SUSY in TGD Universe

M. Pitkänen
Email: matpitka6@gmail.com.
http://tgdtheory.com/.

June 20, 2019

Abstract

This article was inspired by a longer paper "TGD view about McKay Correspondence, ADE Hierarchy, Inclusions of Hyperfinite Factors, and Twistors". I found it convenient to isolate the part of paper related to supersymmetry but it turned out that this led to additional contributions not present in the article. In twistor Grassmannian approach to $\mathcal{N}=4$ SYM twistors are replaced with supertwistors and the extreme elegance of the description of various helicity states using twistor space wave functions suggests that super-twistors are realized at the level of M^8 geometry. These supertwistors are realized at the level of momentum space.

In TGD framework M^8-H duality allows to geometrize the notion of super-twistor in the sense that different components of super-field correspond to components of super-octonion each of which corresponds to a space-time surfaces satisfying minimal surface equations with string world sheets as singularities - this is geometric counterpart for masslessness.

The progress in understanding of M^8-H duality throws also light to the problem whether SUSY is realized in TGD and what SUSY breaking does mean. It is now rather clear that sparticles are predicted and SUSY remains exact but that p-adic thermodynamics causes thermal massivation: unlike Higgs mechanism, this massivation mechanism is universal and has nothing to do with dynamics. This is due to the fact that zero energy states are superpositions of states with different masses. The selection of p-adic prime characterizing the sparticle causes the mass splitting between members of super-multiplets although the mass formula is same for all of them.

The question how to realize super-field formalism at the level of $H=M^4\times CP_2$ led to a dramatic progress in the identification of elementary particles and SUSY dynamics. The most surprising outcome was the possibility to interpret leptons and corresponding neutrinos as local 3-quark composites with quantum numbers of anti-proton and anti-neutron. Leptons belong to the same super-multiplet as quarks and are antiparticles of neutron and proton as far quantum numbers are consided. One implication is the understanding of matter-antimatter asymmetry. Also bosons can be interpreted as local composites of quark and anti-quark.

Hadrons and hadronic gluons would still correspond to the analog of monopole phase in QFTs. Homology charge would appear as space-time correlate for color at space-time level and explain color confinement. Also color octet variants of weak bosons, Higgs, and Higgs like particle and the predicted new pseudo-scalar are predicted. They could explain the successes of conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC).

Contents

1 Introduction

This article is part of a longer paper "TGD view about McKay Correspondence, ADE Hierarchy, Inclusions of Hyperfinite Factors, and Twistors" [L7]. I found it convenient to isolate the part of paper related to supersymmetry. In twistor Grassmannian approach to $\mathcal{N} = 4$ SYM [B5, B2, B3, B4, B7, B6, B1] twistors are replaced with supertwistors and the extreme elegance of the description of various helicity states using twistor space wave functions suggests that super-twistors are realized at the level of M^8 geometry. These supertwistors are realized at the level of momentum space.

In TGD framework $M^8 - H$ duality allows to geometrize the notion of super-twistor in the sense that different components of super-field correspond to components of super-octonion each of which corresponds to a space-time surfaces satisfying minimal surface equations with string world sheets as singularities - this is geometric counterpart for masslessness.

The progress in understanding of $M^8 - H$ duality throws also light to the problem whether SUSY is realized in TGD and what SUSY breaking does mean. It is now rather clear that sparticles are predicted and SUSY remains exact but that p-adic thermodynamics causes thermal massivation: unlike Higgs mechanism, this massivation mechanism is universal and has nothing to do with dynamics. This is due to the fact that zero energy states are superpositions of states with different masses. The selection of p-adic prime characterizing the sparticle causes the mass splitting between members of super-multiplets although the mass formula is same for all of them.

The question how to realize super-field formalism at the level of $H = M^4 \times CP_2$ led to a dramatic progress in the identification of elementary particles and SUSY dynamics. The most surprising outcome was the possibility to interpret leptons and corresponding neutrinos as local 3-quark composites with quantum numbers of anti-proton and anti-neutron. Leptons belong to the same super-multiplet as quarks and are antiparticles of neutron and proton as far quantum numbers are consided. One implication is the understanding of matter-antimatter asymmetry. Also bosons can be interpreted as local composites of quark and anti-quark.

Hadrons and hadronic gluons would still correspond to the analog of monopole phase in QFTs. Homology charge would appear as space-time correlate for color at space-time level and explain color confinement. Also color octet variants of weak bosons, Higgs, and Higgs like particle and the predicted new pseudo-scalar are predicted. They could explain the successes of conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC).

2 SUSY and TGD

What SUSY is in TGD framework is a longstanding question. In the following the most plausible picture assuming $M^8 - H$ duality is discussed.

2.1 What SUSY at fundamental level could mean?

One can imagine two options for SUSY at the fundamental level.

2.1.1 Does TGD allow SUSY at fundamental level?

Generalization of SUSY is strongly suggestive at the level of cognitive representations, where it makes sense to have fermion fields at same point, and would mean that each point can carry all possible quark and lepton states. Consider the situation in M^8 picture for which space-time is a surface in M^8.

1. The formulation of the theory for cognitive representations effectively replaces X^4 with a set of points with M^8 coordinates in extension of rationals. This set of points defines also the WCW coordinates of space-time surface. This set can fix the space-time surface uniquely if it corresponds to a root of octonionic polynomial.

2. In TGD quarks do not carry color as spin like number so that Fermi statistics allows all many-fermion-anti-fermion states such that fermions (antifermions) do not have identical electro-weak and spin quantum numbers. Fermi statistics allows finite number of many-fermion and many-anti-fermion states at given point: one has 4 different states corresponding to 2 helicity states and 2 possible electro-weak states (U and D type quarks, lepton and corresponding neutrino). These states correspond to the components states of $\mathcal{N} = 4$ super-multiplet or even $\mathcal{N} = 8$ SUSY (conserved B and L and both fermion and antifermion as generators of super-symmetries)with conserved B and L. This picture is almost "must" for cognitive representation for which fermions could reside at the points of cognitive representation having coordinates in extension of rationals defined the adele in adelic physics [L4].

3. For this option SUSY would not be broken: the same mass formula would hold true for all members of the SUSY multiplet but mass scale could be different in massivation by p-adic thermodynamics. p-Adic prime characterizing the mass scale of the particle would depend on its quantum numbers. Mass splitting inside SUSY multiplet would occur and spartners could be very heavy.

4. In TGD massless fields correspond to minimal surfaces (apart from string world sheet singularities). The superposition of fields is replaced with the disjoint union of space-time surfaces carrying the superposed fields: a particle touching unavoidably sheets with common M^4 projection experiences the sum of effects of the fields at different space-time sheets. This allows to understand how many-sheeted space-time leads to QFT limit. Octonions replace the space of primary fields and the roots of octonionic polynomial correspond to space-time sheets. The replacement of octonions with super-octonions assigns to each component of super-octonion polynomial a space-time surface so that the super field is geometrized.

   The geometric description of SUSY would be in terms of super-octonions and components of SUSY multiplet would correspond to components of a real polynomial of super-octonion and would in general give rise to minimal space-time surfaces as their roots: one space-time sheet for each component of the super-polynomial.

