

Could large language models be useful in theory development?

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Abstract

This paper presents an analysis of OpenAI's O3 language model to assess its capacity for reasoning about the non-mainstream framework of Topological Geometrodynamics (TGD). Through a series of prompts in a single, continuous session, we evaluated the model's ability to explain core TGD concepts. Our findings reveal several systematic pitfalls in the model's reasoning, including a strong bias towards mainstream physics, hallucination of mathematical formulas and citations, and a fragmented understanding of foundational principles. Despite these significant failures, the exercise proved beneficial. The process of correcting the model's errors forced to study the earlier views in more detail and allowed to fill in the details in some earlier views. We conclude that while current large language models are not reliable authorities for specialized technical claims, they can serve as valuable, interactive tools for getting bird's eye of view of a theoretical structures involving large number of evolving ideas, provided their outputs are subject to deep expert scrutiny.

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1 Introduction

OpenAI's flagship ChatGPT O3 model (GPT in the sequel, see this)—used here through the standard ChatGPT web interface—underpins the research presented in this paper. All questions were prompted in a single continuous session by Marko Manminen (see this) so that the model's internal chain-of-thought engine could preserve context and build upon earlier reasoning steps. Whenever its pre-training knowledge proved insufficient, GPT launched its integrated browser to retrieve citable sources and anchor each claim in publicly available data.

The first goal was to see how realistic answers GPT can give nowadays compared to the answers we got two and half years ago, when ChatGPT 3.5 was released. At that time, there was not much to report since the language models were at their early age without grounding. The second goal was to see whether GPT could be useful from the point of view of TGD. Notably, the TGD view of physics as number theory was not considered in this investigation as we thought it would definitely be too hard for any meaningful inference.

7 prompts were used. The first 3 prompts were questions related to the basic mathematical notions of TGD [L21, L22] in the physics as geometry vision.

1. Explain in detail how the $M^4 \times CP_2$ geometry is induced to the spacetime surface in TGD and how the field equations are solved?
2. What does the holography= holomorphy (H-H) hypothesis mean in TGD?
3. What do induced geometry and induced spinor structure mean? What does the Dirac equation mean in TGD (use the latest material)

There were also 2 prompts related to the relation of TGD to other theories.

1. How does TGD differ from general relativity? How do TGD-inspired cosmology and astrophysics differ from what GRT predicts?
2. How does the particle physics predicted by TGD differ from that predicted by the Standard Model?

The last 2 prompts asked for criticism and tests of TGD and whether this kind of tests have been already carried out.

1. How should we stress test and attack this concept, be sceptic about?
2. Which of those tests have been already carried out?

Having laid out the questions that guided our inquiry, we now turn to the analysis of the session's outcome. Before dissecting the responses to each specific prompt, it is essential to first provide a high-level overview of the model's performance. The following subsections establish this necessary context. We will begin by examining the foundational problem of GPT's conditioning in mainstream physics (Section 1.1), followed by a summary of its most significant basic mistakes and misunderstandings (Section 1.2). Finally, we will reflect on whether the analysis was ultimately useful from the TGD viewpoint, considering the new questions and research directions it inspired (Section 1.3). This preliminary analysis will frame the detailed critiques that follow.

1.1 Conditionings of GPT as the basic problem

The key problem is that GPT's education reflects the attitudinal climate of the recent day physics. In the last 2 prompts GPT returned to the mental landscape of the standard particle physicist and cosmologist.

1. The basic attitude of particle physicists is that physics progresses in infinitesimal leaps and everything is just calculation. Philosophy is seen as something very suspicious and to be avoided.
2. In this intellectual landscape, the basic dogmas are not challenged. Planck length-scale reductionism is taken as such, the fundamental problem of quantum measurement theory is swept under the rug, and physicalism is assumed. The geometrization according to general relativity is accepted despite its problems.

The key attitude of TGD approach is to challenge the basic dogmatics and to continue the pondering the basic philosophical problems of physics known for a century: for Einstein and his temporaries this was very natural. Furthermore, ad hoc assumptions are practically always wrong and one must proceed as a mathematician and philosopher than by adding new parameters to the fit. It is pointless to start doing massive numerical calculations before one really understands the theory. Now the time is starting to be ripe for concrete calculations in the TGD framework but this would require a collective effort. My sincere hope is that LLMs could help here as data gatherers.

For these reasons, the criticism of GPT was not very useful. The conclusions on which the criticism was based were often wrong because they were based on the interpretations and guesses of the standard physicist. On the other hand, the criticism serves as a counterpart for the lacking criticism by colleagues who still refuse to talk about TGD. GPT with all its failures and misunderstandings could provide an excellent simulation of a mainstream colleague.

1.2 Basic mistakes of GPT

The earlier experience with LLMs has been that the answers are polite and do not contain obvious mistakes as long as one does not go to details.

At this time the reactions to the first 3 prompts did not contain fatal errors and even created the impression that GPT understands H-H and ZEO to some extent.

1. In the first prompt, the minimal surface equation as understood by GPT contained an elementary error spoiling its general coordinate invariance. When the question is too detailed, LLMs start to fabricate.
2. The detailed explanations for how the field equations emerge, contained several misunderstandings.
3. GPT had misunderstood how Einstein's equations are obtained in long length scales. Averaging over CP_2 degrees of freedom is not in question. Many-sheeted space-time is in the key role: the contributions to the induced geometric quantities from various space-time sheets are summed and this give the GRT metric and gauge fields of the standard model as effective metric replacing that of M^4 . Almost all information about the space-time topology is lost at this limit.

The reactions to the last two prompts asking for critics, reflected the conditionings produced by the learning process. It became clear GPT does really understand H-H and ZEO. GPT saw TGD as a particular QFT and this led to several fatal mis-interpretations.

It is useful to list the basic mistakes and misunderstandings of GPT as a warning for anyone who wants a rapid summary of TGD to decide whether to take it or leave it.

1. Cosmic strings of TGD were identified as strings of GUTs (see this and this) that have been abandoned long ago. If the identification were correct, one could forget the entire TGD-based cosmology and astrophysics.

In TGD cosmic strings [?, K16, K8] [L18, L11, L12] are space-time surfaces, which look like strings since they have a 2-D M^4 projection. They carry monopole flux and do not decay mostly to gravitons as the cosmic strings of GUTs which are genuinely 1-D defects. The cosmic strings of TGD dominate in the primordial period and are unstable against the thickening of the 2-D M^4 projection decay reducing the string tension. The generation of thickened tangles along long cosmic strings implies their decay to ordinary matter [L19, L18], somewhat analogous to that of inflaton fields, and produces galaxies and stars in this process. The hierarchy of effective Planck constants implies that no exponential expansion is required. Cosmic strings explain the galactic dark matter. TGD cosmic strings lead to a view of cosmic evolution differing dramatically from the standard view. This GPT failed to realize.

2. GPT failed to realize that from the holography=holomorphism (H-H) vision [L28, L17, L24] involving the notion of Hamilton-Jacobi (H-J) structure [L9, L25, L26] and leading to the algebraization of field equations follows in an extremely simple way. GPT also saw H-H suspicious philosophizing, even though it only generalizes what is done in string models, and more generally, in complex analysis. H-H is also extremely predictive. H-H has also a profound analogy to the twistor Grassmann approach [B1, B2] in which the cuts of the scattering amplitudes dictate the amplitudes: this is holography= holomorphy in the context of scattering amplitudes.

The safest way to solve field equations is by Wick rotation [L28] taking M^4 to E^4 , solving the algebraic field equations, and returning back to M^4 by Wick rotation: this is necessary in the regions of the space-time with an Euclidean signature of the induced metric, where hypercomplex coordinate is a dynamical variable.

3. GPT failed to notice that H-H allows us to get rid of the path integral and the divergences associated with it and treated TGD as a one particular QFT. The reduction of dynamics to that for space-time surfaces induced from static geometric structures of H solves myriads of other problems such as gauge anomalies.
4. Zero energy ontology (ZEO) [L4, L10], forced by H-H, solves the quantum measurement problem. GPT seemed to have a gist about what this means but did not like this because it involves philosophical thinking! The problem was solved but in a wrong way!
5. GPT did not realize that Einstein's gravitational theory follows at the field theory limit of TGD [L21, L22] and not at the fundamental level.
6. The reactions of GPT to question how to test TGD was rather unrealistic. GPT seems to think that TGD is one particular model adding some new particles to the standard model so that the challenge would be the calculation of the predicted effects using existing computational machinery. Nothing could be farther from the truth.

1.3 Was the analysis of GPT responses useful from the TGD viewpoint?

The detailed analysis of the GPT responses was technically rather painstaking but forced to poke around earlier writings. This created interaction between the already existing ideas with the new ideas inspired by the work with H-H [L27, L28] and Dirac equations in H and X^4 [L26, L25], and construction of interaction vertices [L23].

1.3.1 Three kinds of questions related to the interpretation of TGD

The analysis created three kinds of questions related to the interpretation of TGD.

1. The idea [L28, L25] about the phase transition between phases described in terms of Dirac equation in H *resp.* X^4 as a generalization of the notion of the deconfinement phase transition *resp.* hadronization replaces the QCD type description with a stringy description in which the intersection of the space-time surfaces of colliding particles consisting of 2-D string worlds sheets determines the scattering amplitudes. In ZEO, this phase transition would involve two "big" state function reductions reversing the arrow of time and the time.
2. From the beginning it has been clear that color $SU(3)$ is isometry group rather than gauge group and that its subgroup $U(2)$ identifiable as a holonomy group acting on H spinors corresponds to a gauge group. The very definition of CP_2 as coset space states this geometrically.
 - (a) Could this mean the reduction of color confinement at the level of spinor quantum numbers to $SU(2)_L$ confinement [L29]? Photons would not be confined, or screened by the pairs of right- and left handed neutrinos screening also the color of leptonic color partial waves [L25].
 - (b) Gluons do not appear as couplings of H spinors. Do gluons exist at all and is the identification of classical gluons as projections of Killing vectors wrong? Or do gluons correspond to electroweak gauge potentials in CP_2 spin degrees of freedom and would therefore correspond to electroweak interactions? But is this consistent with the fact that strong interactions are indeed strong?
3. A further stimulus came from the claim of GPT that already the existing data excludes copies of hadron physics labelled by Mersenne primes and their Gaussian variants. Is this really the case and are the earlier indications about bumps [K9, K10] wrong?
 - (a) Under what conditions does the phase transition between M_{107} and M_{89} hadron physics occur with a significant rate?
 - (b) Is quantum criticality, forcing the Compton scales of ordinary hadrons and dark M_{89} hadrons to be identical, necessary? This is indeed assumed in the model for the bumps as M_{89} mesons reported at LHC. If so, the transition from M_{107} H phase to X^4 phase would occur in the first BSFR and the transition from the X^4 phases to X^4 phase to M_{89} H phase would take place in the second BSFR.
 Just as in TGD inspired biology, the increase of the h_{eff} by factor 512 would require "metabolic" energy feed increasing the quark energies proportional to h_{eff} by this factor. This energy would come from the collision energy of colliding heavy nuclei. The decay of M_{89} hadrons to M_{107} hadrons would occur spontaneously. This kind of decay at the surfaces of the Sun is proposed to be responsible for the generation of solar wind and solar energy [L20].
 - (c) Is the assumption about the labelling of scaled variants of hadron physics by nuclear p-adic length scales too restricted since hadrons (say pions) are labelled also by other p-adic length scales than that of nucleon?
 - (d) Could the hierarchy of hadron physics correspond to the hierarchy color representations for quarks and leptons in 1-1 correspondence and labelled by single integer k appearing in the solution spectrum of the Dirac equation in H [L26, L25]. If so, hadrons and leptons for a given value of k would correspond to several p-adic primes?

1.3.2 Progress in the understanding TGD view of the relation between electroweak and strong interactions

TGD view predicts at the fundamental level strong correlations between electroweak, strong interactions and gravitational interactions. But the precise understanding of these correlations has developed rather slowly. The writing of the comments to the GPT prompts was a rather exhaustive process but it was not a waste of time. It led to considerable progress in this respect.

Gluon couplings do not appear in Dirac equations and in [L23] the possibility that there are no gluon vertices at the fundamental level was discussed so that somehow electroweak couplings also describe strong interactions. The recent general view of interactions allows to make these considerations much more detailed.

1. Also for X^4 Dirac equation one obtains quark color and it would naturally correspond to conformal modes proportional to $(\xi_1, \xi_2, 1)$ possible for the induced Dirac equation and perhaps having interpretation as reduction of color triplet to $U(2)$ doublet plus singlet. The triplet corresponds to different coordinate patches of CP_2 to which the three Z_3 poles can be assigned. Therefore one obtains annihilation to quark pairs in this sense. Conformal invariance could make higher modes gauge degrees of freedom.
2. As noticed, a long standing puzzle has been the fact that electroweak $U(2)$ has a holonomy group of CP_2 is the maximal compact subgroup of $SU(3)$. Could one see electroweak interactions as an aspect of color interactions or vice versa? Could one say that there is a symmetry breaking reducing isometry group $SU(3)$ to its subgroup $U(2)$ identifiable as holonomy group and an electroweak gauge group? Could $CP_2 = SU(3)/U(2)$ realize the gauge group nature of $U(2)$ geometrically.

Could the proposed electroweak confinement by the pairs of left and right-handed neutrinos [L25] screening the weak isospin correspond to $SU(2)_L \subset SU(3)$ confinement in spin degrees of freedom. There would be no color confinement for photons associated with $U(1)$. Full color confinement would take place for the light states formed from the H spinor modes.

3. Why are strong interactions strong? The annihilation rate to quark pairs by the proposed vertices is sum of three pairs and the rate is 9 times higher than for the annihilation to leptons. The electroweak coupling strength is of order $\alpha_{em} = 1/137$ so that the rate for quark pair production corresponds to $\alpha_s = 9\alpha_{em} \sim .1$. This would give a correct order of magnitude estimate!
4. Old-fashioned hadron physics talked about conserved vector currents (CVC) and partially conserved axial currents (PCAC). These notions emerged from the observations that hadronic reaction rates can be expressed in terms of correlations of electroweak currents. This raises the question whether strong interactions could reduce to electroweak interactions in some sense [K21].
5. What happens to the scaled up variants of hadron and electroweak physics if strong and electroweak physics fuse to whatever one might call it (unified physics)? The only way to understand why the range of strong interactions is given by the hadronic length scale is that strong interactions would correspond to electroweak interactions in p-adic length scales, which correspond to hadrons and possibly also quarks. Weak bosons should correspond to a much longer Compton scale.

Nucleons would correspond to the p-adic length scale $L(107)$ and pions to $M(113)$. The original view of weak bosons was that weak interactions correspond to the scale $L(89)$ corresponding to Mersenne prime. Weak boson mass scales turned out to correspond to $L(91)$

However, the original view is rather attractive and would fit with the view that M_{89} hadron physics fuses with ordinary electroweak physics and several p-adic length scales are involved with a given copy. The copies of this unified physics in turn could correspond to color partial waves for Dirac equation in H .

Electro-weak bosons would be special kinds of mesons in the sense that they are superpositions of both quark and lepton pairs. Photon would be even more special in that $SU(2) \subset SU(3)$ confinement would not apply to it because $U(1)$ is abelian.

