Can one apply Occam's razor as a general purpose debunking argument to TGD?

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March 13, 2019
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Abstract

Occarm's razor have been used to debunk TGD. The following arguments provide the information needed by the reader to decide himself. Considerations are at three levels.

The level of "world of classical worlds" (WCW) defined by the space of 3-surfaces endowed with Kähler structure and spinor structure and with the identification of WCW space spinor fields as quantum states of the Universe: this is nothing but Einstein's geometrization program applied to quantum theory. Second level is space-time level.

Space-time surfaces correspond to preferred extremals of Käction in $M^4 \times CP_2$. The number of field like variables is 4 corresponding to 4 dynamically independent imbedding space coordinates. Classical gauge fields and gravitational field emerge from the dynamics of 4-surfaces. Strong form of holography reduces this dynamics to the data given at string world sheets and partonic 2-surfaces and preferred extremals are minimal surface extremals of Kähler action so that the classical dynamics in space-time interior does not depend on coupling constants at all which are visible via boundary conditions only. Continuous coupling constant evolution is replaced with a sequence of phase transitions between phases labelled by critical values of coupling constants: loop corrections vanish in given phase. Induced spinor fields are localized at string world sheets to guarantee well-definedness of em charge.

At imbedding space level the modes of imbedding space spinor fields define ground states of super-symplectic representations and appear in QFT-GRT limit. GRT involves post-Newtonian approximation involving the notion of gravitational force. In TGD framework the Newtonian force correspond to a genuine force at imbedding space level.

I was also asked for a summary about what TGD is and what it predicts. I decided to add this summary to this chapter although it is goes slightly outside of its title.

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1 Introduction

Occam's razor argument is one the standard general purpose arguments used in debunking: the debunked theory is claimed to be hopelessly complicated. This argument is more refined that mere "You are a crackpot!" but is highly subjective and often the arguments pro or con are not given. Combined with the claim that the theory does not predict anything Occam's razor is very powerful argument unless the audience includes people who have bothered to study the debunked theory.

Let us take a closer look on this argument and compare TGD superstring models and seriously ask which of these theories is simple.

In superstring models one has strings as basic dynamical objects. They live in target space M^{10}, which in some mysterious manner (something "non-perturbative" it is) spontaneously compactifies to $M^4 \times C$, C is Calabi-Yau space. The number of them is something like 10^{500} or probably infinite: depends on the counting criterion. And this estimate leaves their metric open. This leads to landscape and multiverse catastrophe: theory cannot predict anything. As a matter fact $M^4 \times C$:s must be allowed to deform still in Kaluza-Klein paradigm in which space-time has Calabi-Yau as small additional dimensions. An alternative manner to obtain space-time is as 3-brane. One obtains also higher-D objects. Again by some "nonperturbative" mechanisms. One does not even know what space-time is! Situation looks to me a totally hopeless mess. Reader can conclude whether to regard this as simple and elegant.

I will consider TGD at three levels. At the level of "world of classical worlds" (WCW), at space-time level, and at the level of imbedding space $H = M^4 \times CP_2$. I hope that I can convince the reader about the simplicity of the approach. The simplicity is actually quite shocking and certainly an embarrassing experience for the unhappy super string theorists meandering around in the landscape and multiverse. Behind this simplicity are however principles - something, which colleagues usually regard as unpractical philosophizing: "shut-up-and-calculate!"!

I was also asked for a summary about what TGD is and what it predicts. I decided to add this summary to this chapter although it is goes slightly outside of its title.

2 Simplicity at various levels

2.1 WCW level: a generalization of Einstein's geometrization program to entire quantum physics

I hope that the reader would read the following arguments keeping in mind the question "Is TGD really hopelessly complicated mess of pieces picked up randomly from theoretical physics?" as one debunker who told that he does not have time to read TGD formulated it.

1. Einstein's geometrization program for gravitation has been extremely successful but has failed for other classical fields, which do not have natural geometrization in the case of abstract four-manifolds with metric. One should understand standard model quantum numbers and also family replication for fermions.

   However, if space-time can be regarded surface in $H = M^4 \times CP_2$ also the classical fields find a natural geometrization as induced fields obtained basically by projecting. Also spinor structure can be induced and one avoids the problems due the fact that generic space-time as abstract 4-manifold does not allow spinor structure. The dynamics of space-time surfaces incredibly simple: only 4 field-like variables corresponding to *four* imbedding space coordinates and induced that of classical geometric fields. Nowadays one would speak of emergence. The complexity emerges from the topology of space-time surfaces giving rise to many-sheeted space-time.

2. Even this view about geometrization is generalized in TGD. Einstein's geometrization program is applied to the entire quantum physics in terms of the geometry of WCW consisting of 3-D surfaces of H. More precisely, in zero energy ontology (ZEO) it consists of pairs of 3-surfaces at opposite boundaries of causal diamond (CD) connected by a preferred extremals of a variational principle to be discussed.

   Quantum states of the Universe would correspond to the modes of formally classical WCW spinor field satisfying the analog of Dirac equation. No quantization: just the construction of WCW geometry and spinor structure. The only genuinely quantal element of quantum theory would be state function reduction and in ZEO its description leads to a quantum theory of consciousness.

To me this sounds not only simple but shockingly simple.

2.1.1 WCW geometry

Consider first the generalization of Einstein's program of at the level of WCW geometry [K20, K6, K4].

1. Since complex conjugation must be geometrized, WCW must allow a geometric representation of imaginary unit as an antisymmetric tensor, which is essentially square root of the negative of the metric tensor and thus allow Kähler

structure coded by Kähler function. One must have 4-D general coordinate invariance (GCI) but basic objects are 3-D surfaces. Therefore the definition of Kähler function must assign to 3-surface a unique 4-surface.

Kähler function should have physical meaning and the natural assumption is that it is Kähler action plus possibly also volume term (twistor lift implies it). Space-time surface would be a preferred extremal of this action. The interpretation is also as an analog of Bohr orbit so that Bohr orbitology would correspond exact rather than only approximate part of quantum theory in TGD framework. One could speak also of quantum classical correspondence.

2. The action principle involves coupling parameters analogous to thermodynamical parameters. Their value spectrum is fixed by the conditions that TGD is quantum critical. For instance Kähler couplings strength is analogous to critical temperature. Different values correspond to different phases. Coupling constant evolution correspond to phase transitions between these phases and loops vanish as in free field theory for $\mathcal{N} = 4$ SYM.

3. The infinite-dimensionality of WCW is a crucial element of simplicity. Already in the case of loop spaces the geometry is essentially unique: loop space is analogous to a symmetric space points of the loop space being geometrically equivalent. For loop spaces Riemann connection exists only of the metric has maximal isometries defined by Kac-Moody algebra.

   The generalization to 3-D case is compelling. In TGD Kac-Moody algebra is replaced by super-symplectic algebra, which is much larger but has same basic structure (conformal weights of two kinds) and a fractal hierarchy of isomorphic sub-algebas with conformal weights coming as multiples of those for the entire algebra is crucial. Physics is unique because of its mathematical existence. WCW decompose to a union of sectors, which are infinite-D variants of symmetric spaces labelled by zero modes whose differentials do not appear in the line element of WCW.

All this sounds to me shockingly simple.

2.1.2 WCW spinor structure

One must construct also spinor structure for WCW [K14, K20].

1. The modes of WCW spinor fields would correspond to the solutions of WCW Dirac equation and would define the quantum states of the Universe. WCW spinors (assignable to given 3-surface) would correspond to fermionic Fock states created by fermionic creation operators. In ZEO 3-surfaces are pairs of 3-surfaces assignable to the opposite boundaries of WCW connected by preferred extremal.

   The fermionic states are superpositions of pairs of fermion states with opposite net quantum numbers at the opposite ends of space-time surface at boundaries of CD. The entanglement coefficients define the analogs of S-matrix elements. The analog of Dirac equation is analog for super-Virasoro conditions in string models but assignable to the infinite-D supersymplectic algebra of WCW defining its isometries.

2. The construction of the geometry of WCW requires that the anticommuting gamma matrices of WCW are expressible in terms of fermionic oscillator operators assignable to the induced spinor fields at space-time surface. Fermionic anti-commutativity at space-time level is not assumed but is forced by the anticommutativity of gamma matrices to metric. Fermi statistics is geometrized.

3. The gamma matrices of WCW in the coordinates assignable to isometry generators can be regarded as generators of superconformal symmetries. They correspond to classical charges assignable to the preferred extremals and to fermionic generators. The fermionic isometry generators are fermionic bilinears and super-generators are obtained from them by replacing the second second quantized spinor field with its mode. Quantum classical correspondence between fermionic dynamics and classical dynamics (SH) requires that the eigenvalues of the fermionic Cartan charges are equal to corresponding bosonic Noether charges.

4. The outcome is that quantum TGD reduces to a theory of formally *classical* spinor fields at the level of WCW and by infinite symmetries the construction of quantum states reduces to the construction of representations of super-symplectic algebra which generalizes to Yangian algebra as twistorial picture suggests. In ZEO everything would reduce to group theory, even the construction of scattering amplitudes! In ZEO the construction of zero energy states and thus scattering amplitudes would reduce to that for the representations of Yangian variant of super-symplectic algebra [A1] [B3, B1, B2].

5. One can go to the extreme and wonder whether the scattering amplitudes as entanglement coefficients for Yangian zero energy states are just constant scalars for given values of zero modes as group invariant for isometries. This would leave only integration over zero modes and if number theoretical universality is assumed this integral reduces to sum over points with algebraic coordinates in the preferred coordinates made possible by the symmetric space property. Certainly this is one of the lines of research to be followed in future.

   Personally I find it hard to imagine anything simpler!

2.2 Space-time level: many-sheeted space-time and emergence of classical fields and GRT space-time

At space-time level one must consider dynamics of space-time surface and spinorial dynamics.

2.2.1 Dynamics of space-time surfaces

Consider first simplicity at space-time level.

1. Space-time is identified as 4-D surface in certain imbedding space required to have symmetries of special relativity - Poincare invariance. This resolves the energy problem and many other problems of GRT [K17].

   This allows also to see TGD as generalization of string models obtained by replacing strings with 3-surfaces and 2-D string world sheets with 4-D space-time surfaces. Small space-time surfaces are particles, large space-time surfaces the background space-time in which these particles "live". There are only 4 dynamical field like variables for 8-D $M^4 \times CP_2$ since GCI eliminates 4 imbedding space coordinates (they can be taken as space-tme coordinates). This should be compared with the myriads of classical fields for 10-D Einstein's theory coupled to matter fields (do not forget landscape and multiverse!)

2. Classical fields are induced at the level of single space-time sheet from their geometric counterparts in imbedding space. A more fashionable way to say the same is that they emerge. Classical gravitational field correspond to the induced metric, electroweak gauge potentials to induced spinor connection of CP_2 and color gauge potentials to projections of Killing vector fields for CP_2.