   What is of crucial importance is that the components would have different degrees so that the extensions defined by the roots would be different. Therefore also the p-adic primes characterizing corresponding particles would be different as ramified primes of extension and in p-adic mass calculations this would mean different p-adic mass scales and breaking of SUSY although the mass formulas would be same for the members of SUSY multiplet. The remaining question is how the ramified prime defining the p-adic prime is selected.

5. Particles are proposed to correspond to points of cognitive representation, whose points have preferred imbedding space coordinates in the extension of rationals defining the particular adele in adelic physics [L4]. These points would be also belong to partonic 2-surfaces identified as intersections of 6-D universal roots r_n of octonionic polynomials in 1-1 correspondence with the roots of the real polynomial with rational coefficients defining the octonionic polynomial. The projections of these surface to M^4 would be $t = r_n, 0 \leq r_M \leq r_n$ balls inside light-cone. The data at partonic 2-surfaces - the points in extension of rationals - would dictates the space-time surface in accordance with strong form of holography. This generalizes to polynomials of super-octonions.

6. This option might be free of divergences, and number theoretical vision requires that loops vanish since they would lead out of extension of rationals essential for adelic physics to make sense. Coupling constant evolution would reduce to discrete sequence of phase transitions between phases characterized by different coupling constants determined by quantum criticality.

   If SUSY is realized, the vertices could be those of SUSY with conserved B and L and describe the decay or fusion of states consisting of some number of elementary fermions and antifermions at same point and describable using $\mathcal{N}=4$ or maybe even $\mathcal{N}=8$ SUSY (generated by quarks, leptons, and and their antiparticles).

7. One could also argue that the formation of stable enough many-fermion states with many fermions at single point is most plausible if there are no gauge interactions between fermions. Right handed neutrino corresponding to covariantly constant CP_2 spinor has no color and electro-weak interactions. This would suggest that $\mathcal{N}=2$ SUSY generated by neutrinos is the least broken one.

8. The counterpart of SUSY at the level of $H=M^4\times CP_2$ would be obtained by M^8-H duality in relatively straightforward manner.

This option is definitely the most elegant and most general and there would be strong connections with SUSYs and even understanding of SUSY breaking in terms of p-adic thermodynamics and different extensions of rationals for various members of the SUSY multiplets.

2.1.2 Does TGD allow dynamically generated SUSY at fundamental level?

I have also played with what might be called dynamically generated SUSY. Consider first no-SUSY option.

1. A stronger condition would be that only single fermion or antifermion at given point of space-time surface is possible. At continuum limit one might argue that this kind of states are too singular and therefore excluded. Particle interaction vertices would involve only re-arrangement of fermion and anti-fermion lines and turning of them backwards in time. There would be no SUSY.

2. For this option one expects that the scattering amplitudes could be obtained as composites of scattering amplitudes for fundamental fermions. If so, the construction should be very simple.

One can however imagine a kind of dynamically generated broken SUSY also for this option.

1. Suppose that fermions and antifermions are associated with singularities of space-time surfae at which sheets intersect each other. For 4-D space-time surface in 8-D space these self-intersections are unavoidable but intersections of more than two branches are expected to be very rare unless some special conditions are required.

2. If one allows fermion-right-handed neutrino pairs at intersections of two branches, one would have almost $\mathcal{N}=2$ SUSY: the states with fermion and pair or right-handed neutrino and antineutrino would be missing.

3. Space-time surfaces would be mapped by M^8-H duality to $H=M^4\times CP_2$. Since the tangent space of of point is parameterized sa CP_2 point, and because tangent spaces of coinciding points at singularity are different, the image would consist of several points of CP_2 but same point of M^4. The points at different sheets would have collinear light-like momenta so that they could be interpreted as members of SUSY multiplet.

4. In this case number theory would not provide a mechanism of SUSY breaking since the intersecting roots correspond to the same polynomial and same extension of rationals.

One could argue that for this option the formation of sparticles are than fundamental sfermions is extremely rare occurrence so that SUSY cannot be realized in this manner.

2.1.3 Do super-twistors make sense at the level of M^8?

By $M^8 - H$ duality [L3] there are two levels involved: M^8 and H. These levels are encountered both at the space-time level and momentum space level. Do super-octonions and super-twistors make sense at M^8 level?

1. At the level of M^8 the high uniqueness and linearity of octonion coordinates makes the notion of super-octonion natural. By $SO(8)$ triality octonionic coordinates (bosonic octet 8_0), octonionic spinors (fermionic octet 8_1), and their conjugates (anti-fermionic octet 8_{-1}) would for triplet related by triality. A possible problem is caused by the presence of separately conserved B and L. Together with fermion number conservation this would require $\mathcal{N} = 4$ or even $\mathcal{N} = 4$ SUSY, which is indeed the simplest and most beautiful SUSY.

2. At the level of the 8-D momentum space octonionic twistors would be pairs of two quaternionic spinors as a generalization of ordinary twistors. Super octo-twistors would be obtained as generalization of these.

Also Grassmannian is replaced with super-Grassmannian and super-coordinates as matrix elements of super matrices are introduced.

1. The integrand of the Grassmannian integral defining the amplitude can be expanded in Taylor series with respect to θ parameters associated with the super coordinates C as rows of super $G(k, n)$ matrix.

2. The delta function $\delta(C, Z)$ factorizing into a product of delta functions is also expanded in Taylor series to get derivatives of delta function in which only coordinates appear. By partial integration the derivatives acting on delta function are transformed to derivatives acting on integrand already expanded in Taylor series in θ parameters. The integration over the θ parameters using the standard rules gives the amplitudes associated with different powers of θ parameters associated with Z and from this expression one can pick up the scattering amplitudes for various helicities of external particles.

The super-Grassmannian formalism is extremely beautiful but one must remember that one is dealing with quantum field theory. It is not at all clear whether this kind of formalism generalizes to TGD framework, where particle are 3-surfaces [L3]. The notion of cognitive representation effectively reducing 3-surfaces to a set of point-like particles strongly suggests that the generalization exists.

The progress in understanding of $M^8 - H$ duality throws also light to the problem whether SUSY is realized in TGD and what SUSY breaking does mean. It seems now clear that sparticles are predicted and SUSY remains in the simplest scenario exact but that p-adic thermodynamics causes thermal massivation: unlike Higgs mechanism, this massivation mechanism is universal and has nothing to do with dynamics. This is due to the fact that zero energy states are superpositions of states with different masses. The selection of p-adic prime characterizing the sparticle causes the mass splitting between members of super-multiplets although the mass formula is same for all of them.

3 How to formulate SUSY at the level of $H = M^4 \times CP_2$?

If SUSY is realized at the level of M^8, it should have a formulation also at the level of H.

1. $M^8 - H$ duality is non-local and means that the dynamics at the level of H is not strictly local but dictated by partial differential equations for super-fields having interpretation as describing purely local many-fermion states made of fundamental fermions with quantum numbers of leptons and quarks (quarks do not possess color as spin like quantum number) ad their antiparticles.

