Some comments about the identification of leptons and matter-antimatter asymmetry

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Abstract

The mathematical formulation of TGD has now reached a stage in which one can seriously consider fixing the details of the physical interpretation of the theory. This new understanding poses strong constraints on the physical interpretation and raises the hope that one could fix the interpretation of the theory at the level of details. In this article, the identification of leptons and the model for the generation of matter-antimatter asymmetry are reconsidered in light of the new understanding.

1 Introduction

The mathematical formulation of TGD has now reached a stage in which one can seriously consider fixing the details of the physical interpretation of the theory. The discussion of the detailed physical interpretation in articles [L3], inspired by what I called Platonization, led to a proposal for a unification of hadron, nuclear, atomic, and molecular physics in terms of the notion of Hamiltonian cycles defined by monopole flux tubes at Platonic solids. This generated quite unexpected insights and killer predictions.

In [L4] a construction of strong, electroweak and gravitational interaction vertices, reducing them to partly topological 2-vertex describing a creation of fermion-antifermion pair in a classical induced electroweak gauge potentials, led to very concrete predictions relating also the topological explanation of family replication phenomenon and its correlation with homology charge of the partonic 2-surface.

In the articles [L7, L6] the identification of the isometries of WCW were considered and explicit realizations of symplectic and holomorphic isometry generators demonstrated that the original intuitive view is almost correct. The new aspects were related to the holography suggesting also a duality between symplectic and holomorphic isometry charges and supercharges. Also the relationship of holography, apparently in conflict with path integral approach, was understood. The dynamics of light-like partonic orbits is almost topological and not completely deterministic, which implies that the finite sum over partonic orbits can be approximated with path integral at QFT limit.

The emergence of all these constraints raises the hope that one could fix the interpretation of the theory at the level of details. In this article, the identification of leptons and matter-antimatter asymmetry are reconsidered in light of the new understanding.

2 About two competing identifications for leptons

In the TGD Universe, one can imagine two competing identifications of leptons.

1. Leptons and quarks correspond to different chiralities of spinors of $H = M^4 \times CP_2$.
2. Only quarks are fundamental fermions and leptons are anti-baryon like objects.

2.1 Option A: Are both leptons and quarks fundamental fermions?

The first option means that both lepton and quark chiralities appear in the modified Dirac action fixed by hermicity once the action fixing space-time surfaces or their lower-dimensional submanifolds such as string world sheets and partonic orbits is known. In accordance with the experimental facts, lepton and quark numbers are conserved separately for this option. This is the original proposal and seems to be the most realistic option although the geometry of "world of classical worlds" (WCW) in terms of anticommutators of WCW gamma matrices, expressible as super generators of symmetries of H inducing isometries of WCW, seems to require only a single fermionic chirality.

The challenge is to explain why both chiralities are needed. It seems now clear that all elementary particles should be assignable to 2-sheeted monopole flux tubes with the fermion lines at wormhole throats (partonic 2-surfaces) of wormhole contacts identifiable as boundaries of string world sheets. The fermion numbers could be also delocalized inside string world sheets inside the flux tubes or inside flux tubes. Also in condensed matter physics states localized to geometric objects of various dimensions are accepted as a basic notion (for TGD view of condensed matter see [L2]).

One can identify several dichotomies, which are analogous to the lepton-quark dichotomy. There is holomorphic-symplectic dichotomy, the dichotomy between light-like partonic orbits and 3-surfaces at the boundaries of $\delta M^4_+ \times CP_2$, the dichotomy between Euclidean and Minkowskian space-time regions and the dichotomy between the 3-D holographic boundary data and interiors of the space-time surface. Could one unify all these dichotomies?

1. Consider first the Minkowskian-Euclidean dichotomy. Leptons could reside inside (string world sheets of) the Minkowskian regions of space-time surface and quarks inside (the string world sheets of) the Euclidean wormhole contacts. Euclidean regions with a fixed Minkowskian region or vice versa could be regarded as two sub-WCWs.

   The nice feature of this option is that it allows us to understand both quark/color confinement without any quark propagation and propagation of quarks in QCD. We would not see free quarks because they live inside the Euclidean regions of the space-time surface and do not propagate inside the Minkowskian regions of the space-time surface. Embedding space spinor spinor fields would however propagate in accordance in H which gives rise to quark propagators in the scattering amplitudes and conforms with the QCD picture. Notice that both quarks and leptons can appear at the partonic orbits forming the interfaces between Euclidean and Minkowskian space-time regions.

2. The holomorphic-symplectic dichotomy for the isometries of WCW is now well-established and one has explicit expression for the corresponding conserved charges and their fermionic counters defining gamma matrices as fermionic super charges which in anticommute to WCW metric.

   The symplectic representations of the fermionic isometry generators associated with the light-like partonic orbits at boundaries of CD defining 3-D holomorphic data could correspond to quarks. In accordance with color confinement, quarks would not appear at Euclidean 3-surfaces at light-cone boundaries $\delta M^4_+ \times CP_2$. Classical gluon fields would define the simplest Hamiltonian fluxes and conserved quantities in the 3-D dynamics would be determined by the Chern-Simons-Kähler action with time defined by the light-like time coordinate. The Hamiltonians of $S^2 \times CP_2$,organized to representations of color group and of rotation group restricted to partonic 2-surface, would define the Hamiltonian fluxes.

The 4-D holomorphic representations in the interior of space-time surfaces and also assignable to the 3-surfaces at the boundaries of space-time surface at $\delta M^4_+ \times CP_2$ would correspond to leptons. Also the anticommutators of the lepton-like gamma matrices would give contributions to the metric of WCW.

