TGD View about Quasars

M. Pitkänen,

February 2, 2024
Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland. ORCID: 0000-0002-8051-4364.

Contents

Abstract

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

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

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

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

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

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

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

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

1 Introduction

The work of Rudolph Schild and his colleagues Darryl Letier and Stanley Robertson (among others) suggests that quasars are not supermassive blackholes but something else [E4] (see `http://tinyurl.com/y9uyzjlp`)- MECOs, magnetic eternally collapsing objects. There is a popular article about the claim (see `http://tinyurl.com/ydcurslo`). Schild *et al* argue that the same applies to galactic blackhole candidates and active galactic nuclei, perhaps even to ordinary blackholes as Abhas Mitra, the developer of the notion of MECO proposes.

1.1 Could quasars be MECOs rather than supermassive blackholes?

The basic claim of Schild *et al* is that quasars are not blackholes but eternally collapsing magnetic objects. This claim is based on long lasting study of quasar Q0957+561.

1.1.1 Methods

Before the publication of their article [E4] authors studied single quasar - Q0957+561 at distance of about billion light years for more than two decades. They also speak of Q0957+561 A,B referring to the two images of this quasar produced by gravitational lensing made possible by the fact that there happens to be a galaxy between us and Q0957+561. This lucky co-incidence has made possible to deduce detailed information about the structure and dynamics of the quasar. Besides galactic lense effect there is micro-lensing caused by the start of galaxy moving between the quasar and galaxy and leading to a variation of the measured luminosity - flickering.

The information about the quasar's structure and dynamics is deduced from the time dependence of the spectrum of the galaxy at various frequencies. Autocorrelation functions provide information about the dynamics of quasar and turn to have a period of about 10 days independent of frequencies. This period must be related to the dynamics and geometry of the quasar and the distance travelled by light in this time must define a basic scale of the quasar.

The repetitions of almost similar temporal patters - features - suggest an interpretation in terms of signal generated in quasar and then reflected as it encounters second part of quasar. Also fluorescence would generate secondary radiation. The time lapse gives direct information about the size and the shape of the structure. Combined with theoretical considerations this this gives a rather detailed view about the geometry and dynamics of the quasar. The fluctuations of the luminosity provide also information.

1.1.2 Findings and interpretation as MECOs

The quasars would indeed differ from blackholes. Quasars would have magnetic moment unlike ordinary blackholes but lack event horizon. Quasars would have relatively complex geometric structure and dynamics. Authors describe their findings in terms of Schild-Vakulik structure (see `http://tinyurl.com/y92m2tah`) with the following anatomy.

1. A central object analogous to blackhole in that the radius is essentially Schwartschild radius r_S (or gravitational radius R_g as authors prefer to call it). The mass of this object is estimated to be $M \sim 3.6 \times 10^9 M_{sun}$. The corresponding Schwartschild radius r_S is by scaling from that of Sun equal to $r_{S,Sun} \simeq 3$ km equal to $r_S = 1.1 \times 10^{10}$ km. Note that the mass of the proposed supermassive black hole in the core of Milky Way is about 4.1 million solar masses and 3 orders of magnitude smaller. Could this mean that that quasar center loses its mass in the process and generates in this way the galaxy so that a kind of time reversal of blackhole would be in question? Note that the mass of the visible part of Milky Way itself is of order 10^{12} solar masses.

2. An empty disk around the central object would be caused by magnetic propellor effect: the radial Lorentz force overcoming gravitational attraction would sweep charged particles from the disk. This effect is possibly inside magnetosphere, where magnetic pressure dominates over the ordinary pressure. Lorentz force would dominate over the gravitational force. An objection against this proposal (see `http://tinyurl.com/ycwd2nho`) is that the gas in this region could be filled with very hot, tenuous gas, which would not radiate much.

3. An inner luminous ring at the inner boundary of the accretion disk having radius $R \sim 74R_g$ would be the luminous object producing the radiation. Instead of r_S authors talk about gravitational radius R_g of the central object, which would be slightly larger than Schwartschild radius. The inner radius would be about $(3.9 \pm .16) \times 10^{11}$ km. The diameter d characterizing the thickness of the inner ring is estimated to be about $d = 5.4 \times 10^9$ km. Note that d is roughly one half of r_S.

   The radius of the disk defines the size of the magnetosphere of the object. Few per cent fluctuation in the luminosity with variance increasing linearly with time has been observed

- the radiation from accretion disk would increase like t^2 or t^3 depending on whether it is optically thick or thin. This observation has motivated the assignment of the luminosity to the ring.

The fluctuations must be generated by some events. The proposed interpretation is that the flow of the matter to the central object causes these events. Second possibility is that the fluctuations are associated with outwards mass flow from the central object colliding with the accretion disk.

4. In the accretion disk gravitation and pressure dominate over magnetic forces and there is a competition between pressure and gravitation. This structure is also associated also with ordinary blackholes. The mass flow could be outwards in the disk.

5. The outer ring as boundary of the accretion disk is called Elvis structure: the name derives from Martin Elvis, who has also studied the structure of quasars [E3] (see `http://tinyurl.com/yd5j9uno`). In the abstract of the article it is stated that a funnel shaped thin shell creates various structures in the inner regions of quasar. The identification of this structure would be in terms of the base of the funnel from which the matter flows out. Funnel has opening angle about 60 degrees. The outflow leads to ask whether the net flow of matter matter from the quasar is outwards rather than inwards. There are also illustrations of the 3-D structure of quasars (see `http://tinyurl.com/y755gc4a`).

   The size R_e of and the vertical location H_e of the Elvis structure above disk are estimated to be $R_e = 2 \times 10^{12}$ km and $H_e = 5 \times 10^{11}$ km. The radial width of UV-luminous Elvis structure would be $\Delta R_e = 4 \times 10^{11}$ km .

   There is also a structure emitting radio waves. Its size R_r and vertical location H_r are estimated to be $R_r = 2 \times 10^{11}$ km and $H_r = 9 \times 10^{11}$ km .

6. The strength of the magnetic field B at the gravitational radius $R_g \simeq r_S$ of the central object is estimated on basis if MECO to be $2.5\times 10^9 \sqrt{7M_{Sun}/M} \simeq 4.4\times 10^4$ Tesla. The dependence of the magnetic field on distance far from the dipole core is $(R_g/R)^3$. The estimate for the observed magnetic field strength extrapolated to $R = R_g$ is given in Table 2 and equals to .77 Tesla being much smaller than 4.4×10^4 Tesla. The latter field correspond to a magnetic field obtained from MECO solution for stellar object by scaling.

The authors propose that a solution of field equations of general relativity found by Abhas Mitra, called (M)ECO ((magnetic) eternally collapsing object) [E1] could provide a model for the empirical findings about the structure and dynamics of the quasars. The original proposal of Mitra is that (M)ECOs could replace blackholes.

Mitra's general argument against blackholes is that the formation of ordinary blackholes is not possible since the collapsing matter should move with superluminal velocity. There are however objections against this argument (see `http://tinyurl.com/ycwd2nho`). (M)ECOs would be free of horizons and represent eternal collapse: at Eddington limit the radiation pressure inside the object would halt the collapse. (M)ECOs can have hair, in particular magnetic moment.

1.2 TGD view

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

TGD is assumed to have standard model and GRT as QFT limit in long length scales. Could MECOs provide this limit? It seems that the answer is negative: MECOs represent still collapsing objects. The energy of inflaton field is replaced with the sum of the magnetic energy of cosmic string and positive volume energy (essentially magnetic energy from 6-D perspective), which both decrease as the thickness of flux tube increases. The liberated energy transforms to ordinary particles and their dark variants in TGD sense. Time reversal of blackhole would be more appropriate interpretation. One can of course ask, whether the blackhole candidates in galactic nuclei are time reversals of quasars in TGD sense.

I am not specialist so that I must concentrate on just what I see the most essential aspects and considerations rely crucially on the general TGD inspired vision about formation of galaxies. Furthermore, quasar dynamics is not a mere straightforward application of TGD but has proceeded through highs and lows - almost moments of total despair! The understanding of the twistor lift of TGD, of cosmological constant, of hierarchy of Planck constants and the notion of gravitational Planck constant are far from complete, and the information coming from the quasar dynamics has provided a valuable input allowing to solve some key puzzles involved.

2 Background about TGD

To develop TGD view about quasars, one must first summarize general vision about the formation of galaxies in TGD Universe. The starting point is the twistor lift of TGD and cosmic strings and their deformations as basic dynamical objects. A further key notion is the hierarchy of Planck constant predicted by adelic physics [L8, L9]. The notion of gravitational Planck constant is still only partially understood and this work forced to develop a more precise view allowing to overcome various objections.

All applications make me aware of some poorly understood aspects of TGD and quasar model was not an exception. It forced to clarify some details related to twistor lift and answer what covering space property and the notion gravitational Planck constant do really mean in TGD. Also the details related to the understanding of cosmological constant emerging from twistor lift of TGD naturally have been clarified considerably.

2.1 General vision

Consider first the general vision about galaxy formation in TGD Universe.

1. In TGD Universe quasars would represent the analog of the decay of inflaton field to matter [L11]. Galaxies associated with long cosmic string would be like pearls in necklace [L14]. The long string like object - magnetic flux tube - would have what I have called knots or tangles along it. The gravitational force created by the long string would automatically explain the flat velocity spectrum of distant stars and galactic dark matter would correspond to the energy assignable to this long string like object: there would be no halo.

   That galaxies are assignable to long linear structures have been known for decades [E5] but for some reason this message has not been taken by the theoreticians believing in dark matter halo. The number of conflicts of the halo model with empirical facts has increased steadily and it now seems that dark matter halo is empirically excluded.

   The galactic tangle would contain stars and even planets as sub-tangles. The topology of the flux tube structure would be analogous to the field line topology of magnetic field field, in reasonable approximation a dipole field in the case of quasar. Knotting and linking would be possible.

2. The dynamics of the flux tubes structures relies on the twistor lift of TGD [K11, K8, K2] predicting that the dimensional reduction of 6-D Kähler action defining twistor structure at space-time surface as twistor structure induced from that of $H = M^4 \times CP_2$ and having the crucial Kähler structure only for this choice of H. Space-time surfaces correspond to the base-spaces of their 6-D twistor spaces as induced twistor structures with S^2 fiber. 8-D twistor structure solves one of the basic problems of ordinary twistor approach due to the condition that particles must be massless. Now particles must be massless in 8-D sense and can therefore be massive in 4-D sense.

   The dimensionally reduced action contains besides 4-D Kähler action also a volume term analogous to cosmological constant term. The interpretation of field equations is as a 4-D generalization of equations of motion for point-like particle with Kähler charge natural since particles are indeed replaced with 3-surfaces in TGD.

Cosmic strings identifiable as 4-surfaces having string world sheets as M^4 projection and complex 2-surface Y^2 as CP_2 projection belong to the basic extremals [K1, K3]. These surfaces are unstable against thickening of 2-D M^4 projection to 4-dimensional one and one can speak of flux tubes.

There are two kinds of flux tubes: those for with Y^2 carries homological charge having interpretation as magnetic charge so that these flux tubes carry monopole flux and those for which Y^2 has vanishing homological charge. The flux tubes of first kind are of special interest as far as formation of galaxies is considered. Whatever happens to this flux tubes, the quantized magnetic flux - homology charge - is conserved.