2. Classical field equations and modified Dirac equation must result from this picture. Induction procedure for the spinors of H must generalize so that spinors are replaced by super-spinors Ψ_s having multi-spinors as components multiplying monomials of θ. The determinant of

metric and modified gamma matrices depend on imbedding space coordinates h replaced with super coordinates h_s so that monomials of θ appear in two different manners. Hermiticity requires that sums of monomial and its hermitian conjugate appear in h_s. Monomials must also have vanishing fermion numbers. Otherwise on can obtained fermionic states propagating like bosons. For Dirac action one must assume tha Ψ_s involves only odd monomials of θ possibly multiplied by monomials appearing in h_s to get only fermionic states and correct kind of propagators.

3. One Taylor expands both bosonic action density (Kähler action plus volume term) Super-Dirac action with respect to the super-coordinates h_s. The coefficients of the monomials of θ:s are obtained are partial derivatives of the action. Since the number of θ parameters is finite and corresponds to the number of spin-weak-isopin states of quarks and leptons, the number of terms is finite if the θ parameters anti-commute to zero. If not, one can get an infinite number of terms from the Taylor series for the action. Number theoretical considerations do not favor this and there should exist a cancellation mechanism for the radiative corrections coming from fermionic Wick contractions.

4. One can interpret the superspace as the exterior algebra of the spinors of H. This reminds of the result that the sections of the exterior algebra of Riemann manifold codes for the Riemann geometry (see `http://tinyurl.com/yxrcr8xv`). This generalizes the observation that one can hear the shape of a drum since the sound spectrum is determined by its frequency spectrum defined by Laplacian.

   Super-fields define a Clifford algebra generated by θ parameters as a kind of square root of exterior algebra which corresponds to the Clifford algebra of gamma matrices. Maybe this algebra could code also for the spinor structure of imbedding space or even that of space-time surface so that the super-fields could be seen as carriers of geometric information about space-time surface as a preferred extremal. In 8-D case there is also $SO(1,8)$ triality suggesting that corresponding three Clifford algebras correspond to exterior algebra fermionic and anti-fermionic algebras.

5. At M^8 level the components of super-octonion correspond to various derivatives of the basic polynomial $P(t)$ so that space-time geometry correlates with the quantum numbers assignable to super-octonion components - this is in accordance with QCC (quantum-classical correspondence). This is highly desirable at the level of H too.

6. Could the space-time surface in M^8 be same for super-field components with degree $d < d_{max}$ in some special cases? The polynomial associated with super octonion components are determined by the derivatives of the basic polynomial $P(t)$ with order determined by the degree of the super-monomial. If they have decomposition $P(t) = P_1^k(t)$, the monomials with degree $d < k$ the roots corresponding to the roots $P_1(t)$ co-incide. Besides this there are additional roots of $d^r P_1/dt^r$ for super-octonion component with r θ parameters.

   A possible interpretation could be as quantum criticality in which there is no SUSY breaking for components having $d < k$ (masses in p-adic thermodynamics could be the same since the extension defined by P_1 and corresponding ramified primes would be same). This would conform with the general vision about quantum criticality.

7. Usual super-field formalism involves Grassmann integration over θ parameters to give the action. M^8 formalism does not involve the θ integral at all. Should this be the case also at the level of H? This would guarantee that different components of H- coordinates as super-field would give rise to different spae-time surface and QCC would be realized. θ integration produces SUSY invariants naturally involved with the definition of vertices involving components of super-fields. Also vertices involving fermionic and bosonic states emerge since bosonic super-field components appear in super-coordinates in super-Dirac action.

3.1 Could super coordinates of H be treated like super-octonion in M^8?

Could one treat super-fields in H in the same manner as in M^8? One would perform the θ integration to obtain action principle for the dynamics of space-time surface or of induced spinor fields. The first guess is that the multi-spinors appearing in bosonic action are classical fields. The super-components of Dirac spinor would be however second quantized. Here one must however keep mind open.

The coefficient actions would be spinorial quantities multiplied by monomials of θ:s and one would solve field equations separately for each multi-spinor component This would be in accordance with the replacement of superposition of fields with disjoint union for space-time surfaces with induced fields.

It seems that the analog of SYM-Super-Dirac action is the only physical option. Bosonic action as analog of SYM action would describe bosons and their spartners and Super-Dirac action fermions and their spartners.

3.1.1 Bosonic action as an analog of SYM action

In bosonic action imbedding space coordinates are supersymmetrized. This option is analogous to pure SYM action without fermions.

1. Space-time would be super-surface in super counterpart of $H = M^4 \times CP_2$ with coordinates h^k having super components proportional to multi-spinors multiplying the monomials of θ parameters treated as independent fields. For M^4 this is expected to work but in the case of CP_2 this approach is not so straightforward. The symmetries and projective space property allowing to use projective coordinates might help to overcome the possible technical problems.

2. The θ parameters associated with θ and $\overline{\theta}$ cannot anti-commute to zero but can be regarded as fermionic creation operators and annihilation operators. Θ parameters and their conjugates can be assigned with both leptons and quarks (or with quarks only as it turns out). If θ parameters and their conjugates anti-commute in standard manner to unity, one can regard them as fermionic oscillator operators. The vacuum expectation value of the action contains only monomials with vanishing B an L.

   A stronger condition is that h_s is hermitian and thus contains only sums of monomials and their conjugates having vanishing B and L. This guarantees super-symmetrization respecting bosonic statistics at the level of propagators since all kinetic terms involve two covariant derivatives - one can indeed transform ordinary derivatives of monomials coming from the Taylor expansion to covariant derivatives involving also the coupling to Kähler form since the total Kähler charge of terms vanishes.

The lack of anti-commutativity of θ:s and their conjugates (also representable as θ derivates) or equivalently of fermionic oscillator operators implies problems.

1. For anti-commuting θ parameters the series would involve a finite number of partial derivatives of action. Wick contractions of oscillator operators would give rise to an infinite series. As such this need not be a problem if the sum converges to a well-defined algebraic extension defining general coordinate invariant action as a kind of effective action expressible as a Taylor series of super field components with vanishing net fermion numbers B and L. The appearance of infinite Taylor series defining the coefficients of super-polynomial is however troublesome from the point of view of number theoretic vision since there is no guarantee that the coefficients are rational functions.

   One manner to avoid problems is to normal order the terms in the action. One can however hope that the normal ordered form results automatically due to the vanishing of c-number terms emerging in the normal ordering process. This condition would be analogous to the vanishing of fermionic loops and this is indeed the basic vision of TGD. By quantum criticality coupling constant evolution is discrete so that loops vanish. This would imply a huge simplification of twistor amplitudes [L6] since only the counterparts of tree diagrams would be obtained.

2. The terms in the action would typically involve n-tuples of partial derivatives

$$L_{k_1\alpha_1,....\alpha_n k_n} = \frac{\partial_n L}{\partial h^{k_1}_{|\alpha_1} ... \partial h^{k_n}_{|\alpha_n}}$$

coming from super-Taylor expansion of action The Taylor expansion must be define recursively by substituting repeatedly the Taylor expansion of Γ_k in terms of super-coordinates. This expansion should stop in finite order. This should be due to the vanishing of terms involving anti-commutators of oscillator operators. In the case of Γ^α and Γ_k the expansion must be carried out recursively and if the contractions coming from anti-commutators of oscillator operators do not vanish, the recursion process is infinite.

