SUSY in TGD Universe

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Abstract

Contrary to the original expectations, TGD seems to allow a generalization of the space-time SUSY to its 8-D variant with masslessness in 4-D sense replaced with masslessness in 8-D sense. The algebra in question is the Clifford algebra of fermionic oscillator operators associated with given partonic 2-surface. In terms of these algebras one can in turn construct generators super-symplectic algebra as stringy Noether charges and also other super-conformal algebras and even their Yangians used to create quantum states. This also forces to generalize twistor approach to give 8-D counterparts of ordinary 4-D twistors.

The 8-D analog of super Poincare algebra emerges at the fundamental level through the anti-commutation relations of the fermionic oscillator operators. For this algebra $\mathcal{N} = \infty$ holds true. Most of the states in the representations of this algebra are massive in $4-D$ sense. The restriction to the massless sector gives the analog of ordinary SUSY with a finite value of $\mathcal{N}$ - essentially as the number of massless states of fundamental fermions to be distinguished from elementary fermions. The addition of a fermion in particular mode defines particular super-symmetry. This super-symmetry is broken due to the dynamics of the Kähler-Dirac operator, which also mixes M^4 chiralities inducing massivation. Since right-handed neutrino has no electro-weak couplings the breaking of the corresponding super-symmetry should be weakest.

The question is whether this SUSY has a restriction to a SUSY algebra at space-time level and whether the QFT limit of TGD could be formulated as a generalization of SUSY QFT. There are several problems involved.

1. In TGD framework super-symmetry means addition of a fermion to the state and since the number of spinor modes is larger states with large spin and fermion numbers are obtained. This picture does not fit to the standard view about super-symmetry. In particular, the identification of theta parameters as Majorana spinors and super-charges as Hermitian operators is not possible.

   The belief that Majorana spinors are somehow an intrinsic aspect of super-symmetry is however only a belief. Weyl spinors meaning complex theta parameters are also possible. Theta parameters can also carry fermion number meaning only the super-charges carry fermion number and are non-hermitian. The general classification of super-symmetric theories indeed demonstrates that for $D = 8$ Weyl spinors and complex and non-hermitian super-charges are possible. The original motivation for Majorana spinors might come from MSSM assuming that right handed neutrino does not exist. This belief might have also led to string theories in D=10 and D=11 as the only possible candidates for TOE after it turned out that chiral anomalies cancel.

   In superstring theory the hermiticity of super generator G_0 giving as its square scaling generator L_0 is strong argument in favor if Majorana spinors since G_0 appears as a propagator. In TGD framework the counterparts of G_0 in quark and lepton sector carry fermion number so that identification as a propagator does not make sense. The recent formulation of scattering amplitudes in terms of Yangian algebra allows to circumvent the problem. Fundamental propagators are fermion propagators for fermions massless in 8-D sense.

2. The spinor components of imbedding space spinors identifiable with physical helicities and with fixed fermion number correspond to the generators of the SUSY algebra at QFT limit. This SUSY is broken due to electroweak and color interactions. Right-handed neutrinos do not have these interactions but there is a mixing with left-handed neutrinos due to the mixing of M^4 and CP_2 gamma matrices in the Kähler-Dirac gamma matrices appearing in the K-D action. Therefore also the $\mathcal{N} = 2$ sub-SUSY generated by right-handed neutrinos is broken.

In this chapter the details of the above general picture are discussed. Also the existing experimental constraints on SUSY are discussed.

1 Introduction

TGD based vision about space-time supersymmetry has developed rather slowly.

1. From the beginning it was clear that super-conformal symmetry is realized in TGD but differs in many respects from the more standard realizations such as $\mathcal{N} = \infty$ SUSY realized in MSSM [B1] involving Majorana spinors in an essential manner.

The covariantly constant right-handed neutrino generates the super-symmetry at the level of CP_2 geometry and the idea was that the construction of super-partners would be more or less equivalent with the addition of covariantly constant right-handed neutrino and antineutrinos. It was however not clear whether space-time supersymmetry is realized at all since one could argue that that these states are just gauge degrees of freedom.Much later it became clear that covariantly constant right handed neutrino indeed represents gauge degree of freedom at space-time level.

2. A more general general SUSY algebra is generated by the modes of the Kähler-Dirac operator at partonic 2-surface. This algebra can be associated with ends of the boundaries of string world sheets and each string defines its own sub-algebra of oscillator operators.

   At first it would seem that the value of $\mathcal{N}$ can be very large-even infinite. If the conformal algebra associate with the spinor modes localized at string world sheets annihilates physical states the algebra becomes however finite-dimensional, and its dimension is the number of spinor components of the imbedding space spinor possessing physical imbedding space helicity. Furthermore, SUSY limit corresponds to the dynamics of the massless states in 4-D rather than 8-D sense so that $\mathcal{N}$ is necessarily finite. For full theory with particles which are massless in 8-D sense $\mathcal{N} = \infty$ indeed holds true.

   It is quite possible that conformal symmetry also for this superconformal algebra is broken so that only the generators for which the conformal weight is proportional to integer $n = 1, 2...$ annihilate the physical states. This increases the value of $\mathcal{N}$ by factor n and a possible interpretation is in terms of improved measurement resolution.

   For this algebra the SUSY in 4-D sense is expected to be broken. First, the notion of masslessness is generalized: fermions associated with the boundaries of string world sheets have light-like 8-momentum and therefore can be massive in 4-D sense: this allows to generalize twistor description to massive case [K21]. Secondly, standard SUSY characterizes the QFT description obtained by replacing many-sheeted space-time time with a slightly curved region of Minkowski space.

   Massless (in 4-D sense) right-handed neutrinos represent the sub-SUSY with minimal breaking induced by the mixing of right- and left handed neutrinos caused by the properties of the Kähler-Dirac gamma matrices for which mixing between M^4 and CP_2 gamma matrices takes place induced breaking of M^4 chirality serving as a signature for massivation.

3. R-parity conservation leading to strong predictions in the case of MSSM is broken since right-handed neutrino can transform to a left-handed one by a coupling induced by the mixing of M^4 and CP_2 type gamma matrices in the Kähler-Dirac gamma matrices. Sparticles can decay to neutrino and particles the life-times of super-partners are finite and there is no lightest sparticle. The right-handed neutrino generated in the decays of sparticles would transform to neutrinos and produce missing energy not traceable to stanard sources.

   The problem of missing missing energy, which is the basic difficulty of the standard SUSY at LHC, might therefore be encountered also in TGD framework. One possibly is that sparticles are dark in TGD sense so that they have non-standard value of Planck constant. In this case sparticles could have the same p-adic mass scale as particles but characteristic quantal time scales would be scaled up by $h_{eff}/h = n$.

It is clear that TGD does not predict standard space-time SUSY (Majorana spinors, etc.). Now it seems also feasible that TGD predicts a variant of space-time SUSY with Dirac fermions with conserved B and L and that it is generated by fermionic oscillator operators at the sting world sheets and has finite $\mathcal{N}$ even if the sub-algebra of conformal algebra annihilating physical statesf is sub-algebra of full algebra isomorphic to it.

TGD based SUSY differs would differ dramatically from the SUSY as it is usually understood and LHC could allow to decide whether the standard view or TGD view is nearer to truth. TGD could explain the failure of LHC to find space-time SUSY: for instance, sparticles could be dark in TGD sense although their mass scales could be same as for particles.

In the following I will describe the evolution of ideas related to SUSY in TGD framework: I however decided to save the reader from documentation of the worst wrong tracks.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. There are concept maps about topics related to the contents of the chapter prepared using CMAP realized as html files. Links to all CMAP files can be found at `http://tgdtheory.fi/cmaphtml.html` [L2]. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L3].

2 Does TGD Allow The Counterpart Of Space-Time Supersymmetry?

The question whether TGD allows space-time super-symmetry or something akin to it has been a longstanding problem. A considerable progress in the respect became possible with the better understanding of the Kähler-Dirac equation.

2.1 Kähler-Dirac Equation

Before continuing one must briefly summarize the recent view about Kähler-Dirac equation.

1. The localization of the induced spinor fields to 2-D string world sheets is crucial. It is demanded both by the well-definedness of em charge and by number theoretical constraints. Induced W boson fields must vanish, and the Frobenius integrability conditions guaranteeing that the K-D operator involves no covariant derivatives in directions normal to the string world sheet must be satisfied.

2. The Kähler-Dirac equation (or Kähler Dirac equation) reads as

$$D_K\Psi = 0 \ . \tag{2.1}$$

   in the interior of space-time surface. The boundary variation of K-D equation gives the term

$$\Gamma^n\Psi = 0 \tag{2.2}$$

   at the light-like orbits of partonic 2-surfaces. Clearly, Kähler-Dirac gamma matrix Γ^n in normal direction must be light-like or vanish.

3. To the boundaries of string world sheets at the orbits of partonic 2-surfaces one assigns 1-D Dirac action in induced metric line with length as bosonic counterpart. By field equations both actions vanish, and one obtains light-like geodesic carrying light-like 8-momentum. Algebraic variant of massless 8-D Dirac equation is satisfied for the 8-momentum parallel to 8-velocity.

   The boundaries of the string world sheets are thus pieces of light-like M^8 geodesics and different fermion lines should have more or less parallel M^4 momenta for the partonic 2-surface to preserve its size. This suggests strongly a connection with quantum field theory and an 8-D generalization of twistor Grassmannian approach encourages also by the very special twistorial properties of M^4 and CP_2.

   One can wonder how this relates to braiding which is one of the key ingredients of TGD. Is the braiding possible unless it is induced by particle exchanges so that the 8-momentum changes its direction and partonic 2-surface replicates. In principle it should be possible to construct the orbits of partonic 2-surfaces in such a manner that braiding occurs. Situation is the reverse of the usual in which one has fixed 3-manifold in which one constructs braid.

4. One can construct preferred extremals by starting from string world sheets satisfying the vanishing of normal components of canonical momentum currents as analogs of boundary conditions. One can also fix 3-D space-like surfaces and partonic orbits and pose the vanishing of super-symplectic charges for a sub-algebra with conformal weights coming as multiples of fixed integer n as conditions selecting preferred extremals.

5. The quantum numbers characterizing zero energy states couple directly to space-time geometry via the measurement interaction terms in Kähler action expressing the equality of classical conserved charges in Cartan algebra with their quantal counterparts for space-time surfaces in quantum superposition. This makes sense if classical charges parametrize zero modes. The localization in zero modes in state function reduction would be the WCW counterpart of state function collapse. Thermodynamics would naturally couple to the space-time geometry via the thermodynamical or quantum averages of the quantum numbers.

2.2 Development Of Ideas About Space-Time SUSY

Let us first summarize the recent overall view about space-time super-symmetry for TGD discussed in detail in chapter “ WCW spinor structure” and also in [K16].

1. Right-handed covariantly constant neutrino spinor ν_R defines a super-symmetry in CP_2 degrees of freedom in the sense that CP_2 Dirac equation is satisfied by covariant constancy and there is no need for the usual ansatz $\Psi = D\Psi_0$ giving $D^2\Psi = 0$. This super-symmetry allows to construct solutions of Dirac equation in CP_2 [**?**, **?**, **?**, **?**].

2. In $M^4 \times CP_2$ this means the existence of massless modes $\Psi = \not{p}\Psi_0$, where Ψ_0 is the tensor product of M^4 and CP_2 spinors. For these solutions M^4 chiralities are not mixed unlike for all other modes which are massive and carry color quantum numbers depending on the CP_2 chirality and charge. As matter fact, massless right-handed neutrino covariantly constant in CP_2 spinor mode is the only color singlet. The mechanism leading to non-colored states for fermions is based on super-conformal representations for which the color is neutralized [K8, K8]. The negative conformal weight of the vacuum also cancels the enormous contribution to mass squared coming from mass in CP_2 degrees of freedom.

3. All spinor modes define conserved fermion super-currents and also the super-symplectic algebra has a fermion representation as Noether currents at string world sheets. WCW metric can be constructed as anti-commutators of super-symplectic Noether currents and one obtains a generalization of AdS/CFT duality to TGD framework from the possibility to express Kähler also in terms of Kähler function (and thus Kähler action). The fact that that super-Poincare anti-commutator vanishes for oscillator operators associated with covariantly constant right-handed neutrino and anti-neutrino implies that it corresponds to a pure gauge degree of freedom.

4. The natural conjecture is that the TGD analog space-time SUSY is generated by the Clifford algebra of the second quantized fermionic oscillator operators at string world sheets. This algebra in turn generalizes to Yangian. The oscillator operators indeed allow the 8-D analog of super-Poincare anti-commutation relations at the ends of 1-D light-like geodesics defined by the boundaries of string world sheets belonging to the orbits of partonic 2-surfaces and carrying 8-D light-like momentum.

   For incoming on mass shell particles one can identify the M^4 part of 8-momentum as gravitational for momentum equal to the inertial four-momentum assignable to imbedding space spinor harmonic for incoming on mass shell state. The square of E^4 momentum giving mass squared corresponds to the eigenvalue of CP_2 d'Alembertian.

   8-D light-like momentum forces an 8-D generalization of the twistor approach and M^4 and CP_2 are indeed unique in that they allow twistor space with Kähler structure [**?**]. The conjecture is that integration over virtual momenta restricts virtual momenta to 8-D light-like momenta but the polarizations of virtual fermions are non-physical.

5. The 8-D generalization of SUSY describes also massive states and one has $\mathcal{N} = \infty$. Ordinary 4-D SUSY is obtained by restricting the states to the massless sector of the theory. The value of $\mathcal{N}$ is finite in this case and corresponds to the value of massless modes for fundamental fermions. Quark and lepton type spinor components with physical helicity for fermions and anti-fermions define the basis of the SUSY algebra as Clifford algebra of oscillator operators with anti-commutators analogous to those associated with super Poincare algebra. Therefore the generators of SUSY correspond to the 4+4 components of imbedding space spinor modes

(quarks and leptons) with vanishing conformal weight so that analogs of $\mathcal{N} = 4$ SUSY are obtained in quark and lepton sectors.

The SUSY is broken due to the electro-weak and color interactions between the fundamental fermions. For right-handed neutrinos these interactions are not present but the mixing with left handed neutrino due to the mixing of M^4 and CP_2 gamma matrices in Kähler-Dirac gamma matrices at string world sheets implies SUSY breaking also now: also R-parity is broken.

Basically a small mixing with the states with CP_2 mass is responsible for the generation of mass and breaking of SUSY. p-Adic thermodynamics describes this mixing. SUSY is broken at QFT limit also due the replacement of the many-sheeted space-time with single slightly curved region of M^4.

6. The SUSY in question is not the conventional $\mathcal{N} = 1$ SUSY. Space-time (in the sense of Minkowski space M^4) $\mathcal{N} = 1$ SUSY in the conventional sense of the word is impossible in TGD framework since it would require require Majorana spinors. In 8-D space-time with Minkowski signature of metric Majorana spinors are definitely ruled out by the standard argument leading to super string model. Majorana spinors would also break the separate conservation of lepton and baryon numbers in TGD framework. What is remarkable is that in 8-D space-time one obtains naturally SUSY with Dirac spinors.

2.3 Summary About TGD Counterpart Of Space-Time SUSY

This picture allows to define more precisely what one means with the approximate super-symmetries in TGD framework.

1. One can in principle construct many-fermion states containing both fermions and anti-fermions at fermion lines located at given light-like parton orbit. The four-momenta of states related by super-symmetry need not be same. Super-symmetry breaking is present and has as the space-time correlate the deviation of the Kähler-Dirac gamma matrices from the ordinary M^4 gamma matrices. In particular, the fact that $\hat{\Gamma}^\alpha$ possesses CP_2 part in general means that different M^4 chiralities are mixed: a space-time correlate for the massivation of the elementary particles.

2. For right-handed neutrino super-symmetry breaking is expected to be smallest but also in the case of the right-handed neutrino mode mixing of M^4 chiralities takes place and breaks the TGD counterpart of super-symmetry. Maybe the correct manner to interpret the situation is to speak about 8-D massless states for which the counterpart of SUSY would not be broken but mass splittings are possible.

3. The fact that all helicities in the state are physical for a given light-like 3-surface has important implications. For instance, the addition of a right-handed antineutrino to right-handed (left-handed) electron state gives scalar (spin 1) state. Also states with fermion number two are obtained from fermions. For instance, for e_R one obtains the states $\{e_R, e_R\nu_R\overline{\nu}_R, e_R\overline{\nu}_R, e_R\nu_R\}$ with lepton numbers $(1,1,0,2)$ and spins $(1/2,1/2,0,1)$. For e_L one obtains the states $\{e_L, e_L\nu_R\overline{\nu}_R, e_L\overline{\nu}_R, e_L\nu_R\}$ with lepton numbers $(1,1,0,2)$ and spins $(1/2,1/2,1,0)$. In the case of gauge boson and Higgs type particles -allowed by TGD but not required by p-adic mass calculations- gauge boson has 15 super partners with fermion numbers $[2,1,0,-1,-2]$.

The cautious conclusion is that the recent view about quantum TGD allows the analog of super-symmetry, which is necessary broken and for which the multiplets are much more general than for the ordinary super-symmetry. Right-handed neutrinos might however define something resembling ordinary super-symmetry to a high extent. The question is how strong prediction one can deduce using quantum TGD and proposed super-symmetry.

1. For a minimal breaking of super-symmetry only the p-adic length scale characterizing the super-partner differs from that for partner but the mass of the state is same. This would allow only a discrete set of masses for various super-partners coming as half octaves of the mass of the particle in question. A highly predictive model results.

2. The quantum field theoretic description could be based on QFT limit of TGD, which I have formulated in terms of bosonic emergence. The idea was that his formulation allows to calculate the propagators of the super-partners in terms of fermionic loops. Similar description of exchanged boson as fermionic loop emerges also in the proposed identification of scattering amplitudes as representations of algebraic computations in Yangian using product and co-product as fundamental vertices assignable to partonic 2-surfaces at which 3-surfaces replicate.

3. This TGD variant of space-time super-symmetry resembles ordinary super-symmetry in the sense that selection rules due to the right-handed neutrino number conservation and analogous to the conservation of R-parity hold true (the mixing of right-handed neutrino with the left-handed one breaks R-parity). The states inside super-multiplets have identical electro-weak and color quantum numbers but their p-adic mass scales can be different. It should be possible to estimate reaction reaction rates using rules very similar to those of super-symmetric gauge theories.

4. It might be even possible to find some simple generalization of standard super-symmetric gauge theory to get rough estimates for the reaction rates. There are however problems. The fact that spins $J = 0, 1, 2, 3/2, 2$ are possible for super-partners of gauge bosons forces to ask whether these additional states define an analog of non-stringy strong gravitation. Note that graviton in TGD framework corresponds to a pair of wormhole throats connected by flux tube (counterpart of string) and for gravitons one obtains 2^8-fold degeneracy.

