutron stars and black-holes in terms of highly entangled string like objects in Hagedorn temperature and in very precise sense analogous to gigantic hadrons.

2 TGD and GRT descriptions of space-time

The absolute minimization of Kähler action does not imply Einstein's equations and the original attempt to understand GRT was as a long length scale limit of TGD for which GRT space-time is kind of quantum average space-time obtained by smoothing out topological non-homogenities representing particles and various structures and describing their presence using various kinds of currents.

An improved picture is based on the new view about energy, the idea that many-sheeted space-time in some sense takes care of the smoothing out procedure itself by providing a hierarchy of smoothed out dynamics, and the realization that Einstein's equations are to some degree a basic property of Riemann geometry rather than something implied by a variational principle. The essential point is that Einstein tensor is obtained by applying a non-linear wave operator to the metric so that topologically condensed space-time sheets act naturally as the sources of metric. This interpretation makes sense also in GRT where one can *define* energy momentum tensor as source of the gravitational field defined by the induced metric by identifying it as Einstein tensor.

2.1 Many-sheeted space-time defines a hierarchy of smoothed out space-times

The notion of quantum average space-time obtained by smoothing out details below the scale of resolution was inspired by renormalization philosophy and for long time I regarded it as a fictive concept. The rough idea was that quantum average effective space-times correspond to the absolute minima 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 is 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. 2.1). 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.

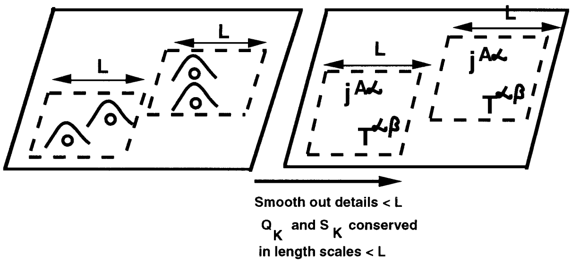

Figure 1: Intuitive definition of length scale dependent space-time

During development of the many-sheeted space-time concept it has become obvious that the notions of classical space-time and of smoothing out of details are not only activities 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 labelled 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 absolute minimum value for 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. Since the dynamics of the induced EYM fields is dictated by the absolute minimization of Kähler action, EYM equations cannot in general be satisfied 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.

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 [C8, C9]. 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 [C3].

5. Dark matter hierarchy whose levels are labelled by the values of Planck constant brings in an additional complication [C9, C3, D3]. Planck constant actually labels the "field bodies" mediating various interactions and gravitational field bodies have a gigantic value of Planck constant.

   The realization of this hierarchy at the level of imbedding space means the replacement of the imbedding space with a book like structure whose pages are copies of imbedding 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.

   The choice of these discrete subgroups realizes the choice of angular momentum and color quantization axes at the level of imbedding 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.

   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.

2.2 The dynamics of "gravitational" charges as dynamics without variational principle

The idea is that the dynamics of topologically condensed matter is about the evolution of "gravitational" counterparts of various currents assignable to Einstein-Yang-Mills (EYM) action with topologically condensed space-time sheets defining naturally their sources. This dynamics does not require any variational principle since Einstein tensor has naturally topologically condensed space-time sheets as its sources. Same applies to the induced YM fields since formally they can be regarded as solutions of YM equations with sources defined by the divergence of field tensor and topologically condensed space-time sheets serve naturally as this kind of sources. The identification of Einstein tensor with energy momentum tensor of YM fields is not implied by this picture.

1. The space-time sheet is a preferred extremal of Kähler action (absolute minimum or a more general preferred extremal [E2]) and classical electro-weak and color fields are determined by this dynamics. The energy momentum tensor of Kähler action characterizes the net four-momentum density. The dynamics of the induced spinor fields is the super-symmetric counterpart of Kähler action and thus corresponds to the "inertial sector" of the theory. The fundamental role of the induced spinor fields in quantum theory suggests the same. That induced Kähler field and induced spinor field do not directly correspond to change or difference of any quantum number and are not directly observable would conform with their "inertial" character.

2. The divergences of classical YM fields are non-vanishing in general and define non-conserved vacuum gauge currents. Also the net divergences of other contributions to the energy momentum tensor must vanish and this gives to the analogs of hydrodynamical equations.

3. This interpretation does not allow to understand why long range gauge fields are present since standard model predicts that gauge fields created by ordinary particles vanish above weak length scale. The identification of these fields is as fields generated by dark matter, this notion understood in a very general sense [A1, A2]. Weak fields behave like massless fields below the p-adic length scale determining the size scale of the space-time sheets of weak bosons and are vacuum screened above this length scale in the sense that they do not feed appreciable gauge fluxes to larger space-time sheets: the weak screening occurs in # contacts modellable using CP_2 type extremals. The causal horizon associated with a # contact behaves as a bound pair of dark partons being partially responsible for these long range forces. As a matter fact, gauge bosons are identifiable as wormhole contacts. Color confinement has the same effect on the color gauge fields as weak vacuum screening.

4. The currents associated with isometries and holonomies are in different position in this description. Poincare currents and color currents can be assigned both to Einstein tensor and to the energy momentum tensor of Kähler action so that they have both inertial and gravitational variants. Electro-weak currents have only gravitational counterparts assignable to the induced electro-weak gauge fields. The induced color gauge field has Abelian holonomy quite generally and is proportional to the induced Kähler form and vanishes identically for vacuum extremals. This is consistent with color confinement in the sense that asymptotic states are color singlets. On the other hand, the vacuum extremals extremizing curvature scalar belong to $M^4 \times S^2$, S^2 homologically trivial geodesic sphere and color charges defined by Einstein tensor belong $SO(3)$ subgroup of $SU(3)$: hence it is not clear whether gravitational

color gauge charges vanish. If not, then one would have failure of Equivalence Principle for color charges.

A more formal prescription goes as follows:

1. The effective action describes the presence of matter using YM currents, particle densities, cosmic strings, etc.. and can be assumed to contain Einstein Yang Mills action for the induced gauge fields plus matter currents. Energy momentum tensor can contain also a hydrodynamics part: typical example comes from cosmology. Not only classical electromagnetic and Z^0 fields but also $W^{\pm}$ and color gauge fields can appear as classical fields in macroscopic length scales. For vacuum extremals which are extremals of curvature scalar classical color gauge fields vanish and electro-weak gauge field is Abelian.

2. For YM fields the interaction term is just the external YM current multiplied with YM gauge potential. For the metric the corresponding term is the trace of energy momentum tensor. This assumption implies the addition of the various interaction terms to the EYM action density

$$\begin{aligned} L_{EYM} &\rightarrow L_{EYM} \\ &+ \sum_a Tr(J^{\alpha}_{a\#} A_{a\alpha}) \\ &+ T^{\alpha\beta}_{\#} g_{\alpha\beta} \quad . \end{aligned} \tag{1}$$

   The YM currents associated with topologically condensed matter are denoted by $J^{\alpha}_{a\#}$, where 'a' refers to a specific component of YM field. The corresponding energy momentum tensor is denoted by $T^{\alpha\beta}_{\#}$.

3. L can be decomposed into a sum of terms corresponding to color and electro-weak interactions and gravitational interaction:

$$L_{EYM} = L_{ew} + L_c + L_{gr} \quad . \tag{2}$$

   The couplings associated with the various actions depend on the length scale considered. For Kähler function, the space-time associated with a given 3- surface is fixed by the requirement that it corresponds to an absolute minimum of the Kähler action. For the maxima of Kähler function also the extremization with respect to X^3 degrees of freedom is performed. This procedure is the same as applied usually, when finding the physically interesting solutions of the effective action. It must be emphasized that the spin glass nature of the TGD Universe might imply complications.

4. Field equations are solved by taking YM equations and Einstein's equations as *definitions* of the source densities associated with various particle types. The remaining field equations are then those describing the motion of the topologically condensed matter and are identically satisfied. One cannot however identify Einstein tensor with the energy momentum tensor of YM fields.

Consider now the general features of this scenario.

1. That the absolute minimization of Kähler action defines the fundamental dynamics means an enormous simplification at the level of principle. For instance, for the topologically condensed cosmic strings the exterior space-time can be regarded as a small deformation of a vacuum extremal which is also an extremal of curvature scalar. For $g > 1$ cosmic string in the center of the void the predicted gravitational field is analogous to the "anti-gravitational" field of a straight string with a negative gravitational string tension in Newtonian approximation. This repulsive force drives $g = 0$ cosmic strings to the boundary of the void. GRT based model predicts flat metric with an angular defect.

2. For sufficiently long length scales the average density of inertial energy vanishes so that the vacuum extremals of the Kähler action should become important. The proposed model for inhomogeneous cosmology leads to the conclusion that the length scale, where vacuum extremals of Kähler action apply is the length scale, at which the density of purely gravitational energy of cosmic strings having no inertial counterpart vanishes . This length scale is estimated to be about the size scale 10^8 light years of large voids at present.

3. The study of the imbeddings of various metrics shows that massive objects are in general accompanied by long range electro-weak fields. Electromagnetic and Z^0 fields are the most plausible candidates, which means that dark gluons and electro-weak bosons with arbitrary small mass scales but not coupling to ordinary matter are predicted.

2.3 Equivalence Principle in TGD framework

How the principle selecting preferred extremals of Kähler action as generalized Bohr orbits can be consistent with Einstein's equations? The energy-momentum tensor of Kähler action is certainly not proportional to the Einstein tensor. Equivalence Principle encourages the identification of the inertial energy with gravitational energy. It however seems obvious that the exact conservation of inertial energy cannot be consistent with the non-conservation of gravitational energy defined by the Einstein tensor.

2.3.1 What Equivalence Principle means?

Basically the problem is about the relationship between inertial and gravitational four-momenta. The real achievement at the level of formal rigor is that inertial and gravitational four-momenta and their generalizations color quantum numbers are well-defined as Noether charges associated with curvature scalar. The most general option is that cosmological constant and gravitational constant are by definition chosen so that gravitational and inertial four-momenta are identical. It however seems un-necssary to introduce cosmological constant and also it seems that one must accept failure of Equivalence Principle although it does not occur for ordinary matter. For instance, string like objects which are vacuum extremals but have gigantic gravitational mass are possible.

Here one must however be very cautious. It is asymptotic behavior of gravitational field created by topologically condensed space-time sheet which matters experimentally, and it is not at all clear under what conditions the mass parameter characterizing the gravitational field equals to the gravitational mass of the space-time sheet defined by Einstein tensor. The reason is that one does not anymore have Einstein's field equations which in linear approximation identify energy momentum tensor as the source of gravitational field.

On the other hand, the covariant divergence of Einstein tensor vanishes and the components of Einstein tensor are essentially what one obtains by applying d'Alembert type operator on components of metric. Hence it is natural to regard topologically condensed space-time sheets as sources of the gravitational field defined by the metric. If these sources corresponds to gravitational charges of the topologically condensed space-time sheets then there are good hopes of obtaining Equivalence Principle at the level of asymptotic behavior of the metric. That pseudo-Riemannian geometry codes for the dynamics of gravitational field without any variational principle is something which is highly non-trivial and means that Einstein's equations derived from EYM action are only a manner to state Equivalence Principle.

The are good reasons to expect that small deformations of vacuum extremals, which are extremals of curvature scalar define in the stationary situation exterior metrics. Field equations state in this kind of situation the conservation of various kinds of gravitational charges. For the simplest exterior metrics one can indeed cast the conservation laws in a form in which one has Einstein tensor at the left hand side of field equations and a term depending on geometric data at the right hand side. The optimistic conjecture is that this more generally is the case but - as noticed - this is not necessary for the realization of Equivalence Principle in the sense of asymptotic behavior.

2.3.2 Is Equivalence Principle satisfied at elementary particle level?

Years later it is easy to ask whether one should accept as a fact that inertial and gravitational four-momenta are different in general. The non-conservation of gravitational four-momentum indeed conforms with experimental facts at the level of cosmology.

TGD predicts gravitational constant as the ratio of gravitational and inertial energies and the quantum expectation value of this ratio is expected to depend on quantum state. This raises the possibility that Equivalence Principle holds true for elementary particles and hadrons and also in the sense of asymptotic behavior of gravitational field.

Topologically condensed CP_2 type vacuum extremals define a model for elementary particle. Their gravitational four-momentum is non-vanishing, light-like, and non-conserved. For free CP_2 type extremal the inertial four-momentum vanishes since Kähler currents vanish in M^4 degrees of freedom. In topological condensation CP_2 type vacuum extremal is however necessarily deformed to non-vacuum extremal. The induced four-metric becomes degenerate at the light-like wormhole throat(s) in the case of fermions (gauge bosons) since the Euclidian signature of metric is changed to Minkowskian one.

The random zitterwebegung of CP_2 type vacuum extremal with light velocity allows to understand the massivation of fermions in terms of p-adic thermodynamics whereas in the case of gauge bosons the dominating contribution comes from Higgs mechanism. If the ratio of the gravitational and inertial masses for CP_2 type extremals is constant, Equivalence Principle for elementary particles follows.

This is not quite enough in the recent picture for hadrons in which hadrons corresponds to string like objects $X^2 \times Y^2 \subset M^4 \times CP_2$, X^2 string orbit in M^4 and Y^2 a complex sub-manifold of CP_2 with genus $g = 1$. The reason for $g = 1$ is that for $g \neq 1$ the gravitational mass string tension is gigantic and negative for $g > 1$. If one assumes that the super-canonical quanta - also deformations of CP_2 type vacuum extremals - are responsible for most of proton mass describable at space-time level in terms of hadronic string tension Equivalence Principle for hadrons follows.

Thus one can say that Equivalence Principle is true if all particles which correspond to CP_2 type vacuum extremals have same inertial to gravitational four-momentum ratio and previous conjectures hold true.

This might be all that is needed and the failure of Equivalence Principle might help to resolve some basic difficulties of recent day cosmology and get rid of cosmological constant.

1. The problem of cosmological constant is the most acute problem of cosmologies based on GRT and string models. The recent experimental discovery of accelerated cosmic expansion supports the view that cosmological constant might be non-vanishing. What happens in TGD framework is not quite obvious.

2. Critical cosmologies are almost unique from the mere existence of the imbedding to $M^4 \times CP_2$. They predict accelerated cosmic expansion. If one accepts the hierarchy of dark matters

as macroscopic quantum phases labelled by arbitrarily large values of gravitational Planck constant, one could interpret the critical cosmologies as space-time correlates for quantum phase transitions. The interpretation as quantum phase transitions increasing the size of large void is especially attractive. There would be no need to introduce genuine cosmological constant and by criticality Λ would characterize the density of dark matter identified as quantum phases with large value of Planck constant rather that that for dark energy.

One can also represent arguments in favor of genuine cosmological constant.

1. Equivalence Principle for the entire four-momentum rather than energy or rest mass mass might require both G and Λ. For string like objects carrying Kähler magnetic field one must indeed introduce both G and Λ since T_K is traceless whereas G has a non-vanishing trace. If one restricts the consideration to exterior metric and requires that it carries only information about gravitational energy, the situation changes.

2. If Einstein's equations emerge as structural equations in TGD, the finite size of space-time sheets could allow a non-vanishing cosmological constant also in TGD. My personal strong belief has been that cosmological constant vanishes and the justification has been that the action with a cosmological constant is unbounded. Unfortunately, the situation changes if Einstein's equations are not derivable from action but are structural equations. Note also that if space-time sheets have a finite temporal extension as in zero energy ontology the volume term in action becomes finite. Hence cosmological constant cannot be excluded.

2.3.3 What it means that Robertson-Walker cosmologies correspond to vacuum extremals?

Robertson-Walker cosmologies are imbeddable into $H = M^4_+ \times CP_2$ but they are vacua with respect to the inertial energy. In zero energy cosmology this does not seem to be such a bad problem since in a given time scale physical states characterized by shorter temporal temporal distance between positive and negative energy parts of the state do not contribute the quantum numbers of the state. At the limit of infinite time scale naturally associated with cosmology one obtains vacuum extremals naturally.

The physical space-times could well be small deformations of vacuum extremals and this is indeed what mathematical consistency requires. The purely gravitational four-momentum of vacuum extremals can correspond to the inertial four-momentum of topologically condensed space-time sheets at the limit when they are idealized with point-like structures.

2.3.4 Can one predict the value of gravitational constant?

A lot remains to be understood. The value of gravitational constant is one important example in this respect. For a given space-time sheet defined as a preferred extremal of Kähler action one can in principle calculate the value of G_{class}. Physical gravitational constant G is however expected to quantum average of G_{class} for a given quantum state.

For years ago I found a nice formula relating G to CP_2 length scale, the p-adic prime p characterizing gravitons and equal to M_{127} in the case of ordinary graviton, and Kähler coupling strength [C5, D3]. Quantum formula is in question since the exponent for the Kähler action for CP_2 type vacuum extremals appears in it. The task would be to calculate explicitly the G_{class} and its quantum expectation value.

What seems clear is that G is state dependent. For instance, for quantum states concentrated around almost vacuum extremals (such as hadronic strings) G should be large since they are almost Kähler vacua and the model for hadrons indeed leads to the identification of strong gravitons with G_{strong} characterized by corresponding p-adic length scale.

One can write the basic hypothesis for the relationship between Kähler coupling strength, CP_2 size R and gravitational constant G [C5, D3] as

$$\frac{exp(-2S_K(CP_2))}{G(p)} = \frac{1}{pR^2} \quad . \tag{3}$$

$S_K(CP_2)$ is Kähler action for CP_2 type vacuum extremals with small renormalization reflecting the fact that entire free CP_2 type extremal is not in question topological condensation. The two sides of this equation suggest an interpretation in terms of two thermodynamics. The vacuum functional defined by Kähler function would define the thermodynamics of the left hand side and Planck mass $M_{Pl}(p) = 1/\sqrt{G(p)}$ defining the fundamental mass equal to Planck mass for $p = M_{127}$ but depending on p as $1/\sqrt{p}$. Right hand side would correspond to p-adic thermodynamics with CP_2 mass $M_{CP_2} = 1/R$ defining the fundamental mass in this case. Thus the formula could be interpreted as stating as equivalence of two different approaches to the calculation of particle masses.

2.4 Equivalence Principle and zero energy ontology

The hypothesis that space-times are 4-D surfaces of a higher-dimensional space-time of form $H = M^4 \times S$ resolves the problem: since Poincare symmetries become symmetries of H rather than space-time itself. Inertial four-momentum can be defined as a conserved Noether charge and also gravitational four-momentum can be regarded as a Noether charge albeit non-conserved. Equivalence Principle can hold true only under some additional conditions. For instance, for the imbeddings of Robertson-Walker cosmologies inertial four-momentum density vanishes unlike gravitational four-momentum density, which for a long time remained quite a mystery. The real understanding of the situation became possible only after the introduction of what I call zero energy ontology [C2].

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. Equivalence Principle is expected to hold true for elementary particles and their composites but not for the quantum states defined around non-vacuum extremals.

More precisely, the inertial four-momentum assignable to the 3-D Chern-Simons action is non-vanishing only if one adds to the CP$_2$ Kähler form a pure gauge part $A_a = constant$, where a denotes light cone proper time [B4]. A breaking of Poincare invariance is implied which is however compensated by the fact that configuration space corresponds to the union of configuration spaces associated with future and past directed light-cones. If the vacuum extremal is also an extremal of the curvature scalar, gravitational four-momentum is conserved.

In the case of CP_2 type vacuum extremal gravitational stationarity transforms the M^4 projection of the extremal from a random light-like curve to a light-like geodesic allowing an interpretation as incoming or outgoing on mass shell particle. General vacuum extremal corresponds to a virtual particle. At the classical level Equivalence Principle requires that the light-like gravitational four-momentum of CP_2 vacuum extremal co-incides with the light-like inertial four-momentum associated with Chern-Simons action in this situation. This condition relates the value of A_a to gravitational constant G and CP_2 radius R. G would thus appear as a fundamental constant and quantum criticality should dictate the ratio G/R^2. The topologically condensed CP_2 type vacuum extremal necessarily creates a non-vacuum region around it and the resulting inertial four-momentum corresponds to the gravitational four-momentum.

The strong form of Equivalence Principle would require that the classical 4-momentum associated with Kähler action of allowed small deformations co-incides with the conserved gravitational four-momentum of the vacuum extremal extremizing curvature scalar: this might have a natural interpretation in terms of Bohr orbitology but is not be consistent with zero energy ontology inspired picture unless one has double sheeted structure with sheets possessing opposite energies such that double sheeted structure is approximated by single sheet with Robertson-Walker cosmology in GRT framework. The identification of gauge bosons as wormhole contacts and gravitons as pairs of wormhole contacts supports double sheeted structure with sheets possessing opposite arrows of geometric time. Near the vicinity of wormhole contacts (pieces of CP_2 type vacuum extremals) the sheets which are originally vacuum extremals are deformed to non-vacuum extremals and carry inertial four-momentum which should be equal to the gravitational four momentum of the vacuum extremal.

2.5 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 energy.

2.5.1 Zero energy ontology and cosmic strings

There are two kinds of cosmic strings: free and topological condensed ones.

1. Free cosmic strings are not absolute minima of the Kähler action (the action has wrong sign). $P3$ would favor cosmic strings and also their electric duals if they exist. Since the magnetic field of cosmic string corresponds to CP_2 degrees of freedom with Euclidian signature electric duals do not probably exist.

2. 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 mechanism need not be local.

The most convincing cancelation mechanism relies on zero energy ontology. If the sign of the Kähler action depends on time orientation it would be opposite for positive and negative energy space-time sheets and the actions associated with them would cancel if the field configurations are identical. Hence zero energy states would naturally have small Kähler action. Obviously this mechanism is non-local.

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.

The earlier picture was based on dynamical cancellation mechanism involving generation of strong Kähler electric fields in the condensation whose action compensated for Kähler magnetic action [17].

2.5.2 Failure of Equivalence Principle for cosmic strings

The empirical fact is that inertial 4-momentum is conserved whereas gravitational momentum is not. This suggests that inertial momentum corresponds to Noether charge associated with Kähler action and gravitational momentum to that associated with curvature scalar for the induced metric. This means that Equivalence Principle does not hold true in general. A detailed analysis demonstrates that Equivalence Principle can remain intact for elementary particles and light string like objects such has hadrons.

For string like objects of form $X^2 \times Y^2 \subset M^4 \times CP_2$, X^2 orbit or string and Y^2 holomorphic surface of CP_2, gravitational mass contains very large contribution coming from the curvature of Y^2 when the genus of Y^2 is different from $g = 1$. For sphere the gravitational string tension is positive and equal to $T_{gr} = dM/dl = 1/4G$. The angle defect would be 2π for the standard almost everywhere flat exterior metric so that it does not make sense. It is however possible to find exterior metric as an extremal of curvature scalar conforming with Newtonian intuition. For $g > 1$ the string tension is $(1 - g)/4G$ and negative for $g > 1$. In this case angle deficit is transformed to angle excess $(g - 1)2\pi > 2\pi$, which make sense also in case of flat exterior metric which however as such is not imbeddable to $M^4 \times CP_2$.

Topological condensation creates wormhole contacts having interpretation as gauge bosons which contribute to gravitational string tension. The natural assumption is that this contribution has the string tension due to Kähler action as a space-time correlate. Thus Equivalence Principle holds for $g = 1$ but not for $g \neq 1$ which corresponds to purely gravitational energy having no inertial counterpart.

It is however possible that in sufficiently long length scales the gravitational energies of $g > 1$ and and $g \leq 1$ strings sum up to zero so that cosmic strings would make them effectively invisible and Equivalence Principle would hold true. This could happen in length scales longer than the size $L \sim 10^8$ ly of large voids [34].

2.5.3 Topological condensation of cosmic strings

1. Exterior metrics of topologically condensed $g > 1$ strings

If the sign of the gravitational string tension is negative the simple imbedding of the metric existing for positive string tension ceases to exist. There exists however a different imbedding for which angle excess is in a good approximation same as for the flat solution. The solution is not flat anymore and this implies outwards radial gravitational acceleration. The imbedding of the exterior metric also fails beyond a critical radius. This is not the only possible exterior metric: also non-flat exterior metric are possible and look actually more plausible and also this metric implies radial outwards acceleration as one might indeed expect. What remains to be shown that these metrics do not only yield small angle defect but are also consistent with Newtonian intuitions as the constant velocity spectrum for distant stars around galaxies suggests.

The natural interpretation would be as a mechanism generating large void around a central cosmic string having $g > 1$ and negative string tension and containing at its boundary $g = 1$ positive energy cosmic strings with string tension equal to Kähler string tension. Since angle surplus instead of angle deficit is predicted for $g > 1$ strings, lense effect transforms in this case to angle divergence and one avoids the basic objection against big cosmic strings. The emergence of preferred axes defined by $g > 1$ strings in the scale of large void could relate to the anomalies observed in Cosmic Microwave Background.

Negative gravitational energy of $g > 1$ cosmic strings could be regarded as that part of gravitational energy which causes the accelerated cosmic expansion by driving galactic strings to the boundaries of large voids which then induces phase transition increasing the size of the voids. This kind of acceleration is encountered already at the level of Newton's equations when some of the gravitational masses are negative.

2. Exterior metrics of topologically condensed $g = 1$ strings

One cannot assume that the exterior metric of the galactic $g = 1$ strings is the one predicted by assuming $G = 0$ 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. This lensing has not been observed.

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.

2.5.4 Dark energy is replaced with dark matter in TGD framework

The first thing that comes in mind is that negative gravitational energy could be the TGD counterpart for the positive dark vacuum energy known to dominate over the mass density in cosmological length scales and believed to cause the accelerated cosmic expansion. This argument is wrong.

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. 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.

2. The essential characteristic of dark energy is its negative pressure. Negative gravitational energy could effectively create this negative pressure during phase transitions increasing the size of large voids. Since negative gravitational mass would be basically responsible for the accelerated expansion, one can assume that dark energy is actually dark matter.

