About the construction of scattering amplitudes in TGD

July 19, 2026

Matti Pitkänen

orcid:0000-0002-8051-4364.
email: matpitka6@gmail.com,
url: `http://tgdtheory.com/public_html/`,
address: Valtatie 8, as. 2, 03600, Karkkila, Finland.

Abstract

Contents

1 Introduction

The purposed of this article is to represent a more detailed view of scattering amplitudes at the level of the imbedding space H by including the latests results, in particular the understandin the role of warping which distinguishes between GRT and TGD and leads to a concrete identification of partonic 2-surfaces as generalized vertices.

It is good to start by representing a general vision of classical and quantum TGD.

1.1 Geometric and number theoretic visions of physics

1.2 Three arenas for dynamics: embedding space, space-time surface and the "world of classical worlds" (WCW)

1.3 Symmetries

1.3.1 Isometries and holonomies of the embedding space

1.3.2 Conformal symmetries as dynamical symmetries at the level of H

What could the criticality and conformal symmetries as analogs of gauge transformations mean?

1. H has 3 complex coordinates and one hypercomplex coordinate. The counterparts of conformal maps of H should act on them. They could be analogs of conformal transformations of string models. The Hamilton-Jacobi structure is the generalization of complex structure to H. The generalized conformal transformations should leave them invariant just like ordinary conformal transformations respect conformal moduli.

2. p-Adic mass calculations rely on the restriction of these general conformal symmetries on partonic orbits. The 3-D light-like boundary M^4 and the 3-D light-partonic orbits allow extended conformal transformation with respect to the complex coordinate and the radial light-like coordinate. There are two conformal weights.

3. Still one further complexity. The conformal algebra generators are labelled by conformal weights $h \geq 0$. They contain a fractal hierarchy of isomorphic subalgebras with weights which are integer multiples $n \times h$ of the weights of the original algebra. This leads to the idea that conformal symmetry breaking corresponds to a reduction of conformal symmetry algebra to this kind of subalgebra.

1.3.3 The world of classical worlds

Quantum TGD leads to a generalization of the geometrization of the physics program of Einstein. The geometrization applies even to the quantum theory itself and the space of space-time surfaces - "the world of classical worlds" (WCW) - becomes the basic object endowed with a Kähler geometry (see the illustration). General Coordinate Invariance (GCI) for space-time surfaces has dramatic implications. A Given 3-surface fixes the space-time surface almost completely as an analog of Bohr orbit (preferred extremal [?]. This implies holography and leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces. Quantum TGD reduces to wave mechanics in the space of these Bohr orbits, the WCW.

Quantum theory is geometrized in terms of the notion of a "world of classical worlds" (WCW) consisting of space-time surfaces identifiable as preferred extremals (PEs) analogous to Bohr orbits. General Coordinate Invariance (GCI) implies 3-D holography and probably also effectively 2-D holography (strong holography (SH)).

The mere existence of WCW Kähler geometry requires a maximal isometry group. This was shown by Freed [?]o be the case for loop spaces. This leads to the vision that physics is unique from its existence. Indeed, the twistor lift of TGD [?]orks only for $H = M^4 \times CP_2$ [?]ince only M^4, E^4, and CP_2 have twistor spaces with the Kähler structure required by the existence of the twistor lift based on 6-D Kähler action. On the number theory side, the octonionic M^8 is the unique choice.

Later it turned out that it might be possible to realize the counterparts of the twistor spaces of M^4 and CP_2 without the introduction of the twistor spaces of H or M^8 as 6-D surfaces in H such that their 4-D intersection defines the space-time surface [?]

1.3.4 Symplectic symmetries at the level of WCW

Symplectic invariance is one of the many arguments supporting the masslessness of photons which would mean long range correlations between space-time surfaces representing Bohr orbits and more concretely, the possibility of massless extremals (MEs) connecting them.

Conformal invariance in 2-D conformal theories also means long range correlations in conformal field theories: there are no dimensional parameters in the theory. Same holds true now by holography= holomorphy vision.

Weak isospin involves M^4 axial currents and they are not conserved. This gives rise to massivation or stated otherwise: the weak isospin is screened by $\nu_R - \nu_L$ pairs and correlations functions become short ranged.

Symplectic and conformal symmetries appear also in string models. They appear in the context of mirror symmetry. In TGD, symplectic symmetries would appear at the level of embedding space H and as isometries at the level of WCW (as the proposal is).

Generalized conformal symmetries would appear at the level of the space-time surface. Symplectic symmetries do not leave the induced metric invariant so that they are not symmetries at the space-time level. This brings to mind the description of incoming and outgoing states in terms of modes of H spinor fields and the description of interacting states in terms of the induced Dirac equation in X^4.

1.4 Quantum criticality

What could criticality and conformal symmetries as analogs of gauge transformations mean?

1. In conformal field theories conformal invariance realizes quantum criticality by giving rise to long range correlations and quantum fluctuations. Massless particles are one aspect of these long range correlations. In TGD, a generalization of the conformal invariance of string theories realizes this.

2. p-Adic mass calculations rely on the restriction of these general conformal symmetries on partonic orbits. The 3-D light-like boundaries of future and past light-cones $M^4_\pm$ and boundaries of causal diamond CD defined as their intersection) allow extended conformal symmetries with respect to the complex coordinate and the radial light-like coordinate. This is true also for the 3-D light-partonic orbits. There are two conformal weights involved corresponding to transversal conformal symmetries of a sphere (partonic 2-surface) and radial conformal symmetries.

3. H has 3 complex coordinates and one hypercomplex coordinate. The counterparts of conformal maps of H should act on them. They could be analogs of conformal transformations of string models. The Hamilton-Jacobi structure is the generalization of complex structure to H. The generalized conformal transformations should leave them invariant just like ordinary conformal transformations respect conformal moduli.

4. There is one further complexity involved. The conformal algebra generators are labelled by conformal weights $h \geq 0$. They contain a fractal hierarchy of isomorphic subalgebras with weights which are integer multiples $n \times h$ of the weights of the original algebra so that generators with coformal weight smaller than n generate dynamical symmmetries. This leads to the idea that conformal symmetry breaking corresponds to a reduction of conformal symmetry algebra to this kind of subalgebra.

1.5 Holography = holomorphy principle

During last years it has become clear that holography reduces to the notion of generalized complex structure for both imbedding space and the space-time surface [**?**]nd space-time surfaces correspond to roots of two functions f_1 and f_2 analytic with respect to the 4 generalized complex coordinates, one of which is real number valued hypercomplex coordinate varying along light-like curves.

This means a general solution of field equations which is universal in the sense that it the same for any general coordinate invariant action constructible in terms of the induced geometry. The dependence on action comes only from, presumably 2-D, singularities at which the generalized holomorphy and the associated minimal surface property fail. There are good reasons to believe that the singularities contain the information needed to construct the scattering amplitudes.

1. The space-time surfaces in the imbedding space $H = M^4 \times CP_2$ are identified common roots for the pair (f_1, f_2) of generalized holomorphic functions defined in H. If the Taylor coefficients of f_i are in an extension of rationals, the conditions defining the space-time surfaces make sense also in an extension of p-adic number fields induced by this extension. As a special case this applies to the case when the functions f_i are polynomials. For the completely Taylor coefficients of generalized holomorphic functions f_i, the p-adicization is not possible. The Taylor series for f_i must also converge in the p-adic sense. For instance, this is the case for $exp(x)$ only if the p-adic norm of x is not smaller than 1.

