Article

On the Relationships Between Weak, Strong Interactions & Quantum Gravity in the TGD Universe

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Abstract

In this article a scenario about the detailed relationship of strong and weak interactions is discussed. In this picture classical electroweak interactions are basically local and only these appear in the TGD analogs of fundamental interactions vertices describing splitting and reconnection of monopole flux tubes. Also strong interactions can be assigned to these topological interactions. The basic problem is to understand how strong interaction can be parity conserving while the classical electroweak dynamics violates parity conservation. The proposed model, argued to overcome this problem, involves several topological elements:

1. The topological explanation of the family replication phenomenon in terms of the genus of partonic 2-surface carrying fermion lines as boundaries of string world sheets.
2. The view of holography as a 4-D analog of holomorphy reducing to 2-D holomorphy for partonic 2-surfaces. This predicts two kinds of partonic 2-surfaces as complex 2-surfaces in CP_2 with a spherical topology. Tor the homologically non-trivial geodesic sphere induced weak fields vanish (no parity violation classically) and for the second complex sphere they do not. A natural working hypothesis is that these two spheres explain the difference between strong and weak interactions.
3. The homology (Kähler magnetic) charge h of the partonic 2-surface correlates with the genus of the partonic 2-surface. For complex partonic 2-surfaces in CP_2, the genus is given $g = (h-1)(h-2)/2-s$, where s is the number of singularities. Only the genera $g=(h-1)(h-2)/2$ are free of singularities. For $g=0$, this includes $h=1$ and $h=2$. Already for $g=2$ there would be singularity. It is however possible to overcome this problem since partonic 2-surfaces can be deformed to M^4 degrees of freedom and one can add handles in this way. A rather detailed picture of partonic 2-surfaces and monopole flux tubes emerges.

1 Introduction

The observations and considerations of the article about what I called Platonization [9] inspired questions about the precise relationship between strong and weak interactions. In the same article I already proposed answers to these questions but since this topic is so important for TGD, I thought that these questions deserve a separate article.

1.1 Basic views of physics in TGD framework

TGD provides two basic perspectives of physics: geometric and number theoretic. It is somewhat a matter of taste whether one should divide geometric view to differential geometric and topological views or whether one should regard topological view as a third perspective.

1. At the level of $H = M^4 \times CP_2$, the color group SU(3) acting as isometries of CP_2 would correspond to the color interactions. The holonomy group $U2)$ of CP_2 embeddable as a subgroup to $SU3)$ would correspond to electroweak interactions as the fact that one has hypercharge and isospin in both sectors. This implies deep correlations between color and electroweak interactions not predicted by QCD.

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2. The differential geometric view involves the notion of induced metric and spinor connection and leads to geometration of the local aspects of the standard model physics. Topological aspects involve non-trivial topology of space-time surfaces in all scales. Kähler magnetic fluxes, monopole flux tubes, the topological explanation of family replication phenomenon, and topological interactions as reconnections of flux tubes are examples of these non-local aspects and in [9] it was found that these aspects are important in all scales and even in atomic physics.

3. At the level of $M^8 = M^4 \times E^4$, $SU(3)$ corresponds to a subgroup of octonionic automorphisms and $U(2)$ could be identified as subgroup of isometries leaving invariant the number theoretic inner product in E^4. This inspired the proposal that strong isospin corresponds to $U(2)$ and hadron-parton duality corresponds to $M^8 - H$ duality basically.

1.2 The basic picture of strong interactions in the TGD framework

This general picture could explain various poorly understood aspects of strong interactions.

1. In the good old times, when strong interactions were not yet "understood" and it was also possible to think instead of merely computing, strange connections between strong and weak interactions were observed. The already mentioned conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC) were formulated and successful quantitative predictions emerged. Note however that only vector currents appear in strong interaction physics but combinations of both vector and axial currents appear in weak interaction physics.

   Vectorial strong isospin is equal to vectorial weak isospin for nucleons but heavier quarks did not fit the picture. (c,s) and (t,b) dublets were assigned quantum numbers such as strangeness and charm, and they are not quantum numbers of weak interactions.

   When perturbative QCD became the dominating science industry, low energy hadron physics was forgotten. Lattice QCD was thought to describe hadrons but the successes were rather meager. Lattice QCD has even mathematical problems such as the description of quarks and the strong CP problem which lead to postulate the existence of axions, which have not been found.

2. In TGD these connections can be understood elegantly.

   (a) The topological description of family replication phenomenon implies that strangeness and charm are not fundamental quantum numbers and the identification of weak and strong isospins makes sense.

   (b) The flux tubes correspond to possibly p-adically scaled mesons and weak bosons in a predicted by the TGD based explanation of family replication phenomenon. Tensegrity is the basic construction principle for hadrons and nuclei and even atoms, for which color octet excitations of leptons define the counterparts of mesons.

   Flux tube ends are bound to quarks or nucleons or electrons by color confinement both in the case of hadrons and lepto-hadrons.

Also the fractality inspired ideas related to p-adically scaled up variants of strong and weak interactions organize to a beautiful picture.

1. p-Adic fractality inspired the idea that both strong and interaction physics appear as p-adically scaled variants. In particular, M_{89} hadron physics would be a p-adically scaled up version of the ordinary hadron physics assignable with M_{107} and would correspond to the same p-adic length scale as weak bosons. Various forgotten anomalies support this proposal [2, 3].

2. Both weak bosons and mesons would be described as string-like entities and stringy dynamics involving reconnections and splitting allows a unified geometrodynamics description of both weak and color interactions. TGD explanation of the family replication phenomenon predicts the analog of family replication phenomenon for weak bosons basically similar to that for mesons and there is evidence for this [2, 3] [10]. From the known spectrum of mesons of ordinary mesons one can predict masses of both M_{89} mesons by using p-adic length scale hypothesis. There is already evidence for the dark counterparts of M_{89} mesons with scaled up Compton length equal to that for M_{107} mesons. Also M_{89} baryons are predicted. Both p-adic and h_{eff} hierarchies of length scales are required in the proposed vision.

The failure of the perturbation series to converge is the basic problem of QCD. How could TGD solve this problem?

1. In the non-perturbative hadronic phase color confinement implies that color interactions are absent and only the topological interactions realized as reconnections of the monopole flux tubes are present.

   What happens in hadronic collisions? The basic idea is simple: when the perturbation theory fails, Nature comes in rescue, and a phase transition increasing the value of h to h_{eff} takes place if needed and scales down the color coupling strength by factor h/h_{eff} [10]. The kinetic energy liberated in a particle collision involving hadrons would make this phase transition possible. h increases when needed.