3. The flux tubes of the tangle like structures along the long cosmic string would increase in thickness so that by flux conservation they would liberate magnetic energy as ordinary particles and their dark variants since magnetic energy density per length behaves like $1/S$, S cross-sectional area. On the other hand, the volume energy proportional to S increases and there is some flux tube radius at which the energy is minimum and expansion cannot continue anymore. This process would eventually give rise to the formation of the galaxy.

   If cosmological constant depends on p-adic length scale like $1/L^2(k)$, one has hierarchy of limiting radii for flux tubes. Interestingly, for the cosmological constant in cosmological scales the flux tube radius deduced from the density of volume energy is about 1 mm, a biological scale, which means connection between cosmology and biology.

   Remark: The volume energy is indeed positive since it is magnetic energy associated with twistor sphere S^2 for dimensionally reduced 6-D Kähler action.

2.2 Twistor lift of TGD

Twistor lift of TGD led to a dramatic progress in the understanding of TGD but also created problems with previous interpretation. The new element was that Kähler action as analog of Maxwell action was replaced with dimensionally reduced 6-D Kähler action decomposing to 4-D Kähler action and volume term having interpretation in terms of cosmological constant.

One can of course ask whether the resulting induced twistor structure is acceptable. Certainly it is not equivalent with the standard twistor structure. In particular, the condition $J^2 = -g$ is lost. In the case of induced Kähler form at X^4 this condition is also lost. For spinor structure the induction guarantees the existence and uniqueness of the spinor structure, and the same applies also to the induced twistor structure being together with the unique properties of twistor spaces of M^4 and CP_2 the key motivation for the notion.

There are some potential problems related to the definition of Kähler function. The most natural identification is as 6-D dimensionally reduced Kähler action.

1. WCW metric must be Euclidian - that positive definite. Since it is defined in terms of second partial derivatives of the Kähler function with respect to complex WCW coordinates and their conjugates, the preferred extremals must be completely stable to guarantee that this quadratic form is positive definite. This condition excludes extremals for which this is not the case. There are also other identifications for the preferred extremal property and stability condition would is a obvious additional condition. Note that at quantum criticality the quadratic form would have some vanishing eigenvalues representing zero modes of the WCW metric.

2. Vacuum functional of WCW is exponent of Kähler function identified as negative of Kähler action for a preferred extremal. The potential problem is that Kähler action contains both electric and magnetic parts and electric part can be negative. For the negative sign of Kähler action the action must remain bounded, otherwise vacuum functional would have arbitrarily large values. This favours the presence of magnetic fields for the preferred extremals and magnetic flux tubes are indeed the basic entities of TGD based physics.

3. One can ask whether the sign of Kähler action for preferred extremals is same as the overall sign of the diagonalized Kähler metric: this would exclude extremals dominated by Kähler electric part of action or at least force the electric part be so small that WCW metric has the same overall signature everywhere.

If one accepts the proposal that the preferred extremals are minimal surfaces (the known extremals are), extremal property is satisfied for both 4-D Kähler action and volume term separately except at finite set of singular points at which there is transfer of conserved charges between the two degrees of freedom. In this principle this would allow the identification of Kähler function as either 4-D Kähler function or 4-D volume term (actually magnetic S^2 part of 6-D Kähler action). This option looks however rather ad hoc.

2.3 Is the cosmological constant really understood?

The interpretation of the coefficient of the volume term as cosmological constant has been a long-standing interpretational issue and caused many moments of despair during years. The intuitive picture has been that cosmological constant obeys p-adic length scale scale evolution meaning that Λ would behave like $1/L_p^2 = 1/p \simeq 1/2^k$ [K2].

This would solve the problems due to the huge value of Λ predicted in GRT approach: the smoothed out behavior of Λ would be $\Lambda \propto 1/a^2$, a light-cone proper time defining cosmic time, and the recent value of Λ - or rather, its value in length scale corresponding to the size scale of the observed Universe - would be extremely small. In the very early Universe - in very short length scales - Λ would be large.

A simple solution of the problem would be the p-adic length scale evolution of Λ as $\Lambda \propto 1/p$, $p \simeq 2^k$. The flux tubes would thicken until the string tension as energy density would reach stable minimum. After this a phase transition reducing the cosmological constant would allow further thickening of the flux tubes. Cosmological expansion would take place as this kind of phase transitions (for a mundane application of this picture see [K5]).

This would solve the basic problem of cosmology, which is understanding why cosmological constant manages to be so small at early times. Time evolution would be replaced with length scale evolution and cosmological constant would be indeed huge in very short scales but its recent value would be extremely small.

I have however not really understood how this evolution could be realized! Twistor lift seems to allow only a very slow (logarithmic) p-adic length scale evolution of Λ [L17]. Is there any cure to this problem?

1. The magnetic energy decreases with the area S of flux tube as $1/S \propto 1/p \simeq 1/2^k$, where $\sqrt{p}$ defines the transversal length scale of the flux tube. Volume energy (magnetic energy associated with the twistor sphere) is positive and increases like S. The sum of these has minimum for certain radius of flux tube determined by the value of Λ. Flux tubes with quantized flux would have thickness determined by the length scale defined by the density of dark energy: $L \sim \rho_{vac}^{-1/4}$, $\rho_{dark} = \Lambda/8\pi G$. $\rho_{vac} \sim 10^{-47}$ GeV^4 (see `http://tinyurl.com/k4bwlzu`) would give $L \sim 1$ mm, which would could be interpreted as a biological length scale (maybe even neuronal length scale).

2. But can Λ be very small? In the simplest picture based on dimensionally reduced 6-D Kähler action this term is not small in comparison with the Kähler action! If the twistor spheres of M^4 and CP_2 give the same contribution to the induced Kähler form at twistor sphere of X^4, this term has maximal possible value!

   The original discussions in [K11, K2] treated the volume term and Kähler term in the dimensionally reduced action as independent terms and Λ was chosen freely. This is however not the case since the coefficients of both terms are proportional to $(1/\alpha_K^2)S(S^2)$, where $S(S^2)$ is the area of the twistor sphere of 6-D induced twistor bundle having space-time surface as base space. This are is same for the twistor spaces of M^4 and CP_2 if CP_2 size defines the only fundamental length scale. I did not even recognize this mistake.

The proposed fast p-adic length scale evolution of the cosmological constant would have extremely beautiful consequences. Could the original intuitive picture be wrong, or could the desired p-adic length scale evolution for Λ be possible after all? Could non-trivial dynamics for dimensional reduction somehow give it? To see what can happen one must look in more detail the induction of twistor structure.

1. The induction of the twistor structure by dimensional reduction involves the identification of the twistor spheres S^2 of the geometric twistor spaces $T(M^4) = M^4 \times S^2(M^4)$ and of T_{CP_2} having $S^2(CP_2)$ as fiber space. What this means that one can take the coordinates of say $S^2(M^4)$ as coordinates and embedding map maps $S^2(M^4)$ to $S^2(CP_2)$. The twistor spheres $S^2(M^4)$ and $S^2(CP_2)$ have in the minimal scenario same radius $R(CP_2)$ (radius of the geodesic sphere of CP_2. The identification map is unique apart from $SO(3)$ rotation R of either twistor sphere possibly combined with reflection P. Could one consider the possibility that R is not trivial and that the induced Kähler forms could almost cancel each other?

2. The induced Kähler form is sum of the Kähler forms induced from $S^2(M^4)$ and $S^2(CP_2)$ and since Kähler forms are same apart from a rotation in the common S^2 coordinates, one has $J_{ind} = J + RP(J)$, where R denotes a rotation and P denotes reflection. Without reflection one cannot get arbitrary small induced Kähler form as sum of the two contributions. For mere reflection one has $J_{ind} = 0$.

   Remark: It seems that one can do with reflection if the Kähler forms of the twistor spheres are of opposite sign in standard spherical coordinates. This would mean that they have have opposite orientation.

   One can choose the rotation to act on (y, z)-plane as $(y, z) \to (cy + sz, -sz + cy)$, where s and c denote the cosines of the rotation angle. A small value of cosmological constant is obtained for small value of s. Reflection P can be chosen to correspond to $z \to -z$. Using coordinates $(u = cos(\Theta), \Phi)$ for $S^2(M^4)$ and (v, Ψ) for $S^2(CP_2)$ and by writing the reflection followed by rotation explicitly in coordinates (x, y, z) one finds $v = -cu - s\sqrt{1-u^2}sin(\Phi)$, $\Psi = arctan[(su/\sqrt{1-u^2}cos(\Phi) + ctan(\Phi)]$. In the lowest order in s one has $v = -u - s\sqrt{1-u^2}sin(\Phi)$, $\Psi = \Phi + scos(\Phi)(u/\sqrt{1-u^2})$.

3. Kähler form J^{ind} is sum of unrotated part $J(M^4) = du \wedge d\Phi$ and $J(CP_2) = dv \wedge d\Psi$. $J(CP_2)$ equals to the determinant $\partial(v, \Psi)/\partial(u, \Phi)$. A suitable spectrum for s could reproduce the proposal $\Lambda \propto 2^{-k}$ for Λ. The S^2 part of 6-D Kähler action equals to $(J^{ind}_{\theta\phi})^2/\sqrt{g_2}$ and in the lowest order proportional to s^2. For small values of s the integral of Kähler action for S^2 over S^2 is proportional to s^2.

   One can write the S^2 part of the dimensionally reduced action as $S(S^2) = s^2F^2(s)$. Very near to the poles the integrand has $1/[sin(\Theta) + O(s)]$ singularity and this gives rise to a logarithmic dependence of F on s and one can write: $F = F(s, log(s))$. In the lowest order one has $s \simeq 2^{-k/2}$, and in improved approximation one obtains a recursion formula $s_n(S^2, k) = 2^{-k/2}/F(s_{n-1}, \log(s_{n-1})$ giving renormalization group evolution with k replaced by anomalous dimension $k_{n,a} = k + 2log[F(s_{n-1}, log(s_{n-1})]$ differing logarithmically from k.

4. The sum $J^{ind} = J + RP(J)$ defining the induced Kähler form in $S^2(X^4)$ is covariantly constant since both terms are covariantly constant by the rotational covariance of J.

5. The embeddings of $S^2(X^4)$ as twistor sphere of space-time surface to both spheres are holomorphic since rotations are represented as holomorphic transformations. Also reflection as $z \to 1/z$ is holomorphic. This in turn implies that the second fundamental form in complex coordinates is a tensor having only components of type $(1, 1)$ and $(-1, -1)$ whereas metric and energy momentum tensor have only components of type $(1, -1)$ and $(-1, 1)$. Therefore all contractions appearing in field equations vanish identically and $S^2(X^4)$ is minimal surface and Kähler current in $S^2(X^4)$ vanishes since it involves components of the trace of second fundamental form. Field equations are indeed satisfied.

6. The solution of field equations becomes a family of space-time surfaces parameterized by the values of the cosmological constant Λ as function of S^2 coordinates satisfying $\Lambda/8\pi G = \rho_{vac} = J \wedge (*J)(S^2)$. In long length scales the variation range of Λ would become arbitrary small.

7. If the minimal surface equations solve separately field equations for the volume term and Kähler action everywhere apart from a discrete set of singular points, the cosmological constant affects the space-time dynamics only at these points. The physical interpretation of

these points is as seats of fundamental fermions at partonic 2-surface at the ends of light-like 3-surfaces defining their orbits (induced metric changes signature at these 3-surfaces). Fermion orbits would be boundaries of fermionic string world sheets.