2. The 6-D surfaces satisfying only the condition $f_i = 0$,$i = 1$ or $i = 2$, have interpretation as analogs of twistor spaces of M^4 and CP_2 and the proposal is that this description is equivalent with the twistor lift of TGD introducing the twistor space of H as a product of twistor spaces of M^4 and CP_2 and defining twistor space of the space-time surface as a 6-D surface.

3. Also the maps defined by analytic functions g in the space of function pairs (f_1, f_2) generate new space-time surfaces. One can assign Galois group and ramified primes to h if it is a polynomial P in an extension of rationals. The composition of polynomials P_i defines inclusion hierarchies with increasing algebraic complexity and as a special case one obtains iterations, an approach to chaos, and 4-D analogs of Mandelbrot fractals.

Holography=holomorphy hypothesis allows to reduce the classical field equations to purely algebraic conditions $(f_1, f_2) = (0, 0)$, where f_i are analytic functions of one hypercomplex and 3 complex coordinates of $H = M^4 \times CP_2$. The solutions are minimal surfaces irrespective of the classical action as long as it is general coordinate invariant and expressible in terms of induced geometry. This means universality of the dynamics and is quantum criticality expressed by the holomorphy. This implies saddle surface property for the spacetime surface meaning that the real parts of f_i do not have minima or maxima in general.

The iterates of a polynomial $(g, 1)$ (say) with prime degree p, define analogs of primes. This leads also to a generalization of the p-adic number fields to function fields with elements expressed as functional power series as powers of g in which the powers g^k are multiplied by polynomials with degree lower than p. This leads to a definition of functional primes providing an explanation for the origin of p-adic length scale hypothesis. One can say that p-adic function fields and the adele form by them emerges from the real dynamics. The p-adic variants of the embedding space and space-time are convenient auxiliary structures but need not be fundamental.

1.6 Zero energy ontology

In Zero Energy Ontology (ZEO), the superpositions of space-time surfaces inside causal diamond (CD) having their ends at the opposite light-like boundaries of CD, define quantum states. CDs form a scale hierarchy (see the this) and this).

1.6.1 The notion of causal diamond

The notion of causal diamond (CD), identified as the intersection of future and past directed lightcones, is the cornerstone of zero energy ontology (ZEO). The notion of CD is discussed in [L4]. In ZEO, the basic physical entities of TGD are not 3-surfaces but their 4-D slightly non-deterministic Bohr orbits inside CD.

CDs form a scale hierarchy and one could see CD as a geometric correlate of physical system at the level of H. The moduli space of CDs Poincare transformations and Lorentz boosts leaving the tip of invariant.

1.6.2 "Big" state function reductions

Quantum jumps occur between superpositions of 4-D time evolutions and the basic problem of the standard quantum measurement theory disappears. Ordinary state function reductions (SFRs) correspond to "big" SFRs (BSFRs) in which the arrow of time changes (see the illustration). This has profound thermodynamic implications and the question about the scale in which the transition from classical to quantum takes place becomes obsolete. BSFRs can occur in all scales but from the point of view of an observer with an opposite arrow of time they look like smooth time evolutions [L2].

The key question is whether there is some general criterion telling when the BSFR takes place. Could BSFR take place when the size of scaled up boundary of CD increases the size scale at which a phase transition breaking the conformal symmetry can occur. An interesting possibility is raised by the fact that conformal algebra allows an infinite fractal hierarchy of sub-algebras isomorphic to it and having conformal weights coming as multiples of the full algebra. In a transition to sub-algebra generators which acted as infinitesimal gauge transformation become generators of dynamical symmetries. Could BSFRs correspond to this kind of phase transitions at least in some cases.

1.6.3 "Small" state function reductions

In "small" SFRs (SSFRs) as counterparts of "weak measurements" the arrow of time does not change and the passive boundary and the states at it remain unchanged (Zeno effect). The sequence of "small" state function reductions (SSFRs) defined the TGD counterpart of the generalized Zeno effect, would correspond to an analysis having as a correlate the decay of 3-surface to smaller 3-surfaces and would also give rise to a conscious entity, self.

1. SSFRs are associated with the classical determinism at 3-D surfaces Y^3 at which generalized holomorphy and smoothness fails. The derivatives are discontinuous for H coordinates. The intersections of Y^3 with light-like partonic orbits X^3 defined partonic 2-surfaces as generalized vertices intersected by fermion lines which are light-like geodesics in H. This gives to the massivation of fermions. The classical loci of non-determinism identified as singularities of smooth structure having interpretation in terms of exotic smooth structures.

2. The discontinuities correspond to the discontinuities of reduced light velocity $c_\#$. It can be assigned to warped flat extremals of any action principle. The notion generalizes to general space-time surfaces if the Hamilton-Jacobi structure generalizes to a warped H-J structure. In electrodynamics the quantity $n = c/c_\#$ corresponds to refractive index and dielectric constant via $n = c/c_\# = \sqrt{\epsilon_r}$. The time evolution of the particles as a generalized Brownian motion could be seen as a sequence of reflections and refractions at the boundaries of regions at which $c_\#$ changes.

1.6.4 How could the arrow of geometric time emerge?

This problem is far from being settled. One can consider the arrow of time at the level of embedding space and space-time surface. One can imagine at several views [L4] based on the assignment of the arrow of time to the sequences of SSFRs.

1. Perhaps the simplest option is that the CD itself is shifted in the direction defined by the active boundary of CD. An argument telling how much the shift per single SSFR is would be needed. This time would correspond to the time shifted between two BSFRs. The inverse for the rate of BSFRs would give an estimate for this rate. Also the p-adic lenghth scale assigned with the CD suggests some idea about this rate.

   A simple example is provided by sleep-awake cycle. Falling a sleep and wake-up would correspond to two subsequent BSFRs and the time would be on the average roughly 12 hours, which correspond to the half of rotation period of the Earth and is also near the the oscillation period of the Earth as a gravitational harmonic oscillator [**?**].

   The problem is that if there is no breaking of time reflection symmetry T, the times travelled towards geometric future and past would compensate each other so that the CD would not move at all on the average. During sleep the distance travelled to future would be compensate by distance travelled to the geometric past. T and CP are broken and matter-antimatter symmetry reflects this breaking in cosmic scales. In this view the CD would be like time-snake.

2. I have also considered the possibility that the size of CD is reduced in BSFR and then grows in the sequence SSFRs. This would conform with the idea that each continous entity experiences evolution starting with a childhood. Also now T and CP breaking might be necessary to give a genuine arrow of geometric time at the level of H.

3. One possibility is that the CD suffers a scaling with respect to its center point in each SSFR. Second option is that the passive boundary remains stationary. The passive boundary of CD would be scaled and shifted but the states at it would not change by conformal invariance (scaling is a conformal transformation).

   The objection is that the size of CD of any system, even elementary particle, would increase steadily and indefinitely and also the period with a given arrow of geometric time would get longer. This is not true for sleep-wake cycle. This suggests that although scalings are possible they are a rare occurrence and possibly correspond to some particylar BSFRs increasing the scale of quantum coherence and would give rise to evolution.

4. At the space-time level, the geometric time as correlate for the subjective time as sequence of SSFRs could correspond to the temporal distance between the tips of CD increasing in the sequence of SSFRs defining the self. The classical non-determinism gives rise to a sequence of singular 3-surfaces as edges of the space-time surface at which standard smoothness fails and exotic smoothness is assumed to replaced it. The increase of CD gradually would gradually reveals more edges as loci of non-determinism.

1.6.5 Sleep-wake cycle and metabolism

To get some more food for thought one can try to relate the sleep-wake cycle for living organisms to the metabolic energy feed from the Sun.