The scaling hypothesis, stating that the mass scales of mesons are scaled by a factor 512 in the transition $M_{107} \rightarrow M_{89}$, is probably too strong but gives testable predictions to start with.

1. One key question concerns the M_{107} counterparts of weak bosons. They would correspond to genus $g = 0$ (u and d quarks). A naive scaling of masses by factor $1/512$ would give a mass scale near 500 MeV. There is no report about the observation of these bosons.

For ρ meson the mass scale without QCD hyperfinite splitting induced by color magnetism is around 500 MeV. Are these weak bosons separate from ρ assumed to involve only quark pairs or do they correspond to ρ ? For the latter option their decays to leptons should reveal this.

2. What about pseudoscalar π accompanying ρ ? Standard model does not predict pseudoscalar electroweak boson. Its counterpart for M_{89} should exist. Evidence is reported for the existence of a pseudoscalar at the intermediate boson mass scale. For $k = 113$, assignable to the Mersenne prime of the nucleus, one obtains the mass estimate 6.3 MeV. There is strong evidence for X-boson [?] with mass around 16-17 MeV and I have considered the interpretation as a weak boson. There is also Ytterbium anomaly which could have the same explanation [?] and Calcium anomaly [?] related to the difference of atomic energy levels of different isotopes of Ca. These anomalies are discussed from the TGD view point in [L3] [K11].
3. What about M_{107} counterpart of Higgs scalar with mass of 125 GeV? By a naive scaling, it should have mass about 250 MeV. There are many candidates for scalar mesons (see this) but they have masses above the mass 500 MeV of sigma boson whose existence is still not confirmed. σ is a very broad Breit-Wigner type resonance, which does not support interpretation as a scaled down Higgs boson. For $k = 113$ the mass should be around 31 MeV, about twice the mass for X boson.

2 Prompt 1: Explain in detail how the $M^4 \times CP_2$ geometry is induced to the spacetime surface in TGD and how the field equations are solved?

[GPT]

Topological Geometrophysics (TGD) treats each physical space-time as a four-dimensional surface X^4 living inside the eight dimensional embedding space $H = M^4 \times CP_2$. The factor M^4 stores familiar Minkowski physics while the compact complex manifold $CP_2 = SU(3)/U(2)$ encodes colour, weak and electromagnetic symmetries. Each point of X^4 has 4-D space-time coordinates and is parametrized by H coordinates. By general coordinate invariance it is possible to select four H -coordinates as coordinates for X^4 .

Because the dynamics follows from a single variational principle, the twistor-lifted Kähler-plus-volume action preferred 4-surfaces automatically reproduce Einstein-like gravity, Yang Mills gauge fields and Dirac spinors without inserting them by hand.

[MP] This statement is not quite correct and should be replaced by the following statement. The twistor-lift of TGD replacing space-time surfaces X^4 with their twistor spaces obtained by inducing twistor structure from the product $T(M^4) \times T(CP_2)$ of twistor spaces of M^4 and CP_2 to X^6 . The dynamics follows from a single variational principle for the 6-D Kähler action and the dimensional reduction produces space-time surfaces as preferred extremals of 4-D Kähler action plus volume action. Since only M^4 and CP_2 allow twistor spaces with Kähler structure, TGD is unique [A1]. These are not the Einstein-Yang-Mills equations: they follow at the quantum field theory limit in long length scales as a remnant of Poincaré symmetry when many-sheeted space-time is replaced with a deformed M^4 . There are no primary boson fields, only free, second quantized spinors fields in H .

2.1 Basic notions

[MP] GPT explains rather nicely the basics in 4 sections with titles "How Geometry of the embedding space $H = M^4 \times CP_2$ ", "From 8-D to 4-D: projective anatomy of a space-time surface", "Action Principle", "Euler-Lagrange field equations".

2.2 Geometry of the embedding space $H = M^4 \times CP_2$

[GPT]

- (a) Exact Poincare symmetry. Selecting M^4 as a factor restores global translations and boosts that are lost in generic curved 4-geometries. TGD thus sidesteps the energy-momentum ambiguity of GR.
- (b) Internal quantum numbers from CP_2 . Killing vectors of the Fubini-Study metric and spinor connection project to classical colour and electroweak gauge fields; conserved chiralities of H-spinor chiralities correspond to leptons and quarks.

2.3 From 8-D to 4-D: projective anatomy of a space-time surface

[GPT]

Write local coordinates x^α on X^4 , m^k on M^4 , and s^k on CP_2 combined to $h^k = (m^k, s^k)$ for H . The embedding $X^4 \subset H$ supplies functions $h^k(m^l)$

The dimension D_{M^4} of the M^4 projection and the dimension $D(CP_2)$ of the CP_2 projection matter.

- (a) $D(CP_2) = 0$ corresponds to vacuum sheets for pure Kähler action. $D(CP_2) < 4$ supports non-trivial gauge fluxes.

[MP] It is not clear to me what non-trivial gauge fluxes does mean. What is clear is that the Lorenz force and instanton current for Kähler form vanishes in this case.

- (b) $D(M^4)$ determines local causal type (Euclidean, Minkowskian, light-like) and the effective gravitational metric.

[MP] $D(M^4) = 4$ corresponds to Einsteinian space-time. $D(M^4) = 2$ to cosmic strings in the TGD sense. $D(M^4) = 1$ corresponds to CP_2 type extremals representing wormhole contacts and isometric to CP_2 itself. The induced metric is Euclidean.

[GPT] Because the induced metric $g_{\alpha\beta} = h_{kl}\partial_\alpha\partial_\beta h^l$ inherits both factors, the shape of the CP_2 projection controls how standard-model charges move in space-time.

2.4 Action principle: Kähler + volume

[GPT]

TGD's classical action on X^4 is $S[X] = \frac{1}{4\pi\alpha_K} \int_{X^4} J \wedge *J + \Lambda \int_{X^4} d^4V$, where J is the induced Kähler 2-form pulled back from CP_2 . The first term is analogous to a Maxwell action for $U(1)_K$ which corresponds to electroweak $U(1)_Y$, while the second is a cosmological volume term fixed by twistor lifting.

Critical aside: the relative strength α_K/Λ is not arbitrary; demanding that cosmic strings remain tension-less at long scales ties Λ to the p-adic length hierarchy.

[MP]

- (a) This action follows by a dimensional reduction from 6-D Kähler action for the twistor lift of TGD [?, K13]. H-H however gives minimal surface equations for any general coordinate invariant action principle expressible in terms of the induced field quantities. An interesting question is whether various actions, maybe 6-D Kähler action with varying Kähler coupling strength but quantum critical, could allow to parametrize number theoretic coupling constant evolution, which is expected to reduce to number theory.
- (b) If M^4 is endowed with Kähler structure, one has two options. The sum of the Kähler gauge potentials of M^4 and CP_2 appears in the Kähler action or the two gauge potentials define their own Kähler actions. It is not quite clear, which option is the correct one since the effect of M^4 Kähler gauge potential at fermion lines is extremely small [L28].

2.5 Euler-Lagrange equations and "preferred extremals"

[GPT]

Varying the embedding coordinates yields three intertwined conditions:

GPT Minimal-surface (volume) equation $\square h^k + \Gamma_{lm}^k \partial_\alpha h^k \partial_\beta h^l = 0$ For $J = 0$ it reduces to the usual mean-curvature-zero condition, so vacuum sheets are true minimal surfaces.

[MP]

- i. The formula for the minimal surface equation is wrong. If one drops the connection terms and defines d'Alembertian as it is usually defined, the formula is correct and breaks general coordinate invariance. A detailed explanation for what the d'Alembertian means for sub-manifolds would be needed.
- ii. $J = 0$ condition indeed reduces the equations to minimal surfaces equations. If Kähler current vanishes, one obtains $\text{Trace}(TH^k) = 0$ where H^k is the second fundamental form and T is the energy momentum tensor for Kähler field. For the known extremals Kähler current can be light-like since its contraction with light-like vector vanishes.

GPT Kähler current conservation $D_\alpha J^{\alpha\beta} = 0$ and vanishing Lorentz force $J^{\alpha\beta} J_{\beta\gamma} = 0$. The latter is equivalent to the Beltrami type constraint. $J \propto \Psi \epsilon_{\alpha\beta\gamma\delta} \partial_\alpha h^k \partial_\beta h^l$

[MP] Both these formulas are wrong.

- i. The first formula says Kähler current is vanishing. Actually it can be light-like. Kähler current is automatically conserved.
- ii. The Beltrami type constraint is not given correctly. Beltrami type constraint guarantees a vanishing dissipation and reads as $j^\alpha J_{\alpha\beta} = 0$. If J is scalar function times its dual $*J$ and the dimension of CP_2 projection is smaller than 4, there is no dissipation since the instanton density $J \wedge J$ vanishes.

GPT Compatibility (Einstein Maxwell analogue). The induced energy-momentum of J must be orthogonal to the second fundamental form; in practice this collapses the PDE system to algebraic constraints on the gradients of embedding functions a striking integrability hint. Besides this Kähler current must be light-like.

[MP] This is not quite correct. Equations contain also a second term involving the contraction of the Kähler current. This contraction vanishes for the known extremals. H-H implies a separate vanishing of both terms.

- (a) Surfaces meeting a these conditions are dubbed preferred extremals. They exhaust classical solutions in zero-energy ontology.

[MP]

GPT does not mention the motivation for preferred extremals, that is holography. The notion of WCW geometry in its original form postulated that the space of 3-surfaces is the configuration space. In order to realize 4-D general coordinate invariance, to obtain classical theory, and to identify Kähler function of defining the WCW geometry as a classical action, one must assign to the 3-surface 4-surface, which is highly unique. This means holography.

It turned out that the holography is slightly non-deterministic (2-D minimal surfaces are non-deterministic in the sense that the same frame spans several soap films). This forces ZEO meaning that 4-surfaces analogous to Bohr orbits become basic objects. The additional, presumably discrete degrees of freedom would be geometric correlates for cognition. This non-determinism would correspond to p-adic non-determinism. The known extremals are minimal surfaces and this could be seen as a motivation for the H-H.

2.6 How standard field equations emerge

2.6.1 Gravitational sector

[GPT]

For long wavelengths one averages over the tiny CP_2 radius. The resulting Einstein tensor G equals the Kähler energy-momentum up to the tiny Λ term; thus preferred extremals satisfy an effective Einstein equation.

[MP] GPT misunderstood how Einstein's equations are obtained in long length scales. Averaging over CP_2 not in question.

- (a) Einstein's equations follow at the quantum field theory limit in long length scales, not at the fundamental level.

The argument for Einstein's equations at QFT in long scales is simple: Poincare invariance is exact at the fundamental level. At the long length scale limit, the replacement of the many-sheeted space-time with Einsteinian space-time identified as slightly curved Minkowski space carrying various fields as sums of induced fields does not have Poincare symmetries anymore. Einstein's equations realize Equivalence Principle as a remnant of Poincare invariance.

- (b) TGD predicts however much more than GRT. The Einsteinian space-time assignable to space-time surfaces with a 4-D M^4 projection is only a special case. Cosmic strings, which are 4-dimensional surfaces and monopole flux tubes are especially important predictions. For cosmic strings M^4 projection is 2-D string world sheet. They dominate the early cosmology, and they are crucial for the formation of galaxies, stars and planets and they explain galactic dark matter. In these fields of cosmology and astrophysics GRT picture has now failed. Cosmic strings would decay to ordinary matter in a process analogous to the decay of inflaton fields.

2.6.2 Gauge and Higgs sector

[GPT]

Projecting the CP_2 isometry connection gives $SU(3) \times SU(2) \times U(1)$ gauge potentials whose curls coincide with components of J . Because $D_\alpha J^{\alpha\beta} = 0$, the resulting Yang Mills equations hold identically on X^4 .

[MP] This is not quite true.

- (a) The vierbein/spinor connection of CP_2 corresponds to electroweak gauge potentials. Color gauge potentials are identified as projections of Killing vectors of $SU(3)$.
- (b) The divergence $D_\alpha J^{\alpha\beta} = 0$ need not vanish but can be a light-like vector field which is contracted in field equations with a light-like vector so that light-like Kähler currents and also other classical electroweak gauge and color gauge currents are possible. The physical interpretation is as classical lightlike gauge currents assignable to massless fermions serving as the source of the induced YM fields.

This picture conforms completely in H-H, which implies that the field equations are satisfied irrespective of the details of the action as long as it is general coordinate invariant and expressible in terms of the induced geometry. Physics outside the partonic orbits and possible boundaries of the space-time surface would be to a high degree universal.

[MP]

GPT did not mention Higgs at all.

- (a) In TGD, the natural candidate for the Higgs field is the second fundamental form which is the H-vector field with both M^4 and CP_2 parts. By H-H, it vanishes field equations outside the partonic orbits and possible boundaries, where the boundary conditions for the action do not allow minimal surface property and a delta function like singularity is generated coupling the canonical momentum currents for the volume and Kähler parts together.

- (b) The generalized Higgs, which is an 8-D vector field rather than scalar (the scalar property would violate separate conservation of baryon and lepton numbers) [L23, L22], would be located at the singularities, just where it is needed. The extreme option suggested by the recent view of scattering amplitudes is that it is located at fermionic vertices at which the boundary of a string world sheet has an edge.
- (c) The M^4 and CP_2 parts of the trace of the second fundamental form represent 8-D acceleration infinite at the vertex [L23] and the proposal is that this could define the gravitational and Higgs vertices at the level of fermion lines. The edge of the fermion line implies a discontinuity of the partial derivatives of the embedding space coordinates so that a delta function singularity is generated and is proportional to the discontinuities of the derivative of the tangent vector of the fermion line.
- (d) What about the remaining vertices? The divergence of the fermion current serves as a natural representation of the anomaly and is non-vanishing at the edge. This would give the electroweak interaction vertices besides gravitational and Higgs vertices but there would be no gluon vertices! The implications of this will be discussed in detail later.

2.6.3 Fermionic sector

[GPT]

A single 8-D massless Dirac equation on H pulls back to two equations on X^4 : one for embedding-space spinors (external states) and one for induced spinors (internal modes). In matching M^4 and CP_2 spectra enforces lepton quark charge differences and integer (or tachyonic) mass squares. Spectra enforces lepton quark charge differences and integer (or tachyonic) mass squares.

[MP] There are Dirac equations associated with H and X^4 and also with WCW.

- (a) The first one is the 8-D Dirac massless (in 8-D sense!) equation for free quark-like and leptonic spinor fields in H . There are two options M^4 with trivial [L26] or non-trivial Kähler structure. The latter option [L25] predicts color confinement since the colored modes (infinite number of them) have CP_2 mass scale. Color singlet states as many-quark states however have vanishing ground states M^4 mass if mass squared is additive and single fermion states are allowed to have also negative M^4 mass squared. p-Adic thermodynamics generates them a small mass [L7]. Each representation of SU(3) defining color partial waves can in principle give rise to a copy of hadron and lepton physics.
- (b) The second one is the 4-D massless Dirac equation for the induced spinor fields X^4 for the restrictions of H s spinor fields to X^4 involving induced or modified gamma matrices. The oscillator operators for X^4 spinor fields can be expressed in terms of those for H spinor fields so that the dynamics is induced by the projection. The solution of the induced/modified Dirac equation universally reduces to holomorphy if H-H is true.
- (c) The induction procedure has an interpretation in terms of quantum measurement theory. At the level of state space, the projection to X^4 corresponds to a projection to sub-state space defining quantum measurement. The projection would be induced by an observer of a particle reaction as interaction of space-time surfaces representing particles. In a non-trivial interaction the space-time surfaces have the same H-J structure so that they have a 2-D intersection consisting of string world sheets [L27]. Otherwise it would consist of discrete points.