3. Note that the pressure is negative during critical period. This is however interpreted as a correlate for the expansion caused by the phase transition increasing Planck constant rather than being due to positive cosmological constant or quintessence with negative pressure.

2.5.5 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 negative pressure now. 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 naive 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.

Classically one can understand the occurrence of the phase transitions increasing the size of the void as resulting when the galactic strings end up to the boundary of the large void in the repulsive gravitational field of the big string.

2.5.6 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 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. The key observation is that vacuum extremals as such are not physically acceptable: small deformations of vacuum extremals to non-vacua are required. The simplest deformation of this kind would induce a radial Kähler electric field and thus 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.

3 Imbedding of the Reissner-Nordström metric

In the following the imbedding of electromagnetically neutral Reissner-Nordström metric to $M^4_+ \times CP_2$ will be studied. The imbedding generalizes to an imbedding of any spherically symmetric metric. The imbeddings as vacuum extremals reduce to imbeddings into 6-dimensional $M^4 \times Y^2$, Y^2 Lagrange manifold (vanishing induced Kähler form). Any vacuum extremal defines a solution of Einstein's equations if energy momentum tensor is defined by Einstein's equations. Non-vacuum imbeddings of Reissner-Nordström solutions would correspond to homologically non-trivial geodesic sphere of CP_2, and it is implausible that non-vacuum imbeddings could be extremals. Whether the imbeddings of the metrics believed to describe rotating objects in GRT Universe are possible at all, is not known but it might well be that the dimension of the imbedding space is too low to allow them. This would mean that the predictions of TGD concerning gravi-magnetism can differ from those of GRT.

3.1 Two basic types of imbeddings

One can construct a large number of imbeddings for Reissner-Nordström metric. These imbeddings need not be extremals of Kähler action except when they are represent vacua.

1. X^4 could be a sub-manifold of $M^4 \times S_i^2$, $i = I, II$, where S_i^2 is one of the geodesic spheres of CP_2. For $i = II$ the imbeddings are vacuum extremals but this is not the case for $i = I$. The properties of these imbeddings are essentially those associated with the spherically symmetric stationary extremals of the Kähler action. Long range electromagnetic and Z^0 fields assignable to dark matter [A1, A2, F6] are present but the corresponding forces are by a factor 10^{-4} weaker than gravitational force, when the parameter ωR is of order one.

2. The vacuum extremals of the Kähler action are the physically most interesting candidates for the imbeddings of solutions of Einstein's equations. For these imbeddings electro-weak fields are in general non-vanishing. Em neutrality is possible to achieve only for $p = sin^2(\theta_W) = 0$. Long ranged W^+ and W^- fields can be present and they induce a small mixing between charged dark lepton and corresponding neutrino spinors.

3.2 The condition guaranteing the vanishing of em, Z^0, or Kähler fields

In order to obtain imbedding with vanishing em, Z^0, or Kähler field, one must pose the condition guaranteing the vanishing of corresponding field (see the Appendix of the book). For extremals of Kähler action em Z^0 fields are always simultaneously present unless Weinberg angle vanishes. In practice only the condition guaranteing vanishing of Kähler field is thus interesting.

Using coordinates $(r, u = cos(\Theta), \Psi, \Phi)$ for CP_2 the surfaces in question can be expressed as

$$\begin{aligned}
r &= \sqrt{\frac{X}{1-X}} \ , \\
X &= D|k+u|^{\epsilon} \ , \\
u &\equiv cos(\Theta) \ , \ D = \frac{r_0^2}{1+r_0^2} \times \frac{1}{C} \ , \quad C = |k + cos(\Theta_0)|^{\epsilon} \ .
\end{aligned} \tag{4}$$

Here C and D are integration constants. The value of the parameter ϵ characterizes which field vanishes:

$$\begin{aligned}
a) \ \epsilon = \tfrac{3+p}{3+2p} \ , \quad b) \ \epsilon = \tfrac{1}{2} \ , \quad c) \ \epsilon = 1 \ , \\
p = sin^2(\Theta_W) \ .
\end{aligned} \tag{5}$$

Here a/b/c corresponds to the vanishing of em/Z^0/Kähler field.

$0 \leq X \leq 1$ 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 $|u + k| = [(1 + r_0^2)/r_0^2)]^{\epsilon}$ achieved only for

$$sign(u+k) \times [\frac{1+r_0^2}{r_0^2}]^{\epsilon} \leq k+1 \ ,$$

where $sign(x)$ denotes the sign of x.

These imbeddings obviously possess a 2-dimensional CP_2 projection. The generation of long range vacuum weak and color electric fields is a purely TGD based phenomenon related to the fact that gauge fields are not primary dynamical variables.

For future purposes it is convenient to list the explicit expressions of relevant gauge field when em or Kähler field vanishes.

1. Using coordinates $(u = cos(\Theta), \Phi)$ the expressions for the Kähler form and Z^0 field for space-time surfaces with vanishing em field read as

$$\begin{aligned} J &= -\frac{p}{3+2p} X du \wedge d\Phi \ \ , \ \ X = D|k+u|^{\frac{3+p}{3+2p}} \\ Z^0 &= -\frac{6}{p} J \ \ . \end{aligned} \tag{6}$$

2. For vacuum extremals ($\epsilon = 1$) classical em and Z^0 fields are proportional to each other:

$$\begin{aligned} Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u} du \wedge d\Phi = (k+u) du \wedge d\Phi \ \ , \\ r &= \sqrt{\frac{X}{1-X}} \ \ , \ \ X = D|k+u| \ \ , \\ \gamma &= -\frac{p}{2} Z^0 \ \ . \end{aligned} \tag{7}$$

   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 only reasonable physical interpretation seems to be in terms of a hierarchy of electro-weak physics with arbitrarily light weak boson mass scales.

The effective form of the CP_2 metric is given by

$$\begin{aligned} ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta} d\Theta^2 + s^{eff}_{\Phi\Phi} d\Phi^2] \ \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X \right] \ \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2 \right] \ \ . \end{aligned} \tag{8}$$

This expression is useful in the construction of electromagnetically neutral imbedding of, say Schwartchild metric. 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.

3.3 Imbedding of Reissner-Nordström metric

The imbedding of R-N metric to be discussed generalizes with minor modifications to an imbedding of a spherically symmetric star model characterized by a mass density $\rho(r_M)$ and pressure $p(r_M)$ since the corresponding line element can be written in the form $ds^2 = A(r_M)dt^2 - B(r_M)dr_M^2 - r_M^2 d\Omega^2$ [23]. For vacuum extremal a solution of field equations results.

Denote the coordinates of M^4_+ by (m^0, r_M, θ, ϕ) and those of X^4 by (t, r_M, θ, ϕ). The expression for Reissner-Nordström metric reads as

$$
\begin{aligned}
ds^2 &= Adt^2 - Bdr_M^2 - r_M^2 d\Omega^2 \ , \\
A &= 1 - \frac{a}{r_M} - \frac{b}{r_M^2} \ , \quad B = \frac{1}{A} \ , \\
a &= 2GM \ , \quad b = G\pi q^2 \ .
\end{aligned} \tag{9}
$$

The imbedding is given by the expression

$$
\begin{aligned}
\Phi &= \omega_1 t + f(r_M) \ , \\
\Psi &= k\Phi = \omega_2 t + kf(r_M) \ , \\
m^0 &= \lambda t + h(r_M) \ , \\
\lambda &= \sqrt{1 + \frac{R^2\omega_1^2}{4} s^{eff}_{\Phi\Phi}(\infty)} \ , \quad k = \frac{\omega_2}{\omega_1} \ .
\end{aligned} \tag{10}
$$

The components of s^{eff} are given by Eq. 8 and general form of imbedding by Eqs. 4 and 5.

The functions $f(r_M)$ and $h(r_M)$ are determined by the condition

$$
\lambda \partial_{r_M} h = \frac{R^2}{4} s^{eff}_{\Phi\Phi} \omega_1 \partial_{r_M} f \tag{11}
$$

resulting from the requirement $g_{tr_M} = 0$ and from the expression for $g_{r_M r_M} = -B$:

$$
\begin{aligned}
h &= \int dr_M \sqrt{Y} \ , \quad Y = \frac{Y_1}{Y_2} \ , \\
Y_1 &= -B + 1 + \frac{R^2}{4} s^{eff}_{\Theta\Theta} \frac{(\partial_{r_M} u)^2}{(1-u^2)} \ , \\
Y_2 &= 1 - \frac{4\lambda^2}{R^2\omega_1^2} \frac{s^{eff}_{\Theta\Theta}}{s^{eff}_{\Phi\Phi}} \ .
\end{aligned} \tag{12}
$$

The condition $Y > 0$ at the limit $r \rightarrow \infty$ gives non-trivial conditions. Y_1 is positive at large values of r_M and this gives

$$
Y_1 = -B + 1 + s^{eff}_{\Theta\Theta} \frac{(\partial_{r_M} u)^2}{(1-u^2)} \geq 0
$$

for the allowed values of r_M. Y_1 can change sign at some critical radius above Schwartschild radius $r_S = 2GM$ since B becomes infinite at r_S: this can be avoided only provided one has $u \rightarrow 1$ at $r_M \rightarrow r_S$. Y_2 must preserve its sign and this is possible if the value of $R\omega_1$ is sufficiently large. Below $r = r_S$ Y_1 has positive and also Y_2 can be positive down to some critical radius. At $r = r_S$ Y_1 has infinite discontinuity in case that Y_1 approaches finite value from above and CP_2 coordinates are continuous. It is easy to see that square root singularity of Θ as a function of $r_M - r_S$ is in question so that the function h is continuous so that the solution is well-defined.

The dependence of $u \equiv cos(\Theta)$ on radial coordinate r_M is determined by the expression for $g_{tt} = A$ giving the condition

$$
A = \lambda^2 - \frac{R^2\omega_1^2}{4} s^{eff}_{\Phi\Phi} \omega_1^2 \ . \tag{13}
$$

The asymptotic behavior of the coordinate $u = cos(\Theta)$ is of form

$$u \simeq u_\infty + \frac{K}{r_M} \ , \tag{14}$$

u_∞ is fixed by the condition $A(\infty) = 1$:

$$\begin{aligned} \lambda^2 &- \frac{R^2\omega_1^2}{4} s^{eff}_{\Phi\Phi}(\infty) = 1 \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ , \ X = D|k+u|^\epsilon \ . \end{aligned} \tag{15}$$

The value of K is given by

$$K = \frac{8GM}{R^2\omega_1^2} \left[\frac{\partial s^{eff}_{\Phi\Phi}}{\partial u}(\infty)\right]^{-1} \ . \tag{16}$$

The values of K and u_∞ depend on parameters $\lambda, R\omega_1, k, D$.

For definiteness one can assume that the value of u at infinity is non-negative:

$$u_\infty \geq 0 \ . \tag{17}$$

There are two different solution types depending on the sign of the parameter K.

1. For $K < 0$ u decreases and approaches to $u_{min} \geq 0$ as r_M decreases.
2. For $K > 0$ u increases and approaches to $u_{max} \leq 1$. The requirement that the solution can be continued below Schwartshild radius allows only this option. Below Schwartshild radius u must transform to a solution of type a).

3.3.1 Imbeddability breaks for a critical value of the radial coordinate

The imbeddability breaks for some critical value of the coordinate r_M. The extremal value of u and the radius r_c below which the imbedding fails corresponds to the maximum possible value of $s^{eff}_{\Phi\Phi}$. This value corresponds either to $u = 0, 1$ or to a vanishing derivative of $s^{eff}_{\Phi\Phi}$

$$\frac{\partial s^{eff}_{\Phi\Phi}}{\partial u} = 0 \ . \tag{18}$$

For $\epsilon = 1$ corresponding to vacuum extremals s_{eff} is a fourth order polynomial as a function of u depending on external parameters. One has

$$s^{eff}_{\Phi\Phi} = D|k+u| \times \left[(1 - D|k+u|)(k+u)^2 + 1 - u^2\right] \ . \tag{19}$$

s_{eff} becomes negative for very large values of u. Hence a restriction of the standard form of the dual of the cusp catastrophe to the range $u \in (0, 1)$ results. Depending on the values of external parameters there are either 2 maxima or single maximum. For $k = 1$ the positive extremum correspond to $u = 1/|D|$.

In the case of the Schwartshild metric this gives for the critical radius the expression

$$
\begin{aligned}
r_c &= \frac{r_S}{\delta} \ , \\
\delta &= 1-\lambda^2+\frac{R^2\omega_1^2}{4}s^{eff}_{\Phi\Phi}(max) \ , \\
r_S &= 2GM \ .
\end{aligned} \tag{20}
$$

The existing evidence for black hole like objects suggests that it would be better to have $\delta >> 1$ in order to get imbeddings of the Schwartshild metric containing also horizon and part of the interior region. A sufficiently large value of $R\omega_1$ indeed allows to have arbitrarily small value of r_c. There the experimental evidence for the existence of black hole like objects leads to no problems.

3.3.2 The vacuum extremal imbeddings of Schwartschild metric possess electro-weak charges

The vacuum imbeddings of Reissner-Nodrström and Scwartshild metric necessarily possess some non-vanishing electro-weak charges. Consider first vacuum extremals. Z^0 electric field Z^0_{tr} is proportional to ω_1

$$
Z^0_{tr_M} = \omega_1(k+u)\partial_{r_M}u \ . \tag{21}
$$

The gauge flux through a sphere with radius r_M depends on r_M so that Z^0 vacuum charge density is necessarily present.

The condition $\theta \propto \sqrt{r-r_S}$ allowing to continue the imbedding below $r_M < r_S$ implies that gauge fluxes, which are proportional to $sin(\Theta)\partial_{r_M}\Theta$, are finite at $r=r_S$ so that the renormalizations of gauge couplings remain finite at least down to Schwartschild radius.

At large distances the gauge flux approaches to

$$
\begin{aligned}
Q_Z(\infty) &= \frac{1}{g_Z}\int_{r_M\rightarrow\infty} Z^0_{tr_M}r_M^2 d\Omega \ , \\
&= \frac{4\pi}{g_Z}\omega_1(k+u_\infty)K = \frac{4\pi}{g_Z}(k+u_\infty)\frac{8GM}{R^2\omega_1}\left[\frac{\partial s^{eff}_{\Phi\Phi}}{\partial u}(\infty)\right]^{-1}
\end{aligned} \tag{22}
$$

at the limit $r_M\rightarrow\infty$. Z^0 charge is proportional to the gravitational mass. The gauge flux grows at small distances in accordance with the general wisdom about the coupling constant evolution of $U(1)$ gauge field.

The requirement that Z^0 force is weaker than gravitational force expressed as the condition

$$
\frac{Q_Z^2}{GM^2} \ll 1
$$

implies

$$
\frac{32\pi}{R\omega_1 g_Z}(k+u_\infty)\left[\frac{\partial s^{eff}_{\Phi\Phi}}{\partial u}(\infty)\right]^{-1} \ll \frac{R}{\sqrt{G}} \ . \tag{23}
$$

It seems that a sufficiently large value of $R\omega_1$ allows arbitrarily small values for both the Z^0 charge and the critical radius r_c. In the earliest scenario, which was based on the assumption that CP_2 radius is of order Planck length the situation was different. It is clear that the larger radius of CP_2 makes it possible to avoid too strong classical electro-weak forces.

The non-extremal imbedding to S^2_I studied in detail here is Kähler charged and therefore also Z^0 charged since the condition $Z^0 = 6J/p$ holds true by electromagnetic neutrality. The value of the Kähler charge for non-vacuum imbedding depends on the distance from the origin

$$\begin{aligned} Q_K(r_M) &= \frac{1}{g_K}\int_{r_M=const} J_{tr_M} r_M^2 d\Omega \ , \\ J_{tr_M} &= -\frac{p}{2(3+p)}\omega_1 |k+u|^{\frac{3+p}{3+2p}}\partial_{r_M} u \ , \end{aligned} \tag{24}$$

The expression for the charge differs only in minor details from that for Z^0 charge for vacuum extremals. Essentially similar conclusions about the behavior of the gauge charges hold true also in the case of vacuum extremals and the expressions differ only by the value of the parameter ϵ characterizing whether em, Z^0, of Kähler field vanishes.

3.3.3 Equivalence Principle and critical radius

When one considers Equivalence Principle, one must keep in mind that the Kähler charged imbeddings of Reissner Nodström and Scwartschild metrics are *not* extremals of Kähler action.

1. Equivalence Principle and imbeddings as vacuum extremals

In the case of vacuum extremals the interpretation is that net inertial energy density of the space-time outside the topologically condensed space-time sheet representing charged system is vanishing but the density of gravitational energy is non-vanishing and non-conserved in general. The gravitational mass of the topologically condensed space-time sheet however consists of both inertial and purely gravitational contribution. For RN solution it is natural to interpret the gravitational mass as the gravitational energy of the classical gauge fields. For genuine RN case the densities of inertial color gauge charges vanish but those for gravitational color gauge charges in $SO(3) \subset SU(3)$ are in general non-vanishing. Schwartschild metric possesses necessarily a vacuum densities of some electro-weak gauge charges but the contribution to the gravitational energy momentum tensor vanishes.

2. Equivalence Principle and imbeddings as non-vacuum extremals

One can consider Equivalence Principle in the case of Kähler charged imbeddings only if one believes that the imbedding is in a reasonable approximation an extremal. Equivalence Principle requires that the Kähler mass of the solution should be smaller than its gravitational mass. This does not pose any conditions on the critical radius since the density of Kähler charge can change sign inside the critical radius (meaning that antimatter dominates inside the critical radius). Thus no constraints results.

The strongest form of Equivalence Principle would require that the Kähler mass of the solution equals to its gravitational mass. It is difficult to see how this could be implied by any deep principle. This requirement poses a lower limit to the critical radius since the Kähler energy outside the critical radius should be smaller than the gravitational mass of the system. In the lowest order approximation this energy is given by the expression

$$\frac{E_K}{M} = \frac{1}{8\pi\alpha_K M}\int_{r_M \geq r_c} \lambda E_K^2 dV$$

$$= \frac{\lambda Q_K^2}{GM^2}\frac{r_S}{r_c} \quad . \tag{25}$$

The requirement that electro-weak interactions are much weak than gravitational interaction imply the condition $Q_K^2/GM^2 \ll 1$ so that the ratio can be equal to 1 as Equivalence Principle requires only if $r_S/r_c \gg 1$ holds true.

3.3.4 Gravitational energy is not conserved for vacuum imbedding of Reissner-Nordström metric

The inertial energy associated with Kähler action inside a ball of given radius is not conserved for Reissner-Nordström metric imbedded as a non-vacuum extremal. This follows from the dependence $m^0 = \lambda t + h(r_M)$ implying that energy current has a radial component and from the non-vanishing of $T^{r_M r_M}$. The non-conservation is not due to the outflow of energy but due to the fact that in the case of Kähler charged imbedding field equations are not satisfied. The basic reason is that the contraction of the energy momentum tensor with the second fundamental form is non-vanishing.

For vacuum extremals it is gravitational energy which fails to be conserved. For instance, for the imbedding of Reissner-Nordström this happens. Only at the limit of Schwartshild metric gravitational energy is conserved. The vacuum extremals which are extremals of Einstein-Hilbert action for the induced metric conserve gravitational four momenta and color charges and are excellent candidates for models of the asymptotic state of star.

The non-stationarity of the vacuum extremal imbedding ($m^0 = \lambda t + h(r_M)$) of R-N metric leads to the following expression for the rate of the change of gravitational energy per time inside a sphere of radius r

$$\begin{aligned}
\frac{dE_{vap}/dt}{E(r_M)} &= \frac{dE(r_M)/dt}{E(r_M)} + X \quad , \\
X &= \frac{\int T^{r_M r_M}\partial_{r_M} m^0 \sqrt{g} d\Omega}{E(r_M)} \quad , \\
E(r_M) &= \int T^{tt}\partial_0 m^0 \sqrt{g} dV \quad .
\end{aligned} \tag{26}$$

The latter term depending on $T^{r_M r_M}$ takes into account the flow of gravitational energy through boundaries of the sphere and is in general non-vanishing for Reissner-Nordström metric.

Since the proposed solution ansatz works also in the more general case of a stationary spherically symmetric star model, characterized by the pressure $p(r_M)$ and the energy density $\rho(r_M)$, one can write a general order of magnitude estimate for the gravitational energy transfer associated with the boundary of the sphere approximating $h(r_M)$ with the corresponding function for the Schwartshild metric for large values of r_M as

$$X \simeq -\partial_{r_M} h(r_M)\frac{4\pi p r_M^2}{M} \quad . \tag{27}$$

The explicit expression for $\partial_{r_M} h(r_M)$ is given by

$$\begin{aligned}
\partial_{r_M} h(r_M) &\simeq \frac{1}{\lambda}\sqrt{\frac{Y_1}{Y_2}} \quad , \\
Y_1 &= -B + 1 + \frac{R^2}{4} s^{eff}_{\Theta\Theta}\frac{(\partial_{r_M} u)^2}{(1-u^2)} \quad , \\
Y_2 &= 1 - \frac{4\lambda^2}{R^2\omega_1^2}\frac{s^{eff}_{\Theta\Theta}}{s^{eff}_{\Phi\Phi}} \quad .
\end{aligned} \tag{28}$$

Here B is determined by the Einstein equations defining the star model and can be approximated with its value for Schwartshild metric.

At the surface of the Sun ($r_M \simeq 6 \cdot 10^8\ m$, particle density $n \simeq 10^{21}/m^3$, $T \simeq 0.5\ eV$, $M \simeq 10^{57} m_p$ and pressure $p \simeq nT$) the order of magnitude of this term is about $X/E \simeq 2\pi K 10^{-13}/year$. For $K \sim 1$ (obtained if the radius of CP_2 is of order Planck length) the loss would be of the same order of magnitude as the inertial energy loss associated with the solar wind: $K \sim 1/k$, $10^4 < k << 10^8$, however implies that the loss is roughly four orders of magnitudes smaller.

It should be noticed that in the case of matter dominated cosmology shows that the rate for the reduction of the gravitational energy is of the order of $(dE/da)/E \simeq 1/a \simeq 10^{-11}/year$, which is of the same order as the fusion energy production of Sun. Thus it would seem that the rate for the change of gravitational energy in cosmological length scales is same as that for the inertial energy in the solar length scale.

3.4 Anomalous time dilation effects due to warping as basic distinction between TGD and GRT

TGD predicts the possibility of large anomalous time dilation effects due to the warping of space-time surfaces, and the experimental findings of Russian physicist Chernobrov about anomalous changes in the rate of flow of time [41, 42] provide indirect support for this prediction.

3.4.1 Anomalous time dilation effect due to the warping

Consider first the ordinary gravitational time dilation predicted by GRT. For simplicity consider a stationary spherically symmetric metric $ds^2 = g_{tt}dt^2 - g_{rr}dr^2 - r^2 d\Omega^2$ in spherical coordinates. The time dilation is characterized by the difference $\Delta = \sqrt{g_{tt}} - 1$. In the weak field approximation one has $g_{tt} = 1 + 2\Phi_{gr}$, where Φ_{gr} is gravitational potential. The ordinary time dilation is given by $\Delta = \sqrt{g_{tt}} - 1 \simeq 2\Phi_{gr}$. At the Earth's surface the gravitational potential of the Earth is about $\Phi_{gr} = GM/R_E \simeq 10^{-9}$.

Consider next the situation for space-time surfaces. There exists an infinite number of warped imbeddings of M^4 to $M^4 \times CP_2$ given by $s^k = s^k(m^0)$, which are metrically equivalent with the canonical imbedding with CP_2 coordinates constant. New M^4 time coordinate is related by a diffeomorphism to the standard one. By restricting the imbedding to $M^4 \times S^1$, where S^1 a geodesic circle with radius $R/2$ (using the chosen convention for the definition CP_2 radius), the time component of the induced metric is $g_{m^0m^0} = 1 - R^2\omega^2/4$. The identification of M^4 coordinates as the preferred natural standard coordinate frame allows to overcome the difficulties related to the identification of the preferred time coordinate in general relativity in the case the metric does not approach asymptotically flat metric. For this choice an anomalous time dilation $\sqrt{1 - R^2\omega^2/4}$ due to the warping results even when gravitational fields are absent. Moreover, the dilation can be large.

The study of the imbeddings of Scwhartshild metric as vacuum extremals demonstrates that this vacuum warping is also seen as the degeneracy of the imbeddings of stationary spherically symmetric metrics. If m^0 is used as a time coordinate, anomalous time dilation is obtained also at $r_M \rightarrow \infty$ and is given by

$$\sqrt{g_{m^0m^0}} = \frac{1}{\lambda} \ . \tag{29}$$

This time dilation is seen only if the clocks to be compared are at different space-time sheets. The anomalous time dilation can be quite large since the order of magnitude for the parameter ωR is naturally of order one for the imbeddings of R-N metrics.

3.4.2 Mechanisms producing anomalous time dilation

Anomalous time dilation could result in many manners.

1. An adiabatic variation of the parameters λ and ω_1 of the space-time sheet containing the clock could be induced by some physical mechanism. For instance, X^4_c could move "over" a large space-time sheet X^4 and gradually form $\#$ and $\#_B$ contacts with it. Topological light rays (MEs) define a good candidate for X^4. The parameter values λ and ω could change quasi-continuously if X^4_c gradually generates CP_2 sized wormhole contacts or join along boundaries bonds connecting it to X^4. This process would not affect the gravitational flux feeded to X^4_c.

   For instance, if X^4 is at rest with respect to Earth, this motion would result from the rotation of Earth and the effect should appear periodically from day to day. If it is at rest with respect to Sun, the effect should appear once a year.

   The generation of vacuum extremals X^4_{vac} (not gravitational vacua), which is in principle possible even by intentional action since conservation laws are not broken, could induce anomalous time dilation by this mechanism.