3. In TGD the space-time of GRT is replaced by many-sheeted space-time constructed from basic building bricks, which are preferred extremals of Kähler action + volume term. This action emerges in twistor lift of TGD existing only for $H = M^4 \times CP_2$: TGD is completely unique since only M^4 and CP_2 allows twistor space with Kähler structure. This also predicts Planck length as radius of twistor sphere associated with M^4. Cosmological constant appears as the coefficient of the volume term and obeys p-adic length scale evolution predicting automatically correct order of magnitude in the scale of recent cosmos. Besides this one has CP_2 size which is of same order of magnitude as GUT scale, and Kähler coupling strength. By quantum criticality the various parameters are quantized.

   Quantum criticality is basic dynamical principle [K6, K24] and discretizes coupling constant evolution: only coupling constants corresponding to quantum criticality are realized and discretized coupling constant evolution corresponds to phase transitions between these values of coupling constants. All radiative corrections vanish so that only tree diagram contribute.

4. Preferred extremals realize strong form of holography (SH) implied by strong form of GCI (SGCI) emerging naturally in TGD framework. That GCI implies SH meaning an enormous simplification at the conceptual level.

   One has two choices for fundamental 3-D objects. They could be light-like boundaries between regions of Minkowskian and Euclidian signatures of the induced metric or they could be pairs of space-time 3-surfaces at the ends of space-time surface at opposite boundaries of causal diamond (CD) (CDs for a scale hierarchy). Both options should be correct so that the intersections of these 3-surfaces consisting of partonic 2-surfaces at which light-like partonic orbits and space-like 3-surfaces intersect should carry the data making possible holography. Also data about normal space of partonic 2-surface is involved.

SH generalizes AdS/CFT correspondence by replacing holography with what is very much like the familiar holography. String world, sheets, which are minimal surfaces carrying fermion fields and partonic 2-surfaces intersecting string world sheets at discrete points determine by SH the entire 4-D dynamics. The boundaries of string world sheets are world lines with fermion number coupling to classical Kähler force. In the interior Kähler force vanishes so that one has "dynamics of avoidance" [L2] required also by number theoretic universality satisfied if the coupling constants do not appear in the field equations at all: they are however seen in the boundary values stating vanishing of the classical super-symplectic charges (Noether's theorem) so that one obtains dependence of coupling constants via boundary conditions and coupling constant evolutions makes it manifest also classically. Hence the preferred extremals from which the space-time surfaces are engineered are extremely simple objects.

5. In twistor formulation the assumption that the inverse of Kähler coupling strength has zeros of Riemann zeta [L1] as the spectrum of its quantum critical values gives excellent prediction for the coupling constant of U(1) coupling constant of electroweak interactions. Complexity means that extremals are extremals of both Kähler action and volume term: minimal surfaces extremals of Kähler action. This would be part of preferred extremal property.

   Why α_K should be complex? If α_K is real, both bosonic and fermionic degrees of freedom for Euclidian and Minkowskian regions decouple completely. This is not physically attractive. If α_K is complex there is coupling between the two regions and the simplest assumption is that there is no Chern-Simons term in the action and one has just continuity conditions for canonical momentum current and hits super counterpart. Note the analogy with the possibility of blackhole evaporation. The presence of momentum exchange is also natural since it gives classical space-time correlates for interactions as momentum exchange.

   The conditions state that sub-algebra of super-symplectic algebra isomorphic to itself and its commutator with the entire algebra annihilate the physical states (classical Noether charges vanish). The condition could follow from minimal surface extremality or provide additional conditions reducing the degrees of freedom. In any case, 3-surfaces would be almost 2-D objects.

6. GRT space-time emerges from many-sheeted space-time as one replaces the sheets of many-sheeted space-time (4-D M^4 projection) to single slightly curved region of M^4 defining GRT space-time. Since test particle regarded as 3-surface touching the space-time sheets of many-sheeted spacetime, test particle experiences the sum of forces associated with the classical fields at the space-time sheets. Hence the classical fields of GRT space-time are sums of these fields. Disjoint union for space-time sheets maps to the sum of the induced fields. This gives standard model and GRT as long range scale limit of TGD.

2.2.2 How to build TGD space-time from legos?

TGD predicts shocking simplicity of both quantal and classical dynamics at space-time level. Could one imagine a construction of more complex geometric objects from basic building bricks - space-time legos?

Let us list the basic ideas.

1. Physical objects correspond to space-time surfaces of finite size - we see directly the non-trivial topology of space-time in everyday length scales.

2. There is also a fractal scale hierarchy: 3-surfaces are topologically summed to larger surfaces by connecting them with wormhole contact, which can be also carry monopole magnetic flux in which one obtains particles as pairs of these: these contacts are stable and are ideal for nailing together pieces of the structure stably.

3. In long length scales in which space-time surface tend to have 4-D M^4 projection this gives rise to what I have called many-sheeted spacetime. Sheets are deformations of canonically imbedded M^4 extremely near to each other (the maximal distance is determined by CP_2 size scale about 10^4 Planck lengths. The sheets touch each other at topological sum contacts, which can be also identified as building bricks of elementary particles if they carry monopole flux and are thus stable. In $D = 2$ it is easy to visualize this hierarchy.

What could be the simplest surfaces of this kind - the legos?

1. Assume twistor lift [K24, K23] so that action contain volume term besides Kähler action: preferred extremals can be seen as non-linear massless fields coupling to self-gravitation. They also simultaneously extremals of Kähler action. Also hydrodynamical interpretation makes sense in the sense that field equations are conservation laws. What is remarkable is that the solutions have no dependence on coupling parameters: this is crucial for realizing number theoretical universality. Boundary conditions however bring in the dependence on the values of coupling parameters having discrete spectrum by quantum criticality.

2. The simplest solutions corresponds to Lagrangian sub-manifolds of CP_2: induced Kähler form vanishes identically and one has just minimal surfaces. The energy density defined by scale dependent cosmological constant is small in cosmological scales - so that only a template of physical system is in question. In shorter scales the situation changes if the cosmological constant is proportional the inverse of p-adic prime.

   The simplest minimal surfaces are constructed from pieces of geodesic manifolds for which not only the trace of second fundamental form but the form itself vanishes. Geodesic sub-manifolds correspond to points, pieces of lines, planes, and 3-D volumes in E^3. In CP_2 one has points, circles, geodesic spheres, and CP_2 itself.

3. CP_2 type extremals defining a model for wormhole contacts, which can be used to glue basic building bricks at different scales together stably: stability follows from magnetic monopole flux going through the throat so that it cannot be split like homologically trivial contact. Elementary particles are identified as pairs of wormhole contacts and would allow to nail the legos together to from stable structures.

Amazingly, what emerges is the elementary geometry. My apologies for those who hated school geometry.

1. Geodesic minimal surfaces with vanishing induced gauge fields

Consider first *static* objects with 1-D CP_2 projection having thus *vanishing* induced gauge fields. These objects are of form $M^1 \times X^3$, $X^3 \subset E^3 \times CP_2$. M^1 corresponds to time-like or possible light-like geodesic (for CP_2 type extremals). I will consider mostly Minkowskian space-time regions in the following.

1. Quite generally, the simplest legos consist of 3-D geodesic sub-manifolds of $E^3 \times CP_2$. For E^3 their dimensions are $D = 1, 2, 3$ and for CP_2, $D = 0, 1, 2$. CP_2 allows both homologically non-trivial resp. trivial geodesic sphere S^2_I resp. S^2_{II}. The geodesic sub-manifolds cen be products $G_3 = G_{D_1} \times G_{D_2}$, $D_2 = 3 - D_1$ of geodesic manifolds G_{D_1}, $D_1 = 1, 2, 3$ for E^3 and G_{D_2}, $D_2 = 0, 1, 2$ for CP_2.

2. It is also possible to have twisted geodesic sub-manifolds G_3 having geodesic circle S^1 as CP_2 projection corresponding to the geodesic lines of $S^1 \subset CP_2$, whose projections to E^3 and CP_2 are geodesic line and geodesic circle respectively. The geodesic is characterized by S^1 wave vector. One can have this kind of geodesic lines even in $M^1 \times E^3 \times S^1$ so that the solution is characterized also by frequency and is not static in CP_2 degrees of freedom anymore.

   These parameters define a four-D wave vector characterizing the warping of the space-time surface: the space-time surface remains flat but is warped. This effect distinguishes TGD from GRT. For instance, warping in time direction reduces the effective light-velocity in the sense that the time used to travel from A to B increases. One cannot exclude the possibility that the observed freezing of light in condensed matter could have this warping as space-time correlate in TGD framework.

   For instance, one can start from 3-D minimal surfaces $X^2 \times D$ as local structures (thin layer in E^3). One can perform twisting by replacing D with twisted closed geodesics in $D \times S^1$: this gives valued map from D to S^1 (subset CP_2) representing geodesic line of $D \times S^1$. This geodesic sub-manifold is trivially a minimal surface and defines a two-sheeted cover of $X^2 \times D$. Wormhole contact pairs (elementary particles) between the sheets can be used to stabilize this structure.

3. Structures of form $D^2 \times S^1$, where D^2 is polygon, are perhaps the simplest building bricks for more complex structures. There are continuity conditions at vertices and edges at which polygons D^2_i meet and one could think of assigning magnetic flux tubes with edes in the spirit of homology: edges as magnetic

flux tubes, faces as 2-D geodesic sub-manifolds and interiors as 3-D geodesic sub-manifolds.

Platonic solids as 2-D surfaces can be build are one example of this and are abundant in biology and molecular physics. An attractive idea is that molecular physics utilizes this kind of simple basic structures. Various lattices appearing in condensed matter physics represent more complex structures but could also have geodesic minimal 3-surfaces as building bricks. In cosmology the honeycomb structures having large voids as basic building bricks could serve as cosmic legos.

4. This lego construction very probably generalizes to cosmology, where Euclidian 3-space is replaced with 3-D hyperbolic space $SO(3,1)/SO(3)$. Also now one has pieces of lines, planes and 3-D volumes associated with an arbitrarily chosen point of hyperbolic space. Hyperbolic space allows infinite number of tesselations serving as analogs of 3-D lattices and the characteristic feature is quantization of redshift along line of sight for which empirical evidence is found.

5. The structures as such are still too simple to represent condensed matter systems. These basic building bricks can glued together by wormhole contact pairs defining elementary particles so that matter emerges as stabilizer of the geometry: they are the nails allowing to fix planks together, one might say.

2. Geodesic minimal surfaces with non-vanishing gauge fields

What about minimal surfaces and geodesic sub-manifolds carrying non-vanishing gauge fields - in particular em field (Kähler form identifiable as U(1) gauge field for weak hypercharge vanishes and thus also its contribution to em field)? Now one must use 2-D geodesic spheres of CP_2 combined with 1-D geodesic lines of E^2. Actually both homologically non-trivial resp. trivial geodesic spheres S^2_I resp. S^2_{II} can be used so that also non-vanishing Kähler forms are obtained.