2.6.4 Critiques and open questions

[GPT]

- (a) Exact solvability? Many preferred extremals are known analytically (string-like, Robertson-Walker, static spherically symmetric), but a fully general classification is still conjectural. The reduction to algebraic conditions is promising yet unproven.

- (b) Role of the Kähler coupling. Running of α_K with p-adic scale is required by cosmology, but no renormalization-group derivation exists. Whether this spoils integrability remains unclear.
- (c) Lorentz symmetry breaking. The twistor lift introduces a tiny M^4 Kähler form, nominally breaking boosts; global wave-functions over the causal-diamond moduli allegedly restore invariance, but the mechanism deserves closer scrutiny.

[MP]

- (a) The physicists proof for the reduction of field equations to algebraic conditions is extremely simple 2-line proof if H-H is accepted. What is involved is a generalization of complex structure to H-J structure so that hypercomplex structure of the Minkowskian subspaces of M^2 and E^2 are locally given hypercomplex and complex structures. The solution of field equations requires for some regions of the space-time surface Wick rotation from hypercomplex M^2 to to complex E^2 and back. Euclidian CP_2 type extremals correspond to this kind of situation.
- (b) In TGD, the continous coupling constant evolution defined by a renormalization group is replaced with a discrete number theoretic evolution. For each extension of rationals defined the coefficients of polynomials (f_1, f_2) of generalized complex coordinates of H [L17, L24], the coupling constant is critical and therefore does not run. This criticality is analogous to thermal criticality and generalized conformal invariance is its mathematical correlate. This has important implications since there are no loops: this conforms with the fact that path integral disappears thanks to H-H.
- (c) M^4 Kähler form is consistent with the Minkowski metric but induces a breaking of Lorentz invariance. H-J structure [L9] as a generalized complex and Kähler structure realizes this breaking. M^4 Kähler form introduces extremely small effects at the level of fermions. There are many motivations for its introduction. Also in QCD the hadrons are described by decomposing degrees of freedom to longitudinal and transversal ones. Same is true in Yang-Mills theories. Byt the basic positive outcome is color confinement for physical states.
- (d) An interesting question is whether M^4 Kähler structure in cosmic scales could break cosmological principle by introducing a preferred rotation axes. It could also serve as a geometric correlate for a local quantization axis of angular momentum.

2.6.5 Takeway

[GPT]

Embedding projections in $M^4 \times CP_2$ are not decorative: they are the fields. By demanding that a 4-surface simultaneously minimises volume and conserves the induced Kähler current, TGD generates gravitational, gauge and fermionic equations in one stroke. The price is conceptual: space-time becomes a living sheet weaving through an 8-D arena whose internal directions store the standard model. Whether this bravely geometric programme is the final word or a sophisticated mirage hinges on proving that every physical solution is a preferred extremal and on confronting the hard phenomenology that follows. Skepticism is still warranted, but the mathematical elegance is hard to dismiss.

[MP]

- (a) An alternative statement would be that surface geometry geomerizes the dynamics of classical fields. Their counterparts in H are completely non-dynamical. One has the dynamics of shadows.
- (b) The notion of the world of classical worlds (WCW) [K7, K4, K12, K22] [L15] as the space of preferred extremals analogous to Bohr orbits of point-like particles replaced with 3-D surfaces is an essential part of the program. Quantum states as WCW spinor fields is the general formulation and involves rather heavy new mathematics.

- (c) The proposed description of interactions as a quantum measurement as a Hilbert space projection induced by the $H \rightarrow X^4$ projection could simplify the situation dramatically. Even the localization to single "Bohr orbit" in WCW can be considered as an analog of a position measurement in WCW, producing maximally classical state and possibly occurring in particle physics experiments. Delocalization in WCW would characterize the incoming and outgoing states. Note the WCW localization occurring in all interactions with the external world would also explain why the sensory experience suggests that we experience living in single space-time rather than their quantum superposition.

3 Prompt 2: Meaning of holography= holomorphy (H-H) hypothesis; how does it solve field equations, imply to ZEO and solve quantum measurement problem?

3.1 What is holography= holomorphy (H-H) hypothesis?

[GPT]

In TGD, it is assumed that any physically valid 4-dimensional spacetime surface can be constructed by intersecting two 6-dimensional twistor fibers defined by the holomorphic equations $f_1 = 0$, $f_2 = 0$ with each other. Holography means that the entire 4-D geometry, and thus all fields, are already encoded in the intersection and boundary surfaces of these two conditions (2-D partonic surfaces and 3-D light-like partonic orbits). Holomorphism refers to the fact that f_i are complex-analytic functions on the three complex coordinates w, ξ_1, ξ_2 . The rigidity of complex analysis makes the equations very restrictive and that is the trick.

Criticism: Although the local conditions are satisfied, no one has proven that all physically acceptable solutions are holomorphic in this way, or that singularities do not creep in.

[MP]

- (a) The first statement is not quite correct. f_i are also functions of a hypercomplex coordinate (real valued), all it u , which has light-like coordinate curves. f_i does not depend on its hypercomplex conjugate v , which also has light-like coordinate curves. The conditions $f_i = 0$, defining space-time as the intersection of 6-D "twistor surfaces", and space-time surface automatically implements the two main variational conditions of TGD: (i) minimal volume and (ii) induced Kähler -2 form no current. As a result, the PDE jungle shrinks to pure algebraic conditions in practice, you solve the spacetime by writing two suitable polynomials.
- (b) The safest way to solve the equations is to perform Wick rotation of the hypercomplex coordinate to complex coordinate, solve the equations in E^8 and return back by a Wick rotation. This allows us to solve the equations also in regions in which the hypercomplex coordinates are dynamical variables and by its reality the hypercomplex coordinate cannot be solved as analytic function of the remaining complex coordinates [L28].
- (c) As noticed, for H-H the induced Kähler form J can define light-like current and indeed does so for a large class of the known extremals.
- (d) The point is that the H-H hypothesis realizes holography required by the geometrization of WCW, since the realization of 4-D general coordinate invariance requires that each 3-surface is accompanied by a highly unique 4-surface. The big idea is that H-H is a more general and more elegant formulation than that based on a highly non-unique variational principle. Physics would reduce to generalize complex analysis.
- (e) The singularities certainly creep in [L23] and suggest universal vertices at the edges of the fermion lines. At partonic surfaces the minimal surface equation does not hold true at them. These surfaces are like the frames spanning a soap film. Boundary conditions stating conservation laws for isometry currents must be true. It is quite possible that these conditions require coupling constant evolution for α_K and possible other parameters appearing in the action. At the number-theoretic side, this would correspond

to a discrete coupling constant evolution for the extension of rationals associated with coefficients of the polynomials or more general analytic functions f_i . Also the degree of the polynomials would matter.

H-H implies minimal surface equations but GPT regards this as a speculation. H-H solves field equations irrespective of the classical variational principle as long as it is general coordinate invariant and expressible in terms of the induced geometry.

- (a) Minimal surface equations follow trivially because the field equations involve contraction of complex 2-tensors which are of different type: The types are (1,1) and (2,0)+(0,2). An additional term given by Kähler action is a contraction of light-like vectors which vanishes (this corresponds to hypercomplex aspect of conformal invariance).
- (b) Contrary to what GPT states, this is not a speculation but a mere 4-D generalization of the fact that Laplace equation in 2-D case follows automatically from holomorphy. Analytic functions in complex 2-space satisfy H-H being expressible in terms of holographic data defined by their poles and cuts. Also the vision of twistor Grassmann approach which states that scattering amplitudes are expressible in terms of their discontinuities as some particles are on mass-shell is analogous to H-H.

3.2 How does H-H solve the field equations?

[GPT]

The classical action of TGD is Kähler action + volume term. The equations of motion are, without the H-H condition, highly nonlinear PDEs for the minimal surface and Kähler flow. The holomorphic trick brings into play two consequences:

- (a) The determinant $\det(g_4)$ of the induced meter vanishes for partonic 3-surfaces \rightarrow a general 4-D Virasoro-type condition, the fulfillment of which follows from the fact that they are holomorphic.
[MP] Actually the rank of g_4 decreases by 2 units.
- (b) The induced/modified Dirac equation, modified in a similar way, holds.
[MP] Now, in addition, mode n defines M^4 and CP_2 chiralities.

[MP] H-H implies minimal surface equations irrespective of the classical variational principle as long as it is general coordinate invariant and expressible in terms of the induced geometry. Kähler action + volume term follows from the twistor lift. Minimal surface equations follow trivially because the field equations involve contraction of complex 2-tensors which are of different types: The types are (1,1) and (2,0)+(0,2). The additional term given by Kähler action is a contraction of light-like vectors, which vanishes (this corresponds to the hypercomplex aspect of conformal invariance).

- (a) Contrary to what GPT states, this is not a speculation but a mere 4-D generalization of the fact that Laplace equation in 2-D case follows automatically from holomorphy. Generalized analytic functions in complex 2-space satisfy H-H being expressible in terms of holographic data defined by their poles and cuts.
- (b) GPT gives a formula for the surface equations in the summary. The formula is wrong. If one drops the connection terms and defines d'Alembertian in the usual way, the formula is correct. A detailed explanation for what the d'Alembertian means for sub-manifolds would be needed.

3.3 Why does H-H lead to the zero-energy ontology (ZEO)?

[GPT]

The holomorphic structure dictates that all dynamics reside on the edge: Every 4-D surface lives between the contours two 3-D light-surface edges. These 3-D light-surfaces are themselves holographic bodies : their 2-D partonic intersections encode quantum numbers.

When a quantum state is described as data from two oppositely energetic edges, the net energy of the entire state is zero: positive energy on one, negative on the other. This gives rise to the ZEO ontology: a physical state is one whose total energy is $E_+ - E_- = 0$

[MP]

- (a) Here the analogy with ordinary minimal surfaces helps. The partonic orbits and other sources of holographic data are analogous to frames spanning the soap film [L5]. At the frames minimal surface property fails and there is coupling between volume part and Kähler part and possible other parts in the action. Soap films are slightly nondeterministic in the sense that there are many films associated with a given frame. In the 4-D case one has reason to expect the same.
- (b) Classical conservation laws imply that classical conserved charges are the same at the opposite boundaries of a causal diamond (CD) [L13]. Zero energy states [K1] just these conservation laws and brings in nothing new unless one assumes that the space-time surfaces inside the CD do not have continuation to larger space-time surfaces. In this case, a kind of vacuum fluctuation would be in question. The interpretation involves a choice between Eastern and Western views. Does the Universe consist of only events, which correspond to a finite collection of CDs within CDs or whether there the geometric realities are infinitely large space-time surfaces involving infinitely many CDs.
- (c) In the quantum case the finite size together with the Uncertainty Principle implies that the Poincare charges are not exactly conserved. The same occurs for the quantization in a 4-D box.

3.4 How does ZEO claim to solve the fundamental problem of measurement theory?

[GPT]

- (a) Two edge times \rightarrow two arrows of time. In TGD, measurement (i.e. state function reduction (SFR)) is an operation only on one edge. The active edge changes after a quantum jump, and the arrow of time reverses. In other words, instead of collapse, we have an arrow change + partial entanglement decoupling.
- (b) Negentropy Maximization Principle (NMP): Reduction chooses the option that reduces entropy the most analogous but inverse to the traditional second law reading. This serves as a hoodwink for the Born rule and gives an idea of why the final result is unambiguous.
- (c) Consequences: No external collapse postulate is needed: the quantum state changes because you activate an edge and make a decision there. The random variation of the direction of time gives the direction of the time as an emergent irreversibility without a thermodynamic basis.

[MP]

- (a) The interpretation that there is no collapse is wrong. The counterpart of the ordinary state function reduction occurring in quantum measurement corresponds to the reduction of entanglement at the active boundary of CD ("big" SFR or BSFR) [K1, L10] transforming it to a passive boundary at which the states do not change. The states change at the active boundary shifting towards the former geometric past in the sequence of "small" SFRs (SSFRs).
- (b) The key idea is that quantum states in ZEO are superpositions of Bohr orbit-like 4-surfaces. An SFR replaces this kind of superposition with a new one. There is no violation of the classical field equations for the Bohr orbits. Since spinor fields obey a Dirac equation in H inducing the fermion dynamics at the space-time surface so that there is no violation of field equations for them either.

- (c) Due to the slight determinism of the classical time evolution there are discrete "cognitive" degrees of freedom at the loci of non-determinism (the counterparts of soap film frames). The sequence of SSFRs is the counterpart for repeated measurements of the same physical observables having no effect in the standard ontology. In TGD they correspond to self-measurements in cognitive degrees of freedom assignable to the slight non-determinism of field equations so that holography is not completely deterministic. In SSFRs, the size of CD increases, say by scalings associated with SSFRs, and this gives rise to self experiencing a flow of subjective time correlating with the geometric time defined by the size of CD. There are two times and two causalities. BSFR means the death of self and its reincarnation with an opposite arrow of time. This is what would happen for instance when one falls asleep.

3.5 Skeptic's check list

3.6 Summary with a critical eye

[GPT]

Holography = holomorphy view is TGD's boldest claim: Draw two complex polynomials you get all of physics. It would trivialize multi-dimensional geometry dynamics, tie field theory to edge data, and open the door to the ZEO world, where quantum measurement gets a new interpretation.

But each chain is only as strong as its weakest link: The mathematical framework is still natural, but incomplete a complete proof of existence and uniqueness is missing. ZEO relies deeply on a philosophical premise that awaits empirical fire. The promise of measurement theory is fascinating, but it must be connected to concrete experiments (decoherence timescale, entanglement-swap gravity experiments). For now, the hypothesis is an elegant idea waiting for a tough test. Until then, the skeptic keeps his eyes open and his pen sharp.

[MP]

- (a) "Draw two complex polynomials..." is a huge exaggeration, to put it mildly. The hierarchy of analytic functions involves an evolutionary hierarchy of polynomials with coefficients belonging to various extensions of rationals, a similar hierarchy is associated with rational functions and general analytic functions. This gives rise to a huge amount of number theoretic physics [K18, K19, K17] [L17, L24], which is completely new from the standard physics point of view and gives hopes of understanding cognition.
- (b) ZEO gives excellent hopes to questions relating to the temporal aspects of decoherence time scale. The size scale of a CD provides a natural identification of this scale.

4 Prompt 3: What do induced geometry and induced spinor structure mean? What does the Dirac equation mean in TGD (use the latest material)

[MP] In the first three sections explaining, induced geometry, induced spinor structure and 3 Dirac equations in TGD, GPT's presentation is rather reasonable.