One would have family of solutions of field equations but particular value of Λ would make itself visible only at the level of elementary fermions by affecting the values of coupling constants. p-Adic coupling constant evolution would be induced by the p-adic coupling constant evolution for the relative rotations R combined with reflection for the two twistor spheres. Therefore twistor lift would not be mere manner to reproduce cosmological term but determine the dynamics at the level of coupling constant evolution.

8. What is nice that also $\Lambda = 0$ option is possible. This would correspond to the variant of TGD involving only Kähler action regarded as TGD before the emergence of twistor lift. Therefore the nice results about cosmology [K10] obtained at this limit would not be lost.

2.4 Does p-adic coupling constant evolution reduce to that for cosmological constant?

One of the chronic problems if TGD has been the understanding of what coupling constant evolution could be defined in TGD.

2.4.1 Basic notions and ideas

Consider first the basic notions and ideas.

1. The notion of quantum criticality is certainly central. The continuous coupling constant evolution having no counterpart in the p-adic sectors of adele would contain as a sub-evolution discrete p-adic coupling constant evolution such that the discrete values of coupling constants allowing interpretation also in p-adic number fields are fixed points of coupling constant evolution.

   Quantum criticality is realized also in terms of zero modes, which by definition do not contribute to WCW metric. Zero modes are like control parameters of a potential function in catastrophe theory. Potential function is extremum with respect to behavior variables replaced now by WCW degrees of freedom. The graph for preferred extremals as surface in the space of zero modes is like the surface describing the catastrophe. For given zero modes there are several preferred extremals and the catastrophe corresponds to the regions of zero mode space, where some branches of co-incide. The degeneration of roots of polynomials is a concrete realization for this.

   Quantum criticality would also mean that coupling parameters effectively disappear from field equations. For minimal surfaces (generalization of massless field equation allowing conformal invariance characterizing criticality) this happens since they are separately extremals of Kähler action and of volume term.

   Quantum criticality is accompanied by conformal invariance in the case of 2-D systems and in TGD this symmetry extends to its 4-D analogas isometries of WCW.

2. In the case of 4-D Kähler action the natural hypothesis was that coupling constant evolution should reduce to that of Kähler coupling strength $1/\alpha_K$ inducing the evolution of other coupling parameters. Also in the case of the twistor lift $1/\alpha_K$ could have similar role. One can however ask whether the value of the 6-D Kähler action for the twistor sphere $S^2(X^4)$ defining cosmological constant could define additional parameter replacing cutoff length scale as the evolution parameter of renormalization group.

3. The hierarchy of adeles should define a hierarchy of values of coupling strengths so that the discrete coupling constant evolution could reduce to the hierarchy of extensions of rationals and be expressible in terms of parameters characterizing them.

4. I have also considered number theoretical existence conditions as a possible manner to fix the values of coupling parameters. The condition that the exponent of Kähler function should

exist also for the p-adic sectors of the adele is what comes in mind as a constraint but it seems that this condition is quite too strong.

If the functional integral is given by perturbations around single maximum of Kähler function, the exponent vanishes from the expression for the scattering amplitudes due to the presence of normalization factor. There indeed should exist only single maximum by the Euclidian signature of the WCW Kähler metric for given values of zero modes (several extrema would mean extrema with non-trivial signature) and the parameters fixing the topology of 3-surfaces at the ends of preferred extremal inside CD. This formulation as counterpart also in terms of the analog of micro-canonical ensemble (allowing only states with the same energy) allowing only discrete sum over extremals with the same Kähler action [L16].

5. I have also considered more or less ad hoc guesses for the evolution of Kähler coupling strength such as reduction of the discrete values of $1/\alpha_K$ to the spectrum of zeros of Riemann zeta or actually of its fermionic counterpart [L1]. These proposals are however highly ad hoc.

2.4.2 Could the area of twistor sphere replace cutoff length?

As I started once again to consider coupling constant evolution I realized that the basic problem has been the lack of explicit formula defining what coupling constant evolution really is.

1. In quantum field theories (QFTs) the presence of infinities forces the introduction of momentum cutoff. The hypothesis that scattering amplitudes do not depend on momentum cutoff forces the evolution of coupling constants. TGD is not plagued by the divergence problems of QFTs. This is fine but implies that there has been no obvious manner to define what coupling constant evolution as a continuous process making sense in the real sector of adelic physics could mean!

2. Cosmological constant is usually experienced as a terrible head ache but it could provide the helping hand now. Could the cutoff length scale be replaced with the value of the length scale defined by the cosmological constant defined by the S^2 part of 6-D Kähler action? This parameter would depend on the details of the induced twistor structure. It was shown above that if the moduli space for induced twistor structures corresponds to rotations of S^2 possibly combined with the reflection, the parameter for coupling constant restricted to that to $SO(2)$ subgroup of $SO(3)$ could be taken to be taken $s = sin(\epsilon)$.

3. RG invariance would state that the 6-D Kähler action is stationary with respect to variations with respect to s. The variation with respect to s would involve several contributions. Besides the variation of $1/\alpha_K(s)$ and the variation of the $S(^2)$ part of 6-D Kähler action defining the cosmological constant, there would be variation coming from the variations of 4-D Kähler action plus 4-D volume term . This variation vanishes by field equations. As matter of fact, the variations of 4-D Kähler action and volume term vanish separately except at discrete set of singular points at which there is energy transfer between these terms. This condition is one manner to state quantum criticality stating that field equations involved no coupling parameters.

   One obtains explicit RG equation for α_K and Λ having the standard form involving logarithmic derivatives. The form of the equation would be

$$\frac{dlog(\alpha_K)}{ds} = -\frac{S(S^2)}{S_K(X^4)+S(S^2)}\frac{dlog(S(S^2))}{ds} \quad . \tag{2.1}$$

   It should be noticed that the choices of the parameter s in the evolution equation is arbitrary so that the identification $s = sin(\epsilon)$ is not necessary.

   The equation contains the ratio $S(S^2)/(S_K(X^4) + S(S^2))$ of actions as a parameter. This does not conform with idea of micro-locality. One can however argue that this conforms with the generalization of point like particle to 3-D surface. For preferred extremal the action is indeed determined by the 3 surfaces at its ends at the boundaries of CD. This implies that the construction of quantum theory requires the solution of classical theory.

In particular, the 4-D classical theory is necessary for the construction of scattering amplitudes, and one cannot reduce TGD to string theory although strong form of holography states that the data about quantum states can be assigned with 2-D surfaces. Even more: $M^8 - H$ correspondence implies that the data determining quantum states can be assigned with discrete set of points defining cognitive representations for given adel This set of points depends on the preferred extremal!

4. How to identify quantum critical values of α_K? At these points one should have $dlog(\alpha_K)/ds = 0$. This implies $dlog(S(S^2)/ds = 0$, which in turn implies $dlog(\alpha_K)/ds = 0$ unless one has $S_K(X^4) + S(S^2) = 0$. This condition would make exponent of 6-D Kähler action trivial and the continuation to the p-adic sectors of adele would be trivial. I have considered also this possibility [L17].

   The critical values of coupling constant evolution would correspond to the critical values of S and therefore of cosmological constant. The basic nuisance of theoretical physics would determine the coupling constant evolution completely! Critical values are in principle possible. Both the numerator $J_{u\Phi}^2$ and the numerator $1/\sqrt{det(g)}$ increase with ϵ. If the rate for the variation of these quantities with s vary it is possible to have a situation in which the one has

$$\frac{dlog(J_{u\Phi}^2)}{ds} = -\frac{dlog(\sqrt{det(g)})}{ds} \quad . \tag{2.2}$$

5. One can make highly non-trivial conclusions about the evolution at general level. For the extremals with vanishing action and for which α_K is critical (vanishing derivate), also the second derivative of $d^2S(S^2)/ds^2 =$ holds true at the critical point. The QFT analogs of these points are points at which beta function develops higher order zero. The tip of cusp catastrophe is second analogy.

   The points at which that the action has minimum are also interesting. For magnetic flux tubes for which one has $S_K(X^4) \propto 1/S$ and $S_{vol} \propto S$ in good approximation, one has $S_K(X^4) = S_{vol}$ at minimum (say for the flux tubes with radius about 1 mm for the cosmological constant in cosmological scales). One can write

$$\frac{dlog(\alpha_K)}{ds} = -\frac{1}{2}\frac{dlog(S(S^2))}{ds} \quad , \tag{2.3}$$

   and solve the equation explicitly:

$$\frac{\alpha_{K,0}}{\alpha_K} = \frac{S(S^2)}{S(S^2)_0})^x \quad , \quad x = 1/2 \quad . \tag{2.4}$$

   A more general situation would correspond to a model with $x \neq 1/2$: the deviation from $x = 1/2$ could be interpreted as anomalous dimension. This allows to deduce numerically a formula for the value spectrum of $\alpha_{K,0}/\alpha_K$ apart from the initial values.

6. One should demonstrate that the critical values of s are such that the continuation to p-adic sectors of the adele makes sense. For preferred extremals cosmological constant appears as a parameter in field equations but does not affect the field equations expect at the singular points. Singular points play the same role as the poles of analytic function or point charges in electrodynamics inducing long range correlations. Therefore the extremals depend on parameter s and the dependence should be such that the continuation to the p-adic sectors is possible.

   A naïve guess is that the values of s are rational numbers. Above the proposal $s = 2^{-k/2}$ motivated by p-adic length scale hypothesis was considered but also $s = p^{-k/2}$ can be considered. These guesses might be however wrong, the most important point is that there is that one can indeed calculate $\alpha_K(s)$ and identify its critical values.

7. What about scattering amplitudes and evolution of various coupling parameters? If the exponent of action disappears from scattering amplitudes, the continuation of scattering amplitudes is simple. This seems to be the only reasonable option. In the adelic approach [L8] amplitudes are determined by data at a discrete set of points of space-time surface (defining what I call cognitive representation) for which the points have M^8 coordinates belong to the extension of rationals defining the adele.

   Each point of $S^2(X^4)$ corresponds to a slightly different X^4 so that the singular points depend on the parameter s, which induces dependence of scattering amplitudes on s. Since coupling constants are identified in terms of scattering amplitudes, this induces coupling constant evolution having discrete coupling constant evolution as sub-evolution.

2.4.3 Could the critical values of α_K correspond to the zeros of Riemann Zeta?

Number theoretical intuitions strongly suggests that the critical values of $1/\alpha_K$ could somehow correspond to zeros of Riemann Zeta. Riemann zeta is indeed known to be involved with critical systems.

The naïvest ad hoc hypothesis is that the values of $1/\alpha_K$ are actually proportional to the non-trivial zeros $s = 1/2 + iy$ of zeta [L1]. A hypothesis more in line with QFT thinking is that they correspond to the imaginary parts of the roots of zeta. In TGD framework however complex values of α_K are possible and highly suggestive. In any case, one can test the hypothesis that the values of $1/\alpha_K$ are proportional to the zeros of ζ at critical line. Problems indeed emerge.

1. The complexity of the zeros and the non-constancy of their phase implies that the RG equation can hold only for the imaginary part of $s = 1/2 + it$ and therefore only for the imaginary part of the action. This suggests that $1/\alpha_K$ is proportional to y. If $1/\alpha_K$ is complex, RG equation implies that its phase RG invariant since the real and imaginary parts would obey the same RG equation.