2. The perturbative color dynamics would be realized at the magnetic body of the system carrying dark variants of quarks and gluons. The collision would correspond to quantum criticality and the increases of h_{eff} would increase the lengths of monopole flux tubes making possible their splittings generating gluons and hadrons. Hadronization would lead to the reduction $h_{eff} \rightarrow h$ and contraction of flux tubes in the reverse phase transition.

What can one say about the relationship between weak interactions and color interactions? Are they different and closely correlated aspects of topological geometrodynamics; are they perhaps dual; or does the description of say weak interactions imply automatically that of color interactions as the fact that only weak gauge potentials couple to fermions suggests?

1. Duality would predict that weak bosons and their predicted exotic counterparts implied by the family replication phenomenon are nothing but the mesons of M_{89} hadron physics, or rather M^{89} physics since strong and weak interactions are in TGD framework aspects of the same purely geometric dynamics.

   This prediction looks unrealistic in light of the parity violation in weak interactions. Furthermore, the classical counterpart $H^A J_{\alpha\beta}$ of color gauge field vanishes for Lagrangian submanifolds of CP_2 whereas weak fields are non-vanishing.

   The classical weak fields could however determine classical color gauge fields and one might consider the possibility that at least at the level of a single space-time surface where color degrees of freedom are not visible (note also color confinement), only electroweak interactions are needed to allow a complete description.

In the sequel a scenario about the detailed relationship of strong and weak interactions is discussed. In this picture classical electroweak interactions are basically local and only these appear in the TGD analogs of fundamental interaction vertices describing splitting and reconnection of monopole flux tubes. Also strong interactions can be assigned to these topological interactions. The basic problem is to understand how strong interaction can be parity conserving while the classical electroweak dynamics violates parity conservation. The proposed model, argued to overcome this problem, involves several topological elements.

1. The topological explanation of the family replication phenomenon in terms of the genus of partonic 2-surface carrying fermion lines as boundaries of string world sheets.

2. The view of holography as a 4-D analog of holomorphy reducing to 2-D holomorphy for partonic 2-surfaces. This predicts two kinds of partonic 2-surfaces as complex 2-surfaces in CP_2 with a spherical topology. Tor the homologically non-trivial geodesic sphere induced weak fields vanish (no parity violation classically) and for the second complex sphere they do not. A natural working hypothesis is that these two spheres explain the difference between strong and weak interactions.

3. The homology (Kähler magnetic) charge h of the partonic 2-surface correlates with the genus of the partonic 2-surface. For complex partonic 2-surfaces in CP_2, the genus is given $g = (h-1)(h-2)/2-s$, where s is the number of singularities. Only the genera $g = (h-1)(h-2)/2$ are free of singularities. For $g = 0$, this includes $h = 1$ and $h = 2$. Already for $g = 2$ there would be singularity. It is however possible to overcome this problem since partonic 2-surfaces can be deformed to M^4 degrees of freedom and one can add handles in this way. A rather detailed picture of partonic 2-surfaces and monopole flux tubes emerges.

2 How do strong and weak interactions relate to each other in the TGD Universe?

In the following the question of how strong interactions emerge at the level of scattering amplitudes. The problem is that, although there is a natural candidate for gluons as induced gauge fields, only electroweak gauge potentials couple to embedding space spinor fields and induced spinor fields.

2.1 How could strong interactions emerge at the level of scattering amplitudes?

The above considerations are dangerous in that the intuitive QFT based thinking based is applied in TGD context where all interactions reduced to the dynamics of 3-surfaces and fields are geometrized by reducing them to the induced geometry at the level of space-time surface. Quantum field theory limit is obtained as an approximation and the applications of its notions at the fundamental level might be dangerous. In any case, it seems that only electroweak gauge potentials appear in the fermionic vertices and this might be a problem.

1. By holography perturbation series is not needed in TGD. Scattering amplitudes are sums of amplitudes associated with Bohr orbits, which are not completely deterministic: there is no path integral. Whether path integral could be an approximate approximation for this sum under some conditions is an interesting question.

2. It is best to start from a concrete problem. Is pair creation possible in TGD? The problem is that fermion and antifermion numbers are separately conserved for the most obvious proposals for scattering amplitudes. This essentially due to the fact that gauge bosons correspond to fermion-antifermion pairs. Intuitively, fermion pair creation means that fermion turns backwards in time. If one considers fermions in classical background fields this turning back corresponds to a 2-particle vertex. Could pair creation in classical fields be a fundamental process rather than a mere approximation in the TGD framework. This would conform with the vision that classical physics is an exact part of quantum physics.

   The turning back in time means a sharp corner of the fermion line, which is light-like elsewhere. M^4 time coordinate has a discontinuous derivative with respect to the internal time coordinate of the line. In [7, 11] a proposal was made that this kind of singularities are associated with vertices involving pair creation and that they correspond to local defects making the differentiable structure of X^4 exotic. The basic problem of GRT would become a victory in the TGD framework and also mean that pair creation is possible only in 4-D space-time.

One can imagine two kinds of turning backs in time.

1. The turning back in time could occur for a 3-D surface such as monopole flux tube and induce the same process the string world sheets associated with the flux tubes and for the ends of the string world sheets as fermion lines ending at the 3-D light-like orbits of partonic 2-surfaces.

2. In the fusion of two 2-sheeted monopole flux tubes along their "ends" identifiable as partonic 2-surfaces wormhole contacts, the ends would fuse instantaneously (this process is analogous to "join along boundaries"). The time reversal of this process would correspond to the splitting of the monopole flux tube inducing a turning back in time for a partonic 2-surface and for fermionic lines as boundaries of string world sheets at the partonic 2-surface.

   This would be analogous to a creation of a fermion pair in a classical induced gauge field, which is electroweak. The same would occur for the partonic 2-surfaces as opposite wormhole throats and for the string world sheets having light-like boundaries at the orbits of partonic 2-suraces.

3. The light-like orbit of a partonic 2-surface contains fermionic lines as light-like boundaries of string world sheets. A good guess is that the singularity is a cusp catastrophe so that the surface turns back in time in exactly the opposite direction. One would have an infinitely sharp knife edge.

What one can say about the scattering amplitudes on the basis of this picture? Can one obtain the analog for the 2-vertex describing a creation of a fermion pair in a classical external field?