4.1 Induced geometry

[GPT]

Basic idea. The space-time surface $X^4 \subset H = M^4 \times CP_2$ get metric has induced metric $g_{\alpha\beta} = h_{kl}\partial_\alpha h^k\partial_\beta h^l$. The same pull-back also produces the Fubini Study Kähler -2 form of CP_2 , the Levi-Civita connection, and the $SU(3) \times U(1)$ vector potentials projected from

the isometric fields of CP_2 . All fields are thus induced geometry; no separate gauge field dynamics are postulated.

[MP] The idea is understood at the general level but the details are wrong. The metric of H , and therefore metrics of M^4 and CP_2 are fixed and non-dynamical. CP_2 spinor connection corresponds to non-dynamical $U(2)$ vector potentials and their projections give rise to dynamical electroweak gauge potentials.

Color gauge potentials can be identified as projections of CP_2 Killing vectors defining generators of $SU(3)$. They do not couple to spinors which means a deep difference between QCD and TGD color. TGD color is not a spin-like quantum number but corresponds to "rotational" motion in CP_2 . This has deep consequences concerning the spectrum of particles following from the spectrum of color partial waves for both quarks and leptons [?, L25], which correspond to different conserved H-chiralities (separate conservation of baryon and lepton number).

4.2 Induced spinor structure

[GPT]

Idea: A spinor field in $H \rightarrow$ a spinor field in X^4 . The gamma matrices Γ_k of H can be projected to the tangent space of the surface: $\Gamma_\alpha = \Gamma_k \partial_\alpha h^k$.

The anticommutation of these produces an induced metric, so X^4 inherits the spinor structure without the well-known spin structure traps of GR. The spinor connection is also a tangent projection of the H connection.

Fermion fields. In TGD, the 8-D free, second quantized spinor field Ψ is used; the induced field $\Psi(x) = \Psi|_{X^4}$ is just a restriction to the surface the propagation is thus free propagation in the embedding space.

[MP]

- (a) The H -spinor field [K22] has quark-like and leptonic parts corresponding to different conserved H -chiralities. They have different couplings to Kähler gauge potential, which explains their different electromagnetic charges [L14]. H -spinor fields are massless in the 8-D sense which does not mean masslessness in the M^4 sense.
- (b) One can also define modified gamma matrices [K22] for which the vanishing of the divergences of the gamma matrices (hermiticity) gives the field equations for the space-time surface so that one has a supersymmetry. The gamma matrices Γ^α are contractions of canonical momentum currents T_k^α derivable in standard way from the classical field equations as partial derivatives of the action with respect to the gradients of the H coordinates and satisfying $D_\alpha T_k^{\alpha\beta} = 0$, with H gamma matrices Γ_k .

The modified gamma matrices do not commute to the induced metric and one can argue that this makes them unacceptable. H-H implies that minimal surface equations are true everywhere except at partonic orbits so that for the induced gamma matrices the supersymmetry would fail at the partonic orbits in the fermionic sector. If H-H is true, the modes of the induced Dirac equation are the same for both kinds of gamma matrices.

4.3 3 Dirac equations in TGD

[GPT]

There are three Dirac equations in TGD: in 8-D embedding space, on the space-time surface and in WCW.

- (a) H : $\Gamma^k D_k \Psi = 0$. Massless in 8-D sense; solutions carry colors, weak isospin and M^4 momentum.

- (b) X^4 : $\Gamma^\alpha D_\alpha \Psi = 0$ induced or modified Dirac equation [L26, L25]. Square root of classical field equations. Hermiticity condition $D^\alpha \Gamma_\alpha = 0$ for the modified gamma matrices gives classical field equations.

Latest revision (2024). The holography = holomorphy vision implies that if X^4 is the intersection of 6-surfaces determined by two holomorphic functions $f_1 = 0$ and $f_2 = 0$, both the classical field equations and the modified Dirac are solved in purely algebraic terms. The PDE jungle shrinks to a relation of gradients.

- (c) WCW: $D\Psi = 0$. Dirac equation in the World of Classical Worlds. Solutions are quantum states (ZEO).

[MP]

- (a) If M^4 has Kähler form, the modes of H Dirac equation [L25, L26] are analogs of harmonic oscillator states and are partially labeled by two integers which are analogous to conformal weights rather than by 4-momentum. The M^4 mass squared is the difference of these non-negative integers and can be negative. However, the masslessness in H requires that the M^4 mass squared is non-negative. Many-fermion states for which the individual M^4 masses are tachyonic but the total M^4 mass squared vanishes are possible and for them color confinement is true. Colored quarks and leptons have CP_2 mass scale.
- (b) "The PDE jungle shrinks to a relation of gradients" is not quite correct. The reduction takes place to algebraic equations. Differential geometry reduces to algebraic geometry.
- (c) The massless Dirac equation in WCW brings in mind the fermionic part of the Super-Virasoro conditions in the string model [K22]. It could correspond to the gauge conditions associated with supersymplectic symmetry and/or generalized superconformal invariance implied by H-H [L15].

4.4 What does the Dirac equation mean in practice?

[GPT]

- (a) When $D\Psi = 0$ and the Hermiticity condition are satisfied, the Dirac equation automatically implies the minimum surface equations and Kähler current conditions; in other words, it is a stricter master condition than the Einstein Maxwell analogs.
- (b) Mass scales. A June 2025 analysis of M^4 with the Kähler structure showed that the mass squares of the M^4 -Dirac operator form an integer harmonic oscillator spectrum, which is bound to the $SU(3)$ -Casimir values of the CP_2 sector. This gives a string-like explanation for the color binding and predicts that no individual quarks are visible outside only colorless combinations.
- (c) Massless quarks? According to the July 2025 diary entry, holomorphic X^4 Dirac solutions yield massless quark states (the Dirac square washes out the spin terms); these correspond to a free QCD phase, which could be dual to the hadronic phase.

[MP]

- (a) There is a slight inaccuracy in the first item. The classical field equations are implied only for the modified gamma matrices [K2]. This has interpretation as supersymmetry, which is however different from the usual SUSY. For induced gamma matrices and assuming H-H, this is still true except at the 3-D light-like partonic orbits unless the boundary conditions reduce to those for the volume part of the action. This requires that the boundary conditions for Kähler action and volume term are separately satisfied. Whether this is possible is not clear but aesthetics strongly favors this conjecture.
- (b) The X^4 Dirac equation with H-H applies to both quarks and leptons. The geometric view is that the intersection of two space-time surfaces as analogs of Bohr orbits gives rise to interactions. In the generic case the intersection is a discrete set of points but if H-J structures are identical, it consists of string world sheets. The interactions would have a string model type description both for quarks and leptons.

4.5 Open questions and the memory list of skeptic

[GPT]

- (a) Global existence. It has not been proven that all physically valid 4-surfaces are holomorphic. The control of singularities is still open.
- (b) Choice of gamma matrices. The modified Γ^α depends on the surface momentum fluxes and finally on the chosen function; is the equation truly universal?
- (c) WCW Dirac spectrum. The zero-energy ontology requires that the WCW zero modes correspond exactly to observable particle states; explicit spectral calculation is in progress.
- (d) Empirical constraints. The whole construction is falsified by, for example, (i) pulsars, if the quantum transition produced by the M^4 -Kähler were visible through the $G\mu$ -value, or (ii) the missing massless quark phases in the LHC data.

[MP]

- (a) Whether to use induced or modified gamma matrices is not clear. Modified gamma matrices imply supersymmetry. Induced gamma matrices break it at the partonic orbits unless the boundary conditions are satisfied separately for all pieces of the action principle. In principle, holomorphy might imply this. The holomorphic solution spectrum of modified Dirac is same as that for the induced Dirac.
- (b) WCW sector would require a collective effort by mathematicians.
- (c) M^4 Kähler structure induces extremely small effects at the fermion level [L28]. $g_{mu} - 2$ should reflect the presence of an infinite number of color representations for the color partial waves of quark and lepton like spinors. A possible interpretation is that this hierarchy corresponds to the hierarchy of p-adic length scales as hadronic length scales. A more plausible option is that several p-adic length scales are associated with a given color partial wave.

The prediction from the string description of interactions in terms of intersection of interacting space-time surfaces is not equivalent with QCD description which was of course obvious from the beginning: color is not a spin-like quantum number at the level of H . Whether color triplets in massless phase correspond to a localization of X^4 spinors near the three poles of CP_2 as analogs of poles of sphere CP_1 is not clear. This is because the holomorphy can hold only in an open region of CP_2 and coordinate patches are excellent candidates in this respect.

4.6 Summary

[GPT]

Induced geometry makes fields pure embedding holograms; induced spinor structure ensures a smooth home for fermions; and a modified Dirac operator acts as a square root of both classical dynamics and quantum states. The 2024 2025 updates holomorphic solution, integer-harmonic mass spectrum, and massless quarks bring new elegance to the picture, but also new testable predictions. Before these escape from computation to the laboratory, the critical mind should keep its pen sharp and ask: how general, how precise, and how falsifiable?

5 Prompt 4: How does TGD differ from general relativity? How do TGD-inspired cosmology and astrophysics differ from what GRT predicts?

5.1 Basic geometry and fields

[GPT]

- (a) Spacetime
 - i. GRT: 4-D (pseudo-)Riemannian manifold with metric $g_{\mu\nu}$ determined by the Einstein equations.
 - ii. TGD: 4-D surface $X^4 \subset H$. Metric, Kähler form, and gauge fields are induced from the geometry of the 8-D base space.
- (b) Symmetries
 - i. GRT: Only local diffeomorphisms; global Poincare shifts vanish in the choice of code points.
 - ii. TGD: Global Poincare symmetries are preserved due to the M^4 factor \rightarrow well-defined total energy impulse.
- (c) Fundamental fields
 - i. GRT: Gravitation is the only geometric field; SM gauge fields are required separately.
 - ii. TGD: $SU(3) \times SU(2) \times U(1)$ potentials appear from the projection of the CP_2 isometry connection, fermions are restrictions of the spinors of the fundamental space.
 [MP] Here GPT is wrong. Only electroweak gauge potentials emerge as induced gauge potentials. Color gauge potentials can be identified as projections of CP_2 Killing vectors and defined classical color gauge field. Color gauge potentials do not decouple to H spinors and color is not a spin-like quantum number.
- (d) Action principle
 - i. Action
 - ii. GRT: Hilbert action $R + 2\Lambda$.
 - iii. TGD: Kähler action + volume action: $S = \int (J \wedge *J + \Lambda) dV_4$. Equations of motion 2nd-order tensor PDEs (Einstein). PDE pair (minimum surface + Kähler currentless). 2024 25 holography = holomorphy hypothesis claims to reduce them to algebraic terms.
 [MP] H-H actually reduces the field equations minimal surfaces equations for much more general action principles than represented here.

5.2 Cosmology: what changes?

- (a) Problem of Λ CDM.
 - i. Inflation & flatness: Exponential expansion driven by the inflaton field.
 - ii. TGD solution gong-wave cosmic strings form a gas in M^4 ; their quantum critical coherence smoothes the geometry without the multiverse problem.
 [MP] Here GPT misinterprets the cosmic strings of TGD as cosmic strings of GUTs. This identification is wrong and would exclude TGD inspired cosmology. Exponential expansion is not needed in TGD since the predicted quantum coherence in even cosmic scales guarantees the almost constant CMB temperature.
- (b) Dark energy
 - i. GRT: Constant-nature Λ ; Planck 2018: $\Omega_\Lambda \sim 0.684$.
 - ii. TGD: The magnetic energy of monopole flux tubes \rightarrow dynamic Λ ; Λ varies with the p-adic length scale.
 [MP] There is recent evidence that Λ changes with cosmic time. This has an interpretation in terms of p-adic length scale dependence, where p-adic length scale characterizes the sized scale of a CD or space-time sheet. The length scale dependence solves the greatest discrepancy in the history of physics. The predicted value of Λ is about 10^{57} times too large!
- (c) Dark matter:
 - i. GRT: Cold DM particle (WIMP/axion), halo profiles.

- ii. TGD: Dark = normal matter with $h_{eff} = nh_0$; located in the shells of flux tubes \rightarrow no large halos, galaxy rotation curves arise from the tension of the chord.

[MP] Here GPT misinterprets. In TGD galactic dark matter corresponds to the dark energy of cosmic strings identifiable as the sum of the Kähler magnetic and volume energies in the simplest model. Dark matter as phases of the ordinary matter with $h_{eff} = nh$ resides at field bodies. $h_{eff} = nh$ is expected to be good approximation: a more general formula is $h_{eff} = nh_0$, $h_0/h \sim 10^{-7}$ so that also $h_{eff} < h$ is possible and there is some evidence for this). The gradual transfer of ordinary matter (baryons) to phases of this kind to the field bodies would explain the missing baryonic matter whose fraction increases with the cosmic evolution. The interpretation would be an increase of number theoretic complexity. The evolution of life would be one particular aspect of this.

- (d) Hubble tension :5 6 σ difference.

- (e) GRT: Planck \leftrightarrow Ne Ia ($H_0 \sim 67$ vs. 74 km/s/Mpc).

- (f) TGD: H_0 varies with local h_{eff} fluctuations; explains two Hubble values without GRT adjustment.

[MP] The TGD explanation is rather abstract. To develop a more concrete picture it is good to notice two empirical facts. Large voids exist and the two different Hubble constants correspond to measurements in short and long scales.

The fractality of TGD Universe and p-adic length scale hierarchy would naturally relate to the Hubble tension. In TGD, mini Big Bangs creating magnetic bubbles are predicted to occur in all scales. They would create structures with matter concentrated at the surfaces of bubbles. Both large voids and planets could be formed in this way. The propagation velocity of light would change inside large voids where the density is reduced. The dropping of photons to this kind of gravitational well and the simultaneous expansion of the well could cause the effect.

- (g) Primordial gravitational radiation background:

- i. GRT: Tensor states \sim quantum fluctuations of the inflaton field; $r \leq 0.036$.
- ii. TGD: Cosmic strings produce nHz mHz background; initial tension $G\mu \sim 2 \times 10^{-7}$. This is already rejected by PTA data (NANOGrav/EPTA).
[MP] Here GPT is wrong. TGD cosmic strings are not GUT strings so that they do not decay preferentially to gravitons but produce ordinary matter in the transformation in which they thicken to monopole flux tubes and liberate ordinary particles somewhat like in inflation. No exponential expansion is involved.

5.3 Astrophysics, black holes, stars

- (a) Black holes

- i. GRT: Kerr geometry + classical horizon, singularity; Hawking radiation.
- ii. TGD: Quantum-critical solitons without global horizon; event layer is the network-like interface of flux tubes \rightarrow no information paradoxes.
[MP] This explanation makes no sense for me. In TGD blackhole-like objects consist of volume filling monopole flux tubes [L20] [K5]). There is entire hierarchy of this kind of objects since the thickness of the monopole flux tube has discrete spectrum. There is no causal horizon and no singularity. One can consider the possibility for analog of Hawking radiation but this could be at much higher energies and could be observable.

- (b) Galaxy rotation curves

- i. GRT: DM halo/MOND.
- ii. The tension of the cosmic string gives $1/\rho$ gravitational field giving a uniform v_r . No need for DM halos.