2. The second - and much deeper - problem is that one has no reason for why $dlog(\alpha_K)/ds$ should vanish at zeros: one should have $dy/ds = 0$ at zeros but since one can choose instead of parameter s any coordinate as evolution parameter, one can choose $s = y$ so that one has $dy/ds = 1$ and criticality condition cannot hold true. Hence it seems that this proposal is unrealistic although it worked qualitatively at numerical level.

It seems that it is better to proceed in a playful spirit by asking whether one could realize quantum criticality in terms of of the property of being zero of zeta.

1. The very fact that zero of zeta is in question should somehow guarantee quantum criticality. Zeros of ζ define the critical points of the complex analytic function defined by the integral

$$X(s_0, s) = \int_{C_{s_0 \to s}} \zeta(s)ds \quad , \tag{2.5}$$

   where $C_{s_0 \to s}$ is any curve connecting zeros of ζ, a is complex valued constant. Here s does not refer to $s = sin(\epsilon)$ introduced above but to complex coordinate s of Riemann sphere.

   By analyticity the integral does not depend on the curve C connecting the initial and final points and the derivative $dS_c/ds = \zeta(s)$ vanishes at the endpoints if they correspond to zeros of ζ so that would have criticality. The value of the integral for a closed contour containing the pole $s = 1$ of ζ is non-vanishing so that the integral has two values depending on which side of the pole C goes.

2. The first guess is that one can define S_c as complex analytic function $F(X)$ having interpretation as analytic continuation of the S^2 part of action identified as $Re(S_c)$:

$$S_c(S^2) = F(X(s,s_0)) \ , \qquad X(s,s_0) = \int_{C_{s_0\rightarrow s}} \zeta(s)ds \ ,$$
$$S(S^2) = Re(S_c) = Re(F(X)) \ , \qquad (2.6)$$
$$\zeta(s) = 0 \ , \qquad Re(s_0) = 1/2 \ .$$

$S_c(S^2) = F(X)$ would be a complexified version of the Kähler action for S^2. s_0 must be at critical line but it is not quite clear whether one should require $\zeta(s_0) = 0$.

The real valued function $S(S^2)$ would be thus extended to an analytic function $S_c = F(X)$ such that the $S(S^2) = Re(S_c)$ would depend only on the end points of the integration path $C_{s_0\rightarrow s}$. This is geometrically natural. Different integration paths at Riemann sphere would correspond to paths in the moduli space $SO(3)$, whose action defines paths in S^2 and are indeed allowed as most general deformations. Therefore the twistor sphere could be identified Riemann sphere at which Riemann zeta is defined. The critical line and real axis would correspond to particular one parameter sub-groups of $SO(3)$ or to more general one parameter subgroups.

One would have

$$\frac{\alpha_{K,0}}{\alpha_K} = (\frac{S_c}{S_0})^{1/2} \ . \qquad (2.7)$$

The imaginary part of $1/\alpha_K$ (and in some sense also of the action $S_c(S^2)$) would determined by analyticity somewhat like the real parts of the scattering amplitudes are determined by the discontinuities of their imaginary parts.

3. What constraints can one pose on F? F must be such that the value range for $F(X)$ is in the value range of $S(S^2)$. The lower limit for $S(S^2)$ is $S(S^2) = 0$ corresponding to $J_{u\Phi} \rightarrow 0$.

   The upper limit corresponds to the maximum of $S(S^2)$. If the one Kähler forms of M^4 and S^2 have same sign, the maximum is $2 \times A$, where $A = 4\pi$ is the area of unit sphere. This is however not the physical case.

   If the Kähler forms of M^4 and S^2 have opposite signs or if one has RP option, the maximum, call it S_{max}, is smaller. Symmetry considerations strongly suggest that the upper limit corresponds to a rotation of 2π in say (y,z) plane ($s = sin(\epsilon) = 1$ using the previous notation).

   For $s \rightarrow s_0$ the value of S_c approaches zero: this limit must correspond to $S(S^2) = 0$ and $J_{u\Phi} \rightarrow 0$. For $Im(s) \rightarrow \pm\infty$ along the critical line, the behavior of $Re(\zeta)$ (see `http://tinyurl.com/y7b88gvg`) strongly suggests that $|X| \rightarrow \infty$. This requires that F is an analytic function, which approaches to a finite value at the limit $|X| \rightarrow \infty$. Perhaps the simplest elementary function satisfying the saturation constraints is

$$F(X) = S_{max} tanh(-iX) \ . \qquad (2.8)$$

   One has $tanh(x + iy) \rightarrow \pm 1$ for $y \rightarrow \pm\infty$ implying $F(X) \rightarrow \pm S_{max}$ at these limits. More explicitly , one has $tanh(-i/2-y) = [-1+exp(-4y)-2exp(-2y)(cos(1)-1)]/[1+exp(-4y)-2exp(-2y)(cos(1)-1)]$. Since one has $tanh(-i/2+0) = 1-1/cos(1) < 0$ and $tanh(-i/2+\infty) = 1$, one must have some finite value $y = y_0 > 0$ for which one has

$$tanh(-\frac{i}{2} + y_0) = 0 \ . \qquad (2.9)$$

   The smallest possible lower bound s_0 for the integral defining X would naturally to $s_0 = 1/2 - iy_0$ and would be below the real axis.

4. The interpretation of $S(S^2)$ as a positive definite action requires that the sign of $S(S^2) = Re(F)$ for a given choice of $s_0 = 1/2 + iy_0$ and for a propertly sign of $y - y_0$ at critical line should remain positive. One should show that the sign of $S = a\int Re(\zeta)(s = 1/2 + it)dt$ is same for all zeros of ζ. The graph representing the real and imaginary parts of Riemann zeta along critical line $s = 1/2 + it$ (see `http://tinyurl.com/y7b88gvg`) shows that both the real and imaginary part oscillate and increase in amplitude. For the first zeros real part stays in good approximation positive but the amplitude for the negative part increase be gradually. This suggests that S identified as integral of real part oscillates but preserves its sign and gradually increases as required.

A priori there is no reason to exclude the trivial zeros of ζ at $s = -2n$, $n = 1, 2, ...$

1. The natural guess is that the function $F(X)$ is same as for the critical line. The integral defining X would be along real axis and therefore real as also $1/\alpha_K$ provided the sign of S_c is positive: for negative sign for S_c not allowed by the geometric interpretation the square root would give imaginary unit. The graph of the Riemann Zeta at real axis (real) is given in MathWorld Wolfram (see `http://tinyurl.com/55qjmj`).

2. The functional equation

$$\zeta(1-s) = \zeta(s)\frac{\Gamma(s/2)}{\Gamma((1-s)/2)} \tag{2.10}$$

allows to deduce information about the behavior of ζ at negative real axis. $\Gamma((1-s)/2)$ is negative along negative real axis (for $Re(s) \leq 1$ actually) and poles at $n + 1/2$. Its negative maxima approach to zero for large negative values of $Re(s)$ (see `http://tinyurl.com/clxv4pz`) whereas $\zeta(s)$ approaches value one for large positive values of s (see `http://tinyurl.com/y7b88gvg`). A cautious guess is that the sign of $\zeta(s)$ for $s \leq 1$ remains negative. If the integral defining the area is defined as integral contour directed from $s < 0$ to a point s_0 near origin, S_c has positive sign and has a geometric interpretation.

3. The formula for $1/\alpha_K$ would read as $\alpha_{K,0}/\alpha_K(s = -2n) = (S_c/S_0)^{1/2}$ so that α_K would remain real. This integration path could be interpreted as a rotation around z-axis leaving invariant the Kähler form J of $S^2(X^4)$ and therefore also $S = Re(S_c)$. $Im(S_c) = 0$ indeed holds true. For the non-trivial zeros this is not the case and $S = Re(S_c)$ is not invariant.

4. One can wonder whether one could distinguish between Minkowskian and Euclidian and regions in the sense that in Minkowskian regions $1/\alpha_K$ correspond to the non-trivial zeros and in Euclidian regions to trivial zeros along negative real axis. The interpretation as different kind of phases might be appropriate.

What is nice that the hypothesis about equivalence of the geometry based and number theoretic approaches can be killed by just calculating the integral S as function of parameter s. The identification of the parameter s appearing in the RG equations is no unique. The identification of the Riemann sphere and twistor sphere could even allow identify the parameter t as imaginary coordinate in complex coordinates in $SO(3)$ rotations around z-axis act as phase multiplication and in which metric has the standard form.

2.4.4 Some guesses to be shown to be wrong

The following argument suggests a connection between p-adic length scale hypothesis and evolution of cosmological constant but must be taken as an ad hoc guess: the above formula is enough to predict the evolution.

1. p-Adicization is possible only under very special conditions [L8], and suggests that anomalous dimension involving logarithms should vanish for $s = 2^{-k/2}$ corresponding to preferred p-adic length scales associated with $p \simeq 2^k$. Quantum criticality in turn requires that discrete p-adic coupling constant evolution allows the values of coupling parameters, which are fixed points of RG group so that radiative corrections should vanish for them. Also anomalous dimensions Δk should vanish.

2. Could one have $\Delta k_{n,a} = 0$ for $s = 2^{-k/2}$, perhaps for even values $k = 2k_1$? If so, the ratio c/s would satisfy $c/s = 2^{k_1} - 1$ at these points and Mersenne primes as values of c/s would be obtained as a special case. Could the preferred p-adic primes correspond to a prime near to but not larger than $c/s = 2^{k_1} - 1$ as p-adic length scale hypothesis states? This suggest that we are on correct track but the hypothesis could be too strong.

3. The condition $\Delta d = 0$ should correspond to the vanishing of dS/ds. Geometrically this would mean that $S(s)$ curve is above (below) $S(s) = xs^2$ and touches it at points $s = x2^{-k}$, which would be minima (maxima). Intermediate extrema above or below $S = xs^2$ would be maxima (minima).

2.5 What does one really mean with gravitational Planck constant?

There are important questions related to the QFT-GRT limit of TGD.

2.5.1 What does one mean with space-time as covering space?

The central idea is that space-time corresponds to n-fold covering for $h_{eff} = n \times h_0$. It is not however quite clear what this statement does mean.

1. How the many-sheeted space-time corresponds to the space-time of QFT and GRT? QFT-GRT limit of TGD is defined by identifying the gauge potentials as sums of induced gauge potentials over the space-time sheets. Magnetic field is sum over its values for different space-time sheets. For single sheet the field would be extremely small in the present case as will be found.

2. A central notion associated with the hierarchy of effective Planck constants $h_{eff}/h_0 = n$ giving as a special case $\hbar_{gr} = GMm/v_0$ assigned to the flux tubes mediating gravitational interactions. The most general view is that the space-time itself can be regarded as n-sheeted covering space. A more restricted view is that space-time surface can be regarded as n-sheeted covering of M^4. But why not n-sheeted covering of CP_2? And why not having $n = n_1 \times n_2$ such that one has n_1-sheeted covering of CP_2 and n_2-sheeted covering of M^4 as I indeed proposed for more than decade ago [K7] but gave up this notion later and consider only coverings of M^4? There is indeed nothing preventing the more general coverings.