1. The action for a geometric object of a given dimension defines modified gamma matrices in terms of canonical momentum currents as $\Gamma^\alpha = T^{\alpha k}\Gamma_k$, $T^\alpha_k = \partial L/partial(\partial_\alpha h^k)$. By hermiticity the covariant divergence $D_\alpha \Gamma^\alpha$ of the vector defined by modified gamma matrices must vanish. This is true if the field equations are satisfied. This implies supersymmetry between fermionic and bosonic degrees of freedom.

   For space-time surfaces, the action is Kähler action plus volume term. For the 3-D light-partonic orbits one has Chern-Simons-Kähler action. For string world sheets one has area action plus the analog of Kähler magnetic flux. For the light-boundaries of string world sheets defining fermion lines one has the integral $\int A_\mu dx^\mu$. The induced spinors are restrictions of the second quantized spinors fields of $H = M^4 \times CP_2$ and the argument is that the modified Dirac equation holds true everywhere, except possibly at the turning points.

2. Consider now the interaction part of the action defining the fermionic vertices. The basic problem is that the entire modified Dirac action density is present and vanishes if the modified Dirac equation holds true everywhere. In perturbative QFT, one separates the interaction term from the action and obtains essentially $\overline{\Psi}\Gamma^\alpha D_\alpha \Psi$. This is not possible now.

   The key observation is that the modified Dirac equation could fail at the turning points! QFT vertices would have purely geometric interpretation. The gamma matrices appearing in the modified Dirac action would be continuous but at the singularity the derivative $\partial_\mu \Psi = \partial_\mu m^k \partial_k \Psi$ of the induced free second quantized spinor field of H would become discontinuous. For a Fourier mode with momentum p^k, one obtains

   $$\partial_\mu \Psi_p = p_k \partial \mu m^k \Psi_p \equiv p_\mu \Psi_p \ \ .$$

   This derivative changes sign in the blade singularity. At the singularity one can define this derivative as an average and this leaves from the action $\overline{\Psi}\Gamma^\alpha D_\alpha \Psi$ only the term $\overline{\Psi}\Gamma^\alpha A_\alpha \Psi$. This is just the interaction part of the action!

3. This argument can be applied to singularities of various dimensions. For $D = 3$, the action contains the modified gamma matrices for the Kähler action plus volume term. For $D = 2$, Chern-Simons-Kähler action defines the modified gamma matrices. For string world sheets the action could be induced from area action plus Kähler magnetic flux. For fermion lines from the 1-D action for fermion in induced gauge potential so that standard QFT result would be obtained in this case.

How does this picture relate to perturbative QFT?

1. The first thing to notice is that in the TGD framework gauge couplings do not appear at all in the interaction vertices. The induced gauge potentials do not correspond to A but to gA. The couplings emerge only at the level of scattering amplitudes when one goes to the QFT limit. Only the Kähler coupling strength and cosmological constant appear in the action.

2. The basic implication is that only the electroweak gauge potentials appear in the vertices. This conforms with the dangerous looking intuition that also strong interactions can be described in terms of electroweak vertices but this is of course a potential killer prediction. One should be able to show that the presence of WCW degrees of freedom taken into account minimally in terms of fermionic color partial waves in CP_2 predicts strong interactions and predicts the value of α_s. Note that the restriction of spinor harmonics of CP_2 to a homologically non-trivial geodesic sphere gives $U(2)$ partial waves with the same quantum numbers as $SU(3)$ color partial waves have.

3. TGD approach differs dramatically from the perturbative QFT. Since $1/\alpha_s$ appears in the vertex, the increase of h_{eff} in the vertex increases it: just the opposite occurs in the perturbative QFT! This seems to be in conflict with QFT intuition suggesting a perturbation series in $\alpha_s \propto 1/\hbar_{eff}$. The explanation is that $1/\alpha_K$ appears as a coupling parameter instead of α_s.

   This reminds of the electric-magnetic duality between perturbative and non-perturbative phases of gauge theories, where magnetic coupling strength is proportional to the inverse of the electric coupling strength. The description in terms of monopole flux tubes is therefore analogous to the description in terms of magnetic monopoles in the QFT framework. In TGD, it is the only natural description at the fundamental level. The decrease of α_K by increase of h_{eff} would indeed correspond to the QFT type description reduction of α_s.

   Could the description based on Maxwellian non-monopole flux tubes correspond to the usual perturbative phase without magnetic monopoles? In the Maxwellian phase there is huge vacuum degeneracy due to the presence of vacuum extremals with a vanishing Kähler form at the limit of vanishing volume action. Could this degeneracy allow path integral as a practical approximation at QFT limit.

4. $h_{eff}/h_0 = n$ is proposed to correspond to the dimension of algebraic extension of rationals associated with the space-time surface and serve as a measure for algebraic complexity. The increase of algebraic complexity of the space-time region defining the strong interaction volume would also make interactions strong. In TGD, the fundamental coupling strength would be α_K and the increase of α_K for ordinary value of h would force the increase of h. This should happen below the electroweak scale or at least the confinement scales and make perturbation theory describing strong interactions possible. This description would involve monopole flux tubes and their reconnections.

5. The basic objection against the proposal is that weak interactions violate parity conservation, which is very small for hadrons. The increase of the length scale below which weak bosons are effectively massless strengthens this effect. The way out of the problem should be based on the dominance of the Kähler part of electroweak fields in the electroweak vertices describing the splitting of flux tubes modelling the emission of gluons. Flux tubes obtained as M^4 deformations of cosmic strings carry vanishing weak fields apart from Z^0 field containing Kähler part so that the parity breaking effects might be small. Kähler form to which also classical color gauge fields are proportional, is

invariant under color rotations whereas color rotations induce non-trivial holonomies for the weak gauge fields. Also this could play a crucial role in minimizing parity breaking effects by making weak contributions to the gluon emission vertex very small. Same is true also for emission of mesons. For Maxwellian flux tubes the situation would be different. The stringy description of quarks, gluons, and hadrons as monopole flux tubes would distinguish between strong and electroweak interactions.

2.2 About the difference between electroweak and strong interactions assuming generalized holomorphy

It is interesting to see what the holography as generalization to 4-D holomorphy hypothesis predicts when combined with the proposed explanation of the family replication phenomenon and the proposal for how parity violation is avoided in strong interactions despite the fact that only electroweak induced fields appear in the fundamental vertices for the creation of various particles identified as closed 2-sheeted monopole flux tubes. This includes mesons and gluons.