The partial derivatives $L_{k_1\alpha_1,....\alpha_n k_n}$ are contracted with quantities $\gamma_{k_1}..\gamma_{k_n} D_{\alpha_1} O_1 ... D_{\alpha_n} O_n$, where O_n are monomials of θ parameters. The resulting terms can be denoted by $\Gamma^{\alpha_1...\alpha_n} O_1 D_{\alpha_1} ... D_{\alpha_n} O_n$.

The terms O_n in the bosonic expectation value representing contributions for Δh_s involve Wick contractions of type $\langle |h_s \overline{h}_s\rangle$. The vacuum expectation values $\langle \Gamma^{\alpha_1...\alpha_n} \prod_i D_{\alpha_i} \Delta h_{s,i}\rangle$ must vanish.

The vanishing of these divergences could be interpreted in terms of conserved Noether currents and therefore symmetries. This condition would be analogous to the vanishing of loops and would be guaranteed by preferred extremal property and field equations for $h_{s,i}$. The experience with preferred extremals of bosonic action, which is sum of Kähler action and volume term tells that preferred extremals are minimal surface apart from string world sheet singularities and the field equations reduce to algebraic conditions. In recent case one might hope that something similar happens.

The simplest situation would be that the vacuum expectations have vanishing multi-divergences:

$$\Gamma^{\alpha_1...\alpha_n} \langle \prod_i D_{\alpha_i} \Delta h_{s,i}\rangle = 0 \ .$$

$n-1$-fold divergence would define a conserved current perhaps assignable to a symmetry as a Noether current. Also for more general assumption that the monomials involve even number of θ and their conjugates similar conservation conditions are obtained. An interesting possibility is that these conditions code for the conjectured Yangian symmetry characterizing also twistorial amplitudes [L6].

3. One does not obtain free field equations. The reason is that the Taylor expansion of the non-linear geometric action gives higher powers of super-parts of imbedding space coordinates.

An interesting possibility in line with the speculations of Nima-Arkani Hamed and others is that space-time as a 4-surface of imbedding space could emerge from anti-commutators of the θ monomials as radiative corrections so that the bosonic action would vanish when the super-part of h_s vanishes.

3.1.2 Super-Dirac action

Before doing anything one can recall what happens in the case of modified Dirac action.

1. One has separate modified Dirac actions $\overline{\Psi} D\Psi$, $D = \Gamma^\alpha D_\alpha$ for quarks and leptons (later it will be found that modified Dirac action for quarks might be enough) and the covariant derivatives differ since there is a coupling to n-ple of included Kähler potential. For leptons one has $n = -3$ and for quarks $n = 1$. This guarantees that em charges come out correctly. This coupling appears in the covariant derivative D_α of fermionic super field.

2. One obtains modified Dirac equations for quarks and leptons by variation with respect to spinors. The variation with respect to the imbedding space coordinates gives quantized versions of classical conservation laws with respect to isometries. One also obtains and infinite number of super-currents as contractions of modes of the modified Dirac operator with Ψ.

3. Classical field equations for the space-time surface emerge as a consistency condition guaranteeing the modified Dirac operator is hermitian: canonical momentum currents of classical action must be conserved and define conserved quantum when contracted with Killing vectors of isometries. Quantum-classical correspondence (QQC) requires than for Cartan algebra of symmetry algebra the classical Noether charges are same as the fermionic Noether charges.

It turns out that the super-symmetrization of modified Dirac equation gives only fermions and they fermionic superpartners in this manner if one requires that propagators are consistent with statistics.

H coordinates are super-symmetrized and induced spinor field becomes a super-spinor $\Psi = \Psi_N \Theta_N$ with Psi_N depending on h_s.

1. As in the case of bosonic action the vacuum expectation value gives modified Dirac action conserving fermion numbers but one could assume that the monomials in the leptonic (quark) modified Dirac action have either non-vanishing L (B) and vanishing B (L). It seems that the lepton (baryon -) number of monomials can vary from 1 to maximum value. A more restrictive condition would be that the value is 1 for all terms.

2. Leptonin/quark like Dirac spinor is expanded in monomials O_N of θ (or fermionic creation operators) as sum $\Psi = \Psi^N O_N$ defining super-spinor field. The multi-spinors Ψ_N are functions of space-time coordinates, which are ordinary numbers. θ parameters are same as for the imbedding space super-coordinates. Only odd monomials are allowed.

3. The metric determinant and modified gamma matrices appearing in the Dirac action are expanded as Taylor series in hermitian super-coordinate $h_s + \overline{h}_s$ with $h = h^N O_N$. This as as in the case of bosonic action. The super-coordinate expansion of the metric determinant $\sqrt{g}$ and modified gamma matrices Γ^α and covariant derivatives D_α involving dependence on H coordinates give additional monomials of θ parameters appear as hermitian monomials. Classical field equations correspond to $D_\alpha \Gamma^\alpha = 0$ guaranteeing the hermiticity of $D = \Gamma^\alpha D_\alpha$.

4. When super-coordinates of H are replaced with ordinary imbedding space coordinates the only Wick contractions are between O^N and $\overline{O}^N$ in the vacuum expectation of Dirac action, and the action reduces to super-Dirac action with components satisfying modified Dirac equation. Propagator is Dirac propagator for all terms and the presence of only odd components in Ψ and even components in h^s guarantees that Fermi statistics is not violated at the level of propagators. The dependence on h_s induces coupling between different components of the super-spinor. The components of super-spinor are interpreted as second quantized objects.

5. The terms in the action would typically involve n-tuples of partial derivatives $L_{k_1\alpha_1...k_n1\alpha_n}$ defined earlier for $L = \sqrt{g}$ coming from super-Taylor expansions. Similar derivatives come from the modified gamma matrices Γ^α.

   Also now one obtains loops from the self contractions in the terms coming from the expression of action and gamma matrices. These terms should vanish and as already found this would requires vanishing of currents perhaps identifiable as Noether currents of symmetries. This guarantees that the Taylor expansion contains only finite number of terms as required by number theoretic vision.

The multi-fermion vertices defined by the action would be non-trivial but involve always contraction of all fermion indices between monomials formed from θ:s in Ψ and their conjugates in $\overline{\Psi}$ if the loop contractions sum up to zero. One could interpret these supersymmetric vertices as a redistribution of fermions of a local many-fermion state between external local many-fermion states particles represented by the monomials appearing in the vertices. The fermions making the initial state would be same as in final state and all distributions of fermion number between sfermion lines would be allowed. The action obtained by contraction would has SUSY as symmetry but the propagation of different sfermions is fermionic and does not look like that for ordinary spartners.

3.1.3 Feedback to M^8 level

Super-symmetrization of bosonic action identified as sum of Kähler action and volume term plus super-Dirac action [L6] seem to define an excellent candidate for the description of TGD basic physics. One could however worry about the asymmetry between M^8 and H.

1. Should one introduce super-spinors also at the level of M^8 as octonion analytic fields and defined scattering amplitudes in terms of them just as in the case of H? The fact is that scattering amplitudes cannot be defined in terms of octonionic surfaces alone.

Also spinor fields are needed and here $SO(1,3)$ triality is suggestive. Spinor fields and anti-spinor fields could be octonion analytic functions (polynomials) of octonion coordinate, which are conjugates of each other. $SO(1,3)$ triality however suggests that only fermions correspond to second imbedding space chirality are allowed: the trio would be formed by fermions, antifermions, and octonionic coordinates. It turns out that one could indeed understand leptons and neutrinos as local analogs of proton and neutron so that only quark chirality would be present at fundamental level. This would simplify dramatically the picture about elementary particles and interactions.