2. A phase transition increasing the value of $\hbar$ increases the size of the space-time sheet in the same proportion. This transition could quite well affect also the parameter λ. If this phase transition occurs for the space-time sheet X^4_c at which the clock feeds its gravitational flux, this mechanism could provide a feasible manner to induce an anomalous time dilation.

3. The system containing the clock could suffer a temporary topological condensation to a smaller space-time sheet and thus feed its gravitational flux to this space-time sheet. This would require coherently occurring splitting of # contacts and their regeneration. It is not possible to say anything definite about the probability of this kind of process except that it does not look very feasible.

3.4.3 The findings of Chernobrov

The findings claimed by Russian researcher V. Chernobrov support anomalous time dilation effect [41, 42]. Chernobrov has studied anomalies in the rate of time flow defined operationally by comparing the readings of clocks enclosed inside a spherical volume with the readings of clocks outside this volume. The experimental apparatus involves a complex Russian doll like structure of electromagnets.

Chernobrov reports a slowing down of time by about 30 seconds per hour inside his experimental apparatus [41] so that the average dilation factor during hour would be about $\Delta = 1/120$. If the dilation is present all the time, the anomalous contribution to the gravitational potential would be by a factor $\sim 10^7$ larger than that of Earth's gravitational potential and huge gravitational perturbations would be required to produce this kind of effect.

The slowing of the time flow is reported to occur gradually whereas the increase for the rate of time flow is reported to occur discontinuously. Time dilation effects were observed in connection with the cycles of moon, diurnal fluctuations, and even the presence of operator.

Consider now the explanation of the basic qualitative findings of Chernobrov.

1. The gradual slowing of the time flow suggests that the parameter values of λ and ω change adiabatically. This favors option 1) since the formation of # contacts occurs with some finite rate.

2. Also the sudden increase of the rate of time flow is consistent with option 1) since the splitting of # contacts occurs immediately when the sheets X^4_c and X^4 are not "over" each other.

3. The occurrence of the effect in connection with the cycles of moon, diurnal fluctuations, and in the presence of operator support this interpretation. The last observation would support the view that intentional generation of almost vacuum space-time sheets is indeed possible.

3.4.4 Vacuum extremals as means of generating time dilation effects intentionally?

Field equations allow a gigantic family of vacuum extremals: any 4-surface having CP_2 projection, which belongs to a 2-dimensional Lagrange manifold with a vanishing induced Kähler form, is a vacuum extremal. Canonical transformations and diffeomorphisms of CP_2 produce new vacuum extremals. Vacuum extremals carry non-vanishing classical electro-weak and color fields which are reduced to some $U(1)$ subgroup of the full gauge group and also classical gravitational field. Although the vacuum extremals are not absolute minima, their small deformations could define such. These vacuum extremals, call them X^4_{vac} for brevity, could be generated by intentional action. In the first quantum jump the p-adic variant of the vacuum extremal representing an intention to create X^4_{vac} would appear and in some subsequent quantum jump it would be transformed to a real space-time sheet.

The creation of these almost vacuum extremals could generate time dilation effects. The material system would gradually generate CP_2 sized wormhole contacts and/or join along boundaries connecting its space-time sheet to X^4_{vac} and this could change the values of the vacuum parameters λ, ω.

3.4.5 Could warping have something to do with condensed matter physics?

Warping predicts the reduction of the effective light velocity. There is a report [45] of an experimental study of a condensed-matter system (graphene, a single atomic layer of carbon, in which electron transport is essentially governed by massless Dirac's equation. According to the report, the charge carriers in graphene mimic relativistic particles with zero rest mass and have an effective 'speed of light' $c_1 = c/300 = 10^6$ m/s.

The study reveals a variety of unusual phenomena that are characteristic of two-dimensional Dirac fermions. Graphene's conductivity never falls below a minimum value corresponding to the quantum unit of conductance, even when the concentrations of charge carriers tend to zero. The integer quantum Hall effect in graphene is anomalous in that it occurs at half-integer filling factors. The cyclotron mass m_c of massless current carriers in graphene is defined in terms of the energy of current carrier as $E = m_c c_1^2$.

The authors believe that these phenomena can be understood in the framework of the ordinary QED and this might be the case. One can however wonder whether the massless Dirac equation for the 2-dimensional system could correspond to the modified Dirac equation for the induced spinor fields and whether the reduction of the maximal signal velocity to c_1 could have the warping of the space-time sheet as a space-time correlate. In the idealization that the CP_2 projection of the space-time surface is a geodesic circle of CP_2, and using M^4 coordinates for space-time surface, so that one would have $\Phi = \omega t$ for S^2 coordinate Φ, one would have $g_{tt} = c_1^2 = 1 - R^2\omega^2/4 = 10^{-4}/9$.

3.5 Evidence for many-sheeted space-time from gamma ray flares

MAGIC collaboration has found evidence for a gamma ray anomaly. Gamma rays in different energy ranges seem to arrive with different velocities from Mkn 501 [62]. The delay in arrival times is about 4 minutes. The proposed explanation is in terms of broken Lorentz invariance. TGD allows to explain the finding in terms of many-sheeted space-time and there is no need to invoke breaking of Lorentz invariance.

3.5.1 TGD based explanation at qualitative level

One of the oldest predictions of many-sheeted space-time is that the time for photons to propagate from point A to B along given space-time sheet depends on space-time sheet because photon travels along lightlike geodesic of space-time sheet rather than lightlike geodesic of the imbedding space and thus increases so that the travel time is in general longer than using maximal signal velocity.

Many-sheetedness predicts a spectrum of Hubble constants and gamma ray anomaly might be a demonstration for the many-sheetedness. The spectroscopy of arrival times would give information about how many sheets are involved.

Before one can accept this explanation, one must have a good argument for why the space-time sheet along which gamma rays travel depends on their energy and why higher energy gamma rays would move along space-time sheet along which the distance is longer.

1. Shorter wavelength means that that the wave oscillates faster. Space-time sheet should reflect in its geometry the the matter present at it. Could this mean that the space-time sheet is more "wiggly" for higher energy gamma rays and therefore the distance travelled longer? A natural TGD inspired guess is that the p-adic length scales assignable to gamma ray energy defines the p-adic length scale assignable to the space-time sheet of gamma ray connecting two systems so that effective velocities of propagation would correspond to p-adic length scales coming as half octaves. Note that there is no breaking of Lorentz invariance since gamma ray connects the two system and the rest system of receiver defines a unique coordinate system in which the energy of gamma ray has Lorentz invariant physical meaning.

2. One can invent also an objection. In TGD classical radiation field decomposes into topological light rays ("massless extremals", MEs) which could quite well be characterized by a large Planck constant in which case the decay to ordinary photons would take place at the receiving end via de-coherence. Gamma rays could propagate very much like a laser beam along the ME. For the simplest MEs the velocity of propagation corresponds to the maximal signal velocity and there would be no variation of propagation time.

   One can imagine two manners to circumvent to the counter argument.

   i) Also topological light rays for which light-like geodesics are replaced with light-like curves of M^4 are highly suggestive as solutions of field equations. For these MEs the distance travelled would be in general longer than for the simplest MEs.

   ii) The gluing of ME to background space-time by wormhole contacts (actually representation for photons!) could force the classical signal to propagate along a zigzag curve formed by simple MEs with maximal signal velocity. The length of each piece would be of order p-adic length scale. The zigzag character of the path of arrival would increase the distance between source and receiver.

3.5.2 Quantitative argument

A quantitative estimate runs as follows.

1. The source in question is quasar Makarian 501 with redshift $z = .034$. Gamma flares of duration about 2 minutes were observed with energies in bands .25-.6 TeV and 1.2-10 TeV. The gamma rays in the higher energy band were near to its upper end and were delayed by about $\Delta\tau = 4$ min with respect to those in the lower band. Using Hubble law $v = Hct$ with $H = 71$ km/Mparsec/s, one obtains the estimate $\Delta\tau/\tau = 1.6 \times 10^{-14}$.

2. A simple model for the induced metric of the space-time sheet along which gamma rays propagate is as a flat metric associated with the flat imbedding $\Phi = \omega t$, where Φ is the angle coordinate of the geodesic circle of CP_2. The time component of the metric is given by

$$g_{tt} = 1 - R^2\omega^2 \ .$$

ω appears as a parameter in the model. Also the imbeddings of Reissner-Norström and Schwartschild metrics contain frequency as free parameter and space-time sheets are quite generally parameterized by frequencies and momentum or angular momentum like vacuum quantum numbers.

3. ω is assumed to be expressible in terms of the p-adic prime characterizing the space-time sheet. The parametrization to assumed in the following is

$$\omega^2 R^2 = Kp^{-r} \ .$$

It turns out that $r = 1/2$ is the only option consistent with the p-adic length scale hypothesis. The naive expectation would have been $r = 1$. The result suggests the formula

$$\omega^2 = m_0 m_p \ \text{ with } \ m_0 = \frac{K}{R} \ .$$

ω would be the geometric mean of a slowing varying large p-adic mass scale and p-adic mass scale m_p.

The explanation for the p-adic length scale hypothesis leading also to a generalization of Hawking-Bekenstein formula assumes that for the strong form of p-adic length scale hypothesis stating $p \simeq 2^k$, k prime, there are two p-adic length scales involved with given elementary particle. L_p characterizes particle's Compton length and L_k characterizes the size of the wormhole contact or throat representing the elementary particle. The guess is that ω is proportional to the geometric mean of these two p-adic length scales:

$$\omega^2 R^2 = \frac{x}{2^{k/2}\sqrt{k}} \ .$$

4. A relatively weak form of the p-adic length scale hypothesis would be $p \simeq 2^k$, k an odd integer. M_{127} corresponds to the mass scale $m_e 5^{-1/2}$ in a reasonable approximation. Using $m_e \simeq .5$ MeV one finds that the mass scales $m(k)$ for $k = 89 - 2n$, $n = 0, 1, 2..., 6$ are $m(k)/TeV = x$, with $x = 0.12, 0.23, 0.47, 0.94, 1.88, 3.76, 7.50$. The lower energy range contains the scales $k = 87$ and 85. The higher energy range contains the scales $k = 83, 81, 79, 77$. In this case the proposed formula does not make sense.

5. The strong form of p-adic length scale hypothesis allows only prime values for k. This would allow Mersenne prime M_{89} (intermediate gauge boson mass scale) for the lower energy range and $k = 83$ and $k = 79$ for the upper energy range. A rough estimate is obtained by assuming that the the two energy ranges correspond to $k_1 = 89$ and $k_2 = 79$.

6. The expression for τ reads as $\tau = (g_{tt})^{1/2} t$. $\Delta\tau/\tau$ is given by

$$\begin{aligned} &\tfrac{\Delta\tau}{\tau} \simeq (g_{tt})^{-1/2} \tfrac{\Delta g_{tt}}{2} \simeq R^2 \Delta\omega^2 = x[(k_2 p_2)^{-1/2} - (k_1 p_1)^{-1/2}] \simeq x(k_2 p_2)^{-1/2} \\ &= x 2^{-79/2} 79^{-1/2} \ . \end{aligned}$$

Using the experimental value for $\Delta\tau/\tau$ one obtains $x \simeq .45$. $x = 1/2$ is an attractive guess.

4 Allais effect and TGD

4.1 Introduction

Allais effect [54, 55] is a fascinating gravitational anomaly associated with solar eclipses. It was discovered originally by M. Allais, a Nobelist in the field of economy, and has been reproduced in several experiments but not as a rule. The experimental arrangement uses so called paraconical pendulum, which differs from the Foucault pendulum in that the oscillation plane of the pendulum can rotate in certain limits so that the motion occurs effectively at the surface of sphere.

4.1.1 Experimental findings

Consider first a brief summary of the findings of Allais and others [55].

1. In the ideal situation (that is in the absence of any other forces than gravitation of Earth) paraconical pendulum should behave like a Foucault pendulum. The oscillation plane of the paraconical pendulum however begins to rotate.

2. Allais concludes from his experimental studies that the orbital plane approach always asymptotically to a limiting plane and the effect is only particularly spectacular during the eclipse. During solar eclipse the limiting plane contains the line connecting Earth, Moon, and Sun. Allais explains this in terms of what he calls the anisotropy of space.

3. Some experiments carried out during eclipse have reproduced the findings of Allais, some experiments not. In the experiment carried out by Jeverdan and collaborators in Romania it was found that the period of oscillation of the pendulum decreases by $\Delta f/f \simeq 5\times 10^{-4}$ [54, 56] which happens to correspond to the constant $v_0 = 2^{-11}$ appearing in the formula of the gravitational Planck constant. It must be however emphasized that the overall magnitude of $\Delta f/f$ varies by five orders of magnitude. Even the sign of $\Delta f/f$ varies from experiment to experiment.

4. There is also quite recent finding by Popescu and Olenici, which they interpret as a quantization of the plane of oscillation of paraconical oscillator during solar eclipse [57]. There is also evidence that the effect is present also before and after the full eclipse. The time scale is 1 hour.

4.1.2 TGD based models for Allais effect

I have already earlier proposed an explanation of the effect in terms of classical Z^0 force [G1]. If the Z^0 charge to mass ratio of pendulum varies and if Earth and Moon are Z^0 conductors, the resulting model is quite flexible and one might hope it could explain the high variation of the experimental results.

The rapid variation of the effect during the eclipse is however a problem for this approach and suggests that gravitational screening or some more general interference effect might be present. Gravitational screening alone cannot however explain Allais effect. Also the combination of gravitational screening and Z^0 force assuming Z^0 conducting structures causing screening fails to explain the discontinuous behavior when massive objects are collinear.

A model based on the idea that gravitational interaction is mediated by topological light rays (MEs) and that gravitons correspond to a gigantic value of the gravitational Planck constant however explains the Allais effect as an interference effect made possible by macroscopic quantum coherence in astrophysical length scales. Equivalence Principle fixes the model to a high degree and one ends up with an explicit formula for the anomalous gravitational acceleration and the general order of magnitude and the large variation of the frequency change as being due to the variation of the distance ratio $r_{S,P}/r_{M,P}$ (S, M,and P refer to Sun, Moon, and pendulum respectively). One can say that the pendulum acts as an interferometer.

4.2 Could gravitational screening explain Allais effect

The basic idea of the screening model is that Moon absorbs some fraction of the gravitational momentum flow of Sun and in this manner partially screens the gravitational force of Sun in a disk like region having the size of Moon's cross subsection. The screening is expected to be strongest in the center of the disk. Screening model happens to explain the findings of Jevardan but fails in the general case. Despite this screening model serves as a useful exercise.

4.2.1 Constant external force as the cause of the effect

The conclusions of Allais motivate the assumption that quite generally there can be additional constant forces affecting the motion of the paraconical pendulum besides Earth's gravitation. This means the replacement $\overline{g} \rightarrow \overline{g}+\Delta\overline{g}$ of the acceleration g due to Earth's gravitation. $\Delta\overline{g}$ can depend on time.

The system obeys still the same simple equations of motion as in the initial situation, the only change being that the direction and magnitude of effective Earth's acceleration have changed so that the definition of vertical is modified. If $\Delta\overline{g}$ is not parallel to the oscillation plane in the original situation, a torque is induced and the oscillation plane begins to rotate. This picture requires that the friction in the rotational degree of freedom is considerably stronger than in oscillatory degree of freedom: unfortunately I do not know what the situation is.

The behavior of the system in absence of friction can be deduced from the conservation laws of energy and angular momentum in the direction of $\overline{g} + \Delta\overline{g}$. The explicit formulas are given by

$$\begin{aligned} E &= \frac{ml^2}{2}(\frac{d\Theta}{dt})^2 + sin^2(\Theta)(\frac{d\Phi}{dt})^2 + mglcos(\Theta) \ , \\ L_z &= ml^2 sin^2(\Theta)\frac{d\Phi}{dt} \ . \end{aligned} \tag{30}$$

and allow to integrate Θ and Φ from given initial values.

4.2.2 What causes the effect in normal situations?

The gravitational accelerations caused by Sun and Moon come first in mind as causes of the effect. Equivalence Principle implies that only relative accelerations causing analogs of tidal forces can be in question. In GRT picture these accelerations correspond to a geodesic deviation between the surface of Earth and its center. The general form of the tidal acceleration would thus the difference of gravitational accelerations at these points:

$$\Delta\overline{g} = -2GM[\frac{\Delta\overline{r}}{r^3} - 3\frac{\overline{r}\cdot\Delta\overline{r}\overline{r}}{r^5}] \ . \tag{31}$$

Here $\overline{r}$ denotes the relative position of the pendulum with respect to Sun or Moon. $\Delta\overline{r}$ denotes the position vector of the pendulum measured with respect to the center of Earth defining the geodesic deviation. The contribution in the direction of $\Delta\overline{r}$ does not affect the direction of the Earth's acceleration and therefore does not contribute to the torque. Second contribution corresponds to an acceleration in the direction of $\overline{r}$ connecting the pendulum to Moon or Sun. The direction of this vector changes slowly.

This would suggest that in the normal situation the tidal effect of Moon causes gradually changing force $m\Delta\overline{g}$ creating a torque, which induces a rotation of the oscillation plane. Together with dissipation this leads to a situation in which the orbital plane contains the vector $\Delta\overline{g}$ so that no torque is experienced. The limiting oscillation plane should rotate with same period as Moon around Earth. Of course, if effect is due to some other force than gravitational forces of Sun and Earth, paraconical oscillator would provide a manner to make this force visible and quantify its effects.

4.2.3 What would happen during the solar eclipse?

During the solar eclipse something exceptional must happen in order to account for the size of effect. The finding of Allais that the limiting oscillation plane contains the line connecting Earth, Moon, and Sun implies that the anomalous acceleration $\Delta|g$ should be parallel to this line during the solar eclipse.

The simplest hypothesis is based on TGD based view about gravitational force as a flow of gravitational momentum in the radial direction.

1. For stationary states the field equations of TGD for vacuum extremals state that the gravitational momentum flow of this momentum. Newton's equations suggest that planets and moon absorb a fraction of gravitational momentum flow meeting them. The view that gravitation is mediated by gravitons which correspond to enormous values of gravitational Planck constant in turn supports Feynman diagrammatic view in which description as momentum exchange makes sense and is consistent with the idea about absorption. If Moon absorbs part of this momentum, the region of Earth screened by Moon receives reduced amount of gravitational momentum and the gravitational force of Sun on pendulum is reduced in the shadow.

2. Unless the Moon as a coherent whole acts as the absorber of gravitational four momentum, one expects that the screening depends on the distance travelled by the gravitational flux inside Moon. Hence the effect should be strongest in the center of the shadow and weaken as one approaches its boundaries.

3. The opening angle for the shadow cone is given in a good approximation by $\Delta\Theta = R_M/R_E$. Since the distances of Moon and Earth from Sun differ so little, the size of the screened region has same size as Moon. This corresponds roughly to a disk with radius $.27 \times R_E$.

   The corresponding area is 7.3 per cent of total transverse area of Earth. If total absorption occurs in the entire area the total radial gravitational momentum received by Earth is in good approximation 92.7 per cent of normal during the eclipse and the natural question is whether this effective repulsive radial force increases the orbital radius of Earth during the eclipse.

   More precisely, the deviation of the total amount of gravitational momentum absorbed during solar eclipse from its standard value is an integral of the flux of momentum over time:

$$
\begin{aligned}
\Delta P^k_{gr} &= \int \frac{\Delta P^k_{gr}}{dt}(S(t))dt \ , \\
\frac{\Delta P^k_{gr}}{dt}(S(t)) &= \int_{S(t)} J^k_{gr}(t)dS \ .
\end{aligned} \tag{32}
$$

   This prediction could kill the model in classical form at least. If one takes seriously the quantum model for astrophysical systems predicting that planetary orbits correspond to

Bohr orbits with gravitational Planck constant equal to GMm/v_0, $v_0 = 2^{-11}$, there should be not effect on the orbital radius. The anomalous radial gravitational four-momentum could go to some other degrees of freedom at the surface of Earth.

4. The rotation of the oscillation plane is largest if the plane of oscillation in the initial situation is as orthogonal as possible to the line connecting Moon, Earth and Sun. The effect vanishes when this line is in the the initial plane of oscillation. This testable prediction might explain why some experiments have failed to reproduce the effect.

5. The change of $|\overline{g}|$ to $|\overline{g} + \Delta\overline{g}|$ induces a change of oscillation frequency given by

$$\frac{\Delta f}{f} = \frac{\overline{g} \cdot \Delta\overline{g}}{g^2} = \frac{\Delta g}{g} cos(\theta) \ . \tag{33}$$

If the gravitational force of the Sun is screened, one has $|\overline{g} + \Delta\overline{g}| > g$ and the oscillation frequency should increase. The upper bound for the effect corresponds to vertical direction is obtained from the gravitational acceleration of Sun at the surface of Earth:

$$\frac{|\Delta f|}{f} \leq \frac{\Delta g}{g} = \frac{v_E^2}{r_E} \simeq 6.0 \times 10^{-4} \ . \tag{34}$$

4.2.4 What kind of tidal effects are predicted?

If the model applies also in the case of Earth itself, new kind of tidal effects are predicted due to the screening of the gravitational effects of Sun and Moon inside Earth. At the night-side the paraconical pendulum should experience the gravitation of Sun as screened. Same would apply to the "night-side" of Earth with respect to Moon.

Consider first the differences of accelerations in the direction of the line connecting Earth to Sun/Moon: these effects are not essential for tidal effects. The estimate for the ratio for the orders of magnitudes of the these accelerations is given by

$$\frac{|\Delta\overline{g}_\perp(Moon)|}{|\Delta\overline{g}_\perp(Sun)|} = \frac{M_S}{M_M}(\frac{r_M}{r_E})^3 \simeq 2.17 \ . \tag{35}$$

The order or magnitude follows from $r(Moon) = .0026$ AU and $M_M/M_S = 3.7 \times 10^{-8}$. These effects are of same order of magnitude and can be compensated by a variation of the pressure gradients of atmosphere and sea water. The effects caused by Sun are two times stronger. These effects are of same order of magnitude and can be compensated by a variation of the pressure gradients of atmosphere and sea water.

The tangential accelerations are essential for tidal effects. They decompose as

$$\frac{1}{r^3}\left[\Delta\overline{r} - 3|\Delta\overline{r}|cos(\Theta)\frac{\overline{r}}{r}\right] \ .$$

$\pi/4 \leq \Theta \leq \pi/2$ is the angle between $\Delta\overline{r}$ and $\overline{r}$. The above estimate for the ratio of the contributions of Sun and Moon holds true also now and the tidal effects caused by Sun are stronger by a factor of two.

Consider now the new tidal effects caused by the screening.

1. Tangential effects on day-side of Earth are not affected (night-time and night-side are of course different notions in the case of Moon and Sun). At the night-side screening is predicted to reduce tidal effects with a maximum reduction at the equator.

2. Second class of new effects relate to the change of the normal component of the forces and these effects would be compensated by pressure changes corresponding to the change of the effective gravitational acceleration. The night-day variation of the atmospheric and sea pressures would be considerably larger than in Newtonian model.

The intuitive expectation is that the screening is maximum when the gravitational momentum flux travels longest path in the Earth's interior. The maximal difference of radial accelerations associated with opposite sides of Earth along the line of sight to Moon/Sun provides a convenient manner to distinguish between Newtonian and TGD based models:

$$\begin{aligned} |\Delta\overline{g}_{\perp,N}| &= 4GM \times \frac{R_E}{r^3} \ , \\ |\Delta\overline{g}_{\perp,TGD}| &= 4GM \times \frac{1}{r^2} \ . \end{aligned} \tag{36}$$

The ratio of the effects predicted by TGD and Newtonian models would be

$$\begin{aligned} \frac{|\Delta\overline{g}_{\perp,TGD}|}{|\Delta\overline{g}_{\perp,N}|} &= \frac{r}{R_E} \ , \\ \frac{r_M}{R_E} &= 60.2 \ , \ \frac{r_S}{R_E} = 2.34 \times 10^4 \ . \end{aligned} \tag{37}$$

The amplitude for the oscillatory variation of the pressure gradient caused by Sun would be

$$\Delta|\nabla p_S| = \frac{v_E^2}{r_E} \simeq 6.1 \times 10^{-4} g$$

and the pressure gradient would be reduced during night-time. The corresponding amplitude in the case of Moon is given by

$$\frac{\Delta|\nabla p_s|}{\Delta|\nabla p_M|} = \frac{M_S}{M_M} \times (\frac{r_M}{r_S})^3 \simeq 2.17 \ .$$

$\Delta|\nabla p_M$ is in a good approximation smaller by a factor of 1/2 and given by $\Delta|\nabla p_M| = 2.8 \times 10^{-4} g$. Thus the contributions are of same order of magnitude.

M_M/M_S	M_E/M_S	R_M/R_E	d_{E-S}/AU	d_{E-M}/AU
3.0×10^{-6}	3.69×10^{-8}	.273	1	.00257
R_E/d_{E-S}	R_E/d_{E-M}	g_S/g	g_M/g	
4.27×10^{-5}	01.7×10^{-7}	6.1×10^{-4}	2.8×10^{-4}	

Table 1. The table gives basic data relevant for tidal effects. The subscript E, S, M refers to Earth, Sun, Moon; R refers to radius; d_{X-Y} refers to the distance between X and Y g_S and g_M refer to accelerations induced by Sun and Moon at Earth surface. $g = 9.8$ m/s^2 refers to the acceleration of gravity at surface of Earth. One has also $M_S = 1.99 \times 10^{30}$ kg and $AU = 1.49 \times 10^{11}$ m, $R_E = 6.34 \times 10^6$ m.

One can imagine two simple qualitative killer predictions assuming maximal gravitational screening.

1. Solar eclipse should induce anomalous tidal effects induced by the screening in the shadow of the Moon.

2. The comparison of solar and moon eclipses might kill the scenario. The screening would imply that inside the shadow the tidal effects are of same order of magnitude at both sides of Earth for Sun-Earth-Moon configuration but weaker at night-side for Sun-Moon-Earth situation.