2.4 SUSY Algebra Of Fermionic Oscillator Operators And WCW Local Clifford Algebra Elements As Super-fields

Whether TGD allows space-time supersymmetry has been a long-standing question. Majorana spinors appear in $N = 1$ super-symmetric QFTs- in particular minimally super-symmetric standard model (MSSM). Majorana-Weyl spinors appear in M-theory and super string models. An undesirable consequence is chiral anomaly in the case that the numbers of left and right handed spinors are not same. For $D = 11$ and $D = 10$ these anomalies cancel, which led to the breakthrough of string models and later to M-theory. The probable reason for considering these dimensions is that standard model does not predict right-handed neutrino (although neutrino mass suggests that right handed neutrino exists) so that the numbers of left and right handed Weyl-spinors are not the same.

In TGD framework the situation is different. Covariantly constant right-handed neutrino spinor acts as a super-symmetry in CP_2. One might think that right-handed neutrino in a well-defined sense disappears from the spectrum as a zero mode so that the number of right and left handed chiralities in $M^4 \times CP_2$ would not be same. For light-like 3-surfaces covariantly constant right-handed neutrino does not however solve the counterpart of Dirac equation for a non-vanishing four-momentum and color quantum numbers of the physical state. Therefore it does not disappear from the spectrum anymore and one expects the same number of right and left handed chiralities.

In TGD framework the separate conservation of baryon and lepton numbers excludes Majorana spinors and also the the Minkowski signature of $M^4 \times CP_2$ makes them impossible. The conclusion that TGD does not allow super-symmetry is however wrong. For $\mathcal{N} = 2N$ Weyl spinors are indeed possible and if the number of right and left handed Weyl spinors is same super-symmetry is possible. In 8-D context right and left-handed fermions correspond to quarks and leptons and since color in TGD framework corresponds to CP_2 partial waves rather than spin like quantum number, also the numbers of quark and lepton-like spinors are same.

The physical picture suggest a new kind of approach to super-symmetry in the sense that the anti-commutations of fermionic oscillator operators associated with the modes of the induced spinor fields define a structure analogous to SUSY algebra in 8-D sense. Massless modes of spinors in 1-1 corresponds with imbedding space spinors with physical helicity are in 1-1 correspondence with the generators of SUSY at space-time level giving $\mathcal{N} = 4 + 4$. Right handed neutrino modes define a sub-algebra for which the SUSY is only slightly broken by the absence of weak interactions and one could also consider a theory containing a large number of $\mathcal{N} = 2$ super-multiplets corresponding to the addition of right-handed neutrinos and antineutrinos at the wormhole throat.

Masslessness condition is essential if super-symmetric quantum field theories and at the fundamental level it can be generalized to masslessness in 8-D sense in terms of Kähler-Dirac gamma matrices using octonionic representation and assuming that they span local quaternionic sub-algebra at each point of the space-time sheet. SUSY algebra has standard interpretation with respect to spin and isospin indices only at the partonic 2-surfaces so that the basic algebra should be formulated at these surfaces: in fact, out that the formulation is needed only at the ends of fermion lines. Effective 2-dimensionality would require that partonic 2-surfaces can be taken to be ends of any light-like 3-surface Y_l^3 in the slicing of the region surrounding a given wormhole throat.

2.4.1 Super-algebra associated with the Kähler-Dirac action

Anti-commutation relations for fermionic oscillator operators associated with the induced spinor fields are naturally formulated in terms of the Kähler-Dirac gamma matrices. The canonical anti-commutation relations for the fermionic oscillator operators at light-like 3-surfaces or at their ends can be formulated as anti-commutation relations for SUSY algebra. The algebra creating physical states is super-symplectic algebra whose generators are expressed as Noether charges assignable to strings connecting partonic 2-surfaces.

Lepton and quark like spinors are now the counterparts of right and left handed Weyl spinors. Spinors with dotted and un-dotted indices correspond to conjugate representations of $SO(3,1)\times SU(4)_L\times SU(2)_R$. The anti-commutation relations make sense for sigma matrices identified as 6-dimensional matrices $1_6, \gamma_7, \gamma_1, ...\gamma_6$.

Consider first induced spinor fields at the boundaries of string world sheets at the orbits of wormhole throats. Dirac action for induced spinor fields and its bosonic counterpart defined by line-length are required by the condition that one obtains fermionic propagators massless in 8-D sense.

1. The localization of induced spinor fields to string world sheets and the addition of 1-D Dirac action at the boundaries of string world sheets at the orbits of partonic 2-surfaces reduces the quantization to that at the end of the fermion line at partonic 2-surface located at the boundary of CD. Therefore the situation reduces to that for point particle.

2. The boundary is by the extremization of line length a geodesic line of imbedding space, which can be characterized by conserved four-momentum and conserved angular momentum like charge - call it hypercharge Y. The square of 8-velocity vanishes: $v_4^2-(v^\phi)^2=0$ and one can choose $v_4^2=1$. 8-momentum is proportional to 8-velocity expressible as (v^k, v^ϕ).

3. Dirac equation gives $\Gamma^t\partial_t\Psi=(\gamma_k v^k+\gamma_\phi)v^\phi)\partial_t\Psi=0$. The non-trivial solution corresponds to $\partial_t\Psi=i\omega\Psi$ and the light-likeness condition. The value of parameter ω defines the mass scale and quantum classical correspondences suggests that ω^2 gives the mass squared identifiable as the eigenvalue of CP_2 Laplacian for spinor modes.

4. Anti-commutation relations must be fixed at either end of fermion line for the oscillator operators associated with the modes of induced spinor field at string world sheet labelled by integer value conformal weight and spin and weak isospin for the H-spinor involved. These anti-commutation relations must be consistent with standard canonical quantization allowing in turn to assign Noether charges to super-symplectic algebra defined as integrals over string world sheet. The identification of WCW gamma matrices as these charges allows to calculate WCW metric as their anti-commutators.

5. The oscillator operators for the modes with different values of conformal weight vanish. Standard anti-commutation relations in massive case are completely fixed and correspond to just Kronecker delta for conformal weights, spin, and isospin.

Space-time supersymmetry and the need to generalize 4-D twistors to 8-D ones suggest the anti-commutation relations obeyed by 8-D analogs of massless Weyl spinors and thus proportional to $p_8^k\sigma_k$, where p_8^k is the 8-momentum associated with the end of the fermion line and σ_k are the 8-D analogs of 2×2 sigma matrices.

1. This requires the introduction of octonionic spinor structure with gamma matrices represented in terms of octonionic units and introducing octonionic gamma matrices. The natural condition is that the octonionic gamma matrices are equivalent with the ordinary one. This is true if fermions are localied at time-like or light-like geodesic lines of imbedding space since they represent- not only quaternionic, but even hypercomplex sub-manifolds of imbedding space. This allows ordinary matrix representations for the gamma matrices at fermion lines.
2. One can avoid the problems with the non-associativity also at string world sheets possible caused by the Kähler Dirac gamma matrices if the two Kähler Dirac gamma matrices span commutative subspace of complexified octonions. The sigma matrices appearing in induced gauge potentials could be second source of non-associativity. By assuming that the solutions are holomorphic spinors (just as in string models) and that in the gauge chosen only holomorphic or anti-holomorphic components of gauge boson fields are non-vanishing, one avoids these problems.
3. It must be admitted that the constraints on string world sheets are strong: vanishing W induced gauge fields, Frobenius integrability conditions, and the condition that K-D gamma matrices span a commutative sub-space of complexified octonions, and I have not really proven that they can be satisfied.

The super-generators of space-time SUSY are proportional to fermionic oscillator operators obeying the canonical anti-commutation relations. It is not quite clear to me whether the proportionality constant can be taken to be equal to one although intuition suggests this strongly. The anti-commutations can contain only the light-like 8-velocity at the right hand side carrying information about the direction of the fermion line.

One can wonder in how strong sense the strong form of holography is realized.

1. Is the only information about the presence of strings at the level of scattering amplitudes the information coded by the anti-commutation relations at their end points? This would be the case if the fermion super-conformal charges vanish or create zero norm states for non-vanishing conformal weights. It could however happen that also the super-conformal generators associated with a sub-algebra of conformal algebra with weights coming as integer multiples of the entire algebra do this. At least this should be the case for the super-symplectic algebra.
2. Certainly one must assume that the 8-velocities associated with the ends of the fermionic string are independent so that strings would imply bi-locality of the dynamics.

2.4.2 Summing up the anti-commutation relations

In leptonic sector one would have the anti-commutation relations

$$\begin{aligned} \{a^{\dagger}_{m\dot{\alpha}}, a^{n}_{\beta}\} &= 2\delta^{n}_{m} D_{\dot{\alpha}\beta} \ , \\ D &= (p_{\mu} + \sum_{a} Q^{a}_{\mu})\sigma^{\mu} \ . \end{aligned} \tag{2.3}$$

In quark sector σ^{μ} is replaced with $\overline{\sigma}^{\mu}$ obtained by changing the signs of space-like sigma matrices in leptonic sector. p_{μ} and Q^{a}_{μ} are the projections of momentum and color charges in Cartan algebra to the space-time surface and their values correspond to those assignable to the fermion line and related by quantum classical correspondence to those associated with incoming spinor harmonic.

The anti-commutation relations define a generalization of the ordinary equal-time anti-commutation relations for fermionic oscillator operators to a manifestly covariant form. Extended SUSY algebra suggest that the anti-commutators could contain additional central charge term proportional to $\delta_{\alpha\beta}$ but the 8-D chiral invariance excludes this term.

In the octonionic representation of the sigma matrices matrix indices cannot be present at the right handed side without additional conditions. Octonionic units however allow a representation as matrices defined by the structure constants failing only when products of more than two octonions are considered. For the quaternionic sub-algebra this does not occur. Both spinor modes and and gamma matrices must belong to the local hyper-quaternionic sub-algebra and do trivially so for fermion lines and string. Octonionic representation reduces $SO(7,1)$ so G_2 as a tangent space group. Similar reduction for 7-dimensional compact space takes place also M-theory.

In standard SUSY local super-fields having values in the Grassmann algebra generated by theta parameters appear. In TGD framework this would mean allowance of many-fermion states at single space-time point and this is perhaps too heavy an idealization since partonic 2-surfaces are the fundamental objects. Multi-stringy generators in the extension of super-symplectic algebra to Yangian is a more natural concept in TGD framework since one expects that partonic 2-surfaces involve several strings connecting them to other partonic 2-surfaces. Super-symplectic charges would be Noether charges assignable to these strings and quantum states would be created by these charges from vacuum. Scattering amplitudes would be defined in terms of Yangian algebra [K21]. Only at QFT limit one can hope that super-field formalism works.

3 Understanding Of The Role Of Right-Handed Neutrino In Supersymmetry

The development of the TGD view about space-time SUSY has been like a sequence of questions loves -doesn't love- loves.... From the beginning it was clear that right-handed neutrino could generate super-conformal symmetry of some kind, and the natural question was whether it generates also space-time SUSY. Later it became clear that all fermion oscillator operators can be interpreted as super generators for the analog of space-time SUSY. After that the challenge was to understand whether all spin-isospin states of fermions correspond super generators.

$\mathcal{N}=1$ SUSY was excluded by separate conservation of B and L but $\mathcal{N}=2$ variant of this symmetry could be considered and could be generated by massless right-handed neutrino and antineutrino mode.

The new element in the picture was the physical realization of the SUSY by adding fermions - in special case right-handed neutrino - to the state associated with the orbit of partonic 2-surface. An important realization was the necessity to localized spinors to string world sheet and the assignment of fernionic oscillator operator with boundaries of string world sheets at them. Variational principles implies that the fermions have light-like 8-momenta and that the fermion lines are light-like geodesics in 8-D sense. This leads to a precise view about the quantization of induced spinor fields. Fermionic oscillator operator algebra would generate Clifford algebra replacing the SUSY algebra and one would obtain the analog of super Poincare algebra from anti-commutation relations.

3.1 Basic Vision

As already explained, the precise meaning of SUSY in TGD framework has been a long-standing head ache. In TGD framework SUSY is inherited from super-conformal symmetry at the level of WCW [K3, K2]. The SUSY differs from $\mathcal{N}=1$ SUSY of the MSSM and from the SUSY predicted by its generalization and by string models. Allowing only right-handed neutrinos as SUSY generators, one obtains the analog of the $\mathcal{N}=4$ SUSY in bosonic sector but there are profound differences in the physical interpretation. The most general view is that all fermion modes with vanishing conformal weights define super charges.

1. One could understand SUSY in very general sense as an algebra of fermionic oscillator operators acting on vacuum states at partonic 2-surfaces. Oscillator operators are assignable to braids ends and generate fermionic many particle states. SUSY in this sense is badly broken and the algebra corresponds to rather large $\mathcal{N}$. The restriction to covariantly constant right-handed neutrinos (in CP_2 degrees of freedom) gives rise to the counterpart of ordinary SUSY, which is more physically interesting at this moment.

2. Right handed neutrino and antineutrino are not Majorana fermions. This is necessary for separate conservation of lepton and baryon numbers. For fermions one obtains the analog $\mathcal{N}=2$ SUSY.

3. Bosonic emergence means the construction of bosons as bound states of fermions and antifermions at opposite throats of wormhole contact. Later it became clear that all elementary particles emerge as bound states of fundamental fermions located at the wormhole throats of a pair of wormhole contacts. Two wormhole contacts are required by the assumption wormhole contacts carry monopole magnetic flux stabilizing them.

   This reduces TGD SUSY to that for fundamental fermions. This difference is fundamental and means deviation from the $\mathcal{N}=4$ SUSY, where SUSY acts on gauge boson states. Bosonic representations are obtained as tensor products of representations assigned to the opposite throats of wormhole contacts. One can also have several fermion lines at given throat but these states are expected to be exotic.

   Further tensor products with representations associated with the wormhole ends of magnetic flux tubes are needed to construct physical particles. This represents a crucial difference with respect to standard approach, where one introduces at the fundamental level both fermions and bosons or gauge bosons as in $\mathcal{N}=4$ SUSY. Fermionic $\mathcal{N}=2$ representations are analogous to "short" $\mathcal{N}=4$ representations for which one half of super-generators annihilates the states.

4. If stringy super-conformal symmetries act as gauge transformations, the analog of $\mathcal{N}=4$ SUSY is obtained in both quark and lepton sector. This extends to $\mathcal{N}=8$ SUSY if parton orbits can carry both quarks and leptons. Lepto-quark is the simplest state of this kind.

5. The introduction of both fermions and gauge bosons as fundamental particles leads in quantum gravity theories and string models to $d=10$ condition for the target space, spontaneous compactification, and eventually to the landscape catastrophe.

   For a supersymmetric gauge theory (SYM) in d-dimensional Minkowski space the condition that the number of transversal polarization for gauge bosons given by $d-2$ equals to the number of fermionic states made of Majorana fermions gives $d-2=2^k$, since the number of fermionic spinor components is always power of 2.

   This allows only $d=3,4,6,10,16,...$ Also the dimensions $d+1$ are actually possible since the number of spinor components for d and $d+1$ is same for d even. This is the standard argument leading to super-string models and M-theory. It it lost - or better to say, one gets rid of it - if the basic fields include only fermion fields and bosonic states are constructed as the tensor products of fermionic states. This is indeed the case in TGD, where spontaneous compactification plays no role and bosons are emergent.

6. Spontaneous compactification leads in string model picture from $\mathcal{N}=1$ SUSY in say $d=10$ to $\mathcal{N}>1$ SUSY in $d=4$ since the fermionic multiplet reduces to a direct sum of fermionic multiplets in $d=4$. In TGD imbedding space is not dynamical but fixed by internal consistency requirements, and also by the condition that the theory is consistent with the standard model symmetries. The identification of space-time as 4-surface makes the induced spinor field dynamical and the notion of many-sheeted space-time allows to circumvent the objections related to the fact that only 4 field like degrees of freedom are present.

3.2 What Is The Role Of The Right-Handed Neutrino?

Whether right-handed neutrinos generate a supersymmetry in TGD has been a long standing open question. $\mathcal{N}=1$ SUSY is certainly excluded by fermion number conservation but already $\mathcal{N}=2$ defining a "complexification" of $\mathcal{N}=1$ SUSY is possible and could generate right-handed neutrino and its antiparticle. Right-handed neutrinos should however possess a non-vanishing light-like momentum since the fully covariantly constant right-handed neutrino generates zero norm states.

The general view about the preferred extremals of Kähler action and application of the conservation of em charge to the Kähler-Dirac equation have led to a rather detailed view about classical and TGD and allowed to build a bridge between general vision about super-conformal symmetries in TGD Universe and field equations. This vision is discussed in detail in [K16].

1. Many-sheeted space-time means that single space-time sheet need not be a good approximation for astrophysical systems. The GRT limit of TGD can be interpreted as obtained by lumping many-sheeted space-time time to Minkowski space with effective metric defined as sum M^4 metric and sum of deviations from M^4 metric for various space-time sheets involved [K14]. This effective metric should correspond to that of General Relativity and Einstein's equations would reflect the underlying Poincare invariance. Gravitational and cosmological constants follow as predictions and EP is satisfied.

2. The general structure of super-conformal representations can be understood: super-symplectic algebra is responsible for the non-perturbative aspects of QCD and determines also the ground states of elementary particles determining their quantum numbers. The hierarchy of breakings of conformal symmetry as gauge gauge symmetry would explain dark matter. The sub-algebra for which super-conformal symmetry remains gauge symmetry would be isomorphic to the original algebra and generated by generators for which conformal weight is multiple of integer $n = h_{eff}/h$. This would would be true for super-symplectic algebra at least and possible for all other conformal algebras involved.

3. Super-Kac-Moody algebras associated with isometries and holonomies dictate standard model quantum numbers and lead to a massivation by p-adic thermodynamics: the crucial condition that the number of tensor factors in Super-Virasoro represention is 5 is satisfied.

4. One can understand how the Super-Kac-Moody currents assignable to stringy world sheets emerging naturally from the conservation of em charge defined as their string world sheet Hodge duals gauge potentials for standard model gauge group and also their analogs for gravitons. Also the conjecture Yangian algebra generated by Super-Kac-Moody charges emerges naturally.

5. One also finds that right handed neutrino is in a very special role because of its lacking couplings in electroweak sector and its role as a generator of the least broken SUSY. The most feasible option is that all modes of the induced spinor field are restricted to 2-D string world sheets. If covariantly constant right-handed neutrino could be de-localized completely it cannot generate ordinary kind of gauge super-symmetry. It is not yet completely clear whether the modes of the induced spinor field are localized at string world sheets also inside the Euclidian wormhole contacts defining the lines of the generalized Feynman diagrams.