The basic legos are now $D \times S^2_i$, $i = I, II$ and they can be combined with the basic legos constructed above. These legos correspond to two kinds of magnetic flux tubes in the ideal infinitely thin limit. There are good reasons to expected that these infinitely thin flux tubes can be thickened by deforming them in E^3 directions orthogonal to D. These structures could be used as basic building bricks assignable to the edges of the tensor networks in TGD.

3. Static minimal surfaces, which are not geodesic sub-manifolds

One can consider also more complex static basic building bricks by allowing bricks which are not anymore geodesic sub-manifolds. The simplest static minimal surfaces are form $M^1 \times X^2 \times S^1$, $S^1 \subset CP_2$ a geodesic line and X^2 minimal surface in E^3.

Could these structures represent higher level of self-organization emerging in living systems? Could the flexible network formed by living cells correspond to a structure involving more general minimal surfaces - also non-static ones - as basic building bricks? The Wikipedia article about minimal surfaces in E^3 suggests the role of minimal surface for instance in bio-chemistry (see http://tinyurl.com/zqlv322).

The surfaces with constant positive curvature do not allow imbedding as minimal surfaces in E^3. Corals provide an example of surface consisting of pieces of 2-D hyperbolic space H^2 immersed in E^3 (see http://tinyurl.com/ho9uvcc. Minimal surfaces have negative curvature as also H^2 but minimal surface immersions of H^2 do not exist. Note that pieces of H^2 have natural imbedding to E^3 realized as light-one proper time constant surface but this is not a solution to the problem.

Does this mean that the proposal fails?

1. One can build approximately spherical surfaces from pieces of planes. Platonic solids represents the basic example. This picture conforms with the notion of monadic manifold having as a spine a discrete set of points with coordinates in algebraic extension of rationals (preferred coordinates allowed by symmetries are in question). This seems to be the realistic option.

2. The boundaries of wormhole throats at which the signature of the induced metric changes can have arbitrarily large M^4 projection and they take the role of blackhole horizon. All physical systems have such horizon and the approximately boundaries assignable to physical objects could be horizons of this kind. In TGD one has minimal surface in $E^3 \times S^1$ rather than E^3. If 3-surface have no space-like boundaries they must be multi-sheeted and the sheets co-incide at some 2-D surface analogous to boundary. Could this 3-surface give rise to an approximately spherical boundary.

3. Could one lift the immersions of H^2 and S^2 to E^3 to minimal surfaces in $E^3 \times S^1$? The constancy of scalar curvature, which is for the immersions in question quadratic in the second fundamental form would pose one additional condition to non-linear Laplace equations expressing the minimal surface property. The analyticity of the minimal surface should make possible to check whether the hypothesis can make sense. Simple calculations lead to conditions, which very probably do not allow solution.

4. Dynamical minimal surfaces: how space-time manages to engineer itself?

At even higher level of self-organization emerge dynamical minimal surfaces. Here string world sheets as minimal surfaces represent basic example about a building block of type $X^2 \times S^2_i$. As a matter fact, S^2 can be replaced with complex sub-manifold of CP_2.

One can also ask about how to perform this building process. Also massless extremals (MEs) representing TGD view about topologically quantized classical radiation fields are minimal surfaces but now the induced Kähler form is non-vanishing. MEs can be also Lagrangian surfaces and seem to play fundamental role in morphogenesis and morphostasis as a generalization of Chladni mechanism [K26, K23]. One might say that they represent the tools to assign material and magnetic flux tube structures at the nodal surfaces of MEs. MEs are the tools of space-time engineering. Here many-sheetedness is essential for having the TGD counterparts of standing waves.

2.2.3 Spherically symmetry metric as minimal surface

Physical intuition and the experience with the vacuum extremals as models for GRT space-times suggests that Kähler charge is not important in the case of astrophysical objects like stars so that it might be possible to model them as minimal surfaces, which in the simplest situation have spherically symmetric metric analogous to Schwartschild solution. The vanishing of the induced Kähler form does not of course exclude the presence of electromagnetic fields. It must be of course emphasized that the assumption that single-sheeted space-time surface can model GRT-QFT limit based on many-sheeted space-time could be un-realistic.

At 90's I studied the imbeddings of Schwartschild-Nordström solution as vacuum extremals of Kähler action and found that the solution is necessarily electromagnetically charged [K13]. This property is unavoidable. The imbedding in coordinates (t, r, θ, ϕ) for X^4, (m^0, r, θ, ϕ) for M^4 and (Θ, Φ) for the trivial geodesic sphere S^2_{II} of CP_2 was not stationary as the first guess might be. m^0 relates to Schwartschild time and radial coordinate r by a shift $m^0 = \Lambda t + h(r)$. Without this shift the perihelion shift would be negligibly small.

One has $(cos(\Theta) = f(r), \Phi = \omega t + k(r))$. Also the dependence of Φ is not the first possibility to come in mind. The shifts $h(r)$ and $k(r)$ are such that the non-diagonal contribution g_{tr} to the induced metric vanishes. The question is whether one obtains spherically symmetric metric as a minimal surface.

5. General form of minimal surface equations

Consider first the minimal surface equations generally.

1. The field equations are analogous to massless wave equations for scalar fields defined by CP_2 coordinates having gravitational self coupling and also covariant derivative coupling due to the non-flatness of CP_2. One might therefore expect that the Newtonian gravitation based on Laplace equation in empty space-time regions follows as an approximation. Therefore also something analogous to Schwartschild metric is to be expected. Note that also massless extremals (MEs) are obtained as minimal surfaces so that also the topologically quantized counterparts of em and gravitational radiation emerge.

2. The general field equations can be written as vanishing of the covariant divergence for canonical momentum current $T^{k\alpha}$

$$\begin{aligned}
D_\alpha(T^{k\alpha}\sqrt{g}) &= \partial_\alpha\left[T^{k\alpha}\sqrt{g}\right] + \left\{ \begin{matrix} k \\ \alpha\ m \end{matrix} \right\} T^{m\alpha}\sqrt{g} = 0 \ , \\
T^{k\alpha} &= g^{\alpha\beta}\partial_\beta h^k \ , \\
\left\{ \begin{matrix} k \\ \alpha\ m \end{matrix} \right\} &= \left\{ \begin{matrix} k \\ l\ m \end{matrix} \right\} \partial_\alpha h^l \ .
\end{aligned} \tag{2.1}$$

D_α is covariant derivative taking into account that gradient $\partial_\alpha h^k$ is imbedding space vector.

3. For isometry currents $j^{A,k}$ (Killing vector fields)

$$T^{A,\alpha} = T^{\alpha k} h_{kl} j^{A,l} \tag{2.2}$$

the covariant divergence simplifies to ordinary divergence

$$\partial_\alpha \left[T^{A,\alpha} \sqrt{g} \right] = 0 \ . \tag{2.3}$$

This allows to simplify the equations considerably.

6. Spherically symmetric stationary minimal surface

Consider now the spherically symmetric stationary metric representable as minimal surface.

1. In the following we consider only the region exterior to the surface defining the TGD counterpart of Schwartschild horizon and the possible horizon at which the signature of the induced metric. The first possibility is $g_{tt} = 0$ at horizon. If g_{rr} remains non-vanishing, the signature changes to Euclidian. If also $g_{rr} = 0$, both g_{tt} and g_{rr} can change sign so that one has a smooth variant of Schwartschild horizon.

   Second possibility is $g_{rr} = 0$ at radius r_E in the region below Schwartschild radius. At r_E the determinant of 4-metric would vanish and the signature of the induced metric would change to Euclidian.

2. The reduction to the conservation of isometry currents can be used for isometry current corresponding to the rotation $\Phi \rightarrow \Phi + \epsilon$ and time translation $m^0 \rightarrow m^0 + \epsilon$.

3. With the experience coming from the imbedding of Reissner-Nordström metric the ansatz is exactly the same and can be written as

$$m^0 = \Lambda t + h(r) \ , \quad \Phi = \omega t + k(r) \ , \quad u \equiv cos(\Theta) = u(r) \ , \tag{2.4}$$

4. The condition $g_{tr} = 0$ gives

$$\Lambda \partial_r h = R^2 \omega sin^2(\Theta) \partial_r k = 0 \ . \tag{2.5}$$

This allows to integrate $h(r)$ in terms of $k(r)$.

5. The interesting components of the induced metric are

$$g_{tt} = \Lambda^2 - R^2\omega^2 sin^2(\Theta) \ , \quad g_{rr} = -1 - R^2(\partial_r\Theta)^2 + \Lambda^2(\partial_r h)^2 \ . \tag{2.6}$$

6. The field equations reduce to conservation laws for various isometry currents. Consider energy current and the current related to the $SO(3) \subset SU(3)$ rotation acting on Φ as shift (call this current isospin current). The stationary character of the induced metric implies that the field equations reduce to the conservation of the radial current for energy current and isospin current. These two equations fix the solution together with diagonality condition. One obtains the following equations

$$\partial_r(\partial_r h \times g^{rr}\sqrt{g}) = 0 \ , \quad \partial_r(sin^2(\Theta)\partial_r k \times g^{rr}\sqrt{g}) = 0) \ . \tag{2.7}$$

These two equations can be satisfied simultaneously only if one has

$$\partial_r h \times g^{rr}r^2\sqrt{g_2} = Asin^2(\Theta)\partial_r k \times g^{rr}r^2\sqrt{g_2} + B \ , \quad g_2 \equiv -g_{tt}g_{rr} \ . \tag{2.8}$$

Note the presence of constant B.

Second implication is

$$g^{rr}\partial_r h\sqrt{g_2} = \frac{C}{r^2} \ , \quad g^{rr}sin^2(\Theta)\partial_r k\sqrt{g_2} = \frac{D}{r^2} \ , \quad C = AD + B \ . \tag{2.9}$$

By substituting the expressions for the metric one has

$$\partial_r h = \sqrt{-\frac{g_{rr}}{g_{tt}}} \times \frac{C}{r^2} \ , \quad sin^2(\Theta)\partial_r k = \sqrt{-\frac{g_{rr}}{g_{tt}}} \times \frac{D}{r^2} \ . \tag{2.10}$$

7. It is natural to look what one obtains in the approximation that the metric is flat expected to make sense at large distances. Putting $g_{tt} = -g_{rr} = 1$, one obtains

$$\partial_r h \simeq \frac{C}{r^2} \ , \quad sin^2(\Theta)\partial_r k \simeq \frac{D}{r^2} \ . \tag{2.11}$$

The time component of the induced metric is given by

$$g_{tt} = \Lambda^2 - R^2\omega^2 sin^2(\Theta) \simeq \Lambda^2 - \frac{D}{r^2\partial_r k} \ . \tag{2.12}$$

This gives $1/r$ gravitational potential of a mass point if one has $\partial_r k \simeq E/r$ giving for $\Lambda = 1$

$$g_{tt} = 1 - \frac{r_S}{r} \ , \quad r_S = 2GM = \frac{D}{E} \ . \tag{2.13}$$

with the identification $r_S = 2GM = D/E$ inspired by the behavior of the Scwartschild metric. It seems that one can take $\Lambda = 1$ without a loss of generality.