4.2.5 An interesting co-incidence

The value of $\Delta f/f = 5 \times 10^{-4}$ in experiment of Jeverdan is exactly equal to $v_0 = 2^{-11}$, which appears in the formula $\hbar_{gr} = GMm/v_0$ for the favored values of the gravitational Planck constant. The predictions are $\Delta f/f \leq \Delta p/p \simeq 3 \times 10^{-4}$. Powers of $1/v_0$ appear also as favored scalings of Planck constant in the TGD inspired quantum model of bio-systems based on dark matter [M3]. This co-incidence would suggest the quantization formula

$$\frac{g_E}{g_S} = \frac{M_S}{M_E} \times \frac{R_E^2}{r_E^2} = v_0 \tag{38}$$

for the ratio of the gravitational accelerations caused by Earth and Sun on an object at the surface of Earth.

It must be however admitted that the larger variation in the magnitude and even sign of the effect does not favor this kind of interpretation.

4.2.6 Summary of the predicted new effects

Let us sum up the basic predictions of the model assuming maximal gravitational screening.

1. The first prediction is the gradual increase of the oscillation frequency of the conical pendulum by $\Delta f/f \leq 3 \times 10^{-4}$ to maximum and back during night-time in case that the pendulum has vanishing Z^0 charge. Also a periodic variation of the frequency and a periodic rotation of the oscillation plane with period co-inciding with Moon's rotation period is predicted. Already Allais observed both 24 hour cycle and cycle which is slightly longer and due to the fact that Moon rates around Earth.

2. A paraconical pendulum with initial position, which corresponds to the resting position in the normal situation should begin to oscillate during solar eclipse. This effect is testable by fixing the pendulum to the resting position and releasing it during the eclipse. The amplitude of the oscillation corresponds to the angle between $\overline{g}$ and $\overline{g} + \Delta\overline{g}$ given in a good approximation by

$$sin[\Theta(\overline{g}, \overline{g} + \Delta\overline{g})] = \frac{\Delta g}{g} sin[\Theta(\overline{g}, \Delta\overline{g})] \ . \tag{39}$$

   An upper bound for the amplitude would be $\Theta \leq 3 \times 10^{-4}$, which corresponds to .015 degrees. Z^0 charge of the pendulum would modify this simple picture.

3. Gravitational screening should cause a reduction of tidal effects at the "night-side" of Moon/Sun. The reduction should be maximum at "midnight". This reduction together with the fact that the tidal effects of Moon and Sun at the day side are of same order of magnitude could explain some anomalies know to be associated with the tidal effects [61]. A further prediction is the day-night variation of the atmospheric and sea pressure gradients with amplitude which is for Sun $3 \times 10^{-4} g$ and for Moon $1.3 \times 10^{-3} g$.

To sum up, the predicted anomalous tidal effects and the explanation of the limiting oscillation plane in terms of stronger dissipation in rotational degree of freedom could kill the model assuming only gravitational screening.

4.2.7 Comparison with experimental results

The experimental results look mutually contradictory in the context provided by the model assuming only screening. Some experiments find no anomaly at all as one learns from [54]. There are also measurements supporting the existence of an effect but with varying sign and quite different orders of magnitude. Either the experimental determinations cannot be trusted or the model is too simple.

1. The *increase* (!) of the frequency observed by Jeverdan and collaborators reported in Wikipedia article [54] for Foucault pendulum is $\Delta f/f \simeq 5 \times 10^{-4}$ would support the model even quantitatively since this value is only by a factor 5/3 higher than the maximal effect allowed by the screening model. Unfortunately, I do not have an access to the paper of Jeverdan *et al* to find out the value of $cos(\Theta)$ in the experimental arrangement and whether there is indeed a decrease of the period as claimed in Wikipedia article. In [60] two experiments supporting an effect $\Delta g/g = x \times 10^{-4}$, $x = 1.5$ or 2.6 but the sign of the effect is different in these experiments.

2. Allais reported an anomaly $\Delta g/g \sim 5 \times 10^{-6}$ during 1954 eclipse [59]. According to measurements by authors of [60] the period of oscillation increases and one has $\Delta g/g \sim 5 \times 10^{-6}$. Popescu and Olenici report a decrease of the oscillation period by $(\Delta g/g)cos(\Theta) \simeq 1.4 \times 10^{-5}$.

3. In [58] a *reduction* of vertical gravitational acceleration $\Delta g/g = (7.0 \pm 2.7) \times 10^{-9}$ is reported: this is by a factor 10^{-5} smaller than the result of Jeverdan.

4. Small pressure waves with $\Delta p/p = 2 \times 10^{-5}$ are registered by some micro-barometers [59] and might relate to the effect since pressure gradient and gravitational acceleration should compensate each other. $\Delta g cos(\Theta)/g$ would be about 7 per cent of its maximum value for Earth-Sun system in this case. The knowledge of the sign of pressure variation would tell whether effective gravitational force is screened or amplified by Moon.

4.3 Allais effect as evidence for large values of gravitational Planck constant?

One can represent rather general counter arguments against the models based on Z^0 conductivity and gravitational screening if one takes seriously the puzzling experimental findings concerning frequency change.

1. Allais effect identified as a rotation of oscillation plane seems to be established and seems to be present always and can be understood in terms of torque implying limiting oscillation plane.

2. During solar eclipses Allais effect however becomes much stronger. According to Olenici's experimental work the effect appears always when massive objects form collinear structures.

3. The behavior of the change of oscillation frequency seems puzzling. The sign of the frequency increment varies from experiment to experiment and its magnitude varies within five orders of magnitude.

4.3.1 What one an conclude about general pattern for $\Delta f/f$?

The above findings allow to make some important conclusions about the nature of Allais effect.

1. Some genuinely new dynamical effect should take place when the objects are collinear. If gravitational screening would cause the effect the frequency would always grow but this is not the case.

2. If stellar objects and also ring like dark matter structures possibly assignable to their orbits are Z^0 conductors, one obtains screening effect by polarization and for the ring like structure the resulting effectively 2-D dipole field behaves as $1/\rho^2$ so that there are hopes of obtaining large screening effects and if the Z^0 charge of pendulum is allow to have both signs, one might hope of being to able to explain the effect. It is however difficult to understand why this effect should become so strong in the collinear case.

3. The apparent randomness of the frequency change suggests that interference effect made possible by the gigantic value of gravitational Planck constant is in question. On the other hand, the dependence of $\Delta g/g$ on pendulum suggests a breaking of Equivalence Principle. It however turns out that the variation of the distances of the pendulum to Sun and Moon can explain the experimental findings since the pendulum turns out to act as a sensitive gravitational interferometer. An apparent breaking of Equivalence Principle could result if the effect is partially caused by genuine gauge forces, say dark classical Z^0 force, which can have arbitrarily long range in TGD Universe.

4. If topological light rays (MEs) provide a microscopic description for gravitation and other gauge interactions one can envision these interactions in terms of MEs extending from Sun/Moon radially to pendulum system. What comes in mind that in a collinear configuration the signals along S-P MEs and M-P MEs superpose linearly so that amplitudes are summed and interference terms give rise to an anomalous effect with a very sensitive dependence on the difference of S-P and M-P distances and possible other parameters of the problem. One can imagine several detailed variants of the mechanism. It is possible that signal from Sun combines with a signal from Earth and propagates along Moon-Earth ME or that the interferences of these signals occurs at Earth and pendulum.

5. Interference suggests macroscopic quantum effect in astrophysical length scales and thus gravitational Planck constants given by $\hbar_{gr} = GMm/v_0$, where $v_0 = 2^{-11}$ is the favored value, should appear in the model. Since $\hbar_{gr} = GMm/v_0$ depends on both masses this could give also a sensitive dependence on mass of the pendulum. One expects that the anomalous force is proportional to $\hbar_{gr}$ and is therefore gigantic as compared to the effect predicted for the ordinary value of Planck constant.

4.3.2 Model for interaction via gravitational MEs with large Planck constant

Restricting the consideration for simplicity only gravitational MEs, a concrete model for the situation would be as follows.

1. The picture based on topological light rays suggests that the gravitational force between two objects M and m has the following expression

$$
\begin{aligned}
F_{M,m} &= \frac{GMm}{r^2} = \int |S(\lambda,r)|^2 p(\lambda) d\lambda \\
p(\lambda) &= \frac{h_{gr}(M,m)2\pi}{\lambda} \quad , \quad \hbar_{gr} = \frac{GMm}{v_0(M,m)} \quad .
\end{aligned}
\tag{40}
$$

$p(\lambda)$ denotes the momentum of the gravitational wave propagating along ME. v_0 can depend on (M,m) pair. The interpretation is that $|S(\lambda,r)|^2$ gives the rate for the emission of gravitational waves propagating along ME connecting the masses, having wave length λ, and being absorbed by m at distance r.

2. Assume that $S(\lambda,r)$ has the decomposition

$$\begin{aligned}
S(\lambda,r) &= R(\lambda)exp\left[i\Phi(\lambda)\right]\frac{exp\left[ik(\lambda)r\right]}{r} \quad , \\
exp\left[ik(\lambda)r\right] &= exp\left[ip(\lambda)r/\hbar_{gr}(M,m)\right] \quad , \\
R(\lambda) &= |S(\lambda,r)| \quad .
\end{aligned} \tag{41}$$

The phases $exp(i\Phi(\lambda))$ might be interpreted in terms of scattering matrix. The simplest assumption is $\Phi(\lambda)=0$ turns out to be consistent with the experimental findings. The substitution of this expression to the above formula gives the condition

$$\int |R(\lambda)|^2\frac{d\lambda}{\lambda} = v_0 \quad . \tag{42}$$

Consider now a model for the Allais effect based on this picture.

1. In the non-collinear case one obtains just the standard Newtonian prediction for the net forces caused by Sun and Moon on the pendulum since $Z_{S,P}$ and $Z_{M,P}$ correspond to non-parallel MEs and there is no interference.

2. In the collinear case the interference takes place. If interference occurs for identical momenta, the interfering wavelengths are related by the condition

$$p(\lambda_{S,P}) = p(\lambda_{M,P} \quad . \tag{43}$$

This gives

$$\frac{\lambda_{M,P}}{\lambda_{S,P}} = \frac{\hbar_{M,P}}{\hbar_{S,P}} = \frac{M_M}{M_S}\frac{v_0(S,P)}{v_0(M,P)} \quad . \tag{44}$$

3. The net gravitational force is given by

$$\begin{aligned}
F_{gr} &= \int |Z(\lambda,r_{S,P})+Z(\lambda/x,r_{M,P})|^2p(\lambda)d\lambda \\
&= F_{gr}(S,P)+F_{gr}(M,P)+\Delta F_{gr} \quad , \\
\Delta F_{gr} &= 2\int Re\left[S(\lambda,r_{S,P})\overline{S}(\lambda/x,r_{M,P}))\right]\frac{\hbar_{gr}(S,P)2\pi}{\lambda}d\lambda \quad , \\
x &= \frac{\hbar_{S,P}}{\hbar_{M,P}} = \frac{M_S}{M_M}\frac{v_0(M,P)}{v_0(S,P)} \quad .
\end{aligned} \tag{45}$$

Here $r_{M,P}$ is the distance between Moon and pendulum. The anomalous term ΔF_{gr} would be responsible for the Allais effect and change of the frequency of the oscillator.

4. The anomalous gravitational acceleration can be written explicitly as

$$\begin{aligned} \Delta a_{gr} &= 2\frac{GM_S}{r_S r_M}\frac{1}{v_0(S,P)} \times I \ , \\ I &= \int R(\lambda)R(\lambda/x)cos\left[\Phi(\lambda)-\Phi(\lambda/x)+2\pi\frac{(y_S r_S - x y_M r_M)}{\lambda}\right]\frac{d\lambda}{\lambda} \ , \\ y_M &= \frac{r_{M,P}}{r_M} \ , \ y_S = \frac{r_{S,P}}{r_S} \ . \end{aligned} \tag{46}$$

Here the parameter y_M (y_S) is used express the distance $r_{M,P}$ ($r_{S,P}$) between pendulum and Moon (Sun) in terms of the semi-major axis r_M (r_S)) of Moon's (Earth's) orbit. The interference term is sensitive to the ratio $2\pi(y_S r_S - x y_M r_M)/\lambda$. For short wave lengths the integral is expected to not give a considerable contribution so that the main contribution should come from long wave lengths. The gigantic value of gravitational Planck constant and its dependence on the masses implies that the anomalous force has correct form and can also be large enough.

5. If one poses no boundary conditions on MEs the full continuum of wavelengths is allowed. For very long wave lengths the sign of the cosine terms oscillates so that the value of the integral is very sensitive to the values of various parameters appearing in it. This could explain random looking outcome of experiments measuring $\Delta f/f$. One can also consider the possibility that MEs satisfy periodic boundary conditions so that only wave lengths $\lambda_n = 2r_S/n$ are allowed: this implies $sin(2\pi y_S r_S/\lambda) = 0$. Assuming this, one can write the magnitude of the anomalous gravitational acceleration as

$$\begin{aligned} \Delta a_{gr} &= 2\frac{GM_S}{r_{S,P} r_{M,P}} \times \frac{1}{v_0(S,P)} \times I \ , \\ I &= \sum_{n=1}^{\infty} R(\frac{2r_{S,P}}{n})R(\frac{2r_{S,P}}{nx})(-1)^n cos\left[\Phi(n)-\Phi(xn)+n\pi\frac{x y_M}{y_S}\frac{r_M}{r_S}\right] \ . \end{aligned} \tag{47}$$

If $R(\lambda)$ decreases as λ^k, $k > 0$, at short wavelengths, the dominating contribution corresponds to the lowest harmonics. In all terms except cosine terms one can approximate $r_{S,P}$ *resp.* $r_{M,P}$ with r_S *resp.* r_M.

6. The presence of the alternating sum gives hopes for explaining the strong dependence of the anomaly term on the experimental arrangement. The reason is that the value of xyr_M/r_S appearing in the argument of cosine is rather large:

$$\frac{x y_M}{y_S}\frac{r_M}{r_S} = \frac{y_M}{y_S}\frac{M_S}{M_M}\frac{r_M}{r_S}\frac{v_0(M,P)}{v_0(S,P)} \simeq 6.95671837 \times 10^4 \times \frac{y_M}{y_S} \times \frac{v_0(M,P)}{v_0(S,P)} \ .$$

The values of cosine terms are very sensitive to the exact value of the factor $M_S r_M / M_M r_S$ and the above expression is probably not quite accurate value. As a consequence, the values and signs of the cosine terms are very sensitive to the values of y_M/y_S and $\frac{v_0(M,P)}{v_0(S,P)}$.

The value of y_M/y_S varies from experiment to experiment and this alone could explain the high variability of $\Delta f/f$. The experimental arrangement would act like interferometer measuring the distance ratio $r_{M,P}/r_{S,P}$. Hence it seems that the condition

$$\frac{v_0(S,P)}{v_0(M,P)} \neq const. \quad (48)$$

implying breaking of Equivalence Principle is not necessary to explain the variation of the sign of $\Delta f/f$ and one can assume $v_0(S,P) = v_0(M,P) \equiv v_0$. One can also assume $\Phi(n) = 0$.

4.3.3 Scaling law

The assumption of the scaling law

$$R(\lambda) = R_0(\frac{\lambda}{\lambda_0})^k \quad (49)$$

is very natural in light of conformal invariance and masslessness of gravitons and allows to make the model more explicit. With the choice $\lambda_0 = r_S$ the anomaly term can be expressed in the form

$$\begin{aligned} \Delta a_{gr} &\simeq \frac{GM_S}{r_S r_M}\frac{2^{2k+1}}{v_0}(\frac{M_M}{M_S})^k R_0(S,P)R_0(M,P) \times \sum_{n=1}^{\infty}\frac{(-1)^n}{n^{2k}} cos\left[\Phi(n) - \Phi(xn) + n\pi K\right] \ , \\ K &= x \times \frac{r_M}{r_S} \times \frac{y_M}{y_S} \ . \end{aligned} \quad (50)$$

The normalization condition of Eq. 42 reads in this case as

$$R_0^2 = v_0 \times \frac{1}{2\pi \sum_n (\frac{1}{n})^{2k+1}} = \frac{v_0}{\pi\zeta(2k+1)} \ . \quad (51)$$

Note the shorthand $v_0(S/M,P) = v_0$. The anomalous gravitational acceleration is given by

$$\begin{aligned} \Delta a_{gr} &= \sqrt{\frac{v_0(M,P)}{v_0(S,P)}}\frac{GM_S}{r_S^2} \times XY \times \sum_{n=1}^{\infty}\frac{(-1)^n}{n^{2k}} cos\left[\Phi(n) - \Phi(xn) + n\pi K\right] \ , \\ X &= 2^{2k} \times \frac{r_S}{r_M} \times (\frac{M_M}{M_S})^k \ , \\ Y &= \frac{1}{\pi \sum_n (\frac{1}{n})^{2k+1}} = \frac{1}{\pi\zeta(2k+1)} \ . \end{aligned} \quad (52)$$

It is clear that a reasonable order of magnitude for the effect can be obtained if k is small enough and that this is essentially due to the gigantic value of gravitational Planck constant.

The simplest model consistent with experimental findings assumes $v_0(M,P) = v_0(S,P)$ and $\Phi(n) = 0$ and gives

$$\begin{aligned} \frac{\Delta a_{gr}}{g cos(\Theta)} &= \frac{GM_S}{r_S^2 g} \times XY \times \sum_{n=1}^{\infty}\frac{(-1)^n}{n^{2k}} cos(n\pi K) \ , \\ X &= 2^{2k} \times \frac{r_S}{r_M} \times (\frac{M_M}{M_S})^k \ , \\ Y &= \frac{1}{\pi \sum_n (\frac{1}{n})^{2k+1}} = \frac{1}{\pi\zeta(2k+1)} \ , \\ K &= x \times \frac{r_M}{r_S} \times \frac{y_M}{y_S} \ , \ x = \frac{M_S}{M_M} \ . \end{aligned} \quad (53)$$

4.3.4 Numerical estimates

To get a numerical grasp to the situation one can use $M_S/M_M \simeq 2.71\times 10^7$, $r_S/r_M \simeq 389.1$, and $(M_S r_M/M_M r_S) \simeq 1.74\times 10^4$. The overall order of magnitude of the effect would be

$$\begin{aligned} \frac{\Delta g}{g} \sim XY \times \frac{GM_S}{R_S^2 g} cos(\Theta) \ , \\ \frac{GM_S}{R_S^2 g} &\simeq 6\times 10^{-4} \ . \end{aligned} \tag{54}$$

The overall magnitude of the effect is determined by the factor XY.

1. For $k=0$ the normalization factor is proportional to $1/\zeta(1)$ and diverges and it seems that this option cannot work.

2. The table below gives the predicted overall magnitudes of the effect for $k = 1, 2/2$ and $1/4$.

k	1	1/2	1/4
$\frac{\Delta g}{gcos(\Theta)}$	1.1×10^{-9}	4.3×10^{-6}	1.97×10^{-4}

   For $k=1$ the effect is too small to explain even the findings of [58] since there is also a kinematic reduction factor coming from $cos(\Theta)$. Therefore $k<1$ suggesting fractal behavior is required. For $k = 1/2$ the effect is of same order of magnitude as observed by Allais. The alternating sum equals in a good approximation to -.693 for $y_S/y_M = 1$ so that it is not possible to explain the finding $\Delta f/f \simeq 5\times 10^{-4}$ of Jeverdan.

3. For $k=1/4$ the expression for Δa_{gr} reads as

$$\begin{aligned} \frac{\Delta a_{gr}}{gcos(\Theta)} &\simeq 1.97\times 10^{-4} \sum_{n=1}^{\infty} \frac{(-1)^n}{n^{1/2}} cos(n\pi K) \ , \\ K &= \frac{y_M}{y_S} u \ , \ u = \frac{M_S}{M_M}\frac{r_M}{r_S} \simeq 6.95671837\times 10^4 \ . \end{aligned} \tag{55}$$

   The sensitivity of cosine terms to the precise value of y_M/y_S gives good hopes of explaining the strong variation of $\Delta f/f$ and also the findings of Jeverdan. Numerical experimentation indeed shows that the cosine sum alternates and increases as y_M/y_S increases in the range $[1, 2]$.

The eccentricities of the orbits of Moon *resp.* Earth are $e_M = .0549$ *resp.* $e_E = .017$. Denoting semimajor and semiminor axes by a and b one has $\Delta = (a-b)/a = 1-\sqrt{1-e^2}$. $\Delta_M = 15\times 10^{-4}$ *resp.* $\Delta_E = 1.4\times 10^{-4}$ characterizes the variation of y_M *resp.* y_M due to the non-circularity of the orbits of Moon *resp.* Earth. The ratio $R_E/r_M = .0166$ characterizes the range of the variation of $\Delta y_M = \Delta r_{M,P}/r_M \leq R_E/r_M$ due to the variation of the position of the laboratory. All these numbers are large enough to imply large variation of the argument of cosine term even for $n=1$ and the variation due to the position at the surface of Earth is especially large.

The duration of full eclipse is of order 8 minutes which corresponds to angle $\phi = \pi/90$ and at equator roughly to a $\Delta y_N = (\sqrt{r_M^2 + R_E^2 sin^2(\pi/90)} - r_M)/r_M \simeq (\pi/90)^2 R_E^2/2r_M^2 \simeq 1.7\times 10^{-7}$. Thus the change of argument of $n=1$ cosine term during full eclipse is of order $\Delta\Phi = .012\pi$ at equator. The duration of the eclipse itself is of order two 2 hours giving $\Delta y_M \simeq 3.4\times 10^{-5}$ and the change $\Delta\Phi = 2.4\pi$ of the argument of $n=1$ cosine term.

4.3.5 Other effects

There are also other strange effects involved.

1. One should explain also the recent finding by Popescu and Olenici, which they interpret as a quantization of the plane of oscillation of paraconical oscillator during solar eclipse [57]. A possible TGD based explanation would be in terms of quantization of $\Delta\overline{g}$ and thus of the limiting oscillation plane. This quantization could reflect the quantization of the angular momentum of the dark gravitons decaying into bunches of ordinary gravitons and providing to the pendulum the angular momentum inducing the change of the oscillation plane. The knowledge of friction coefficients associated with the rotation of the oscillation plane would allow to deduce the value of the gravitational Planck constant if one assumes that each dark gravitons corresponds to its own approach to asymptotic oscillation plane. The flux would be reduced in a stepwise manner during the solar eclipse as the distance traversed by the flux through Moon increases and reduced in a similar manner after the maximum of the eclipse.

2. There is also evidence for the effect before and after the main eclipse [57]. The time scale is 1 hour. A possible explanation is in terms of a dark matter ring analogous to rings of Jupiter surrounding Moon. From the average orbital velocity $v = 1.022$ km/s of the Moon one obtains that the distance traversed by moon during 1 hour is $R_1 = 3679$ km. The mean radius of moon is $R = 1737.10$ km so that one has $R_1 = 2R$ with 5 per cent accuracy ($2 \times R = 3474$ km). The Bohr quantization of the orbits of inner planets discussed in [D7] with the value $\hbar_{gr} = GMm/v_0$ of the gravitational Planck constant predicts $r_n \propto n^2 GM/v_0^2$ and gives the orbital radius of Mercury correctly for the principal quantum number $n = 3$ and $v_0/c = 4.6 \times 10^{-4} \simeq 2^{-11}$. From the proportionality $r_n \propto n^2 GM/v_0^2$ one can deduce by scaling that in the case of Moon with $M(moon)/M(Sun) = 3.4 \times 10^{-8}$ the prediction for the radius of $n = 1$ Bohr orbit would be $r_1 = (M(Moon)/M(Sun)) \times R_M/9 \simeq .0238$ km for the same value of v_0. This is too small by a factor 6.45×10^{-6}. $r_1 = 3679$ km would require $n \sim 382$ or $n = n(Earth) = 5$ and $v_0(Moon)/v_0(Sun) \simeq 2^{-4}$.

4.4 Could Z^0 force be present?

One can understand the experimental results without a breaking of Equivalence Principle if the pendulum acts as a quantum gravitational interferometer. One cannot exclude the possibility that there is also a dependence on pendulum. In this case one would have a breaking of Equivalence Principle, which could be tested using several penduli in the same experimental arrangement. The presence of Z^0 force could induce an apparent breaking of Equivalence Principle. The most plausible option is Z^0 MEs with large Planck constant. One can consider also an alternative purely classical option, which does not involve large values of Planck constant.

4.4.1 Could purely classical Z^0 force allow to understand the variation of $\Delta f/f$?

In the earlier model of the Allais effect (see the Appendix of [G1]) I proposed that the classical Z^0 force could be responsible for the effect. TGD indeed predicts that any object with gravitational mass must have non-vanishing em and Z^0 charges but leaves their magnitude and sign open.

1. If both Sun, Earth, and pendulum have Z^0 charges, one might even hope of understanding why the sign of the outcome of the experiment varies since he ratio of Z^0 charge to gravitational mass and even the sign of Z^0 charge of the pendulum might vary. Constant charge-to-mass ratio is of course the simplest hypothesis so that only an effective scaling of gravitational constant would be in question. A possible test is to use several penduli in the same experiment and find whether they give rise to same effect or not.

2. If Moon and Earth are Z^0 conductors, a Z^0 surface charge cancelling the tangential component of Z^0 force at the surface of Earth is generated and affects the vertical component of the force experienced by the pendulum. The vertical component of Z^0 force is $2F_Z cos(theta)$ and thus proportional to $cos(\Theta)$ as also the effective screening force below the shadow of Moon during solar eclipse. When Sun is in a vertical direction, the induced dipole contribution doubles the radial Z^0 force near surface and the effect due to the gravitational screening would be maximal. For Sun in horizon there would be no Z^0 force and gravitational tidal effect of Sun would vanish in the first order so that over all anomalous effect would be smallest possible: for a full screening $\Delta f/f \simeq \Delta g^2/4g^2 \simeq 4.5 \times 10^{-8}$ would be predicted. One might hope that the opposite sign of gravitational and Z^0 contributions could be enough to explain the varying sign of the overall effect.