- (c) Quasars & SM-BHs

- i. GRT: Seed-BH + Eddington growth after inflation.
 - ii. TGD: Flux-tube ends(?), which rapidly accrete mass \rightarrow explains $z \geq 7$ supermassive black holes without super-Eddington.
[MP] This does not make sense to me. In TGD, these blackhole-like objects could be analogs of white holes, being cosmic string tangles decaying to ordinary matter. This would give rise to the formation of quasars and galaxies. The flow of matter would be from the blackhole-like objects rather than to it. Ordinary blackhole-like objects could be time reversals of these.
- (d) Solar corona heating
- i. GRT: MHD reconnection + Alfven waves.
 - ii. TGD: Flux-tube quantum critical phase transitions pump energy into the corona; 10^6 K explained by Planck constant jumps.
[MP] I am not quite sure whether I understand this explanation. Solar models have several anomalies and TGD leads to the question of whether the entire view of how radiative energy and solar wind are produced in the Sun [L20]. Does nuclear fusion in the core really produce them? The proposal is that M_{89} nuclei could be feeded to the surface layer of the Sun along monopole flux tubes from the galactic center, say the central blackhole. They would transform to ordinary nuclei by p-adic cooling involving a sequence of phase transitions reducing the value of p-adic prime as prime near power of 2 and producing solar wind and radiation. This could also explain the heating of the solar corona. Also dark fusion could take place at the corona [L1].
- (e) Pioneer/Flyby anomalies
- i. GRT: Irregular systematic errors.
 - ii. TGD: h_{eff} shift of dark matter shells orbiting the Earth $\rightarrow a \sim H_0 c$.
[MP] I do not understand this explanation. I have considered these anomalies and suggests the possibility of a dark matter layer. The notion of mini Big Bang suggests that the explosions throwing out from the surface of the Sun a magnetic flux tube layer, consisting of dark matter, might have led to the formation of planets. Could this kind layer could explain Pioneer/Flyby anomalies [K15]?

5.4 Summary of differences

- (a) Ontology: GRT describes geometry but not the origin of matter; TGD geometrizes everything, including gauge dynamics and the quantum measurement process (ZEO).
[MP]
- i. Matter is indeed geometrized. In Einstein's theory, matter is still introduced as a phenomenological energy-momentum tensor. Now there is no need for this: geometry itself determines the equivalent for this.
 - ii. The quantum measurement process also requires a new quantum ontology (ZEO) that does not reduce to geometry, although the new ontology is forced by holography= holomorphic vision. Here GPT misunderstands.
- (b) Cosmology: Λ CDM is empirically very accurate, but requires dark particles; TGD tries to do without separate DM/DE particles by replacing them with flux-tube energies and Planck constant layers.
[MP] Here again there is a lack of understanding. The whole idea is that TGD allows one to get rid of the particle physicist's attempt to describe dark matter with new particles. These attempts have failed repeatedly.
- Cosmic strings and their dynamics are fully predicted by the field equations of TGD, they are not ad hoc structures. They describe the formation of galactic dark matter as well as galaxies, stars and planets. The result is a flat velocity spectrum for stars without any additional assumptions.
- The latest setback of the Λ CDM model is that dwarf galaxies form correlated clusters. This should not happen for dark matter in the standard sense, and now it has been

suggested that they are not dark with respect to each other but there are additional interactions between particles of dark matter. In TGD, the correlations are a consequence of the galaxies being produced by the entanglement of the same cosmic string.

- (c) Astrophysics: TGD offers a unified explanation for rotation curves, coronal temperature, gravitational anomalies and early SMBH observations but some of the predictions are already in sharp conflict with the latest data (e.g. cosmic string tensions).

[MP]

- i. I don't understand this last statement at all. Here, GPT could be asked to clarify what he means by cosmic strings and their string tension.

The concept of a cosmic string for GPT is most likely what it has learned in training, i.e. a cosmic string in GUTs. In GUTs, a string is a defect in the gauge field. In TGD, it is a 4-surface with a 2-D M^4 projection. GUT cosmic strings decay primarily to gravitons and radiation (see this and this) and this decay process is totally different from the decay of TGD cosmic strings to ordinary matter analogous to the decay of inflaton fields. The important distinction is that TGD cosmic strings carry monopole flux so that they can decay to shorter closed strings only by reconnection.

- ii. Furthermore, the thickening of the cosmic strings in TGD as ordinary matter is released reduces the string tension and a whole spectrum of tensions is obtained. For example, hadronic string tension is the result.

- (d) Critical note: TGD cosmology has not yet produced a Planck-like precision prediction for the CMB spectrum, the baryon fraction, or the Big Bang nucleosynthesis.

[MP]

- i. TGD cannot yet predict the details of the CMB spectrum because it would require numerical calculations. We are still far from a situation where this is possible and we must continue to think instead of calculating.

- ii. Now it is clear, however, what happens in particle reactions. Here the previous phenomenological picture turned out to be correct and now follows from the TGD-based measurement theory.

Two BSFRs occur implying a temporary time reversal. If the surfaces the same H-J structure, the reactions occur at the intersection of colliding space-time surfaces consisting of very simple string world sheets whose boundaries correspond to fermion lines. If the H-J structures are not same, the interaction consists of discrete points. This phase would correspond to the QCD phase, but string theory would provide the dynamics. Annihilation and production of fermion pairs in the fusion and splitting of strings would be the basic vertices associated with splitting or fusion of string world sheets. Also scattering from the classical background at an edge for the fermion line is possible.

- iii. It should not be forgotten that Λ CDM has numerous difficulties due to the fact that the homogeneity and isotropy assumptions for the CMB are rapidly broken. As far as I understand, the scale for temperature fluctuations cannot be predicted. Also, in the Λ CDM modeling of galaxies, many anomalies are encountered. The way of thinking is that when 90 percent is understood, everything is understood. In TGD, the way of thinking is completely opposite.

- iv. Some observations suggest that there is no dark matter in the galaxy at all. Of course, it fits with the fact that it has been concentrated as dark energy at cosmic strings.

- v. The latest JWST observations suggest that the origin of the entire CMB may be something else than what the Standard Model assumes. The CMB would have been created when galaxies formed as cosmic strings formed local tangles and thickened, releasing ordinary matter as energy (this is the TGD equivalent of inflation but without the exponential expansion and inflation fields).

- vi. The prediction of the baryon fraction is also interesting. The fraction decreases in cosmic evolution and is difficult to understand in the Standard Model. In TGD, this

would correspond to the transition of protons and other particles to the field body as an dark matter-like phase (large h_{eff}). This is consistent with the number-theoretic increase in complexity, which is an inevitable prediction.

- vii. Even cosmological nucleosynthesis has to be questioned. The Standard Model for Big Bang nucleosynthesis runs into problems already with ^4He . Regarding nucleosynthesis, TGD is expected to deviates most strongly from the Standard Model.
- viii. Big Bang nucleosynthesis is also questioned if the hierarchy of hadron physics and the TGD view nuclear physics is true.

TGD predicts a whole spectrum of hadronic physics characterized by Mersenne primes. This prediction follows directly from the Dirac equation in H if M^4 has a Kähler structure. This could completely change the picture of what happened after the dominance of cosmic strings of primordial cosmology was replaced by the dominance of radiation.

The fundamental challenge is to build a detailed model for the formation of galaxies, stars and planets. It seems that at least in early cosmology the gravitational-condensation model of galaxy formation is replaced by the decay of cosmic strings into ordinary matter as an analogue of inflation.

6 Prompt 5: How does the particle physics predicted by TGD differ from that predicted by the Standard Model?

[MP] Here it is helpful to read the introduction, where the recent view about what happens to the standard model in the TGD framework is briefly explained.

6.1 Key differences

[GPT]

- (a) The Standard Model (SM) is a quantum field theory of $SU(3)_c \times SU(2)_L \times U(1)_Y$ gauge fields, with three families of particles and one Higgs scalar. The TGD, on the other hand, produces all the same fields as geometric projections from the 8-dimensional space $H = M^4 \times CP_2$.
- (b) TGD imposes entirely new structures on top of them ($U(1)_K$).
- (c) p-Adic mass hierarchy, dark h_{eff} sectors, cosmic strings). In the following, point by point, where the predictions really deviate from SM.

[MP] GPT gets wrong about $U(1)_K$ for CP_2 . It is not new but corresponds to $U(1)_Y$ in CP_2 . When M^4 Kähler comes in, there are two options. Photon and Z^0 only receives an additional contribution from the M^4 Kähler form or M^4 Kähler form defines its own gauge potential.

The effects produced by M^4 Kähler are extremely small for the fermion-level induced X^4 spinors [L28]. At the H level they are crucial because M^4 Kähler implies quark confinement [L25] and more generally that only color singlets are light. This result follows solely from the Dirac equation.

6.2 Gauge symmetries and interactions

[GPT]

- (a) Basic symmetry
 - i. SM: $SU(3) \times U(2)$
 - ii. The same triplet plus possibly $U(1)_K$. M^4 Kähler photon. Why do the exist
- (b) Why these symmetries?

- i. SM: Are assumed in the standard model.
- ii. Follow as projections of CP_2 isometries; long-range color and weak force fields are inevitable consequences.
 [MP] There is a slight misinterpretation here. Classical electroweak gauge potentials are projections of the CP_2 vierbein connection. Classical color potentials are projections of the Killing vectors of $SU(3)$ in a similar way to Kaluza-Klein theory. They do not appear in the Dirac equations. This is a major difference from the Standard Model.
 Classically, long-range weak forces are predicted and the size of the spacetime surface gives an estimate for the range as the quantum coherence length. For intermediate bosons, the geometric size naturally corresponds to the Compton wavelength. In the description of interactions the intersection of the space-time surfaces consisting of string world sheets determines the range. As explained in the introduction, the description of electroweak and color interactions differs dramatically from that of standard model and all interactions reduce to electroweak vertices.
 At the quantum level, $\nu_L - \nu_R$ pairs screen the weak force because they make the particle-equivalent closed monopole flux neutral with respect to the weak isospin. This mechanism also produces massless color singlets and color confinement.
 Long range correlates with large h_{eff} . The geometric size of the particle scales as h_{eff} .
- (c) Gravity.
 - i. SM: External addition.
 - ii. Part of the same geometry 4-surface minimizes volume & Kähler energy.
 [MP] The claim that the Kähler energy is minimized is not correct. The sum of the Kähler and volume term is extremized and H-H predicts minimal surfaces equations. An interesting possibility is that the H-H implies minimal volume. H-H means huge symmetry and minima are often highly symmetric.
- (d) Difference to be tested: The $U(1)_K$ component predicts a small, macroscopic mixing of the shadow photon with the real photon; it would introduce an additional force on the millimeter scale that SM does not know. Laboratory experiments have not yet been done with sufficient sensitivity.
 [MP] It seems that the effect at the fermion line level is much much smaller and not measurable.

6.3 Particles

[GPT]

- (a) The number of families
 - i. 3 families (PDG2024)
 - ii. Finite but fractal tower: for each initial prime (Mersenne, Fermat) there is a copy of the SM, mass scales $m \propto \sqrt{p}$.
 [MP] Here GPT confuses fermion families and p-adic length scale hierarchy. Families correspond to topologies for partonic 2-surfaces. There is an argument [K3] that only the 3 lowest genera for the partonic 2-surfaces represent ordinary particles. The handles of sphere behave like particles and this suggests a continuous mass spectrum. For $g = 2$ however the Z_2 global conformal symmetry for $g \leq 3$ makes possible a bound state.
- (b) New fermions
 - i. Not mandatory
 - ii. 4th, 5th families of copies; expected mass range of the lightest copy 1 3 TeV.
 [MP] As mentioded the partonic topologies with $g \geq 2$ handles could give rise to analogs of many-particle states than single particle states.

(c) New bosons

i. Only Higgs.

ii. Kähler's $U(1)_K$ boson, possible lepto- and diquark resonances in p-adic families.

[MP] Whether there is a new $U(1)_K$ boson assignable to M^4 Kähler action depends on whether the sum of M^4 and CP_2 Kähler fields defines Kähler action or whether they define their own Kähler actions. The predicted effects at the level of fermion lines are extremely small.

(d) Experimental situation. ATLAS + CMS Run-3 have not found 250 GeV 9 TeV resonances \rightarrow the first copy window of the entire TGD has already shrunk significantly. Still, there is still a lot of parameter space left for >9 TeV or very weak couplings.

[MP] Here one must take these claims very cautiously. First of all, it is now clear that TGD means a radical departure from QCD and standard model description of interactions. Secondly, the rates for the generation of hadrons of M_{89} hadron physics in the collisions of the ordinary M_{107} hadrons might be very low since the Compton lengths differ dramatically. The proposal is that M_{89} hadrons are generated at quantum criticality for the phase transition interpreted as deconfinement in QCD framework [K9, K10] [L21, L22]. The increase of h_{eff} by factor 512 would give for M_{89} hadrons the same Compton lengths as for ordinary hadrons. There are several bumps, which could correspond to dark M_{89} mesons created in this way.

6.4 The origin of masses and mixings

[GPT]

(a) Standard Model Yukawa couplings to the Higgs field \rightarrow are implemented as free parameters.

(b) TGD: p-adic thermodynamics: mass $m^2 \propto p^{-n}$, where p is the p-adic length scale of the particle and n is the Virasoro weight; no Higgs equation is needed. The same rule applies to baryons & mesons 1 3 % accuracy for PDG tables (no update until 2025).

[MP] The mass formula for fermions assumes $n = 1$. n is not conformal weight. Rather $T_p = 1/n$ is the p-adic temperature which for number-theoretic reasons is a positive integer [?].

(c) Distinct prediction. Mass ratios are integer combinations of \sqrt{p} scales; if future precise measurements (e.g. $m_t, m_{T_{cc}}$) deviate from this formula, the p-adic description collapses.

[MP] This statement is not quite correct. p-Adic length scale hypothesis states that preferred p-adic primes correspond to primes near powers of 2 [L7]. $1/\sqrt{p}$ serves as mass unit and the mass squared is expressible as extremely rapidly converging series in powers of p with small integers appearing as coefficients. Already two lowest orders give a practically exact result since the primes are really large ($p = 2^{127} - 1$ for electron).

6.5 Hierarchy of Planck constants and dark matter

[GPT]

(a) TGD allows quantum states with effective Planck constant $h_{eff} = nh$. When $n \geq 1$, the system behaves macroscopically quantum mechanically \rightarrow providing an explanation for the smooth rotation curves of galaxies and the ANITA/CMB anomaly without WIMP particles.

(b) SM has no mechanism for varying \hbar values.

[GPT] Empirical difference: If $h_{eff} \neq h$ phases exist, their magnetic, thermal or quantum perturbations could appear as random fluctuations in atomic clocks or plane interferometers measurement campaigns are still being planned.

[MP] Here the general formula is $h_{eff} = nh_0$: $h/h_0 \simeq 10^7$. There are however reasons to believe that $h_{eff} = nh$ is true rather generally. There is some evidence for $h_{eff} < h$ [L2]. For instance, the TGD view of number theoretic evolution predicts that the values of h_{eff} tend to increase. In biology the feed of metabolic energy tends to prevent the decays reducing h_{eff} and even to increase them. TGD makes large number predictions related to living matter and here testing could be rewarding.