   Intermediate gauge boson decay widths require that sparticles are either heavy enough or dark in the sense of having non-standard value of Planck constant. Darkness would provide an elegant explanation for their non-observability. It should be emphasized that TGD predicts that all fermions act as generators of badly broken super-symmetries at partonic 2-surfaces but these super-symmetries could correspond to much higher mass scale as that associated with the de-localized right-handed neutrino. The following piece of text summarizes the argument.

6. Ordinary SUSY means that apart from kinematical spin factors sparticles and particles behave identically with respect to standard model interactions. These spin factors would allow to distinguish between particles and sparticles. This requires strong correlations between fermion and right-handed neutrino: in fact, they should be at rest with respect to each other. Right-handed neutrinos have vanishing color and electro-weak quantum numbers. How it is possible to have sparticles as bound states with ordinary particle and right-handed neutrino?

   The localization of induced spinor fields to string world sheets suggests a solution to the problem.

   (a) The localization forces the fermions to move in parallel although they have no interactions. The 8-momenta and 8-velocities of fermion are light-like and they move along light-like 8-geodesics. Since the size of the partonic 2-surface should not change much. If all fundamental fermions involved are massive one can assume that they are at rest and in this manner geometrically stable state.

   (b) If one has massive fermion and massless right-handed neutrino, they should be at rest with respect to each other. What looks paradoxical that one cannot reduce the velocity to exactly zero in any coordinate system since covariantly constant right-handed neutrino represents a pure gauge degree of freedom. It is of course possible to assume that the relative velocity is some sufficiently low velocity. One can also argue that sparticles are unstable and that this is basically due to a geometric instability implied by the non-parallel 3-momenta of fundamental fermions.

   (c) If one assumes that the 4-momentum squared corresponds to that associated with the imbedding space spinor harmonics, one can to estimate the mass of the sparticle once the energy of the right-handed neutrino is fixed. This argument applies also to n-fermion states at associated with the wormhole contact pairs.

   (d) p-Adic mass calculations however give to mass squared also other contributions that that coming from the spinor harmonic, in particular negative ground state contribution and that the mass squared of the fundamental fermion vanishes for lowest states which would therefore have vanishing CP_2 velocity. Why the light-like four-momentum of the resulting state should not characterize the fermion line? In this picture p-adic thermal excitations would make the state unstable. One could in fact turn this argument to an explanation for why the stable physical particles must parallel 4-momenta.

   (e) What is still not well-understood is the tachyonic contribution to four-momentum. One possibility is that wormhole contact gives imaginary contribution to four-momentum. Second possibility is that the generating super-symplectic conformal weights are the negatives for the zeros of zeta. For non-trivial zeros the real part of the conformal would be -1/2.

So called massless extremals (MEs) define massless represent classical field pattern moving with light velocity and preserving its shape. This suggests that particle represented as a magnetic flux tube structure carrying monopole flux with two wormhole contacts and sliced between two MEs could serve as a starting point in attempts to understand the role of right handed neutrinos and how $\mathcal{N}=2$ or $\mathcal{N}=4$ type SYM emerges at the level of space-time geometry.

3.3 The Impact From LHC And Evolution Of TGD Itself

The missing energy predicted standard SUSY seems to be absent at LHC. The easy explanation would be that the mass scale of SUSY is unexpectedly high, of order 1-10 TeV. This would however destroy the original motivations for SUSY. The arguments developed in the following manner.

1. One must distinguish between imbedding space spinor harmonics and the modes of the induced spinor field. Right-handed neutrino with vanishing color quantum numbers and thus covariantly constant in CP_2 is massless. All other modes of the induced spinor field are massive and in according to the p-adic mass calculations negative conformal weight of the ground state and the presence of Kac-Moody and super-symplectic generators make possible massless states having thermal excitations giving to the state a thermal mass. Right-handed neutrino can mix with left-handed neutrino ad can get mass. One can assign to any fermion a super-multiplet with 4 members.

   One cannot assign full super-4-plet also to non-colored right handed neutrino itself: the multiplet would contain only 3 states. The most natural possibility is that the ground state is now a color excitation of right-handed neutrino and massless non-colored right-handed neutrinos give rise to the 4-plet. The colored spinor mode at imbedding space level is however a mixture or left- and right handed neutrinos.

2. In TGD framework the natural first guess is that right-handed neutrinos carrying four-momentum can give rise to missing energy. The assumption that fermions correspond to color partial waves in H implies that color excitations of the right handed neutrino that would appear in asymptotic states are necessarily colored. It could happen that these excitations are color neutralized by super-conformal generators. If this is not the case, these neutrinos would be like quarks and color confinement would explain why they cannot be observed as asymptotic states in macroscopic scales.

Second possibility is that SUSY itself is generated by color partial waves of right-handed neutrino, octet most naturally. This option is however not consistent with the above model for one-fermion states and their super-partners.

3.4 Supersymmetry In Crisis

Supersymmetry is very beautiful generalization of the ordinary symmetry concept by generalizing Lie-algebra by allowing grading such that ordinary Lie algebra generators are accompanied by super-generators transforming in some representation of the Lie algebra for which Lie-algebra commutators are replaced with anti-commutators. In the case of Poincare group the super-generators would transform like spinors. Clifford algebras are actually super-algebras. Gamma matrices anti-commute to metric tensor and transform like vectors under the vielbein group (SO(n) in Euclidian signature). In supersymmetric gauge theories one introduced super translations anti-commuting to ordinary translations.

Supersymmetry algebras defined in this manner are characterized by the number of super-generators and in the simplest situation their number is one: one speaks about $\mathcal{N}=1$ SUSY and minimal super-symmetric extension of standard model (MSSM) in this case. These models are most studied because they are the simplest ones. They have however the strange property that the spinors generating SUSY are Majorana spinors- real in well-defined sense unlike Dirac spinors. This implies that fermion number is conserved only modulo two: this has not been observed experimentally. A second problem is that the proposed mechanisms for the breaking of SUSY do not look feasible.

LHC results suggest MSSM does not become visible at LHC energies. This does not exclude more complex scenarios hiding simplest $\mathcal{N}=1$ to higher energies but the number of real believers is decreasing. Something is definitely wrong and one must be ready to consider more complex options or totally new view abot SUSY.

What is the analog of SUSY in TGD framework? I must admit that I am still fighting to gain understanding of SUSY in TGD framework [K17]. That I can still imagine several scenarios shows that I have not yet completely understood the problem but I am working hardly to avoid falling to the sin of sloppying myself.

At the basic level one has super-conformal invariance generated in the fermion sector by the super-conformal charges assignable to the strings emanating from partonic 2-surfaces and connecting them to each other. For elementary particles one has 2 wormhole contacts and 4 wormhole throats. If the number of strings is just one, one has symplectic super-conformal symmetry, which is already huge. Several strings must be allowed and this leads to the Yangian variant of super-conformal symmetry, which is multi-local (multi-stringy).

One can also say that fermionic oscillator operators generate infinite-D super-algebra. One can restrict the consideration to lowest conformal weights if spinorial super-conformal invariance acts as gauge symmetry so that one obtains a finite-D algebra with generators labelled by electro-weak quantum numbers of quarks and leptons. This super-symmetry is badly broken but contains the algebra generated by right-handed neutrino and its conjugate as sub-algebra.

The basic question is whether covariantly constant right handed neutrino generators $\mathcal{N}=\in$ SUSY or whether the SUSY is generated as approximate symmetry by adding massless right-handed neutrino to the state thus changing its four-momentum. The problem with the first option is that it the standard norm of the state is naturally proportional to four-momentum and vanishes at the limit of vanishing four-momentum: is it possible to circumvent this problem somehow? In the following I summarize the situation as it seems just now.

1. In TGD framework $\mathcal{N}=1$ SUSY is excluded since B and L and conserved separately and imbedding space spinors are not Majorana spinors. The possible analog of space-time SUSY should be a remnant of a much larger super-conformal symmetry in which the Clifford algebra generated by fermionic oscillator operators giving also rise to the Clifford algebra generated by the gamma matrices of the "world of classical worlds" (WCW) and assignable with string world sheets. This algebra is indeed part of infinite-D super-conformal algebra behind quantum TGD. One can construct explicitly the conserved super conformal charges accompanying ordinary charges and one obtains something analogous to $\mathcal{N}=\infty$ super algebra. This SUSY is however badly broken by electroweak interactions.

2. The localization of induced spinors to string world sheets emerges from the condition that electromagnetic charge is well-defined for the modes of induced spinor fields. There is however an exception: covariantly constant right handed neutrino spinor ν_R: it can be de-localized along entire space-time surface. Right-handed neutrino has no couplings to electroweak fields. It couples however to left handed neutrino by induced gamma matrices except when it is covariantly constant. Note that standard model does not predict ν_R but its existence is necessary if neutrinos develop Dirac mass. ν_R is indeed something which must be considered carefully in any generalization of standard model.

3.4.1 *Could covariantly constant right handed neutrinos generate SUSY?*

Could covariantly constant right-handed spinors generate exact $\mathcal{N} = 2$ SUSY? There are two spin directions for them meaning the analog $\mathcal{N} = 2$ Poincare SUSY. Could these spin directions correspond to right-handed neutrino and antineutrino. This SUSY would not look like Poincare SUSY for which anti-commutator of super generators would be proportional to four-momentum. The problem is that four-momentum vanishes for covariantly constant spinors! Does this mean that the sparticles generated by covariantly constant ν_R are zero norm states and represent super gauge degrees of freedom? This might well be the case although I have considered also alternative scenarios.

3.4.2 *What about non-covariantly constant right-handed neutrinos?*

Both imbedding space spinor harmonics and the Kähler-Dirac equation have also right-handed neutrino spinor modes not constant in M^4 and localized to the partonic orbits. If these are responsible for SUSY then SUSY is broken.

1. Consider first the situation at space-time level. Both induced gamma matrices and their generalizations to Kähler-Dirac gamma matrices defined as contractions of imbedding space gamma matrices with the canonical momentum currents for Kähler action are superpositions of M^4 and CP_2 parts. This gives rise to the mixing of right-handed and left-handed neutrinos. Note that non-covariantly constant right-handed neutrinos must be localized at string world sheets.

   This in turn leads neutrino massivation and SUSY breaking. Given particle would be accompanied by sparticles containing varying number of right-handed neutrinos and antineutrinos localized at partonic 2-surfaces.

2. One an consider also the SUSY breaking at imbedding space level. The ground states of the representations of extended conformal algebras are constructed in terms of spinor harmonics of the imbedding space and form the addition of right-handed neutrino with non-vanishing four-momentum would make sense. But the non-vanishing four-momentum means that the members of the super-multiplet cannot have same masses. This is one manner to state what SUSY breaking is.

3.4.3 *What one can say about the masses of sparticles?*

The simplest form of massivation would be that all members of the super-multiplet obey the same mass formula but that the p-adic length scales associated with them are different. This could allow very heavy sparticles. What fixes the p-adic mass scales of sparticles? If this scale is CP_2 mass scale SUSY would be experimentally unreachable. The estimate below does not support this option.

One can consider the possibility that SUSY breaking makes sparticles unstable against phase transition to their dark variants with $h_{eff} = n \times h$. Sparticles could have same mass but be non-observable as dark matter not appearing in same vertices as ordinary matter! Geometrically the addition of right-handed neutrino to the state would induce many-sheeted covering in this case with right handed neutrino perhaps associated with different space-time sheet of the covering.

This idea need not be so outlandish at it looks first.

1. The generation of many-sheeted covering has interpretation in terms of breaking of conformal invariance. The sub-algebra for which conformal weights are n-tuples of integers becomes the algebra of conformal transformations and the remaining conformal generators do note represent gauge degrees of freedom anymore. They could however represent conserved conformal charges still.

2. This generalization of conformal symmetry breaking gives rise to infinite number of fractal hierarchies formed by sub-algebras of conformal algebra and is also something new and a fruit of an attempt to avoid sloppy thinking. The breaking of conformal symmetry is indeed expected in massivation related to the SUSY breaking.

The following poor man's estimate supports the idea about dark sfermions and the view that sfermions cannot be very heavy.

1. Neutrino mixing rate should correspond to the mass scale of neutrinos known to be in eV range for ordinary value of Planck constant. For $h_{eff}/h = n$ it is reduced by factor $1/n$, when mass kept constant. Hence sfermions could be stabilized by making them dark.

2. A very rough order of magnitude estimate for sfermion mass scale is obtained from Uncertainty Principle: particle mass should be higher than its decay rate. Therefore an estimate for the decay rate of sfermion could give a lower bound for its mass scale.

3. Assume the transformation $\nu_R \rightarrow \nu_L$ makes sfermion unstable against the decay to fermion and ordinary neutrino. If so, the decay rate would be dictated by the mixing rate and therefore to neutrino mass scale for the ordinary value of Planck constant. Particles and sparticles would have the same p-adic mass scale. Large h_{eff} could however make sfermion dark, stable, and non-observable.

3.4.4 *A rough model for the neutrino mixing in TGD framework*

The mixing of neutrinos would be the basic mechanism in the decays of sfermions. The following argument tries to capture what is essential in this process.

1. Conformal invariance requires that the string ends at which fermions are localized at wormhole throats are light-like curves. In fact, light-likeness gives rise to Virasosoro conditions.

2. Mixing is described by a vertex residing at partonic surface at which two partonic orbits join. Localization of fermions to string boundaries reduces the problem to a problem completely analogous to the coupling of point particle coupled to external gauge field. What is new that orbit of the particle has edge at partonic 2-surface. Edge breaks conformal invariance since one cannot say that curve is light-like at the edge. At edge neutrino transforms from right-handed to left handed one.

3. In complete analogy with $\overline{\Psi}\gamma^t A_t \Psi$ vertex for the point-like particle with spin in external field, the amplitude describing $nu_R - \nu_L$ transition involves matrix elements of form $\overline{\nu}_R \Gamma^t(CP_2) Z_t \nu_L$ at the vertex of the CP_2 part of the Kähler-Dirac gamma matrix and classical Z^0 field.

   How Γ^t is identified? The Kähler-Dirac gamma matrices associated with the interior need not be well-defined at the light-like surface and light-like curve. One basis of weak form of electric magnetic duality the Kähler-Dirac gamma matrix corresponds to the canonical momentum density associated with the Chern-Simons term for Kähler action. This gamma matrix contains only the CP_2 part.

The following provides as more detailed view.

1. Let us denote by $\Gamma^t_{CP_2}(in/out)$ the CP_2 part of the Kähler-Dirac gamma matrix at string at at partonic 2-surface and by Z^0_t the value of Z^0 gauge potential along boundary of string world sheet. The direction of string line in imbedding space changes at the partonic 2-surface. The question is what happens to the Kähler-Dirac action at the vertex.

2. For incoming and outgoing lines the equation

$$D(in/out)\Psi(in/out) = p^k(in,out)\gamma_k\Psi(in/out) \ ,$$

   where the Kähler-Dirac operator is $D(in/out) = \Gamma^t(in/out)D_t$, is assumed. ν_R corresponds to ”in” and ν_R to ”out”. It implies that lines corresponds to massless M^4 Dirac propagator and one obtains something resembling ordinary perturbation theory.

   It also implies that the residue integration over fermionic internal momenta gives as a residue massless fermion lines with non-physical helicities as one can expect in twistor approach. For physical particles the four-momenta are massless but in complex sense and the imaginary part comes classical from four-momenta assignable to the lines of generalized Feynman diagram possessing Euclidian signature of induced metric so that the square root of the metric determinant differs by imaginary unit from that in Minkowskian regions.

3. In the vertex $D(in/out)$ could act in $\Psi(out/in)$ and the natural idea is that $\nu_R - \nu_L$ mixing is due to this so that it would be described the classical weak current couplings $\overline{\nu}_R\Gamma^t_{CP_2}(out)Z^0_t(in)\nu_L$ and $\overline{\nu}_R\Gamma^t_{CP_2}(out)Z^0_t(in)\nu_L$.

To get some idea about orders of magnitude assume that the CP_2 projection of string boundary is geodesic circle thus describable as $\Phi = \omega t$, where Φ is angle coordinate for the circle and t is Minkowski time coordinate. The contribution of CP_2 to the induced metric g_{tt} is $\Delta g_{tt} = -R^2\omega^2$.

1. In the first approximation string end is a light-like curve in Minkowski space meaning that CP_2 contribution to the induced metric vanishes. Neutrino mixing vanishes at this limit.

2. For a non-vanishing value of ωR the mixing and the order of magnitude for mixing rate and neutrino mass is expected to be $R \sim \omega$ and $m \sim \omega/h$. p-Adic length scale hypothesis and the experimental value of neutrino mass allows to estimate m to correspond to p-adic mass to be of order eV so that the corresponding p-adic prime p could be $p \simeq 2^{167}$. Note that $k = 127$ defines largest of the four Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$ appearing in the length scale range 10 nm -2.5 μm. Hence the decay rate for ordinary Planck constant would be of order $R \sim 10^{14}$/s but large value of Planck constant could reduced it dramatically. In living matter reductions by a factor 10^{-12} can be considered.

To sum up, the space-time SUSY in TGD sense would differ crucially from SUSY in the standard sense. There would no Majorana spinors and sparticles could correspond to dark phase of matter with non-standard value of Planck constant. The signatures of the standard SUSY do not apply to TGD. Of course, a lot of professional work would be needed to derive the signatures of TGD SUSY.

3.5 Right-Handed Neutrino As Inert Neutrino?

There is a very interesting posting by Jester in Resonaances with title “How many neutrinos in the sky?” (see `http://tinyurl.com/y8scxzqr`) [C2]. Jester tells about the recent 9 years WMAP data [C25] and compares it with earlier 7 years data. In the earlier data the effective number of neutrino types was $N_{eff} = 4.34 \pm 0.87$ and in the recent data it is $N_{eff} = 3.26 \pm 0.35$. WMAP alone would give $N_{eff} = 3.89 \pm 0.67$ also in the recent data but also other data are used to pose constraints on N_{eff}.

To be precise, N_{eff} could include instead of fourth neutrino species also some other weakly interacting particle. The only criterion for contributing to N_{eff} is that the particle is in thermal equilibrium with other massless particles and thus contributes to the density of matter considerably during the radiation dominated epoch.

Jester also refers to the constraints on N_{eff} from nucleosynthesis (see `http://tinyurl.com/y8fkfn5y`) , which show that $N_{eff} \sim 4$ us slightly favored although the entire range $[3,5]$ is consistent with data.

It seems that the effective number of neutrinos could be 4 instead of 3 although latest WMAP data combined with some other measurements favor 3. Later a corrected version e `http://`

`tinyurl.com/y9er8szf`) of the eprint appeared [C25] telling that the original estimate of N_{eff} contained a mistake and the correct estimate is $N_{eff} = 3.84 \pm 0.40$.

An interesting question is what $N_{eff} = 4$ could mean in TGD framework?