8. Using $g_{tr} = 0$ condition this gives for h the approximate expression

$$\partial_r h \simeq \frac{D}{r^2} \ , \quad D = \frac{R^2\omega^2}{\Lambda} \ . \tag{2.14}$$

so that the field equations are consistent with the $1/r$ behavior of gravitational potential. The solution carries necessarily a non-vanishing Abelian electroweak gauge field.

9. The asymptotic behaviors of k and h would be

$$k \simeq k_0 log(\frac{r}{r_0}) \ , \quad h \simeq h_0 - \frac{C}{r} \ . \tag{2.15}$$

7. Two horizons and layered structure as basic prediction

A very interesting question is whether $g_{tt} = 0$ defines Schwartschild type horizon at which the roles of the coordinates t and r change or whether one obtains horizon at which the signature of the induced metric becomes Euclidian. The most natural option turns out to be Schwartschild like horizon at which the roles of time and radial coordinate are changed and second inner horizon at which g_{rr} changes sign again so that the induced metric has Euclidian signature below this inner horizon.

1. Unless one has $g_{tt}g_{rr} = C \neq 0$ ($C = -1$ holds true in Scwhartschild-Nordström metric) the surface $g_{tt} = 0$ - if it exists - defines a light-like 3-surface identifiable as horizon at which the signature of the induced metric changes. The conditions $g_{tt} = 0$ gives

$$\Lambda^2 - R^2\omega^2(1-u^2) = 0 \ . \tag{2.16}$$

giving

$$0 < sin^2(\Theta) = 1 - u^2 \ = \ \frac{\Lambda^2}{R^2\omega^2} < 1 \ . \tag{2.17}$$

For $\Lambda = 1$ this condition implies that ω is a frequency of order of the inverse of CP_2 radius R. Note that $g_{tt} = 0$ need mean change of the metric signature to Euclidian if the analog of Schwarschild horizon is in question.

2. $g_{tt} = 0$ surface is light-like surface if g_{rr} has non-vanishing and finite value at it. g_{rr} could diverges at this surface guaranteeing $g_{tt}g_{rr} > 0$. The quantities $\partial_r h$ and $sin^2(\Theta)\partial_r k$ are proportional to $\sqrt{g_{rr}/g_{tt}}$, which diverges for $g_{tt} = 0$ unless also g_{rr} vanishes so that also these derivatives would diverge. The behavior of g_{rr} at this surface is

$$g_{rr} = -1 - R^2 \tfrac{(\partial_r u)^2}{1-u^2} + \Lambda^2(\partial_r h)^2 \ , \quad u \equiv cos(\Theta) \ . \tag{2.18}$$

There are several options to consider.

(a) Option I: The divergence of $(\partial_r h)^2$ as cause for the divergence of g_{rr} is out of question. If this quantity increases for small values of r, g_{rr} can change sign for with finite value of $\partial_r h$ and $u^2 < 1$ at some larger radius r_S analogous to Schwartschild radius. Since it is impossible to have two time-like directions also the sign of g_{tt} must change so that one would have the analog of Schwartschild horizon at this radius - call it r_S: $r_S = 2GM$ need not hold true. The condition $g_{tt} = 0$ at this radius fixes the value of $sin^2(\Theta)$ at this radius

$$sin^2(\Theta_S) \quad = \quad \frac{\Lambda^2}{R^2\omega^2} \ . \tag{2.19}$$

If g_{rr} has finite value and is continuous, the metric has Euclidian signature in interior. If g_{rr} is discontinuous and changes sign as in the case of Schwartschild metric, one has counterpart of Scwartschild horizon without infinities. This option will be called Option I.

(b) Second possibility giving rise to would be that u becomes equal 1. This is not consistent with $sin^2(\Theta_S) = 0$.

(c) Option II: Voth g_{tt} and g_{rr} change their sign and vanish at r_S. This however requires both radial and time-like direction become null directions locally. Space-time surface would become locally metrically 2-dimensional at the horizon. This would conform with the idea of strong form of holography (SH) but it is not possible to have two different light-like directions simultaneously unless these directions are actually same. Mathematically it is certainly possible to have surfaces for which the dimension is locally reduced from the maximal one but it is difficult to visualize what this kind of metric reduction of local space-time dimension could mean. This option will be considered in what follows.

To sum up, g_{rr} changes sign at horizon. For Option I g_{rr} is finite and discontinuous. For Option II g_{rr} vanishes and is continuous. Whether g_{rr} vanishes at horizon or not, remains open.

3. For Schwartschild-Nordström metric g_{rr} becomes infinite and changes sign at horizon. The change of the roles of g_{tt} and g_{rr} could for Option II take place

smoothly so that both could become zero and change their sign at r_S. This would keep $\partial_r h$ and $sin^2(\Theta)\partial_r k$ finite. One would have the analog of the interior of Schwartschild metric.

What happens at the smaller radii? The obvious constraint is that $sin^2(\Theta)$ remains below unity. If g_{rr}/g_{tt} remains bounded, the condition for $sin^2(\Theta)\partial_k$ however suggests that $sin^2(\Theta) = 1$ is eventually achieved. This is the case also for the imbedding of Schwartschild metric. Could this horizon correspond to a surface at which the signature of the metric changes? g_{rr} should becomes zero in order to obtain light-like surface. g_{rr} contains indeed a term proportional to $1/sin^2(\Theta)$ which diverges at $u = 1$ so that g_{rr} must change sign for second time already above the radius for $sin^2(\Theta) = 1$ if h and k behaves smoothly enough. At this radius - call it r_E - g_{tt} would be finite and the signature would become Euclidian below this radius.

One would therefore have two special radii r_S and r_E and a layer between these radii. $r_S = 2GM$ need not hold true but is expected to give a reasonable order of magnitude estimate.

Is there any empirical evidence for the existence of two horizons? There is evidence that the formation of the recently found LIGO blackhole (discussed from TGD view point in [L4]) is not fully consistent with the GRT based model (see `http://tinyurl.com/zbbz58w`). There are some indications that LIGO blackhole has a boundary layer such that the gravitational radiation is reflected forth and back between the inner and outer boundaries of the layer. In the proposed model the upper boundary would not be totally reflecting so that gravitational radiation leaks out and gave rise to echoes at times .1 sec, .2 sec, and .3 sec. It is perhaps worth of noticied that time scale .1 sec corresponds to the secondary p-adic time scale of electron (characterized by Mersenne prime $M_{127} = 2^{127} - 1$). If the minimal surface solution indeed has two horizons and a layer like structure between them, one might at least see the trouble of killing the idea that it could give rise to repeated reflections of gravitational radiation.

The proposed model (see `http://tinyurl.com/zbbz58w`) assumes that the inner horizon is Schwarstchild horizon. TGD would however suggests that the outer horizon is the TGD counterpart of Schwartschild horizon. It could have different radius since it would not be a singularity of g_{rr} (g_{tt}/g_{rr} would be finite at r_S which need not be $r_S = 2GM$ now). At r_S the tangent space of the space-time surface would become effectively 2-dimensional for $g_{rr} = 0$: the interpretation in terms of strong holography (SH) has been already mentioned.

The condition that the normal components of the canonical momentum currents for Kähler action and volume term are finite implies that $g^{nn}\sqrt{g_4}$ is finite at both sides of the horizon. Also the weak form of electric magnetic duality for Kähler form requires this. This condition can be satisfied if g_{tt} and g_{nn} approach to zero in the same manner at both sides of the horizon. Hence it seems that strong form of holography in the horizon is forced by finiteness.

One should understand why it takes rather long time $T = .1$ seconds for radiation to travel forth and back the distance $L = r_S - r_E$ between the horizons. The maximal signal velocity is reduced for the light-like geodesics of the space-time surface but the reduction should be rather large for $L \sim 20$ km (say). The effective light-velocity is measured by the coordinate time $\Delta t = \Delta m^0 + h(r_S) - h(r_E)$ needed to travel the distance from r_E to r_S. The Minkowski time Δm^0_{-+} would be the from null geodesic property and $m^0 = t + h(r)$

$$\Delta m^0_{-+} = \Delta t - h(r_S) + h(r_E) \ , \quad \Delta t = \int_{r_E}^{r_S} \sqrt{\frac{g_{rr}}{g_{tt}}} dr \equiv \int_{r_E}^{r_S} \frac{dr}{c_\#} \ . \tag{2.20}$$

Note that $c\#$ approaches zero at horizon if g_{rr} is non-vanishing at horizon.

The time needed to travel forth and back does not depend on h and would be given by

$$\Delta m^0 = 2\Delta t = 2\int_{r_E}^{r_S} \frac{dr}{c_\#} \ . \tag{2.21}$$

This time cannot be shorter than the minimal time $(r_s - r_E)/c$ along light-like geodesic of M^4 since light-like geodesics at space-time surface are in general time-like curves in M^4. Since .1 sec corresponds to about 3×10^4 km, the average value of $c_\#$ should be for $L = 20$ km (just a rough guess) of order $c\# \sim 2^{-11}c$ in the interval $[r_E, r_S]$. As noticed, $T = .1$ sec is also the secondary p-adic time assignable to electron labelled by the Mersenne prime M_{127}. Since g_{rr} vanishes at r_E one has $c_\# \to \infty$. $c_\#$ is finite at r_S.

There is an intriguing connection with the notion of gravitational Planck constant. The formula for gravitational Planck constant given by $h_{gr} = GMm/v_0$ characterizing the magnetic bodies topologically for mass m topologically condensed at gravitational magnetic flux tube emanating from large mass M [K11, K10, K18, K19]. The interpretation of the velocity parameter v_0 has remained open. Could v_0 correspond to the average value of $c_\#$? For inner planets one has $v_0 \simeq 2^{-11}$ so that the order of magnitude is same as for the estimate for $c_\#$.

Remark: More than year after after writing the above text I learned about additional evidence for blackhole echoes. Sabine Hossenfelder (see `http://tinyurl.com/ybd9gswm`) tells about the new evidence reported by Niayesh Afshordi, Professor of astrophysics at Perimeter Institute in the article "*Echoes from the Abyss: A highly spinning black hole remnant for the binary neutron star merger GW170817*" (see `https://arxiv.org/abs/1803.10454`). Now the earlier 2.5 sigma evidence has grown into 4.2 sigma evidence. 5 sigma is regarded as a criterion for discovery.

2.2.4 What about TGD inspired cosmology?

Before the discovery of the twistor lift TGD inspired cosmology has been based on the assumption that vacuum extremals provide a good estimate for the solutions of Einstein's equations at GRT limit of TGD [K13, K12] . One can find imbeddings of Robertson-Walker type metrics as vacuum extremals and the general finding is that the cosmological with super-critical and critical mass density have finite duration after which the mass density becomes infinite: this period of course ends before this. The interpretation would be in terms of the emergence of new space-time sheet at which matter represented by smaller space-time sheets suffers topological condensation. The only parameter characterizing critical cosmologies is their duration.