6.6 Consequences from the data

[GPT]

- (a) Muon $g - 2$:
 - i. SM: tension 2σ (2025).
 - ii. TGD: Copy-SM loops could yield $1 - 3 \times 10^{-10}$; value not given in advance, so test is left open.
[MP] At this stage it is not possible to estimate $g - 2$ without constructing a QFT limit. A more attractive approach is to construct scattering amplitudes at the fundamental level first.
- (b) Cosmic predictions: $G\mu$
 - i. SM: No obligation
 - ii. TGD: TGD predicted 2×10^{-7} . PTA limits $\leq 10^{-9.5}$ rejected the original value \rightarrow theory had to adjust h_{eff} dilution.
[MP] Here GPT misinterprets TGD cosmic strings and those of GUTs so that the constraint does not apply.
- (c) HL-LHC resonances
 - i. SM: No observations
 - ii. TGD: First p-adic tower out of action in the range 250 GeV - 9 TeV
[MP] As already mentioned the production of mesons of M_{89} hadron physics from the hadrons of M_{107} hadron physics is very non-trivial so that these limits cannot be taken too seriously. There are indications for bumps having an explanation in terms of M_{89} hadron physics related to the phase transition usually interpreted as color deconfinement.

6.7 Short memory list of differences

[GPT]

- (a) Higgs mechanism
 - i. SM: Yes
 - ii. TGD: No; masses from p-adic thermodynamics
- (b) Number of families 3
 - i. SM: 3
 - ii. TGD: Infinite fractal tower. [MP] TGD predicts three families as single particle-like states.
- (c) Dark matter
 - i. SM: New particles
 - ii. TGD: Ordinary matter in $h_{eff} \geq h$ phase [MP] Here one must distinguish between galactic dark matter which corresponds in TGD dark energy of cosmic strings and $h_{eff} \geq h$ phases which are of special importance in biology.
- (d) Additional fields
 - i. SM: No
 - ii. TGD: $U(1)_K$, long-range color & weak
[MP] It is not clear whether $U(1)_K$ only modifies the electroweak $U(1)$ force.

6.8 Bottom line

[GPT]

- (a) The particle physics of TGD includes SM, but extends it to geometric (fields = projections of the copy surface),
- (b) fractal (families of copies),
- (c) thermodynamic (p-adic mass rule),
- (d) and quantum hierarchical (h_{eff} layers).

Some of these additional predictions cosmic strings and the first copy level have already been rejected by hard data; many others ($U(1)_K$ force, h_{eff} signals) are still waiting for their first proper test. This makes TGD an interesting, but for now highly speculative counterpart to the Standard Model.

7 Prompt 6: How should we stress test and attack this concept, be skeptic about?

7.1 Quick take summary

[GPT] TGD claims that all known physics arises from that for 4-surfaces $X^4 \subset H = M^4 \times CP_2$ that extremize Kähler + volume action.

To stress-test this idea one should

- (a) Prove or disprove the mathematics: verify that the Euler Lagrange system is well-posed, free of gauge/Lorentz anomalies, and admits the required spectrum of solutions.
- (b) Cross-examine precision data: force the predicted gauge couplings, masses and cosmic-string tension to run the gauntlet of PDG electroweak fits and current gravitational-wave/CMB bounds.
- (c) Exploit falsifiable signatures: hunt for TGD-unique phenomena p-adic mass hierarchies, large- \hbar sectors, twistor-lifted CP-violating cosmic strings where the Standard Model (SM) expects none.

[MP] This I have indeed done but the most easily testable predictions are outside particle physics since TGD Universe is fractal and reductionism does not hold true. For this reason particle physics colleges do not take these predictions seriously.

This three-axis assault applies Popper's falsification credo: a theory survives only if every deliberate attempt to kill it fails.

7.2 Mathematical consistency checks

7.2.1 Well-posedness of the field equations

- (a) Existence & uniqueness. Show that the mixed minimal-surface + Kähler system on X^4 is elliptic/hyperbolic in the appropriate gauge and that solutions cannot blow up in finite volume. No peer-reviewed proof exists; Pitkänen's own papers admit this as an open problem.

[MP] An essential feature is that the solutions are surfaces. For instance, solutions representable as graphs from M^4 to CP_2 in general do not exist. Rather, the solutions have finite spatial volume and are many-sheeted both with respect to M^4 and CP_2 . This leads to the notion of many-sheeted space-time realized elegantly in H-H vision [L17, L24, L27, L9, L28], which distinguishes dramatically between TGD and QFTs in M^4 . GRT type description emerges only at the QFT limit in long length scales.

- i. Here GPT lives in the standard vision of what classical and quantum theories as QFTs are. At the classical level, the initial value problem would be solved. At the quantum level, the fields are quantized and the path integral is done and divergences are eliminated and normalized if possible. This is not what happens in TGD.
 - ii. H-H gives an explicit general solution for the space-time surfaces via a local algebraization. It is not necessary to solve an initial value problem. H-H transforms Riemannian geometry to algebraic geometry.
What needs to be solved are the boundary conditions at partonic orbits. They state that the isometry charges do not flow out. The most elegant solution is that also boundary conditions are solved at by holomorphy.
 - iii. In TGD, there is no problem of fixing the gauge since TGD is not a gauge theory. CP_2 spinors connection is not dynamical and has a natural gauge, which corresponds to the choice of the vielbein connection to be consistent with the Kähler structure.
 - iv. Kähler coupling does not appear in the couplings to spinors since it is in geometric approach absorbed to the definition of the Kähler gauge potential. Same applies also to other induced gauge potentials.
In the number-theoretic vision, the continuous coupling constant evolution associated with the renormalization is replaced by a discrete one and corresponds to the hierarchy of rational algebraic extensions. One can say that the systems are quantum critical for each extension in the hierarchy.
There is no perturbative theory with loops since by holography space-time surfaces are analogs to Bohr orbits so that there is no path integral. There is however a summation due to the slight non-determinism of the action principles. An interesting question is whether this sum could be approximate by a path integral.
- (b) Embedding a Lorentzian sheet inside Euclidean CP_2 risks light-cone collapse. Derive energy conditions on the induced metric and look for counter-examples numerically.
—MP] The concept of such an embedding is absurd. In CP_2 type space-time regions, there can be 2-D Euclidean sheets but no Minkowskis.

7.2.2 Gauge, Lorentz and chiral anomalies

[GPT] TGD projects $SU(3) \times SU(2) \times U(1)$ from CP_2 Killing vectors, but it must still cancel ABJ anomalies the same way the SM does. An explicit Jacobian-determinant calculation for the induced spinor measure is missing; reproducing the SM's anomaly cancellation is not a given.

- (a) Here GPT acts according to his conditioning and sees TGD as a gauge theory. The $SU(3)$ symmetry corresponds to a Kac-Moody type symmetry which is in many respects similar to gauge symmetry. H-H implies that the path integral is not needed so gauge, Lorentz and chiral anomalies and sABJ anomalies disappear.
- (b) The fermionic Jacobian determinant is related to the fermionic path integral and is not needed. The spinor fields in H are free second quantized spinor fields and the solution for Dirac can be written directly.

7.2.3 Renormalizability vs. effective-field-theory (EFT) safety net

[GPT]

Because the action contains a dimensionful Kähler coupling, the 4-surface description looks power-counting non-renormalisable. One could argue that TGD is an EFT in the sense of higher-dimensional brane models, but then one must specify a UV completion or else accept cut-off dependence.

[MP] This comment reflects the fact that GPT is trying to twist TGD into an ordinary quantum field theory. It cannot do anything else due to its conditioning.

- (a) GPTs response is based on a huge misunderstanding. It took 8 years to learn that there is no hope of carrying the path integral and H-H eliminates it. The discovery that general coordinate invariance for WCW in 4-D sense requires holography led to the concept of WCW. I did not however use the terms holography and WCW at that time (around 1990) [K7, K4, K12, K22] [L15]
- (b) The CP_2 scale is dimensional but something completely different from the dimensional coupling of string models because it is a purely geometric parameter and it does not "run". The 4-D Kähler coupling is dimensionless. The 6-D Kähler coupling strength for the twistor lift [K13] is dimensional but proportional to the CP_2 scale and the ordinary Kähler coupling strength.

7.3 Compatibility with established physics

7.3.1 Electroweak and flavour observables

[GPT] Feed the predicted running couplings and Z, W self-energies into the global electroweak fit; any 2σ mis-match already kills the model. The 2024 PDG review summarises these constraints. In particular, verify whether TGD's fractal dark copies of the SM (a hallmark of Pitkänen's p-adic hierarchy) evade current LHC heavy-flavour and invisible-width bounds.

[MP] Here GPT does not live in this world.

- (a) TGD is not a model but a theory in formation and in its recent form is unable to make high precision predictions (in string theory the challenge is to find whether the theory can predict anything!). This would require a collective effort. The description of particle reactions in TGD is analogous to string model description and a huge amount of work would be required in order to get to the level of details. The existing knowhow from the superstring theory would certainly help here.
- (b) There are however very general predictions distinguishing between QCD and TGD views of color. The existence of scaled variants of hadron +electroweak physics is one such prediction. TGD already predicts the possibility of M_{89} hadron physics [K9, K9] and proposes it is seen at quantum criticality for what in the QCD framework is identified as a deconfinement phase transition. This quantum criticality is possible only at very special conditions (see Introduction).
In TGD, dark M^{89} hadrons with the Compton scale of ordinary hadrons (nuclei) would be formed and decay to ordinary hadrons. A naive scaling argument states that the mass scale would be 512 times the mass scale for ordinary hadrons. There is some evidence for bumps allowing this kind of identification [?, ?]. Since they did not allow interpretation as bosons predicted by SUSY, they were forgotten as statistical fluctuations.
- (c) M_{89} hadron physics suggest a thorough revision of the physics of the Sun plagued by anomalies [L20]. A more fruitful approach could be checking of whether this view could be killed or even work.

7.3.2 Cosmic string sector

[GPT]

TGD expects CP_2 -wrapped string-like defects whose tension is set by α_K . Current CMB spectra and pulsar-timing arrays limit dimensionless tension to $G\mu \leq 10^{-7} - 10^{-10}$. If TGD needs a higher value to seed structure formation, it is already ruled out.

[MP] Here GPT makes a fatal mistake.

- (a) As already described (see Introduction), the identification of the TGD cosmic strings as GUTc cosmic strings is wrong. TGD cosmic strings [K6, K16, K8] [L18] are 4-D surfaces with 2-D M^4 projection rather than defects of gauge theory. They decay to ordinary matter monopole flux tubes giving rise to galaxies and stars rather than mainly

to gravitons. Therefore the GUT limits do not apply. The velocity value for distant stars rotating galaxies give an estimate for the string tension as a density of energy per unit length of the cosmic string and it conforms with the theoretical estimate. If the effect of cosmic strings at the field theory limit of TGD is the same as general relativity predicts, they induce a bending of light, which might serve as a test.

- (b) More fruitful tests would direct attention to the notions of cosmic string and monopole flux tube. The monopole flux tubes appear universally in all scales from the cosmic strings of the early cosmology to hadronic strings and to biomolecules [L18]. This provides a lot of single bit predictions which might kill the notion or force to modify the interpretations.

7.3.3 Gravitational wave signatures

[GPT] Future PTA and LISA data can probe the nanohertz-to-millihertz background predicted by cosmic strings an opportunity to falsify or confirm TGD string tension within a decade.

[MP] The fatal misinterpretation of TGD cosmic strings destroys also this objection.

- (a) A already explained (see Introduction), TGD cosmic strings [L18] are not GUT strings so that this test is not appropriate. It would be very interesting to figure out what would be the corresponding prediction for the TGD cosmic strings and monopole flux tubes.
- (b) A more creative way to kill TGD would be based on the predictions of TGD. A basic prediction is a fractal network of TGD involving cosmic strings and monopole flux tubes having galaxies, stars, and planets at its nodes. A completely new element is gravitational quantum coherence in astrophysical and even cosmological scales so that inflation as exponential expansion is not required.

For instance, the network could correspond to the recently observed filamentary network in cosmic scales. One particular prediction is long range correlation between galaxies associated with the same cosmic string and these have been observed as also the formation of long linear structures formed by galaxies. Also the recently observed background gravitational radiation could be understood in terms of diffraction assignable to the lattice-like structure formed by field bodies of stars as H^3 tessellation.

7.4 Empirical attack vectors

- (a) Collider: Extra resonances from higher p-adic families ; deviations in Higgs couplings LHC Run-3 and HL-LHC can exclude $O(1 \text{ TeV})$ scale copies.

[MP] Extra resonances might provide support for the hierarchy hadron physics (and also electroweak physics) [?, ?] (see Introduction). The Higgs particle exists in the TGD Universe but the Higgs mechanism is replaced by p-adic thermodynamics. An open question is whether it applies only at H level (for hadrons, leptons, and gauge bosons) or also at the X^4 level (fundamental fermions as quarks and leptons).

The problem of these tests is that one must know very precisely what one is searching since the signal-to-noise ratio is so low. I have already mentioned the indications for the bumps having an interpretation as M_{89} mesons and explained why the production of M_{89} hadrons is not easy (see Introduction).

- (b) Low-energy precision $g_\mu - 2$, electric dipole moments. Any unaccounted CP_2 induced CP-violation shows up here.

[MP] This is one of the key tests but requires a lot of work and a collective effort of mathematicians. The TGD view of strong interactions and QCD color differs dramatically from the QCD view. If the interaction region identified as the intersection of two space-time surfaces with the same H-J structure [L9, L28], leads to a stringy picture of

all interactions. Only free fermions and antifermions of H are involved and the interaction vertices as edges of fermion lines can be understood as defects of the standard smooth structure.

GPT CMB B-mode and μ -distortions (μ is tension of GUT cosmic string) from string networks. Sensitivity is already within TGD's expected $G\mu$.

[MP] Here GPT misinterprets TGD cosmic strings.

- (c) Quantum-information: Tests of gravity-induced entanglement versus classical mediation.
- (d) Recent no-go theorems draw a line that a purely classical Kähler sector cannot cross.

7.5 Numerical and constructive stress tests

- (a) Finite-element simulation of preferred extremals. Discretise X^4 as a moving mesh in H and monitor stability; blow-ups expose hidden inconsistencies.

[MP] The algebraic solution of field equations using H-H indeed requires the mesh.

- (b) Monte-Carlo over moduli space. Randomly sample embeddings and compute induced gauge spectra; measure how fine-tuned the surfaces must be to hit observed couplings.

[MP] The moduli space of space-time surfaces corresponds to WCW basically but there are important sub-WCWs. Due to the generalized conformal symmetries implying the 4-D analog of modular invariant.

- i. WCW space might contain as an important subspace the moduli space of H-J structures for given topologies of partonic 2-surface [L9]. Also polynomials and more general analytic functions with coefficients in a given extension of rationals could be highly interesting sub-WCWs. I have tried to understand the structure of the moduli space of 4-D conformal structures as a generalization of that from 2-D case discussed from the TGD point of view in [K3]. A given point of this space would correspond to a slicing of the space-time surface by partonic 2-surfaces and string world sheets transversal to them. Each partonic 2-surface has induced metric and corresponding ordinary conformal moduli.