1. One poses to the modes of the Kähler-Dirac equation the following condition: electric charge is conserved in the sense that the time evolution by Kähler-Dirac equation does not mix a mode with a well-defined em charge with those with different em charge. The implication is that all modes except pure right handed neutrino are restricted at string world sheets. The first guess is that string world sheets are minimal surfaces of space-time surface (rather than those of imbedding space). One can also consider minimal surfaces of imbedding space but with effective metric defined by the anti-commutators of the Kähler-Dirac gamma matrices. This would give a direct physical meaning for this somewhat mysterious effective metric.

   For the neutrino modes localized at string world sheets mixing of left and right handed modes takes place and they become massive. If only 3 lowest genera for partonic 2-surfaces are light, one has 3 neutrinos of this kind. The same applies to all other fermion species. The argument for why this could be the case relies on simple observation [K1]: the genera g=0, 1, 2 have the property that they allow for all values of conformal moduli Z_2 as a conformal symmetry (hyper-ellipticity). For $g > 2$ this is not the case. The guess is that this additional conformal symmetry is the reason for lightness of the three lowest genera.

2. Only purely right-handed neutrino is completely de-localized in 4-volume so that one cannot assign to it genus of the partonic 2-surfaces as a topological quantum number and it effectively gives rise to a fourth neutrino very much analogous to what is called sterile neutrino. De-localized right-handed neutrinos couple only to gravitation and in case of massless extremals this forces them to have four-momentum parallel to that of ME: only massless modes are possible. Very probably this holds true for all preferred extremals to which one can assign massless longitudinal momentum direction which can vary with spatial position.

3. The coupling of ν_R is to gravitation alone and all electroweak and color couplings are absent. According to standard wisdom de-localized right-handed neutrinos cannot be in thermal equilibrium with other particles. This according to standard wisdom. But what about TGD?

   One should be very careful here: de-localized right-handed neutrinos is proposed to give rise to SUSY (not $\mathcal{N} = 1$ requiring Majorana fermions) and their dynamics is that of passive spectator who follows the leader. The simplest guess is that the dynamics of right handed neutrinos at the level of amplitudes is completely trivial and thus trivially supersymmetric. There are however correlations between four-momenta.

   (a) The four-momentum of ν_R is parallel to the light-like momentum direction assignable to the massless extremal (or more general preferred extremal). This direct coupling to the geometry is a special feature of the Kähler-Dirac operator and thus of sub-manifold gravity.

   (b) On the other hand, the sum of massless four-momenta of two parallel pieces of preferred extremals is the - in general massive - four-momentum of the elementary particle defined by the wormhole contact structure connecting the space-time sheets (which are glued along their boundaries together since this is seems to be the only manner to get rid of boundary conditions requiring vacuum extremal property near the boundary). Could this direct coupling of the four-momentum direction of right-handed neutrino to geometry and four-momentum directions of other fermions be enough for the right handed neutrinos to be counted as a fourth neutrino species in thermal equilibrium? This might be the case!

   One cannot of course exclude the coupling of 2-D neutrino at string world sheets to 4-D purely right handed neutrinos analogous to the coupling inducing a mixing of sterile neutrino with ordinary neutrinos. Also this could help to achieve the thermal equilibrium with 2-D neutrino species.

3.6 Experimental Evidence For Sterile Neutrino?

Many physicists are somewhat disappointed to the results from LHC: the expected discovery of Higgs has been seen as the main achievement of LHC hitherto. Much more was expected. To my opinion there is no reason for disappointment. The exclusion of the standard SUSY at expected energy scale is very far reaching negative result. Also the fact that Higgs mass is too small to be stable without fine tuning is of great theoretical importance. The negative results concerning heavy dark matter candidates are precious guidelines for theoreticians. The non-QCD like behavior in heavy ion collisions and proton-ion collisions is bypassed my mentioning something about AdS/CFT correspondence and non-perturbative QCD effects. I tend to see these effects as direct evidence for M_{89} hadron physics [K9].

In any case, something interesting has emerged quite recently. Resonaances tells that the recent analysis (see `http://tinyurl.com/ycf4vbkq`) [C22] of X-ray spectrum of galactic clusters claims the presence of monochromatic 3.5 keV photon line. The proposed interpretation is as a decay product of sterile 7 keV neutrino transforming first to a left-handed neutrino and then decaying to photon and neutrino via a loop involving W boson and electron. This is of course only one of the many interpretations. Even the existence of line is highly questionable.

One of the poorly understood aspects of TGD is right-handed neutrino, which is obviously the TGD counterpart of the inert neutrino.

1. The old idea is that covariantly constant right handed neutrino could generate $\mathcal{N}=2$ supersymmetry in TGD Universe. In fact, all modes of induced spinor field would generate superconformal symmetries but electroweak interactions would break these symmetries for the modes carrying non-vanishing electroweak quantum numbers: they vanish for ν_R. This picture is now well-established at the level of WCW geometry [K18]: super-conformal generators are labelled angular momentum and color representations plus two conformal weights: the conformal weight assignable to the light-like radial coordinate of light-cone boundary and the conformal weight assignable to string coordinate. It seems that these conformal weights are independent. The third integer labelling the states would label genuinely Yangian generators: it would tell the poly-locality of the generator with locus defined by partonic 2-surface: generators acting on single partonic 2-surface, 2 partonic 2-surfaces, ...

2. It would seem that even the SUSY generated by ν_R must be badly broken unless one is able to invent dramatically different interpretation of SUSY. The scale of SUSY breaking and thus the value of the mass of right-handed neutrino remains open also in TGD. In lack of better one could of course argue that the mass scale must be CP_2 mass scale because right-handed neutrino mixes considerably with the left-handed neutrino (and thus becomes massive) only in this scale. But why this argument does not apply also to left handed neutrino which must also mix with the right-handed one!

3. One can of course criticize the proposed notion of SUSY: wonder whether fermion + extremely weakly interacting ν_R at same wormhole throat (or interior of 3-surface) can behave as single coherent entity as far spin is considered [K17] ?

4. The condition that the modes of induced spinor field have a well-defined electromagnetic charge eigenvalue [K16] requires that they are localized at 2-D string world sheets or partonic 2-surfaces: without this condition classical W boson fields would mix the em charged and neutral modes with each other. Right-handed neutrino is an exception since it has no electroweak couplings. Unless right-handed neutrino is covariantly constant, the Kähler-Dirac gamma matrices can however mix the right-handed neutrino with the left handed one and this can induce transformation to charged mode. This does not happen if each Kähler-Dirac gamma matrix can be written as a linear combination of either M^4 or CP_2 gamma matrices and Kähler-Dirac equation is satisfied separately by M^4 and CP_2 parts of the Kähler-Dirac equation.

5. Is the localization of the modes other than covariantly constant neutrino to string world sheets a consequence of dynamics or should one assume this as a separate condition? If one wants similar localization in space-time regions of Euclidian signature - for which CP_2

type vacuum extremal is a good representative - one must assume it as a separate condition. In number theoretic formulation string world sheets/partonic 2-surfaces would be commutative/co-commutative sub-manifolds of space-time surfaces which in turn would be associative or co-associative sub-manifolds of imbedding space possessing (hyper-)octonionic tangent space structure. For this option also right-handed neutrino would be localized to string world sheets. Right-handed neutrino would be covariantly constant only in 2-D sense.

One can consider the possibility that ν_R is de-localized to the entire 4-D space-time sheet. This would certainly modify the interpretation of SUSY since the number of degrees of freedom would be reduced for ν_R.

6. Non-covariantly constant right-handed neutrinos could mix with left-handed neutrinos but not with charged leptons if the localization to string world sheets is assumed for modes carrying non-vanishing electroweak quantum numbers. This would make possible the decay of right-handed to neutrino plus photon, and one cannot exclude the possibility that ν_R has mass 7 keV.

   Could this imply that particles and their spartners differ by this mass only? Could it be possible that practically unbroken SUSY could be there and we would not have observed it? Could one imagine that sfermions have annihilated leaving only states consisting of fundamental fermions? But shouldn't the total rate for the annihilation of photons to hadrons be two times the observed one? This option does not sound plausible.

   What if one assumes that given sparticle is charactrized by the same p-adic prime as corresponding particle but is dark in the sense that it corresponds to non-standard value of Planck constant. In this case sfermions would not appear in the same vertex with fermions and one could escape the most obvious contradictions with experimental facts. This leads to the notion of shadron: shadrons would be [K17] obtained by replacing quarks with dark squarks with nearly identical masses. I have asked whether so called X and Y bosons having no natural place in standard model of hadron could be this kind of creatures.

The interpretation of 3.5 keV photons as decay products of right-handed neutrinos is of course totally ad hoc. Another TGD inspired interpretation would be as photons resulting from the decays of excited nuclei to their ground state.

1. Nuclear string model [K10] predicts that nuclei are string like objects formed from nucleons connected by color magnetic flux tubes having quark and antiquark at their ends. These flux tubes are long and define the "magnetic body" of nucleus. Quark and antiquark have opposite em charges for ordinary nuclei. When they have different charges one obtains exotic state: this predicts entire spectrum of exotic nuclei for which statistic is different from what proton and neutron numbers deduced from em charge and atomic weight would suggest. Exotic nuclei and large values of Planck constant could make also possible cold fusion [K5].

2. What the mass difference between these states is, is not of course obvious. There is however an experimental finding [C26] (see *Analysis of Gamma Radiation from a Radon Source: Indications of a Solar Influence* at `http://tinyurl.com/d9ymwm3`) that nuclear decay rates oscillate with a period of year and the rates correlate with the distance from Sun. A possible explanation is that the gamma rays from Sun in few keV range excite the exotic nuclear states with different decay rate so that the average decay rate oscillates [K10]. Note that nuclear excitation energies in keV range would also make possible interaction of nuclei with atoms and molecules.

3. This allows to consider the possibility that the decays of exotic nuclei in galactic clusters generates 3.5 keV photons. The obvious question is why the spectrum would be concentrated at 3.5 keV in this case (second question is whether the energy is really concentrated at 3.5 keV: a lot of theory is involved with the analysis of the experiments). Do the energies of excited states depend on the color bond only so that they would be essentially same for all nuclei? Or does single excitation dominate in the spectrum? Or is this due to the fact that the thermal radiation leaking from the core of stars excites predominantly single state? Could $E = 3.5$ keV correspond to the maximum intensity for thermal radiation in stellar

core? If so, the temperature of the exciting radiation would be about $T \simeq E/3 \simeq 1.2 \times 10^7$ K. This in the temperature around which formation of Helium by nuclear fusion has begun: the temperature at solar core is around 1.57×10^7 K.

3.7 Delicacies of the induced spinor structure and SUSY mystery

The discussion of induced spinor structure leads to a modification of an earlier idea (one of the many) about how SUSY could be realized in TGD in such a manner that experiments at LHC energies could not discover it and one should perform experiments at the other end of energy spectrum at energies which correspond to the thermal energy about .025 eV at room temperature. I have the feeling that this observation could be of crucial importance for understanding of SUSY.

3.7.1 Induced spinor structure

The notion of induced spinor field deserves a more detailed discussion. Consider first induced spinor structures.

1. Induced spinor field are spinors of $M^4 \times CP_2$ for which modes are characterized by chirality (quark or lepton like) and em charge and weak isospin.

2. Induced spinor spinor structure involves the projection of gamma matrices defining induced gamma matrices. This gives rise to superconformal symmetry if the action contains only volume term.

   When Kähler action is present, superconformal symmetry requires that the modified gamma matrices are contractions of canonical momentum currents with imbedding space gamma matrices. Modified gammas appear in the modified Dirac equation and action, whose solution at string world sheets trivializes by super-conformal invariance to same procedure as in the case of string models.

3. Induced spinor fields correspond to two chiralities carrying quark number and lepton number. Quark chirality does not carry color as spin-like quantum number but it corresponds to a color partial wave in CP_2 degrees of freedom: color is analogous to angular momentum. This reduces to spinor harmonics of CP_2 describing the ground states of the representations of super-symplectic algebra.

   The harmonics do not satisfy correct correlation between color and electroweak quantum numbers although the triality t=0 for leptonic waves and t=1 for quark waves. There are two manners to solve the problem.

   (a) Super-symplectic generators applied to the ground state to get vanishing ground states weight instead of the tachyonic one carry color and would give for the physical states correct correlation: leptons/quarks correspond to the same triality zero(one partial wave irrespective of charge state. This option is assumed in p-adic mass calculations [K8].

   (b) Since in TGD elementary particles correspond to pairs of wormhole contacts with weak isospin vanishing for the entire pair, one must have pair of left and right-handed neutrinos at the second wormhole throat. It is possible that the anomalous color quantum numbers for the entire state vanish and one obtains the experimental correlation between color and weak quantum numbers. This option is less plausible since the cancellation of anomalous color is not local as assume in p-adic mass calculations.

The understanding of the details of the fermionic and actually also geometric dynamics has taken a long time. Super-conformal symmetry assigning to the geometric action of an object with given dimension an analog of Dirac action allows however to fix the dynamics uniquely and there is indeed dimensional hierarchy resembling brane hierarchy.

1. The basic observation was following. The condition that the spinor modes have well-defined em charge implies that they are localized to 2-D string world sheets with vanishing W boson gauge fields which would mix different charge states. At string boundaries classical induced

W boson gauge potentials guarantee this. Super-conformal symmetry requires that this 2-surface gives rise to 2-D action which is area term plus topological term defined by the flux of Kähler form.

2. The most plausible assumption is that induced spinor fields have also interior component but that the contribution from these 2-surfaces gives additional delta function like contribution: this would be analogous to the situation for branes. Fermionic action would be accompanied by an area term by supersymmetry fixing modified Dirac action completely once the bosonic actions for geometric object is known. This is nothing but super-conformal symmetry.

   One would actually have the analog of brane-hierarchy consisting of surfaces with dimension D= 4,3,2,1 carrying induced spinor fields which can be regarded as independent dynamical variables and characterized by geometric action which is D-dimensional analog of the action for Kähler charged point particle. This fermionic hierarchy would accompany the hierarchy of geometric objects with these dimensions and the modified Dirac action would be uniquely determined by the corresponding geometric action principle (Kähler charged point like particle, string world sheet with area term plus Kähler flux, light-like 3-surface with Chern-Simons term, 4-D space-time surface with Kähler action).

3. This hierarchy of dynamics is consistent with SH only if the dynamics for higher dimensional objects is induced from that for lower dimensional objects - string world sheets or maybe even their boundaries orbits of point like fermions. Number theoretic vision [K19] suggests that this induction relies algebraic continuation for preferred extremals. Note that quaternion analyticity [K20] means that quaternion analytic function is determined by its values at 1-D curves.

4. Quantum-classical correspondences (QCI) requires that the classical Noether charges are equal to the eigenvalues of the fermionic charges for surfaces of dimension $D = 0, 1, 2, 3$ at the ends of the CDs. These charges would not be separately conserved. Charges could flow between objects of dimension $D + 1$ and D - from interior to boundary and vice versa. Four-momenta and also other charges would be complex as in twistor approach: could complex values relate somehow to the finite life-time of the state?

   If quantum theory is square root of thermodynamics as zero energy ontology suggests, the idea that particle state would carry information also about its life-time or the time scale of CD to which is associated could make sense. For complex values of α_K there would be also flow of canonical and super-canonical momentum currents between Euclidian and Minkowskian regions crucial for understand gravitational interaction as momentum exchange at imbedding space level.

5. What could be the physical interpretation of the bosonic and fermionic charges associated with objects of given dimension? Condensed matter physicists assign routinely physical states to objects of various dimensions: is this assignment much more than a practical approximation or could condensed matter physics already be probing many-sheeted physics?

3.7.2 SUSY and TGD

From this one ends up to the possibility of identifying the counterpart of SUSY in TGD framework [K17, K6].

1. In TGD the generalization of much larger super-conformal symmetry emerges from the super-symplectic symmetries of WCW. The mathematically questionable notion of super-space is not needed: only the realization of super-algebra in terms of WCW gamma matrices defining super-symplectic generators is necessary to construct quantum states. As a matter of fact, also in QFT approach one could use only the Clifford algebra structure for super-multiplets. No Majorana condition on fermions is needed as for $\mathcal{N} = 1$ space-time SUSY and one avoids problems with fermion number non-conservation.

2. In TGD the construction of sparticles means quite concretely adding fermions to the state. In QFT it corresponds to transformation of states of integer and half-odd integer spin to each

other. This difference comes from the fact that in TGD particles are replaced with point like particles.

3. The analog of $\mathcal{N}=2$ space-time SUSY could be generated by covariantly constant right handed neutrino and antineutrino. Quite generally the mixing of fermionic chiralities implied by the mixing of M^4 and CP_2 gamma matrices implies SUSY breaking at the level of particle masses (particles are massless in 8-D sense). This breaking is purely geometrical unlike the analog of Higgs mechanism proposed in standard SUSY.

There are several options to consider.

1. The analog of brane hierarchy is realized also in TGD. Geometric action has parts assignable to 4-surface, 3-D light like regions between Minkowskian and Euclidian regions, 2-D string world sheets, and their 1-D boundaries. They are fixed uniquely. Also their fermionic counterparts - analogs of Dirac action - are fixed by super-conformal symmetry. Elementary particles reduce so composites consisting of point-like fermions at boundaries of wormhole throats of a pair of wormhole contacts.

   This forces to consider 3 kinds of SUSYs! The SUSYs associated with string world sheets and space-time interiors would certainly be broken since there is a mixing between M^4 chiralities in the modified Dirac action. The mass scale of the broken SUSY would correspond to the length scale of these geometric objects and one might argue that the decoupling between the degrees of freedom considered occurs at high energies and explains why no evidence for SUSY has been observed at LHC. Also the fact that the addition of massive fermions at these dimensions can be interpreted differently. 3-D light-like 3-surfaces could be however an exception.

2. For 3-D light-like surfaces the modified Dirac action associated with the Chern-Simons term does not mix M^4 chiralities (signature of massivation) at all since modified gamma matrices have only CP_2 part in this case. All fermions can have well-defined chirality. Even more: the modified gamma matrices have no M^4 part in this case so that these modes carry no four-momentum - only electroweak quantum numbers and spin. Obviously, the excitation of these fermionic modes would be an ideal manner to create spartners of ordinary particles consting of fermion at the fermion lines. SUSY would be present if the spin of these excitations couples - to various interactions and would be exact.

   What would be these excitations? Chern-Simons action and its fermionic counterpart are non-vanishing only if the CP_2 projection is 3-D so that one can use CP_2 coordinates. This strongly suggests that the modified Dirac equation demands that the spinor modes are covariantly constant and correspond to covariantly constant right-handed neutrino providing only spin.