1. Monopole flux tubes can be regarded as M^4 deformations of cosmic strings representable as Cartesian products of string world sheet $X^2 \subset M^4$ and 2-surface $Y^2 \subset CP_2$. Partonic 2-surfaces would appear as "ends" of 2-sheeted monopole flux tubes. If the holomorphic realization of holography makes sense, the space-time surfaces are complex algebraic surfaces. In the simplest situation the 2-D cross section of a cosmic string is a complex surface of CP_2. A more general option is as a complex algebraic curve in $E^2 \times CP_2$.

2. Riemann-Roch theorem (see) allows to define geometric genus (see) of a complex algebraic curve in CP_2 as

$$g = (d-1)(d-2)/2 - s \ ,$$

   noindent where s is the number of singularities, which are cones and as a special case cusps (infinitely sharp cones). According to the Wikipedia article, this formula generalizes to algebraic surfaces in higher than 2-D complex manifolds, or at least projective space.

   From this one can conclude for the $(d-1)(d-2)/2 \geq g$ for partonic 2-surfaces as complex surfaces in CP_2 there are always singularities. For $s = 0$, $g = 0$ allows $d = 0$ and $d = 1$. For $s = 0$, $g = 1$ allows $d = 3$ related to elliptic functions. Already for $g = 2$ one has $s \geq 1$. The genera $g = (d-1)(d-2)/2$ are special in that they also allow $s = 0$.

3. It is known (see) that for $s = 0$ the topological genus, algebraic genus and arithmetic genus are identical. This might be relevant for the definition of genus for the p-adic counterparts of partonic 2-surfaces, where the topological genus does not make sense. This could make $g \in \{0, 1, (d-1)(d-2)2\}$ cognitively special. It would seem that p-adic variants of $g = 2$ partonic 2-surfaces do not make sense unless one can eliminate the singularities by a deformation of Y^2 to a complex 2-surface in $E^2 \times Y^2$. One should also be able to represent $g > 0$ surfaces as surfaces in $E^2 \times CP_2$, where CP_1 corresponds to either $d = 1$ of $d = 2$.

2.2.1 Generalized holomorphy, difference between strong and weak interactions, and family replication phenomenon

It is instructive to consider the CP_2 option and its generalization in more detail from the perspective of weak and strong interactions and family replication phenomenon.

1. $g = 0$ option is the most natural one for cosmic strings and allows polynomials of degree $d = 1$ and $d = 2$. $d = 1$ would correspond to the homologically non-trivial geodesic sphere of CP_2 and $d = 2$ a more complex surface. For the homologically non-trivial sphere only the Kähler form would

contribute to the vertex related to the splitting of the cosmic string. This could explain why the generation of hadronic and gluonic monopole strings does not lead to a parity violation.

For $d = 2$ and $g = 0$ induced electroweak fields are non-vanishing and parity violations are predicted. Could photons and gluons correspond to cosmic strings with cross section as $d = 1$ surface of CP_2? Could parity violating weak bosons relate to cosmic strings with a $d = 2$ spherical cross section so that the difference between strong and weak interactions would reduce to algebraic geometry?

2. The genus $g = 1$ could be also realized for cosmic strings with $d = 3$ to which elliptic functions. In this case, the induced weak fields would be present for the CP_2 option. This does not conform with the idea that parity breaking effects do not depend on the genus (generation of fermion).

   Could the deformations of partonic 2-surfaces in M^4 degrees of freedom come in rescue? For partons as complex 2-surfaces in $E^2 \times S^2 \subset E^2 \times CP_2$, S^2 homologically non-trivial geodesic sphere, no charged weak fields would be present. If this picture is correct the deformations in E^2 degrees of freedom would distinguish between fermion families but the difference should be subtle. I do not know whether the formula for algebraic surfaces in projective spaces still holds true.

3. Genus $g = 2$ partonic 2-surface in CP_2 would have at least one singular point. Is this physically acceptable? Is it possible to avoid the singularity for the $Y^2 \subset E^2 \times S^2 \subset E^2 \times CP_2$ option? Blowing up of the singularities by removing a small disk of S^2 around the singularity and gluing back a disk of $E^2 \times S^2$ is what comes to mind. Blowup, in particular a blowup at a given point of complex manifold, such as a cone singularity of complex surface, is described in the Wikipedia article (see).

   Topologically this means construction of a connected sum with the projective space CP_1 by removing a small disk around the singularity. The realization of this operation would now occur in $E^2 \times Y^2$. If the genus $g = d(d-1)/2 - r$ is preserved in the blowup so that one would obtain non-singular representatives also in $g = 2$ case. Obviously the formula for the genus would not hold anymore.

4. Since all quark genera $g \leq 2$ appear in strong interactions, which do not violate parity, one should have a way of constructing $g > 0$ surfaces from the homologically non-trivial sphere $CP_1 \subset CP_2$ with $n = 1$ complex surface in $E^2 \subset CP_1$. Addition of handles should be the way. These surfaces would be associated with quarks, gluons and mesons, which all would correspond to 2-sheeted monopole fluxe tubes.

   This operation should be possible also for the $d = 2$ complex sphere carrying induced weak gauge fields. The predicted higher families of weak bosons as analogs of mesons could be obtained from $d = 2$ monopole flux tubes. The existence of strong and weak interactions would reflect the existence of $d = 1$ and $d = 2$ complex spheres of CP_2. In particular, one obtains non-singular $g = 2$ fermions. Also leptons could correspond to $d = 2$ spheres.

2.2.2 About the relationship between Kähler magnetic charge and genus

What can one say about the homological (Kähler magnetic) charge of a partonic 2-surface with a given genus. At least homological charges ± 1 and ± 2 should be realized for the partonic 2-surfaces. For about 4 decades ago, my friend Lasse Holmström, who is a mathematician, gave me as a gift a Bulletin of American Mathematical Society [1] containing articles about 4-D topology and also about topology of CP_2. At page 124 there were interesting results related to the realization of homologically non-trivial 2-surfaces in CP_2, in particular there were conditions on the minimal genus of these surfaces.

The basic result was that a surface with homology charge h can be realized as a surface with genus $g = (h-1)(h-2)/2$ and there are no known realizations with a smaller genus. For $d = h$, this sequence would correspond to the sequence $g = (d-1)(d-2)/2$ for complex surfaces without singularities. This correlation between genus and homology charge troubled me since in the TGD framework $h \in \{\pm 1, \pm 2\}$ should be possible for all genera. The addition of handles to $d = 1, 2$ complex spheres of $CP_1 \subset CP_1 \subset E^2$ would solve the problem. An interesting question is whether the sequence $0, 1, 6, 10, 15, ...$ of homologically special genera could have a physical interpretation and perhaps predict a hierarchy of analogs of strong and weak interactions.