2. This picture forces to consider alternative interpretation for octonion analyticity. Could the vanishing of the real or imaginary part in quaternionic sense have interpretation as a condition of super-spinor - kind of super-selection rule.

3.2 Could SYM action plus Super-Dirac action for quarks explain elementary particle spectrum?

TGD based SUSY involves super-spinors and super-coordinates. Suppose that one has a cognitive representation defined by the points of space-time surface with coordinates in an extension of rationals defining adele and belonging to the partonic 2-surfaces defined by the intersections of 6-D roots of octonionic polynomials with 4-D roots. This representation has H counterpart.

Cognitive representation gives rise to a tensor product of these algebras and the oscillator operators define a discretized version of fermionic oscillator operator algebra of quantum field theories. One would have interpretation as many-fermion states but the local many-fermion states would have particle interpretation. This would replace fermions of the earlier identification of elementary particles with SUSY multiplets in the proposed sense. This brings in large number of new particles. One can however ask whether the return to the original picture in which single partonic 2-surface corresponds to elementary particle could be possible. Certainly it would simplify the picture dramatically.

Could this picture explain elementary particle spectrum and how it would modify the recent picture?: these are the questions.

3.2.1 Attempt go gain bird's eye of view

Rather general arguments suggest that SYM action plus Super-Dirac action could explain elementary particle spectrum. Some general observations help to get a bird's eye of view about the situation.

1. The antisymmetric tensor products for fermions and anti-fermions produce states with same spectrum of electro-weak quantum numbers irrespectively of whether the fermion and anti-fermion are at same point or at different points. Which option is correct or are these options correspond analogous to to two different phases of lattice gauge theory in which nodes *resp.* links determine the states? Only multi-local states containing fermions with identical spin and weak isospin at different points are not possible as local states.

   There is no point in denying the existence of either kind of states. What suggests itself is the generalization of electric-magnetic duality relating perturbative Coulomb phase in which ordinary particles dominate and the non-perturbative phase in which magnetic monopoles dominate. I have considered what I have called weak form of electic-magnetic duality already earlier [?] but as a kind of self-duality stating that for homologically charged partonic 2-surfaces electric and magnetic fluxes are identical. The new picture would conform with the view of ordinary QFT about this duality.

2. The basic distinction between TGD and standard model is that color is not spin-like quantum number but represented as color partial waves basically reducing to the spinor harmonics plus super-symplectic generators carrying color quantum numbers. Spinor harmonics as such have non-physical correlation between color and electro-weak quantum numbers [?] although quarks and leptons correspond to triality $t = 1$ and triality $t = 0$ states.

3. It turns out that one could understand quarks, leptons, and electro-weak gauge bosons and their spartners as states involving only single partonic 2-surface [**?**]: this would give essentially the original topological model for family replication in which partonic 2-surfaces were identified as boundary components of 3-surface. In principle one can allow also quarks and gluons with unit charge matrix with color partial waves defining Lie-algebra generator as bosonic states. Could these states correspond to free partons for which perturbative QCD applies at high energies?

   Also color octet partial waves of electro-weak bosons and Higgs and the predicted additional pseudo-scalar - something totally new - are possible as both local and bi-local states. There would be no mixing of $U(1)_Y$ state and neutral $SU(2)_w$ states for color octet gluon. In this sense electro-weak symmetry breaking would be absent.

4. Electro-weak group as holonomy group of CP_2 can be mapped to the Cartan group of color group, and electro-weak and color quantum numbers would relate like spin and angular momentum to each other. This encourages to think that there are deep connections between electro-weak physics and color physics, which have remained hidden in standard model.

   The conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC) of hadron physics suggests a strong connection between color physics and electro-weak physics. There is also evidence for so called X bosons with mass 16.7 MeV [**?**] [L2] suggesting in TGD framework that weak physics could have fractally scaled down copy in hadronic and even nuclear scales.

   Could ordinary gluons be responsible for CVC whereas colored variants of weak bosons and Higgs/pseudo-scalar Higgs would be responsible for PCAC? Usually strong force in hadronic sense is assigned with pion exchange. This approach does not work perturbatively. Could one assign strong force with the exchange of pseudo-scalar, and colored variants of gluons, pseudo-scalar, and Higgs?

5. Hitherto it has been assumed that homology charges (Kähler magnetic charges) characterize flux tubes connecting the two wormhole throats associated with the monopole flux of elementary particle. Could one understand the bi-local or multi-local objects of this kind as exotic phase analogous to magnetic monopole dominated phase of gauge theories as dual of Coulomb phase?

   Hadrons would certainly be excellent candidates for monopole dominated phase. Gluons would be pairs of quarks associated with homologically charged partonic 2-surfaces with opposite homology charges. Gluons would literally serve as “glue” in the spirit of lattice QCD. Gluons and hadrons would be multi-local states made from quarks and gluons as homologically trivial configurations with vanishing total homology charge.

6. Is there a correlation between color hyper-charge and homology charge forcing quarks and gluons to be always in this phase and forcing leptons to be homologically neutral? This could provide topological realization of color confinement. The simplest option is that valence quarks have homology charges $2, -1, -1$ summing up to zero. This was one of the first ideas in TGD about 38 years ago.

   One can also imagine that the homological quark charges $(3, -2, -1)$ summing up to zero define a classical correlate for the color triplet of quarks, a realization of Fermi statistics, and allow to understand color confinement topologically. The color partial waves in H would emerge at the imbedding space level and characterize the ground states of super-symplectic representations. Color triplets of quarks and antiquarks could thus correspond to homology charges $(3, -2, -1)$ and $(-3, 2, 1)$ and neutral gluons could be superpositions of pairs of form $(q, -q)$, $q = 3, -1, -1$. Charged gluons as flux tubes would not be possible in the confined phase.

7. Is monopole phase possible also for leptons as general QFT wisdom suggests? For instance, could Cooper pairs could be flux tubes having members of Cooper pair - say electrons - at its ends and photons in this phase be superposition of fermion and anti-fermion at the ends of the flux tube and monopole confinement would make the length of flux tube short and photon massive in superconducting phase.

3.2.2 The recent TGD inspired view about elementary particles as an analog of monopole dominated phase

The recent speculative view about elementary particles in TGD Universe would naturally correspond to the TGD analog of the magnetic monopole dominated phase of QFTs.

1. Ordinary bosons (and also fermions) are identified as many-fermion states. The fermions and anti-fermions would reside at different throats of the 2 wormhole contacts associated with a closed monopole flux tube associated with the elementary particle and going through wormhole contact to second space-time sheet. All elementary particles would be analogous to hadron-like entities. One can raise objections against this idea: leptons are known to be very point-like.

2. Electro-weak massivation has been assumed to involve screening of electro-weak isospin by a neutrino pair at the second wormhole contact. The screening is not actually necessary in p-adic thermodynamics in its recent form since the thermal massivation is due to the mixing of different mass eigenstates. This simplifies the model considerably since there is no need to add pairs of right- and left-handed neutrino to screen the weak charges in the scale of flux tube.