1. Here the notion of stochastic resonance is suggestive. It occurs for bistable systems in presence of noise and periodic force. In stochastic resonance the average time τ_K spent in a given potential well is one half of the time of the periodic perturbation T. In the recent case T would correspond to 24 hours and τ_K the average period of sleep/wake.

   The states of the bistable system, describable as a potential well, would correspond to sleep and wake as states of consciousness. Under a suitable condition the rate for jumps between potential stochastic resonance occurs and the periodic signal is amplified.

2. Plants cannot store energy like animals and would be strongly dependent on the solar energy feed and sleep-wake cycle would be very regular and also explain why they cannot survive over winter time. Animals would not be so depending on solar energy feed but could not stay too long a period awake.

3. The feed of the metabolic energy is necessary during daytime. During the night-time this feed is absent. If the organisms are conscious during the period with the opposite arrow of time, they should receive metabolic energy from the Sun. This energy must be negative however! The Sun must be able to send both positive and negative energy photons. Negative energy photons do indeed exist and phase conjugate light rays are a basic example of them.

   The Sun has a Sunspot period of about 22 years. Could this correspond to the sleep wake cycle of the Sun at the level of its field body? Denote the half-periods of the sleep wake cycle of the Sun by W and S and corresponding periods at the Earth by w and s. During w, the organism should receive positive energy photons from the Sun from the temporarily nearest period W. During S this would be the W preceding it. During s the organism should receive negative energy photons from the Sun from the temporarily nearest period S. During W this would be the geometrically next S.

   This could have rather dramatic implications on the understanding of wake-up consciousness in long time scales. There would be a periodic dependence on the half-period of the Sunspot cycle. By the predicted universality of consciousness, these periodic dependence would not be restricted to human consciousness but appear even in microscopic scales.

4. There indeed exists evidence about the correlations with astrophysical rhythms. For instance, Shnoll [E1, E4, E5, E2, E6, E3] reported that radioactive decay rates, chemical reaction rates and biological interactions correlate with astrophysical periods. There are claims about similar correlations in the economy. I have tried to understand the findings of Shnoll in the TGD framework [L6]. These correlations are impossible in the framework of standard physics; it is not surprising that the mainstream regards these findings as an anomaly due to flawed methodology.

1.7 Twistor lift of TGD

1.7.1 A preferred classical action from the twistor lift

1.8 M^8-H duality

One could interpret M^8–H duality as generalization of momentum position duality from point-like particles to 3-surfaces or more precisely, their Bohr orbits. They would have counterpats at the level of M^8 and the duality would relate these description like Fourier transform. Challenging questions relate to the M^8 counterpart of time evolution in H. What to the 4-surfaces in 8-D momentum space mean?

2 The view of the dynamics at the space-time level

2.1 Hamilton-Jacobi structures

2.1.1 Warping and twisted H-J structures

2.2 Holography = holomorphy principle

2.2.1 Minimal surface property is satisfied outside singularities

2.2.2 Dynamics is universal outside singularities

Only the singularities depend on classical action.

2.2.3 Classical non-determinism, failure of holomorphy and emergence of space-time edges as analogs of frames for soap films

2.2.4 Edges and partonic orbits as singularities

2.2.5 Chern-Simons term at partonic orbits

2.3 Boundary conditions at partonic orbits and edges

2.3.1 Expressions for isometry currents

1. General expression for isometry current for given action
2. Contributions from the volume action
3. Contribution from Kähler action

   Decomposes into contributions froming from the variation of the metric and K̈hler form.
4. Kähler-Chern-Simons (K-C-S) action is only possible action for light-like partonic orbits. It would emerge from the instanton term for Kähler action. It is needed as a modified Dirac action associated with the partonic orbit and would give rise to modified Dirac action which can be restricted to fermion lines.

2.3.2 Modified Dirac action and - equation

1. General formula for the modified gamma matrices.

   Generalized super symmetry. Conservation law for the super counterparts of isometry currents.
2. At the light-like partonic orbit fermion line K-C-S action is possible. Is there a coupling between the parton orbit and exterior. The difference of the two modified Dirac equations is zero by boundary condition.
3. The restriction of the modified Dirac equation on the fermion lines makes? What about fermion line?

Questions:

1. Is supersymmetry violated for standard smooth structure at the edge but not volated for exotic smooth structure. The non-triviality of the vertex is due to the violation of fermion number conservation at the fermion annilation vertex for ordinary smooth structure. Time orientation changes and gives rise to conservation. Fermion turns backwards in time and transforms to antifermion.
2. Could it be that only metric part is present in gamma matrices in the interior. Both options seem to be possible by holomorphy predicting minimal surfaces always.

2.3.3 Field equations

The requirement that the action defined by the sum of Kähler action and volume term is stationary leads to the following field equations implying the conservation of isometry currents in the interior of the four-surface.

There are two contributions to the field equations coming from the variations of the induced metric and Kähler form.

$$\begin{aligned} D_\beta(T^{\alpha\beta}h^k_\alpha) &- j^\alpha J^k{}_l\partial_\alpha h^l = 0 \ , \\ T^{\alpha\beta} &= J^{\nu\alpha}J_\nu{}^\beta - \frac{1}{4}g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu} \ . \end{aligned} \tag{2.1}$$

Here $T^{\alpha\beta}$ denotes the sum of the traceless canonical energy momentum tensor associated with the Kähler action and of the energy momentum tensor associated with the volume action. An equivalent form for the first equation is

$$\begin{aligned} T^{\alpha\beta}H^k_{\alpha\beta} &- j^\alpha(J_\alpha{}^\beta h^k{}_\beta + J^k{}_l\partial_\alpha h^l) = 0 \ . \\ H^k_{\alpha\beta} &= D_\beta\partial_\alpha h^k \ . \end{aligned} \tag{2.2}$$

$H^k_{\alpha\beta}$ denotes the components of the second fundamental form and $j^\alpha = D_\beta J^{\alpha\beta}$ is the gauge current associated with the Kähler field.

Holography = holomorphy hypothesis implies that the field equations are separately satisfied for the metric and Kähler parts outside the singularities so that one has minimal surfaces. The reason is that the contribution of the metric variation to the field equations involves a contraction of complex tensors of type (1,1) and (1,0)+(0,1). The variation with respect to the Kähler form gives a contraction of light-like current with a light-like vector and also vanishes. At edge singularities and partonic orbits holomorphy, smoothness and minimal surface property fails and these surfaces are analogous to the frames spanning soap films. The field equations reduce to continuity conditions at the singularities.

2.3.4 Boundary conditions for space-time edges and flux tubes

Intersections of the edges and partonic orbit are define 2-D partonic surfaces as generalized vertices. If the condition that the string world sheet defines the contact interaction reduces the 2-D partonic vertex to a discrete set of points. Fermionic vertices as intersections with fermion of Hdefines which null geodesics of H.

There are two cases to be considered.

1. $c_\#$ characterizing H-J structure changes at the edge. $c_\#$ characterizes fermion lines and H-J structures for fermionic surfaces. Edge could be a surface with a time-like normal but also space-like normals can be considered.

2. Partonic orbit is 3-D light-like surface. 4-metric degenerates to effectively 2-D metric. The technical challenge is to understand the boundary conditions.

The boundary conditions apply to both classical action and modified Dirac action. Conservation of isometry currents defines the boundary conditions.