2.2.3 About the number of complex deformations of a given partonic 2-surface

It is interesting to ask about how many deformations a given partonic 2-surface represents as a complex surface in $E^2 \times CP_1$, where CP_1 corresponds to the surface of CP_2 with $d \in \{1,2\}$. For the deformations of CP_1 with $d = 1,2$, one can express E^2 complex coordinate as a meromorphic function of CP_1 complex coordinate. More generally, one can consider the partonic 2-surface in $E^2 \times S^2$ as a surface with given genus g and consider the complex deformations of this surface. The dimension of the space of these deformations is of obvious physical interest if generalized holomorphy is accepted.

In the case of a pole, the E^2 point would go to infinity so that poles are not allowed. If the notion of Hamilton-Jacobi structure [12] makes sense, one can slice M^4 also using closed partonic 2-surfaces with complex coordinates so that meromorphic functions with poles are allowed. In TGD, rational functions with rational coefficients of corresponding polynomials are favoured.

These functions can be characterized by so-called principal divisors expressible as formal superpositions $D = \sum \nu_k P_k$. Here P_k are the singular points (zeros for $\nu_k > 0$ and poles for $\nu_k < 0$). One can assign also to complex one-forms divisors: this kind of divisor is known as canonical divisor and is unique apart from addition of principal divisor, which corresponds to a multiplication of the 1-form with a meromorphic function. The degree of the divisor can be defined as $deg(D) = \sum \nu_k$.

Riemann-Roch theorem applies also to algebraic surfaces such as complex surfaces in $E^2 \times CP_1$, and allows to get grasp about the numbers of the surfaces obtained as deformations of CP_1 with a given divisor D for a surface with a given genus g. These numbers correspond to the dimensions of the linear spaces of rational functions, whose poles are not worse than the coefficients of D, where P_k are the singular points (zeros for $n_k > 0$ and poles for $n_k < 0$). The Riemann-Roch formula reads as

$$\ell(D) - \ell(K - D) = \deg(D) - g + 1.$$

Here $\ell(D)$ is the dimension of the space of meromorphic functions h for which all the coefficients of $(h)+D$ are non-negative (no poles). The term $-\ell(K-D)$ is a correction term present only for low degrees $deg(D)$ defining the analog of polynomial degree characterizing the winding number of h. Because $\ell(K - D)$ is a dimension of vector space, it cannot be negative and vanishes for large enough degrees. For large values of $deg(D)$ the formula reads therefore as $\ell(D) = \deg(D) - g + 1$.

3 Questions related to the generalized holomorphies and fundamental vertices according to TGD

We had very inspiring discussions with Marko Manninen at a birthday meal with wine. During the way home some questions and ideas emerged. Could the 4-D generalization of holomorphy realizing holography allow an explicit realization of an infinite hierarchy of conserved charges generalizing the Super Virasoro algebra? Could the only particle vertex in TGD correspond to a creation of fermion-antifermion pair: in this 2-vertex fermion state and fermionic line, partonic orbit, or Bohr orbit turns back in time? Can one identify the graviton emission vertex?

3.1 Questions related to the generalized holomorphies and symplectic transformations

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3.1.1 4-D generalization of the holomorphy allows conserved charges associated with the generalized holomorphies

Does the 4-D analogy of holomorphy as a realization of holography give rise to conserved quantities? Now the symmetries would not be isometries, nor some other symmetries of the action, but dynamic symmetries satisfied only by the Bohr orbits. A little calculation that one can do in your head shows that one obtains conserved currents: the reason is the same as in the case of field equations. The divergence of the Noether current is a contraction of tensors with no common index pairs for the generalization of complex coordinates.

Unlike those associated with the general coordinate invariance, these conserved quantities do not vanish. They correspond to the 4-D generalization of conformal transformations and give rise to a generalization of the Virasoro algebra and also of Super Virasoro algebra realized in terms of the modified Dirac action for the induced spinor fields obtained from the free second quantized spinor fields of H.

In the string model, these conformal charges are assumed to annihilate the physical states. In TGD, I have proposed that only a subalgebra that is isomorphic to the whole algebra, having conformal weights which are integer multiples of the entire algebra, does this. In TGD framework, the conformal weights are necessarily non-negative and ZEO allows this. One obtains a whole hierarchy of subalgebras and a sub-hierarchy of algebras for which conformal symmetry as gauge symmetry is "broken" to dynamical Lie symmetries for physical states having conformal weight below some maximum value. These hierarchies could correspond to the hierarchies of algebraic extensions for rationals defined by composite polynomials.

Generalized holomorphy algebra generalizes the Super-Virasoro algebra and the Super-Kac-Moody algebra related to the conformal invariance of the string model. The corresponding Noether charges are conserved. Modified Dirac action allows to construct the supercharges having interpretation as WCW gamma matrices. This suggests an answer to a longstanding question related to the isometries of the "world of the classical worlds" (WCW).

1. Either the generalized holomorphies or the symplectic symmetries of $H = M^4 \times CP_2$ or both together define WCW isometries and corresponding super algebra. One can ask whether the symplectic symmetries induced from H are necessarily needed and whether they might correspond to symplectic symmetries of WCW. One would obtain a close similarity with the string model, except that one has half-algebra for which conformal weights are proportional to non-negative integers and gauge conditions only apply to an isomorphic subalgebra. These are labeled by positive integers and one obtains a hierarchy.

2. By their light-likeness, the light cone boundary and orbits of partonic 2-surfaces allow an infinite-dimensional isometry group. This is possible only in dimension four. Its transformations are generalized conformal transformations of 2-sphere (partonic 2-surface) depending on light-like radial coordinate such that the radial scaling compensates for the usual conformal scaling of the metric. The WCW isometries would thus correspond to the isometries of the parton orbit and of the boundary of the light cone! These two representations could provide alternative representations for the charges if the strong form of holography holds true and would realize a strong form of holography. Perhaps these realizations deserve to be called inertial and gravitational charges.

   For the light-cone boundary, the conservation looks obvious if the light-cone is sliced by time translates of the light-cone boundary. A slicing defined by the Hamilton-Jacobi structure [12] would be naturally associated with the partonic orbits and possible light-like boundaries of space-time surface [8]. For the partonic slicing, time direction and also slices are light-like: a limiting case of ordinary slicing by Euclidian slices is in question. One can see the entire partonic orbit as analog of a 3-D Euclidian surface at which holographic data are given.