3. Holography as a dichotomy would suggest at quantum level that in an information theoretic sense the 4-D holomorphic dynamics of leptons represents the 3-D symplectic dynamics of quarks. The possibility of a kind of holography-like relation was already discussed in [L3], where it was found that the states of nuclei could be in rather precise correspondence with the states of atomic electrons. A generalization of this holography would correspond to a kind of quark-lepton holography.

One can argue that this general view could lead to a conflict with the possible holography-like relation between ordinary and dark quarks considered in [L5] as a way to guarantee that perturbation theory converges.

1. According to an intuitive argument, strong coupling strength is proportional to $1/h_{eff}$ so that the increase of effective Planck constant h_{eff} could guarantee the convergence of QFT type description expected at QFT limit of TGD. Ordinary quarks could transform in the $h \rightarrow h_{eff}$ transition to states, which consist of pair of quark and dark antiquark with a vanishing total color, electroweak quantum numbers and spin whereas the second dark quark with a larger value of h_{eff} would have quantum numbers of the ordinary quark.

   The proposal was that dark quark and antiquark reside at the Minkowskian string world sheet. This does not conform with the above proposal, which requires that all quarks are at the partonic orbits.

2. This problem can be solved. Many-sheeted space-time however makes it possible to imagine that the dark quark and antiquark reside at the wormhole contacts of a larger space-time sheet and form a dark meson-like object. For instance, the ordinary quark would be associated with a wormhole contact connecting the other large space-time sheet to a third smaller space-time sheet, itself part of the monopole flux tube defining the ordinary quark. This would conform with the hierarchy formed by flux tubes topologically condensed to larger flux tubes.

2.2 Option B: Are only quarks fundamental fermions?

The second option stating that only quarks are fundamental particles, was motivated by the fact that only single fermion chirality seemed to be needed to construct WCW geometry. Leptons would be antibaryon-like states such that the 3 antiquarks are associated with single wormhole contact [L1]. Lepton itself would be a closed monopole flux tube with geometric size defined by the Compton scale.

1. The first critical question is whether it makes sense to put 3 quarks to the same wormhole contact defining 2-D surface in CP_2 when the color degrees of freedom correspond to the "rotational" degrees of freedom in CP_2 but realized as spinor modes. One would have at least 2 antiquarks at the same wormhole contact. If the partonic 2-surface is homologically non-trivial geodesic sphere, the reduction of symmetry from $SU(3)$ to $U(2)$ subgroup with the same Cartan algebra occurs and the rotational degrees of freedom reduce to those at the partonic 2-surface. Wave functions for quarks would be wave functions for the end of the string at a partonic 2-surface having well-defined U(2) quantum numbers.

2. If multi-quark states at partonic 2-surfaces make sense, one can ask how to avoid the counterparts of Δ baryons with spin 3/2. Statistics constraint does not help to achieve this. Oscillator operators for color partial waves of quarks are anticommuting and there seems to be no reason excluding these states. In this sense color quantum numbers are like spin-like quantum numbers. One could of course hope that Δ-like states have a very high mass scale.

3. The third critical question concerns the origin of the CP breaking which would allow baryons as stable 3-quark states and only leptons as stable bound states of 3 antiquarks. Matter antimatter asymmetry would correspond to the stable condensation of antiquarks to leptons and quarks to baryons. This mechanism looks really elegant.

3 How matter antimatter asymmetry could be generated?

Both options A and B for the identification of leptons must be able to explain the generation of matter-antimatter asymmetry.

1. CP breaking involving M^4 and/or CP_2 Kähler forms could explain the matter antimatter asymmetry along the same lines as in the standard picture. For Option A a small asymmetry between the densities of fermions and antifermions should be generated in the early cosmology and annihilation would lead to the antisymmetry. There would be space-time regions with opposite sign of asymmetries. For Option B the densities of leptons and antileptons and baryons and antibaryons would be slightly different before the annihilation and there would be no actual asymmetry.

2. For both A and B option, many-sheeted space-time and the hierarchy of magnetic bodies makes it possible to imagine many different realizations for the separation of fermion and antifermion numbers. For instance, cosmic strings could contain antimatter. The ordinary matter would be generated in the decay of the energy of cosmic strings to ordinary matter. This process is the TGD counterpart of inflation and highly analogous to black hole evaporation.

   In the simplest model, this energy would be associated with classical M^4 type Kähler electric fields and CP_2 type Kähler magnetic fields inside the cosmic string. The decay of the volume energy and the energy of the classical electroweak fields would take place by a generation of fermion-antifermion pairs via fermion 2-vertex and classical electroweak gauge potentials would appear in the vertex.

3. If the CP breaking induced by the classical Kähler fields makes it more probable for antifermions to remain inside the monopole flux tubes, antimatter-matter asymmetry is generated. Also the CP breaking observed in meson decays could relate to the asymmetry caused by the induced Kähler field of the meson-like monopole flux tube.

4. In QCD, the topological instanton term gives rise to strong CP breaking as a CP violation of the vacuum state which is not invariant under CP (so called theta parameter describes the situation) [C1].

   In the TGD framework, the "instanton density" $\int J \wedge J$ for the induced Kähler field is non-vanishing and analogous to the theta therm. As a matter fact, instanton density is equal to the gluonic istanto action for the classical gluon field $g_A = H_A J$. Instanton density can be transformed to the Chern-Simons-Kähler action as a boundary term and their contribution to the action is analogous to instanton number in QCD although it need not be integer valued. The Chern-Simons-Kähler action gives a contribution to the modified Dirac action at partonic orbits giving rise to fermionic vertices.

   The strong Kähler magnetic fields at the monopole flux tubes give rise to the analog of strong CP violation and provide a possible quantitative description for the generation of the matter-antimatter asymmetry in the decay of the energy of cosmic strings to fermion-antifermion pairs and bosons. For cosmic strings the Kähler magnetic field is extremely strong.

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