3. $n = n_1 \times n_2$ covering can be illustrated for an electric engineer by considering a coil in very thin 3 dimensional slab having thickness L. The small vertical direction would serve and as analog of CP_2. The remaining 2 large dimensions would serve as analog for M^4. One could try to construct a coil with n loops in the vertical direction direction but for very large n one would encounter problems since loops would overlap because the thickness of the wire would be larger than available room L/n. There would be some maximum value of n, call it n_{max}.

   One could overcome this limit by using the decomposition $n = n_1 \times n_2$ existing if n is prime. In this case one could decompose the coil into n_1 parallel coils in plane having $n_2 \geq n_{max}$ loops in the vertical direction. This provided n_2 is small enough to avoid problems due to finite thickness of the coil. For n prime this does not work but one can of also select n_2 to be maximal and allow the last coil to have less than n_2 loops.

   An interesting possibility is that preferred extremal property implies the decomposition $n_{gr} = n_1 \times n_2$ with nearly maximal value of n_2, which can vary in some limits. Of course, one of the n_2-coverings of M^4 could be in-complete in the case that n_{gr} is prime or not divisible by nearly maximal value of n_2. We do not live in ideal Universe, and one can even imagine that the copies of M^4 covering are not exact copies but that n_2 can vary.

4. In the case of $M^4 \times CP_2$ space-time sheet would replace single loop of the coil, and the procedure would be very similar. A highly interesting question is whether preferred extremal property favours the option in which one has as analog of n_1 coils n_1 full copies of n_2-fold coverings of M^4 at different positions in M^4 and thus defining an n_1 covering of CP_2 in M^4 direction. These positions of copies need not be close to each other but one could still have quantum coherence and this would be essential in TGD inspired quantum biology [L12].

Number theoretic vision [L8, L9] suggests that the sheets could be related by discrete isometries of CP_2 possibly representing the action of Galois group of the extension of rationals defining the adele and since the group is finite sub-group of CP_2, the number of sheets would be finite.

The finite sub-groups of $SU(3)$ are analogous to the finite sub-groups of $SU(2)$ and if they action is genuinely 3-D they correspond to the symmetries of Platonic solids (tetrahedron,cube,octahedron, icosahedron, dodecahedron). Otherwise one obtains symmetries of polygons and the order of group can be arbitrary large. Similar phenomenon is expected now. In fact the values of n_2 could be quantized in terms of dimensions of discrete coset spaces associated with discrete sub-groups of $SU(3)$. This would give rise to a large variation of n_2 and could perhaps explain the large variation of G identified as $G = R^2(CP_2)/n_2$ suggested by the fountain effect of superfluidity [L15].

5. There are indeed two kinds of values of n: the small values $n = h_{em}/h_0 = n_{em}$ assigned with flux tubes mediating em interaction and appearing already in condensed matter physics [L6, L13, L3] and large values $n = h_{gr}/h_0 = n_{gr}$ associated with gravitational flux tubes. The small values of n would be naturally associated with coverings of CP_2. The large values $n_{gr} = n_1 \times n_2$ would correspond n_1-fold coverings of CP_2 consisting of complete n_2-fold coverings of M^4. Note that in this picture one can formally define constants $\hbar(M^4) = n_1\hbar_0$ and $\hbar(CP_2) = n_2\hbar_0$ as proposed in [K7] for more than decade ago.

2.5.2 Planck length as CP_2 radius and identification of gravitational constant G

There is also a puzzle related to the identification of gravitational Planck constant. In TGD framework the only theoretically reasonable identification of Planck length is as CP_2 length $R(CP_2)$, which is roughly $10^{3.5}$ times longer than Planck length [L15]. Otherwise one must introduce the usual Planck length as separate fundamental length. The proposal was that gravitational constant would be defined as $G = R^2(CP_2)/\hbar_{gr}$, $\hbar_{gr} \simeq 10^7\hbar$. The G indeed varies in un-expectedly wide limits and the fountain effect of superfluidity suggests that the variation can be surprisingly large.

There are however problems.

1. Arbitrary small values of $G = R^2(CP_2)/\hbar_{gr}$ are possible for the values of $\hbar_{gr}$ appearing in the applications: the values of order $n_{gr} \sim 10^{13}$ are encountered in the biological applications. The value range of G is however experimentally rather limited. Something clearly goes wrong with the proposed formula.

2. Schwartschild radius $r_S = 2GM = 2R^2(CP_2)M/\hbar_{gr}$ would decrease with $\hbar_{gr}$. One would expect just the opposite since fundamental quantal length scales should scale like $\hbar_{gr}$.

3. What about Nottale formula [E2] $\hbar_{gr} = GMm/v_0$? Should one require self-consistency and substitute $G = R^2(CP_2)/\hbar_{gr}$ to it to obtain $\hbar_{gr} = \sqrt{R^2(CP_2)Mm/v_0}$. This formula leads to physically un-acceptable predictions, and I have used in all applications $G = G_N$ corresponding to $n_{gr} \sim 10^7$ as the ratio of squares of CP_2 length and ordinary Planck length.

Could one interpret the almost constancy of G by assuming that it corresponds to $\hbar(CP_2) = n_2\hbar_0$, $n_2 \simeq 10^7$ and nearly maximal except possibly in some special situations? For $n_{gr} = n_1 \times n_2$ the covering corresponding to $\hbar_{gr}$ would be n_1-fold covering of CP_2 formed from n_1 n_2-fold coverings of M^4. For 1 $n_{gr} = n_1 \times n_2$ the covering would decompose to n_1 disjoint M^4 coverings and this would also guarantee that the definition of r_S remains the standard one since only the number of M^4 coverings increases.

If n_2 corresponds to the order of finite subgroup G of $SU(3)$ or number of elements in a coset space G/H of G (itself sub-group for normal sub-group H), one would have very limited number of values of n_2, and it might be possible to understand the fountain effect of superfluidity [L15] from the symmetries of CP_2, which would take a role similar to the symmetries associated with Platonic solids. In fact, the smaller value of G in fountain effect would suggest that n_2 in this case is larger than for G_N so that n_2 for G_N would not be maximal.

3 TGD view about quasars

TGD based model for quasar does not identify it as a blackhole like entity digesting matter around it but identified it as source of matter and energy resulting in the decay of the magnetic field of the flux time representing thickened cosmic string liberating also gravitational energy since the volume energy is indeed negative for a positive sign of volume action.

3.1 Overall view about the model

Consider now the basic picture about quasars and galaxies provided by TGD.

1. The authors still believe in restricted blackhole paradigm and assume that this structure "digests" matter from surroundings. The unit would have mass $10^{-3}M_{Sun}$ or $10^{-5}M_{Sun}$ - depending on estimate. Here TGD based view differs: the quasar need not digest matter around it but to feed it to the surroundings!

   The cleaning of charged matter from the inner disk would achieved if the total current vanishes so that the rotation velocities are opposite for charges with opposite sign and the directions of the Lorentz force are same, outwards or inwards both. The horizonal ring like structure would be a closed magnetic flux tube along which charged particles would rotate in the field created by the flux tubes of dipole field.

   The matter would flow into the central object if the Lorentz force is opposite: this is the case if the rotation velocities are opposite. Time reversal of this object analogous to blackhole would be in question and quasar could perhaps be seen as time reversed blackhole like entity analogous to time reversal of MECO. Note that in TGD time reversal symmetry T (and CP) are slightly broken. TGD predicts time reversals of the conscious entities assignable to cosmologies (and sub-cosmologies in Russian doll cosmology of TGD) and for them things would happen in opposite time direction fin the standard time frame [L11]: this cosmology is in some aspects analogous to the cosmology proposed by Penrose.

2. TGD based model leads to the proposal that the cylindrical magnetic dipole in the central region could (but certainly need not) be many-sheeted structure - n_1-sheeted covering of CP_2 consisting of disjoint flux tubes and n_2-sheeted covering of M^4 Minkowski space with $n_2 \simeq 10^7$ assigned with the Newtonian value G_N of G identified as $G_N = R^2(CP_2)/n_2\hbar$. This entity would be completely analogous to what I call magnetic body distinguishing between Maxwell's theory TGD (in many-sheeted space-time any system has field identity - field body - in the sense that its fields are associated with different space-time sheets than those of other systems).

   Magnetic body would serve as intentional agent in living systems and would be characterized by a large value of gravitational Planck constant (the notion is originally due to Nottale [E2]) $\hbar_{gr} = GMm(CP_2)/v_0 = (n_{gr}/6) \times \hbar$, $\hbar = 6 \times \hbar_0$. n_{gr} characterizes in adelic TGD [L9, L7] the algebraic complexity as dimension of extension of rationals.

   In the case of quasar M would be the mass of the central blackhole like object - about 3.6×10^9 solar masses as also the candidate for the galactic blackhole in Milky Way. $m(CP_2)$ is CP_2 mass about $10^{-3.5}$ Planck masses and would take the role of Planck mass. G would be identified as $G = R^2(CP_2)/\hbar_2$ rather than $R^2(CP_2)/\hbar_{gr}$ as in [L15], where it was assumed that $n_1 = 1$ so that one indeed had $n_{gr} = n_2$. n_{gr} would have a spectrum realized as a discrete scaling invariance in M^4 such that scaling acts also in G. It remains to be shown that the modification of the formula $G = R^2(CP_2)/\hbar_{gr}$ to $G = R^2(CP_2)/\hbar_2$ preserves the argued scaling invariance in M^4. The interpretation $v_0 < c$ is discussed in [L10].

   It was already discussed how one can understand the approximate constancy of G in this framework. In the simplest situation the coverings involved is $n_{gr} = n_1 \times n_2$ covering such that there is n_1-fold covering of CP_2 correspond to disjoint flux tubes in M^4 and n_2-fold M^4 covering associated with each flux tube. $n_2 \simeq 10^7$ would predict that gravitational constant $G = R^2/\hbar$ is near to its Newtonian value G_N.

3. The algebraic complexity of the galactic magnetic body identified as the cylindrical dipole part of the dipole field represented as flux tubes would be huge. The return flux outside the

dipole would consist of simpler structures having smaller number of sheets and fusing to the dipole structure at the galactic nucleus. The flux tubes could wander to rather large distances and the stars would correspond to looped sub-tangles with flux tube structure mimicking the topology of field lines of dipole field.

n_{gr} plays the role of IQ in TGD based model of living matter as governed by magnetic body. This forces to consider the possibility that quasars and galaxies are living organisms - much above us in hierarchy - having stars, planets,.... , us,... as sub-systems, sub-selves representing their mental images. One can say that the galactic dipole would represent the brain of galaxy. It is needless to say that this would completely revolutionize our world view. We would not be desperate cosmic loners anymore but children of the Universe living and conscious in all scales.

Is there any empirical support for this speculative picture? There is evidence that galactic day as opposed to solar is period for precognitive events studied by people taking seriously "paranormal" phenomena which they prefer to call remote mental interactions [K4]. The reason would be that galactic magnetic field and therefore galactic magnetic body with strength of order nanoTesla is involved.

3.2 Estimate for the strength of the poloidal component B_θ of the magnetic field just below r_S

The estimate for the strength of the poloidal component of the magnetic field deduced from MECO solution just below $R_g \simeq r_S$ is $2.5 \times 10^9 \sqrt{7M_{Sun}/M} \simeq 4.4 \times 10^4$ Tesla. Could one say something about this field in TGD framework.