Critical (over-critical) cosmologies having $SO3 \times E^3$ ($SO(4)$) as isometry group is the duration and the CP_2 projection at homologically trivial geodesic sphere S^2: the condition that the contribution from S^2 to g_{rr} component transforms hyperbolic 3-metric to that of E^3 or S^3 metric fixes these cosmologies almost completely. Sub-critical cosmologies have one-dimensional CP_2 projection.

Do Robertson-Walker cosmologies have minimal surface representatives? Recall that minimal surface equations read as

$$\begin{aligned} D_\alpha(g^{\alpha\beta}\partial_\beta h^k\sqrt{g}) &= \partial_\alpha\left[g^{\alpha\beta}\partial_\beta h^k\sqrt{g}\right] + \left\{ {k \atop \alpha\ m} \right\} g^{\alpha\beta}\partial_\beta h^m\sqrt{g} = 0 \ , \\ \left\{ {k \atop \alpha\ m} \right\} &= \left\{ {k \atop l\ m} \right\}\partial_\alpha h^l \ . \end{aligned} \tag{2.22}$$

Sub-critical minimal surface cosmologies would correspond to $X^4 \subset M^4 \times S^1$. The natural coordinates are Robertson-Walker coordinates, which co-incide with light-cone coordinates $(a = \sqrt{(m^0)^2 - r_M^2}, r = r_M/a, \theta, \phi)$ for light-cone M^4_+. They are related to spherical Minkowski coordinates (m^0, r_M, θ, ϕ) by $(m^0 = a\sqrt{1+r^2}, r_M = ar)$. $\beta = r_M/m_0 = r/\sqrt{1+r^2}$ corresponds to the velocity along the line from origin (0,0) to (m^0, r_M). r corresponds to the Lorentz factor $\gamma\beta = \beta/\sqrt{1-\beta^2}$. The metric of M^4_+ is given by the diagonal form $[g_{aa} = 1, g_{rr} = a^2/(1+r^2), g_{\theta\theta} = a^2r^2, g_{\phi\phi} = a^2r^2sin^2(\theta)]$. One can use the coordinates of M^4_+ also for X^4.

The ansatz for the minimal surface reads is $\Phi = f(a)$. For $f(a) = constant$ one obtains just the flat M^4_+. In non-trivial case one has $g_{aa} = 1 - R^2(df/da)^2$. The g^{aa} component of the metric becomes now $g^{aa} = 1/(1-R^2(df/da)^2)$. Metric determinant is scaled by $\sqrt{g_{aa}} = 1 \rightarrow \sqrt{1 - R^2(df/da)^2}$. Otherwise the field equations are same as for M^4_+. Little calculation shows that they are not satisfied unless one as $g_{aa} = 1$.

Also the minimal surface imbeddings of critical and over-critical cosmologies are impossible. The reason is that the criticality alone fixes these cosmologies almost uniquely and this is too much for allowing minimal surface property.

Thus one can have only the trivial cosmology M^4_+ carrying dark energy density as a minimal surface solution! This obviously raises several questions.

1. Could $\Lambda = 0$ case for which action reduces to Kähler action provide vacuum extremals provide single-sheeted model for Robertson-Walker cosmologies for the GRT limit of TGD for which many-sheeted space-time surface is replaced with a slightly curved region of M^4? Could $\Lambda = 0$ correspond to a genuine phase present in TGD as formal generalization of the view of mathematicians about reals as $p = \infty$ p-adic number suggest. p-Adic length scale would be strictly infinite implying that $\Lambda \propto 1/p$ vanishes.

2. Second possibility is that TGD is quantum critical in strong sense. Not only 3-space but the entire space-time surface is flat and thus M^4_+. Only the local gravitational fields created by topologically condensed space-time surfaces would make it curved but would not cause smooth expansion. The expansion would take as quantum phase transitions reducing the value of $\Lambda \propto 1/p$ as p-adic prime p increases. p-Adic length scale hypothesis suggests that the

preferred primes are near but below powers of 2 $p \simeq 2^k$ for some integers k. This led for years ago to a model for Expanding Earth [K5].

3. This picture would explain why individual astrophysical objects have not been observed to expand smoothly (except possibly in these phase transitions) but participate cosmic expansion only in the sense that the distance to other objects increase. The smaller space-time sheets glued to a given space-time sheet preserving their size would emanate from the tip of M^4_+ for given sheet.

4. RW cosmology should emerge in the idealization that the jerk-wise expansion by quantum phase transitions and reducing the value of Λ (by scalings of 2 by p-adic length scale hypothesis) can be approximated by a smooth cosmological expansion.

One should understand why Robertson-Walker cosmology is such a good approximation to this picture. Consider first cosmic redshift.

1. The cosmic recession velocity is defined from the redshift by Doppler formula.

$$z = \frac{1+\beta}{1-\beta} - 1 \simeq \beta = \frac{v}{c} \quad . \tag{2.23}$$

In TGD framework this should correspond to the velocity defined in terms of the coordinate r of the object.

Hubble law tells that the recession velocity is proportional to the proper distance D from the source. One has

$$v = HD \ , \quad H = (\frac{da/dt}{a}) = \frac{1}{\sqrt{g_{aa}}a} \quad . \tag{2.24}$$

This brings in the dependence on the Robertson-Walker metric.

For M^4_+ one has $a = t$ and one would have $g_{aa} = 1$ and $H = 1/a$. The experimental fact is however that the value of H is larger for non-empty RW cosmologies having $g_{aa} < 1$. How to overcome this problem?

2. To understand this one must first understand the interpretation of gravitational redshift. In TGD framework the gravitational redshift is property of observer rather than source. The point is that the tangent space of the 3-surface assignable to the observer is related by a Lorent boost to that associated with the source. This implies that the four-momentum of radiation from the source is boosted by this same boost. Redshift would mean that the Lorentz boost reduces the momentum from the real one. Therefore redshift would be consistent with momentum conservation implied by Poincare symmetry.

g_{aa} for which a corresponds to the value of cosmic time for the observer should characterize the boost of observer relative to the source. The natural guess is that the boost is characterized by the value of g_{tt} in sufficiently large rest system assignable to observer with t is taken to be M^4 coordinate m^0. The value of g_{tt} fluctuates do to the presence of local gravitational fields. At the GRT limit g_{aa} would correspond to the average value of g_{tt}.

3. There is evidence that H is not same in short and long scales. This could be understood if the radiation arrives along different space-time sheets in these two situations.

4. If this picture is correct GRT description of cosmology is effective description taking into account the effect of local gravitation to the redshift, which without it would be just the M^4_+ redshift.

Einstein's equations for RW cosmology [K13, K12] should approximately code for the cosmic time dependence of mass density at given slightly deformed piece of M^4_+ representing particular sub-cosmology expanding in jerkwise manner.

1. Many-sheeted space-time implies a hierarchy of cosmologies in different p-adic length scales and with cosmological constant $\Lambda \propto 1/p$ so that vacuum energy density is smaller in long scale cosmologies and behaves on the average as $1/a^2$ where a characterizes the scale of the cosmology. In zero energy ontology given scale corresponds to causal diamond (CD) with size characterized by a defining the size scale for the distance between the tips of CD.

2. For the comoving volume with constant value of coordinate radius r the radius of the volume increases as a. The vacuum energy would increase as a^3 for co-moving volume. This is in sharp conflict with the fact that the mass decreases as $1/a$ for radiation dominated cosmology, is constant for matter dominated cosmology, and is proportional to a for string dominated cosmology.

   The physical resolution of the problem is rather obvious. Space-time sheets representing topologically condensed matter have finite size. They do not expand except possibly in jerkwise manner but in this process Λ is reduced - in average manner like $1/a^2$.

   If the sheets are smaller than the cosmological space-time sheet in the scale considered and do not lose energy by radiation they represent matter dominated cosmology emanating from the vertex of M^4_+. The mass of the co-moving volume remains constant.

   If they are radiation dominated and in thermal equilibrium they lose energy by radiation and the energy of volume behaves like $1/a$.

   Cosmic strings and magnetic flux tubes have size larger than that the space-time sheet representing the cosmology. The string as linear structure has energy proportional to a for fixed value of Λ as in string dominated cosmology. The reduction of Λ decreasing on the average like $1/a^2$ implies that the contribution of given string is reduced like $1/a$ on the average as in radiation dominated cosmology.

3. GRT limit would code for these behaviours of mass density and pressure identified as scalars in GRT cosmology in terms of Einstein's equations. The time dependence of g_{aa} would code for the density of the topologically condensed matter and its pressure and for dark energy at given level of hierarchy. The vanishing of covariant divergence for energy momentum tensor would be a remnant of Poincare invariance and give Einstein's equations with cosmological term.

4. Why GRT limit would involve only the RW cosmologies allowing imbedding as vacuum extremals of Kähler action? Can one demand continuity in the sense that TGD cosmology at $p \to \infty$ limit corresponds to GRT cosmology with cosmological solutions identifiable as vacuum extremals? If this is assumed the earlier results are obtained. In particular, one obtains the critical cosmology with 2-D CP_2 projection assumed to provide a GRT model for quantum phase transitions changing the value of Λ.

If this picture is correct, TGD inspired cosmology at the level of many-sheeted space-time would be extremely simple. The new element would be many-sheetedness which would lead to more complex description provided by GRT limit. This limit would however lose the information about many-sheetedness and lead to anomalies such as two Hubble constants.

2.2.5 Induced spinor structure

The notion of induced spinor field deserves a more detailed discussion. Consider first induced spinor structures [K14].

1. Induced spinor field are spinors of $M^4 \times CP_2$ for which modes are characterized by chirality (quark or lepton like) and em charge and weak isospin.

2. Induced spinor spinor structure involves the projection of gamma matrices defining induced gamma matrices. This gives rise to superconformal symmetry if the action contains only volume term.

   When Kähler action is present, superconformal symmetry requires that the modified gamma matrices are contractions of canonical momentum currents with imbedding space gamma matrices. Modified gammas appear in the modified Dirac equation and action, whose solution at string world sheets trivializes by super-conformal invariance to same procedure as in the case of string models.

3. Induced spinor fields correspond to two chiralities carrying quark number and lepton number. Quark chirality does not carry color as spin-like quantum number but it corresponds to a color partial wave in CP_2 degrees of freedom: color is analogous to angular momentum. This reduces to spinor harmonics of CP_2 describing the ground states of the representations of super-symplectic algebra.

   The harmonics do not satisfy correct correlation between color and electroweak quantum numbers although the triality t=0 for leptonic waves and t=1 for quark waves. There are two manners to solve the problem.

(a) Super-symplectic generators applied to the ground state to get vanishing ground states weight instead of the tachyonic one carry color and would give for the physical states correct correlation: leptons/quarks correspond to the same triality zero(one partial wave irrespective of charge state. This option is assumed in p-adic mass calculations [K7].