   If the spin of the right-handed neutrino adds to the spin of the particle and the net spin couples to dynamics, $\mathcal{N}=2$ SUSY is in question. One would have just action with unbroken SUSY at QFT limit? But why also right-handed neutrino spin would couple to dynamics if only CP_2 gamma matrices appear in Chern-Simons-Dirac action? It would seem that it is independent degree of freedom having no electroweak and color nor even gravitational couplings by its covariant constancy. I have ended up with just the same SUSY-or-no-SUSY that I have had earlier.

3. Can the geometric action for light-like 3-surfaces contain Chern-Simons term?

   (a) Since the volume term vanishes identically in this case, one could indeed argue that also the counterpart of Kähler action is excluded. Moreover, for so called massless extremals of Kähler action reduces to Chern-Simons terms in Minkowskian regions and this could happen quite generally: TGD with only Kähler action would be almost topological QFT as I have proposed. Volume term however changes the situation via the cosmological constant. Kähler-Dirac action in the interior does not reduce to its Chern-Simons analog at light-like 3-surface.

(b) The problem is that the Chern-Simons term at the two sides of the light-like 3-surface differs by factor $\sqrt{-1}$ coming from the ratio of $\sqrt{g_4}$ factors which themselves approach to zero: oOne would have the analog of dipole layer. This strongly suggests that one should not include Chern-Simons term at all.

Suppose however that Chern-Simons terms are present at the two sides and α_K is real so that nothing goes through the horizon forming the analog of dipole layer. Both bosonic and fermionic degrees of freedom for Euclidian and Minkowskian regions would decouple completely but currents would flow to the analog of dipole layer. This is not physically attractive.

The canonical momentum current and its super counterpart would give fermionic source term $\Gamma^n\Psi_{int,\pm}$ in the modified Dirac equation defined by Chern-Simons term at given side $\pm$: $\pm$ refers to Minkowskian/Euclidian part of the interior. The source term is proportional to $\Gamma^n\Psi_{int,\pm}$ and Γ^n is in principle mixture of M^4 and CP_2 gamma matrices and therefore induces mixing of M^4 chiralities and therefore also 3-D SUSY breaking. It must be however emphasized that Γ^n is singular and one must be consider the limit carefully also in the case that one has only continuity conditions. The limit is not completely understood.

(c) If α_K is complex there is coupling between the two regions and the simplest assumption has been that there is no Chern-Simons term as action and one has just continuity conditions for canonical momentum current and hits super counterpart.

The cautious conclusion is that 3-D Chern-Simons term and its fermionic counterpart are absent.

4. What about the addition of fermions at string world sheets and interior of space-time surface ($D = 2$ and $D = 4$). For instance, in the case of hadrons $D = 2$ excitations could correspond to addition of quark in the interior of hadronic string implying additional states besides the states obtained assuming only quarks at string ends. Let us consider the interior ($D = 4$). For instance, inn the case of hadrons $D = 2$ excitations could correspond to addition of quark in the interior of hadronic string implying additional states besides the states obtained assuming only quarks at string ends. The smallness of cosmological constant implies that the contribution to the four-momentum from interior should be rather small so that an interpretation in terms of broken SUSY might make sense. There would be mass $m \sim .03$ eV per volume with size defined by the Compton scale $\hbar/m$. Note however that cosmological constant has spectrum coming as inverse powers of prime so that also higher mass scales are possible.

   This interpretation might allow to understand the failure to find SUSY at LHC. Sparticles could be obtained by adding interior right-handed neutrinos and antineutrinos to the particle state. They could be also associated with the magnetic body of the particle. Since they do not have color and weak interactions, SUSY is not badly broken. If the mass difference between particle and sparticle is of order $m = .03$ eV characterizing dark energy density ρ_{vac}, particle and sparticle could not be distinguished in higher energy physics at LHC since it probes much shorter scales and sees only the particle. I have already earlier proposed a variant of this mechanism but without SUSY breaking.

   To discover SUSY one should do very low energy physics in the energy range $m \sim .03$ eV having same order of magnitude as thermal energy $kT = 2.6 \times 10^{-2}$ eV at room temperature 25 °C. One should be able to demonstrate experimentally the existence of sparticle with mass differing by about $m \sim .03$ eV from the mass of the particle (one cannot exclude higher mass scales since Λ is expected to have spectrum). An interesting question is whether the sfermions associated with standard fermions could give rise to Bose-Einstein condensates whose existence in the length scale of large neutron is strongly suggested by TGD view about living matter.

3.8 Conclusions

The conclusion that the standard SUSY ($\mathcal{N} = 1$ SUSY with Majorana spinors) is absent in TGD Universe and also in the real one looks rather feasible in light of various arguments discussed in this chapter and also conforms with the LHC data. A more general SUSY with baryon and lepton conservation and Dirac spinors is however possible in TGD framework.

During the attempts to understand SUSY several ideas have emerged and the original discussions are retained as such in this chapter. It is interesting to see that their fate is if standard SUSY has no TGD counterpart.

1. One of the craziest ideas was that spartners indeed exists and even with the same p-adic mass scale but might be realized as dark matter. Same mass scale is indeed a natural prediction if right-handed neutrino and particle have same mass scale. Therefore even the mesons of ordinary hadron physics would be accompanied by smesons - pairs of squark and anti-squark. In fact, this is what the most recent form of the theory predicts: unfortunately there is no manner to experimentally distinguish between fermion and pseudo-sfermion if ν_R is zero momentum state lacking even gravitational interactions.

2. There are indications that charmonium as exotic states christened as X and Y mesons and the question was that they could correspond to mesons built either from colored excitations of charged quark and antiquark or from squark and anti-squark. The recent view leaves only the option based on colored excitations alive. The states in question would be analogous to pairs of color excitations of leptons introduced to explain various anomalies in leptonic sector [K13]. The question was whether lepto-hadrons could correspond to bound states of colored sleptons and have same p-adic mass scale as leptons have [K13]. The original form of lepto-hadron hypothesis remains intact.

3. Evidence that pion and also other hadrons have what could be called infrared Regge trajectories has been reported, and one could ask whether these trajectories could include spion identified as a bound state of squarks. Also this identification is excluded and the proposed identification in terms of stringy states assignable to long color magnetic flux tubes accompanying hadron remains under consideration. IR Regge trajectories would serve as a signature for the non-perturbative aspects of hadron physics.

4. The latest idea along these lines is that spartners are obtained by adding right-handed neutrinos to the interior of space-time surface assignable to the particle. SUSY would not be detectable at high energies, which would explain the negative findings at LHC. Spartners could be discovered at low energy physics perhaps assignable to the magnetic bodies of particles: the mass scale could be as low .03 eV determined by cosmological constant in the scale of cosmology. Note however that cosmological constant has spectrum coming as inverse powers of prime.

4 Experimental Situation

The experimental situation in the case of SUSY is still open but it there are excellent hopes that the results from LHC will determine the fate of the MSSM SUSY and also constraint more general scenarios. Unfortunately, the research concentrates to the signatures of MSSM and its variants quite different from those of TGD SUSY so that it might happen that TGD SUSY will be discovered accidentally if its there: say by the decays of spartner to partner and neutrino. Already from the recent results it is clear that the allowed parameter space for MSSM SUSY is very small and that superpartners of quarks and also weak gauge bosons must be very heavy if MSSM SUSY is realized. This leads to difficulties with the only known evidence for SUSY coming from the g-2 anomaly of muon. TGD based SUSY allows light masses and also SUSY explanation of g-2 anomaly if sneutrino masses are light.

The representation involves a lot of references to blog postings and this might irritate so called serious scientists. I however feel that since blogs provide my only contact to the particle physics it is only fair to make clear that this communication tool is absolutely essential for a scientist working as out-of-law in academic community. Blogs could indeed bring democracy to science and mean end of the era of secrecy and censorship by the referee system.

4.1 Almost Predictions Related To SUSY

4.1.1 Electroweak symmetry breaking

The recent view about electroweak symmetry breaking is less than year old. The basic realization was that wormhole throats carrying elementary particle quantum numbers possess Kähler magnetic charge (in homological sense- CP_2 has non-trivial second homology). This magnetic charge must be compensated and this is achieved if the particle wormhole throat is connected to a second wormhole throat by a magnetic flux tube. The second wormhole would carry a weak charge of neutrino pair compensating the weak isospin of the particle so that weak interactions would be screened above the weak length scale. For colored states the compensation could also occur in longer length scale and corresponds to color confinement.

This does not actually require the length scale of flux tubes associated with all elementary particles to be the weak length scale as I have thought. Rather, the flux tube length for a particle at rest could correspond to the Compton length of the particle. For instance, for electron the maximal flux tube length would be about 10^{-13} meters. For particles not at rest the length would get shorter by length contraction. For very light but massive particles such as photon and graviton the maximum length of flux tube would be very long. The interaction of very low energy photons and gravitons would be essentially classical and induced by the classical oscillations of induced gauge fields induced by a long flux tube connecting the interacting systems. For high energy quanta this interaction would be essentially quantal and realized as absorption of quanta with flux tube length -essentially wave length of quantum- much shorter than the distance between the interacting systems. Gravitational waves would interact essentially classically even when absorbed since absorption would mean that the flux tube would connects two parts of the measurement apparatus. For large $\hbar$ gravitons the length of flux tube could correspond to the distance between interaction systems.

A fascinating possibility is that electronic Cooper pairs of superconductors with large value of $\hbar$, could correspond to long flux tubes with electron's quantum numbers at both ends. Maybe this takes place in high T_c super conductors.

4.1.2 Some details of the SUSY predictions

TGD SUSY differs from the standard SUSY in many respects.

1. All fermionic oscillator operators assignable to the wormhole throats generate supersymmetries. These oscillator operators differ from ordinary ones in that they do not have momentum label and momentum can be only assigned to the entire state. Therefore the interpretation of all states assignable to wormhole throats as large SUSY multiplet is possible. This SUSY is badly broken and there is hierarchy of breakings defined by the interactions inducing the breaking in turn define by the quantum numbers of SUSY generators. For quark generators the breaking is largest and the smallest breaking is associated with the oscillator operators assignable to right-handed neutrinos since they have only gravitational interactions.

2. The symmetry generators are not Majorana spinors and this does not lead to any difficulties as has been found. Only if one would try stringy quantization trying to define stringy diagrams in terms of stringy propagators defined by stringy form of super-conformal algebra, one would end up with difficulties. Majorana property is also excluded by the separate conservation of baryon and lepton number.

   For single wormhole throat one can see the situation in terms of N=2 SUSY with right handed neutrino and its antiparticle appearing as SUSY generators carrying conserved fermion number. One can classify the superpartners by their right-handed neutrino number which is +/-1. For instance, for single wormhole throat one obtains fermion and its partner containing ν_R pair, and fermion number 0 and fermion number 2 sfermions. In the case of gauge bosons and Higgs similar degeneracy is obtained for both wormhole throats.

3. Since induced gamma matrices and Kähler-Dirac gamma matrices are mixtures of M^4 and CP_2 gamma matrices right handed neutrino is mixed with the left handed neutrino meaning breaking of R-parity. The simplest decays of sparticles are of form $P \rightarrow P+\nu$ and can be said to be gravitationally induced since the mixing of gamma matrices is indeed a characteristic

phenomenon of induced spinor structure. Also more complex decays with neutrino replaced with charge lepton are possible. The basic signature is lonely lepton not possible in decays of weak bosons.

4. The basic outcome of SUSY QFT limit of TGD [K6] is that wormhole throat can carry only spin 0, 1/2, 1 corresponding to fermion and fermion pair if one wants to obtain standard propagator: otherwise one obtains $1/p^n$, $n > 2$ and this is not an ordinary particle pole. The reason is that one cannot assign to fermionic oscillator operators independent momenta but only common momentum so they propagate effectively collinearly.

   One can criticize this argument as being inconsistent with the twistorial approach combined with zero energy ontology implying that wormhole throats are massless even for on mass shell states. In this approach one in principle avoids completely the use of propagators which would of course diverge for on shell wormhole throats. Also for twistor diagrams the counterparts of virtual particles are massless and off shell. The so called region momentum replaces momentum in Grassmannian twistor approach and has a direct counterpart as eigenvalue of the Kähler-Dirac operator so that the analog of propagator exists in TGD framework. Since QFT limit must be a reasonable approximation to the full theory, one might hope that the QFT based argument makes sense when one replaces momentum with region momentum (or pseudo momentum as I have called it in TGD framework).

5. Should one allow both $\nu_R$and its antiparticle as SUSY generators? This would mean more states as in standard SUSY for which only $\overline{\nu}_R$ would be allowed for fermion. This would assign to a given wormhole throat with fermion number 1 spin 1 and spin 0 super partner and companion of fermion containing $\nu_R - \overline{\nu}_R$ pair. For this state however propagator would behave like $1/p^3$ should that again strong SUSY breaking would occur for this extended SUSY. Only one half of SUSY would be broken weakly by the mixing of M^4 and CP_2 gamma matrices appearing in Kähler-Dirac gamma matrices: the mixing would not involve weak or color interactions but could be said to be gravitational but not in the sense of abstract for geometry but induced geometry.

   The breaking of symmetries by this mechanism would be a beautiful demonstration that it is sub-manifold geometry rather than abstract manifold geometry that matters. Again string theorists managed to miss the point by effectively eliminating induced geometry from the original string model by inducing the metric of space-time sheet as an independent variable. The motivation was that it became easy to calculate! The price paid was symmetry breaking mechanisms involving hundreds of three parameters.

6. Single wormhole contact could carry spin J=2 and give rise to graviton like state. If one constructs from this gravitino by adding right-handed neutrinos, and if SUSY QFT limit makes sense, one obtains particle with propagator decreasing faster at either throat so that gravitino in standard sense would not exist. This would represent strong SUSY breaking in gravitational sector. These results are of utmost importance since the basic argument in favor dimension D=10 or D=11 for the target space of superstring models is that higher dimensions would give fundamental massless particles with higher spin.

   Note that the replacement of wormhole throats by flux tubes having neutrino pair at the second end of the flux tube complicates the situation since one can add right handed neutrino also to the neutrino end. The SUSY QFT criterion would however suggest that these states are not particle like.

4.1.3 Super-symplectic bosons

TGD predicts also exotic bosons which are analogous to fermion in the sense that they correspond to single wormhole throat associated with CP_2 type vacuum extremal whereas ordinary gauge bosons corresponds to a pair of wormhole contacts assignable to wormhole contact connecting positive and negative energy space-time sheets. These bosons have super-conformal partners with quantum numbers of right handed neutrino and thus having no electro-weak couplings. The bosons are created by the purely bosonic part of super-symplectic algebra [K3, K16], whose generators belong to the representations of the color group and 3-D rotation group but have vanishing electroweak quantum numbers. Their spin is analogous to orbital angular momentum whereas the spin of ordinary gauge bosons reduces to fermionic spin. Recall that super-symplectic algebra is crucial for the construction of WCW Kähler geometry. If one assumes that super-symplectic gluons suffer topological mixing identical with that suffered by say U type quarks, the conformal weights would be (5, 6, 58) for the three lowest generations. The application of super-symplectic bosons in TGD based model of hadron masses is discussed in [K11] and here only a brief summary is given.

As explained in [K11], the assignment of these bosons to hadronic space-time sheet is an attractive idea.

1. Quarks explain only a small fraction of the baryon mass and that there is an additional contribution which in a good approximation does not depend on baryon. This contribution should correspond to the non-perturbative aspects of QCD. A possible identification of this contribution is in terms of super-symplectic gluons. Baryonic space-time sheet with $k = 107$ would contain a many-particle state of super-symplectic gluons with net conformal weight of 16 units. This leads to a model of baryons masses in which masses are predicted with an accuracy better than 1 per cent.

2. Hadronic string model provides a phenomenological description of non-perturbative aspects of QCD and a connection with the hadronic string model indeed emerges. Hadronic string tension is predicted correctly from the additivity of mass squared for $J = 2$ bound states of super-symplectic quanta. If the topological mixing for super-symplectic bosons is equal to that for U type quarks then a 3-particle state formed by 2 super-symplectic quanta from the first generation and 1 quantum from the second generation would define baryonic ground state with 16 units of conformal weight. A very precise prediction for hadron masses results by assuming that the spin of hadron correlates with its super-symplectic particle content.

3. Also the baryonic spin puzzle caused by the fact that quarks give only a small contribution to the spin of baryons, could find a natural solution since these bosons could give to the spin of baryon an angular momentum like contribution having nothing to do with the angular momentum of quarks.

4. Super-symplectic bosons suggest a solution to several other anomalies related to hadron physics. The events observed for a couple of years ago in RHIC [C21] suggest a creation of a black-hole like state in the collision of heavy nuclei and inspire the notion of color glass condensate of gluons, whose natural identification in TGD framework would be in terms of a fusion of hadronic space-time sheets containing super-symplectic matter materialized also from the collision energy. In the collision, valence quarks connected together by color bonds to form separate units would evaporate from their hadronic space-time sheets in the collision, and would define TGD counterpart of Pomeron, which experienced a reincarnation for few years ago [C23]. The strange features of the events related to the collisions of high energy cosmic rays with hadrons of atmosphere (the particles in question are hadron like but the penetration length is anomalously long and the rate for the production of hadrons increases as one approaches surface of Earth) could be also understood in terms of the same general mechanism.

4.2 Goodbye Large Extra Dimensions And MSSM

New results giving strong constraints on large extra dimensions and on the parameters of minimally supersymmetric standard model (MSSM) have come from LHC and one might say that both larger extra dimensions and MSSM are experimentally excluded.

4.2.1 The problems of MSSM

According to the article "The fine-tuning price of the early LHC" (see `http://tinyurl.com/y9vlajys`) by A. Strumia [C7] the results from LHC reduce the parameter space of MSSM dramatically. Recall that the king idea of MSSM is that the presence of super partners tends to cancel the loop corrections from ordinary particles giving to Higgs mass much larger correction that the mass itself. Note that the essential assumption is that R-parity is an exact symmetry so that the lightest superpartner is stable. The signature of SUSY is indeed missing energy resulting in the decay chain beginning with the decay of gluino to chargino and quark pair followed by the decay of chargino to W boson and neutralino representing missing energy.

The article "Search for supersymmetry using final states with one lepton, jets, and missing transverse momentum with the ATLAS detector in $s^{1/2} = 7$ TeV pp collisions" (see `http://tinyurl.com/ybqmhr5b`) [C5] by ATLAS collaboration at LHC poses strong limits on the parameters of MSSM implying that the mass of gluino is above 700 GeV in the case that gluino mass is same as that of squark. In Europhysics 1011 meeting the lower bounds for squark and gluino masses were raised to about 1 TeV. The experimental lower bounds on masses of superpartners are so high and the upper bound on Higgs mass so low that the superpartners cannot give rise to large enough compensating corrections to stabilize Higgs. This requires fine-tuning even in MSSM known as little hierarchy problem (see `http://tinyurl.com/y9qj88uj`).