- ii. If the string world sheet has no handles and is determined completely by the orbits of the partonic 2-surfaces which it connects, then the moduli for a given space-time surface would mean an assignment of a point p of space-time surface the ordinary conformal moduli for the partonic 2-surface $X^2(p)$ to which it belongs. The local moduli p would correspond to a point of the moduli space of complex structures for $X^2(p)$ characterized topologically by its genus g . The moduli assignable to $X^2(p)$ at partonic orbits are expected to be of special importance in the calculations of scattering amplitudes. The moduli spaces of complex structures for a given genus g are central in the TGD based view of family replication phenomenon.

One can ask whether these moduli could correspond to zero modes, which by definition do not contribute to the WCW line element at all but appear as parameters in the WCW metric?

GPT Automatic theorem-proving. Use computer algebra to verify anomaly-cancellation identities symbolically on the pulled-back connection.

[MP] H-H eliminates path integral and there is no need for the anomaly considerations in the sense of gauge theories. The physically most important anomalies are the edges of fermion lines acting as vertices and conjectured to correspond to defects of the standard smooth structure making it exotic smooth structure.

- (c) Each attempt should be documented and published even negative results tighten the noose.

[MP] To my own view the development of mathematical theory and tightening its connections with empirical reality continues to be the most promising approach. Trying to kill TGD by forcing it to the shoe of the QFT based thinking is not a very good idea.

7.6 Philosophical hygiene

GPT Apply Popper's falsification rule: catalogue crisp, risky predictions first, defer untestable metaphysics (e.g. zero-energy ontology).

[MP] ZEO is of course testable. ZEO leads to dramatic predictions such as the reversal of the arrow of time in the TGD counterparts of ordinary SFRs. The predictions emerge in all scales, even cosmological (stars and galaxies older than the Universe [L16, L18] [K20]). ZEO leads to the theory of consciousness with very strong and testable predictions [K1, L10]. Here GPT reflects directly its conditionings to the philosophy of the physicalist, of rather the idea that philosophical thinking is not needed at all.

- (a) Guard against immunising stratagems: the temptation to invoke ever more elaborate p-adic sectors or cosmological eras whenever data disagree. Every ad-hoc layer dilutes explanatory power.

[MP] I have not yet felt any need for this kind activities but have been following the desperate fight of particle physicists and cosmologists to save their dogmas (Λ CDM, inflation, the view about blackhole-like objects, ..).

7.7 Failure modes to watch for

- (a) Non-closure under radiative corrections running couplings drift away from the CP_2 values, spoiling unification.

[MP] GPT thinks that TGD is ordinary QFT. H-H implies that there is no path integral and this changes completel the computational framework. Coupling constant evolution is discrete and each extension of rationals corresponds to its own coupling constants which are quantum critical.

- (b) Anomalous breakdown of Lorentz symmetry from the background M^4 Kähler form.

[MP] The effects of M^4 Kähler form as compared to those of CP_2 Kähler form are extremely small for fermion lines. M^4 metric is not affected but it is an interesting question whether the choice of preferred local plane $M^2 \subset M^4$ could have effects in the long scales via the H Dirac equation. Could this fix a quantization axis in long length scales, perhaps at the field bodies?

- (c) Predictive void: parameter freedom so large that anything can be fitted post-facto, violating falsifiability.

[MP] In TGD the only free parameters are CP_2 radius and α_K everything else follows as a prediction. There is of course the freedom to choose the space-time surfaces as solutions of field equations used to model a system but this is true in any physical theory.

- (d) Empirical no-shows: absence of predicted cosmic strings or fractal SM copies after the next generation of experiments.

[MP] As noticed, GPT misinterprets TGD cosmic strings. Cosmic strings and monopole flux tubes lead to a totally new view of cosmology. The testing of this prediction might be extremely useful.

7.8 Roadmap for a rigorous crash-test programme

[GPT]

- (a) Mathematical sprint (1-2 y): publish a rigorous existence-and-uniqueness theorem or a counter-example.
- (b) Precision data sweep (2-4 y): plug TGD couplings into global SMEFT fits; confront HL-LHC, $g - \mu - 2$, and EDM updates.
- (c) Cosmic-string watch (now-2030): coordinate with PTA and CMB-S4 teams for dedicated TGD string templates.

- (d) Quantum-gravity table-top (parallel): exploit entanglement-mediated force experiments that challenge classical-metric pictures.
- (e) Annual kill-report: list every failed prediction; if too many accumulate without a prior mechanism to discard the model, declare the theory defunct.

Here GPT demonstrates its lack of real understanding of the situation and just associates to the prompt familiar phrases from its particle physics education. This attitude makes sense if TGD was a proposal about addition of some new particle to the standard model: now however a new world view, which is not a small perturbation of the standard model, is proposed. I can understand the feelings of a string theorist required to give detailed fit of the string theory predictions to the entire LHC data. Huge amount of mathematical work and collective effort is required to develop TGD to the level at which this is possible.

TGD predicts new physics in all scales based on universal principles. A more promising approach is to develop the applications of TGD in various scales to see whether the predicted new phenomena exist. These kinds of predictions are few bit predictions but these bits are killer bits and relevant for the entire world view.

7.9 Bottom line

[GPT]

- (a) TGD particle physics includes SM, but extends it to geometric (fields = projections of the copy surface), fractal (copy families), thermodynamic (p-adic mass rule), and quantum hierarchical (h_{eff}).
- (b) Some of these additional predictions cosmic strings and the first copy level have already been rejected by hard data; many others ($U(1)_K$ force, h_{eff} signals) are still waiting for their first proper test. This makes TGD an interesting, but so far highly speculative counterpart to the Standard Model.

[MP]

- (a) As I have already stated TGD cosmic strings are not those of GUTs and their string tension is consistent with the velocity spectrum implied by galactic dark matter.
- (b) One problem of GPT is the failure to realize the world of TGD is fractal. Also ZEO and even number-theoretic vision are included as new elements. Predictions come at all scales rather than from particle physics scales or even Planck scale. GPT sees the world through the eyes of a particle physicist.

8 Prompt 7: Which of those tests have already been done?

[GPT]

In brief: Most of the attack-vectors we listed remain untouched by dedicated TGD analyses. Where independent data do overlap with TGD's published numbers, the score card is mixed to negative:

- (a) Cosmic-string tension: TGD's early value $G\mu \simeq 2 \times 10^{-7}$ is now ruled out by pulsar-timing array limits of $G\mu \leq 10^{-9} - 10^{-9.5}$

[MP] This claim is based on the wrong identification of TGD cosmic strings and cosmic strings of GUT's. The estimate for the string tension [K6, K16, K8] follows the typical rotation velocity of distant stars in the galactic plane.

- (b) Muon $g_\mu - 2$: Pitkänen's qualitative explanation survives, but the final 2025 Fermilab measurement sits only 2σ above the revised SM prediction and no quantitative TGD number was published in advance.

[MP] The reason is simply that TGD cannot predict high precision numbers at this stage (I would guess that the situation is the same in M-theory!). TGD predicts a hierarchy of hadron + electroweak physics (see the introduction) labelled by the color partial waves assignable to H-spinors and this predicts contributions $g - 2$. The TGD counterpart of QCD description is "stringy" approach which applies to all interactions, not only strong. Situation is somewhat like it was for the parton model of Feynman when QCD emerged. A huge amount of work is needed.

- (c) Extra TeV-scale resonances: ATLAS and CMS have scanned 13.6 TeV data to 140 fb^{-1} without seeing the scalar/leptoquark towers TGD anticipated.

[MP] TGD suggests M_{89} hadron physics [K9, K10] and scaled up versions of ordinary mesons and nucleons mass scaled by 512 times that for nucleons (a naive assumption). They could be associated with the deconfinement phase expected in QCD, which would actually mean a transition to dark M_{89} phase with the nuclear Compton length and residing at the field bodies possibly explaining quite generally the failure to observe dark matter.

Quantum criticality, possibly reached in the high energy collisions of heavy nuclei, is required to make possible the phase transition from M_{107} hadron phase to M_{89} hadron phase by two BSFRs. The phase transition interpreted as deconfinement phase transition is a good candidate in this respect. This occurs always but now dark quark phase with 512 times larger h_{eff} is required and requires a lot of energy and high energy heavy ion collisions might provide it (see Introduction).

TGD does not predict leptoquarks: they are not color singlets and if they exist they have mass of order CP_2 mass.

- (d) p-Adic mass spectrum: the original 2001 fit still matches PDG pole masses at the 1-3 % level, but critics note the fit used post-dictive scaling freedom and has not been updated with the 2012- 2024 heavy-flavour discoveries.

[MP] Does this comment mean that TGD is known in professional circles? Professionals have not given any signal that this could be the case!

- (e) Gravitational-entanglement table-tops: only proposals exist; no experiment yet confronts TGD's claim that classical Kähler gravity suffices.

[MP] TGD does not claim that classical Kähler gravity is enough. TGD predicts gravitons. There is no path integral and vertices involve classical fields at the singularities which would correspond to defects of the standard smooth structure making it exotic smooth structure. Classical fields at vertices appear also in the path integral formalism. The notion of gravitational Planck constant, introduced originally by Nottale [E1], makes possible quantum entanglement in astrophysical scales [L21, L22, L6, L8]. The gravitational Compton length for the pair (m, M) would not depend on the small mass m and would be proportional to the Schwarzschild radius of the large mass M (Equivalence Principle). For instance, for the Sun the gravitational Compton length would be the Earth radius divided by 2. For the Earth it would be about 1 cm.

- (f) Mathematical foundations (existence/uniqueness, anomaly cancellation, renormalisation): still open problems; no peer-reviewed proofs or counter-examples have appeared.

[MP] As noticed, H-H allows to get rid of the path integral and replaces it with a well-defined functional integral over 3-surfaces which in ZEO is replaced with a functional integral, or rather, sum over the analogs of Bohr orbits. Even the occurrence of a localization to a single preferred extremal can be considered in the interactions.

Gauge fixing, anomaly cancellation and renormalization do not make sense since there is no path integral over gauge potentials but functional integral over analogs of Bohr orbits. TGD is essentially a wave mechanics for particles as 3-D surfaces replaceable by their Bohr orbits in order to realize 4-D general coordinate invariance.

Coupling constants are discrete and in number theoretic vision induced by the hierarchies of extensions of rationals. At this state, mathematical proofs must be left to mathematicians. Dirac's bra-ket formalism is still outside a real mathematical proof.

8.1 Precision electroweak and flavour tests

The Particle-Data-Group's 2024 global fit pins the weak-mixing angle, gauge couplings and oblique parameters to sub-per-mille precision. TGD has not supplied explicit numeric predictions, so nothing falsifiable has been scored; nevertheless any future TGD fit must land inside the narrow PDG ellipse.

8.2 Muon magnetic anomaly

[GPT]

What TGD said: multiple blog posts argue that fractal copies of the SM add a few $\times 10^{-10}$ to a_μ , potentially explaining the Brookhaven 2001 excess.

What the lab saw: Fermilab's final combined result $a_\mu^{exp} = 11659204.00410^{-10}$ preserves a mild tension with the updated lattice-plus-R-ratio SM average.

Status: TGD offered no parameter-free number, so the test remains inconclusive but the dwindling anomaly leaves less room for exotic contributions.

[MP] At this moment, TGD cannot predict this kind of high precision numbers. TGD view of color implies that the QCD lattice calculation is not reliable. The deduction of a_μ from hadronic data is more reliable and predicts an anomaly. TGD predicts new particles, which might contribute to the anomaly. The TGD approach, based on string model type calculation for what happens in hadronic collision, would replace the QCD calculation.

It is not at all clear whether the copies of hadron physics involving different color partial waves can contribute to anomaly significantly. If the transitions between different hadron physics with widely different p-adic length scales characterizing Compton lengths require quantum criticality allowing to change the value of h_{eff} for the final state phase, their contributions could be negligible.

8.3 Cosmic-string sector

[GPT] TGD's Kähler action predicts GUT-scale strings with $G\mu = 2 \times 10^{-7}$. Latest limits: EPTA-DR2 and the NANOGrav+EPTA combined analysis cap the tension at $G\mu = 2 \times 10^{-9.5} - 10^{-9.5}$ (95 % CL) if the nano-hertz background is from strings; even stricter if it is not.

Outcome: Original value excluded by 1.5 2 orders of magnitude. Pitkänen has responded by invoking a variable effective Planck constant to dilute tension, but the mechanism is ad-hoc and not yet published in a calculable form.

[MP] The latter part of the comment claiming my reponse does not make sense to me: it is fabrication. As explained, the problem is that GPT sees the cosmic strings of TGD as GUT strings.

8.4 Collider searches for new resonances

[MP] Quite generally this kind of tests are appropriate if one has a modification of standard obtain by addition of some new particles. TGD predicts profound change of the physical world view.

8.4.1 ATLAS & CMS heavy-boson scans

[GPT] No excess in Z' , diboson, diphoton, tt , or multijet channels up to 6.9 TeV.

[MP] About this TGD cannot say anything. TGD does not predict Z' type particles but allows scaled up copies weak physics. About remaining channels TGD cannot say. A highly develop calculational apparatuses and numerics would be required. This is like requiring that string model represents detailed parameterization of particle physics data.

8.4.2 Exotics and long-lived signatures

[GPT]

Run-3 analyses on emerging jets and hidden-valley topologies likewise null.

Verdict: every explicit mass window flagged in Pitkänen's 2010 2015 white papers is now excluded. Remaining loopholes demand either heavier or very feebly coupled states both in tension with the original p-adic scaling rules.

[MP] I do not understand what the explicit mass windows claimed to be flagged in Pitkänen's 2010 2015 white papers could mean so that I cannot comment. I mentioned already dark M_{89} hadrons possible related to what is regarded as deconfinement phase transition known to have poorly understood aspects.

8.4.3 p-Adic mass tables

[GPT]

TGD's 2001 ScienceDirect paper reported 1-3 percent agreement for 39 hadron and lepton masses using a single scaling law. When confronted with the expanded 2024 PDG database the fit deteriorates (e.g. $m_{\chi_{cc^{++}}}, m_{T_{cc}^+}, m_{\tau_h}$), but no updated chi-square has appeared.

[MP] Quite possible the problem is that p-adic thermodynamics for quarks is questionable. In the recent view of TGD, one can argue that it applies only to massless color singlets, that is hadrons and leptons but not to quarks.

8.4.4 Gravity-mediated entanglement proposals

[GPT]

Table-top schemes (QGEM, photonic simulators) test whether classical gravity can entangle quantum systems. Current papers show the effect can be mimicked by Newtonian dynamics, leaving the question open; no laboratory result yet constrains TGD's classical-Kähler stance.

[MP] To my view, the interesting predictions related to the very large effective Planck constants related to long range gravitational and electric fields. These provide a very nice view about how quantum coherence in living matter is realized. It might be very useful to test this sector. But a detailed view of notion of field body is needed. This requires a lot of mathematical thought.

8.4.5 Un-addressed mathematical consistency checks

- (a) Euler Lagrange well-posedness: still unproved.

[MP] The problem is that H-H gives an explicit recipe for constructing the preferred extremals but solves the problem in the wrong way. I should have started from initial value problem standard field theory framework.

- (b) Gauge/Lorentz anomaly cancellation: no published path-integral or Fujikawa calculation.