1. Edges are not light-like 3-surfaces so that K-C-S action is not necessary. For partonic orbits would give modified Dirac equation as K-C-S Dirac for the fermion line as a special case. At the edge the normal component of the total isometry current is continuous:

$$\Delta T^n_A = 0 \ .$$

2. At the partonic orbit its equal to the K-C-S current flowing along the partonic orbit in the partonic case:

$$\Delta T^n_A = T^n_A(K-C-S) \ .$$

In Kähler action there are two contributions to the isometry currents coming from the variations of the induced metric and of Kähler form. Also Kähler form of M^4 having only transversal component could be present and is suggested by the twistor lift.

2.3.5 Observations about boundary conditions

In the boundary conditions the divergence is replaced with difference of normal components at the two sides. Explicit expressions for the normal components of isometry currents are btained from the general formula for the isometry.

1. The boundary conditions at space-time edges pose a constraint on the value of cosmological constant Λ, which from twistor life is dynamical and determined by the p-adic length scale hypothesis and approaches zero at long scales. Kähler action density $J^{\mu\nu}J_{\mu\nu}$ and the scale Λ are of the same order of magnitude. In long scales $J_{\mu\nu}$ approaches zero. This solves the problem related to the huge value of Λ

2. For K-C-S case boundary conditions are very delicate. If the diverging quantities $g^{n_i\alpha}\sqrt{g_4}$ become proportional to 3-D delta function dominating at the partonic orbit over other terms in the boundary conditions and the boundary conditions are well-defined for the volume term of the action.

3. For Kähler action the vanishing of $g_{n_1\alpha}$ *resp.* $g_{n_2\alpha}$ and of $J_{n_1\alpha}$ *resp.* $J_{n_2\alpha}$ implies that also for Kähler action 3-D delta function gives the dominating term. 4-metric and Kähler form metrically 2-D. One would obtain square of 3-D deltafunction from the presence of two contravariant components of induced metric without the vanishing of $J_{n_1\alpha}$ and $J_{n_2\alpha}$. This follows by explicit study of the standard formulas for the components of contravariant 4-metric at the partonic orbit.

2.3.6 Model for the light-like partonic orbit

One should develope a model for the light-like partonic orbit and fermion line at it.

1. Could the partonic orbit X^3 be regarded as a homologically non-trivial geodesic 2-sphere S^2 moving along a light-like geodesic of H. It would be sphere rotating in CP_2 with frequency ω. Non-vanishing K-C-S action (and of Kähler form requires a homologically non-trivial geodesic sphere.

2. Fermion line would be light-like geodesic having projection to $M^4 \times S^1 \subset H = M^4 \times CP_2$, S^1 is a geodesic line. It is characterized by frequency ω: $m^0 = t$, $\Phi = \omega t$. Φ is the angle coordinate for the geodesic circle S^1. Any coordinate line of X2 along which t varies would be a light-like geodesic of and could serve as a fermion line.

   The the induced metric at the fermion line would be $g_{tt} = 1 - R^2\omega^2 = c_{\#}^2$, where $c_{\#}$ is the reduced light velocity. Fermion behaves like a massless particle in H and in X^4. The M^4 component of 4-velocity is constant and equal to $v = R\omega$. Fermion behaves like a massive particle in M^4 with mass: a good guess for the mass is $m = \hbar_{eff}\omega$. This is one way to express M^4 massivation of fermions in TGD as a consequence of masslessness in H. Warping of the space-time surfaces distinguishing between GRT and TGD in turn justifies the masslessness in X^4 and the generalization of QCD approach to scattering amplitudes to TGD. I have discussed warping for Allais anomaly and fluctuations of gravitational constant in [L8] and its application to neutrinos in [L7].

3. Light-likeness of the partonic orbit implies that the covariant induced 4-metric is effectively 2-D and reduces to 2-metric for the partonic 2-surface X^2. Boundary conditions imply that this must be true also for the induced Kähler form. Metric and Kähler form are transversal: this is a geometric way to state gauge invariance means.

4. The induced metric cannot appear in the action for the light-like partonic orbit and K-C-S (Kähler-Chern-Simons action is in question. The topological instanton term for Kähler

action gives the K-C-S action as a boundary term but also the volume term of the action can contribute to it as a boundary term.

The contravariant 4-metric and 3-metric are singular at the partonic orbit and must approach to something finite times a 3-D delta function if one wants to make sense of the boundary conditions. The difference of the isometry currents of Kähler action plus volume term at the two sides of partonic orbit is equal to the isometry current associated with K-C-S action.

K-C-S Dirac action can be defined as supersymmetric counterpart of K-C-S action.

1. The Dirac counterpart $\overline{\Psi}\Gamma^\mu D_\mu \Psi$ of the K-C-S action is defined for modified gamma matrices given by

$$\Gamma^\alpha = \frac{\partial L_{K-C-S}}{\partial_\alpha h^k}\Gamma^k \quad . \tag{2.3}$$

The spinor modes at X^3 satisfy induced Dirac equation and it is also satisfied from fermion lines.

2. Fermion satisfies the modified Dirac equation associated with the K-C-S action restricted to the light-like fermion line at the light-like partonic orbit.

3 A general view of construction of scattering amplitudes

3.1 QCD as a role model

Consider first the general view of the construction of the scattering amplitudes.

1. Generalizaton of the hadron phase: H:

2. Generalization of quark-gluon phase. X^4. Fermions Bosonic correlation functions in WCW replace ordinary boson propagators.

S-matrix factorizes to product of a part corresponding to the generalization of hadronization and to a part generalizing quark gluon plasma. Now only induced spinors appear as quantum fields obtained from the free spinor fields of H.

Hadronic reaction as a pair of BSFRs in which the arrow of geometric time temporarily changes. Interpretation is as quantum tunnelling. The period between BSFRs is a sequence of SSFRs involving state function reduction. This period corresponds to a reversed arrow of time during which CD increases and the states at its passive boundary are unaffected. This conforms with the view of perturbative QCD involving both kinetic description in terms of parton densities f and quark-hadron fragmentation functions D. The alternative proposal would be that the sequences of SSFRs are replaced with the analog of Feynman description so that no SFR would actually occur and there would be a product of unitary matrices. This alternative does not conform with the QCD view and with the TGD based view of consciousness.

3.2 Interactions as contact interactions

The assumption that interactions are contact interactions and are described in terms of data provided by string sheets identified as intersections of space-time surfaces representing "Bohr orbits" of 3-D particles implies that he scattering amplitudes can be formulated using the data provided by fermion fields associated with the string world sheets. This would be string model type description.

A stronger assuption is that fermion fields can be restricted on fermion lines defined by the intersections of string world sheets with 3-D light-like partonic orbits. This reduces the fermionic vertices to points as in QFTs. The vertex is the intersection of fermion line with 3-D edge singularity. One could justify this assumption by hypercomplex analyticy: imbedding space coordinates and induced fermion fields depend only on the second hypercomplex coordinate which varies along fermion lines.

3.3 Quantum criticality and generalized conformal invariance

The "spin-glass degeneracy of the maxima of the Kähler function" was the non-physical (pure-Kähler-action) limit. The physical degeneracy we should have named is the weak classical non-determinism of the minimal surfaces — the soap-film frames where the minimal-surface property fails. Thank you for this; it corrects exactly the point we had flagged to you as uncertain.

3.4 Fractal hierarchy of standard model physics

3.5 ZEO and the role classical nondeterminism

Classical non-determinism predicted by H-H principle could be the cornerstone of both classical and quantum dynamics.

3.5.1 Classical non-determinism, warping, and dynamics as generalized Brownian motion

Classical non-determinism suggests the following picture.

