Official top quark and toponium as particles of M_{89} hadron physics?

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Abstract

The anomalies of the standard model have begun to accumulate. The existence of toponium is the newest anomaly. The lifetime of the official top quark candidate is too short for the toponium to form by hadronic interactions. The new view of quark color predicted by TGD, predicts an entire fractal hierarchy of hadron physics characterized by the color multiplets defined by color partial waves in CP_2. p-Adic length scale hypothesis, having now number theoretic justification, suggests that ordinary and Gaussian Mersenne primes label these copies characterized by a p-adic length scale coming as some powers of 2. M_{89} hadron physics corresponds to a hadronic mass scale, which is 512 times that for ordinary hadron physics. For top quark there exist unorthodox candidates at masses 28 and 30 GeV and there is also a candidate for toponium with mass 56 GeV. The official top quark has suspiciously large mass: if it corresponds to s quark of M_{89} hadron physics, its mass is predicted correctly by the scaling argument. The recently identified dark matter candidate in turn has the mass of the u/d quark of M_{89} hadron physics and could indeed be dark in the sense that it has $h_{eff} = 512h$.

1 Introduction

I watched an excellent video about what we have learned at LHC (see). Three runs RUN1, RUN2, and RUN3 have been completed and now we know where the limits for the applicability of the Standard Model are.

The immediate successor of LHC will be high-luminosity LHC operating from 2029- 2030 onwards for ten years. Future circular collider (FCC) will start to operate in the late 2040s.

Electrons and positrons will collide and the collider (Higgs factory) will act as a high precision collider.

The philosophy is that high precision might allow us to develop a theory allowing us to solve the various anomalies of the standard model. In future, the experimentalists would not be merely testing whether a given extension of the standard model might solve some anomalies but trying to identify more general deviations from the standard model. But is this enough? What has been lacking from theoretical physics since the times of Einstein and his contemporaries, is philosophical thinking challenging the basic assumptions. Can one make progress by merely measuring more precisely?

The video explains the basic anomalies. The anomalies are also discussed in detail by Crivellin and Mellado [C2]. The following list defines the boundaries of the region of phenomena that the standard model can explain.

1. Toponium exists although it should not.
2. W mass deviates from the predicted mass.
3. g-2 anomaly of muon is claimed to disappear in lattice calculations using only quarks and gluons but does not disappear when hadronic data are used as an input.
4. Lepton universality is violated in some meson decays.
5. Penta and tetra quarks, whose existence is not denied but not predicted by the standard model.
6. There are anomalies associated with the CP violation of the CKM matrix.
7. The axions, proposed to solve the problem due to the strong CP violation predicted by QCD, have not been found and the strong CP violation is too weak to explain matter antimatter asymmetry.
8. Quark-gluon plasma predicted by QCD did not behave like gas but a perfect liquid and the transition to quark gluon plasma seems to occur at several energies rather than single phase transition point.
9. SUSY was believed to solve the hierarchy problem involving the fine tuning of the Higg couplings but no evidence for SUSY particles was found.
10. WIMPs as candidates for galactic dark matter have not been found.

2 Toponium anomaly as an indication for M_{89} hadron physics

I have discussed various anomalies from the TGD point of view in various articles. Here I will consider only the discovery of the toponium, which is one of the latest surprises.

2.1 What toponium is?

The Standard model does not deny toponium's existence but according to the standard intuition it should not exist.

1. The lifetime of the top quark is too short for the formation of toponium. There are of course proposals for solving this and also other anomalies but the problem is that these proposals typically solve only one anomaly. The lifetime of the standard top quark candidate with mass $m \simeq 172.5$ GeV is $\tau = 5 \times 10^{-25}$ s. This time is shorter than required for QCD hadronization processes ($10^{-23} - 10^{-24}$ s). This is why it has been believed that toponium does not exist.

2. The toponium was however discovered both by LHC and ATLAS and its lifetime is estimated to be 2.5×10^{-25} s. Toponium is suggested to be a quasi-bound state or a resonance appearing when top quarks are produced very near to the threshold energy (see this and this). Toponium decay is triggered by a weak decay of one of its constituents rather than being a strong decay. Both ATLAS and CMS verified the existence of this state with a resonance width of about 3 GeV.