[MP] H-H allows to get rid from the path integral. I used 8 years to make sense of path integral and finally realized that a radical revision is needed. The notion of world of classical worlds (WCW) requires association of a discrete set of space-time surfaces to a 3-surface. This is holography. H-H provides its solution.

- (c) Renormalisation: running of the Kähler coupling remains a conjecture. No lattice or functional-RG study exists.

[MP] The basic principle is quantum criticality analogous to quantum criticality and quantizes various couplings as analogs of critical temperature. This forces holography and generalizes conformal invariance as a realization of quantum criticality. There are no running coupling constants since there is no path integral. Coupling constant evolution is discrete and number theoretical vision predicts that it is induced a hierarchy of extensions for rationals.

The problem is that GPT is conditioned to the QFT picture and it decides that also TGD is QFT.

9 Conclusions

9.1 Analysis of O3’s recurring pitfalls

Several consistent failure modes surfaced while we queried O3 in the same session about the highly non-standard framework of Topological Geometrodynamics. They stem from the way the model blends mainstream training data with on-the-fly browsing and from inherent limitations of large-language-model reasoning.

9.1.1 Mainstream bias and conceptual over-projection

Because the bulk of O3’s pre-training corpus mirrors orthodox high-energy physics and Λ CDM cosmology, the model instinctively interprets unfamiliar notions through that lens. TGD’s “cosmic strings” were repeatedly mapped onto grand-unified-theory strings, leading to an incorrect application of pulsar-timing tension bounds. Similar over-projection occurred with the “holography = holomorphy” ansatz, which O3 treated as a philosophical aside instead of a concrete device that trivialises TGD’s field equations.

9.1.2 Hallucinated mathematics and spurious citations

In areas where browsing returned no authoritative derivation, the model fabricated plausible-looking equations and even DOIs. One example was a minimal-surface formula stripped of its covariant terms; another was a nonexistent reference purporting to fix the Kähler coupling. These hallucinations were always delivered with the same confident style as genuine results, making them hard to spot without manual checking.

9.1.3 Fragmented treatment of core concepts

Key TGD ideas— p -adic mass hierarchies, number theoretic hierarchy of effective Planck constants, the zero-energy ontology—were split into isolated fragments and then recombined with standard quantum-field-theoretic jargon. The result was a narrative in which a “fractal tower of extra families” coexisted with conventional Higgs-Yukawa masses, even though the two notions are mutually exclusive inside TGD.

9.1.4 Erroneous test agendas

Because of its mainstream bias, O3 proposed conventional collider searches and grand-unification string bounds as “definitive falsifiers,” disregarding TGD’s own scale assignments for its additional sectors. The most fatal mistake was the identification of cosmic strings of GUTs as TGD cosmic strings. That mismatch produced premature claims that the theory was dead simply because LHC had not found heavy resonances in the usual mass windows. The physical reason for this would be that the transition between two hadron physics requires very special conditions not met in standard collisions.

9.1.5 Opaque internal reasoning and reproducibility limits

While the transcript logs every browsing call, the hidden chain-of-thought that decides which pages to open, which equations to trust, and why a particular analogy is invoked remains inaccessible. Two identical prompts submitted hours apart sometimes produced different browsing paths and, occasionally, divergent conclusions.

9.2 Concrete Payoffs from the O3-Assisted TGD session

Yet the exercise paid dividends for TGD itself. By tracking down and repairing O3’s slips forced to study in detail the earlier views about construction of scattering amplitudes, in particular the interaction vertices. This allowed a much more detailed formulation of

- (a) a string-based description of the generalization of deconfinement/hadronisation transitions [L28] suggested by the dual Dirac equations,
- (b) an explicit general formula for the interaction vertices in terms of divergence of the current defined by Dirac equation [L23],
- (c) a sharper hypothesis that colour confinement in spin degrees of freedom reduces to that $SU(2)$ as a subgroup of the holonomy group of $U(2)$ of CP_2 identifiable as subgroup of color group — raising the possibility that gluons are really electroweak boson in disguise supported by the observation that the predicting color coupling strength has correct size,
- (d) a proposal that the predicted hierarchy of standard model physics corresponds to the hierarchy of color representations for the color partial waves of H Dirac equation, and
- (e) a more detailed formulation of the criterion for when Mersenne-labelled copies of hadron physics can (or cannot) emerge at the LHC and in solar-surface processes.

For now, O3—and any current “deep-research reasoning” language model—is best used as a quick-fire ideation partner and language-polishing aid, not as a stand-alone authority on TGD’s technical claims, because distinguishing its potential hallucinations from genuine TGD statements still demands decades of specialist expertise.

References

Mathematics

- [A1] N. Hitchin. Kählerian twistor spaces. *Proc London Math Soc*, 8(43):133–151, 1981.. Available at: <https://tinyurl.com/pb8zpqo>.

Theoretical Physics

- [B1] Skinner D Bullimore M, Mason L. Twistor-Strings, Grassmannians and Leading Singularities, 2009. Available at: <https://arxiv.org/abs/0912.0539>.
- [B2] Arkani-Hamed N et al. The S-Matrix in Twistor Space, 2009. Available at: <https://arxiv.org/abs/0903.2110>.

Astrophysics

- [E1] Nottale L Da Rocha D. Gravitational Structure Formation in Scale Relativity, 2003. Available at: <https://arxiv.org/abs/astro-ph/0310036>.

Books about TGD

- [K1] Pitkänen M. Some comments related to Zero Energy Ontology (ZEO). In *TGD and Nuclear Physics*. <https://tgdtheory.fi/tgdhtml/Bnucl.html>. Available at: <https://tgdtheory.fi/pdfpool/zeoquestions.pdf>, 2019.
- [K2] Pitkänen M. About Preferred Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I*. <https://tgdtheory.fi/tgdhtml/Btgdclass1.html>. Available at: <https://tgdtheory.fi/pdfpool/prext.pdf>, 2023.
- [K3] 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.
- [K4] Pitkänen M. Construction of WCW Kähler Geometry from Symmetry Principles. In *Quantum Physics as Infinite-Dimensional Geometry*. <https://tgdtheory.fi/tgdhtml/Btgdgeom.html>. Available at: <https://tgdtheory.fi/pdfpool/compl1.pdf>, 2023.
- [K5] Pitkänen M. Cosmic string model for the formation of galaxies and stars. Available at: <https://tgdtheory.fi/pdfpool/galaxystars.pdf>, 2023.
- [K6] Pitkänen M. Cosmic Strings. In *Physics in Many-Sheeted Space-Time: Part II*. <https://tgdtheory.fi/tgdhtml/Btgdclass2.html>. Available at: <https://tgdtheory.fi/pdfpool/cstrings.pdf>, 2023.
- [K7] Pitkänen M. Identification of the WCW Kähler Function. In *Quantum Physics as Infinite-Dimensional Geometry*. <https://tgdtheory.fi/tgdhtml/Btgdgeom.html>. Available at: <https://tgdtheory.fi/pdfpool/kahler.pdf>, 2023.
- [K8] Pitkänen M. More about TGD Inspired Cosmology. In *Physics in Many-Sheeted Space-Time: Part II*. <https://tgdtheory.fi/tgdhtml/Btgdclass2.html>. Available at: <https://tgdtheory.fi/pdfpool/cosmore.pdf>, 2023.
- [K9] Pitkänen M. New Physics Predicted by TGD: Part I. In *p-Adic Physics*. <https://tgdtheory.fi/tgdhtml/Bpadphys.html>. Available at: <https://tgdtheory.fi/pdfpool/TGDnewphys1.pdf>, 2023.
- [K10] Pitkänen M. New Physics Predicted by TGD: Part II. In *p-Adic Physics*. <https://tgdtheory.fi/tgdhtml/Bpadphys.html>. Available at: <https://tgdtheory.fi/pdfpool/TGDnewphys2.pdf>, 2023.
- [K11] Pitkänen M. Nuclear String Hypothesis. In *TGD and Nuclear Physics*. <https://tgdtheory.fi/tgdhtml/Bnucl.html>. Available at: <https://tgdtheory.fi/pdfpool/nucstring.pdf>, 2023.
- [K12] Pitkänen M. Recent View about Kähler Geometry and Spin Structure of WCW. In *Quantum Physics as Infinite-Dimensional Geometry*. <https://tgdtheory.fi/tgdhtml/Btgdgeom.html>. Available at: <https://tgdtheory.fi/pdfpool/wcwnew.pdf>, 2023.
- [K13] Pitkänen M. Some questions related to the twistor lift of TGD. In *Quantum TGD: Part III*. <https://tgdtheory.fi/tgdhtml/Btgdquantum3.html>. Available at: <https://tgdtheory.fi/pdfpool/twistquestions.pdf>, 2023.
- [K15] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II*. <https://tgdtheory.fi/tgdhtml/Btgdclass2.html>. Available at: <https://tgdtheory.fi/pdfpool/astro.pdf>, 2023.
- [K16] Pitkänen M. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time: Part II*. <https://tgdtheory.fi/tgdhtml/Btgdclass2.html>. Available at: <https://tgdtheory.fi/pdfpool/cosmo.pdf>, 2023.
- [K17] Pitkänen M. TGD as a Generalized Number Theory: Infinite Primes. In *TGD as a Generalized Number Theory: Part I*. <https://tgdtheory.fi/tgdhtml/Btgdnumber1.html>. Available at: <https://tgdtheory.fi/pdfpool/visionc.pdf>, 2023.

- [K18] Pitkänen M. TGD as a Generalized Number Theory: p-Adicization Program. In *Quantum Physics as Number Theory: Part I*. <https://tgdtheory.fi/tgdhtml/Btgdnumber1.html>. Available at: <https://tgdtheory.fi/pdfpool/visiona.pdf>, 2023.
- [K19] Pitkänen M. TGD as a Generalized Number Theory: Quaternions, Octonions, and their Hyper Counterparts. In *TGD as a Generalized Number Theory: Part I*. <https://tgdtheory.fi/tgdhtml/Btgdnumber1.html>. Available at: <https://tgdtheory.fi/pdfpool/visionb.pdf>, 2023.
- [K20] Pitkänen M. TGD view of the engine powering jets from active galactic nuclei. Available at: <https://tgdtheory.fi/pdfpool/galjets.pdf>, 2023.
- [K21] Pitkänen M. The Recent Status of Lepto-hadron Hypothesis. In *p-Adic Physics*. <https://tgdtheory.fi/tgdhtml/Bpadphys.html>. Available at: <https://tgdtheory.fi/pdfpool/leptc.pdf>, 2023.
- [K22] Pitkänen M. WCW Spinor Structure. In *Quantum Physics as Infinite-Dimensional Geometry*. <https://tgdtheory.fi/tgdhtml/Btgdgeom.html>. Available at: <https://tgdtheory.fi/pdfpool/cspin.pdf>, 2023.

Articles related to TGD

- [L1] Pitkänen M. Cold Fusion Again . Available at: https://tgdtheory.fi/public_html/articles/cfagain.pdf, 2015.
- [L2] Pitkänen M. Hydrinos again. Available at: https://tgdtheory.fi/public_html/articles/Millsagain.pdf, 2016.
- [L3] Pitkänen M. X boson as evidence for nuclear string model. Available at: https://tgdtheory.fi/public_html/articles/Xboson.pdf, 2016.
- [L4] Pitkänen M. Some comments related to Zero Energy Ontology (ZEO). Available at: https://tgdtheory.fi/public_html/articles/zeroquestions.pdf, 2019.
- [L5] Pitkänen M. What could 2-D minimal surfaces teach about TGD? https://tgdtheory.fi/public_html/articles/minimal.pdf, 2021.
- [L6] Pitkänen M. Comparison of Orch-OR hypothesis with the TGD point of view. https://tgdtheory.fi/public_html/articles/penrose.pdf, 2022.
- [L7] Pitkänen M. Two objections against p-adic thermodynamics and their resolution. https://tgdtheory.fi/public_html/articles/padmass2022.pdf, 2022.
- [L8] Pitkänen M. About long range electromagnetic quantum coherence in TGD Universe. https://tgdtheory.fi/public_html/articles/hem.pdf, 2023.
- [L9] 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.
- [L10] Pitkänen M. Is Negentropy Maximization Principle needed as an independent principle? https://tgdtheory.fi/public_html/articles/NMPcrit.pdf, 2023.
- [L11] Pitkänen M. Magnetic Bubbles in TGD Universe: Part I. https://tgdtheory.fi/public_html/articles/magnbubble1.pdf, 2023.
- [L12] Pitkänen M. Magnetic Bubbles in TGD Universe: Part II. https://tgdtheory.fi/public_html/articles/magnbubble2.pdf, 2023.
- [L13] Pitkänen M. New result about causal diamonds from the TGD view point of view. https://tgdtheory.fi/public_html/articles/CDconformal.pdf, 2023.
- [L14] 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.
- [L15] Pitkänen M. Symmetries and Geometry of the "World of Classical Worlds" . https://tgdtheory.fi/public_html/articles/wcwsymm.pdf, 2023.

- [L16] Pitkänen M. TGD view of the paradoxical findings of the James Webb telescope . https://tgdtheory.fi/public_html/articles/JWagain.pdf, 2023.
- [L17] Pitkänen M. About Langlands correspondence in the TGD framework. https://tgdtheory.fi/public_html/articles/Frenkel.pdf, 2024.
- [L18] Pitkänen M. About the Recent TGD Based View Concerning Cosmology and Astrophysics. https://tgdtheory.fi/public_html/articles/3pieces.pdf, 2024.
- [L19] Pitkänen M. About the TGD counterpart of the inflationary cosmology. https://tgdtheory.fi/public_html/articles/inflatgd2024.pdf, 2024.
- [L20] Pitkänen M. Some solar mysteries. https://tgdtheory.fi/public_html/articles/Haramein.pdf, 2024.
- [L21] Pitkänen M. TGD as it is towards the end of 2024: part I. https://tgdtheory.fi/public_html/articles/TGD2024I.pdf, 2024.
- [L22] Pitkänen M. TGD as it is towards the end of 2024: part II. https://tgdtheory.fi/public_html/articles/TGD2024II.pdf, 2024.
- [L23] Pitkänen M. What gravitons are and could one detect them in TGD Universe? https://tgdtheory.fi/public_html/articles/whatgravitons.pdf, 2024.
- [L24] Pitkänen M. A more detailed view about the TGD counterpart of Langlands correspondence. https://tgdtheory.fi/public_html/articles/Langlands2025.pdf, 2025.
- [L25] Pitkänen M. About Dirac equation in $H = M^4 \times CP_2$ assuming Kähler structure for M^4 . https://tgdtheory.fi/public_html/articles/HJdireq.pdf, 2025.
- [L26] Pitkänen M. About the structure of Dirac propagator in TGD. https://tgdtheory.fi/public_html/articles/dirprop.pdf, 2025.
- [L27] Pitkänen M. Gödel, Lawvere and TGD. https://tgdtheory.fi/public_html/articles/Gtgd.pdf, 2025.
- [L28] Pitkänen M. Holography= holomorphy vision and a more precise view of partonic orbits . https://tgdtheory.fi/public_html/articles/HHpartons.pdf, 2025.
- [L29] Pitkänen M. The violation of isospin symmetry in strong interactions and .511 MeV anomaly: evidence for TGD view of quark color. https://tgdtheory.fi/public_html/articles/isospinbreak.pdf, 2025.