3. It seems necessary to have a screening effect associated with gravitational force in order to understand the rapid variation of the effect during the eclipse. The fact that the maximum effect corresponds to a maximum gravitational screening suggests that it is present and determines the general scale of variation for the effect. If the maximal Z^0 charge of the pendulum is such that Z^0 force is of the same order of magnitude as the maximal screening of the gravitational force and of opposite sign (that is attractive), one could perhaps understand the varying sign of the effect but the effect would develop continuously and begin before the main eclipse. If the sign of Z^0 charge of pendulum can vary, there is no difficulty in explaining the varying sign of the effect. An interesting possibility is that Moon, Sun and Earth have dark matter halos so that also gravitational screening could begin before the eclipse. The real test for the effect would come from tidal effects unless one can guarantee that the pendulum is Z^0 neutral or its Z^0 charge/mass ratio is always the same.

4. As noticed also by Allais, Newtonian theory does not give a satisfactory account of the tidal forces and there is possibility that tides give a quantitative grasp on situation. If Earth is Z^0 conductor tidal effects should be determined mainly by the gravitational force and modified by its screening whereas Z^0 force would contribute mainly to the pressure waves accompanying the shadows of Moon and Sun. The sign and magnitude of pressure waves below Sun and Moon could give a quantitative grasp of Z^0 forces of Sun and Moon. Z^0 surface charge would have opposite signs at the opposite sides of Earth along the line connecting Earth to Moon *resp.* Sun and depending on sign of Z^0 force the screening and Z^0 force would tend to amplify or cancel the net anomalous effect on pressure.

5. A strong counter argument against the model based on Z^0 force is that collinear configurations are reached in continuous manner from non-collinear ones in the case of Z^0 force and the fact that gravitational screening does not conform with the varying sign of the discontinuous effect occurring during the eclipse. It would seem that the effect in question is more general than screening and perhaps more like quantum mechanical interference effect in astrophysical length scale.

4.4.2 Could Z^0 MEs with large Planck constant be present?

The previous line of arguments for gravitational MEs generalizes in a straightforward manner to the case of Z^0 force. Generalizing the expression for the gravitational Planck constant one has $\hbar_{Z^0} = g_Z^2 Q_Z(M)Q_Z(m)/v_0$. Assuming proportionality of Z^0 charge to gravitational mass one obtains formally similar expression for the Z^0 force as in previous case. If Q_Z/M ratio is constant, Equivalence Principle holds true for the effective gravitational interaction if the sign of Z^0 charge is fixed. The breaking of Equivalence Principle would come naturally from the non-constancy of the $v_0(S,P)/v_0(M,P)$ ratio also in the recent case. The variation of the sign of $\Delta f/f$ would be explained in a trivial manner by the variation of the sign of Z^0 charge of pendulum but this explanation is not favored by Occam's razor.

5 A model for the final state of the star

As found, the energy production by fusion inside stars is of the same order of magnitude as the rate of change for the gravitational energy associated with the recent matter dominated cosmology. Since no energy is produced in the final state of the star, the stationary solutions provide a natural model for the final state of the star.

Besides stationarity, there is also a second new element, namely color and electro-weak long ranged forces coupling to the dark matter. For instance, for Kähler charged extremals one necessary has classical Z^0 force even when classical em force can vanish. For Schwartshild solution this force becomes very strong at small values of the radial distance. Therefore the presence of the Z^0 force, and presumably also other classical electro-weak forces, are expected play crucial role in the dynamics of the compact objects. The most plausible physical interpretation is in terms of dark matter.

The topics to be discussed in the following are:

1. Spherically symmetric stationary model for the final state of the star. It is found that the model cannot be completely realistic since the stationarity assumption fails at the origin and at the surface of the star.
2. Generalization of the model to what could be called dynamo model in order to achieve stationarity.
3. The possible consequences of long range weak and color forces associated with dark matter, in particular the Z^0 force, concerning the dynamics of the compact objects.

The original discussion was based on a different view about energy and motivated the study of Kähler charged solutions with the stationarity property. These 4-surfaces are *not* extremals of the Kähler action. The replacement of the stationary solutions with vacuum extremals requires however only the replacement of the geodesic sphere S^2_I with S^2_{II} implying that both em and Z^0 fields are unavoidably present (or even $W^{\pm}$ fields, depending on vacuum extremal). A serious limitation of the model is that it is single-sheeted. Indeed, the fact that the rotation axis and magnetic axis of super novae are different can be seen as a signal of many-sheeted-ness: the dominantly em and Z^0 fields would reside at different space-time sheets and would correspond to ordinary and dark matter. Of course, entire hierarchy of space-time sheets are expected to be present.

5.1 Spherically symmetric model

The simplest model for the final state of the star that one can imagine is obtained by assuming time translation invariance plus spherical symmetry and imbeddability to $M^4 \times S^2_i$, where S^2_i, $i = I, II$ is the geodesic sphere of CP_2. For the homologically non-trivial sphere S^2_I the solution is *not* an extremal whereas S^2_{II} gives an extremal with a vanishing density of inertial energy. In the original discussion cosmological constant was assumed to vanish. There are excellent reasons to assume that this constant is so small that it does not have any appreciable effects in the scale of the star and can thus be neglected. The nice feature of this kind of model is that symmetry assumptions plus stationarity requirement fix almost completely the model: no assumptions about the equation of state for the matter inside the star are needed.

The solution ansatz giving rise to vacuum extremal corresponds to a surface $X^4 \subset M^4_+ \times S^2_{II}$, where S^2_{II} is the homologically trivial geodesic sphere of CP_2. The solution ansatz has the same general form as the imbedding of spherically symmetric metric.

$$
\begin{aligned}
m^0 &= \lambda t + h(r) \ , \\
\Theta &= \Theta(r) \ , \\
\Phi &= \omega t + k(r) \ .
\end{aligned} \tag{56}
$$

The requirement that g_{tr} vanishes, implies a relationship between the functions $h(r)$ and $k(r)$. One might think that the simplest model is obtained, when the functions $h(r)$ and $k(r)$ vanish identically. One doesn't however obtain physically acceptable solutions in this manner: this is seen by expressing the g_{rr} component of the metric in terms of the mass function

$$
-g_{rr} = 1 + \frac{R^2}{4}(\partial_r\Theta)^2 = \frac{1}{1-\frac{2GM(r)}{r}} \ .
$$

At the radii of order star radius (larger than Schwartshild radius $r_S = 2GM$) the gradient of Θ must be of the order of 1/R and this is inconsistent with the finite range of possible values for Θ.

As already shown the field equations $G^{\alpha\beta}D_\beta\partial_\alpha h^k = 0$ are obtained by varying the integral of the curvature scalar over the space time surface. Field equations reduce to conservation conditions for suitably chosen conserved current: for instance the relevant components of the gravitational 4-momentum and gravitational color currents and express the conservation of gravitational four-momentum current and corresponding color currents.

The expression for the induced metric is given by

$$
\begin{aligned}
ds^2 &= Bdt^2 - Adr^2 - r^2 d\Omega^2 \ , \\
B &= \lambda^2 - \frac{R^2\omega^2}{4} sin^2\Theta \ , \\
A &= 1 + \frac{R^2}{4}(\partial_r\Theta)^2 + \frac{R^2}{4} sin^2\Theta(\partial_r k)^2 - (\partial_r h)^2 \ .
\end{aligned} \tag{57}
$$

The vanishing of the g_{tr} component of the metric implies the condition

$$
\lambda\partial_r h - \frac{R^2}{4}\sin^2\Theta\omega\partial_r k = 0 \ . \tag{58}
$$

The expressions for the components of Einstein tensor for spherically symmetric stationary metric are given by

$$
\begin{aligned}
G^{rr} &= \frac{1}{A^2}(-\frac{\partial_r B}{Br} + \frac{(A-1)}{r^2}) \ , \\
G^{\theta\theta} &= \frac{1}{r^2}[-\frac{\partial_r^2 B}{2BA} + \frac{1}{2Ar}(\frac{\partial_r A}{A} - \frac{\partial_r B}{B}) \\
&+ \frac{\partial_r B}{4AB}(\frac{\partial_r A}{A} + \frac{\partial_r B}{B}] \ , \\
G^{tt} &= \frac{1}{AB}(-\frac{\partial_r A}{Ar} + \frac{(1-A)}{r^2}) \ .
\end{aligned} \tag{59}
$$

A solution of the field equations with one-dimensional CP_2 projection and vanishing gauge fields is obtained by specifying the solution ansatz in the following manner

$$
\begin{aligned}
\Theta &= \frac{\pi}{2} \ , \\
h(r) &= hr \ , \\
k(r) &= kr \ .
\end{aligned} \tag{60}
$$

The requirement that g_{rt} vanishes gives the condition

$$h\lambda = R^2\omega k/4 \ .$$

The functions A and B are in this case just constants. Since A differs from unity, the resulting metric is however non-flat and the non-vanishing components of the Einstein tensor are given by the expressions

$$
\begin{aligned}
G^{tt} &= \frac{(1-A)}{ABr^2} \ , \\
G^{rr} &= -\frac{(1-A)}{A^2r^2} \ .
\end{aligned} \tag{61}
$$

Field equations can be written as conservation conditions, say for the components of gravitational 4-momentum and the conserved "gravitational" color charges associated with the symmetry $\Phi \rightarrow \Phi + \varepsilon$. Quite generally, "gravitational" isometry currents have only time and radial components and radial component represent radial flow to or from the origin. Since the time component is time independent, the field equations state that radial flow is constant so that radial component of the current must behave as $1/r^2$. This is guaranteed provided the condition

$$\partial_r(G^{rr}\sqrt{g}) = 0 \tag{62}$$

holds true: this is indeed the case since G^{rr} is proportional to $1/r^2$.

The radial flow of gravitational energy is non-vanishing due to $m^0 = \lambda tt + h(r)$ behavior and given by the expression

$$J^r = \frac{G^{rr}h}{16\pi G} \ .$$

The conservation condition for J^r fails to be satisfied at origin, which acts as a source or a sink for the gravitational energy. Conservation law fails also at the surface of the star.

One can consider several interpretations.

1. Gravitational mass could be genuinely non-conserved at these locations. Dark particles *resp.* antiparticles with positive *resp.* negative energy would be created in the center of star such that the net density of inertial energy remains zero. Positive and negative energy particles would flow along their own space-time sheets to the outer surface and annihilate there so that there would be no net growth of the gravitational mass. The simplest possibility is that # contacts, which correspond to bound states of parton and negative energy antiparton [F6], split to give rise to particles of opposite inertial energy. At the outer surface # contacts fuse together again.

2. Second option assumes the conservation of gravitational four-momentum. At the surface the non-conservation could result from the flow of the gravitational 4-momentum to a larger space-time sheet via join along boundaries bonds. No net flow of inertial energy would be

involved since positive and negative energy flows must cancel each other. For example, for a physically acceptable solution the gravitational energy might flow radially from or towards the z-axis, flow to say north pole at the surface of the object and return back along z-axis. Gravitational energy could also flow at origin to a second space-time sheet and return back at the surface of the star.

The (gravitational) mass function of the solution is given by the expression

$$M(r) \quad = \quad \frac{\lambda}{16\pi G}\frac{(A-1)}{AB}\sqrt{AB}r \ . \tag{63}$$

Mass is positive for Minkowskian metric with $B > 0$ and Euclidian metric but negative for the interior black hole metric ($A < 0, B < 0$). Mass is proportional to the radius of the star and in order to obtain an object with about Schwartshild radius one must assume that the parameter k is of the order of $1/R$.

Concerning the physical interpretation of the $\Theta = \pi/2$ solution following remarks are in order:

1. Various gauge fields vanish since CP_2 projection is actually a geodesic circle. The interpretation is that various gauge charges vanish. Note that one-dimensional CP_2 projection conforms with the similar property of Robertson Walker cosmologies.

2. Both gravitational, color and weak forces vanish inside the star and the motion along radial geodesics takes place with constant velocity. This is consistent with the radial flow of gravitational energy.

3. Solution ansatz allows generalizations. For example, the following modification is stationary with respect to energy: $m^0 = \lambda t$, $\Phi = \omega_1 t + k_1 r$, $\Psi = \omega_2 t + k_2 r$, $u = constant < \infty$, $\Theta = \pi/2$. By choosing the values of the parameters suitably all the field equations are satisfied but stationarity is not achieved.

4. The solution should allow gluing to the Schwartshild metric at $\Theta = \pi/2$. As found, for the imbedding of Schwartshild metric the $\Theta = 0$ correspond to the Schwartchild radius so that $\Theta = \pi/2$ would most naturally correspond to $r_M < r_S$. Since radial gauge fluxes are non-vanishing and finite at Schwartshild radius, they must be non-vanishing $\Theta = \pi/2$ surface too, so that the star would carry surface charges and behave somewhat like a conducting sphere.

5.2 Dynamo model

The previous considerations have shown that the spherically symmetric solution is probably not physically realistic as such and it seems also clear that spherical symmetry must be given up and be replaced with a symmetry with respect to rotations around z-axis in order to obtain more realistic solutions. Since realistic stars rotate and have strong magnetic fields it is natural to ask whether rotation and magnetic fields might provide remedy for the pathological features of the solution. The rotation of the gauge charged matter (in "gravitational" sense) indeed creates classical gauge magnetic fields, which become very strong near the surface of the star, where the condition $\Theta \simeq \pi/2$ holds. If matter is approximately gauge neutral in the interior, the gauge fields should vanish to a very good approximation in the interior and the previous solution should be a good approximation to the actual situation. The rotating star could therefore be regarded as a rotating electro-weak conductor. Both Z^0 and em fields are present for a vanishing Kähler field and the ratio of field strengths is $\gamma/Z^0 = -sin^2(\theta_W)/2 \simeq -1/8$ (see Appendix) so that Z^0 field dominates.

The generation of strong em and Z^0 electric and magnetic fields suggests a mechanism guaranteing the stability of the solution: star behaves like a dynamo. For solutions with a 2-dimensional CP_2 projection em and Z^0 electric and magnetic fields are automatically orthogonal. For $\Theta \simeq \pi/2$ they are very strong and dominate over gravitation and centrifugal force. Therefore the stability of the surface region naturally results from the cancellation of the electric and magnetic em and Z^0 forces ($\bar{E} + \bar{v} \times \bar{B} = 0$), which takes place, when the velocity field of the matter is suitably chosen. This condition is completely analogous to the vanishing of Kähler Lorentz 4-force which seems to be a general property of the solutions of field equations [D1] and there are reasons to hope non-vacuum extremals describing rotating star can be found.

5.2.1 Conditions for the vanishing of the induced Kähler field

Although the situation becomes too complicated in order to allow the finding of exact solutions describing rotating star, one can identify some general properties of the solution ansatz describing the rotating configuration with Kähler electric and magnetic fields. In order to study the general properties of the solution ansatz in its most general form the explicit expressions for the line element and Kähler form of CP_2 given by the expression

$$\begin{aligned}
ds^2 &= \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos(\Theta)d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2(\Theta)d\Phi^2) \ , \\
J &= \frac{r}{2F^2}dr \wedge (d\Psi + cos(\Theta)d\Phi) + \frac{r^2}{2F}sin\Theta d\Theta \wedge d\Phi \ , \\
F &= 1 + r^2 \ ,
\end{aligned} \tag{64}$$

0
are needed.

The vanishing of Kähler field is can be guaranteed by the conditions (not the most general ones, canonical transformations generate new solutions)

$$\begin{aligned}
\Phi &= q\Psi \ , \\
\frac{dr}{d\theta} &= -qrF\frac{sin(\theta)}{1 + qcos(\theta)} \ .
\end{aligned} \tag{65}$$

Note that this ansatz excludes the case $qcos(\Theta) = -1$ for which only $W^{\pm}$ fields are non-vanishing. For this ansatz the expressions for em and Z^0 fields (see Appendix for general formulas) are

$$\begin{aligned}
&\gamma = -sin^2(\Theta_W)R_{03} \ , \qquad Z^0 = 2R_{03} \ , \\
&R_{03} = -qr^2Fsin(\theta)d\Theta \wedge d\Psi \ .
\end{aligned} \tag{66}$$

Here R_{03} denotes a component of spinor curvature.

5.2.2 Topological quantum numbers

The crucial point is that the expansions for the angle coordinates Φ and Ψ using spherical coordinates contain linear terms in t, r and ϕ

$$\begin{aligned}
\Phi &= n_1\phi + \omega_1 t + k_1 \ , \\
\Psi &= n_2\phi + \omega_2 t + k_2 \ .
\end{aligned} \tag{67}$$

The functions k_1 and k_2 corresponds to Fourier expansion in terms of the plane waves $exp(in\phi)$ with coefficients depending on the coordinates (t, r, θ).

The terms depending linearly on ϕ imply a nontrivial topological structure for the gauge fields not present for the ordinary Maxwell fields. What happens is that space-time divides into regions, which correspond to different values of the topological quantum numbers (n_1, n_2). In the boundaries of these regions the values of the coordinates u and Θ must be such that different values of Φ and Ψ correspond to same point of CP_2. From the expression of the line element one finds that for Ψ the point $u = 0$ and the sphere $u = \infty$ corresponds to these kinds of points. For Φ the surfaces $u = 0$ and $u = \infty$, $\Theta = 0$ correspond to these kinds of surfaces. The form of Φ and Ψ implies that both electric and magnetic gauge fields are nontrivial and rather closely related as is clear from the expression for the Kähler form. Therefore the non-triviality of the winding numbers n_1 and n_2 is what seems to be the crucial, purely TGD based feature of rotating gauge field structures.

5.2.3 Stationary, axially symmetric ansatz with a non-vanishing Kähler field

To make the discussion more concrete, let us assume that the induced metric is invariant with respect to rotations around z-axis and time translations. This is achieved if CP_2 coordinates (apart from linear dependence on ϕ) depend on the coordinates r_M and θ only.

$$\begin{aligned} r &= r(r_M, \theta) \\ \Theta &= \Theta(r_M, \theta) \ , \\ k_i &= k_i(r_M, \theta) \ , \quad i = 1, 2 \ . \end{aligned} \tag{68}$$

This kind of ansatz is clearly consistent: field equations reduce to four equations since second fundamental form is orthogonal to the four-surface and there are four free functions of r and θ: one has effectively two dimensional field theory. Since the general solution ansatz for field equations relies on the vanishing of the Lorentz Kähler force central for the dynamo mechanism, it is of interest to study the general properties of the solution ansatz with a non-vanishing Kähler field. This ansatz can give as special cases space-time sheets carrying Z^0 and em fields with magnetic fields having different rotation axis.

In order to further simplify the discussion let us assume that X^4 corresponds to a sub-manifold of $M^4 \times S^2_I$. For instance, the ansatz

$$\begin{aligned} r &= \infty \ , \\ \Theta &= \Theta(r_M, \theta) \ , \\ \Phi &= n\phi + \omega t + k(r_M, \theta) \ . \end{aligned} \tag{69}$$

is consistent with this assumption. A simpler ansatz is obtained by assuming $k(r_M, \theta) = 0$. This ansatz has the following properties.

1. Induced Kähler (and Z^0-) electric and magnetic fields are automatically orthogonal since CP_2 projection is two-dimensional. In fact, the orthogonality holds to an excellent approximation also for the values of u different but near to $u = \infty$ since the resulting additional components of the Kähler field are extremely small. Kähler electric and magnetic fields are given by

$$\begin{aligned} E_{r_M} &= J_{r_M t} = -\partial_{r_M} cos(\Theta)\omega/2 \ , \\ E_\theta &= -\partial_\theta cos(\Theta)\omega/2 \ , \end{aligned}$$

$$
\begin{aligned}
B_\theta &= -\partial_{r_M} cos(\Theta) n/2 \ , \\
B_{r_M} &= -\partial_\theta cos(\Theta) n/2 \ .
\end{aligned}
\tag{70}
$$

The field strengths are related by

$$
\begin{aligned}
E &= vB \ , \\
v &= \frac{\omega}{n}\sqrt{-\frac{g_{\phi\phi}}{g_{tt}}} \simeq \frac{\omega}{n}\rho \ ,
\end{aligned}
\tag{71}
$$

where ρ denotes radial distance from the rotation axis. v can be interpreted as a velocity type parameter. The requirement that $v < 1$ gives a lower bound for the value of n: $n > \omega r_0$, where r_0 denotes the radius of the star: the condition implies that n must be larger than the mass of the star using Planck mass as unit. Somewhat counter intuitively, small rotation velocities seem to correspond to large values of n.

2. Kähler electric and magnetic fields indeed provide a possible mechanism guaranteing the stability of the star at the surface, where Z^0 forces dominate over gravitation and centrifugal force. Star behaves like a dynamo: matter rotates with a velocity guaranteing the vanishing of the Z^0 force. It should be noticed that no upper bound for the rotation velocity except that resulting from causality is obtained ($\Omega < 1/r_0$). Therefore this mechanism might explain the observed very large rotation velocities (for instance in Super Nova SN1987A), which are hard to understand in GRT based models [24].

3. The ansatz indeed describes a rotating object. First, the dynamo mechanism for the stability necessitates the presence of rotation and determines rotation velocity also. Secondly, the presence of Kähler magnetic field can be understood as being created by the rotation of gauge charges. Thirdly, the $g_{t\phi}$ component of the induced metric and therefore the angular momentum density $J^t_z \propto G^{t\phi} r^2 sin^2\theta$ is non-vanishing. A rough order of magnitude estimate for the angular momentum gives $J \simeq M\sqrt{G}n$. In order to obtain angular momentum of order $MR \simeq GM^2$ the order of magnitude for the parameter n must be $n \simeq M\sqrt{G}$ or the mass of the star using Planck mass as unit or: notice that also the Kähler charge of the star is of the same order of magnitude.

4. The gluing of the solution to Schwartshild solution realized as a vacuum extremal is possible at a surface $\Theta = 0$, which corresponds to Scwartschild radius, since at this surface different values of Φ correspond to same point of CP_2. The gluing condition gives additional constraint $u = \infty$ at $r_M = r_S$.

5. The experience with the radially symmetric solution ansatz suggests that Θ is very nearly constant $\Theta \simeq \pi/2$ in the interior and varies considerably only at the surface of the star where Θ must go to zero in order to allow gluing to Schwartshild metric at $r = r_S$. A possible picture is therefore the following. On z-axis there is a Z^0 charged vortex creating radial Z^0 electric field and Z^0 magnetic field in the direction of the vortex. In order to obtain cyclic energy flow matter velocity near the surface of the star must have besides the rotational component a component in θ direction (Z^0 force vanishes in this direction).

6. An interesting possibility is that the vortex actually corresponds to a Kähler charged cosmic string which has gradually lost its enormous inertial mass by a generating pairs of positive and negative energy particles, such that positive energy particles have left the string and

participated in the formation of the star. The weakening of the magnetic field would have forced a gradual thickening of the cosmic string to an ordinary magnetic flux tube. This 'stars as pearls in necklace' picture would be consistent with the idea that cosmic strings serve as seeds of galaxy and star formation. Both negative and positive energy strings should be present in order to guarantee vanishing of net inertial energy and one can wonder whether the axis of Z^0 and em magnetic fields correspond to these two kinds of strings.

5.2.4 Does Sun have a solid surface?

The model for the asymptotic state of star predicts that mass at given space-time sheet is concentrated in a spherical shell so that star would have a multi-sheeted onion-like structure. This brings in mind the model for the formation of planetary systems in which spherical layers of quantum coherent dark matter serve as templates for the formation of visible matter which eventually condensed to planets [D7, J6]. It would not be surprising if also younger stars and also planets would possess similar structure. This picture is in conflict with the simplest model of Sun as a gas sphere.

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 [44]. 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 Moshina [44] 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 [44] 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 structure rotate uniformly.

The existence of rigid structures idealizable as spherical shells in the first approximation would conform with the model for the final state of star extrapolated to a qualitative picture about the structure younger stars.

5.3 Z^0 force and dynamics of compact objects

The fact that long ranged color fields and weak fields, in particular Z^0 electric fields, could become strong under certain conditions and in fact dominate over gravitation might have interesting consequences in the physics of compact objects. Besides the dynamo mechanism guaranteing the stability of the compact object the following ideas come immediately into mind.

1. In GRT based models Super Nova explosion is explained in terms of the pressure of the collapsed matter. Numerical simulations however fail to produce the explosion [24] and it might even be that GRT based models in fact predict the collapse to black hole. Z^0 and em

electric fields created by dark matter plus the existence of particles with Z^0 charge, which are suggested by TGD based model of nucleus and condensed matter to be present already in ordinary condensed matter, might provide a natural mechanism preventing the formation of the black hole (also excluded by the failure of complete imbeddability). When matter collapses to a sufficiently small volume the value of Θ approaches $\pi/2$ in the surface region and very strong repulsive radial Z^0 force is generated and could indeed lead to the explosion. Very light exotic variants of Higgs bosons identified as wormhole contacts having lefthanded weak charge provides a possible mechanism generating Z^0 charge.

2. The strong Z^0 fields at the surface of the star might provide energy source and acceleration mechanism for very high energy cosmic rays and a mechanism producing very high energy X-rays. These rays would be dark matter particles but could transform to ordinary matter by the mechanism discussed in [F9, J6]. For instance, one can imagine the ejection of a particle beam from the surface of a compact object: particles in dark matter phase gain very high energies in the Z^0 electric field and emit brehmstrahlung in the direction of their motion: most intense emission appears in the region very near the surface of the star, where the Z^0 electric field is strongest. This kind of mechanism might provide alternative explanation for the pulsars. In standard explanations the emission takes place in the direction of the magnetic axis, which does not coincide with the rotation axis. In present case the emission point could be anywhere on the surface of the star and magnetic and rotation axes might well coincide as they do in the simplest model. What one has to do is to invent a mechanism creating the surface instability pushing the matter from the surface of the star to the Kähler electric field.