3. An absolutely essential point is that generalized holomorphisms are *not* symmetries of Kähler function since otherwise Kähler metric involving second derivatives of type (1,1) with respect to complex coordinates of WCW is non-trivial if defined by these symmetry generators as differential operators.

If Kähler function is equal to Kähler action, as it seems, Kähler action cannot be invariant under generalized holomorphies.

Noether's theorem states that the invariance of the action under a symmetry implies the conservation of corresponding charge but does *not* claim that the existence of conserved Noether currents implies invariance of the action. Since Noether currents are conserved now, one would have a concrete example about a situation in which the inverse of Noether's theorem does not hold true. In a string model based on area action, conformal transformations of complex string coordinates give rise to conserved Noether currents as one can easily check and the area element defined by the induced metric suffers a conformal scaling so that the action is not invariant in this case.

4. What makes this so interesting is that, due to the light-likeness of δM^4_+, the algebra of isometries of $\delta M^4_+ \times CP_2$ corresponds to the infinite-dimensional algebra of holomorphisms of S^2 localized with respect to the light-like radial coordinate δM^4_+! Radially localized holomorphisms would act as isometries of the light-cone boundary and induce isometries of WCW! Same is true at the light-like orbits of partonic 2-surfaces. Also the generalized Kac-Moody algebra could define infinitesimal isometries.

5. What about Poincare symmetries? They would act on the center of mass coordinates of causal diamonds (CDs) as found already earlier [13]. CDs form the "spine" of WCW, which can be regarded as fiber space with fiber for a given CD containing as a fiber the space-time surfaces inside it.

The super-symmetric counterparts of holomorphic charges for the modified Dirac action and bilinear in fermionic oscillator operators associated with the second quantization of free spinor fields in H, define gamma matrices of WCW. Their anticommutators define the Kähler metric of WCW. There is no need to calculate either the action defining the classical Kähler action defining the Kähler function or its derivatives with respect to WCW complex coordinates and their conjugates. What is important is that this makes it possible to speak about WCW metric also for number theoretical discretization of WCW with space-time surfaces replaced with their number theoretic discretizations.

3.1.2 Challenging the existing picture of WCW geometry

These findings make it possible to challenge and perhaps sharpen the existing speculations concerning the metric and isometries of WCW.

I have considered the possibility that also the symplectomorphisms of $\delta M^4 + \times CP_2$ could define WCW isometries. This actually the original proposal. One can imagine two options.

1. The continuation of symplectic transformations to transformations of the space-time surface from the boundary of light-cone or from the orbits partonic 2-surfaces should give rise to conserved Noether currents but it is not at all obvious whether this is the case.

2. One can assign conserved charges to the time evolution of the 3-D boundary data defining the holographic data: the time coordinate for the evolution would correspond to the light-like coordinate of light-cone boundary or partonic orbit. This option I have not considered hitherto. It turns out that this option works!

The conclusion would be that generalized holomorphies give rise to conserved charges for 4-D time evolution and symplectic transformations give rise to conserved charged for 3-D time evolution associated with the holographic data.

3.1.3 About extremals of Chern-Simons-Kähler action

Let us look first the general nature of the solutions to the extremization of Chern-Simons-Kähler action.

1. The light-likeness of the partonic orbits requires Chern-Simons action, which is equivalent to the topological action $J \wedge J$, which is total divergence and is a symplectic in variant. The field equations at the boundary cannot involve induced metric so that only induced symplectic structure remains. The 3-D holographic data at partonic orbits would extremize Cherns-Simons-Kähler action. Note that at the ends of the space-time surface about boundaries of CD one cannot pose any dynamics.

2. If the induced Kähler form has only the CP_2 part, the variation of Chern-Simons-Kähler form would give equations satisfied if the CP_2 projection is at most 2-dimensional and Chern-Simons action would vanish and imply that instanton number vanishes.

3. If the action is the sum of M^4 and CP_2 parts, the field equations in M^4 and CP_2 degrees of freedom would give the same result. If the induced Kähler form is identified as the sum of the M^4 and CP_2 parts, the equations also allow solutions for which the induced M^4 and CP_2 Kähler forms sum up to zero. This phase would involve a map identifying M^4 and CP_2 projections and force induce Kähler forms to be identical. This would force magnetic charge in M^4 and the question is whether the line connecting the tips of the CD makes non-trivial homology possible. The homology charges and the 2-D ends of the partonic orbit cancel each other so that partonic surfaces can have monopole charge.

   The conditions at the partonic orbits do not pose conditions on the interior and should allow generalized holomorphy. The following considerations show that besides homology charges as Kähler magnetic fluxes also Hamiltonian fluxes are conserved in Chern-Simons-Kähler dynamics.

3.1.4 Can one assign conserved charges with symplectic transformations or partonic orbits and 3-surfaces at light-cone boundary?

The geometric picture is that symplectic symmetries are Hamiltonian flows along the light-like partonic orbits generated by the projection A_t of the Kähler gauge potential in the direction of the light-like time coordinate. The physical picture is that the partonic 2-surface is a Kähler charged particle that couples to the Hamilton $H = A_t$. The Hamiltonians H_A are conserved in this time evolution and give rise to conserved Noether currents. The corresponding conserved charge is integral over the 2-surface defined by the area form defined by the induced Kähler form.

Let's examine the change of the Chern-Simons-Kähler action in a deformation that corresponds, for example, to the CP_2 symplectic transformation generated by Hamilton H_A. M^4 symplectic transformations can be treated in the same way:here however M^4 Kähler form would be involved, assumed to accompany Hamilton-Jacobi structure as a dynamically generated structure.

1. Instanton density for the induced Kähler form reduces to a total divergence and gives Chern-Simons-Kähler action, which is TGD analog of topological action. This action should change in infinitesimal symplectic transformations by a total divergence, which should vanish for extremals and give rise to a conserved current. The integral of the divergence gives a vanishing charge difference between the ends of the partonic orbit. If the symplectic transformations define symmetries, it should be possible to assign to each Hamiltonian H_A a conserved charge. The corresponding quantal charge would be associated with the modified Dirac action.

2. The conserved charge would be an integral over X^2. The surface element is not given by the metric but by the symplectic structure, so that it is preserved in symplectic transformations. The 2-surface of the time evolution should correspond to the Hamiltonian time transformation generated by the projection $A_\alpha = A_k \partial_\alpha s^k$ of the Kähler gauge potential A_k to the direction of light-like time coordinate $x^\alpha \equiv t$.