2.2 TGD predicts a fractal hierarchy of standard model physics

Consider now the basic ideas of TGD view of hadron physics and standard model in general. TGD leads to almost inescapable conclusion that there must exist an entire hierarchy of standard model physics assignable to the triality ± 1 color representations defined by color partial waves of quarks and antiquarks in CP_2. Leptons would appear in triality 0 color partial waves [L8, L7].

1. The color multiplets of quarks of a given standard model physics would combine to form color triplets, which would serve as building bricks of hadrons of a given hadron physics [L9, L12, L6, L11]. These hadrons would correspond to a hierarchy of p-adic mass scales, proposed to be labelled by ordinary and Gaussian Mersenne primes. The longer the p-adic scale, the higher the dimension of the color multiplet.

   For the observed leptons, color representations would combine to form color singlets but also analogs of mesons as bound states of colored leptons might be possible [K5]. Only at energies near CP_2 mass would color deconfinement for incoming and outgoing states be possible.

2. Ordinary hadrons would correspond to the Mersenne prime M_{107}. The nucleon of M_{89} hadron physics would correspond to the mass scale $512 m_n$ and therefore to the LHC energy scale. The transition from M_{107} hadron physics to M_{89} hadron physics would take place at quantum criticality. The phase transition usually interpreted as a creation of the quark-gluon phase could correspond to this phase transition [L10]. At quantum criticality the value h_{eff}/h would scale up the Compton length scale of M_{89} hadrons. This would reflect long range quantum fluctuations. This re-interpretation of what has been identified as quark gluon-plasma would solve various anomalies associated with this identification mentioned already in the list of anomalies [L10, L9]. The existence of M_{89} hadron physics can have dramatic implications. For instance, a dramatic modification of the model of the Sun [L4] can be considered.

3. The ratio of the p-adic length scales associated with M_{107} and M_{89}, characterizing the Compton lengths and also defining the geometric size of nucleons as 3-surfaces, is 512. The assumption is that the geometric size of the M_{89} hadron with a large h_{eff} is the same as for M_{107} hadron at quantum criticality implies $h_{eff}/h = 512$. The sizes of M_{89} hadrons would be the same as for ordinary hadrons at quantum criticality for the transition from M_{89} hadron physics to M_{107} hadron physics.

4. I have proposed the identification of various bumps observed at LHC, originally identified first as candidates for SUSY particles but then rejected, in terms of M_{89} mesons [K2, K3].

2.3 Could the official top quark be a quark of M_{89} hadron physics?

The large mass of the official top quark raises the question whether it could be M_{89} quark created at quantum criticality.

1. A natural guess is that the lifetime of top quark at quantum criticality is scaled up $h_{eff}/h = 512$ to $.25 \times 10^{-21}$ s. The corresponding distance scale would be $.75 \times 10^{-13}$ m, which is longer than the nuclear size scale!

2. A reasonable guess is that the hadronization time scale for M_{89} is for h_{eff}/h scaled down by factor 1/512 due to decrease of the p-adic length scales. This p-adic length scale corresponds to the geometric size scale of the causal diamond $CD = cd \times CP_2$ assignable to the region

in which the phase transition occurs. This local phase transition is discussed in [L12]. The increase $h_{eff} \rightarrow 512 h_{eff}$ keeps the geometric time scale associated for hadronization the same as it would be for ordinary hadrons and determined by the p-adic time scale $L(107)$ assignable to ordinary hadrons.

What happens to the rate of hadronization? The phase transition increasing the value of h_{eff} guarantees that the TGD counterpart of perturbative theory,, still applies. "Mother Nature loves her theoreticians" [L2] is one way to express this principle. Since the zeroth order term in the TGD counterpart of the perturbative expansion, giving the classical approximation, does not depend on h_{eff}, the classical approximation improves as h_{eff} increases.

The rate for M_{89} hadronization is proportional to the hadronic mass scale $m(89) = 512m(107)$. Since the geometric time scale is $L(107)$ by quantum criticality, the short lifetime of top does not prevent the formation of toponium. Quantum criticality could quite generally increase the probabilities for the formation of bound states of very short-lived particles.

The basic objection is that the official top quark as M_{89} quark would most naturally correspond to some M_{107} quark. The actual $g = 2$ U type quark should have a lower mass that the official top quark.