3. The topological character of the magnetic structures might have applications also in the physics of the ordinary stars. It is known that solar magnetic fields correspond to definite isolated structures [25]. Since electromagnetic fields must be accompanied by Kähler fields it is tempting to assume that these structures indeed correspond to the structures predicted by TGD. At the surface of the Sun the value of Θ near $\pi/2$ are possible and therefore Z^0 force can be very strong inside the magnetic structures.

5.4 Correlation between gamma ray bursts and supernovae and dynamo model for the final state of the star

The correlation between gamma ray bursts and supernovae is certainly the cosmological discovery of the year 2003 [26, 27].

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 [26]. 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 [28], 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 [30]. 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 [29] 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.

According to the updated model discussed in detail in [D5], 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 and assignable to dark matter. 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 [F8] and condensed matter [F9] 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, which according to TGD based explanation of tritium beta decay anomaly [F8] should have the same mass scale as ordinary 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 [29].

5.5 $\mathbf{Z^0}$ force and Super Nova explosion

The mechanism behind Super Nova explosion is not completely understood. The general picture is roughly the following.

1. The formation of iron means the end of the nuclear processes. The inner parts of the star contract and the degeneracy pressure of the non-relativistic electrons ($E_F \propto \rho^{2/3}$) increases and compensates the gravitational force. The equilibrium state is not stable. When the mass of the iron core approaches Chandrasekhar mass $1.4 M_{Sun}$ electrons become relativistic. The milder dependence of the electron Fermi energy on density $E_F \propto \rho^{1/3}$ at the relativistic limit leads to the loss of stability. The high Fermi energy of the electrons allows also the reactions $p + e^- \to n + \nu_e$ implying decrease of the electronic pressure and neutronization of nuclear matter in the core. Gravitational collapse starts.

2. Collapse stops, when the density of the core reaches the density of the nuclear matter. The degeneracy pressure of the neutrons stops contraction, a shock wave is created and the shock

wave and neutrino radiation blow the outer regions of the star away so that Super Nova explosion results.

The problem of this scenario is that numerical simulations do not lead to a strong enough Super Nova explosion and the star tends to collapse into a black hole. A repulsive long ranged Z^0 force predicted by TGD based model of atomic nuclei [F8] generating an additional pressure provides a possible mechanism hindering the collapse and leading to the explosion.

1. The TGD based model for nuclei [F8] and condensed matter [F9] 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. Weak charge is due to the charged color bonds between nucleons: for instance, tetraneutron can be understood as an alpha particle containing two negatively charged color bonds [F8]. This weak charge is vacuum screened above L_w and by dark particles below it. The charged bonds could exist and also generated between nucleons of different nuclei during collapse.

   Dark neutrinos, which according to the TGD based explanation of tritium beta decay anomaly [F8] should have the same mass scale as ordinary neutrinos, are good candidates for screening dark weak force partially below length scale L_w. In equilibrium color force compensates the partially screened Z^0 force in the bonds. For the ordinary condensed matter densities vacuum screening effectively eliminates the force between neighboring nuclei, and the force makes it visible only via low compressibility. The gravitational collapse could be hindered by the strong additional pressure created by the repulsive L_w-ranged weak interaction between nucleons becoming manifest in the resulting dense phase.

2. In the initial state Z^0 charge is screened by dark neutrinos below L_w so that the repulsive Z^0 force is weaker than gravitational force and attractive color force associated with the bonds. Neutronization reactions $p + e^- \rightarrow n + \nu_e$ trigger the collapse. During collapse density increases so that dark neutrinos are not able to screen the anomalous Z^0 charge density. The dark neutrino radiation escaping from the star can also reduce the Z^0 screening. The resulting repulsive weak force implies a rapid increase of pressure with increasing density and thus a very low compressibility as it is proposed to imply also in the case of ordinary condensed matter[F9]. The repulsive weak force thus stops the collapse to black-hole.

3. The study of the spherically symmetric star models as 4-surfaces imbedded in $M^4_+ \times CP_2$ shows that the extreme nonlinearity of Kähler action implies that Z^0 force dominates over gravitation near the surface of the star.

5.6 Microscopic description of black-holes in TGD Universe

In TGD framework the imbedding of the metric for the interior of Schwartshild black-hole fails below some critical radius. This strongly suggests that only the exterior metric of black-hole makes sense in TGD framework and that TGD must provide a microscopic description of black-holes. Somewhat unexpectedly, I ended up with this description from a model of hadrons.

Super-canonical algebra is a generalization of Kac-Moody algebra obtained by replacing the finite-dimensional group G with the group of symplectic transformations of $\delta M^4_\pm \times CP_2$. This algebra defines the group of isometries for the "world of classical worlds" and together with the Kac-Moody algebra assignable to the deformations of light-like 3-surfaces representing orbits of 2-D partonic surfaces it defines the mathematical backbone of quantum TGD as almost topological QFT.

From the point of view of experimentalist the basic question is how these super-canonical degrees of freedom reflect themselves in existing physics and the pleasant surprise was that super-canonical bosons explain what might be called the missing hadronic mass and spin. The point is that quarks explain only about 170 MeV of proton mass. Also the spin puzzle of proton is known for years. Also precise mass formulas for hadrons emerge.

Super-canonical degrees of freedom represent dark matter in electro-weak sense and highly entangled hadronic strings in Hagedorn temperature are very much analogous to black-holes. This indeed generalizes to a microscopic model for black-holes created when hadronic strings fuse together in high density.

5.6.1 Super-canonical 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-canonical algebra [B2, B3, B4], 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-canonical algebra is crucial for the construction of configuration space Kähler geometry. If one assumes that super-canonical 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-canonical bosons in TGD based model of hadron masses is discussed in [F4] and here only a brief summary is given.

As explained in [F4], 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-canonical gluons. Baryonic space-time sheet with $k = 107$ would contain a many-particle state of super-canonical 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.

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-canonical quanta. If the topological mixing for super-canonical bosons is equal to that for U type quarks then a 3-particle state formed by 2 super-canonical 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-canonical 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-canonical bosons suggest a solution to several other anomalies related to hadron physics. The events observed for a couple of years ago in RHIC [21] 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-canonical 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 [22]. 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.

5.6.2 Are ordinary black-holes replaced with super-canonical 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-hole like states associated with super-canonical gravitons with strong gravitational constant defined by the hadronic string tension. The proposal is that super-canonical black-holes have been already seen in Hera, RHIC, and the strange cosmic ray events.

Baryonic super-canonical 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-canonical 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-canonical black-hole and ordinary black-holes would be naturally replaced with super-canonical 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

$$S_p = (\frac{M}{m(CP_2)})^2 \times log(p) \ , \tag{72}$$

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-canonical particles it gives the entire mass.

2. If p-adic length scale hypothesis $p \simeq 2^k$ holds true, one obtains

$$S_p = klog(2) \times (\frac{M}{m(CP_2)})^2, \tag{73}$$

$m(CP_2) = \hbar/R$, 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

$$S = \frac{A}{4G} \times \hbar = \pi G M^2 \times \hbar \ . \tag{74}$$

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-canonical black-holes modified area law results if the radius of the large wormhole throat equals to Schwartschild radius. Schwartschild radius is indeed natural: 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 [D7] 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

$$\hbar_{gr} = \frac{GM^2}{v_0}\hbar_0 \ , \quad v_0 = 1/2 \ . \tag{75}$$

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 [D7]. 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-canonical 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-canonical black-hole. This kind of minimally interacting state is a natural final state of star. Ideal super-canonical 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-canonical particles so that super-canonical black-hole would be single gigantic super-canonical parton. The interior of super-canonical 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.

6 Gravimagnetism and TGD

Gravimagnetism is one of the predictions of GRT which is being tested experimentally. TGD predicts deviations from the predictions of GRT which unfortunately are not seen in the satellite experiment to be discussed below. The claimed discovery of gravimagnetic effect in super-conductors having strength 20 orders of magnitude larger than predicted by GRT raises the question whether TGD might explain the effect.

6.1 Gravity Probe B and TGD

Gravity Probe B experiment tests the predictions o General Relativity related to gravimagnetism. Only the abstract [31] of the talk C. W. Francis Everitt summarizing the results is available when I am writing this.

The NASA Gravity Probe B (GP-B) orbiting gyroscope test of General Relativity, launched from Vandenberg Air Force Base on 20 April, 2004, tests two consequences of Einstein's theory: 1) the predicted 6.6 arc-s/year geodetic effect due to the motion of the gyroscope through the curved space-time around the Earth; 2) the predicted 0.041 arc-s/year frame-dragging effect due to the rotating Earth. The mission has required the development of cryogenic gyroscopes with drift-rates 7 orders of magnitude better than the best inertial navigation gyroscopes. These and other essential technologies, for an instrument which once launched must work perfectly, have come into being as the result of an intensive collaboration between Stanford physicists and engineers, NASA and industry. GP-B entered its science phase on August 27, 2004 and completed data collection on September 29, 2005. Analysis of the data has been in continuing progress during and since the mission. This paper will describe the main features and challenges of the experiment and announce the first results.

The article [32] gives an excellent summary of various test of GRT. The predictions tested by GP-B relate to gravimagnetic effects. The field equations of general relativity in post-Newtonian approximation with a choice of a preferred frame can in good approximation ($g_{ij} = -\delta_{ij}$) be written in a form highly reminiscent of Maxwell's questions with g_{tt} component of metric defining the counterpart of the scalar potential giving rise to gravito-electric field and g_{ti} the counterpart of vector potential giving rise to the gravimagnetic field.

Rotating body generates a gravimagnetic field so that bodies moving in the gravimagnetic field of a rotating body experience the analog of Lorentz force and gyroscope suffers a precession similar to that suffered by a magnetic dipole in magnetic field (Thirring-Lense effect or frame-drag). Besides this there is geodetic precession due to the motion of the gyroscope in the gravito-electric field present even in the case of non-rotating source which might be perhaps understood in terms of gravito-Faraday law. Both these effects are tested by GP-B.

In the following I represent some general comments about how TGD and GRT differs and also say something about the predictions of TGD concerning GP-B experiment.

6.1.1 TGD and GRT

Consider first basic differences between TGD and GRT.

1. In TGD local Lorentz invariance is replaced by exact Poincare invariance at the level of the imbedding space $H = M^4 \times CP_2$. Hence one can use unique global Minkowski coordinates for the space-time sheets and gets rids of the problems related to the physical identification of the preferred coordinate system.

2. General coordinate invariance holds true in both TGD and GRT.

3. The basic difference between GRT and TGD is that in TGD framework gravitational field is induced from the metric of the imbedding space. One important cosmological implication is that the imbeddings of the Robertson-Walker metric for which the gravitational mass density is critical or overcritical fail after some value of cosmic time. Also classical gauge potentials are induced from the spinor connection of H so that the geometrization applies to all classical fields. Very strong constraints between fundamental interactions at the classical level are implied since CP_2 are the fundamental dynamical variables at the level of macroscopic space-time.

4. Equivalence Principle holds in TGD only in a weak form in the sense that gravitational energy momentum currents (rather than tensor) are not identical with inertial energy momentum currents. Inertial four-momentum currents are conserved but not gravitational ones. This explains the non-conservation of gravitational mass in cosmological time scales. At the more fundamental parton level (light-like 3-surfaces to which an almost-topological QFT is assigned) inertial four-momentum can be regarded as the time-average of the non-conserved gravitational four-momentum so that equivalence principle would hold in average sense. The non-conservation of gravitational four-momentum relates very closely to particle massivation.

6.1.2 TGD and GP-B

There are excellent reasons to expect that Maxwellian picture holds true in a good accuracy if one uses Minkowski coordinates for the space-time surface. In fact, TGD allows a static solutions with 2-D CP_2 projection for which the prerequisites of the Maxwellian interpretation are satisfied (the deviations of the spatial components g_{ij} of the induced metric from $-\delta_{ij}$ are negligible).

Schwartschild and Reissner-Norström metrics allow imbeddings as 4-D surfaces in H but Kerr metric [33] assigned to rotating systems probably not. If this is indeed the case, the gravimagnetic field of a rotating object in TGD Universe cannot be identical with the exact prediction of GRT but could be so in the Post-Newtonian approximation. Scalar and vector potential correspond to four field quantities and the number of CP_2 coordinates is four. Imbedding as vacuum extremals with 2-D CP_2 projection guarantees automatically the consistency with the field equations but requires the orthogonality of gravito-electric and -magnetic fields. This holds true in post-Newtonian approximation in the situation considered.

Hence apart from restrictions caused by the failure of the global imbedding at short distances it *might* be possible to imbed Post-Newtonian approximations into H in the approximation $g_{ij} = -\delta_{ij}$. If so, the predictions for Thirring-Lense effect would not differ measurably from those of GRT. The predictions for the geodesic precession involving only scalar potential would be identical in any case.

The imbeddability in the post-Newtonian approximation is however questionable if one assumes vacuum extremal property and small deformations of Schwartschild metric indeed predict a gravimagnetic field differing from the dipole form.

1. Simplest candidate for the metric of a rotating star

The simplest situation for the metric of rotating start is obtained by assuming that vacuum extremal imbeddable to $M^4 \times S^2$, where S^2 is the geodesic sphere of CP_2 with vanishing homological charge and induce Kähler form. Use coordinates (Θ, Φ) for S^2 and spherical coordinates (t, r, θ, ϕ) in space-time identifiable as M^4 spherical coordinates apart from scaling and r-dependent shift in the time coordinate.

1. For Schwartschild metric one has

$$\Phi = \omega t \ , \ sin(\Theta) = f(r) \ . \tag{76}$$

   f is fixed highly uniquely by the imbedding of Schwartschild metric and asymptotically one must have

$$f = f_0 + \frac{C}{r}$$

   in order to obtain $g_{tt} = 1 - 2GM/r$ ($\equiv 1 + \Phi_{gr}$) behavior for the induced metric.

2. The small deformation giving rise to the gravimagnetic field and metric of rotating star is given by

$$\Phi = \omega t + n\phi \tag{77}$$

   There is obvious analogy with the phase of Schödinger amplitude for angular momentum eigenstate with $L_z = n$ which conforms with the quantum classical correspondence.

3. The non-vanishing component of A^g is proportional to gravitational potential Φ_{gr}

$$A^g_\phi = g_{t\phi} = (n/\omega)\Phi_{gr} \ . \tag{78}$$

4. A little calculation gives for the magnitude of B^θ_g from the curl of A^g the expression

$$B^\theta_g = \frac{n}{\omega} \times \frac{1}{sin(\theta)} \times \frac{2GM}{r^3} \ . \tag{79}$$

   In the plane $\theta = \pi/2$ one has dipole field and the value of n is fixed by the value of angular momentum of star.

5. Quantization of angular momentum is obtained for a given value of ω. This becomes clear by comparing the field with dipole field in $\theta = \pi/2$ plane. Note that GJ, where J is angular momentum, takes the role of magnetic moment in B_g [32] appears as a free parameter analogous to energy in the imbedding and means that the unit of angular momentum varies. In TGD framework this could be interpreted in terms of dynamical Planck constant having in the most

general case any rational value but having a spectrum of number theoretically preferred values. Dark matter is interpreted as phases with large value of Planck constant which means possibility of macroscopic quantum coherence even in astrophysical length scales. Dark matter would induce quantum like effects on visible matter. For instance, the periodicity of small n states might be visible as patterns of visible matter with discrete rotational symmetry.

2. Comparison with the dipole field

The simplest candidate for the gravimagnetic field differs in many respects from a dipole field.

1. Gravitomagnetic field has $1/r^3$ dependence so that the distance dependence is same as in GRT.

2. Gravitomagnetic flux flows along z-axis in opposite directions at different sides of $z = 0$ plane and emanates from z-axis radially and flows along spherical surface. Hence the radial component of B_g would vanish whereas for the dipole field it would be proportional to $cos(\theta)$.

3. The dependence on the angle θ of spherical coordinates is $1/sin(\theta)$ (this conforms with the radial flux from z-axis whereas for the dipole field the magnitude of B_g^θ has the dependence $sin(\theta)$. At $z = 0$ plane the magnitude and direction coincide with those of the dipole field so that satellites moving at the gravimagnetic equator would not distinguish between GRT and TGD since also the radial component of B_g vanishes here.

4. For other orbits effects would be non-trivial and in the vicinity of the flux tube formally arbitrarily large effects are predicted because of $1/sin(\theta)$ behavior whereas GRT predicts $sin(\theta)$ behavior. Therefore TGD could be tested using satellites near gravito-magnetic North pole.

5. The strong gravimagnetic field near poles causes gravi-magnetic Lorentz force and could be responsible for the formation of jets emanating from black hole like structures. This additional force might have also played some role in the formation of planetary systems and the plane in which planets move might correspond to the plane $\theta = \pi/2$ where gravimagnetic force has no component orthogonal to the plane. Same applies in the case of galaxies.

3. Consistency with the model for the asymptotic state of star

In TGD framework natural candidates for the asymptotic states of the star are solutions of field equations for which gravitational four-momentum is locally conserved. Vacuum extremals must therefore satisfy the field equations resulting from the variation of Einstein's action (possibly with cosmological constant) with respect to the induced metric. Quite remarkably, the solution representing asymptotic state of the star is necessarily rotating.

The proposed picture is consistent with the model of the asymptotic state of star. Also the magnetic parts of ordinary gauge fields have essentially similar behavior. This is actually obvious since CP_2 coordinates are fundamental dynamical variables and the field line topologies of induced gauge fields and induced metric are therefore very closely related.

As already discussed, the physicists M. Tajmar and C. J. Matos and their collaborators working in ESA (European Satellite Agency) have made an amazing claim of having detected strong gravimagnetism with gravimagnetic field having a magnitude which is about 20 orders of magnitude higher than predicted by General Relativity [46, 47, 48]. Hence there are some reasons to think that gravimagnetic fields might have a surprise in store.

When I am writing this (day later than what is above I have learned that the error bars for the frame-dragging effect are still twice the size of the effect as predicted by GRT. Already this information would have killed TGD inspired model unless the satellite would have been at the equator.

6.2 Does horizon correspond to a degenerate four-metric for the rotating counterpart of Schwartshild metric?

The metric determinant at Schwartschild radius is non-vanishing. This does not quite conform with the interpretation as an analog of a light-like partonic 3-surface identifiable as a wormhole throat for which the determinant of the induced 4-metric vanishes and at which the signature of the induced metric changes from Minkowskian to Euclidian.

An interesting question is what happens if one makes the vacuum extremal representing imbedding of Schwartshild metric a rotating solution by a very simple replacement $\Phi \to \Phi + n\phi$, where Φ is the angle angle coordinate of homologically trivial geodesic sphere S^2 for the simplest vacuum extremals, and ϕ the angle coordinate of M^4 spherical coordinates. It turns out that Schwartschild horizon is transformed to a surface at which $det(g_4)$ vanishes so that the interpretation as a wormhole throat makes sense.

The modification implies that the components $g_{t\phi}$ and $g_{r\phi}$ of the Schwartschild metric become non-vanishing and $g_{\phi\phi}$ component receives a small modification. Using the notations of the subsection *"Imbedding of Reissner-Nordström metric"*, one has

$$\begin{aligned} g_{t\phi} &= \omega_1 n \times \frac{R^2}{4} s^{eff}_{\phi\phi} \ , \\ g_{r\phi} &= \partial_{r_M} f n \times \frac{R^2}{4} s^{eff}_{\phi\phi} \ , \\ \Delta g_{\phi\phi} &= n^2 \times \frac{R^2}{4} s^{eff}_{\phi\phi} \ . \end{aligned} \tag{80}$$

It is easy to see that $g_{r\phi}/g_{t\phi}$ is of order $\sqrt{r_S/r}$, $r_S = 2GM$, so that in an excellent approximation $g_{r\phi} = 0$ holds true at large distances and previous considerations related to gravimagnetic fields remain true.

The vanishing of the 4-D metric determinant reduces to that for 3-D metric determinant $det(g_3)$ associated with (t, r, ϕ). In the case of the Scwartshild metric this determinant is given by

$$\begin{aligned} det(g_3) &= -g_{\phi\phi} - A g^2_{r\phi} + \frac{g^2_{t\phi}}{A} \ , \\ A &= 1 - \frac{2GM}{r} \equiv 1 - u \ . \end{aligned} \tag{81}$$

Since A changes sign at Schwartchild radius $r_s = 2GM$, the determinant can indeed vanish near r_s. In a good approximation can neglect the contribution of $g_{r\phi}$ in the equation and put $r = r_S$ in the slowly varying functions. This gives

$$\frac{R^2}{4}\omega_1^2 s^{eff}_{\phi\phi} \simeq \lambda^2 \tag{82}$$

from the condition $u = r_S/r = 1$ applied to the induced metric. This gives

$$\begin{aligned} g_{\phi\phi} &\simeq -r_S^2 sin^2(\theta) - \frac{n^2}{\omega^2}\lambda^2 \ , \\ g_{t\phi} &\simeq -\frac{n}{\omega}\lambda^2 \ . \end{aligned} \tag{83}$$

The singular surface for which $det(g_3)$ vanishes satisfies the approximate equation

$$u - 1 = \frac{g_{t\phi}^2}{g_{\phi\phi}}(r = r_S) = \frac{n^2\lambda^4}{\omega^2 r_S^2 sin^2(\theta) - n^2\lambda^2} \quad . \tag{84}$$

Since the left hand side can have both signs, the solution certainly exists but it can happen that part of it is inside and part outside Schwartshild radius.

$\theta = 0$ allows solution only for $r > r_S$: hence some portion of the surface is always outside r_S. If the condition

$$\lambda^2 > \frac{\omega^2 r_S^2}{n^2} \tag{85}$$

is satisfied, the surface belongs belongs as a whole to the region $r > r_S$. The singular surface has a cigar like shape approaching sphere $r = \lambda^2 r_S$, $\lambda > 1$ at large quantum number limit $n \to \infty$. For $n = 0$ no solution is obtained. If one assumes that black hole horizon is analogous to a wormhole contact, only rotating black hole like structures with quantized angular momentum are possible in TGD Universe.

6.3 Has strong gravimagnetism been observed?

Physicists M. Tajmar and C. J. Matos and their collaborators working in ESA (European Satellite Agency) have made an amazing claim of having detected strong gravimagnetism with gravimagnetic field having a magnitude which is about 20 orders of magnitude higher than predicted by General Relativity [47]. If the findings are replicable they mean a revolution in the science of gravity and, as one might hope, force a long-waited serious reconsideration of the basic assumptions of the dominating super-string approach.

The starting point of the theory of Tajmar and Matos [46] is the so called Thomson magnetic moment generated in rotating charged super-conductors adding a constant contribution to the exponentially damped Meissner contribution to the magnetic field. This contribution can be understood as being due to the massivation of photons in super-conductors. The modified Maxwell equations are obtained by just adding scalar potential mass term to Gauss law and vector potential mass term to the equation related the curl of the magnetic field to the em current.

The expression for the Thomson magnetic field is given by

$$B = 2\omega_R n_s \times \lambda_\gamma^2 \quad , \tag{86}$$

where ω_R is the angular velocity of superconductor, n_s is charge density of super-conducting particles and $\lambda_\gamma = \hbar/m_\gamma$ is the wave length of a massive photon at rest. In the case of ordinary superconductor one has $\lambda_\gamma = \sqrt{m^*/q^* n_s}$, where $m^* \simeq 2m_e$ and $q^* = -2e$ are the mass and charge of Cooper pair. Hence one has

$$B = -2\frac{m^*}{2e}\omega_R \quad . \tag{87}$$

Magnetic field extends also outside the super-conductor and by measuring it with a sufficient accuracy outside the super-conductor one can determine the value of the electron mass. Instead of the theoretical value $m^*/2m_e = .999992$ which is smaller than one due to the binding energy of the Cooper pair the value $m^*/2m_e = 1.000084$ was found by Tate [48]. This inspired the theoretical work generalizing the notion of Thomson field to gravimagnetism and the attemnpt to explain the anomaly in terms of the effects caused by the gravimagnetic field.

Note that in the case of ordinary matter the equations would lead to an inconsistency at the limit $m_\gamma = 0$ since the value of Thomson magnetic field would become infinite. The resolution of the problem proposed in [46] is based on the replacement of rotation frequency ω with electron's spin precession frequency $\omega_L = -eB/2m$ so that the consistency equation becomes $B = -B = 0$ for a unique choice $1/\lambda_\gamma^2 = -\frac{q}{m}n$. One could also consider the replacement of ω with electron's cyclotron frequency $\omega_c = 2\omega_L$. To my opinion there is no need to assume that the modified Maxwell's equations hold true in the case of ordinary matter.

6.3.1 Gravimagnetic field

The perturbative approach to the Einstein equations leads to equations which are essentially identical with Maxwell's equations. The g_{tt} component of the metric plays the role of scalar potential and the components g_{ti} define gravitational vector potential. Also the generalization to the super-conducting situation in which graviphotons develop a mass is straightforward. Just add the scalar potential mass term to the counterpart of Gauss law and vector potential mass term to the equation relating the curl of the gravimagnetic field to the gravitational mass current.

In the case of a rotating superconductor Thomson magnetic moment is replaced with its gravimagnetic counterpart

$$B_{gr} = -2\omega_R \rho_m \lambda_g^2 \ . \tag{88}$$

Obviously this formula would give rise to huge gravimagnetic fields in ordinary matter approaching infinite values at the limit of vanishing gravitational mass. Needless to say, these kind of fields have not been observed.