1. Flux quantization in the dipole core where the return flux of looping long cosmic string enters repeatedly to the dipole region and has the same direction would be integer multiple of unit flux assignable in the simplest case also to the long cosmic string: also this flux is quantized as integer multiples of a basic flux and predicts that the velocity is quantized as $\sqrt{n}$ if the contribution of volume term to the string tension is negligible. This is indeed expected due the smallness of Λ. Note that the long cosmic string makes the looping and after than continues.

   As already described one would have naturally $n_2 \sim 10^7$-fold covering of M^4 for the Newtonian value of G. Therefore one would have n_{gr}/n_2 disjoint flux tubes forming quantum coherent unit, the magnetic body of the quasar.

2. The Nottale proposal for the gravitational Plack constant $\hbar_{gr} = \hbar_{eff} = n_{gr}\hbar_0$, $\hbar = 6h_0$ suggest that the dipole has unit flux but with unit $\hbar_{gr} = GMm(CP_2)/v_0$, $m_{CP_2} = \hbar/R(CP_2)$. In the most original form of the hypothesis the second mass m was any mass but one can argue that since h_{gr} cannot be smaller than h, one must assume that m must have $m(CP_2)$ as lower bound. This leads also to other problems if m is too small. The interpretation in terms of quantum coherent structures with mass coming as multiple of $m(CP_2)$ is discussed in [L12].

3. This allows to estimate the value of the magnetic field from $eBS = n_{gr}\hbar_0 = n_{gr}\hbar/6$. Substituting the estimate $R_{CP_2} = 10^{3.5}l_P \simeq 5.1 \times 10^{-32}$ m, $r_S = 10^{10}$ km. Assume first that one has $n_2 = 1$ - no covering over M^4 so that one has disjoint flux tubes. A monopole flux through a closed surface is in question and there is no boundary and the area should be replaced with area of a topological sphere, which is the CP_2 geodesic sphere deformed in M^4 direction and having area $S = 4\pi R^2$ rather than $S = \pi R^2$ for a disk like cross section of flux tube. Spherical deformation is of course idealized assumption and the area could larger if the sphere is not spherical.

$$eB = \frac{GMm(CP_2)\hbar}{8v_0\pi r_S^2} = \frac{1}{8\pi v_0}\frac{\hbar}{X} \ , \quad X = R(CP_2)r_S \simeq 10^{-18}\ m^2 \ . \tag{3.1}$$

This gives for the magnetic length $l_B = \sqrt{\hbar/eB}$ and magnetic field B the expressions

$$
\begin{array}{l}
l_B = \sqrt{\frac{\hbar}{eB}} = \sqrt{8\pi v_0 \times X} \simeq \sqrt{\pi v_0}\ nm \ , \\
\frac{B}{Tesla} = (\frac{l_B}{26\ nm})^{-2} = \frac{26^2}{8\pi\beta_0} \ .
\end{array}
\quad (3.2)
$$

The smallest value is obtained at the limit $\beta = v_0/c = 1$ and equals $B_{min} = 26.9$ Tesla.

4. From the conclusions section of the article one learns that the the poloidal component of the magnetic field just below radius $R_g \simeq r_S$ is estimated to be about $B \sim \sqrt{7M_{Sun}/M}10^{13}$ Gauss giving $B \sim 4.4\times 10^4$ Tesla. This gives $v_0 \simeq 6\times 10^{-4}$. This is quite near to the estimate $v_0 = 2^{-11} \simeq 4.9 \times 10^{-4}$ obtained from the Bohr orbit model for the inner planet orbits in solar system [K9, **?**].

   This estimate was for $n_2 = 1$ but this is very special situation. For $n_2 = 10^7$ the value of the magnetic field for single sheet one would have $B \to B/n_2 \simeq 44$ Gauss. This option is the realistic one in the proposed framework. For $n_2 = n_{gr}$ corresponding to single flux tube with this number of sheets over M^4 $B \to B/n_{gr}$ which is extremely weak field.

   The effective value $B_{eff} \sim 4.4 \times 10^4$ of the magnetic field would correspond to the sum of n_{gr} copies of this field over all sheets of all tubes. If one has quantum coherence, this field value appears in the formula for cyclotron energies and this formula is crucial in biological applications allowing to have cyclotron energies in visible and UV range for dark photons with cyclotron frequency in EEG range.

3.3 Intelligent blackholes?

I received from Nikolina Benedikovic an interesting link to Leonard Susskinds's interview (see `http://tinyurl.com/yco7pd55` and for arousing my curiosity. In the link one learns that Leonard Susskind has admitted that superstrings do not provide a theory of everything. This is actually not a mind blowing surprise since very few can claim that the news about the death of superstring theory would be premature. Congratulations in any case to Susskind: for a celebrated super string guru it requires courage to change one's mind publicly. I will not discuss in the following the tragic fate of superstrings. Life must continue despite the death of superstring theory and there are much more interesting ideas to consider.

Susskind is promoting an idea about growing blackholes increasing their volume as they swallow matter around them (see `http://tinyurl.com/ybw78hpn`). The idea is that the volume of the blackhole measures the complexity of the blackhole and from this its not long way to the idea that information - may be conscious information (I must admit that I cannot imagine any other kind of information) - is in question.

Some quantum information theorists find this idea attractive. Quantum information theoretic ideas find a natural place also in TGD. Magnetic flux tubes would naturally serving as space-time correlates for entanglement (the p-adic variants of entanglement entropy can be negative and would serve as measures of conscious information) and this leads to the idea about tensor networks formed by the flux tubes [L2] (see `http://tinyurl.com/y9lmfrbz`). So called strong form of holography states that 2-D objects - string world sheets and partonic 2-surfaces as sub-manifolds of space-time surfaces carry the information about space-time surface and quantum states. $M^8 - M^4 \times CP_2$ correspondence [L5] would realize quantum information theoretic ideas at even deeper level and would mean that discrete finite set of data would code for the given space-time surface as preferred extremal.

In TGD Universe long cosmic strings thickened to flux tubes would be key players in the formation of galaxies and would contain galaxies as tangles along them. These tangles would contain sub-tangles having interpretation as stars and even planets could be such tangles.

In the proposed model quasars need not be blackholes in GRT sense but have structure including magnetic moment (blackhole has no hair), an empty disk around it created by the magnetic propeller effect caused by radial Lorentz force, a luminous ring and accretion disk, and so called Elvis structure involving outwards flow of matter. One could call them quasi- blackholes - I will later explain why.

1. Matter would not fall in blackhole but magnetic and volume energy in the interior would transform to ordinary matter and mean thickening of the flux tubes forming a configuration analogous to flow lines of dipole magnetic fields by looping. Think of formation of dipole field by going around flux line replaced by flux tube, returning and continuing along another flux line/tube.

2. The dipole part of the structure would be cylindrical volume in which flux tubes would form structure consisting analogous to a coil in which one makes $n_2 \simeq 10^7$ ($G_N = R^2/n_2 h_0$) windings in CP_2 direction and continues in different position in M^4 and repeats the same. This is like having a collection of coils in M^4 but each in CP_2 direction. This collection of coils would fill the dipole cylinder having the case of quasar studied a radius smaller than the Schwartshild radius $r_S \simeq 5 \times 10^9$ km but with the same order of magnitude. The wire from given coil would continue as a field line of the magnetic dipole field and return back at opposite end of dipole cylinder and return along it to opposite pole. The total number of loops in the collection of n_1 dipole coils with n_2 windings in CP_2 direction is $n_1 \times n_2$.

3. What is unexpected that although the volume contribution to action assignable to cosmological constant is positive as it must be, the energy is negative (I have checked this many times but cannot find mistake)! Could the expansion of flux tubes liberating ordinary and dark matter particles (in TGD sense) as analog of the decay of inflaton field continue without limit? At certain flux tube radius the total energy becomes zero - this corresponds roughly to a biological length scale about 1 mm for the value of cosmological constant in the length scale of the observed universe. Could the string tension become negative so that ordinary matter could be created without limit? It is quite possible that preferred extremal property prevents negative values of string tension but I have not found a good argument for this.

   Remark: Note that the twistor lift of TGD allows to consider entire hierarchy of cosmological constants behaving like $1/L(k)^2$, where $L(k)$ is p-adic length scale corresponding to $p \simeq 2^k$.

4. Cosmological expansion would naturally relate to the thickening of the flux tubes, and one can also consider the possibility that the long cosmic string gets more and more looped (dipole field gets more and more loops) so that the quasi-blackhole would increase in size by swallowing more and more of long cosmic string spaghetti to the dipole region and transforming it to the loops of dipole magnetic field.

5. The quasar (and also galactic blackhole candidates and active galactic nuclei) would be extremely intelligent fellows with number theoretical intelligence quotient (number of sheets of the space-time surfaces as covering) about

$$\frac{h_{eff}}{h} = \frac{n}{6} = \frac{n_1 \times n_2}{6} \geq \frac{GMm(CP_2)}{v_0} \times \hbar = \frac{r_S}{R(CP_2)} \times \frac{1}{2\beta_0} ,$$

   where one has $\beta_0 = v_0/c$, where v_0 is roughly of the order $10^{-3}c$ is a parameter with dimensions of velocity, r_S is Schwartschild radius of quasi-blackhole of order 5×10^9 km, and $R(CP_2)$ is CP_2 radius of order 10^{-32} meters. If this blackhole like structure is indeed cosmic string eater, its complexity and conscious intelligence increases and it would represent the brains of the galaxy as a living organism. This picture clearly resembles the vision of Susskind about blackholes.

6. This cosmic spaghetti eater has also a time reversed version for which the magnetic propellor effect is in opposite spatial direction: mass consisting of ordinary particles flows to the interior. Could this object be the TGD counterpart of blackhole? Or could one see both these objects as e blackholes dual to each other (maybe as analogs of white holes and blackholes)? The quasar like blackhole would eat cosmic string and its time reversal would swallow from its environment the particle like matter that its time reversed precedessor generated. Could one speak of breathing? Inwards breath and outwards breath would be time reversals of each other. This brings in mind the TGD inspired living cosmology based on zero energy ontology (ZEO) [L11] as analog of Penrose's cyclic cosmology, which dies and re-incarnates with opposite arrow of time again and again.

A natural question is whether also the ordinary blackholes are quasi-blackholes of either kind. In the fractal Universe of TGD this would look extremely natural.

1. How to understand the fusion of blackholes (or neutron stars, I will however talk only about blackholes in the sequel) to bigger blackhole observed by LIGO if quasi-blackholes are in question? Suppose that the blackholes indeed represent dipole light tangles in cosmic string. If they are associated with the same cosmic string, they collisions would be much more probable than one might expect. One can imagine two extreme cases for the motion of the blackholes. There are two options.

   (a) Tangles plus matter move along string like along highway. The collision would be essentially head on collision.

   (b) Tangles plus matter around them move like almost free particles and string follows: this would however still help the blackholes to find each either. The observed collisions can be modelled as a formation of gravitational bound state in which the blackholes rotate around each other first.

   The latter option seems to be more natural.

2. Do the observed black-hole like entities correspond to quasar like objects or their time reversals (more like ordinary blackholes). The unexpectedly large masses would suggests that they have not yet lost their mass by thickening as stars usually so that they are analogs of quasars. These objects would be cosmic string eaters and this would also favour the collisions of blackhole like entities associated with the same cosmic string.