(b) Since in TGD elementary particles correspond to pairs of wormhole contacts with weak isospin vanishing for the entire pair, one must have pair of left and right-handed neutrinos at the second wormhole throat. It is possible that the anomalous color quantum numbers for the entire state vanish and one obtains the experimental correlation between color and weak quantum numbers. This option is less plausible since the cancellation of anomalous color is not local as assume in p-adic mass calculations.

The understanding of the details of the fermionic and actually also geometric dynamics has taken a long time. Super-conformal symmetry assigning to the geometric action of an object with given dimension an analog of Dirac action allows however to fix the dynamics uniquely and there is indeed dimensional hierarchy resembling brane hierarchy.

1. The basic observation was following. The condition that the spinor modes have well-defined em charge implies that they are localized to 2-D string world sheets with vanishing W boson gauge fields which would mix different charge states. At string boundaries classical induced W boson gauge potentials guarantee this. Super-conformal symmetry requires that this 2-surface gives rise to 2-D action which is area term plus topological term defined by the flux of Kähler form.

2. The most plausible assumption is that induced spinor fields have also interior component but that the contribution from these 2-surfaces gives additional delta function like contribution: this would be analogous to the situation for branes. Fermionic action would be accompanied by an area term by supersymmetry fixing modified Dirac action completely once the bosonic actions for geometric object is known. This is nothing but super-conformal symmetry.

   One would actually have the analog of brane-hierarchy consisting of surfaces with dimension D= 4,3,2,1 carrying induced spinor fields which can be regarded as independent dynamical variables and characterized by geometric action which is D-dimensional analog of the action for Kähler charged point particle. This fermionic hierarchy would accompany the hierarchy of geometric objects with these dimensions and the modified Dirac action would be uniquely determined by the corresponding geometric action principle (Kähler charged point like particle, string world sheet with area term plus Kähler flux, light-like 3-surface with Chern-Simons term, 4-D space-time surface with Kähler action).

3. This hierarchy of dynamics is consistent with SH only if the dynamics for higher dimensional objects is induced from that for lower dimensional objects - string world sheets or maybe even their boundaries orbits of point like fermions.

Number theoretic vision [K21] suggests that this induction relies algebraic continuation for preferred extremals. Note that quaternion analyticity [K24] means that quaternion analytic function is determined by its values at 1-D curves.

4. Quantum-classical correspondences (QCI) requires that the classical Noether charges are equal to the eigenvalues of the fermionic charges for surfaces of dimension $D = 0, 1, 2, 3$ at the ends of the CDs. These charges would not be separately conserved. Charges could flow between objects of dimension $D + 1$ and D - from interior to boundary and vice versa. Four-momenta and also other charges would be complex as in twistor approach: could complex values relate somehow to the finite life-time of the state?

   If quantum theory is square root of thermodynamics as zero energy ontology suggests, the idea that particle state would carry information also about its life-time or the time scale of CD to which is associated could make sense. For complex values of α_K there would be also flow of canonical and super-canonical momentum currents between Euclidian and Minkowskian regions crucial for understand gravitational interaction as momentum exchange at imbedding space level.

5. What could be the physical interpretation of the bosonic and fermionic charges associated with objects of given dimension? Condensed matter physicists assign routinely physical states to objects of various dimensions: is this assignment much more than a practical approximation or could condensed matter physics already be probing many-sheeted physics?

2.2.6 SUSY and TGD

From this one ends up to the possibility of identifying the counterpart of SUSY in TGD framework [K15].

1. In TGD the generalization of much larger super-conformal symmetry emerges from the super-symplectic symmetries of WCW. The mathematically questionable notion of super-space is not needed: only the realization of super-algebra in terms of WCW gamma matrices defining super-symplectic generators is necessary to construct quantum states. As a matter of fact, also in QFT approach one could use only the Clifford algebra structure for super-multiplets. No Majorana condition on fermions is needed as for $\mathcal{N} = 1$ space-time SUSY and one avoids problems with fermion number non-conservation.

2. In TGD the construction of sparticles means quite concretely adding fermions to the state. In QFT it corresponds to transformation of states of integer and half-odd integer spin to each other. This difference comes from the fact that in TGD particles are replaced with point like particles.

3. The analog of $\mathcal{N} = 2$ space-time SUSY could be generated by covariantly constant right handed neutrino and antineutrino. Quite generally the mixing of fermionic chiralities implied by the mixing of M^4 and CP_2 gamma matrices

implies SUSY breaking at the level of particle masses (particles are massless in 8-D sense). This breaking is purely geometrical unlike the analog of Higgs mechanism proposed in standard SUSY.

There are several options to consider.

1. The analog of brane hierarchy is realized also in TGD. Geometric action has parts assignable to 4-surface, 3-D light like regions between Minkowskian and Euclidian regions, 2-D string world sheets, and their 1-D boundaries. They are fixed uniquely. Also their fermionic counterparts - analogs of Dirac action - are fixed by super-conformal symmetry. Elementary particles reduce so composites consisting of point-like fermions at boundaries of wormhole throats of a pair of wormhole contacts.

   This forces to consider 3 kinds of SUSYs! The SUSYs associated with string world sheets and space-time interiors would certainly be broken since there is a mixing between M^4 chiralities in the modified Dirac action. The mass scale of the broken SUSY would correspond to the length scale of these geometric objects and one might argue that the decoupling between the degrees of freedom considered occurs at high energies and explains why no evidence for SUSY has been observed at LHC. Also the fact that the addition of massive fermions at these dimensions can be interpreted differently. 3-D light-like 3-surfaces could be however an exception.

2. For 3-D light-like surfaces the modified Dirac action associated with the Chern-Simons term does not mix M^4 chiralities (signature of massivation) at all since modified gamma matrices have only CP_2 part in this case. All fermions can have well-defined chirality. Even more: the modified gamma matrices have no M^4 part in this case so that these modes carry no four-momentum - only electroweak quantum numbers and spin. Obviously, the excitation of these fermionic modes would be an ideal manner to create spartners of ordinary particles consting of fermion at the fermion lines. SUSY would be present if the spin of these excitations couples - to various interactions and would be exact in absence of coupling to interior spinor fields.

   What would be these excitations? Chern-Simons action and its fermionic counterpart are non-vanishing only if the CP_2 projection is 3-D so that one can use CP_2 coordinates. This strongly suggests that the modified Dirac equation demands that the spinor modes are covariantly constant and correspond to covariantly constant right-handed neutrino providing only spin.

   If the spin of the right-handed neutrino adds to the spin of the particle and the net spin couples to dynamics, $\mathcal{N} = 2$ SUSY is in question. One would have just action with unbroken SUSY at QFT limit? But why also right-handed neutrino spin would couple to dynamics if only CP_2 gamma matrices appear in Chern-Simons-Dirac action? It would seem that it is independent degree of freedom having no electroweak and color nor even gravitational couplings by its covariant constancy. I have ended up with just the same SUSY-or-no-SUSY that I have had earlier.

3. Can the geometric action for light-like 3-surfaces contain Chern-Simons term?

   (a) Since the volume term vanishes identically in this case, one could indeed argue that also the counterpart of Kähler action is excluded. Moreover, for so called massless extremals of Kähler action reduces to Chern-Simons terms in Minkowskian regions and this could happen quite generally: TGD with only Kähler action would be almost topological QFT as I have proposed. Volume term however changes the situation via the cosmological constant. Kähler-Dirac action in the interior does not reduce to its Chern-Simons analog at light-like 3-surface.

   (b) The problem is that the Chern-Simons term at the two sides of the light-like 3-surface differs by factor $\sqrt{-1}$ coming from the ratio of $\sqrt{g_4}$ factors which themselves approach to zero: oOne would have the analog of dipole layer. This strongly suggests that one should not include Chern-Simons term at all.

       Suppose however that Chern-Simons terms are present at the two sides and α_K is real so that nothing goes through the horizon forming the analog of dipole layer. Both bosonic and fermionic degrees of freedom for Euclidian and Minkowskian regions would decouple completely but currents would flow to the analog of dipole layer. This is not physically attractive.

       The canonical momentum current and its super counterpart would give fermionic source term $\Gamma^n\Psi_{int,\pm}$ in the modified Dirac equation defined by Chern-Simons term at given side $\pm$: $\pm$ refers to Minkowskian/Euclidian part of the interior. The source term is proportional to $\Gamma^n\Psi_{int,\pm}$ and Γ^n is in principle mixture of M^4 and CP_2 gamma matrices and therefore induces mixing of M^4 chiralities and therefore also 3-D SUSY breaking. It must be however emphasized that Γ^n is singular and one must be consider the limit carefully also in the case that one has only continuity conditions. The limit is not completely understood.

   (c) If α_K is complex there is coupling between the two regions and the simplest assumption has been that there is no Chern-Simons term as action and one has just continuity conditions for canonical momentum current and hits super counterpart.

   The cautious conclusion is that 3-D Chern-Simons term and its fermionic counterpart are absent.

4. What about the addition of fermions at string world sheets and interior of space-time surface ($D = 2$ and $D = 4$). For instance, in the case of hadrons $D = 2$ excitations could correspond to addition of quark in the interior of hadronic string implying additional states besides the states obtained assuming only quarks at string ends. Let us consider the interior ($D = 4$). For instance, inn the case of hadrons $D = 2$ excitations could correspond to addition of quark in the interior of hadronic string implying additional states besides the states obtained assuming only quarks at string ends. The smallness of cosmological constant implies that the contribution to the four-momentum from interior

should be rather small so that an interpretation in terms of broken SUSY might make sense. There would be mass $m \sim .03$ eV per volume with size defined by the Compton scale $\hbar/m$. Note however that cosmological constant has spectrum coming as inverse powers of prime so that also higher mass scales are possible.

This interpretation might allow to understand the failure to find SUSY at LHC. Sparticles could be obtained by adding interior right-handed neutrinos and antineutrinos to the particle state. They could be also associated with the magnetic body of the particle. Since they do not have color and weak interactions, SUSY is not badly broken. If the mass difference between particle and sparticle is of order $m = .03$ eV characterizing dark energy density ρ_{vac}, particle and sparticle could not be distinguished in higher energy physics at LHC since it probes much shorter scales and sees only the particle. I have already earlier proposed a variant of this mechanism but without SUSY breaking.

To discover SUSY one should do very low energy physics in the energy range $m \sim .03$ eV having same order of magnitude as thermal energy $kT = 2.6\times 10^{-2}$ eV at room temperature 25 °C. One should be able to demonstrate experimentally the existence of sparticle with mass differing by about $m \sim .03$ eV from the mass of the particle (one cannot exclude higher mass scales since Λ is expected to have spectrum). An interesting question is whether the sparticles associated with standard fermions could give rise to Bose-Einstein condensates whose existence in the length scale of large neutron is strongly suggested by TGD view about living matter.

2.3 Imbedding space level

In GRT the description of gravitation involve only space-time and gravitational force is eliminated. In TGD also imbedding space level is involved with the description [K24].