1. The moments of time involving classical non-determinism should correspond to 3-D singularities at which the derivatives of H coordinates are discontinuous and minimal surface property fails. The field equations state the conservation of isometry currents and would be satisfied in the sense that the normal components of isometry currents are cntinuous.

   One has an edge of space-time and holomorphy and smoothness fail at the edge. The proposal is that an exotic smooth structure replaces the ordinary smooth structure having these 3-D surfaces as defects [**?**]. Exotic smooth structures are possible only in space-time dimension $D = 4$ and they are a problem of GRT and cosmic censorship is required to get rid of them. The time evolution looks like Brownian walk just like path integral at the limit $\Delta T \rightarrow 0$. However, instead of analog of path integral one would has a sequence of SSFRs implying decoherence.

2. The phenomenon of warping distinguishes between GRT and TGD [L8, L7]. Space-time surfaces with flat metric but reduced light velocity given by $c_{\#} = \sqrt{g_t t}$ are possible. This suggests a generalization of the notion of Hamilton-Jacobi structure [L3] such that M^4 and CP_2 degrees become correlated. Fermion lines and the associated space-time surfaces would be characterized by $c_{\#}$.

3.5.2 The two alternatives for what could happen in quantum scattering event?

One can consider two alternative options.

1. It would be nice to interpret the sequence of these edge discontinuities as an analog of a similar sequence for Feynman path integral for which the time difference ΔT between the discontinuities goes to zero. This would require giving up the idea SSFR is a genuine state function reduction giving rise to decoherence. This would mean giving up the basic idea of TGD inspired theory of conciousness.

2. On the other hand, I propose that QCD serves as a role model for the TGD view of scattering events and thus involves incoming and outgoing particles as states defined in terms of fermionic oscillator operators for the free fermion fields in H. Fermion fields in H satisfy massless Dirac equation in 8-D sense and are massive.

   Quark gluon phase would be replaced with phases involving only induced fermion fields satisfying the massless Dirac equation. It seems that an excellent approximation is to consider fermions localized to fermion lines as massless light-like geode sics in CP_2 restricted to similar geodesics in X^4 but with reduced light velocity $c_{\#}$.

3. The formation of quark gluon phase would be a unitary transformation from H phase for fermions ton X^4 phase and hadronization would be a unitary transformation in an opposite direction.

4. The question is whether also the SSFRs actually just unitary transformations or whether they are genuine SFRs as TGD inspired consciousness requires?

   QCD is a strange looking mixture of QFT and kinetic theory. Scattering amplitudes are calculated by QFT but one has parton densities f and quark-hadron fragmentation functions, which belong to kinetic theory involving quantum statistics and therefore state function reductions.

   If QCD view is correct, SSFRs are indeed genuine SFRs involving a loss of coherence and only the periods between two SSFRs would be unitary evolutions.

3.6 Propagators

3.6.1 Fermionic propagators

Singularities: discontinuities of derivatives appear at edges. Connection with warping. Phase transitions changing the reduced light velocity $c_{\#}$. $c_{\#}$ characterizes fermion line and naturally also the H-J structure of the fermionic space-time sheet.

Could the solutions of the modified Dirac equation for K-C-S action be restricted to the the fermion lines using local values of $J_{\alpha\beta}$ and A_α.

3.6.2 Bosonic propagators as WCW correlation functions

The translational degrees of freedom for space-time surfaces as Bohr orbits gives rise to momentum degrees of freedom after Fourier transform. Poincare invariance (exact at the limit of infinitely large CD) makes natural the dependence on s,u,t. Generalization of the conformal invariance makes natural the assumption that the analog of bosonic propagator as a correlation function in WCW degrees of freedom has the behavior predicted by conformally invariant theories.

Masslessness have several representations: minimal surfaces are analogous to non-linear massless fields, fundamental fermions are massless in $H = M^4 \times CP_2$ but massive in M^4 . Induces spinor fields are massless in X^4. The latest finding is that warped space-time surface realized masslessness in H and and X^4 but represent massivation at the level of M^4. The particle mass is directly coded to the properties of a light-like geodesics of H representing the fermion line [L7].

When only the cm degrees of freedom for partonic orbits are left, point-like limit of QFT should emerge and give massless bosonic propagators for say photons and gravitons. For instance, super conformal invariance applied in p-adic mass calculations states that only transversal degrees of freedom are physical. In holography-holomorphy principle longitudinal degrees of freedom correspond to hypercomplex degrees of freedom.

3.7 Vertices as intersections of partonic orbits and edges of space-time surface

3.7.1 Vertices as singular covariant divergences of fermion current at the edges of the space-time surface and exotic smooth structures

....

In ZEO one assigns to the opposite boundaries of CD opposite arrow s of time and opposite time orientations. The natural question is how this relates to the matter and antimatter. The proposal is that these two vacuum states for fermion correspond at least formally to Dirac seas for positive *resp.* negative energy particle.

The description of fermion pair creation as turning of a fermion backwards in time forces to look the situation again. The interpretation would be as time reflection in which the sign of the energy changes. This guarantees energy conservation and at the opposite boundary there must be for intance boson with the energy equal the sum of energies of fermion and antifermion.

The fermion line beginning from the positive energy boundary of CD is time reflected and returns back with positive energy and opposite time arrow . If the time reflection of creation operator transforms if to creation operator for antifermion, the standard view is obtained.

It seems that one must take events as basic notion rather than states. H-H principle indeed implies this at classical level. Bohr orbits are the basic notion in pair creation the Bohr orbit turns backward in time after time reflection. Also refraction is possible and would naturally occur at 3-surfaces where the value of $c_{\#}$ changes this could be interpreted as scattering from classical fields. The generalized Brownian motion would involve both refraction and reflection at the intersection of partonic orbits and singular 3-surfaces.

Annihilation of fermions and antifermions in cosmology, could be due to quantum transitions transforming pairs of fermion lines as boundaries of string world sheets identified as intersections of space-time surfaces (including self-intersections) connecting the opposite boundaries of CD to V-shaped lines connecting the points of the same boundary. Refraction would be replaced with reflection.

Could this new view provide new insights to the matter antimatter asymmetry? As in the standard cosmology, CP breaking implying generation of regions with slight excess of fermions over antifermions or vice versa is necessary to prevent complete annihilation of fermions and antifermions.

3.7.2 Is the proposed picture consistent with the standard view of fermions

In TGD bosons would consist of fermion antifermion pairs. Do the members of pairs have opposite arrows of time? If boson is a pair of collinear massless on-mass-shell fermions and its antifermion in M^4, its spin vanishes. If the momenta are opposite, the spin equals 1 but the state is massive. What about massless spin 1 particles like photon? This problem disappears when one notices that in chiral symmetry is raised to the level of H and becomes separate conservation of quark and lepton numbers. The massivation of fermions implies that fermion and antifermion are mixtures of both helicities.

In TGD inspired theory of consciousness, the proposed mechanism of memory involves signalling backwards in time and time reflection. This time reflection reflection could also correspond to a time reflection for fermions, say neutrinos and also time reflection for bosons as fermion antifermion pairs. The reflected light provides information about the surface from which it is reflected.

3.8 Number theoretic view of coupling constant evolution

Correlation functions in WCW define fermion-boson coupling constants and their evolution reflecting the algebraic structure of the space-time surface if H-H holds true.

In the TGD framework, Weinberg angle and other coupling than Kähler coupling can in principle be computed when Kähler coupling is given. Also the spectrum of the Kähler coupling would be fixed by quantum criticality as an analog of critical temperature.