3. This picture would provide a possible explanation for the evidence for gravitational echoes and evidence for magnetic fields in the case of blackholes formed in the fusion of blackholes in LIGO [L4] (see `http://tinyurl.com/y79yqw6q`). The echoes would result from the repeated reflection of the radiation from the inner blackhole like region and from the ring bounding the accretion disk.

   Note that I have earlier proposed a model of ordinary blackholes in which there would be Schwartschild radius but at some radius below it the space-time surface would become Euclidian. In the recent case the Euclidian regions would be however associated only with wormhole contacts with Euclidian signature of metric bounded by light-like orb its of partonic 2-surfaces and might have sizes of order Compton length scaled up by the value of h_{eff}/h for dark variants of particle and therefore rather small as compared to blackhole radius.

4. The latest news tells that 28 August 2019 LIGO observed two gravitational waves with a time lapse of 21 minutes in the same direction (see `http://tinyurl.com/yxpblf4p`). The events are christened as S190828j and S190828l. This suggests that the signals coule originate from same event. Gravitational lense effect could be one explanation.

   TGD suggests an alternative explanation based on the notion of gravitational flux tubes. Magnetic flux tubes, in particular gravitational flux ones, form loops. The later signal could have spent 21 minutes by rotating around this kind of loop. This rotation can occur several times but the intensity of signal is expected to diminish exponentially if only a constant fraction remains in loop at each turn.

   This sticking of radiation inside magnetic loops predicting echo like phenomenon is a general prediction of TGD and I have considered the possible occurrence of this phenomenon for cosmic gamma rays arriving in solar solar system in a model for solar cycle [L18] (see `http://tinyurl.com/y2nltfpz`.

   This kind of repetition of the signal has been observed already earlier for gravitational waves and has been dubbed "blackhole echoes" (see `http://tinyurl.com/yahxk2ca`this) but in a time scale of .1 seconds (fundamental bio-rhythm by the way). I have considered possible TGD based explanations of blackhole echoes in [L4] (see `http://tinyurl.com/y79yqw6q`) and [K6] (see `http://tinyurl.com/yy5f6wll`).

The two time scales differ by four orders of magnitude but one cannot exclude same explanation. With light velocity Earth sized loop would correspond to a time lapse of about .1 seconds. Light travels in 21 minutes over a distance of 378 million kilometers to be compared with astronomical unit AU = 150 million kilometers defining the distance of Earth from Sun. Therefore loops in the scale of Earth's orbit around Sun could be involved and perhaps associated with the magnetic body of the collapsed system. .1 seconds defining the time scale for the blackhole echoes in turn corresponds to a circumference of order Earth circumference.

4 Appendix: Explicit formulas for the evolution of cosmological constant

What is needed is induced Kähler form $J(S^2(X^4)) \equiv J$ at the twistor sphere $S^2(X^4) \equiv S^2$ associated with space-time surface. $J(S^2(X^4))$ is sum of Kähler forms induced from the twistor spheres $S^2(M^4)$ and $S^2(CP_2)$.

$$J(S^2(X^4) \equiv J = P[J(S^2(M^4)) + J(S^2(CP_2))] \ , \tag{4.1}$$

where P is projection taking tensor quantity T_{kl} in $S^2(M^4)\times S^2(CP_2)$ to its projection in $S^2(X^4)$. Using coordinates y^k for $S^2(M^4)$ or $S^(CP_2)$ and x^μ forS^2, P is defined as

$$P : T_{kl} \rightarrow T_{\mu\nu} = T_{kl}\frac{\partial y^k}{\partial x^\mu}\frac{\partial y^l}{\partial x^\nu} \ . \tag{4.2}$$

For the induced metric $g(S^2(X^4)) \equiv g$ one has completely analogous formula

$$g = P[g(J(S^2(M^4)) + g(S^2(CP_2))] \ . \tag{4.3}$$

The expression for the coefficient K of the volume part of the dimensionally reduced 6-D Kähler action density is proportional to

$$L(S^2) = J^{\mu\nu}J_{\mu\nu}\sqrt{det(g)} \ . \tag{4.4}$$

(Note that $J_{\mu\nu}$ refers to S^2 part 6-D Kähler action). This quantity reduces to

$$L(S^2) = (\epsilon^{\mu\nu}J_{\mu\nu})^2\frac{1}{\sqrt{det(g)}} \ . \tag{4.5}$$

where $\epsilon^{\mu\nu}$ is antisymmetric tensor density with numerical values +,-1. The volume part of the action is obtained as an integral of K over S^2:

$$S(S^2) = \int_{S^2} L(S^2) = \int_{-1}^{1} du \int_0^{2\pi} d\Phi \frac{J^2_{u\Phi}}{\sqrt{det(g)}} \ . \tag{4.6}$$

$(u,\Phi) \equiv (cos(\Theta,\Phi)$ are standard spherical coordinates of S^2) varying in the ranges $[-1,1]$ and $[0,2\pi]$.

This the quantity that one must estimate.

4.1 General form for the embedding of twistor sphere

The embedding of $S^2(X^4) \equiv S^2$ to $S^2(M^4)\times S^2(CP_2)$ must be known. Dimensional reduction requires that the embeddings to $S^2(M^4)$ and $S^2(CP_2)$ are isometries. They can differ by a rotation possibly accompanied by reflection

One has

$$(u(S^2(M^4)), \Phi(S^2(M^4)) = (u(S^2(X^4), \Phi(S^2(X^4)) \equiv (u, \Phi) \ ,$$

$$\big[u(S^2(CP_2)), \Phi(S^2(CP_2))\big] \equiv (v, \Psi) = RP(u, \Phi)$$

where RP denotes reflection P following by rotation R acting linearly on linear coordinates (x,y,z) of unit sphere S^2). Note that one uses same coordinates for $S^2(M^4)$ and $S^2(X^4)$. From this action one can calculate the action on coordinates u and Φ by using the definite of spherical coordinates.

The Kähler forms of $S^2(M^4)$ resp. $S^2(CP_2)$ in the coordinates $(u = cos(\Theta), \Phi)$ resp.(v, Ψ) are given by $J_{u\Phi} = \epsilon = \pm 1$ resp. $J_{v\Psi} = \epsilon = \pm 1$. The signs for $S^2(M^4)$ and $S^2(CP_2)$ are same or opposite. In order to obtain small cosmological constant one must assume either

1. $\epsilon = -1$ in which case the reflection P is absent from the above formula (RP $\rightarrow$ R).
2. $\epsilon = 1$ in which case P is present. P can be represented as reflection $(x, y, z) \rightarrow (x, y, -z)$ or equivalently $(u, \Phi) \rightarrow (-u, \Phi)$.

Rotation R can represented as a rotation in (y,z)-plane by angle ϕ which must be small to get small value of cosmological constant. When the rotation R is trivial, the sum of induced Kähler forms vanishes and cosmological constant is vanishing.

4.2 Induced Kähler form

One must calculate the component $J_{u\Phi}(S^2(X^4)) \equiv J_{u\Phi}$ of the induced Kähler form and the metric determinant $det(g)$) using the induction formula expressing them as sums of projections of M^4 and CP_2 contributions and the expressions of the components of $S^2(CP_2)$ contributions in the coordinates for $S^2(M^4)$. This amounts to the calculation of partial derivatives of the transformation R (or RP) relating the coordinates (u, Φ) of $S^2(M^4)$ and to the coordinates (v, Ψ) of $S^2(CP_2)$.

In coordinates (u, Φ) one has $J_{u\Phi}(M^4) = \pm 1$ and similar expression holds for $J(v\Psi)S^2(CP_2)$. One has

$$J_{u\Phi} = 1 + \frac{\partial(v, \Psi)}{\partial(u, \Phi)} \ . \tag{4.7}$$

where right-hand side contains the Jacobian determinant defined by the partial derivatives given by

$$\frac{\partial(v,\Psi)}{\partial(u,\Phi)} = \frac{\partial v}{\partial u}\frac{\partial \Psi}{\partial \Phi} - \frac{\partial v}{\partial \Phi}\frac{\partial \Psi}{\partial u} \ . \tag{4.8}$$

4.3 Induced metric

The components of the induced metric can be deduced from the line element

$$ds^2(S^2(X^4) \equiv ds^2 = P[ds^2(S^2(M^4)) + ds^2(S^2(CP_2))] \ .$$

where P denotes projection. One has

$$P(ds^2(S^2(M^4))) = ds^2(S^2(M^4)) = \frac{du^2}{1-u^2} + (1-u^2)d\Phi^2 \ .$$

and

$$P[ds^2(S^2(CP_2))] = P[\frac{(dv)^2}{1-v^2} + (1-v^2)d\Psi^2] \ ,$$

One can express the differentials $(dv, d\Psi)$ in terms of $(du, d\Phi)$ once the relative rotation is known and one obtains

$$P[ds^2(S^2(CP_2))] = \frac{1}{1-v^2}[\frac{\partial v}{\partial u}du + \frac{\partial v}{\partial \Phi}d\Phi]^2 + (1-v^2)[\frac{\partial \Psi}{\partial u}du + \frac{\partial \Psi}{\partial \Phi}d\Phi]^2 \ .$$

This gives

$$
\begin{array}{l}
P[ds^2(S^2(CP_2))] \\
= [(\frac{\partial v}{\partial u})^2\frac{1}{1-v^2} + (1-v^2)(\frac{\partial \Psi}{\partial u})^2]du^2 \\
+[(\frac{\partial v}{\partial \Phi})^2\frac{1}{1-v^2} + (\frac{\partial \Psi}{\partial \Phi})^2 1-v^2]d\Phi^2 \\
+2[\frac{\partial v}{\partial u}\frac{\partial v}{\partial \Phi}\frac{1}{(1-v^2)} + \frac{\partial \Psi}{\partial u}\frac{\partial \Psi}{\partial \Phi}(1-v^2)]dud\Phi \ .
\end{array}
$$

From these formulas one can pick up the components of the induced metric $g(S^2(X^4)) \equiv g$ as

$$
\begin{array}{l}
g_{uu} = \frac{1}{1-u^2} + (\frac{\partial v}{\partial u})^2\frac{1}{1-v^2} + (1-v^2)(\frac{\partial \Psi}{\partial u})^2] \ , \\
g_{\Phi\Phi} = 1-u^2 + (\frac{\partial v}{\partial \Phi})^2\frac{1}{1-v^2} + (\frac{\partial \Psi}{\partial \Phi})^2(1-v^2) \\
g_{u\Phi} = g_{\Phi u} = \frac{\partial v}{\partial u}\frac{\partial v}{\partial \Phi}\frac{1}{(1-v^2)} + \frac{\partial \Psi}{\partial u}\frac{\partial \Psi}{\partial \Phi}(1-v^2) \ .
\end{array} \tag{4.9}
$$

The metric determinant $det(g)$ appearing in the integral defining cosmological constant is given by

$$det(g) = g_{uu}g_{\Phi\Phi} - g_{u\Phi}^2 \ . \tag{4.10}$$

4.4 Coordinates (v,Ψ) in terms of (u,Φ)

To obtain the expression determining the value of cosmological constant one must calculate explicit formulas for (v,Ψ) as functions of (u,Φ) and for partial derivations of (v,Ψ) with respect to (u,Φ).

Let us restrict the consideration to the RP option.