Equivalence Principle however suggests that the gravimagnetic field must be assigned with the rotating coordinate frame of the super-conductor. Equivalence principle would state that seing the things in a rotating reference frame is equivalent of being in a gravimagnetic field $B_{gr} = -2\omega_R$ in the rest frame. This fixes the graviphoton mass to

$$\frac{1}{\lambda_{gr}^2} = (\frac{m_{gr}}{\hbar})^2 = G\rho_m \ . \tag{89}$$

For a typical condensed matter density parameterized as $\rho_m = Nm_p/a^3$, $a = 10^{-10}$ m this gives the order of magnitude estimate $m_{gr} \sim N^{1/2}10^{-21}/a$ so that graviton mass would be extremely small.

If this is all what is involved, gravimagnetic field should have no special effects. In [46] it is however proposed that in superconductors a small breaking of Equivalence Principle occurs. The basic assumptions are following.

1. Super-conducting phase and the entire system obey separately their gravitational analogs of Maxwell field equations.

2. The ad hoc assumption is that for super-conducting phase the sign of the gravimagnetic field is opposite to that for the ordinary matter. If purely kinematic effect were in question so that graviphotons were pure gauge degrees of freedom, the value of m_{gr}^2 should should be proportional to ρ_m^* and $\rho_m - \rho_m^*$ respectively.

3. Graviphoton mass is same for both ordinary and super-conducting matter and corresponds to the net density ρ_m of matter. This is essential for obtaining the breaking of Equivalence Principle.

With these assumptions the gravimagnetic field giving rise to acceleration field detected in the rest system would be given by

$$B^*_{gr} = \frac{\rho^*_m}{\rho} \times 2\omega \quad (90)$$

This is claimed to give rise to a genuine acceleration field

$$g^* = -\frac{\rho^*_m}{\rho} a \quad (91)$$

where a is the radial acceleration due to the rotational motion.

6.3.2 Explanation for the too high value of measured electron mass in terms of gravimagnetic field

A possible explanation of the anomalous value of the measured electron mass [48] is in terms of gravimagnetic field affecting the flux Bohr quantization condition for electrons by adding to the electromagnetic vector potential term q^*A_{em} gravitational vector potential m^*A_{gr}. By requiring that the quantization condition

$$\oint (m^*v + q^*A_{em} + m^*A_{gr})dl = 0 \quad (92)$$

is satisfied for the superconducting ring, one obtains

$$B = -\frac{2m}{e}\omega - \frac{m}{e}B_{gr} \ . \quad (93)$$

This means that the magnetic field is slightly stronger than predicted and it has been known that this is indeed the case experimentally.

The higher value of the magnetic field could explain the slightly too high value of electron mass as determined from the magnetic field. This gives

$$B_{gr} = \frac{\Delta m_e}{m_e} \times 2\omega = \frac{\Delta m_e}{m_e} \times em_e \times B \ . \quad (94)$$

The measurement implies $\Delta m_e/m_e = 9.2 \times 10^{-5}$. The model discussed in [46] predicts $\Delta m_e/m_e \sim \rho^*/\rho$. The prediction is about 23 time smaller than the experimental result.

6.4 Is the large gravimagnetic field possible in TGD framework?

TGD allows top consider several alternative solutions for the claimed effect.

1. TGD predicts the possibility of classical electro-weak fields at larger space-time sheets. If these couple to Cooper pairs generate exotic weak charge at super-conducting space-time sheets the Bohr quantization conditions modify the value of the magnetic field. Exotic weak charge would however mean also exotic electronic em charge so that this option is excluded. It would also require that the Z^0 charge of test bodies used to measure the acceleration field is proportional to their gravitational mass.

2. TGD suggests a hierarchy of strong gravities analogous to those generated by spin 2 mesons. These gravitons behave like massless particles below the appropriate Compton length. This Compton length can be arbitrarily long at higher levels of dark matter hierarchy. Electrons do not however couple to these gravitons so that this option soes not seem to work.

3. The rotation of the super-conductor would correspond quite concretely to a rotation of the corresponding space-time sheet. Also the space-time sheet defining the magnetic and gravitomagnetic body of the system could participate to the rotation. Since the rotation affects the shape of the space-time surface the breaking of the Equivalence Principle is unavoidable. This predicts gravitational analogs of the effects found in rotating magnetic systems [43], for instance the radial gravitational field $E^{gr} = vB^{gr}$ but does not seem to be enough to understand what is involved.

4. As already noticed, the failure of Equivalence Principle could be understood if the gravimagnetic fields of super-conducting and ordinary matter do not interfere. Many-sheeted space-time suggest the lack of interference is caused by the fact that super-conducting and ordinary matter reside at different space-time sheets. If the measurement of the gravimagnetic field (or rather its change causing Faraday effect and tangential acceleration) is carried out at either space-time sheet a breaking of Equivalence Principle is observed. In the similar manner magnetic field is affected via Bohr rules for angular momentum and gives rise to the desired effect. In this framework the model of [46] looks rather plausible one.

5. Induced field concept implies extremely tight correlations between induced classical gauge fields and induced gravitational field and one expects that the magnetic field associated with the rotating super-conductor gives rise to a gravimagnetic field so that ordinary Meissner and Thompson effects would force their gravitational counterparts. This is not at all obvious in standard physics framework. It turns out however that the predicted gravimagnetic field is far two small in the simplest model.

6. The dependence of the mass of graviphoton on magnetic penetration length involves Planck constant. TGD predicts a hierarchy of Planck constants $\hbar(k) = \lambda^k \hbar_0$. This means that for given value of m_γ and m_{gr} there is a hierarchy of increasing photon graviton rest Compton length defining the penetration depths for superconductors. It turns out that if graviphotons are dark, one can indeed understand the huge value of gravimagnetic field in TGD framework.

6.4.1 Key observations

Two observations are essential for what follows.

1. It would seem that the superposition of the of the gravimagnetic fields of the superconducting and ordinary ordinary matter gives the net gravimagnetic field which would not give any anomalous effects. The breaking of Equivalence Principle could be understood if these fields do not interfere in the experimental situation. In TGD framework the separation of ordinary matter and Cooper pairs at separate space-time sheets can explain the absence of the interference.

2. In order to obtain large enough an effect one must assume that ρ_m^* contains an additional contribution besides Cooper pairs. In TGD framework the presence of also other particles besides Cooper pairs at super-conducting space-time sheets could increase the value of ρ_m^* by a factor of order 23. For instance, the space-time sheet could contain $23m_e/m_p$ protons $23m_e/Am_p$ heavier atoms per electron.

6.4.2 Could gravimagnetism and breaking of Equivalence Principle be forced by the induced field concept?

The safest starting point seems to be that the separation of super-conducting phase to its own space-time sheet induces the reduction $\rho_m \rightarrow \rho_m - \rho_m^*$ at the space-time of ordinary matter. If the photograviton is not modified correspondingly one has in inertial frame effective B_{gr} obtained by the replacement $\rho - \rho_m \rightarrow -\rho_m^*$ in the defining formula as one goes to rest system. This gives also the sign of the gravimagnetic field correctly. The task is to find whether the notion of induced gauge field is consistent with or can even predict the generation of B_{gr}.

TGD predicts an extremely tight correlation between various kinds of classical fields so that the Thomson magnetic field associated with super-conductor is expected to be accompanied by a gravimagnetic field which need not have a value consistent with the Equivalence Principle.

The assumption that the space-time sheet in question has a CP_2 projection belonging to either Lagrange manifold Y^2 of CP_2, say homologically trivial geodesic sphere, or to a non-trivial geodesic sphere allows to model the situation in a simple manner. For the homologically trivial sphere field equations are identically satisfied by the vacuum extremal property. The treatments are essentially identical so that the consideration is restricted to the non-vacuum case for definiteness.

For the simplest cylindrically symmetric situations CP_2 coordinates can be expressed as $(\Theta = f(\rho), \Phi = \omega t - n\phi)$ cylindrical coordinates for M^4. Kähler magnetic field would be $g_K B^K_{\rho\phi} = sin(\Theta)\rho n$ and gravimagnetic vector potential would have the non-vanishing component $A^{gr}_\phi = g_{t\phi} = -R^2 \sin^2(\Theta) n\omega$. This would give $B^{gr}_{\rho\phi} = -2R^2\omega sin(\Theta) g_K B^K_{\rho\phi}$. For the ratio $2m_e B_{gr}/g_K B^K$ one would obtain

$$\frac{2m_e B^{gr}}{g_K B^K} = -2R^2\omega m_e sin(\Theta) \ . \quad (95)$$

Equivalence Principle would require $2m_e B_{gr}/eB_{em} = 1$ so that one would have

$$2R^2\omega m_e sin(\Theta) = -x \ . \quad (96)$$

where one has $eB_{em} \equiv x g_K B_K$. The value of x is completely fixed for homologically non-trivial geodesic sphere. In the appendix of [1] it is shown to be $x = 3 - 2sin^2(\theta_W)$, where $sin^2(\theta_W) \simeq .23$ denotes Weinberg angle.

The condition is impossible to satisfy in precise sense since $sin(\Theta)$ cannot be constant so that at least a small breaking of Equivalence Principle is unavoidable but probably does not offer an explanation of the effect. The assumption that that B^K is constant implies $sin(\Theta) = \alpha + \beta\rho^2$ and implies that also B_{gr} is constant in the lowest order approximation.

The condition above would require an extremely large value of the parameter ω of order $\omega \sim 1/m_e R^2 \sim 10^{19}/R$. This would imply that the induced metric has Euclidian signature by $g_{tt} < 1 - R^2\omega^2 sin^2(\Theta) < 0$. It would also imply a huge Kähler electric field $g_K E^K = g_K B^K_{\rho\phi}\omega/n$. The situation is obviously same also in the case that the value gravimagnetic field has the value needed to explain the experimental findings of Tate.

6.4.3 Could the large gravimagnetic field correspond to dark graviphotons?

A possible way out of the difficulty is based on the assumption that the graviphotons are dark and have a large value of Planck constant increasing in turn the value of λ_{gr} and thus gravimagnetic field.

The TGD based model for the hierarchy of Planck constants associated with the dark matter hierarchy assumes that the various values $\hbar = \lambda^k \hbar_0$, $\lambda \simeq 2^{11}$ correspond at the level of imbedding space to a book like structure. Different algebraic extensions of rational numbers and p-adic numbers correspond to different values of Planck constant and copies of imbedding space. The metrics for these different copies differ by a scaling in M^4 degrees of freedom and are glued together by along a subset of rationals such that the distances of the glued points from the common origin of glued copies of M^4 are identical. The configuration space of 3-surfaces decomposes into sectors labelled by unions of future and past light cones and the dips of these light cones define the preferred origins.

The key observation is that the role of Planck constant in the d'Alembertian at the level of the imbdding space is to multiply M^4 part of the d'Alembertian but leave CP_2 part unaffected. This is in accordance with the fact that induced spinor connection corresponds to gauge couplings not involving $\hbar$ and also with the fact that the scaling of CP_2 spinor connection does not make sense. At the level of induced spinor fields Planck constant in turn corresponds to the scaling factor of the M^4 part of the induced metric.

Hence it is natural to assume that contravariant M^4 metric scales as $\hbar^2(k) \propto \lambda^{2k}$. $\lambda \simeq 2^{11}$ as a function of $\hbar$ whereas CP_2 metric is not affected. This would mean that M^4 contribution to the induced covariant metric scales as λ^{-2k}: this implies that Kähler action can be seen as a function of the value of Planck constant and thus codes for the higher level corrections in powers of $\hbar$. This allows to have TGD to predict a series of higher order corrections in powers of $\hbar$ although the perturbation theory defined by the configuration space functional integral could reduce to the lowest order approximation as the general number theoretic and integrability arguments inspired by symmetric space property of the zero mode constant sectors of the configuration space suggest.

Using scaled coordinates in which M^4 metric is represented by a unit tensor, this geometrization of the dynamics of Planck constant would mean an effective scaling $R^2 \rightarrow \lambda^{2k}R^2$ for the CP_2 radius R increasing the contribution of the CP_2 metric to the induced metric. This is just what is needed to preserve the Minkowskian signature of the induced metric in ultrastrong gravimagnetic fields.

For a dynamical Planck constant the expression for ω would become $\omega \sim 1/m_e\lambda^{2k}R^2 \sim 10^{19}/\lambda^{2k}R$. The requirement that the signature of the induced metric is Minkowskian gives $g_{tt} = 1 - R^2\lambda^{2k}\omega^2 > 0$. This boils down to the conditions

$$\begin{aligned} \lambda^k &> \frac{x}{Rm_e} \sim 10^{19}x \ , \\ \omega &\leq \frac{m_e}{x^2} \ , \end{aligned} \tag{97}$$

where x is the numerical constant defined earlier. Using $\lambda \simeq 2^{11}$ this would give $k \geq 6$. The hierarchy of dark matter levels associated with living matter contains $k = 7$ levels relevant to human consciousness and $k = 7$ corresponds to a characteristic time scale of about 50 years [M3].

One can deduce an estimate for the dark graviphoton mass by assuming the value for λ_{gr} implied by B_{gr} necessary to explain the anomaly observed by Tate [48]. This would give

$$m_{gr} \sim \sqrt{\frac{N}{10}} \times \frac{1}{10^2 a} \ , \tag{98}$$

where gravitational mass density has been parameterized as $\rho_m = Nm_p/a^2$, $a = 10^{-10}$ m. Note that the rest energy is above the thermal threshold at room temperature. The mass corresponds to an ordinary Compton length of order 10 nm, size scale for Cooper pairs and cell membrane thickness which emerges as a fundamental length scale characterizing Cooper pairs in the TGD based model for high T_c super-conductor [J1, J2, J3]. TGD inspired model of living matter predicts that also the magnetic structures corresponding to scaled up variants of cell membrane having sizes scaled up by λ^k are fundamental [M3].

A possible physical interpretation for the origin of the ordinary graviphoton mass would be that the confinement of longitudinal graviton inside a magnetic flux tube of thickness $L(151) = 10$ nm gives its a non-vanishing effective rest mass due to the confinement in transversal degrees of freedom which is same for all scaled up variants. The effect would be completely analogous to the generation effective photon mass in waveguide. For $k = 6$ level the Compton length of the dark graviphoton would be about 10^{11} m, the size scale of the solar system, so that a genuine long range interaction would be in question.

The gravitational mass of the photon associated with super-conductivity would be enormous for ordinary value of Planck constant. For the ordinary value of Planck constant the mass would be around $m_\gamma \simeq 10^{-3} m_e$ and for $k = 6$ one would have $m_\gamma \simeq 10^{16} m_e$. This weird implication suggests that super-conducting photons are ordinary. In this case the wavelength would be of order one nanometer and of the same order of magnitude as the wavelength of ordinary graviphoton, which supports the interpretation that transversal confinement to magnetic flux tubes gives rise to the mass in both cases.

The model ties together both electron mass scale, the order of magnitude for the size of Cooper pairs, cell membrane thickness crucial for high T_c super-conductivity, and the size scale of the solar system which in the case finite space-time sheets would give natural estimate for the much lower mass scale of the ordinary graviphoton. This raises the hope that the model might have at least something to do with reality. The model also suggest that dark gravimagnetism might be of importance in living systems.

6.4.4 Other explanations

One can consider also other explanations for the strong gravimagnetic effect.

1. Are p-adically scaled variants of graviton in question?

The recent view about coupling constant evolution assumes that Kähler coupling strength is invariant under p-adic coupling constant evolution whereas gravitational constant is proportional to L_p^2 [C5]. In this framework gravitons correspond to the Mersenne prime $M_{127} = 2^{127} - 1$ defining the p-adic length scale of electron. The motivation comes from the hypothesis that gauge bosons in general correspond to Mersenne primes and that M_{127} is the largest Mersenne prime, which does not correspond to completely super-astrophysical p-adic length scale.

One can however consider the possibility that in some situations -perhaps in the case of super-conductor - the space-time sheet mediating gravitational interaction - gravitonic field body - corresponds to some larger prime. The scaling of G by a factor 10^{20} would require scaling of electronic p-adic length scale by a factor of order 10^{10} to give 2.5 cm length scale.

2. Super-canonical strong gravitation

TGD predicts also super-canonical spin two quanta and these give rise to strong gravitation with G or order L_p^2. Super-canonical bosons are responsible for the non-perturbative aspects of hadron physics [F4, F5] and super-canonical strong gravitation relates very closely to the stringy description of hadrons. There are good reasons to believe that strong gravitation prevails only at the hadronic space-time sheet. Also black-holes would in TGD framework correspond to gigantic hadron like structures resulting when the hadronic space-time sheets have fused together to form single highly entangled string like structure [F5]. Thus it would seem that super-canonical strong gravitation cannot give rise to a gravimagnetic effect.

7 Is gravitational constant really constant?

The most convincing TGD based model for the p-adic coupling constant evolution identified hitherto [C5] predicts that gravitational coupling constant is proportional to the square of p-adic length scale: $G \propto L_p^2$. Together with p-adic length scale hypothesis this would predict that gravitational coupling strength can have values differing from its standard value by a power of 2. $p = M_{127}$ would characterize the space-time sheet mediating ordinary gravitational interactions. In the following possible indications for the variation of G is discussed.

7.1 The case of Bullet cluster

The studies of the Bullet cluster [37, 38], provide the best evidence to date for the existence of dark matter. Bullet cluster [36] consists of two colliding clusters of galaxies (strictly speaking, the term refers to the smaller one of the two clusters). The major components of the cluster pair, stars, gas and the putative dark matter, behave differently during collision, allowing them to be studied separately.

The stars of the galaxies, observable in visible light, were not greatly affected by the collision, and most passed right through, gravitationally slowed but not otherwise altered. The hot gas of the two colliding components, seen in X-rays, represents about 90 per cent of the mass of the ordinary matter in the cluster pair. The gases interact electromagnetically, so that the velocity change for the gases of clusters is larger than for the stars of clusters. The dominating dark matter component was detected indirectly by its gravitational lensing. The observation that the lensing is strongest in two separated regions near the visible galaxies, confirms with the assumption that most of the mass in the cluster pair is in the form of collisionless dark matter.

Particularly compelling results were inferred from the Chandra observations of the bullet cluster. Those authors report that the cluster is undergoing a high-velocity [around 4500 km/s] merger, evident from the spatial distribution of the hot, X-ray emitting gas, but this gas lags behind the sub-cluster galaxies. Furthermore, the dark matter clump, revealed by the weak-lensing map, is coincident with the collisionless galaxies, but lies ahead of the collisional gas.

Later came the work of Glennys Farrar, Rachel Rosen, and Volker Springler [39] suggesting that the situation might not be as simple as this (for a popular article see [40]). The velocity of the bullet of dark matter is higher than it should be in the cold dark matter scenario (CDM). The proposal is that dark matter has its own additional attractive interaction of finite range, "fifth force". Since the finite range of the force is not actually significant in the situation considered, the model is mathematically equivalent with a model assuming that dark gravitational coupling strength. A good fit is obtained by assuming that the net effective gravitational force is by a factor 2 stronger than gravitational force.

The hypothesis is claimed to solve also some other problems of the cold dark matter scenario (CDM). The number of dwarf galaxies around ordinary galaxies is considerably smaller than predicted by CDM. The strong binding of dark matter in dwarfs would make them more compact and this in turn would mean that the binding of visible matter is weaker so that ordinary galaxies would have ripped this matter off and dwarfs would be more difficult to detect. CDM also predicts less galaxy clusters and stronger attraction for dark matter could resolve the problem.

TGD predicts that gravitational constant is proportional to the square of p-adic length scale: $G \propto L_p^2 \equiv L(k)^2$, $p \simeq 2^k$, k integer, in particular power of prime. Ordinary gravitational constant would correspond to $p = M_{127} = 2^{127} - 1$, which is the largest Mersenne prime which is not completely super-astrophysical and corresponds to electron's p-adic length scale. One can however ask whether it might be possible to have situations in which the p-adic length scale assigned to the space-time sheets mediating gravitational interaction differs from M_{127}. $L(k)$ $k = 2^7 = 128$, would would correspond to $G \rightarrow 2G$. The growth of the gravitational coupling strength could be a transient phenomenon taking place only during the collision.

7.2 Shrinking kilogram

The definition of kilogram [49] is not the topics number one in coffee table discussions and definitely not so because it could lead to heated debates. The fact however is that even the behavior of standard kilogram can open up fascinating questions about the structure of space-time.

The 118-year old International Prototype Kilogram is an alloy with 90 per cent Platinum and 10 per cent Iridium by weight (gravitational mass). It is held in an environmentally monitored vault in the basement of the BIPMs House of Breteuil in Sevres on the outskirts of Paris. It has forty copies located around the world which are compared with Sevres copy with a period of 40 years.

The problem is that the Sevres kilogram seems to behave in a manner totally in-appropriate taking into account its high age if the behavior of its equal age copies around the world is taken as the norm [49, 50]. The unavoidable conclusion from the comparisons is that the weight of Sevres kilogram has been reduced by about 50 μg during 118 years which makes about

$$\frac{dlog(m)}{dt} = -4.2 \times 10^{-10}/year \quad .$$

for Sevres copy or relative increase of same amout for its copies.

Specialists have not been able to identify any convincing explanation for the strange phenomenon. For instance, there is condensation of matter from the air in the vault which increases the weight and there is periodic cleaning procedure which however should not cause the effect.

7.2.1 Could the non-conservation of gravitational energy explain the mystery?

The natural question is whether there could be some new physics mechanism involved. If the copies were much younger than the Sevres copy, one could consider the possibility that gravitational mass of all copies is gradually reduced. This is not the case. One can still however look what this could mean.

In TGD Equivalence Principle is not a basic law of nature and in the generic case gravitational energy is non-conserved whereas inertial energy is conserved (I will not go to the delicacies of zero energy ontology here). This occurs even in the case of stationary metrics such as Reissner-Nordström exterior metric and the metrics associated with stationary spherically symmetric star models imbedded as vacuum extremals as has been found.

The basic reason is that Schwartschild time t relates by a scaling and shift to Minkowski time m^0:

$$m^0 = \lambda t + h(r)$$

such that the shift depends on the distance r to the origin. The Minkowski shape of the 3-volume containing the gravitational energy changes with M^4 time but this does not explain the effect. The key observation is that the vacuum extremal of Kähler action is not an extremal of the curvature scalar (these correspond to asymptotic situations). What looks first really paradoxical is that one obtains a constant value of energy inside a fixed constant volume but a non-vanishing flow of energy to the volume. The explanation is that the system simply destroys the gravitational energy flowing inside it! The increase of gravitational binding energy compensating for the feed of gravitational energy gives a more familiar looking articulation for the non-conservation.

Amusingly, the predicted rate for the destruction of the inflowing gravitational energy is of same order of magnitude as in the case of kilogram. Note also that the relative rate is of order $1/a$, a the value of cosmic time of about 10^{10} years. The spherically symmetric star model also predicts a rate of same order.

This approach of course does not allow to understand the behavior of the kilogram since it predicts no change of gravitational mass inside volume and does not even apply in the recent situation since all kilograms are in same age. The co-incidence however suggests that the non-conservation of gravitational energy might be part of the mystery. The point is that if the inflow satisfies Equivalence Principle then the inertial mass of the system would slowly increase whereas gravitational mass would remain constant: this would hold true only in steady state.

7.2.2 Is the change of inertial mass in question?

It would seem that the reduction in weight should correspond to a reduction of the inertial mass in Sevres or its increase of its copies. What would distinguish between Sevres kilogram and its cousins? The only thing one can imagine is that the cousins are brought to Sevres periodically. The transfer process could increase the kilogram or stop its decrease.

Could it be that the inertial mass of every kilogram increases gradually until a steady state is achieved? When the system is transferred to another place the saturation situation is changed to a situation in which genuine transfer of inertial and gravitational mass begins again and leads to a more massive steady state. The very process of transferring the comparison masses to Sevres would cause their increase.

In TGD Universe the increase of the inertial (and gravitational) mass is due to the flow of matter from larger space-time sheets to the system. The additional mass would not enter in via the surface of the kilogram but like a Trojan horse from the interior and it would be thus impossible to control using present day technology. The flow would continue until a flow equilibrium would be reached with as much mass leaving the kilogram as entering it.

7.2.3 A connection with gravitation after all?

Why the in-flow of the inertial energy should be of same order of magnitude as that for the gravitational energy predicted by simple star models? Why Equivalence Principle should hold for the in-flow although it would not hold for the body itself? A possible explanation is in terms of the increasing gravitational binding energy which in a steady situation leaves gravitational energy constant although inertial energy could still increase.

This would however require rather large value of gravitational binding energy since one has

$$\Delta E_{gr} = \frac{\Delta M_I}{M} \ .$$

The Newtonian estimate for E_{gr}/M is of order GM/R, where $R \simeq .1$ m the size of the system. This is of order 10^{-26} and too small by 16 orders of magnitude.

TGD predicts that gravitational constant is proportional to p-adic length scale squared

$$G \propto L_p^2 \ .$$

Ordinary gravitation can be assigned to the Mersenne prime M_{127} associated with electron and thus to p-adic length scale of $L(127) \simeq 2.5 \times 10^{-14}$ meters. The open question has been whether the gravities corresponding to other p-adic length scales are realized or not.

This question together with the discrepancy encourages to ask whether the value of the p-adic prime could be larger inside massive bodies (analogous to black holes in many respects in TGD framework) and make gravitation strong? In the recent case the p-adic length scale should correspond to a length scale of order $10^8 L(127)$. $L(181) \simeq 3.2 \times 10^{-4}$ m (size of a large neuron by the way) would be a good candidate for the p-adic scale in question and considerably smaller than the size scale of order .1 meter defining the size of the kilogram.

This discrepancy brings in mind the strange finding of Tajmar and collaborators [46, 47, 48]. suggesting that rotating super-conductors generate a gravimagnetic field with a field strength by a factor of order 10^{20} larger than predicted by General Relativity. I have considered in this chapter a model of the finding based on dark matter. An alternative model could rely on the assumption that Newton's constant can in some situations correspond to p larger than M_{127}. In this case the p-adic length scale needed would be around $L(193) \simeq 2$ cm.