3. The effect of the generator $j_A^k = J^{kl}\partial_l H_A$ on the Kähler potential A_l is given by $j_A^k \partial_k A_l$. This can be written as $\partial_k A_l = J_{kl} + \partial_l A_k$. The first term gives the desired total divergence $\partial_\alpha(\epsilon^{\alpha\beta\gamma} J_{\beta\gamma} H_A)$.

   The second term is proportional to the term $\partial_\alpha H_A - \{A_\alpha, H\}$. Suppose that the induced Kähler form is transversal to the light-like time coordinate t, i.e. the induced Kähler form does not have components of form $J_{t\mu}$. In this kind of situation the only possible choice for α corresponds to the time coordinate t. In this situation one can perform the replacement $\partial_\alpha H_A - \{A_\alpha, H\} \rightarrow dH_A/dt - \{A_t, H\}$ This corresponds to a Hamiltonian time evolution generated by the projection A_t acting as a Hamiltonian. If this is really a Hamiltonian time evolution, one has $dH_A/dt - \{A, H\} = 0$. Because the Poisson bracket represents a commutator, the Hamiltonian time evolution equation is analogous to the vanishing of a covariant derivative of H_A along light-like curves: $dH_A/dt + [A, H_A] = 0$. The physical interpretation is that the partonic surface develops like a particle with a Kähler charge. As a consequence the change of the action reduces to a total divergence.

   An explicit expression for the conserved current $J_A^\alpha = H_A \epsilon^{\alpha\beta\gamma} J_{\beta\gamma}$ can be derived from the vanishing of the total divergence. Symplectic transformations on X^2 generate an infinite-dimensional symplectic algebra. The charge is given by the Hamiltonian flux $Q_A = \int H_A J_{\beta\gamma} dx^\alpha \wedge dx^\beta$.

4. If the projection of the partonic path CP_2 or M^4 is 2-D, then the light-like geodesic line corresponds to the path of the parton surface. If A_l can be chosen parallel to the surface, its projection in the direction of time disappears and one has $A_t = 0$. In the more general case, X^2 could, for example, rotate in CP_2. In this case A_t is nonvanishing. If J is transversal (no Kähler electric field), charge conservation is obtained.

Do the above observations apply at the boundary of the light-cone?

1. Now the 3-surface is space-like and Chern-Simons-Kähler action makes sense. It is not necessary but emerges from the "instanton density" for the Kähler form. The symplectic transformations of $\delta M_+^4 \times CP_2$ are the symmetries. The most time evolution associated with the radial light-like coordinate would be from the tip of the light-cone boundary to the boundary of CD. Conserved charges as homological invariants defining symplectic algebra would be associated with the 2-D slices of 3-surfaces. For closed 3-surfaces the total charges from the sheets of 3-space as covering of δM_+^4 must sum up to zero.

2. Interestingly, the original proposal for the isometries of WCW was that the Hamiltonian fluxes assignable to M^4 and CP_2 degrees of freedom at light-like boundary act define the charges associated with the WCW isometries as symplectic transformations so that a strong form of holography would have been be realized and space-time surface would have been effectively 2-dimensional. The recent view is that these symmetries pose conditions only on the 3-D holographic data. The holographic charges would correspond to additional isometries of WCW and would be well-defined for the 3-surfaces at the light-cone boundary.

To sum up, one can imagine many options but the following picture is perhaps the simplest one and is supported by mathematical facts. The isometry algebra of $\delta M_+^4 \times CP_2$ consists of generalized conformal and KM algebras at 3-surfaces in $\delta M_+^4 \times CP_2$ and symplectic algebras at the light cone boundary and 3-D light-like partonic orbits. The latter symmetries give constraints on the 3-D holographic data. It is still unclear whether one can assign generalized conformal and Kac-Moody charges to Chern-Simons-Kähler action. The isomorphic subalgebras labelled by a positive integer and their commutators with the entire algebra would annihilate the physical states. The isomorphic subalgebras labelled by a positive integer and their commutators with the entire algebra would annihilate the physical states. These two representations would generalize the notions of inertial and gravitational mass and their equivalence would generalize the Equivalence Principle.

3.1.5 The TGD counterparts of the gauge conditions of string models

The string model picture forces to ask whether the symplectic algebras and the generalized conformal and Kac-Moody algebras could act as gauge symmetries.

1. In string model picture conformal invariance would suggest that the generators of the generalized conformal and KM symmetries act as gauge transformations annihilate the physical states. In the TGD framework, this does not however make sense physically. This also suggests that the components of the metric defined by supergenerators of generalized conformal and Kac Moody transformations vanish. If so, the symplectomorphisms $\delta M^4_+ \times CP_2$ localized with respect to the light-like radial coordinate acting as isometries would be needed. The half-algebras of both symplectic and conformal generators are labelled by a non-negative integer defining an analog of conformal weight so there is a fractal hierarchy of isomorphic subalgebras in both cases.

2. TGD forces to ask whether only subalgebras of both conformal and Kac-Moody half algebras, isomorphic to the full algebras, act as gauge algebras. This applies also to the symplectic case. Here it is essential that only the half algebra with non-negative multiples of the fundamental conformal weights is allowed. For the subalgebra annihilating the states the conformal weights would be fixed integer multiples of those for the full algebra. The gauge property would be true for all algebras involved. The remaining symmetries would be genuine dynamical symmetries of the reduced WCW and this would reflect the number theoretically realized finite measurement resolution. The reduction of degrees of freedom would also be analogous to the basic property of hyperfinite factors assumed to play a key role in thee definition of finite measurement resolution.

3. For strong holography, the orbits of partonic 2-surfaces and boundaries of the spacetime surface at δM^4_+ would be dual in the information theoretic sense. Either would be enough to determine the space-time surface.

3.2 Are fermionic 2-vertices all that is needed in TGD?

In quantum field theories, already the interaction vertex for 3 particles leads to divergences. In a typical 3-vertex, fermion emits a boson or boson decays to a fermion-antifermion pair. In TGD, the situation changes.

1. Fermions are the only fundamental particles in TGD. Since fundamental bosons are missing, there is no vertex representing emission of a fundamental boson emission from fermion or a vertex producing fermion antifermion pair from a fundamental boson. In TGD, bosons as elementary particles (distinguished from fundamental bosons) are fermion-antifermion pairs, and the emission of elementary bosons is possible. However, the problem is that the total fermion and antifermion numbers are separately conserved. Unless it is possible to create fermion pairs from classical fields!