1. There is indeed evidence for a top quark-like state at much lower mass from Aleph. The mass is estimated to be about 30 GeV or 28 GeV [C1, **?**]. This has motivated the question whether the two candidates for the top quark could correspond to a scaled variant of the top. In the TGD framework, the p-adic length scale hypothesis might allow this [K2] [L6].
2. What about the toponium in this case? There is an old anomaly reported by Aleph at 56 GeV (see `https://arxiv.org/pdf/hep-ph/9608264.pdf`) and there is reference to an old paper: ALEPH Collaboration, D. Buskulic *et al*, CERN preprint PPE/96–052. What was observed was 4-jet events consisting of dijets with invariant mass around 55 GeV. What makes this interesting is that the mass of 28 GeV particle candidates would be one half of the mass of a particle with a mass of 56 GeV particle, quite near to 55 GeV. Could this state be the toponium as $g = 2$ U quark [K2] [L6]?

From the ratio 512 of the mass scales for M_{89} and M_{107} hadron physics one can estimate the mass of M_{89} top quark to be in the range 1450-1500 GeV. By using the scaling argument it is possible to also estimate the masses of the M_{89} quarks. Here a report about finding dark matter candidate at LUX-ZEPLIN detector came in rescue.

2.4 The dark matter particle detected by the LUX-ZEPLIN detector is identifiable as a dark pion of M_{89} hadron physics predicted by TGD!

It took 5 months for me to learn of a claim about a direct detection of dark matter. The news was published already towards the end of 2025 (see this). I will glue part of the news here.

The LUX-ZEPLIN detector (see this) at the Sanford Underground Research Facility, located 1,500 meters beneath the former Homestake Gold Mine, recorded 8 candidate dark matter interaction events over 1,000 days of operation that carry statistical certainty of 5.2 sigma crossing the discovery threshold physicists require for particle physics announcements. The detector uses 10 tonnes of ultra-pure liquid xenon cooled to minus 108 degrees Celsius, surrounded by water tanks shielding against cosmic rays that would overwhelm the faint dark matter signal at shallower depths.

Dark matter particles theorized as Weakly Interacting Massive Particles with masses between 10 and 1,000 times the proton mass produce tiny flashes of scintillation light and ionization when they collide with xenon nuclei, distinguishable from radioactive background through their characteristic dual-signal fingerprint.

The detected events carry particle masses consistent with a 65 proton-mass dark matter candidate, within the theoretical range predicted by supersymmetric extensions of the standard model. Independent verification is already underway at the PandaX-4T detector in China and the XENONnT detector in Italy's Gran Sasso Laboratory, with results expected within six months.

What does TGD say about the claimed 5.2 sigma discovery?

1. One of the most dramatic predictions of TGD is a scale hierarchy of standard model physics labelled by Mersenne primes and their Gaussian counterparts [L8, L7, L9] based on number theoretic vision [L3, L5]. This hierarchy would correspond to the hierarchy of color partial waves associated with the Dirac equation in $H = M^4 \times CP_2$ in which space-times are 4-surfaces obeying a slightly non-deterministic holography. The failure of strict classical determinism of the holography at the level of space-time surfaces, forcing what I call zero energy ontology (ZEO), is crucial for both the non-triviality of quantum TGD and for TGD inspired theory of consciousness.

   The mass scales of leptons and hadrons of a standard model physics associated with a given pair of quark-like and leptonic color partial wave multiplets is conjecture to be proportional to the inverse of the square root of the Mersenne or Gaussian Mersenne characterizing the scaled copy: for the most recent articles about p-adic thermodynamics, replacing Higgs mechanism [L1, L6, L11]. For instance, for electrons one would correspond to Mersenne prime $M_{127} = 2^{127} - 1$.

2. Ordinary hadrons would correspond to Mersenne prime $M_{107} = 2^{107} - 1$. The Mersenne prime M_{89} would correspond to a mass scale, which is 512 times the mass scale of ordinary hadron physics. During about 2 decades pieces of evidence for M_{89} hadron physics at LHC have been accumulating [L9] [K2, K3]. M_{89} hadron physics would dramatically modify the model for the energy production in the Sun [L4].