1. Holography = holomorphy principle predicts that outside the singularities minimal surface equations are true irrespective of the action principle as long as it is general coordinate invariant and depends only on the induced geometry. The coefficients of polynomials or even more general functions (f_1, f_2) belonging to extension of rationals would quite generally give rise to theoretical coupling constant evolution in terms of number. The polynomials f_i form also hierarchies hierarchy with respect to the degree.

2. The proposal motivated by the notion of generalized Langlands correspondence between geometric and number theoretic visions is that the values coupling parameters depend on number theoretical invariants. The extension E of rationals appearing in map $f = (f_1, f_2)$ (polynomial hierarchy is the simplest guess) defining space-time surface as their root; the generalized Galois group acting as a flow a permuting the roots of (f_1, f_2) as space-time regions, and the ordinary Galois group tentatively assigned with partonic 2-surfaces.

3. The positions and shape of the singular surfaces depend on coupling parameters. The reason is that the boundary conditions guaranteeing the conservation of isometry charges at partonic orbits and at the edges of the space-time pose constraints on the coupling parameters. For instance, for mere volume action edges and partonic orbits are impossible. The contributions from volume action and, say, Kähler action must compensate each other in the boundary conditions.

If the conditions defining edges and partonic orbits are algebraic equations, their intersection as a partonic 2-surface defining the generalized vertex satisfies algebraic equations. H-H principle implies that the addition of a third function f_3 having the same dependence of hypercomplex coordinate as f_i and vanishing at the partonic 2-surface selects a finite set of points as its roots. These points are in general roots of an algebraic equation and the roots of algebraic equations for algebraic functions with coefficients in extension of rationals quite generally allow the analog of the Galois group.

4. What about the coefficient of the volume term interpreted as cosmological constant Λ? Kähler action action as 6-D action for the twistor lift of TGD gives as extremals 6-D surfaces with with induced twistor structure meaing S^2 bundle structure. The twistor space of H is the product of twistor spaces of M^4 and CP_2. Only these two spaces have a twistor space with Kähler structure. 6-D Kähler action is dimensionally reduced to 4-D Kähler action and volume term coming from the S^2 fiber of X^6.

   The coefficient Λ of volume term is dynamically generated and depends on p-adic length scale approaching zero in long scales. There is no explicit breaking of conformal symmetry present if Λ is put in by hand.

3.9 How to understand unitarity in TGD framework

What does one mean with the second variation of massless extremal (ME)? Assume that one has a maximum, say massless extremal.

1. It should respect the holography-holography principle. In H-H vision variations for the Taylor coefficients of (f_1, f_2) would be in question. If f_i are polynomials, are the degrees of polynomials allowed to vary? Should one decompose WCW to sub-WCWs using criteria selecting extension of rationals for coefficients, degrees of f_i :s, etc... This would give discretization of WCW.

2. What happens to Kähler action, which vanishes for ME, in its deformation. Does it suffer mere conformal scaling so that the action remains zero? From the point of view of Kähler action the allowed deformations would be zero modes. If so, the volume term gives the only contribution to the second variation. This brings in mind string models.

4 An estimate for the Weinberg angle from WCW counterpart of the bosonic propagator

An estimate for the Weinberg angle θ_W can be deduced by considering the TGD counterpart of a bosonic propagator. The semiclassical estimate carried in my thesis (1982) [K1] [L1] for the Weinberg angle $p \equiv sin^2(\theta_W)$ comes the condition that the electroweak YM action for the induced gauge fields contains no γZ_0 cross term. The simplest estimate gave $p = 9/28$, which is somewhat smaller than $p = 3/8 = 9/27$ of a typical GUT. In the recent formulation of quantum TGD, the classical electroweak YM action is replaced with Kähler action plus volume term so that the estimate is lost.

In the sequel, the first aim is to describe the results of the earlier estimate and to demonstrate the picture about mixing implies the predictions of the Weinberg theory for the electroweak gauge couplings. The basic difference between TGD and standard model is that the TGD counterpart of the standard model gauge potential A is A_{ind}/g, where A_{ind} is the induced gauge potential and g is the corresponding coupling constant. The explicit identification of the induced gauge potentials indeed implies the standard model formulas for the electroweak couplings in terms of the Weinberg angle. The value of $U(1)$ coupling strength as Kähler coupling strength determined by the quantum criticality condition would determine the overall scale of couplings and Weinberg angle would determine their ratios.

The second aim is to formulate a quantum version for the classical argument determining Weinberg angle.

1. The natural condition is that the quantum correlation $\langle\gamma_1, Z_2\rangle$ for a pair of partonic 2-surfaces at the ends of the counterpart of effective bosonic propagator line, identified as edges of fermion lines, vanishes.

2. The assumption that the propagator factorizes for ground state to a product $\langle\gamma_1\rangle\langle Z_2\rangle >$ implies $\langle\gamma_1\rangle = 0$. This condition fixes the Weinberg angle. The alternative interpretation is that the vanishing of γ_{ind} defines a ground state around which small fluctuations give rise to a radiation field.

3. The averages are estimated as expectation values of the classical induced fields A_{ind} acting as local multiplicative operators acting on the induced spinor field at the position of the vertex. The average is proportional to a diagonal matrix element for a fermionic partial wave at the partonic 2-surface. Since fermionic matrix elements are involved, gauge invariance associated with vierbein rotations of CP_2 is not lost.

   It turns out that there are strong conditions from the unitarity forcing the localization of the spinorial modes to rather small values of the radial coordinate of the partonic surface as the Riemann sphere CP_1. It took a considerable effort to realize the importance of this localization. This implies a geometric interpretation of the coupling constant evolution of the Weinberg angle.

4. The transitions between different spinor modes changing the expectation value of the Weinberg angle are possible. The different modes would give rise to a coupling constant evolution for Weinberg angle and other coupling constants.

   One would have full partonic dynamics. It would involve the geometrodynamics of the partonic giving also rise to a topological description of CKM mixing in terms of different topological mixings of partonic 2-topologies [K2] and also the transitions between the modes of modified Dirac equation inducing changes of the Weinberg angle describing Weinberg mixing.

5. The modified Dirac equation associated with Kähler-Chern-Simons action at the partonic orbit is analogous to the Dirac equation in a monopole field. For a homologically non-trivial geodesic sphere of CP_2 the situation is especially simple. The expectation is that the analogs of harmonic oscillator states in the magnetic field are obtained and they are localized at radii corresponding to Bohr orbit radii.

4.1 The earlier view of the Weinberg angle

I proposed in my thesis published 1982 a model predicting the value of the Weinberg angle assuming Weinberg mixing of the TGD counterparts of the U(1) gauge potential identified as as as multiple of Kähler gauge potential and B_3 component of $SU(2)_L$ gauge potential.

The basic formulas of the standard model are

$$\gamma = cos(\theta_W)B_0 + sin(\theta_W)B_3 \ , \quad Z^0 = -sin(\theta_W)B_0 + cos(\theta_W)B_3 \ . \tag{4.1}$$

The moldel determines the ratios of standard model couplings so that only the $U(1)$ coupling g_1 is free. In TGD it corresponds to Kähler coupling and its discrete spectrum would be determined by quantum criticality. The analogy of Kähler coupling strength with critical temperature is important since in TGD path integral is replaced by functional integral and the mathematical analogy with thermodynamics becomes strong.

In standard model one obtains conditions on the ration of coupling constants g_1, g, g_Z and e associated with the gauge potentials for $U(1)$, charged $SU(2)_L$ bosons ,Z_0 and γ.

$$\frac{g_1}{g} = tan(\theta_W) \quad \frac{g_Z}{g} = \frac{1}{cos(\theta_W)} \quad \frac{e}{g} = sin(\theta_W) \ . \tag{4.2}$$

In TGD the induced gauge potentials B_{ind} correspond to the standard model gauge potentials gB_{st}, where g is the corresponding coupling constant. The reason is that in the purely geometric approach it is not possible to identify the couplings g at the level of the action principle.

