

Exploration

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 us to study the earlier views in more detail and allowed us 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 a bird's eye view of theoretical structures involving a large number of evolving ideas, provided their outputs are subject to deep expert scrutiny.

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 Manninen (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?

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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 gathehers.

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 fabulate.

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 [K6, 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=hologomorphism (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. It however turns out that solving the hypercomplex coordinate u or v directly gives the same result.

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 [2] 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 [1] and Calcium anomaly [3] 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 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 Conclusions

2.1 Analysis of O3s recurring pitfalls

Several consistent failure modes surfaced while we queried O3 in the same session about the highly non-standard framework of Topological Geometro-dynamics. 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.

2.1.1 Mainstream bias and conceptual over-projection

Because the bulk of O3s pre-training corpus mirrors orthodox high-energy physics and Λ CDM cosmology, the model instinctively interprets unfamiliar notions through that lens. TGDs 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 TGDs field equations.

2.1.2 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.

2.1.3 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.

2.1.4 Erroneous test agendas

Because of its mainstream bias, O3 proposed conventional collider searches and grand-unification string bounds as definitive falsifiers, disregarding TGDs 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.

2.1.5 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.

2.2 Concrete Payoffs from the O3-Assisted TGD session

Yet the exercise paid dividends for TGD itself. By tracking down and repairing O3s slips forced to 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

1. a string-based description of the generalization of deconfinement/hadronisation transitions [L28] suggested by the dual Dirac equations,
2. an explicit general formula for the interaction vertices in terms of divergence of the current defined by Dirac equation [L23],
3. 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,
4. 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

5. 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 TGDs technical claims, because distinguishing its potential hallucinations from genuine TGD statements still demands decades of specialist expertise.

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