8 Machian Principle and TGD

Machian Principle has not played any role in the development of TGD. Hence it is somewhat surprising that this principle allows several interpretations in TGD framework.

8.1 Non-conserved gravitational four-momentum and conserved inertial momentum at 4-D space-time level

Consider first the situation at the level of classical theory identifiable in terms of classical dynamics for space-time surfaces.

1. In TGD framework one must distinguish between non-conserved gravitational four-momentum and conserved inertial four-momentum identified as conserved Poincare four-momentum at the level of 4-D space-time dynamics and associated with the preferred extremals of Kähler action defining the analogs of Bohr orbits (no path integral over all possible space-time surfaces but functional integral over light-like partonic 3-surfaces). A collection of conserved vector currents rather than tensor results and this resolves the problems due to ill-definedness of four-momentum in General Relativity which served as the primary motivation for the identification of space-times as 4-surfaces of $H = M^4 \times CP_2$.

2. Non-conserved gravitational four-momentum densities can be identified as a linear combination of Einstein tensor and metric tensor (cosmological constant) by contracting them with the Killing vectors of M^4 translations. Collection of, in general non-conserved, 4-currents result but gravitational four-momentum is well-defined quite generally unlike in General Relativity. Only for the asymptotic stationary cosmologies corresponding to extremals of the curvature scalar plus constant for the induced metric gravitational four-momentum is conserved.

8.2 Inertial four-momentum as the average of gravitational four-momentum

The first question is how non-conserved gravitational and conserved inertial four-momentum relate to each other. Certainly Equivalence Principle in a strong form cannot hold true.

1. In zero energy ontology the total quantum numbers of states vanish and positive and negative energy parts of states have interpretation as initial and final states of particle reaction at elementary particle level where geometro-temporal distance between them is short (TGD inspired theory of consciousness forces to distinguish between geometric time and subjective time). Positive energy ontology emerges as an effective ontology at observational level when the temporal distance between positive and negative energy parts of the state is long as compared to the time scale of conscious observer. The recent understanding about bosons as wormhole contacts between space-time sheets with positive and negative time orientation suggests that the two space-time sheets in question correspond to positive and negative energy parts of the state. This brings in mind the picture of Connes about Higgs mechanism involving two copies of Minkowski space.

2. The intuitive idea is that the conserved inertial four-momentum assignable to the positive energy part of the state is the average of the non-conserved gravitational four momentum and depends on the p-adic length scale characterizing the pair of space-time sheets connecting

positive and negative energy states. The average is over a p-adic time scale characterizing the temporal span of the space-time sheet. This average is coded by the classical dynamics for the preferred extremal of Kähler action defining the generalized Bohr orbit.

8.3 Non-conserved gravitational four-momentum and conserved inertial momentum at parton level

A deeper level description of the situation is achieved at parton level. For light-like partonic 3-surfaces the dynamics is defined by almost topological QFT defined by Chern-Simons action for the induced Kähler form. The extrema have 2-D CP_2 projection. Light-likeness implies the replacement of "topological" with "almost topological" by bringing in the notions of metric and four-momentum.

1. The world of classical worlds (WCW) decomposes into a union of sub-WCW:s associated with preferred points of imbedding space $H = M^4_{\pm} \times CP_2$. The selection of preferred point of H means means a selection of tip of future/past directed light-cone in the case of $M^4_{\pm}$ and selection of U(2) subgroup of SU(3) in the case of CP_2. There is a further selection fixing rest system and angular momentum quantization axis (preferred plane in M^4 defining non-physical polarizations for massless bosons) and quantization axis of color isospin and hypercharge. That configuration space geometry reflects these choices conforms with quantum-classical correspondence requiring that everything quantal has a geometric correlate.

2. At the level of S-matrix the preferred points of H defining past/future directed light-cones correspond to the arguments of n-point function. In the construction of S-matrix one integrates over the tips of the light-cones parameterizing sub-WCW:s consisting of partonic 3-surfaces residing inside these light-cones ($\times CP_2$). Hence a full Poincare invariance results meaning the emergence of conserved four-momentum identifiable as inertial four-momentum assignable to the preferred extremals of Kähler action defining Bohr orbits. These light-cones give rise to Russian doll cosmology with cosmologies within cosmologies such that elementary particles formally correspond to the lowest level in the hierarchy.

3. Parton dynamics is associated with a given future/past light-cone. At parton level one has Lorentz invariance and only the mass squared is conserved for the partonic time evolution dictated by random light-likeness. There is a very delicate point involved here. Partonic four-momentum is non-vanishing only if CP_2 Kähler gauge potential has also $M^4_{\pm}$ component which is pure gauge. Mass squared is conserved (Lorentz invariance) if this component is in the direction of proper time coordinate a of the light-cone and if its magnitude is constant. From the point of view of spinor structure $M^4_{\pm}$ and CP_2 are not totally decoupled. This does not break gauge invariance since Kähler gauge potential does not give rise to U(1) gauge degeneracy but only to 4-D spin glass degeneracy.

4. The natural identification of the conserved classical partonic four-momentum is as the non-conserved gravitational four-momentum defined for a space-time sheet characterized by a p-adic time scale. In accordance with zero energy ontology, a length scale dependent notion is in question. At single parton level Equivalence Principle would state that the conserved gravitational mass is equal to inertial mass but would not require equivalence of four-momenta.

8.4 Inertial four-momentum as average of partonic four-momentum and p-adic thermodynamics

1. The natural hypothesis is that inertial four-momentum at partonic level is the temporal average of non-conserved gravitational four-momentum. This implies particle massivation

in general since the motion of light-like parton is in general random zitterbewegung so that only mass squared is conserved. The average is defined always in some time scale identifiable as the p-adic time scale defining the mass scale via Uncertainty Principle. There is actually hierarchy of p-adic time scales coming as powers of p. Inertial mass vanishes only if the motion is non-random in the time scale considered and this never occurs exactly for even photon and graviton.

2. The quantitative formulation of the averaging relies on p-adic thermodynamics for the integer valued conformal weight characterizing the particle [F2]. By number theoretic universality this description must be equivalent to real thermodynamics with quantized temperature. Quantization of the mass scale is purely number theoretical: p-adic thermodynamics based on standard Boltzman weight $exp(L_0/T)$ does not make sense since $exp(x)$ has always unit p-adic norm so that partition sum does not converge. One can however replace this Boltzman weight with p^{L_0/T_p}, which exists for $T_p = 1/n$, $n = 1, 2, ...$, if L_0 is a generator of conformal scaling having non-negative integer spectrum. This predicts a discrete spectrum of p-adic mass scales and real thermodynamics is obtained by reversing the sign of exponent.

   Assuming a reasonable cutoff on conformal weight (only two lowest terms give non-negligible contributions to thermal average) and a prescription for the mapping of p-adic mass squared to its real counterpart the two descriptions are equivalent. Note that mass squared is the average of conformal weight rather than the average of four-momentum squared so that Lorentz invariance is not lost. Note also that in the construction of S-matrix four-momenta emerge only via the Fourier transform of n-point function and do not appear at fundamental vertices.

3. Also the coupling to Higgs gives a contribution to the mass [F2]. Higgs corresponds to a wormhole contact with wormhole throats carrying fermion and anti-fermion quantum numbers as do all gauge bosons. Higgs expectation should have space-time correlate appearing in the modified Dirac operator. A good candidate is p-adic thermal average for the generalized eigenvalue of the modified Dirac operator vanishing for the zero modes. Thermal mass squared as opposed to Higgs contribution would correspond to the average of integer valued conformal weight. For bosons (in particular Higgs boson!) it is simply the sum of expectations for the two wormhole throats.

4. Both contributions are basically thermal which raises the question whether the interpretation in terms of coherent state of Higgs field (and essentially quantal notion) is really appropriate unless also thermal states can be regarded as genuine quantum states. The matrix characterizing time-like entanglement for the zero energy quantum state can be also thermal S-matrix with respect to the incoming and outgoing partons (hyper-finite factors of type III allow the analog of thermal QFT at the level of quantum states [C3]). This allows also a first principle description of p-adic thermodynamics.

8.5 Various interpretations of Machian Principle

TGD allows several interpretations of Machian Principle and leads also to a generalization of the Principle.

1. Machian Principle is true in the sense that the notion of completely free particle is nonsensible. Free CP_2 type extremal (having random light-like curve as M^4 projection) is a pure vacuum extremal and only its topological condensation creates a wormhole throat (two of them) in the case of fermion (boson). Topological condensation to space-time sheet(s) generates all quantum numbers, not only mass. Both thermal massivation and massivation

via the generation of coherent state of Higgs type wormhole contacts are due to topological condensation.

2. Machian Principle has also interpretation in terms of p-adic physics [E1]. Most points of p-adic space-time sheets have infinite distance from the tip light-cone in the real sense. The discrete algebraic intersection of the p-adic space-time sheet with the real space-time sheet gives rise to effective p-adicity of the topology of the real space-time sheet if the number of these points is large enough. Hence p-adic thermodynamics with given p also assigned to the partonic 3-surface by the modified Dirac operator makes sense. The continuity and smoothness of the dynamics corresponds to the p-adic fractality and long range correlations for the real dynamics and allows to apply p-adic thermodynamics in the real context. p-Adic variant of Machian Principle says that p-adic dynamics of cognition and intentionality in literally infinite scale in the real sense dictates the values of masses among other things.

3. A further interpretation of Machian Principle is in terms of number theoretic Brahman=Atman identity or equivalently, Algebraic Holography [E3]. This principle states that the number theoretic structure of the space-time point is so rich due to the presence of infinite hierarchy of real units obtained as ratios of infinite integers that single space-time point can represent the entire world of classical worlds. This could be generalized also to a criterion for a good mathematics: only those mathematical structures which are representable in the set of real units associated with the coordinates of single space-time point are really fundamental.

References

Online books about TGD

[1] M. Pitkänen (2006), *Topological Geometrodynamics: Overview.* http://www.helsinki.fi/∼matpitka/tgdview/tgdview.html.

[2] M. Pitkänen (2006), *Quantum Physics as Infinite-Dimensional Geometry.* http://www.helsinki.fi/∼matpitka/tgdgeom/tgdgeom.html.

[3] M. Pitkänen (2006), *Physics in Many-Sheeted Space-Time.* http://www.helsinki.fi/∼matpitka/tgdclass/tgdclass.html.

[4] M. Pitkänen (2006), *Quantum TGD.* http://www.helsinki.fi/∼matpitka/tgdquant/tgdquant.html.

[5] M. Pitkänen (2006), *TGD as a Generalized Number Theory.* http://www.helsinki.fi/∼matpitka/tgdnumber/tgdnumber.html.

[6] M. Pitkänen (2006), *p-Adic length Scale Hypothesis and Dark Matter Hierarchy.* http://www.helsinki.fi/∼matpitka/paddark/paddark.html.

[7] M. Pitkänen (2006), *TGD and Fringe Physics.* http://www.helsinki.fi/∼matpitka/freenergy/freenergy.html.

Online books about TGD inspired theory of consciousness and quantum biology

[8] M. Pitkänen (2006), *Bio-Systems as Self-Organizing Quantum Systems.* http://www.helsinki.fi/∼matpitka/bioselforg/bioselforg.html.

[9] M. Pitkänen (2006), *Quantum Hardware of Living Matter.*
http://www.helsinki.fi/~matpitka/bioware/bioware.html.

[10] M. Pitkänen (2006), *TGD Inspired Theory of Consciousness.*
http://www.helsinki.fi/~matpitka/tgdconsc/tgdconsc.html.

[11] M. Pitkänen (2006), *Mathematical Aspects of Consciousness Theory.*
http://www.helsinki.fi/~matpitka/genememe/genememe.html.

[12] M. Pitkänen (2006), *TGD and EEG.*
http://www.helsinki.fi/~matpitka/tgdeeg/tgdeeg/tgdeeg.html.

[13] M. Pitkänen (2006), *Bio-Systems as Conscious Holograms.*
http://www.helsinki.fi/~matpitka/hologram/hologram.html.

[14] M. Pitkänen (2006), *Magnetospheric Consciousness.*
http://www.helsinki.fi/~matpitka/magnconsc/magnconsc.html.

[15] M. Pitkänen (2006), *Mathematical Aspects of Consciousness Theory.*
http://www.helsinki.fi/~matpitka/magnconsc/mathconsc.html.

References to the chapters of books

[A1] The chapter *An Overview about the Evolution of TGD* of [1].
http://www.helsinki.fi/~matpitka/tgdview/tgdview.html#tgdevo. The chapter *An Overview about the Evolution of Quantum TGD* of [1].
http://www.helsinki.fi/~matpitka/tgdview/tgdview.html#tgdevo.

[A2] The chapter *An Overview about the Quantum TGD* of [1].
http://www.helsinki.fi/~matpitka/tgdview/tgdview.html#tgdevo. The chapter *An Overview about the Evolution of Quantum TGD* of [1].
http://www.helsinki.fi/~matpitka/tgdview/tgdview.html#tgdevo.

[B2] The chapter *Construction of Configuration Space Kähler Geometry from Symmetry Principles: Part I* of [2].
http://www.helsinki.fi/~matpitka/tgdgeom/tgdgeom.html#compl1.

[B3] The chapter *Construction of Configuration Space Kähler Geometry from Symmetry Principles: Part II* of [2].
http://www.helsinki.fi/~matpitka/tgdgeom/tgdgeom.html#compl2.

[B4] The chapter *Configuration Space Spinor Structure* of [2].
http://www.helsinki.fi/~matpitka/tgdgeom/tgdgeom.html#cspin.

[C1] The chapter *Construction of Quantum Theory: Symmetries* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#quthe.

[C2] The chapter *Construction of Quantum Theory: S-matrix* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#towards.

[C3] The chapter *Hyper-Finite Factors and Construction of S-matrix* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#HFSmatrix.

[C5] The chapter *Is it Possible to Understand Coupling Constant Evolution at Space-Time Level?* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#rgflow.

[C8] The chapter *Was von Neumann Right After All* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#vNeumann.

[C9] The chapter *Does TGD Predict the Spectrum of Planck Constants?* of [4].
http://www.helsinki.fi/~matpitka/tgdquant/tgdquant.html#Planck.

[D1] The chapter *Basic Extremals of Kähler Action* of [3].
http://www.helsinki.fi/~matpitka/tgdclass/tgdclass.html#class.

[D2] The chapter *General Ideas about Topological Condensation and Evaporation* of [3].
http://www.helsinki.fi/~matpitka/tgdclass/tgdclass.html#topcond.

[D3] The chapter *General Ideas about Many-Sheeted Space-Time: Part II* of [3].
http://www.helsinki.fi/~matpitka/tgdclass/tgdclass.html#newviews.

[D5] The chapter *Cosmic Strings* of [3].
http://www.helsinki.fi/~matpitka/tgdclass/tgdclass.html#cstrings.

[D6] The chapter *TGD and Cosmology* of [3].
http://www.helsinki.fi/~matpitka/tgdclass/tgdclass.html#cosmo.

[D7] The chapter *TGD and Astrophysics* of [3].
http://www.helsinki.fi/~matpitka/tgdclass/tgdclass.html#astro.

[E1] The chapter *TGD as a Generalized Number Theory: p-Adicization Program* of [5].
http://www.helsinki.fi/~matpitka/tgdnumber/tgdnumber.html#visiona.

[E2] The chapter *TGD as a Generalized Number Theory: Quaternions, Octonions, and their Hyper Counterparts* of [5].
http://www.helsinki.fi/~matpitka/tgdnumber/tgdnumber.html#visionb.

[E3] The chapter *TGD as a Generalized Number Theory: Infinite Primes* of [5].
http://www.helsinki.fi/~matpitka/tgdnumber/tgdnumber.html#visionc.

[F2] The chapter *Massless States and Particle Massivation* of [6].
http://www.helsinki.fi/~matpitka/paddark/paddark.html#mless.

[F3] The chapter *p-Adic Particle Massivation: Hadron Masses* of [6].
http://www.helsinki.fi/~matpitka/paddark/paddark.html#padmass2.

[F4] The chapter *p-Adic Particle Massivation: Hadron Masses* of [6].
http://www.helsinki.fi/~matpitka/paddark/paddark.html#padmass3.

[F5] The chapter *p-Adic Particle Massivation: New Physics* of [6].
http://www.helsinki.fi/~matpitka/paddark/paddark.html#padmass4.

[F6] The chapter *Topological Condensation and Evaporation* of [6].
http://www.helsinki.fi/~matpitka/paddark/paddark.html#padaelem.

[F8] The chapter *TGD and Nuclear Physics* of [6].
http://www.helsinki.fi/~matpitka/paddark/paddark.html#padnucl.

[F9] The chapter *Dark Nuclear Physics and Living Matter* of [6].
http://www.helsinki.fi/∼matpitka/paddark/paddark.html#exonuclear.

[G1] The chapter *Anomalies Related to the Classical Z^0 Force and Gravitation* of [7].
http://www.helsinki.fi/∼matpitka/freenergy/freenergy.html#Zanom.

[J1] The chapter *Bio-Systems as Super-Conductors: part I* of [9].
http://www.helsinki.fi/∼matpitka/bioware/bioware.html#superc1.

[J2] The chapter *Bio-Systems as Super-Conductors: part II* of [9].
http://www.helsinki.fi/∼matpitka/bioware/bioware.html#superc2.

[J3] The chapter *Bio-Systems as Super-Conductors: part III* of [9].
http://www.helsinki.fi/∼matpitka/bioware/bioware.html#superc3.

[J6] The chapter *Coherent Dark Matter and Bio-Systems as Macroscopic Quantum Systems* of [9].
http://www.helsinki.fi/∼matpitka/bioware/bioware.html#darkbio.

[K1] The chapter *Time, Spacetime and Consciousness* of [13].
http://www.helsinki.fi/∼matpitka/hologram/hologram.html#time.

[M3] The chapter *Dark Matter Hierarchy and Hierarchy of EEGs* of [12].
http://www.helsinki.fi/∼matpitka/tgdeeg/tgdeeg/tgdeeg.html#eegdark.

[16] The chapter *TGD and GRT* of "Topological Geometrodynamics" (older version of this chapter), http://www.helsinki.fi/∼matpitka/tgd.html#cstrings.

[17] The chapter *Cosmic Strings* of "Topological Geometrodynamics" (older version of chapter with same name), http://www.helsinki.fi/∼matpitka/tgd.html#cstrings.

Mathematics related references

[18] V. Jones (2003), *In and around the origin of quantum groups*, arXiv:math.OA/0309199.

[19] V. F. R. Jones (1983), *Index for Subfactors*, Invent. Math. (72),1-25.

Particle physics and nuclear physics

[20] B. B. Back *et al*(2002), Nucl. Phys. A698, 416 (2002).

[21] B. B. Back *et al*(2002), Phys. Rev. Lett. Vol. 89, No 22, 25 November. See also
http://www.scienceblog.com/community/modules.php?name=News&file=article&sid= 357.

[22] M. Derrick *et al*(1993), Phys. Lett B 315, p. 481.

Cosmology and astrophysics

[23] Weinberg, S. (1967): *Gravitation and Cosmology.* Wiley,New York .

[24] Shapiro, S., L., Teukolsky, S., A. (1986): *Black Holes, White Dwarfs and Neutron Stars.* John Wiley & Sons, Inc.

[25] Durrant, C., J.(1988): *The Atmosphere of the Sun.* IOP Publishing Ltd..

[26] S. Dado, A. Dar, A. De Rujula (2003), *The Supernova associated with GRB030329*, arXiv:/astro-ph/0304106.

[27] J. Hjorth *et al*(2003), *A very energetic supernova associated with the gamma-ray burst of 29 March 2003*, Nature, 423, 847.

[28] A. Middleditch (2003), *A White Dwarf Merger Paradigm for Supernovae and Gamma-Ray Bursts*, arXiv:astro-ph/0311484.

[29] W. Coburn and S. E. Boggs (2003), *Polarization of Prompt γ-ray emission from the γ-ray burst of 6 December 2002* , arXiv:astro-ph/0305377. Nature, 2003, May 22, 423, 415-417.
See also *Twisted secrets of gamma-ray bursts*, New Scientist vol 178 issue 2398 - 07 June 2003, page 25.

[30] W. Meikle *et al* (1987), Nature 329, 262.
P. Nisenson *et al* (1999), Astrophysics Journal 320, L15.

[31] C. W. F Everitt (2007), *Results from Gravity Probe B.*
http://meetings.aps.org/Meeting/APR07/Event/64567.

[32] C. M. Will (2006), *Confrontation between General Relativity and Experiment*,
http://arxiv.org/PS_cache/gr-qc/pdf/0510/0510072v2.pdf.

[33] *Kerr metric*, http://en.wikipedia.org/wiki/Kerr_metric.

[34] *Voids*, http://en.wikipedia.org/wiki/Void_%28astronomy%29.

[35] Λ-*CDM model*, http://en.wikipedia.org/wiki/Lambda-CDM_model.

[36] *Bullet Cluster*, http://en.wikipedia.org/wiki/Bullet_cluster.

[37] D. Clowe, A. Gonzales and M. Markevitch (2003), *Weak lensing mass reconstruction of the interacting cluster 1E0657-558: Direct evidence for the existence of dark matter.*
http://arxiv.org/astro-ph/0312273.

[38] D. Clove *et al*(2006), *A direct empirical proof of the existence of dark matter*, http://arxiv.org/abs/astro-ph/0608407.

[39] V. Springel and G. Farrar (2007), *The speed of the 'bullet' in the merging galaxy cluster 1E0657-56*,
http://arxiv.org/astro-ph/pdf/0703232.

[40] Zeeya Merali (2007), *Dark Matter gets its own dark force*, New Scientist , Vol 193, No 2587, 20.

Physics related anomalies

[41] V. Chernobrov (1996), *Experiments on the Change of Direction and Rate of Time Motion*, Proc. of III Int. Conf. On Problems of Space, Time, and Gravitation, Russian Academi of Sciences, St. Petersburg, Russia.

[42] D. Reed (2003), *Conceptual Hurdles to New Millennium Physics*, Explore!, vol 12, No 1.

[43] Roshchin, V.V and Godin, S.M., *An Experimental Investigation of the Physical Effects in a Dynamic Magnetic System*, New Energy Technologies Issue #1 July-August 2001.

[44] M. Moshina (2005), *The surface ferrite layer of Sun*, http://www.thesurfaceofthesun.com/TheSurfaceOfTheSun.pdf.

[45] K. S. Novoselov *et al* (2005), *Two-dimensional gas of massless Dirac fermions in graphene*, Letter Nature 438, 197-200 . (10 November).

[46] M. Tajmar and C. J. de Matos (2006), *Local Photon and Graviton Mass and Its Consequences*, arXiv.org gr-gc 0603032.

[47] M. Tajmar *et al* (2006), *Experimental Detection of Gravimagnetic London Moment*,arXiv.org gr-gc 0603033. See also the popular article "Towards new tests of general relativity", at http://www.esa.int/SPECIALS/GSP/SEM0L6OVGJE_0.html.

[48] J. Tate *et al* (1989), Phys. Rev. Lett. 62 (8), 845-848.
Ibid. (1990), Phys. Rev. B 42(13), 7885-7893.

[49] *Kilogram*, http://en.wikipedia.org/wiki/Kilogram.

[50] *Shrinking kilogram bewilders physicists*,
http://www.breitbart.com/article.php?id=D8RK5MR00&show_article=1&catnum=0

[51] M. Chaplin (2005), *Water Structure and Behavior*,
http://www.lsbu.ac.uk/water/index.html.
For 41 anomalies see http://www.lsbu.ac.uk/water/anmlies.html.
For the icosahedral clustering see http://www.lsbu.ac.uk/water/clusters.html.

[52] D. Da Roacha and L. Nottale (2003), *Gravitational Structure Formation in Scale Relativity*, astro-ph/0310036.

[53] *Paraconical pendulum*, http://en.wikipedia.org/wiki/Paraconical_pendulum.

[54] *Allais effect*, http://en.wikipedia.org/wiki/Allais_effect.

[55] M. Allais (1959), *Should the Laws of Gravitation Be Reconsidered: Part I,II,III?*,
http://home.t01.itscom.net/allais/blackprior/allais/lawgravit/lawgrav-one.pdf
http://home.t01.itscom.net/allais/blackprior/allais/lawgravit/lawgrav-two.pdf.
M. Allais, *The Allais effect and my experiments with the paraconical pendulum 1954-1960.*
http://www.allais.info/alltrans/nasareport.pdf.

[56] G. T. Jeverdan, G. I. Rusu, and V. Antonescu, *Experiments using the Foucault pendulum during the solar eclipse of 15 February, 1961*, Biblical Astronomer 1 (55), 1820 (1981).

[57] V. A. Popescu, D. Olenici (2007), *A confirmation of the Allais and Jeverdan-Rusu-Antonescu effects during the solar eclipse from 22 September 2006, and the quantization behavior of pendulum.*
http://www.hessdalen.org/sse/program/Articol.pdf.

[58] Qian-Shen Wang *et al* (2000), *Precise measurement of gravity variations during a total solar eclipse*, Phys. Rev. D, vol. 62, 041101(R),
http://home.t01.itscom.net/allais/blackprior/wang/wangetal.pdf.

[59] *French Nobel Laureate turns back clock: Marshall's global experiment, von Braun memories evoked during August 11 solar eclipse*,
http://science.nasa.gov/newhome/headlines/ast12oct99$_1$.htm.

[60] I. Mihaila *et al* (2003), *A new confirmation of the Allais effect during the solar eclipse of 31 2003 May*.
http://home.t01.itscom.net/allais/blackprior/mihaila/2003/mihaila2003.pdf

[61] *Tides*, http://en.wikipedia.org/wiki/Tides.

[62] MAGIC collaboration (2007), *Probing Quantum Gravity using Photons from a Mkn 501 Flare observed in MAGIC*, arXiv:0708.2889[astro-ph].
http://arxiv.org/abs/0708.2889.