The induced gauge potentials are given by the formulas

$$g_1B_0 \leftrightarrow 3Be^3 = 6re^3 \ \ , \ \ gB_3 \leftrightarrow -sin(\theta_W)(2r+1/r)e^3 \ \ , \ \ e\gamma \leftrightarrow [(6-2sin^2(\theta_W))r - sin^2(\theta_W)/r]e^3 \ . \tag{4.3}$$

Note that one has the Kähler form is given by $J = dB$.

A little calculation demonstrates that these identifications imply the standard model relationships between the electroweak couplings so that CP_2 geometry indeed describes the Weinberg mixing.

In the thesis and also in [L5] led to the representation $\gamma = aX + bY$ and $Z^0 = Y - X$. The formula $Z^0 = -r + 1/r$ allows the identification of X and Y apart from an additive constant, i.e. the replacement $(Y, X) = (r, 1/r) \to (r + \Delta, 1/r + \Delta)$ is possible. γ is affected in this replacement: $\gamma = [(6-2p)r - p/r] \to [(6-2p)r - p/r] + (6-3p)\Delta$. The transformation does not affect the values of a and b but not the formula

$$sin^2(\theta_W) = \frac{3b}{2(a+b)} \ . \tag{4.4}$$

for the Weinberg angle in terms of a and b. A possible interpretation is in terms of a gauge transformations adding to the gauge potentia a constant term.

4.2 The model for the counterpart of the bosonic propagator

One must consider the analog of a bosonic propagator as a WCW correlation function.

1. Here the holography = holomorphy vision and the assumption that fermion vertices are associated with the intersections of the 3-D edges of the space-time surface with light-like partonic 3-surfaces. If the interaction is contact interaction then it is associated with the string world sheets as the intersection and it intersects partonic orbit along fermion line intersection partonic 2-surface at point.

2. The WCW counterpart of the gauge boson propagator must be studied and its ends correspond to two fermion vertices associated with to separate space-time edges. One can study either t-channel exchange or s-channel resonance.

3. The partonic 2-surface has a complex 2-surface of CP_2 as projection and a homologically non-trivial geodesic sphere corresponding to the lowest generation without topological mixing inducing CKM mixing is a natural simplifying assumption. For higher generations complex surfaces with higher genus are needed.

   It is natural to assign to the position of the fermion vertex (or by ZEO the position of the associated light-like fermion line) a wave function. The first guess was that it corresponds to the spinor harmonic at the CP_2 projection of the partonic 2-surface associated with the vertex. For a sphere S^2, the harmonics are powers of $z/\sqrt{1+r^2}$, $r^2 = z\overline{z}$ and its conjugate forming an SU(2) doublet. It turned out that this guess gave $sin^2(\theta_W) \equiv p > 1$.

   In the case of CP_2 one has a quark triplet and its conjugate. In the case of $S^2 = CP_1$ there would be doublets corresponding partial wave and its conjugate. The volume element of $S^2 = CP_1$ is $dA = dzd\overline{z}/(1+r^2)$.

4. These spinor harmonics have a maximum at $r = 1$ geodesic line of S^2 defining its equation, which corresponds to the equator. The equator is conformally invariant under the transformation $z \to 1/z$ and could play a special role concerning the calculation of boson propagators. Conformal invariance could determine to a high degree the massless bosonic propagators and coupling constants. On the other hand, the breaking of electroweak symmetries means breaking of conformal invariance.

5. What suggests itself is that the coupling constants involve from the averages of fermion wave functions at the fermion vertices determining in turn the bosonic correlation function. Preferred extremal property and holography = holomorphy principle are expected to give

rise to strong correlations between the two partonic 2-surfaces. In particular, they could have the same geodesic sphere of S^2 as CP_2 projection when the distance is below the weak scale.

6. The formulas needed in the estimate of the Weinberg angle are for gauge potentials appearing in γ and $Z^0 = R_0 2$

$$\begin{array}{ll} V_{03} = (r - \frac{1}{r})e^3 \ , & V_{12} = (2r + \frac{1}{r})e^3 \ , \\ B = 2re^3 \ , & \\ e^3 = \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ , & F = 1 + r^2 \ . \end{array} \quad (4.5)$$

r is the radius of $U(2)$ invariant 3-sphere S^3 of CP_2 and also corresponds to a radial coordinate for the homologically non-trivial geodesic sphere S^2.

7. The classical induced gauge fields γ and Z^0 are given by

$$\gamma = (3J - pR_{12}) \ , \quad Z = R_{03} \ . \quad (4.6)$$

For the corresponding gauge potentials one has using $J = dB$, $B = 2re^3$

$$\gamma = [(6r - p(2r + 1/r)]e^3 \ , \quad Z^0 = (r - 1/r)e^3 \ . \quad (4.7)$$

Here one has $s_W = sin(\theta_W)$ and e^3 is projected to the direction of the geodesic line of CP_2 connecting the end points of the fermion line. Also contraction of e^3 with CP_2 gamma matrices is involved

8. The correlator $\langle \gamma_1, Z_2^0 \rangle$ can be written as

$$\begin{array}{l} \langle \gamma_1, Z_2^0 \rangle \equiv \langle A, B \rangle \ , \\ Z^0 \equiv (r - 1/r)e^3 \ , \quad \gamma \equiv [(6 - 2p)r - p/r)]e^3. \end{array} \quad (4.8)$$

The correlation functions are symmetric under the exchange $1 \leftrightarrow 2$. Here A corresponds to the Z^0 boson field and B to the photon field γ. There is a symmetry under the exchange of indices "1" and "2".

4.3 The assumption that there is no correlation between spinorial wave functions of different partonic orbits

One can estimate the value of s_W explicitly if one makes the approximation that the correlation functions for bosonic fields reduce to products of spinorial averages. The assumption that there is no correlation between spinorial wave functions for the vertices involve implies that the correlation function $\langle \gamma, Z_0 \rangle$ reduces to a product $\langle \gamma \rangle \langle Z_0 \rangle$. The vanishing of the correlation would require that either $\langle \gamma \rangle$ or $\langle Z^0 \rangle$ vanishes.

The vanishing of $\langle \gamma \rangle$ could be also interpreted as a geometric counterpart for the statement that photon field corresponds to fluctuations around vanishing value of the classical gauge potential $\gamma = 6re^3 - p(2r + 1/r)$, $p = p$.

1. The vanishing of $\langle \gamma \rangle$ determines the value of the Weinberg angle:

$$p = \frac{6\langle r \rangle}{\langle 2r + 1/r \rangle} \ . \quad (4.9)$$

2. One can estimate the condition for the vanishing for spinor harmonics $\Psi_n = (r/(1+r^2)^{1/2})^n$. The outcome is that the value of p is larger than 1. The reason is that the moduli squared for fermionic wave functions approach the value 1 for large values of r.

3. The idea that one can consider is that there is approximate localisation of spinor waves for the position of the fermion vertex to a partonic 2-surface at $r = r_0$ and in this ground state classical photon field is vanishing: gamma=0. Assuming that expectations reduce to products, the vanishing of the correlation is obtained for $\gamma(r_0) = 0$

   This could be seen as the TGD counterpart of the idea that the photon gauge potential fluctuates around $\gamma = 0$. This might be an essential element of massivation since the condition is not true for other fields.