3. TGD predicts a hierarchy of effective Planck constants h_{eff} coming as integer multiples of its minimal value, which is considerably smaller than the ordinary Planck constant. The phases with non-standard value of Planck constant would behave like dark matter since vertices involving fermions with particles having different values of h_{eff} are not possible. The 2-vertex changing the value of h_{eff} is however possible and phase transitions changing h_{eff} are possible.

4. A TGD based explanation for the LUX-ZEPLIN events interpreted in terms of dark matter would be as a pion of M_{89} hadron physics identifiable as a scaled up copy of ordinary M_{107} hadron with a mass scale which is 512 times higher but having a non-standard value of effective Planck constant so that the M_{89} hadrons would be like dark matter. The scaling of the mass .134 MeV of the ordinary pion by factor 512 gives mass of 67 GeV. This is exactly the reported mass if proton mass 940 MeV is approximated as 1 GeV (the error is 6 per cent)!

   M_{89} hadrons would be created as a phase of ordinary matter with scaled up valued of effective Planck constant guaranteeing that at quantum criticality for the phase transition the Compton lengths of M_{89} hadrons, scaled by factor h_{eff}/h are same as for ordinary hadrons. This requires that the ratio of h_{eff}/h equals to the ratio p-adic length scales associated with M_{107} and M_{89} equal to $2^{(107-89)/2} = 2^9 = 512$.

One can apply the scaling argument to estimate masses of the scaled variants of other quarks.

1. The mass of M_{89} s quark would be 176 GeV, which is not far from top quark mass $m_t = 173$ GeV. The original proposal that the top quark corresponds to M_{89} u quark. I did not realize that the scaling argument allows only the interpretation as M_{89} s quark.

2. The mass of c quark is estimated to be 1.5 GeV or 1.275 GeV. The M_{89} c quark is estimated to have mass of 750 GeV or 63.75 GeV.

3. The mass of b quark is estimated to be in the range 4.2-4.7 GeV M_{89} b quark is estimated to have mass in the range 2400 GeV-2350 GeV.

4. If the real top has mass of 28 GeV or 30 GeV explaining the Aleph anomaly, the mass of M_{89} t quark is in the range 1400-1500 GeV.

These kind of estimates can be made also for leptons and baryons. M_{89} electron would have mass about 250 GeV. The naive scaling of proton mass would give the mass of 512 GeV for M_{89}

nucleon. Needless to say, these predictions mean an entire scaled hadron physics to be tested at LHC.

If this picture is correct, the official top quark would more naturally correspond to genus $g = 1$ and therefore to M_{89} s quark. Could the poor understanding of the family replication phenomenon and of the origin of the CKM mixing explain this mis-interpretation?

1. The CKM matrix V is empirically determined from charged currents (W decays). The matrix elements of type V^U_D, $U \in \{u, c\}$, $V \in \{d, s\}$ reflect the CKM mixing of d and s quarks. Unitary conditions bring in the matrix elements V^t_D and dependence on top quark mass. Both beta decays and kaon decays provide information about V^U_D, $U \in \{u, c\}$, $V \in \{d, s\}$. These two kinds of constraints lead to slightly different outcomes [C2] for V.

2. Could a wrong identification of the top quark mass cause the discrepancy? In TGD, the official top as the $g = 0$ quark of "dark" M_{89} hadron physics created in the transition to quark-gluon plasma would induce a leakage of probability inducing a genuine violation of the unitary for the CKM matrix.

3. In TGD, the description of family replication has a topological explanation and CKM mixing reduces to topological mixing discussed in [K1, K4]. A model for the transition between M_{107} and M_{89} is needed to see whether the new interpretation can be consistent with what is known about creation of official top quarks.

4. The prediction is that the official top as an M_{89} s quark is accompanied by an M_{89} c quark with considerably large mass. The toponium as a counterpart of neutral K meson should be a member of an isospin doublet. There should be two doublets and CP breaking at the level of M_{89} hadron physics. In particular, toponium should have short lived and long lived versions with slightly different life times.

   The M_{89} counterparts of various mesons such as π and ρ should exist and the mass of the recently discovered dark matter candidate indeed has an identification as the M_{89} variant of pion. The discovery of the M_{89} counterpart of the hadron spectroscopy would give a dramatic support for the TGD view.

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