   Bosons could be simply pairs of fermion anti-fermion located at the opposite ends of flux tubes and fermions could be associated with single throat. This would simplify the topological description of particle reactions. In the case of quarks however the homological space-time correlate of color confinement is attractive and forces monopole flux tubes. It turns out that this picture is corresponds to the simplest level in the $h_{eff} = nh_0$ hierarchy.

3. In vertices fermions would be redistributed between different orbits of partonic 2-surfaces meeting at the 6-D braney object in M^8 picture or turn backwards in time - the interpretation for this might be in terms of interaction with classical induce gauge field.

   One must assume that the genus of the 4 throats is same for known elementary particles: this assumption looks rather natural but can be criticized. The correlations forced by preferred extremal property could however force the genera of wormhole throats to be identical. The original identification of particles as single partonic 2-surface predicts genus-generation correspondence without additional assumptions. The model predicts also higher gauge boson genera for which some evidence exists: TGD predictions for the masses are correct.

4. All particles would correspond to closed monopole flux tubes. In the case of quarks this allows homological description of color confinement at space-time level but for leptons and electro-weak gauge bosons the assumption is not necessary but would allow to understand phases like super-conductivity involving massivation of photons (Meissner effect). Also strongly interaction phases of electrons could be understood. It however seems that the assumption that all particles involve pair of wormhole contancs might be un-necessarily strong.

3.2.3 Are quarks enough as fundamental fermions?

For the first option - call it Option a) - quarks and leptons would define their own super-spinors. Whether only quark or lepton-like spinors are enough remains still an open question.

1. I have also considered the possibility that quarks are actually anti-leptons carrying homology charge and have anomalous em charge equal to $-1/3$ units. One might perhaps say that quarks are kind of anyonic states [**?**]. It is however difficult to understand how the coupling to Kähler form could be dynamical and have values $n = -3$ and $n = 1$ for homologically neutral and charged states respectively. This would mean that only lepton like θ parameters appear in super-coordinates and only leptonic Dirac action is needed.

2. For this option proton would be bound state of homologically charged leptons. This in principle allows decays of type $p \rightarrow e^+ ...$ and $p \rightarrow e^+ + e^+ + \overline{\nu}$ requiring that the 3 partonic 2-surfaces fused with non-trivial homology charges fuse to single homologically trivial 2-surface. This form of proton instability would be different from that of GUTs. The topology changing process is expected to be slow. Is the introduction of two super-octonionic θ parameters natural assignable to B and L or is single parameter enough?

3. The coupling to Kähler form is not explicitly visible on the bosonic action but is visible in modified Dirac action. Could leptonic modified Dirac action transform to quark type modified Dirac action? This does not seem plausible.

The super-Dirac action for quarks however suggests another option, call it Option b). Leptons could be local 3-quark states.

1. Could one identify leptons as local 3 quark composites - essentially anti-baryons as far as quantum numbers are considered - but with different p-adic scale and emerging from the super-Dirac action for quarks as purely local states with super-degree $d = 3$? Could one imagine totally new approach to the matter antimatter asymmetry?

   Leptons would be purely local 3-quark composites and baryons non-local 3-quark composites so that charge neutrality alone would would guarantee matter-antimatter symmetry at fundamental level. Anti-quark matter would prefer to be purely local and quark matter 3-local. The small CP violation due to the M^4 part of Kähler action forced by twistor lift should explain this asymmetry.

2. The local baryons would have much simpler spectrum and would correspond for given genus g (lepton generation) to the baryons formed from u and d quarks having however no color. There would be no counterparts for higher quarks. This would suggests that (L, ν_L) could be local analog of (p, n).

   For ordinary baryons statistics is a problem and this led to the introduction of quark color absent for local states. The isospin structure of the local analogs of p and n is not a problem. In uud (udd) type states allowed by statistics the spins of the u (d) quarks must have opposite spin. The analogs of Δ resonances are not possible so that one would obtain only the analogs of p and n!

3. The widely different mass scales for leptons and quarks would be due to locality making possible different ramified primes for the extension of rationals. The widely differing p-adic length scales of leptons and neutrinos could be undersood if the ramified prime for given extension can be different for the particles super-multiplets with same degree of octonionic polynomial. This could be caused by electroweak symmetry breaking. The vanishing electroweak quantum numbers of right-handed neutrino implies a dynamics in sharp contrast with that of neutron, whose dynamics would be dictated by non-locality.

   Also local pions are possible. The lepto-pions of lepto-hadron hypothesis [?] could correspond to either local pions or to pion-like bound states of lepton and anti-leptons. There is evidence also for the muon- and tau-pions.

4. This idea might provide a mathematically extremely attractive solution to the matter antimatter asymmetry: matter and antimatter would be staring us directly into eyes. The alternative TGD inspired solution would be that small CP breaking would induce opposite matter-antimatter asymmetries inside long cosmic strings and in their exteriors so that annihilation period would lead to the observed asymmetry.

3.2.4 What bosons the super counterpart of bosonic action predicts?

It has been already noticed that the spectra of fermion-antifermion states are identical for local and bi-local states if one assumes that the wave function in the relative coordinate of fermion and anti-fermion is symmetric. This does not yet imply that the particle spectrum is realistic in the case of the bosonic action.

The situation is simplified considerably by the facts that color is not spin-like quantum number but analogous to momentum and can therefore be forgotten, family replication can be explained topologically, and depending B and L are separately conserved for Option a) but for Option b) L reduces to B since leptons would be local 3-quark composites. Let us restrict first the considered to Option b).

1. What kind of spectrum would be predicted? Consider first quark Clifford algebra formed by θ parameters defining the spartners of quark. Forgetting color, one has 8 states coming from left and right handed weak doublet and their anti-doublets. The numbers of elements in Clifford algebra with given lepton number $N(q) - N(\overline{q})$ is given by $N(q) - N(\overline{q}) = \sum 0 \leq k \leq 4 - qB(4, q+k) \times B(4,k)$ in terms of binomial coefficients. For $B = 0$ one obtains $N(0) = \sum 0 \leq k \leq 4B(4,k)^2 = 70$ states. The states corresponding to the same degree of octonion polynomial and therefore having fixed $q + \overline{q} = B + \overline{B}$ have same masses. For $q - \overline{q} = 0$ bosonic state having $q = \overline{q} = 0$ with fixed k one has $q + \overline{q} = 4 + k$ so that one has $N(k) = B(4,k)^2$ ($N(k)$ states with same mass even after p-adic massivation). The numbers $N(k)$ are $(1, 4^2 = 16, 6^2 = 36, 4^2 = 16, 1)$.

2. The number of $q\overline{q}$ type states is 16. If one considers super-symmetrization of the bosonic action, these states would correspond to bosons. Could these states allow an interpretation in terms of the known gauge bosons and Higgs? Weak bosons correspond to 4 helicity doublets giving 8 states. Higgs doublet corresponds to doublet and its conjugate. There is also a pseudo-scalar doublet and its conjugate.

   Gluon cannot belong to this set of states, which actually conforms with the fact that gluon corresponds to CP_2 isometries rather than holonomies and gluon corresponds to CP_2 partial wave since color is not spin-like quantum number. Known particle would give 8+2+2=12 states and pseudo-scalar doublets the remaining 4. This kind of pseudo-scalar states are predicted both as local and the bi-local states. As already explained, one can however also understand gluons in this picture as octet color partial waves. Also color octet variants of $SU(2)_w$ weak bosons are predicted.