4. One obtains the following equivalent conditions

$$p \equiv sin^2(\theta_W) = \frac{3r_0}{r_0+1/r_0} \quad , \quad r_0 = \frac{p}{3-p} \quad . \tag{4.10}$$

   $p \leq 1$ gives the upper bound $r_0 \leq 1/2$. $p = .2315$ gives $r_0 = .0836$. In this scenario, spinor harmonics as a model for the vertex position are not a practical approach since they delocalize towards large values of r. One must have a superposition of harmonics given by destructive interference localization to small values of r.

5. There should be a localization to small values of r for which $B = 6r^2$ is small. Partonic 2-surfaces carried an analog of magnetic monopole field and this suggests that spinor harmonics could be analogous to harmonic oscillator wave functions in a magnetic field. Their identification as modes of the modified Dirac equation for light-like partonic orbits determined by Kähler-Chern-Simons-Kähler (K-C-S) action with coupling to the monopole magnetic field defined by the Kähler form at partonic 2-surface would be natural. The localization around say, to the radius corresponding to that for $n = 1$ Bohr orbit, could give the required localization and bring in the field strength as a parameter determining the Weinberg angle.

4.4 $sin^2(\theta_W)$ is larger than 1 for spinor modes $(z/\sqrt{1+r^2})^n$

The spinor modes $\Psi_n = (z/\sqrt{1+r^2})^n$ were the natural first guess for the wave functions for the the position of fermion vertex as an edge of the fermion line at geodesic sphere S^2 but are expected to yield values of $sin^2(\theta_W) \equiv p > 1$. The estimation of the expectation values is relatively straight forward and allows to see concretely why these spinor modes violate unitarity so that a physics inspired approach based on fermionic magnetic harmonic oscillator modes partonic 2-surface, implying a localization to small values of r, is plausible.

1. One must calculate the expectation values of re_3 *resp.* e_3/r. e_3 is proportional to factor $r/(1+r^2)$ so that this gives expectation value of $r^2/(1+r^2)$ *resp.* $1/(1+r^2)$. The area element dS of S^2 is proportional to $rdr/(1+r^2)^2$. Spinor harmonics are proportional to $r/\sqrt{1+r^2}$ so that the expectation value gives factor $r^2/(1+r^2)$.

2. For $n = 1$ harmonic, the expectation value of re_3 *resp.* e_3/r gives rise to a radial integral of $I_{5,4} = \int_0^\infty r^5/(1+r^2)^4$ *resp.* $I_{3,4} = \int_0^\infty r^3/(1+r^2)^4$. The normalization factor associated with the spinor harmonic gives a radial integral $I_{3,3} = \int_0^\infty r^3/(1+r^2)^3$.

3. In the general case, the integrals can be calculated by partial integration giving the recursion formula

$$\begin{aligned} I_{n,m} &= \frac{n-1}{2(m-1)} I_{n-2,m-1} \quad , \\ I_{1,m} &= \int \frac{r}{(1+r^2)^m} dr = \frac{1}{2(m-1)} \quad . \end{aligned} \tag{4.11}$$

   This gives

$$
\begin{aligned}
&I_{5,4} = (2/3)I_{3,3} = (2/3)(2/4)I_{1,2} = (2/3)(2/4)(1/2) = 1/6 \ , \\
&I_{3,4} = (1/3)I_{1,3} = 1/12 = I_{5,4}/2 \ , \\
&I_{3,3} = (1/2)I_{1,2} = 1/4 \ .
\end{aligned}
\tag{4.12}
$$

4. The expectation of $\langle B\rangle \leftrightarrow (r-1/r)e_3$ equals $I_{5,4} - I_{3,4} = 1/12$ and the expectation of $\langle A\rangle = (6-2p)r - 2p/r)e_3$ equals $(6-2p)I_{5,4} - 2pI_{3,4} = (6-2p)/6 - p/12$. The vanishing condition for $\langle\gamma\rangle$ gives $p = 12/5$ so that unitarity fails.

   For $n = 2$ similar calculation using using $I_{7,5} = (3/4)I_{5,4} = 3/24$ and $I_{5,5} = (1/2)I_{3,4} = 1/24$. The vanishing condition gives $p = 2 + 1/4$. Clearly, the value of Weinberg angle increases with the with n.

REFERENCES

Mathematics

Theoretical Physics

Particle and Nuclear Physics

Condensed Matter Physics

Cosmology and Astro-Physics

[E1] Shnoll SE et al. Realization of discrete fluctuations in macroscopic processes. *Physics-Uspekhi*, 41(10):1025–1035.

[E2] Shnoll SE et al. Experiments with rotating collimators cutting out pencil of α-particle at radiactive decay of ^{239}Pu evidence sharp anisotropy of space. *Progr Phys*, pages 81–83, 2005. Available at: https://www.ptep-online.com/index_files/2005/PP-01-11.PDF.

[E3] Shnoll SE et al. Fine structure of histograms of alpha-activity measurements depends on direction of alpha particles flow and the Earth rotation: experiments with collimators, 2008. Available at: https://www.cifa-icef.org/shnoll.pdf.

[E4] Shnoll SE Panchelyuga VA. On the Dependence of a Local-Time Effect on Spatial Direction. *Progr Phys*, pages 51–54, 2007. Available at: https://www.ptep-online.com/index_files/2007/PP-10-11.PDF.

[E5] Shnoll SE Panchelyuga VA. On the Dependence of a Local-Time Effect on Moving Sources of Fluctuations. *Progr Phys*, pages 55–56, 2007. Available at: https://www.ptep-online.com/index_files/2007/PP-10-12.PDF.

[E6] Panchelyuga VA Shnoll SE. The Palindrome effect. *Progr Phys*, 2:151–153, 2008. Available at: https://www.ptep-online.com/index_files/2008/PP-13-20.PDF.

Physics of Earth

Fringe Physics

Biology

Neuroscience and Consciousness

Books related to TGD

[K1] Pitkänen M. *Topological Geometrodynamics.* 1983. Thesis in Helsinki University 1983.

[K2] Pitkänen M. Construction of elementary particle vacuum functionals. In *p-Adic Physics.* *https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/elvafu.pdf, 2023.

Articles about TGD

[L1] Pitkänen M. Topological Geometrodynamics. *Int J Theor Phys*, 22(7), 1983.

[L2] Pitkänen M. Copenhagen interpretation dead: long live ZEO based quantum measurement theory! Available at: https://tgdtheory.fi/public_html/articles/Bohrdead.pdf., 2019.

[L3] Pitkänen M. Holography and Hamilton-Jacobi Structure as 4-D generalization of 2-D complex structure. https://tgdtheory.fi/public_html/articles/HJ.pdf., 2023.

[L4] Pitkänen M. New result about causal diamonds from the TGD view point of view. https://tgdtheory.fi/public_html/articles/CDconformal.pdf., 2023.

[L5] Pitkänen M. Reduction of standard model structure to CP_2 geometry and other key ideas of TGD. https://tgdtheory.fi/public_html/articles/cp2etc.pdf., 2023.

[L6] Pitkänen M. Shnoll effect decade later. https://tgdtheory.fi/public_html/articles/ShnollTGD.pdf., 2023.

[L7] Pitkänen M. Comparing the S-matrix descriptions of fundamental interactions provided by standard model and TGD. https://tgdtheory.fi/public_html/articles/hadroQCDTGD.pdf., 2025.

[L8] Pitkänen M. Allais effect again. 2026. Available at: https://tgdtheory.fi/public_html/articles/Allaisagain.pdf. .