1. P corresponds to $z \rightarrow -z$ and to

$$u \rightarrow -u \ . \tag{4.11}$$

2. The rotation R $(x,y,z) \rightarrow (x',y',z')$ corresponds to

$$x' = x, \quad y' = sz + cy = su + c\sqrt{1-u^2}sin(\Phi) \ , \quad z' = v = cu - s\sqrt{1-u^2}sin(\Phi) \ . \tag{4.12}$$

Here one has $(s,c) \equiv (sin(\epsilon), cos(\epsilon)$, where ϵ is rotation angle, which is extremely small for the value of cosmological constant in cosmological scales.

From these formulas one can pick v and $\Psi = arctan(y'/x)$ as

$$v = cu - s\sqrt{1-u^2}sin(\Phi) \quad \Psi = arctan[\frac{su}{\sqrt{1-u^2}}cos(\Phi) + tan(\Phi)] \ . \tag{4.13}$$

3. RP corresponds to

$$v = -cu - s\sqrt{1-u^2}sin(\Phi) \quad \Psi = arctan[-\frac{su}{\sqrt{1-u^2}}cos(\Phi) + tan(\Phi)] \ . \tag{4.14}$$

4.5 Various partial derivatives

Various partial derivates are given by

$$\begin{aligned}
\frac{\partial v}{\partial u} &= -1 + s\frac{u}{\sqrt{1-u^2}}sin(\Phi) \ , \\
\frac{\partial v}{\partial \Phi} &= -s\frac{u}{\sqrt{1-u^2}}cos(\Phi) \ , \\
\frac{\partial \Psi}{\partial \Phi} &= (-s\frac{u}{\sqrt{1-u^2}}sin(\Phi) + c)\frac{1}{X} \ , \\
\frac{\partial \Psi}{\partial u} &= \frac{scos(\Phi)(1+u-u^2)}{(1-u^2)^{3/2}}\frac{1}{X} \ , \\
X &= cos^2(\Phi) + [-s\frac{u}{\sqrt{1-u^2}} + csin(\Phi)]^2 \ .
\end{aligned} \qquad (4.15)$$

Using these expressions one can calculate the Kähler and metric and the expression for the integral giving average value of cosmological constant. Note that the field equations contain S^2 coordinates as external parameters so that each point of S^2 corresponds to a slightly different space-time surface.

4.6 Calculation of the evolution of cosmological constant

One must calculate numerically the dependence of the action integral S over S^2 as function of the parameter $s = sin(\epsilon))$. One should also find the extrema of S as function of s.

Especially interesting values are very small values of s since for the cosmological constant becomes small. For small values of s the integrand (see Eq. 4.6) becomes very large near poles having the behaviour $1/\sqrt{g} = 1/(sin(\Theta)+O(s))$ coming from $\sqrt{g}$ approaching that for the standard metric of S^2. The integrand remains finite for $s \neq 0$ but this behavior spoils the analytic dependence of integral on s so that one cannot do perturbation theory around $s = 0$. The expected outcome is a logarithmic dependence on s.

In the numerical calculation one must decompose the integral over S^2 to three parts.

1. There are parts coming from the small disks D^2 surrounding the poles: these give identical contributions by symmetry. One must have criterion for the radius of the disk and the natural assumption is that the disk radius is of order s.

2. Besides this one has a contribution from S^2 with disks removed and this is the regular part to which standard numerical procedures apply.

One must be careful with the expressions involving trigonometric functions which give rise to infinite if one applies the formulas in straightforward manner. These infinities are not real and cancel, when one casts the formulas in appropriate form inside the disks.

1. The limit $u \rightarrow \pm 1$ at poles involves this kind of dangerous quantities. The expression for the determinant appearing in $J_{u\Phi}$ remains however finite and $J^2_{u\phi}$ vanishes like s^2 at this limit. Also the metric determinant $1/\sqrt{g}$ remains finite expect at $s = 0$.

2. Also the expression for the quantity X in $\Psi = arctan(X)$ contains a term proportional to $1/cos(\Phi)$ approaching infinity for $\Phi \rightarrow \pi/2, 3\pi/2$. The value of $\Psi = arc(tan(X)$ remains however finite and equal to $\pm\Phi$ at this limit depending on on the sign of us.

Concerning practical calculation, the relevant formulas are given in Eqs. 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, and 4.15.

The calculation would allow to test/kill the key conjectures already discussed.

1. There indeed exist extrema satisfying $dS(S^2)/ds = 0$.

2. These extrema are in one-one correspondence with the zeros of zeta.

There are also much more specific conjctures to be killed.

1. These extrema correspond to $s = sin(\epsilon) = 2-k$ or more generally $s = p^{-k}$. This conjecture is inspired by p-adic length scale hypothesis but since the choice of evolution parameter is to high extent free, the conjecture is perhaps too spesific.

2. For certain integer values of integer k the integral $S(S^2)$ of Eq. 4.6 is of form $S(S^2) = xs^2$ for $s = 2^{-k}$, where x is a universal numerical constant.

   This would realize the idea that p-adic length scales realized as scales associated with cosmological constant correspond to fixed points of renormalization group evolution implying that radiative corrections otherwise present cancel. In particular, the deviation from $s = 2^{-d/2}$ would mean anomalous dimension replacing $s = 2^{-d/2}$ with $s^{-(d+\Delta d)/2}$ for $d = k$ the anomalies dimension Δd would vanish.

   The condition $\Delta d = 0$ should be equivalent with the vanishing of the dS/ds. Geometrically this means that $S(s)$ curve is above (below) $S(s) = xs^2$ and touches it at points $s = x2^{-k}$, which would be minima (maxima). Intermediate extrema above or below $S = xs^2$ would be maxima (minima).

REFERENCES

Cosmology and Astro-Physics

[E1] Mitra A. Sources of stellar energy, Einstein Eddington timescale of gravitational contraction and eternally collapsing objects. *New Astronomy*, 12(2):146–160, 2006. Available at: https://www.sciencedirect.com/science/article/pii/S1384107606000923.

[E2] Nottale L Da Rocha D. Gravitational Structure Formation in Scale Relativity, 2003. Available at: https://arxiv.org/abs/astro-ph/0310036.

[E3] Elvis M. A Structure for Quasars. *Astrophys. J*, 545(1):63–76, 2000. Available at: https://tinyurl.com/yd5j9uno.

[E4] Robertson SL Schild RE, Leiter DJ. Observations Supporting the Existence of an Intrinsic Magnetic Moment Inside the Central Compact Object Within the Quasar Q0957+561. *Astron. J*, 132:420–432, 2006. Available at: https://arxiv.org/abs/astro-ph/0505518.

[E5] Shandarin SF Zeldovich YaV, Einasto J. Giant Voids in the Universe. *Nature*, 300, 1982.

Books related to TGD

[K1] Pitkänen M. About Preferred Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/prext.pdf, 2023.

[K2] Pitkänen M. About twistor lift of TGD? In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/hgrtwistor.pdf, 2023.

[K3] Pitkänen M. Basic Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/class.pdf, 2023.

[K4] Pitkänen M. Bio-Systems as Conscious Holograms. In *TGD Universe as a Conscious Hologram. https://tgdtheory.fi/tgdhtml/Bholography.html*. Available at: https://tgdtheory.fi/pdfpool/hologram.pdf, 2023.

[K5] Pitkänen M. Expanding Earth Model and Pre-Cambrian Evolution of Continents, Climate, and Life. In *Physics in Many-Sheeted Space-Time: Part I. https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/expearth.pdf., 2023.

[K6] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II.* *https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/qastro.pdf, 2023.

[K7] Pitkänen M. Quantum Hall effect and Hierarchy of Planck Constants. In *TGD and Condensed Matter.* *https://tgdtheory.fi/tgdhtml/BTGDcondmat.html*. Available at: https://tgdtheory.fi/pdfpool/anyontgd.pdf, 2023.

[K8] Pitkänen M. Some questions related to the twistor lift of TGD. In *Quantum TGD: Part III.* *https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/twistquestions.pdf, 2023.

[K9] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II.* *https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/astro.pdf, 2023.

[K10] Pitkänen M. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time: Part II.* *https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/cosmo.pdf, 2023.

[K11] Pitkänen M. The classical part of the twistor story. In *Quantum TGD: Part III.* *https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/twistorstory.pdf, 2023.

Articles about TGD

[L1] Pitkänen M. Does Riemann Zeta Code for Generic Coupling Constant Evolution? . Available at: https://tgdtheory.fi/public_html/articles/fermizeta.pdf., 2015.

[L2] Pitkänen M. Holography and Quantum Error Correcting Codes: TGD View. Available at: https://tgdtheory.fi/public_html/articles/tensornet.pdf., 2016.

[L3] Pitkänen M. Hydrinos again. Available at: https://tgdtheory.fi/public_html/articles/Millsagain.pdf., 2016.

[L4] Pitkänen M. LIGO and TGD. Available at: https://tgdtheory.fi/public_html/articles/ligotgd.pdf., 2016.

[L5] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry? Available at: https://tgdtheory.fi/public_html/articles/ratpoints.pdf., 2017.

[L6] Pitkänen M. Does valence bond theory relate to the hierarchy of Planck constants? Available at: https://tgdtheory.fi/public_html/articles/valenceheff.pdf., 2017.

[L7] Pitkänen M. p-Adicization and adelic physics. Available at: https://tgdtheory.fi/public_html/articles/adelicphysics.pdf., 2017.

[L8] Pitkänen M. Philosophy of Adelic Physics. Available at: https://tgdtheory.fi/public_html/articles/adelephysics.pdf., 2017.

[L9] Pitkänen M. Philosophy of Adelic Physics. In *Trends and Mathematical Methods in Interdisciplinary Mathematical Sciences*, pages 241–319. Springer.Available at: https://link.springer.com/chapter/10.1007/978-3-319-55612-3_11, 2017.

[L10] Pitkänen M. About the physical interpretation of the velocity parameter in the formula for the gravitational Planck constant . Available at: https://tgdtheory.fi/public_html/articles/vzero.pdf., 2018.

[L11] Pitkänen M. Conformal cyclic cosmology of Penrose and zero energy ontology based cosmology. Available at: https://tgdtheory.fi/public_html/articles/ccctgd.pdf., 2018.

[L12] Pitkänen M. Could cancer be a disease of magnetic body? Available at: https://tgdtheory.fi/public_html/articles/nanotesla.pdf., 2018.

[L13] Pitkänen M. Dark valence electrons and color vision. Available at: https://tgdtheory.fi/public_html/articles/colorvision.pdf., 2018.

[L14] Pitkänen M. Five new strange effects associated with galaxies. Available at: https://tgdtheory.fi/public_html/articles/3galeffects.pdf., 2018.

[L15] Pitkänen M. Is the hierarchy of Planck constants behind the reported variation of Newton's constant? Available at: https://tgdtheory.fi/public_html/articles/variableG.pdf., 2018.

[L16] Pitkänen M. New insights about quantum criticality for twistor lift inspired by analogy with ordinary criticality. Available at: https://tgdtheory.fi/public_html/articles/zeocriticality.pdf., 2018.

[L17] Pitkänen M. TGD view about coupling constant evolution. Available at: https://tgdtheory.fi/public_html/articles/ccevolution.pdf., 2018.

[L18] Pitkänen M. Solar Surprise. Available at: https://tgdtheory.fi/public_html/articles/solarsycle.pdf., 2019.