3. There are actually some indications for a Higgs like state with mass 96 GeV (see `http://tinyurl.com/yxnmy8c7`) . Could this be the pseudo-scalar state. Higgs mass 125 GeV is very nearly the minimal mass for $k = 89$. The minimal mass for $k = 90$ would be 88 GeV so that the interpretation as pseudo-scalar with $k = 90$ might make sense. The proposal that gluons could have also weak counterparts suggests that also the pseudo-scalar could have this kind of counterpart. The scaling of the mass of the Higgs like state with $k = 90$ to $k = 112$ ($k = 113$ corresponds to nuclear p-adic scale) would give mass $m(107) = 37.5$ MeV. Kh.U. Abraamyan et al have found evidence for pion like boson with mass 38 MeV [**?**, **?**, **?**] (see `http://tinyurl.com/y7zer8dw`).

Option b) involving only quarks as fundamental fermions does not predict unobserved gauge bosons whereas Option a) involving both leptons and quarks as fundamental fermions does so.

1. For Option a) taking into account quarks and restricting to electro-weak bosonic states to those with ($B = L = 0$) leads to a doubling of bosonic states at $k = 2$ level. The couplings of gauge bosons require that the states are superpositions of quark and lepton pairs with coefficients proportional to the coupling parameters. There are two orthogonal superpositions of quark and lepton pairs having orthogonal charge matrices with inner product defined by trace for the product. Ordinary gauge bosons correspond to the first combination.

   The orthogonality of charge matrices gives a condition on them. The charged matrices having vanishing trace can be chosen that they have opposite signs for opposite H-chiralities. For charge matrices involving unit matrix one must have charge matrices proportional to (-3,1) for (L,q) one must have (1,3) for second state. For gluons there is no condition if one treats color octet as Lie algebra generator with vanishing trace. The problem is that there is no experimental evidence for these bosons.

2. For Option b) leptons would be local 3-quark states and spartners of quarks. There would be no doubling gauge bosons since only one H-chirality would be present. The observed bosons would be basically superpositions of quark-anti-quark pairs - either local or non-local.

There would be two phases of matter corresponding to local and bi-local states (baryons would be 3-local states).

1. For both phases electro-weak bosons and also gluons with electro-weak charge matrix 1 to bosonic super action as states involving only single partonic 2-surface. As already mentioned, also color counterparts of $SU(2)_w$ bosons are possible. Also graviton could correspond to spartner for bosonic super-action. This would give essentially the original model for family replication. 2-surfaces would be homologically trivial in this phase analogous to Coulomb phase.

2. In the dual phase the bi-local states would correspond to non-vanishing homology charges for quarks at least. In this phase one should assign also to leptons 2 wormhole contacts. In super-conducting phase it could the second electron of Cooper pair. Massive photons in this phase would consist of homologically charged fermion pairs. Lepton could also involve screening lepton-neutrino pair at second wormhole contact.

The universality of gauge boson couplings provides a test for the model.

1. In bi-local model gauge bosons would correspond to representations of a dynamical symmetry group $SU(3)_g$ associated with the 3 genera [?]. Bosons would correspond to octet and singlet representations and one expects that the 3 color neutral states are light. This would give 3 gauge boson generations. Only the couplings of the singlet representation of $SU(3)_g$ would be universal and higher generations would break universality both for both gluons and electro-weak bosons. There is evidence the breaking of universality as also for second and third generation of some weak bosons and the mass scales assigned with Mersenne primes above M^{89} are correct [?].

2. If also fermions correspond to closed flux tubes with 2 wormhole contacts, the fermion boson couplings would correspond to the gluing of two closed flux tube strings along their both "ends" defined by wormhole contacts. A pair of 3-vertices for Feynman diagrams would be in question. If fermions are associated with single wormhole contact, its is not so easy to imagine how the closed bosonic flux tube could transform to single wormhole contact in the process. The wormhole contacts that meet and have opposite fermion numbers should disappear. This is allowed in the scenario involving 6-branes if the magnetic flux is trivial as it must be. For quarks and gluons the homology charges must be opposite if wormhole contact is to disappear.

3. If gauge bosons correspond to local fermion pairs, the most natural boson states have fixed value of g apart from topological mixing giving rise to CKM mixing just like fermions and universality is not natural. One can of course assume topological mixing guaranteeing it. Ordinary gauge bosons should be totally de-localized in the space of 3 lowest genera [?] (analogous to constant plane waves) in order to have universality. The vertices could be understood as a fusion of partonic 2-surfaces. One should however understand why the mixing is so different for fermions and bosons. SUSY would suggest identical mixings.

The simplest model corresponds to quarks as fundamental fermions. Leptons and various bosons would be local composites in perturbative phase. In monopole dominate phase hadronic quarks would have homology charges and gluons would be pairs of quark and anti-quark at opposite throats of closed monopoleflux tube. Basically particle reaction vertices would correspond to gluing of 3-surfaces along partonic 2-surfaces at 3-spheres defining $t = r_n$ hyperplanes of M^4.

3.2.5 What is the role of super-symplectic algebra?

This picture is not the whole story yet. Super-symplectic approach predicts that the super-symplectic algebra (SSA) generated essentially by the Hamiltonians of $S^2 \times CP_2$ assignable to the representations of $SO(3) \times SU(3)$ localized with the respect to the light-like radial coordinate of light-cone boundary characterize the states besides electro-weak quantum numbers. Color quantum numbers would correspond to Hamiltonians in octet representation. This would predict huge number of additional states.

There are however gauge conditions stating that sub-algebra of SSA having radial conformal weights coming as n-ples of SSA and isomorphic to SSA and its commutator with SSA annihilate physical states. This reduces the degrees of freedom considerably but the number of symplectic Hamiltonians is still infinite: measurement resolution very probably makes this number to finite.

3.3 $M^8 - H$ duality and SUSY

$M^8 - H$ duality and $h_{eff}/h_0 = n$ hypothesis pose strong constraints on SUSY in TGD sense.

1. $h_{eff}/h_0 = n$ interpreted as dimension of extension of rationals gives constraints. Galois extensions are defined by irreducible monic polynomials $P(t)$ extended to octonionic polynomials, whose roots correspond to 4-D space-surfaces and in special case 6-spheres at 7-D light-cones of M^8 taking the role of branes.

   The condition that the roots of extension defined by Q are preserved for larger extension $P \circ Q$ is satisfied if P has zero as root:

   $$P(0) = 0 \ .$$

   This simple observation is of crucial importance, and suggests an evolutionary hierarchy $P \circ Q$ with simplest possible polynomials Q at the bottom of the hierarchy are very naturally assignable to elementary particles. These polynomials have degree two and are of form $Q = x^2 \pm n$. Discriminant equals to $D = 2n$ and has the prime factors of n as divisors defining ramified primes identified as p-adic primes assignable to particles.

   Remark: Also polynomials $P(t) = t - c$ are in principle possible. The corresponding space-time surfaces at the level of H would be M^4 and CP_2 and they are extremals of Kähler action but do not have particle interpretation.