1. The incoming and outgoing states of particle reaction are labelled by the quantum numbers associated with the isometries of the imbedding space and by the contributions of super-symplectic generators and isometry generators to the quantum numbers. This follows from the fact that the ground states of super-symplectic representations correspond to the modes of imbedding space spinors fields. These quantum numbers appear in the S-matrix of QFT limit too. In particular, color quantum numbers as angular momentum like quantum numbers at fundamental level are transformed to spin-like quantum numbers at QFT limit.

2. In GRT the applications rely on Post-Newtonian approximation (PNA). This means that the notion of gravitational force is brought to the theory although it has been eliminated from the basic GRT. This is not simple. One could argue that there is genuine physics behind this PNA and TGD suggests what this physics is.

   At the level of space-time surfaces particles move along geodesic lines and in TGD minimal surface equation states the generalization of the geodesic line property for 3-D particles. At the imbedding space level gravitational interaction involves exchanges of four-momentum and in principle of color quantum numbers too. Indeed, there is an exchange of classical charges through the light-like 3-surfaces defining the boundaries of Euclidian regions defining Euclidian regions as "lines" of generalized scattering diagrams. This however requires that Kähler coupling strength is allowed to be complex (say correspond to zero of Riemann Zeta). Hence in TGD also Newtonian view would be correct and needed.

3 Some questions about TGD

In Face Book I was made a question about general aspects of TGD. It was impossible to answer the question with few lines and I decided to write a blog posting, which then gave rise to this section. This text talks from different perspective about same topics as the article *Can one apply Occams razor as a general purpose debunking argument to TGD?* [L3] trying o emphasize the simplicity of the basic principles of TGD and of the resulting theory.

3.1 In what aspects TGD extends other theory/theories of physics?

I will replace "extends" with "modifies" since TGD also simplifies in many respects. I shall restrict the considerations to the ontological level which to my view is the really important level.

1. Space-time level is where TGD started from. Space-time as an abstract 4-geometry is replaced as space-time as 4-surface in $M^4 \times CP_2$. In GRT space-time is small deformation of Minkowski space.

   In TGD both Relativity Principle (RP) of Special Relativity (SRT) and General Coordinate Invariance (GCI) and Equivalence Principle (EP) of General Relativity hold true. In GRT RP is given up and leads to the loss of conservation laws since Noether theorem cannot be applied anymore: this is what led to the idea about space-time as surface in H. Strong form of holography (SH) is a further principle reducing to strong form of GCI (SGCI).

2. TGD as a physical theory extends to a theory of consciousness and cognition. Observer as something external to the Universe becomes part of physical system - the notion of self - and quantum measurement theory which is the black sheet of quantum theory extends to a theory of consciousness and also of cognition relying of p-adic physics as correlate for cognition. Also quantum biology becomes part of fundamental physics and consciousness and life are seen as basic elements of physical existence rather than something limited to brain.

   One important aspect is a new view about time: experienced time and geometric time are not one and same thing anymore although closely related. ZEO explains how the experienced flow and its direction emerges. The prediction is that both arrows of time are possible and that this plays central role in living matter.

3. p-Adic physics is a new element and an excellent candidate for a correlate of cognition. For instance, imagination could be understood in terms of non-determinism of p-adic partial differential equations for p-adic variants of space-time surfaces. p-Adic physics and fusion of real and various p-adic physics to adelic physics provides fusion of physics of matter with that of cognition in TGD inspired theory of cognition. This means a dramatic extension of ordinary physics. Number Theoretical Universality states that in certain sense various p-adic physics and real physics can be seen as extensions of physics based on algebraic extensions of rationals (and also those generated by roots of e inducing finite-D extensions of p-adics).

4. Zero energy ontology (ZEO) in which so called causal diamonds (CDs, analogs Penrose diagrams) can be seen as being forced by very simple condition: the volume action forced by twistor lift of TGD must be finite. CD would represent the perceptive field defined by finite volume of imbedding space $H = M^4 \times CP_2$.

   ZEO implies that conservation laws formulated only in the scale of given CD do not anymore fix select just single solution of field equations as in classical theory. Theories are strictly speaking impossible to test in the old classical ontology. In ZEO testing is possible be sequence of state function reductions giving information about zero energy states.

   In principle transition between any two zero energy states - analogous to events specified by the initial and final states of event - is in principle possible but Negentropy Maximization Principle (NMP) as basic variational principle of state function reduction and of consciousness restricts the possibilities by forcing generation of negentropy: the notion of negentropy requires p-adic physics.

   Zero energy states are quantum superpositions of classical time evolutions for 3-surfaces and classical physics becomes exact part of quantum physics: in QFTs this is only the outcome of stationary phase approximation. Path integral is replaced with well-defined functional integral- not over all possible space-time surface but pairs of 3-surfaces at the ends of space-time at opposite boundaries of CD.

   ZEO leads to a theory of consciousness as quantum measurement theory in which observer ceases to be outsider to the physical world. One also gets rid of the basic problem caused by the conflict of the non-determinism of state function reduction with the determinism of the unitary evolution. This is obviously an extension of ordinary physics.

5. Hierarchy of Planck constants represents also an extension of quantum mechanics at QFT limit. At fundamental level one actually has the standard value of h but at QFT limit one has effective Planck constant $h_{eff}/h = n$, $n = 1, 2, ...$ This generalizes quantum theory. This scaling of h has a simple topological interpretation: space-time surface becomes n-fold covering of itself

and the action becomes n-multiple of the original which can be interpreted as $h_{eff}/h = n$.

The most important applications are to biology, where quantum coherence could be understood in terms of a large value of h_{eff}/h. The large n phases resembles the large N limit of gauge theories with gauge couplings behaving as $\alpha \propto 1/N$ used as a kind of mathematical trick. Also gravitation is involved: h_{eff} is associated with the flux tubes mediating various interactions (being analogs to wormholes in ER-EPR correspondence). In particular, one can speak about h_{gr}, which Nottale introduced originally and $h_{eff} = h_{gr}$ plays key role in quantum biology according to TGD.

3.2 In what sense TGD is simplification/extension of existing theory?

1. Classical level: Space-time as 4-surface of H means a huge reduction in degrees of freedom. There are only 4 field like variables - suitably chosen 4 coordinates of $H = M^4 \times CP_2$. All classical gauge fields and gravitational field are fixed by the surface dynamics. There are no primary gauge fields or gravitational fields nor any other fields in TGD Universe and they appear only at the QFT limit [K1, K22, K23].

   GRT limit would mean that many-sheeted space-time is replaced by single slightly curved region of M^4. The test particle - small particle like 3-surface - touching the sheets simultaneously experience sum of gravitational forces and gauge forces. It is natural to assume that this superposition corresponds at QFT limit to the sum for the deviations of induced metrics of space-time sheets from flat metric and sum of induce gauge potentials. These would define the fields in standard model + GRT. At fundamental level effects rather than fields would superpose. This is absolutely essential for the possibility of reducing huge number field like degrees of freedom. One can obviously speak of emergence of various fields.

   A further simplification is that only preferred extremals for which data coding for them are reduced by SH to 2-D string like world sheets and partonic 2-surfaces are allowed. TGD is almost like string model but space-time surfaces are necessary for understanding the fact that experiments must be analyzed using classical 4-D physics. Things are extremely simple at the level of single space-time sheet.

   Complexity emerges from many-sheetedness. From these simple basic building bricks - minimal surface extremals of Kähler action (not the extremal property with respect to Kähler action and volume term strongly suggested by the number theoretical vision plus analogs of Super Virasoro conditions in initial data) - one can engineer space-time surfaces with arbitrarily complex topology - in all length scales. An extension of existing space-time concept emerges. Extremely simple locally, extremely complex globally with topological information added to the Maxwellian notion of fields (topological field quantization allowing to talk about field identify of system/field body/magnetic body.

Another new element is the possibility of space-time regions with Euclidian signature of the induced metric. These regions correspond to 4-D "lines" of general scattering diagrams. Scattering diagrams has interpretation in terms of space-time geometry and topology.

2. The construction of quantum TGD using canonical quantization or path integral formalism failed completely for Kähler action by its huge vacuum degeneracy. The presence of volume term still suffers from complete failure of perturbation theory and extreme non-linearity. This led to the notion of world of classical worlds (WCW) - roughly the space of 3-surfaces. Essentially pairs of 3-surfaces at the boundaries of given CD connected by preferred extremals of action realizing SH and SGCI.

   The key principle is geometrization of the entire quantum theory, not only of classical fields geometrized by space-time as surface vision. This requires geometrization of hermitian conjugation and representation of imaginary unit geometrically. Kähler geometry for WCW [K6, K4, K20] makes this possible and is fixed once Kähler function defining Kähler metric is known. Kähler action for a preferred extremal of Kähler action defining space-time surface as an analog of Bohr orbit was the first guess but twistor lift forced to add volume term having interpretation in terms of cosmological constant.

   Already the geometrization of loop spaces demonstrated that the geometry - if it exists - must have maximal symmetries (isometries). There are excellent reasons to expect that this is true also in $D = 3$. Physics would be unique from its mathematical existence!

3. WCW has also spinor structure [K14, K20]. WCW spinors correspond to fermionic Fock states using oscillator operators assignable to the induced spinor fields - free spinor fiels. WCW gamma matrices are linear combinations of these oscillator operators and Fermi statistics reduces to spinor geometry.

4. There is **no quantization** in TGD framework at the level of WCW [K3, K24]. The construction of quantum states and S-matrix reduces to group theory by the huge symmetries of WCW. Therefore zero energy states of Universe (or CD) correspond formally to **classical** WCW spinor fields satisfying WCW Dirac equation analogous to Super Virasoro conditions and defining representations for the Yangian generalization of the isometries of WCW (so called super-symplectic group assignable to $\delta M^4_+ \times CP_2$. In ZEO stated are analogous to pairs of initial and final states and the entanglement coefficients between positive and negative energy parts of zero energy states expected to be fixed by Yangian symmetry define scattering matrix and have purely group theoretic interpretation. If this is true, entire dynamics would reduce to group theory in ZEO.

3.3 What is the hypothetical applicability of the extension - in energies, sizes, masses etc?

TGD is a unified theory and is meant to apply in all scales. Usually the unifications rely on reductionistic philosophy and try to reduce physics to Planck scale. Also super string models tried this and failed: what happens at long length scales was completely unpredictable (landscape catastrophe).

Many-sheeted space-time however forces to adopt fractal view. Universe would be analogous to Mandelbrot fractal down to CP_2 scale. This predicts scaled variants of say hadron physics and electroweak physics. p-Adic length scale hypothesis and hierarchy of phases of matter with $h_{eff}/h = n$ interpreted as dark matter gives a quantitative realization of this view.