2. In the standard theory fermion-antifermion pairs can be indeed created in classical gauge fields. This creation is an experimental fact but it is thought that this description is only a convenient approximation. In TGD however, the classical fields associated with the Bohr orbits of 3-surfaces are an exact part of quantum theory. Could this description be accurate in TGD? In the classical induced fields associated with particles, pairs could arise. Approximation would become exact in TGD.

A 2-vertex for creation of fermion-antifermion pair (or corresponding boson) is needed. In this vertex, the fermion turns must turn backwards in time.

1. I managed to identify the fermionic 2-vertex was specified towards the end of this year as I realized the connection to the problem of general relativity, which arises from the existence of GRT spacetimes for which the 4-D diffeo structure is non-standard. There are a lot of these. For an exotic

diffeo structure, the standard diffeo structure can be said to have point-like defects analogous to lattice defects.

2. Remarkably, this problem is encountered only in the space-time dimension 4 [11]! Physical intuition suggests that it must be possible to turn this problem from a disaster to victory. In TGD, this is what actually happens: these point-like diffeo-defects can be identified as interaction vertices, the fermion turns back in the direction of time. Pair creation would be possible only in space-time dimension 4!

   A generalization of the classical fermion pair creation vertex has the same general form as in QFT. As a special case the pair can correspond to a boson as a fermion-antifermion bound state. This vertex also has geometric variants in different dimensions. A fermion line, string world sheet, the orbit of a partonic 2-surface and also the Bohr orbit of 3 surface can turn backwards in time and the fermion states associated with the induced spinor fields do the same.

This inspires two questions.

1. Is the creation of a pair actually the only vertex or is it possible to have a geometric 3-vertex and is it really needed? At the fermion level only the 2-vertex described above is not possible, but for the topological reactions of surfaces one could think of 3-vertices and in the earlier picture I thought these are needed. They do not seem to be necessary however.

   If so, the theory would be extremely simple compared to quantum field theories. There dangerous genuine 3-vertices would be absent and diffeo defects defining 2 vertices, which give all that is needed! At the geometric level, monopole fluxes would replicate and break and join. Intriguingly, this is what would happen at the magnetic bodies of DNA and induce similar reactions at the level of DNA molecules! Maybe biology has been doing its best to tell us what the fundamental particle dynamics is!

2. Since only the induced electroweak gauge potentials couple to fermions, the question arises whether color and strong interactions are obtained. How is it possible to have strong interactions without parity violation when basic vertices involve weak parity violation? I have already discussed this question.

3.3 Vertex for graviton emission

There is still one crucially important question left. Is it possible and what would happen in it? Can one obtain a vertex, where the analog for a contraction $T^{\alpha\beta}\delta g_{\alpha\beta}$ of energy-momentum tensor with the deviation of the metric from the Minkowski metric appears?

1. In TGD all elementary particles, also gravitons, are identified as closed 2-sheeted monopole flux tubes with two wormhole contacts at its ”ends” and opposite wormhole throats carrying fermions and antifermions [9]. For gravitation one has 1 fermion or antifermion for each wormhole throat.

   Splitting of a monopole flux tube would give rise to the basic topological vertex appearing in all particle vertices. This process would generalize the splitting of an open string to two pieces. The flux tubes at the opposite sheets of the monopole flux tube representing a particle would touch at a single point. This would lead to a homologically trivial wormhole contact, which would evolve to a contact carrying a pair of opposite fluxes. This structure would further develop to a pair of wormhole contacts touching at a single point. This structure would then split to a pair of homologically trivial wormhole contacts with opposite fluxes at the ends of a pair of resulting monopole flux tubes.

   The graviton emission vertex should correspond to a splitting of monopole flux tubes. Mopole flux tubes with fermion-antifermion pairs assignable to both wormhole contacts should appear. The fermion and antifermion should reside at the opposite throats of each wormhole contact. This should happen in the splitting of a monopole flux tube and second monopole flux tube would correspond to graviton. That two bosonic vertices are involved with the emission, brings to mind the proposal that gravitation is in some sense a square of gauge theory.

2. The vertex is the same as for gauge boson emission and for a creation of a fermion-antifermion pair. The definition of the modified gamma matrices as $\Gamma^\alpha = T^\alpha_k \Gamma^k$ appearing in the modified Dirac action [4], involving the modified Dirac operator $\Gamma^\mu D_\mu$ makes it possible to identify the gravitational part of the vertex. Here the quantities $T^\alpha_k = \partial L/\partial(\partial_\alpha h^k)$ are canonical momentum currents associated with the action defining the space-time surface and also the analog of the energy-momentum tensor.

   Modified gamma matrices are required by hermiticity forcing the vanishing of the divergence of Γ^α giving classical field equations for space-time surfaces. This implies a supersymmetry between the dynamics of fermions and 3-surfaces. The gravitational interaction would correspond to the deviation of the induced metric from the induced metric defined by induced CP_2 metric. CP_2 radius must correspond to Planck length l_P. This requires that the CP_2 as $R \sim 10^4 l_P$ must correspond to $h = nh_0$, $n \sim 10^7$ as found already earlier.

3. The cosmological term in GRT has coefficient $1/8\pi G\Lambda \equiv 1/R^4$ so that the modified gamma matrices would contain a term proportional to $1/R^4$ plus a term coming from the Kähler action. In the TGD framework [5, 6], cosmological constant Λ depends on the p-adic length scale, which is assumed to correspond to a ramified prime for an extension of rationals associated with the polynomial P determining to high degree the space-time surface and approaches to zero in cosmic scales. The cosmological value corresponds to $R \simeq 10^{-4}$ meters, i.e. cell length scale and a scale near neutrino Compton length.

   In the general coordinate invariant formalism, one does not assign dimension to the coordinates or to covariant derivative D_α. Metric has dimension 2. The scale dimension of $T^\alpha_k \sqrt{g}$ is the same dimension of $L\sqrt{g}$ and thus vanishes. Γ^α has scale dimension -1. The modified Dirac action must be dimensionless so that the induced spinors must have scale dimension 1/2.

4. The cosmological constant as the coefficient of the action depends on the p-adic length scale. This term contributes to the string tension of string-like objects an additional term, which among other things can explain hadronic string tension. This term is visible also in the interaction vertices. The Kähler part of the bosonic action terms comes from the deviation of the induced metric from the flat metric and should give the usual gravitational interactions with matter.

5. Holomorphy hypothesis allows any general coordinate invariant action constructible in terms of the induced geometry. Although preferred extremals are always minimal surfaces, the properties of the action are visible via classical conservation laws, via the field equation at singular 3-surfaces involving the entire action, and via the vertices.

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