In typical models this also means that the bounds on slepton masses are too high to be able to explain the muonic g-2 anomaly, which was one of the original experimental motivations for MSSM. Therefore the simplest candidates for supersymmetric unifications are lost. This strengthens the suspicion that something is badly wrong with the standard view about SUSY forcing among other things to assume instability of proton due to non-conservation of baryon and lepton numbers separately.

4.2.2 The difficulties of large extra dimensions

The results from LHC do not leave much about the dream of solving hierarchy problem using SUSY. One must try something else. One example of this something else are large extra dimensions implying massive graviton, which could provide a new mechanism for massivation based on the idea that massive particle in Minkowski space are massless particles in higher dimensional space (also essential element of TGD). This could perhaps the little hierarchy problem if the mass of Kaluza-Klein graviton is in TeV range.

The article "LHC bounds on large extra dimensions" (see `http://tinyurl.com/ybvtvzn8`) by A. Strumia and collaborators [C3] poses very strong constraints on large extra dimensions and mass and effective coupling constant parameter of massive graviton. Kaluza-Klein graviton would appear in exchange diagrams and loop diagrams for 2-jet production and could become visible in higher energy proton-proton collisions at LHC. KK graviton would be also produced as invisible KK-graviton energy in proton-proton collisions. The general conclusion from data gathered hitherto shrinks dramatically the allowed parameter space for the KK-graviton. Does this mean that we are left with the anthrophic option?

4.2.3 Also M-theorists admit that there are reasons for the skepticism

Michael Dine admits in the article "Supersymmetry From the Top Down" (see `http://tinyurl.com/ydc9uzu7`) [C6] that there are strong reasons for skepticism. Dine emphasizes that the hierarchy problem related to the in-stability of Higgs mass due to the radiative corrections is the main experimental motivation for SUSY but that little hierarchy problem remains the greatest challenge of the approach. As noticed, in TGD this problem is absent. The same basic vision based on zero energy ontology and twistors predicts among other things

- the cancellation of UV and IR infinities in generalized Feynman (or more like twistor-) diagrammatics,
- predicts that in the electroweak scale the stringy character of particles identifiable as magnetically charged wormhole flux tubes should begin to make itself manifest,
- particles regarded usually as massless eat all Higgs like particles accompanying them (here "predict" is perhaps too strong a statement),
- also pseudo-scalar counterparts of Higgs-like particles, which avoid the fate of their scalar variants (there already exist indications for pseudo-scalar gluons (see `http://tinyurl.com/y83nv2f5`).

Combined with the powerful predictions of p-adic thermodynamics for particle masses these qualitative successes make TGD a respectable candidate for the follower of string theory.

4.2.4 Could TGD approach save super-symmetry?

In TGD framework the situation is not at all so desolate. Due to the differences between the induced spinor structure and ordinary spinors, Higgs corresponds to SU(2) triplet and singlet in TGD framework rather than complex doublet. The recent view about particles as bound states of massless wormhole throats forced by twistorial considerations and emergence of physical particles as bound states of wormhole contacts carrying fermion number and vibrational degrees of freedom strongly suggests- I do not quite dare to say "implies" - that also photon and gluons become massive and eat their Higgs partners to get longitudinal polarization they need. No Higgs- no fine tuning of Higgs mass- no hierarchy problems.

Note that super-symmetry is not given up in TGD but differs in many essential respects from that of MSSM. In particular, super-symmetry breaking and breaking of R-parity are automatically present from the beginning and relate very closely to the massivation.

1. If the gamma matrices were induced gamma matrices, the mixing would be large by the light-likeness of wormhole throats carrying the quantum numbers. Induced gamma matrices are however excluded by internal consistency requiring Kähler-Dirac gamma matrices obtained as contractions of canonical momentum densities with imbedding space gamma matrices. Induced gamma matrices would require the replacement of Kähler action with 4-volume and this is unphysical option.

2. In the interior Kähler action defines the canonical momentum densities and near wormhole throats the mixing is large: one should note that the condition that the Kähler-Dirac gamma matrices multiplied by square root of metric determinant must be finite. One should show that the weak form of electric-magnetic duality guarantees this: it could even imply the vanishing of the limiting values of these quantities with the interpretation that the space-time surfaces becomes the analog of Abelian instanton with Minkowski signature having vanishing energy momentum tensor near the wormhole throats. If this is the case, Euclidian and Minkowskian regions of space-time surface could provide dual descriptions of physics in terms of generalized Feynman diagrams and fields.

3. At wormhole throats Abelian Chern-Simons-Kähler action with the constraint term guaranteeing the weak form of electric-magnetic duality defines the Kähler-Dirac gamma matrices. Without the constraint term Chern-Simons gammas would involve only CP_2 gamma matrices and no mixing of M^4 chiralities would occur. The constraint term transforming TGD from topological QFT to almost topological QFT by bringing in M^4 part to the Kähler-Dirac gamma matrices however induces a mixing proportional to Lagrange multiplier. It is difficult to say anything precise about the strength of the constraint force density but one expect that the mixing is large since it is also large in the nearby interior.

If the mixing of the Kähler-Dirac gamma matrices is indeed large, the transformation of the right-handed neutrino to its left handed companion should take place rapidly. If this is the case, the decay signatures of spartners are dramatically changed as will be found and the bounds on the masses of squarks and gluinos derived for MSSM do not apply in TGD framework.

1. Proposal for the mass spectrum of sfermions

In TGD framework p-adic length scale hypothesis (stating that preferred p-adic primes come as $p \simeq 2^k$, k integer) allows to predict the masses of sleptons and squarks modulo scaling by a powers $\sqrt{2}$ determined by the p-adic length scale by using information coming from CKM mixing induced by topological mixing of particle families in TGD framework. Also natural guesses for the mass scales of ew gauginos and gluinos are obtained.

1. If one assumes that the mass scale of SUSY corresponds to Mersenne prime M_{89} assigned with intermediate gauge bosons one obtains unique predictions for the various masses apart from uncertainties due to the mixing of quarks and neutrinos [K8].

2. In first order the p-adic mass formulas for fermions read as

$$\begin{aligned} m_F &= \sqrt{\frac{n_F}{5}} \times 2^{(127-k_F)/2} \times m_e \ , \\ n_L &= (5,14,65) \ , \ n_\nu = (4,24,64) \ , \ n_U = (5,6,58) \ , \ n_D = (4,6,59) \ . \end{aligned} \tag{4.1}$$

   Here k_F is the integer characterizing p-adic mass scale of fermion via $p \simeq 2^{k_F}$. The values of k_F are not listed here since they are not needed now. Note that electroweak symmetry breaking distinguish U and D type fermions is very small when one uses p-adic length scale as unit.

   By taking $k_F = 89$ for super-partners as a reference mass scale, one obtains in good approximation (the first calculation contained erratic scaling factor)

$$\begin{aligned} \frac{m_{\tilde{L}}}{GeV} &= 2^{(89-k_F)/2}(262,439,945) \ , \\ \frac{m_{\tilde{\nu}}}{GeV} &= 2^{(89-k_F)/2}(235,423,938) \ , \\ \frac{m_{\tilde{U}}}{GeV} &= 2^{(89-k_F)/2}(262,287,893) \ , \\ \frac{m_{\tilde{D}}}{GeV} &= 2^{(89-k_F)/2}(235,287,900) \ . \end{aligned} \tag{4.2}$$

   Charged leptons correspond to subsequent Mersennes or Gaussian Mersennes. The first guess is that this holds true also for charged sleptons. This would give $k_F(\tilde{e}) = 89$, $k_F(\tilde{\mu}) = 79$, and $k_F(\tilde{\tau}) = 61$. For quarks one has $k_F(q) \geq 113$ ($k = 113$ corresponds to Gaussian Mersenne). If one generalizes this to $k_F(\tilde{q}) \leq 79$, all sfermion masses expect those of selectron and sneutrinos are above 13 TeV. This option might well be consistent with the recent experimental data require that squark masses are above 1 TeV. The possible problem is selectron mass 262 GeV.

3. The simplest possibility is that ew gauginos are characterized by $k = 89$ and have same masses as W and Z in good approximation. Therefore $\tilde{W}$ could be the lightest supersymmetric particle and could be observed directly if the neutrino mixing is not too fast and allowing the decay $\tilde{W} + \nu$. Also gluinos could be characterized by M_{89} and have mass of order intermediate gauge boson mass. For this option to be discussed below the decay scenario of MSSM changes considerably.

4. It should be noticed that the single strange event reported 1995 [C30] discussed in [**?**]ives for the mass of selectron the estimate 131 GeV, which corresponds to M_{91} instead of M_{89} and is thus one half of the selectron mass for Mersenne option. This event allowed also to estimate the masses of Zino and corresponding Higgsino. The results are summarized by the following table:

$$m(\tilde{e}) = 131 \ \ GeV \ \ , \ \ m(\tilde{Z}^0) = 91.2 \ \ GeV \ \ , \ \ m(\tilde{h}) = 45.6 \ \ GeV \ \ . \tag{4.3}$$

   If one takes these results at face value one must conclude either that M_{89} hypothesis is too strong or M_{SUSY} corresponds to M_{91} or that M_{89} is correct identification but also sfermions can appear in several p-adic mass scales.

The decay cascades searched for in LHC are initiated by the decay $q \rightarrow \tilde{q} + \tilde{g}$ and $g \rightarrow \tilde{q} + \tilde{q}_c$. Consider first R-parity conserving decays. Gluino could decay in R-parity conserving manner via $\tilde{g} \rightarrow \tilde{q} + q$. Squark in turn could decay via $\tilde{q} \rightarrow q_1 + \tilde{W}$ or via $\tilde{q} \rightarrow q + \tilde{Z}^0$. For the proposed first guess about masses the decay $\tilde{W} \rightarrow \nu_e + \tilde{e}$ or $\tilde{Z}^0 \rightarrow \nu_e + \tilde{\nu}_e$ would not be possible on mass shell.

If the mixing of right-handed and left-handed neutrinos is fast enough, R-parity is not conserved and the decays $\tilde{g} \rightarrow g + \nu$ and $\tilde{q} \rightarrow q + \nu$ could take place by the mixing $\nu_R \rightarrow \nu_L$ following by electroweak interaction between ν_L quark or antiquark appearing as composite of gluon. The decay signature in this case would be pair of jets (quark and antiquark or gluon gluon jet both containing a lonely neutrino not accompanied by a charged lepton required by electroweak decays. Also the decays of electroweak gauginos and sleptons could produce similar lonely neutrinos.

The lower bound to quark masses from LHC (see `http://tinyurl.com/6klqzds`) is about 600 GeV and 800 GeV for gluon masses assuming light neutralino is slightly above the proposed masses of lightest squarks [C20]. In Europhysics 2011 lower bounds were raised to 1 TeV for both gluino and squark masses. These bounds are consistent with the above speculative picture. These masses are allowed for R-parity conserving option if the decay rate producing chargino is reduced by the large mass of chargino the bounds become weaker. If the decay via R-parity breaking is fast enough no bounds on masses of squarks and gluinos are obtained in TGD framework but jets with neutrino unbalanced by a charged lepton should be observed.

2. How to relate MSSM picture to TGD picture?

In order to utilize MSSM calculation in TGD framework one must relate MSSM picture to TGD picture. The basic constraint is that Higgs is absent. This could apply also to Higgsino. This certainly simplifies the formulas. A further condition is that superpartners obey the same mass formulas as partners for same pa-dic length scale.

It has been proposed that the loops involving superpartners (see `http://tinyurl.com/ybzmre9z`) could explain the anomaly [C17]. In one-loop order one would have the processes $\mu \rightarrow \tilde{\mu} + \tilde{Z}^0$ and $\mu \rightarrow \tilde{\nu}_\mu + \tilde{W}^0$. The situation is complicated by the possible mixing of the gauginos and Higgsinos and in MSSM this mixing is described by the mixing matrices called X and Y. The general conclusion is however clear: if muonic sneutrino is light, it is possible to have sizeable contribution to the g-2 anomaly.

1. Magnetic moment operator mixes different M^4 chiralities. For simplest one-loop diagrams this corresponds in TGD framework to coupling in the Kähler-Dirac equation mixing different chiralities describable as an effective mass term. The couplings between right and left handed sfermions also contributes to the magnetic moment and these couplings reduce to those of sfermions being basically induced by the fermionic chirality mixing which reduces to the fact that Kähler-Dirac gamma matrices are superpositions of M^4 and CP_2 gamma matrices.

2. The basic outcome in the standard SUSY approach is that the mixing is proportional to the factor m_μ^2/m_{SUSY}^2. One expects that in the recent situation $m_{SUSY} = m_W$ is a reasonable first guess so that the mixing is large and could explain the anomaly. Second guess is as M_{89} p-adic mass scale.

3. MSSM calculations for anomalous g-2 involve the mixing of both $\tilde{f}_L$ and $\tilde{f}_R$ and of gauginos and Higgsinos. In MSSM the mixing matrices involve the parameter $tan(\beta)$ where the angle β characterizes the ratio of mass scales of U and D type fermions fixed by the ratio of Higgs expectations for the two complex Higgs doublets [C17]. $tan(\beta)$ also characterizes in MSSM the ratio of vacuum expectation values of two Higgses assignable to U and D type quarks and cannot be fixed from this criterion since in TGD framework one has one scalar Higgs and pseudo-scalar Higgs decomposing to triplet and singlet under SU(2) and the mass ratio is fixed by p-adic mass calculations.

The question is what happens if Higgs and Higgsino are absent and what one can conclude about the value of β in TGD framework where p-adic mass calculations give the dominant contribution to fermion masses and the mass formulas for particles and sparticles should be identical for a fixed p-adic prime.

2.1 Mixing of charged gauginos and Higgsinos

Consider first the mixing between charged gauginos and Higgsinos. The angle β characterizes also the mixing of $\tilde{W}$ and charged Higgsino parametrized by the mass matrix

$$X = \begin{pmatrix} M_2 & M_W\sqrt{2}sin(\beta) \\ M_W\sqrt{2}cos(\beta) & \mu \end{pmatrix} . \tag{4.4}$$

The $tan(\beta)$ gives the ratio of mass scales of U and D type quarks in MSSM. In MSSM $tan(\beta)$ reduces to the ratio of Higgs vacuum expectations and it would be better to get rid of the entire parameter in TGD framework. The maximally symmetric situation corresponds to the same mass scale for U and D type quarks and this suggests that one has $sin(\beta) = cos(\beta) = 1/\sqrt{2}$ implying $tan(\beta) = 1$. In MSSM $tan(\beta) > 2$ is required and this is due to the large value of the m_{SUSY}.

Whether this parameterization makes sense in TGD framework depends on whether one allows Higgsino.

1. If also Higgsino is absent the formula does not make sense. A natural condition is that the value of $tan(\beta)$ does not appear at all in the limiting formulas for the anomalous g-2. Note that in p-adic mass calculations do not contain this kind of a priori continuous parameter. There the simplest TGD based option is that the Higgsino is just absent and the mass matrix reduces 1×1 matrix M_2 giving wino mass. The idea that particle and sparticles have identical masses for the same p-adic mass scale would give $M_2 = M_W$. One must however remember that in TGD framework mass operator acts like a preferred combination of gamma matrices in CP_2 degrees of freedom mixing M^3 chiralities.

2. If one allows Higgsinos, the simplest guess is that apart from p-adic mass scale same has $M_2 = -\mu = m$: this guarantees identical masses for the mixed states in accordance with the ideas that different masses for particles and sparticles result from the different p-adic length scale. For $cos(\beta) = 1/\sqrt{2}$ this would give mass matrix with eigen values $(M, -M)$, $M = \sqrt{m^2 + m_W^2}$ so that mass squared values of of the mixed states would be identical and above m_W mass for $p = M_{89}$. Symmetry breaking by an increase of the p-adic length scale could however reduce the mass of other state by a power of $\sqrt{2}$.

   If also winos and zinos eat the higgsinos, one can argue that the determinant of X must vanish so that the eigenstate with vanishing eigen value would correspond to an unphysical state meaning the elimination of second state from the spectrum. This would require $M_2\mu - M_W^2 sin(2\beta) = 0$. $sin(\beta) = 1/\sqrt{2}$ and $M_2 = \mu = M_W$ is the simplest solution to the condition. This looks tricky.

2.2 Mixing of neutral gauginos and Higgsinos

In MSSM 4 × 4 matrix is needed to describe the mixing of neutral gauginos and two kinds of neutral Higgsinos. In TGD framework second Higgs (if it exists at all) is pseudo-scalar and does not contribute and the 2 × 2 matrices describe the mixing also now.

$$X = \begin{pmatrix} \begin{pmatrix} M_1 & 0 \\ 0 & M_2 \end{pmatrix} & M_Z \begin{pmatrix} s_W cos(\beta) & s_W sin(\beta) \\ c_W cos(\beta) & c_W sin(\beta) \end{pmatrix} \\ M_Z \begin{pmatrix} s_W cos(\beta) & s_W sin(\beta) \\ c_W cos(\beta) & c_W sin(\beta) \end{pmatrix} & -\mu \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \end{pmatrix} . \tag{4.5}$$

For $sin(\beta) = cos(\beta) = 0$ the non-diagonal part of the mass matrix is degenerate.

Again there are two options depending on whether Higgsinos are present and if they are absent the dependence on the angle β vanishes. Indeed, if Higgsinos are absent the matrix reduces to a diagonal 2×2 mass matrix for U(1) gaugino $\tilde{B}$ and neutral SU(2) gaugino $\tilde{W}^3$. If one takes seriously MSSM, there would be no mixing. On the other hand, TGD suggests that neutral gauginos mix in the same manner as neutral gauge bosons so that Weinberg angle would characterize the mixing with photino and zino appearing as mass eigen states. Again for same value of p-adic prime the values of mass squared for gauge bosons and gauginos should be identical.

One can also consider the option with Higgsino.

1. Since Higgs and Higgsino have representation content 3+1 with respect to electroweak SU(2) in TGD framework, one can speak about $\tilde{h}_B$, $B = W, Z, \gamma$. An attractive assumption is that Weinberg angle characterizes also the mixing giving rise to $\tilde{Z}$ and $\tilde{\gamma}$ on one hand and $\tilde{h}_\gamma$ and $\tilde{h}_Z$ on the other hand if these belong to the spectrum. This would reduce the mixing matrix to two 2 × 2 matrices: the first one for $\tilde{\gamma}$ and $\tilde{h}_\gamma$ and the second one for $\tilde{Z}$ and $\tilde{h}_Z$.

2. A further attractive assumption is that the mass matrices describing mixing of gauginos and corresponding Higgsinos are in some sense universal with respect to electroweak interactions. The form of the mixing matrix would be essentially same for all cases. This would suggest that M_W is replaced in the above formula with the mass of Z^0 and photon in these matrices (recall that it is assumed that photon gets small mass by eating the neutral Higgs). Note that for photino and corresponding Higgsino the mixing would be small. The guess is $M_2 = -\mu = m_Z$. For photino one can guess that M_2 corresponds to M_{89} mass scale.