1. p-Adic physics shows itself also at the level of real physics [K16]. One ends up to the vision that particle mass squared has thermal origin: the p-adic variant of particle mass square is given as thermal mass squared given by p-adic thermodynamics mappable to real mass squared by what I call canonical identification. p-Adic length scale hypothesis states that preferred p-adic primes characterizing elementary particles correspond to primes near to power of 2: $p \simeq 2^k$. p-Adic length scale is proportional to $p^{1/2}$.

   This hypothesis is testable and it turns out that one can predict particle mass rather accurately. This is highly non-trivial since the sensitivity to the integer k is exponential. So called Mersenne primes turn out to be especially favoured. This part of theory was originally inspired by the regularities of particle mass spectrum. I have developed arguments for why the crucial p-adic length scale hypothesis - actually its generalization - should hold true. A possible interpretation is that particles provide cognitive representations of themselves by p-adic thermodynamics.

2. p-Adic length scale hypothesis leads also to consider the idea that particles could appear as different p-adically scaled up variants. For instance, ordinary hadrons to which one can assign Mersenne prime $M_{107} = 2^{107} - 1$ could have fractally scaled variants. M_{89} and $M_{G,107}$ (Gaussian prime) would be two examples and there are indications at LHC for these scaled up variants of hadron physics [K8, K9]. These fractal copies of hadron physics and also of electroweak physics would correspond to extension of standard model.

3. Dark matter hierarchy predicts zoomed up copies of various particles. The simplest assumption is that masses are not changed in the zooming up. One can however consider that binding energy scale scales non-trivially. The dark phases would emerge are quantum criticality and give rise to the associated long range correlations (quantum lengths are typically scaled up by $h_{eff}/h = n$).

3.4 What is the leading correction/contribution to physical effects due to TGD onto particles, interactions, gravitation, cosmology?

1. Concerning particles I already mentioned the key predictions.

   (a) The existence of scaled variants of various particles and entire branches of physics. The fundamental quantum numbers are just standard model quantum numbers code by CP_2 geometry.

   (b) Particle families have topological description meaning that space-time topology would be an essential element of particle physics [K2]. The genus of partonic 2-surfaces (number of handles attached to sphere) is $g = 0, 1, 2, ...$ and would give rise to family replication. $g < 2$ partonic 2-surfaces have always global conformal symmetry Z_2 and this suggests that they give rise to elementary particles identifiable as bound states of g handles. For $g > 2$ this symmetry is absent in the generic case which suggests that they can be regarded as many-handle states with mass continuum rather than elementary particles. 2-D anyonic systems could represent an example of this.

   (c) A hierarchy of dynamical symmetries as remnants of super-symplectic symmetry however suggests itself [K3, K20]. The super-symplectic algebra possess infinite hierarchy of isomorphic sub-algebras with conformal weights being n-multiples of for those for the full algebra (fractal structure again possess also by ordinary conformal algebras). The hypothesis is that sub-algebra specified by n and its commutator with full algebra annihilate physical states and that corresponding classical Noether charges vanish. This would imply that super-symplectic algebra reduces to finite-D Kac-Moody algebra acting as dynamical symmetries. The connection with ADE hierarchy of Kac-Moody algebras suggests itself. This would predict new physics. Condensed matter physics comes in mind.

   (d) Number theoretic vision suggests that Galois groups for the algebraic extensions of rationals act as dynamical symmetry groups. They would act on algebraic discretizations of 3-surfaces and space-time surfaces necessary to realize number theoretical universality. This would be completely new physics.

2. Interactions would be mediated at QFT limit by standard model gauge fields and gravitons. QFT limit however loses all information about many-sheetedness and there would be anomalies reflecting this information loss. In many-sheeted space-time light can propagate along several paths and the time taken to travel along light-like geodesic from A to B depends on space-time sheet since the sheet is curved and warped. Neutrinos and gamma rays from SN1987A arriving at different times would represent a possible example of this. It is quite possible that the outer boundaries of even macroscopic objects correspond to boundaries between Euclidian and Minkowskian regions at the space-time sheet of the object.

The failure of QFTs to describe bound states of say hydrogen atom could be second example: many-sheetedness and identification of bound states as single connected surface formed by proton and electron would be essential and taken into account in wave mechanical description but not in QFT description.

3. Concerning gravitation the basic outcome is that by number theoretical vision all preferred extremals are extremals of both Kähler action and volume term. This is true for all known extremals what happens if one introduces the analog of Kähler form in M^4 is an open question) [K23].

   Minimal surfaces carrying no Kähler field would be the basic model for gravitating system. Minimal surface equation are non-linear generalization of d'Alembert equation with gravitational self-coupling to induce gravitational metric. In static case one has analog for the Laplace equation of Newtonian gravity. One obtains analog of gravitational radiation as "massless extremals" and also the analog of spherically symmetric stationary metric.

   Blackholes would be modified. Besides Schwartschild horizon which would differ from its GRT version there would be horizon where signature changes. This would give rise to a layer structure at the surface of blackhole [K23].

4. Concerning cosmology the hypothesis has been that RW cosmologies at QFT limit can be modelled as vacuum extremals of Kä hler action. This is admittedly ad hoc assumption inspired by the idea that one has infinitely long p-adic length scale so that cosmological constant behaving like $1/p$ as function of p-adic length scale assignable with volume term in action vanishes and leaves only Kähler action [K19]. This would predict that cosmology with critical is specified by a single parameter - its duration as also over-critical cosmology [K12]. Only sub-critical cosmologies have infinite duration.

   One can look at the situation also at the fundamental level. The addition of volume term implies that the only RW cosmology realizable as minimal surface is future light-cone of M^4. Empty cosmology which predicts non-trivial slightly too small redshift just due to the fact that linear Minkowski time is replaced with light-cone proper time constant for the hyperboloids of M^4_+. Locally these space-time surfaces are however deformed by the addition of topologically condensed 3-surfaces representing matter. This gives rise to additional gravitational redshift and the net cosmological redshift. This also explains why astrophysical objects do not participate in cosmic expansion but only comove. They would have finite size and almost Minkowski metric.

   The gravitational redshift would be basically a kinematical effect. The energy and momentum of photons arriving from source would be conserved but the tangent space of observer would be Lorentz-boosted with respect to source and this would course redshift.

   The very early cosmology could be seen as gas of arbitrarily long cosmic strings in H (or M^4) with 2-D M^4 projection [K12, K25]. Horizon would be infinite and TGD suggests strongly that large values of h_{eff}/h makes possible long range quantum correlations. The phase transition leading to generation of space-time sheets with 4-D M^4 projection would generate many-sheeted space-time giving rise to GRT space-time at QFT limit. This phase transition would be the counterpart of the inflationary period and radiation would be generated in the decay of cosmic string energy to particles.

REFERENCES

Mathematics

[A1] Yangian symmetry. Available at: http://en.wikipedia.org/wiki/Yangian.

Theoretical Physics

[B1] Witten E Dolan L, Nappi CR. Yangian Symmetry in $D = 4$ superconformal Yang-Mills theory. Available at: http://arxiv.org/abs/hep-th/0401243, 2004.

[B2] Plefka J Drummond J, Henn J. Yangian symmetry of scattering amplitudes in $\mathcal{N} = 4$ super Yang-Mills theory. Available at: http://cdsweb.cern.ch/record/1162372/files/jhep052009046.pdf, 2009.

[B3] Arkani-Hamed N et al. The All-Loop Integrand For Scattering Amplitudes in Planar N=4 SYM. Available at: https://arxiv.org/abs/1008.2958, 2010.

Books related to TGD

[K1] Pitkänen M. Basic Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#class, 2006.

[K2] Pitkänen M. Construction of elementary particle vacuum functionals. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#elvafu, 2006.

[K3] Pitkänen M. Construction of Quantum Theory: Symmetries. In *Towards M-Matrix*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#quthe, 2006.

[K4] Pitkänen M. Construction of WCW Kähler Geometry from Symmetry Principles. In *Quantum Physics as Infinite-Dimensional Geometry*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#compl1, 2006.

[K5] Pitkänen M. Expanding Earth Model and Pre-Cambrian Evolution of Continents, Climate, and Life. In *Genes and Memes*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#expearth, 2006.

[K6] Pitkänen M. Identification of the WCW Kähler Function. In *Quantum Physics as Infinite-Dimensional Geometry*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#kahler, 2006.

[K7] Pitkänen M. Massless states and particle massivation. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#mless, 2006.

[K8] Pitkänen M. New Particle Physics Predicted by TGD: Part I. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#mass4, 2006.

[K9] Pitkänen M. New Particle Physics Predicted by TGD: Part II. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#mass5, 2006.

[K10] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#qastro, 2006.

[K11] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#astro, 2006.

[K12] Pitkänen M. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#cosmo, 2006.

[K13] Pitkänen M. The Relationship Between TGD and GRT. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#tgdgrt, 2006.

[K14] Pitkänen M. WCW Spinor Structure. In *Quantum Physics as Infinite-Dimensional Geometry*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#cspin, 2006.

[K15] Pitkänen M. SUSY in TGD Universe. In *p-Adic Physics*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#susychap, 2012.

[K16] Pitkänen M. *p-Adic length Scale Hypothesis*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html, 2013.

[K17] Pitkänen M. Why TGD and What TGD is? In *Topological Geometrodynamics: an Overview*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#WhyTGD, 2013.

[K18] Pitkänen M. Criticality and dark matter. In *Hyper-finite Factors and Dark Matter Hierarchy*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#qcritdark, 2014.

[K19] Pitkänen M. Quantum gravity, dark matter, and prebiotic evolution. In *Genes and Memes*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#hgrprebio, 2014.

[K20] Pitkänen M. Recent View about Kähler Geometry and Spin Structure of WCW . In *Quantum Physics as Infinite-Dimensional Geometry*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#wcwnew, 2014.

[K21] Pitkänen M. Unified Number Theoretical Vision. In *TGD as a Generalized Number Theory*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#numbervision, 2014.

[K22] Pitkänen M. About Preferred Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#prext, 2015.

[K23] Pitkänen M. About twistor lift of TGD? In *Towards M-Matrix*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#hgrtwistor, 2016.

[K24] Pitkänen M. From Principles to Diagrams. In *Towards M-Matrix*. Online book.Available at: http://www.tgdtheory.fi/tgdhtml.html#diagrams, 2016.

[K25] Pitkänen M. More about TGD Inspired Cosmology. In *Physics in Many-Sheeted Space-Time*. Online book. Available at: http://www.tgdtheory.fi/tgdhtml.html#cosmomore, 2016.

[K26] Pitkänen M. The anomalies in rotating magnetic systems as a key to the understanding of morphogenesis? In *TGD based view about living matter and remote mental interactions: Part I*. Available at: http://www.tgdtheory.fi/tgdhtml.html#godin, 2016.

Articles about TGD

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

[L2] Pitkänen M. About minimal surface extremals of Kähler action. Available at: http://tgdtheory.fi/public_html/articles/minimalkahler.pdf, 2016.

[L3] Pitkänen M. Can one apply Occams razor as a general purpose debunking argument to TGD? Available at: http://tgdtheory.fi/public_html/articles/simplicity.pdf, 2016.

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