2. Octonionic super-polynomials decompose to a sum of octonionic polynomials with θ monomials having varying degree d. One can assign octonionic super-coordinates to both leptons and quarks for Option a). Option b) identifying leptons as local 3-quark local composites and thus spartners of quarks would mean that quarks (anti-quark) appear in the octonionic polynomial (its conjugate). This would realize $SO(1,7)$ triality.

3. This has important implications for SUSY in TGD sense. The degree d for the monomial of super-octonion polynomial in M^8 would corresponds to the degree $d = F + \overline{F}$ for the super-field in H. The number of fermions and anti-fermions giving rise to spartner is d.

   If the degree n of the octonionic polynomial is smaller than the number $N = 16$ of maximal degree of θ polynomial, only a fraction of spartners are possible. SUSY is realized only partially and one can say that part of spartners are absent at the lowest levels of evolutionary hierarchy. At the lowest level of hierarchy corresponding to $n = 2$ only fermions (quarks) would be present as local states and would form non-local states such as baryons and mesons. Gauge bosons and Higgs like state would be bi-local states and graviton 4-local state.

   Remark: Gauge bosons and Higgs like states as local fermion-anti-fermion composites at level $n = 2 \times 2$. For the option involving only quarks (color is not spin like quantum number). Note that the value of $n_0 = 3 \times 2 = 6$ in $h = n_0 \times h_0$ suggested by the findings of Randel Mills [L1, L5] would allow the known elementary particles.

3.4 How is the p-adic mass scale determined?

p-Adic prime identified as a ramified prime of extension of rationals is assumed to determine the p-adic mass scale. There are however several ramified primes and somehow the quantum numbers of particle should dictate with ramified prime is chosen. There are two options to consider depending on whether both the extension and ramified prime are same for all spartners Option 1) or whether spartners can have different ramified primes (Option 2)). There also options depending on whether both leptons and quarks appear in their own super-Dirac actions (Option a) or whether only quarks appear in super-Dirac action (Option b). Call the 4 composite options Option 1a), 2a), 1b), 2b) respectively.

1. Consider first Options 1a) and 1b). The ramified prime is same for all states corresponding to the same degree of θ monomial and thus same value of $F + \overline{F}$. At the lowest $k = 2$ level containing only fermions as local states the p-adic thermal masses of quarks and leptons are same for Option 1a) at least for single generation and for all generations if Q_2 does not

depend on the genus g of the partonic 2-surface. For Option 1b) the masses would *not* be same for leptons and quarks since they would correspond to different degrees of super-octonionic polymials. For both options would have $n = n(g)$.

2. For Option 2 ramified prime depends on the state of the SUSY multiplet. This would require that for fermions with $k = 2$ the integer n in $Q_2(x) = x^2 \pm n$ has the p-adic primes assignable to leptons and quarks as factors.

   There are 6 different quarks and 6 different leptons with different p-adic mass scales. For Option 2a) n should have 12 prime factors which are near to power of 2. For leptons the factors correspond to Mersenne primes M_k, $k \in \{107, 127\}$ and Gaussian Mersenne $k = 113$. Gaussian Mersenne is complex integer. TGD requires complexification of octonions with imaginary unit i commuting with octonionic units so that also Gaussian primes are possible. This would resolve the question whether $P(t)$ can have complex coefficients $m + in$.

   For option 2b) quarks and leptons as local proton and neutron would have different extensions since the polynomials would be different. The p-adic primes for 6 quark states quarks would depend on genus. The value of n need not depend on genus g since the ramified primes p depends on g: $p = p(g)$.

   Since the polynomials describing higher levels of the dark hierarchy would be composites $P \circ Q_2$ with $P(0) = 0$, Q_2 would be a really fundamental polynomial in TGD Universe. For Option 2b) it would be associated with quarks and would code for the elementary particles physics. The higher levels such as leptons would represent dark matter levels.

3. The crucial test is whether the mass scales of gauge bosons can be understood. If one assumes additivity of p-adic mass squares so that the masses for 2-local bosons would be p-adically sums of mass squared at the "ends" of the flux tube. If the discriminant $D = 2n$ of Q_2 contains high enough number of factors this is possible. The value of the factor p for photon would be rather larger from the limits on photon mass. For graviton the value p would be even larger.

To sum up, the vision about dark phases suggests that the monopole phase is possible already for the minimal value $n = 2$ involving only fundamental quarks for Option 2b), which is the simplest one and could solve the probelm of matter antimatter asymmetry. Bosons and leptons as purely local composites of quarks are possible for $n = 6$. Rather remarkably, also empirical constraints [L1, L5] led to the conclusion $h = 6h_0$. The condition is actually weaker: $h/h_0 \ mod \ 6 = 0$.

REFERENCES

Theoretical Physics

[B1] Trnka Y Arkani-Hamed N. The Amplituhedron. Available at: `http://arxiv.org/abs/1312.2007`, 2013.

[B2] Witten E Dolan L, Nappi CR. Yangian Symmetry in $D = 4$ superconformal Yang-Mills theory. Available at: `http://arxiv.org/abs/hep-th/0401243`, 2004.

[B3] Plefka J Drummond J, Henn J. Yangian symmetry of scattering amplitudes in $\mathcal{N} = 4$ super Yang-Mills theory. Available at: `http://cdsweb.cern.ch/record/1162372/files/jhep052009046.pdf`, 2009.

[B4] Huang Y-T Elvang H. Scattering amplitudes. Available at: `http://arxiv.org/pdf/1308.1697v1.pdf`, 2013.

[B5] Arkani-Hamed N et al. The All-Loop Integrand For Scattering Amplitudes in Planar N=4 SYM. Available at: `https://arxiv.org/abs/1008.2958`, 2010.

[B6] Arkani-Hamed N et al. The All-Loop Integrand For Scattering Amplitudes in Planar N=4 SYM. Available at: `http://arxiv.org/abs/1008.2958`, 2011.

[B7] Trnka Y. Grassmannian Origin of Scattering Amplitudes. Available at: https://www.princeton.edu/physics/graduate-program/theses/theses-from-2013/Trnka-Thesis.pdf, 2013.

Articles about TGD

[L1] Pitkänen M. Hydrinos again. Available at: http://tgdtheory.fi/public_html/articles/Millsagain.pdf, 2016.

[L2] Pitkänen M. X boson as evidence for nuclear string model. Available at: http://tgdtheory.fi/public_html/articles/Xboson.pdf, 2016.

[L3] Pitkänen M. Does $M^8 - H$ duality reduce classical TGD to octonionic algebraic geometry? Available at: http://tgdtheory.fi/public_html/articles/ratpoints.pdf, 2017.

[L4] Pitkänen M. Philosophy of Adelic Physics. Available at: http://tgdtheory.fi/public_html/articles/adelephysics.pdf, 2017.

[L5] Pitkänen M. Dark valence electrons and color vision. Available at: http://tgdtheory.fi/public_html/articles/colorvision.pdf, 2018.

[L6] Pitkänen M. The Recent View about Twistorialization in TGD Framework. Available at: http://tgdtheory.fi/public_html/articles/smatrix.pdf, 2018.

[L7] Pitkänen M. TGD view about McKay Correspondence, ADE Hierarchy, Inclusions of Hyperfinite Factors, $M^8 - H$ Duality, SUSY, and Twistors. Available at: http://tgdtheory.fi/public_html/articles/McKaygeneral.pdf, 2019.