These assumptions of course define only the first maximally symmetric guess and the simplest modification that one can imagine is due to the different p-adic mass scales. If the above discussed values for zino and neutralino masses deduced from the 1995 event [C30] are taken at face value, the eigenvalues would be $\pm\sqrt{M_Z^2 + m^2}$ with $m = M_2 = -\mu$ for $\tilde{Z} - \tilde{h}_Z$-mixing and the other state would have p-adic length scale $k = 91$ rather than $k = 89$. M and μ would have opposite signs as required by the correct sign for the $g - 2$ anomaly for muon assuming that smuons correspond to $p = M_{89}$ as will be found.

2.3 The relationship between masses of charged sleptons and sneutrinos

In MSSM approach one has also the formula relating the masses of sneutrinos and charged sleptons [C17]:

$$m_{\tilde{\nu}}^2 = m_{\tilde{L}}^2 + \frac{1}{2}M_Z^2 cos(2\beta) \quad . \tag{4.6}$$

For $\beta = \pm\pi/4$ one would have $tan(\beta) = 1$ and

$$m_{\tilde{\nu}}^2 = m_{\tilde{L}}^2 \quad .$$

In p-adic mass calculations this kind of formula is highly questionable and could make sense only if the particles involved correspond to same value of p-adic prime and therefore would not make sense after symmetry breaking.

3. The anomalous magnetic moment of muon as a constraint on SUSY

The anomalous magnetic moment $a_\mu \equiv (g-2)/2$ of muon has been used as a further constraint on SUSY. The measured value of a_μ is $a_\mu^{exp} = 11659208.0(6.3) \times 10^{10}$. The theoretical prediction decomposes to a sum of reliably calculable contributions and hadronic contribution for which the low energy photon appearing as vertex correction decays to virtual hadrons. This contribution is not easy to calculate since non-perturbative regime of QCD is involved. The deviation between prediction and experimental value is $\Delta a_\mu(exp - SM) = 23.9(9.9) \times 10^{-10}$ giving $\Delta a_\mu(exp - SM/)a_\mu = 2\times10^{-6}$. The hadronic contribution (see `http://tinyurl.com/ybk4twsr`) is estimated to be 692.3×10^{-10} so that the anomaly is 3 per cent from the hadronic contribution [C17]. One can ask whether the uncertainties due to the non-perturbative effects could explain the anomaly.

The following calculation is a poor man's version of MSSM calculation [C17]. Also now SUSY requires that the electroweak couplings between particles dictate those between sparticles. Supersymmetry for massivation suggests that in TGD framework higgsinos do not belong to the spectrum. Light sfermions appear as single copy with vanishing fermion number so that various mixing matrices of MSSM reduce to unit matrices. This leads to a rough recipe: take only the one loop contributions to g-2 and assume trivial mixing matrices and drop off summations. At least a good order of magnitude estimate should result in this manner.

3.1 A rough MSSM inspired estimate g-2 anomaly

Consider now a rough estimate for the g-2 anomaly by using the formulas 56-58 of [C17]. One obtains for the charged loop the expression

$$\Delta a_\mu^{\pm} = -\frac{21 g_2^2}{32\pi^2} \times (\frac{m_\mu}{m_W})^2 \times sign(\mu M_2) \quad . \tag{4.7}$$

This however involves a formula relating sneutrino and charged slepton masses. There is no reason to expect this formula to hold true in TGD framework.

For neutral contribution the expression is more difficult to deduce. As physical intuition suggests, the expression inversely proportional to $1/m_W^2$ since m_W corresponds now m_{SUSY} although this is not obvious on the basis of the general formulas suggesting the proportionality toi $1/m_{\tilde{\nu}_\mu}^2$. The p-adic mass scale corresponding to M_{89} is the natural guess for M_{SUSY} and would give $M_{SUSY} = 104.9$ GeV. The fact that the correction has positive sign requires that μ and M_2 have opposite signs unlike in MSSM. The sign factor is opposite to that in MSSM because sfermion mass scales are assumed to be much higher than weak gaugino mass scale.

The ratio of the correction to the lowest QED estimate $a_{\mu,0} = \alpha/2\pi$ can be written as

$$\frac{\Delta a_\mu^+}{a_{\mu,0}} = \frac{21}{4sin^2(\theta_W)} \times (\frac{m_\mu}{m_{SUSY}})^2 \simeq 2.73 \times 10^{-5} \quad . \tag{4.8}$$

which is roughly 10 times larger than the observed correction. The contribution Δa_μ^0 could reduce this contribution. At this moment I am however not yet able to transform the formula for it to TGD context. Also the scaling up of the m_{SUSY} by a factor of order $2^{3/2}$ could reduce the correction.

The parameter values $(tan(\beta) = 1, M_{SUSY} = 100$ GeV) corresponds to the boundary of the region allowed by the LHC data and $g-2$ anomaly is marginally consistent with these parameter values (see figure 16 of [C17]). The reason is that in the recent case the mass of lightest Higgs particle does not pose any restrictions (the brown region in the figure). Due to the different mixing pattern of gauginos and higgsinos in neutral sector TGD prediction need not be identidal with MSSM prediction.

The contribution from Higgs loop (see `http://tinyurl.com/y894edqd`) is not present if Higgs is eaten by photon [C28]. This contribution by a factor of order $(m_\mu/h_H)^2$ smaller than the estimate for the SUSY contribution so that the dropping of Higgs contribution does not affect considerably the situation.

$$\Delta a_\mu^H = \frac{2}{2.24^2}(\frac{m_\mu}{m_H})^4) \times (log((\frac{m_H}{m_\tau})^2) - \frac{3}{2}) \quad . \tag{4.9}$$

The proposed estimate is certainly poor man's estimate since it is not clear how near the proposed twistorial approach relying on zero energy ontology is to QFT approach. It is however encouraging that the simplest possible scenario might work and that this is essentially due to the p-adic length scale hypothesis.

3.2 An improved estimate for g-2 anomaly

An attractive scenario for sfermion masses marginally consistent with the recent data from LHC generalizes the observation that charged lepton masses correspond to subsequent Mersenne primes of Gaussian Mersennes. The only sfermions lighter than about 13 TeV are selectron with mass 262 GeV ($k = 89$) and sneutrinos, which can have much smaller masses. $\tilde{W}\tilde{\nu}_\mu$ virtual state would be mostly responsible for the muonic g-2 anomaly since the largest term in the correction is proportional to $m(\mu)m(\tilde{W})/m^2(\tilde{\nu}_\mu)$ and the anomaly might allow to determine $m(\tilde{\nu}_\mu)$. This option should be explain the g-2 anomaly.

The following estimate demonstrates that there are hopes about this. Using the formulas of [C17] one can write the one loop contributions to the anomalous contribution $a(\mu)$ as

$$\begin{aligned} a_\mu^{\chi^0} &= \frac{m(\mu)}{16\pi^2}\sum_{i,m} X_{im} \quad , \\ X_{im} &= -\frac{m(\mu)}{12m^2(\tilde{\mu}_m)}\left[|n_{im}^L|^2 + |n_{im}^R|^2\right] F_1^N(x_{im}) + \frac{m(\chi_i^0)}{3m^2(\tilde{\mu}_m)} Re\left[n_{im}^L n_{im}^R\right] F_2^N(x_{im}) \quad , \end{aligned} \tag{4.10}$$

and

$$\begin{aligned} a_\mu^{\chi^\pm} &= \frac{m(\mu)}{16\pi^2}\sum_k X_k \ , \\ X_k &= -\frac{m(\mu)}{12m^2(\tilde{\nu}_\mu)}\left[|c_k^L|^2+|c_k^R|^2\right]F_1^C(x_k)+\frac{2m(\chi_k^\pm)}{3m^2(\tilde{\nu}_\mu)}Re\left[c_k^L c_k^R\right]F_2^C(x_k) \ . \end{aligned} \tag{4.11}$$

Here $i=1,...,4$ denotes neutralino indices which should reduce to two if also Higgsinos disappear from the spectrum. $k=1,2$ denotes the neutral and charginos indices reducing to single index now. $m=1,2$ denotes smuon index. Note that TGD suggests strongly that the masses of $\tilde{\mu}_R$ and $\tilde{\mu}_L$ are degenerate. The matrices n_{im}^L, n_{im}^L and c_k^L and c_k^R relate to the mixing of mass eigenstates and are given explicitly in MSSM [C17].

The kinematic variables are defined as the mass ratios $x_{im}=m^2(\chi_i^0)/m^2(\tilde{\mu}_m)$ and $x_k = m^2(\chi_k^\pm)/m^2(\tilde{\nu}_\mu)$ and the loop functions are given by

$$\begin{aligned} F_1^N(x) &= \frac{2}{(1-x)^4}\left[1-6x+3x^2+2x^3-6x^2log(x)\right] \ , \\ F_2^N(x) &= \frac{3}{(1-x)^3}\left[1-x^2+2xlog(x)\right] \ , \\ F_1^C(x) &= \frac{2}{(1-x)^4}\left[2+3x-6x^2+x^3+6xlog(x)\right] \ , \\ F_2^C(x) &= \frac{3}{(1-x)^3}\left[-3+4x-x^2-2log(x)\right] \ . \end{aligned} \tag{4.12}$$

If one does not assume any relationship betwen sneutrino and charged slepton masses then for $m(\tilde{\nu}_\mu)/m(\tilde{\mu}) << 1$, $m(\mu)/m(\chi^\pm) << 1$, and $m(\chi_k^0)/m(\tilde{\mu}) << 1$ the functions F_1^N and $F_2^N(x)$ are in good approximation constant and the corresponding contributions are negligible. One has $F_1^C(x)\simeq 1/x$ and $F_2^C(x)\simeq 3/x$. It rurns out that the terms proportional to $F_1^C(x)$ and $F_2^C(x_k)$ are of the same order of magnitude. If Higgsinos do not belong to the spectrum one has $U_{k2}=0$ giving $V_{k1}U_{k2}=0$ leaving only the F_1^C contribution.

Consider now the mixing matrices for sfermions.

1. One has

$$\begin{aligned} c_k^L &= -g_2V_{k1} \ , \ c_k^R = y_\mu U_{k2} \ , \\ y_\mu &= \frac{m(\mu)}{m(W)}\frac{g_2}{\sqrt{2}cos(\beta)} \ , g_2=\frac{e}{sin(\theta_W)} \ . \end{aligned} \tag{4.13}$$

   Here the index k refers to the mixed states of L and R type sfermions. Since they are formed from fermion and right-handed neutrino, one expects that at higher energies the mixing is negligible. Mixing is however present and induced by the mixing of right and left handed fermion so that the mixing matrices are non-trivial at low energies and give relate closely to the massivation of sfermions and fermions.

2. One obtains

$$\begin{aligned} c_k^Lc_k^R &= -g_2^2\frac{m(\mu)}{m(W)}\frac{1}{\sqrt{2}cos(\beta)}V_{k1}U_{k2} = -\frac{m(\mu)}{m(W)}\times\frac{4\pi\alpha}{sin^2(\theta_W)}\times\frac{1}{\sqrt{2}cos(\beta)}V_{k1}U_{k2} \ , \\ |c_k^L|^2+|c_k^R|^2 &= g_2^2\left[|V_{k1}|^2+\frac{m^2(\mu)}{m^2(W)}\frac{1}{2cos^2(\beta)}|U_{k2}|^2\right] \ . \end{aligned} \tag{4.14}$$

Using these results one obtains explicit expressions for the two terms in a_μ.

1. The expressions for the term resulting from mixing of right and left handed sfermions is given by

$$\begin{aligned} a_\mu^{mix,k} &= \frac{m(\mu)}{8\pi^2 m(\chi_k^\pm)} \sum_k Re[c_k^L c_k^R] \\ &= \frac{1}{8\pi^2} \frac{4\pi\alpha}{sin^2(\theta_W)\sqrt{2}cos(\beta)} \frac{m^2(\mu)}{m(W)m(\chi_k^\pm)} Re[V_{k1}U_{k2}] \ . \end{aligned} \tag{4.15}$$

2. Second term is diagonal and non-vanishing also when Higgsino is absent from the spectrum.

$$a_\mu^{diag,k} = \frac{1}{8\pi^2}\frac{m^2(\mu)}{m^2(\chi^\pm)}\left[|c_k^L|^2 + |c_k^R|^2\right] \ . \tag{4.16}$$

Note that $|c_k^R << c_k^L$ holds true unless $cos(\beta)$ is very small.

3. The ratio of the contributions is

$$|\frac{a_\mu^{diag,k}}{a_\mu^{mix,k}}| = \frac{m(W)}{m(\chi^\pm)_k}\sqrt{2}cos(\beta) \times |\frac{V_{k1}}{U_{k_2}}| \ . \tag{4.17}$$

For $c_k^R = 0$ (no Higgsino) one has

$$a_\mu \simeq a_\mu^{diag,k} = \frac{1}{8\pi^2}\frac{m^2(\mu)}{m^2(\chi^\pm)}\sqrt{2}cos(\beta)\frac{4\pi\alpha}{sin^2(\theta_W)}|V_{k1}|^2 \ . \tag{4.18}$$

The dependence on the mass of muonic sneutrino disappears so that one cannot conclude anything about its value in this approximation. a_μ is determined by the mass scale of $\tilde{W}$, which should be of the same order of magnitude as W boson mass. The sign of the diagonal term is positive so that this contribution gives to g-2 a contribution which is of correct sign. This encourages to consider the option for which Higgsinos disappear from the spectrum.

The experimental value of the anomaly is equal to $\Delta a_\mu \simeq 23.9 \times 10^{-10}$. The order of magnitude estimate obtained by assuming $(cos(\beta) = 1/\sqrt{2}, V_{k1} = 1, U_{k2} = 0)$ one obtains $a_\mu = 82.7 \times 10^{-10} \times (m(W)/m(\chi^\pm)^2$, which for $m(W)/m(\chi^\pm) = 1$ is roughly 3.46 times larger than the anomaly. The p-adic scaling $k(\tilde{W}) = 89 \rightarrow k(\tilde{W}) - 2 = 87$ would give a value of a_μ near to the observed one. The mass of $\tilde{W}$ would be 160.8 GeV. Clearly the TGD inspired view about SUSY leads to a remarkably simple picture explaining the g-2 anomaly.

4. Basic differences between MSSM and TGD

The basic differences between TGD and MSSM (see `http://tinyurl.com/p99xrd`) [B8] and related approaches deserve to be noticed (see also the article about the experimental side (see `http://tinyurl.com/yaz7c85r`) [C11]). If Higgses and Higgsinos are absent from the spectrum, SUSY in TGD sense does not introduce flavor non-conserving currents (FNCC problem plaguing MSSM type approaches). In MSSM approach the mass spectrum of superpartners can be only guessed using various constraints and in a typical scenario masses of sfermions are assumed to be same in GUT unification scales so that at long length scales the mass spectrum for sfermions is inverted from that for fermions with stop and stau being the lightest superpartners. In TGD framework p-adic thermodynamics and the topological explanation of family replication phenomenon changes the situation completely and the spectrum of sfermions is very naturally qualitatively similar to that of fermions (genus generation correspondence is the SUSY invariant answer to the famous question of Rabi “Who ordered them?” !). This is essential for the explanation of g-2 anomaly for instance. Note that the experimental searches concentrating on finding the production of stop or stau pairs are bound to fail in TGD Universe.

Another key difference is that in TGD the huge number of parameters of MSSM is replaced with a single parameter- the universal coupling characterizing the decay

sparticle → particle+right handed neutrino,

which by its universality is very "gravitational". The gravitational character suggests that it is small so that SUSY would not be badly broken meaning for instance that sparticles are rather long-lived and R-parity is a rather good symmetry.

One can try to fix the coupling by requiring that the decay rate of sfermion is proportional to gravitational constant G or equivalently, to the square of CP_2radius

$$R \simeq 10^{7+1/2}(\frac{G}{\hbar_0})^{1/2} \ .$$

Sfermion-fermion-neutrino vertex coupling to each other same fermion M^4 chiralities involves the gradient of the sfermion field. Yukawa coupling - call it L - would have dimension of length. For massive fermions in M^4 it would reduce to dimensionless coupling g different M^4 chiralities. In equal mass case g would be proportional to $L(m_1+m_2)/\hbar$, where m_i are the masses of fermions.

1. For the simplest option L is expressible in terms of CP_2 geometry alone and corresponds to

   $$L = kR \ .$$

   k is a numerical constant of order unity. $\hbar_0$denotes the standard value of Planck constant, whose multiple the effective value of Planck constant is in TGD Universe in dark matter sectors. The decay rate of sfermion would be proportional to

   $$k^2R^2(\frac{M}{hbar})^3 \simeq k^2 \times 10^7 \times \frac{G}{\hbar_0} \times (\frac{M}{\hbar})^3 \ ,$$

   where M is the mass scale characterizing the phase space volume for the decays of sfermion and is given by the mass of sfermion multiplied by a dimensionless factor depending on mass ratios. The decay rate is extremely low so that R-parity conservation would be an excellent approximate symmetry. In cosmology this could mean that zinos and photinos would decay by an exchange of sfermions rather than directly and could give rise to dark matter like phase as in MSSM.

2. Second option carries also information about Kähler action one would have apart from a numerical constant of order unity $k = \alpha_K$. The Kähler coupling strength

   $$\alpha_K = \frac{g_K^2}{4\pi \times \hbar_0} \simeq 1/137$$

   is the fundamental dimensionless coupling of TGD analogous to critical temperature.

3. For the option which "knows" nothing about CP_2 geometry the length scale would be proportional to the Schwartchild radius

   $$L = kGM \ .$$

   In this case the decay rate would be proportional to $k^2G^2M^2(M/\hbar)^3$ and extremely low.

4. The purely kinematic option which one cannot call "gravitational" "knows" only about sfermion mass and f Planck constant, and one would have

   $$L = k \times \frac{\hbar}{M} \ .$$

   The decay rate would be proportional to the naive order of magnitude guess $k^2(M/\hbar)$ and fast unlike in all "gravitational cases". R-parity would be badly broken. Again$k \propto \alpha_K$ option can be considered.

Note that also in mSUGRA gravitatational sector in short length scales determines MSSM parameters via flavor blind interactions and also breaking of SUSY via breaking of local SUSY in short scales.

4.2.5 Experimental indication for space-time super-symmetry

There is experimental indication for super-symmetry dating back to 1995 [C30]. The event involves $e^+e^-\gamma\gamma$ plus missing transverse energy $\not{E}_T$. The electron-positron pair has transversal energies $E_T = (36, 59)$ GeV and invariant mass $M_{ee} = 165$ GeV. The two photons have transversal energies (30, 38) GeV. The missing transverse energy is $\not{E}_T = 53$ GeV. The cross sections for these events in standard model are too small to be observed. Statistical fluctuation could be in question but one could also consider the event as an indication for super-symmetry.

In [C19] an explanation of the event in terms of minimal super-symmetric standard model (MSSM) was proposed.

1. The collision of proton and antiproton would induce an annihilation of quark and antiquark to selectron pair $\tilde{e}^-\tilde{e}^+$ via virtual photon or Z^0 boson with the mass of $\tilde{e}$ in the range (80, 130) GeV (the upper bound comes from the total energy of the particles involved.

2. $\tilde{e}^{\pm}$ would in turn decay to $e^{\pm}$ and neutralino χ_2^0 and χ_2^0 in turn to the lightest super-symmetric particle χ_1^0 and photon. The neutralinos are in principle mixtures of the super partners associated with γ, Z^0, and neutral higgs h (there are two of them in minimal super-symmetric generalization of standard model). The highest probability for the chain is obtained if χ_2^0 is zino and χ_1^0 is higgsino.

3. The kinematics of the event allows to deduce the bounds

$$\begin{aligned} 80 &< m(\tilde{e})/GeV < 130 \ , \\ 38 &\leq m(\chi_2^0)/GeV \leq min\left[1.12m(\tilde{e})/GeV - 37, 95 + 0.17m(\chi_1^0)/GeV\right] \ , \\ m(\chi_1^0)/GeV &\leq m(\chi_2^0)/GeV \leq min\left[1.4m(\tilde{e})/GeV - 105, 1.6m(\chi_2^0)/GeV - 60\right] \ . \end{aligned} \quad (4.19)$$

   Note that the bounds give no lower bound for $m(\chi_1^0)$ so that it could correspond to neutrino.

4. Sfermion production rate depends only on masses of the sfermions, so that slepton production cross section decouples from the analysis of particular scenarios. The cross section is at the level of $\sigma = 10$ fb and consistent with data (one event!). The parameters of MSSM are super-symmetric soft-breaking parameters, super-potential parameters, and the parameter $tan(\beta)$. This allows to derive more stringent limits on the masses and parameters of MSSM.

Consider now the explanation of the event in TGD framework.

1. For the simplest TGD inspired option both Higgs and higgsino would disappear from the spectrum in the massivation and χ_2^0 would decay to photon and neutrino so that the missing energy would consist of neutrinos.

2. By the properties of super-partners the production rate for $\tilde{e}^-\tilde{e}^+$ is predicted to be same as in MSSM for $\tilde{e} = e_R\overline{\nu}_R$. Same order of magnitude is predicted also for more exotic super-partners such as $e_L\overline{\nu}_R$ with spin 1.

3. In TGD framework it is safest to use just the kinematical bounds on the masses and p-adic length scale hypothesis. If super-symmetry breaking means same mass formula from p-adic thermodynamics but in a different p-adic mass scale, $m(\tilde{e})$ is related by a power of $\sqrt{2}$ to $m(e)$. Using $m(\tilde{e}) = 2^{(127-k(\tilde{e}))/2}m(e)$ one finds that the mass range [80, 130] GeV allows two possible masses for selectron corresponding to $p \simeq 2^k$, $k = 91$ with $m(\tilde{e}) = 131.1$ GeV and $k = 92$ with $m(\tilde{e}) = 92.7$ GeV. The bounds on $m(Z)$ leave only the option $m(\tilde{Z}) = m(Z) = 91.2$ GeV and $m(\tilde{e}) = 131.1$ GeV.

4. In the earlier variant of the TGD inspired model the existence of Higgs was considered as a realistic option. The indirect determinations of Higgs masses from experimental data seemed to converge to two different values. The first one seemed to correspond to $m(h) = 129$ GeV and $k(h) = 94$ and second one to $m(h) = 91$ GeV with $k(h) = 95$ [K8]. The fact that

already the TGD counterpart for the Gell-Mann-Okubo mass formula in TGD framework requires quarks to exist at several p-adic mass scales [K11], suggests that Higgs can exist in both of these mass scales depending on the experimental situation. The mass of Higgsino would correspond to some half octave of $m(h)$. Note that the model allows to conclude that Higgs indeed exists also in TGD Universe although it does not seem to play the same role in particle massivation as in the standard model. The bounds allow only $k(\tilde{h}) = k(h) + 3 = 97$ and $m(\tilde{h}) = 45.6$ GeV for $m(h) = 129$ GeV. The same same mass is obtained for $m(h) = 91$ GeV. Therefore the kinematic limits plus super-symmetry breaking at the level of p-adic mass scale fix completely the masses of the super-particles involved in absence of mixing effects for sneutralinos.

To sum up, the masses of sparticles involved for the option allowing Higgs are predicted to be

$$m(\tilde{e}) = 131 \ \ GeV \ \ , \quad m(\tilde{Z}^0) = 91.2 \ \ GeV \ \ , \quad m(\tilde{h}) = 45.6 \ \ GeV \ \ . \tag{4.20}$$

If Higgs and Higgsino are both eaten in the massivation, the third condition drops off. The argument to be represented below suggests that also sleptons could correspond to Mersennes and Gaussian Mersennes: this option predictions $k(\tilde{e}) = 89$ so that the mass would be 250 GeV: this excludes the proposed interpretation of the strange event.

4.3 Do X And Y Mesons Provide Evidence For Color Excited Quarks Or Squarks?

Now and then come the days when head is completely empty of ideas. One just walks around and gets more and more frustrated. One can of course make authoritative appearances in blog groups and express strong opinions but sooner or later one is forced to look for web if one could find some problem. At this time I had good luck. By some kind of divine guidance I found myself immediately in Quantum Diaries and found a blog posting with title *Who ordered that?! An X-traordinary particle?* (see `http://tinyurl.com/3k9pts5`) [L1].

Not too many unified theorists take meson spectroscopy seriously. Although they are now accepting low energy phenomenology (*the* physics for the rest of us) as something to be taken seriously, meson physics is for them a totally uninteresting branch of botany. They could not care less. As a crackpot I am however not well-informed about what good theoretician should do and shouldn't do and got interested. Could this give me a problem that my poor crackpot brain is crying for?

The posting told me that in the spectroscopy of $c\overline{c}$ type mesons is understood except for some troublesome mesons christened imaginatively with letters X and Y plus brackets containing their mass in MeVs. X(3872) is the firstly discovered troublemaker and what is known about it can be found in the blog posting and also in Particle Data Tables (see `http://tinyurl.com/y7x23br5`) [C4]. The problem is that these mesons should not be there. Their decay widths seem to be narrow taking into account their mass and their decay characteristics are strange: in particular the kinematically allow decays to $D\overline{D}$ dominating the decays of $\Psi(3770)$ with branching ratio 93 per cent has not been observed whereas the decay to $D\overline{D}\pi^0$ occurs with a branching fraction $> 3.2 \times 10^{-3}$. Why the pion is needed? $X(3872)$ should decay to photon and charmonium state in a predictable way but it does not.

4.3.1 Could these be the good questions?

TGD predicts a lot of exotic physics and I of course started to exclude various alternatives. First one must however try to invent a good question. Maybe the following questions might satisfy the criterion of goodness.

1. Why these exotic states appear only for mesons made of heavy quark and antiquark? Why not for light mesons? Why not for mesons containing one heavy quark and light quark? Could it be that also $b\overline{b}$ mesons could have exotic partners not yet detected? Could it be that also exotic $b\overline{c}$ type mesons could be there? Why the presence of light quark would eliminate the exotic partner from the spectrum?

2. Do the decays obey some selection rules? There is indeed this kind of rule: the numbers of c and $\overline{c}$ quarks in the final state are equal to one.
    (a) If c and $\overline{c}$ exist in the initial state and the decay involves only strong interactions, the rule holds true.
    (b) If c and $\overline{c}$ are not present in the initial state the only option that one can imagine is the exhange of two W bosons transforming d type quarks to c type quarks must be present. If this were the case the initial state should correspond to $d\overline{d}$ like state rather than $c\overline{c}$ and this looks very strange from the standard physics point of view. Also the rate for this kind of decays would be very small and it seems that this option cannot make sense.

4.3.2 Both leptons and quarks have color excitations in TGD Universe

TGD predicts that both leptons and quarks have color excitations [K13]. For leptons they correspond to color octets and there is a lot of experimental evidence for them. Why we do not have any evidence for color excited quarks? Or do we actually have?! Could these strange X: s and Y: s provide this evidence?

Ordinary quarks correspond to triality one color triplet partial waves in CP_2. The higher color partial waves would also correspond to triality one states but in higher color partial waves in CP_2. The representations of the color group are labelled by two integers (p, q) and the dimension of the representation is given by

$$d = \frac{(p+1)(q+1)(p+q+2)}{2} \quad .$$

A given $t = \pm 1$ representation is accompanied by its conjugate with the same dimension and opposite triality $t = \mp 1$. $t = 1$ representations satisfy $p - q = 1$ modulo 3 and come as (1, 0), (0, 2), (3, 0), (2, 1), with dimensions 3, 6, 10, 15, ... The simplest candidate for the color excitations would correspond to the representation $\overline{6}$. It does not correspond directly the a solution of the Dirac equation in CP_2 since physical states involve also color Kac-Moody generators [K8].

Some remarks are in order:

1. The tensor product of gluon octet with $t = 1$ with color triplet representation contains $8 \times 3 = 24$ states and decomposes into $t = 1$ representations as $3 \oplus \overline{6} \oplus 15$. The coupling of gluons by Lie algebra action can couple given representation only with itself. The coupling between triplet and $\overline{6}$ and 15 is therefore not by Lie algebra action. The coupling constant between quarks and color excited quarks is *assumed* to be proportional to color coupling.
2. The existence of this kind of coupling would explain the selection rules elegantly. If this kind of coupling is not allowed then only the annihilation of exotic quark to gluon decaying to quark pair can transform exotic mesons to ordinary ones and I have not been able to explain selection rules using this option.

The basic constraint applying to all variants based on exotic states of quarks comes from the fact that the decay widths of intermediate gauge bosons do not allow new light particles. This objection is encountered already in the model of lepto-hadrons [K13]. The solution is that the light exotic states are possible only if they are dark in TGD sense having therefore non-standard value of Planck constant and behaving as dark matter. The value of Planck constant is only effective and has purely geometric interpretation in TGD framework. This implies that a phase transition transforming quarks and gluons to their dark counterparts is the key element of the model. After this a phase transition a gluon exchange would transform the quark pair to an exotic quark pair.

4.3.3 Also squarks could explain exotic charmonium states

Supersymmetry provides an alternative mechanism. Right-handed neutrino generates super-symmetries in TGD Universe and quarks are accompanied by squarks consisting in a well-defined sense of of quark and right-handed neutrino. Super-symmetry would allow completely standard couplings to gluons by adding to the spectrum squarks and gluinos.Exactly the same selection rules result if these new states are mesonlike states from from squark and anti-squark and the exchange of gluino after the $\hbar$ changing phase transition transforms exotic meson to ordinary one and vice versa.

In the sequel it will be shown that the existence of color excited quarks or of their superpartners could indeed allow to understand the origin of X and Y mesons and also the absence of analogous states accompanying mesons containing light quarks or antiquarks.

This picture would lead to a completely new view about detection of squarks and gluinos.

1. In the standard scenario the basic processes are production of squark and gluino pair. The creation of squark-antisquark pair is followed by the decay of squark (anti-squark) to quark (antiquark) and neutralino or chargino. If R-parity is conserved, the decay chain eventually gives rise to at least two hadron jets and lightest neutralinos identifiable as missing energy. Gluinos in turn decay to quark and anti-squark (squark and antiquark) and squark (anti-squark) in turn to quark (anti-quark) and neutralino or chargino. At least four hadron jets and missing energy is produced. In TGD framework neutralinos would decay eventually to zinos or photinos and right-handed neutrino transforming to ordinary neutrino (R-parity is not conserved). This process might be however slow.

2. In the recent case quite different scenario relying on color confinement and “shadronization” suggests itself. By definition smesons consist of squarks and antisquark. Sbaryons could consist of two squarks containing right-handed neutrino and its antineutrino ($\mathcal{N} = 2$ SUSY) and one quark and thus have same quantum numbers as baryon. Note that the squarks are dark in TGD sense.

   Also now dark squark or gluino pair would be produced at the first step and would require $\hbar$ changing phase transition of gluon. These would shadronize to form a dark shadron. One can indeed argue that the required emisson of winos and zinos and photinos is too slow a process as compared to shadronization. Shadrons (mostly smesons) would in turn decay to hadrons by the exchange of gluinos between squarks. No neutralinos (missing energy) would be produced. This would explain the failure to detect squarks and gluinos at LHC.

   This mechanism does not however apply to sleptons so that it seems that the p-adic mass scale of sleptons must be much higher for sleptons than that for squarks as I have indeed proposed.

4.3.4 Could exotic charmonium states consist of color excited c and $\overline{c}$ or of their spartners?

Could one provide answers to the questions presented in the beginning assuming that exotic charmonium states consists of dark color excited c and $\overline{c}$: or more generally, a mixture of ordinary charmonium and exotic charmonium state? The mixing is expected since $\hbar$ changing phase transition followed by a gluon exchange can transform these meson states to each other. Also annihilation to gluon and back to quark pair can induce this mixing. The mixing is however small for heavy quarks for which $\alpha_s \simeq .1$ holds true. Exactly the same arguments apply to the meson like bound states of squarks and in the following only the first option will be discussed.

1. In the case of charged leptons colored excitations have have same p-adic mass scale: for τ however several p-adic mass scales appear as the model if the two year old CDF anomaly is taken seriously [K13]. Assume that p-adic mass scales - but not necessarily masses- are the same also now. This assumption might be non-sensical since also light mesons would have exotic counterparts and somehow they should disappear from the spectrum. To simplify the estimates one could even assume even that the masses are same.

2. In the presence of small mixing the decay amplitude would come solely from the small contribution of the ordinary $c\overline{c}$ state present in the state dominated by color excited pair. The two manners to see the situation should give essentially the same answer.

3. The decays would take place via strong interactions.

The challenge is to understand why the dominating decays to $D\overline{D}$ with branching fraction of 93 per cent are not allowed whereas $D\overline{D}\pi^0$ takes place. Why the pion is needed? The second challenge is to understand why X does not decay to charmonium and photon.

1. For ordinary charmonium the decay to $D\overline{D}$ could take place by the emission of gluon from either c or $\overline{c}$ which then decays to light quark pair whose members combine with c and $\overline{c}$ to form D and $\overline{D}$. Now this mechanism does not work. At least *two* gluons must be emitted to transform colored excited $c\overline{c}$ to ordinary $c\overline{c}$. If these gluons decay to light quark pairs one indeed obtains an additional pion in hadronization. The emission of two gluons instead of only one is expected to reduce the rate roughly by $\alpha_s^2 \simeq 10^{-2}$ factor.
2. Also ordinary decays are predicted to occur but with a slower rate. The first step would be an exchange of gluon transforming color excited charmed quark pair to an ordinary charmed quark pair. After the transformation to off mass shell $c\overline{c}$ pair, the only difference to the decays of charmonium states would be due to the fact that charmonium would be replaced with $c\overline{c}$ pair. The exchange of the gluon preceding this step could reduce the decay rate with respect to charmonium decay rates by a factor of order $\alpha_s^2 \simeq 10^{-2}$. Therefore also the ordinary decay modes should be there but with a considerably reduced rate.
3. Why the direct decays to photon and charmonium state do not occur in the manner predicted by the model of charmonium? For ordinary charmonium the decay proceeds by an emission of photon by either quark or antiquark. Same mechanism applies for exotic charmonium states but leads to final state which consists of *exotic* charmonium and photon. In the case of $X(3872)$ there exists no lighter exotic charmonium state so that the decay is forbidden in this order of perturbation theory. Heavier exotic charmonium states can however decay to photon plus exotic charmonium state in this order of perturbation theory if discrete symmetries favor this.

Essentially identical arguments go through if c and $\overline{c}$ are replaced with their dark spartners and exchange of gluon by the emission of gluino. The transformation of gluon to its dark variants is an essential element in the process.

4.3.5 Why the color excitations/spartners of light quarks would be effectively absent?

Can one understand the effective absence of mesons consisting of color excited light quarks or squarks if the excitations have same mass scale and even mass as the light quarks? The following arguments are for color excited quarks but they apply also to squarks.

1. Suppose that the mixing induced by $\hbar$ changing phase transition followed by a gluon exchange and annihilation is described by mass squared matrix containing besides diagonal components $M_1^2 = M_2^2$ also non-diagonal component $M_{12}^2 = \overline{M_{21}^2}$. The eigenstates of the mass squared matrix correspond to the physical states which are mixtures of states consisting of ordinary quark pair and pair of color excited quarks. The non-diagonal elements of the mass squared matrix corresponds to gluon exchange and since color interactions get very strong at low energy scales, one expects that these elements get very large. In the degenerate case $M_1^2 = M_2^2$ the mass squared eigen values are given by

$$M_\pm^2 = M_0^2 \pm |M_{12}|^2 \ . \tag{4.21}$$

2. Suppose that $M_0^2 = 0$ holds true in accordance with approximate pseudo Goldstone nature of pion and more generally all light pseudo-scalar mesons. In fact assume that this is the case before color magnetic spin-spin splitting has taken place so that in this approximation pion and ρ would have same mass $m_\pi^2 = m_\rho^2 = M_0^2$. In TGD based model for color magnetic spin-spin splitting M_0^2 energy is replaced with mass squared [K11] and M_0^2 is obtained in terms of physical masses of π and ρ from the basic formulas

$$\begin{aligned} m_\pi^2 &= M_0^2 - \frac{1}{4}\Delta \ , \ m_\rho^2 = M_0^2 + \frac{3}{4}\Delta \ , \\ M_0^2 &= \frac{m_\rho^2 + 3m_\pi^2}{2} \ , \ \Delta = m_\rho^2 - m_\pi^2 \ . \end{aligned} \tag{4.22}$$

The exotic π and ρ would have masses

$$\begin{aligned} m^2_{\pi_{ex}} &= -M_0^2 - \frac{1}{4}\Delta = m_\pi^2 - 2M_0^2 \ , \\ m^2_{\rho_{ex}} &= -M_0^2 + \frac{3}{4}\Delta = m^2_{rho} - 2M_0^2\Delta \ . \end{aligned} \tag{4.23}$$

For $m_\pi = 140 MeV$ and $m_\rho = 770$ MeV the calculation gives $m_{\pi_{ex}} = i \times 685$ MeV so a tachyon would be in question. For ρ one would have $m_{\pi_{ex}} = 323$ MeV so that the mass would not be tachyonic.

One can try to improve the situation by allowing $M_1^2 \neq M_2^2$ giving additional flexibility and hopes about tachyonicity of the exotic ρ.

1. In this case one obtains the equations

$$\begin{aligned} m_\pi^2 &= M_+^2 - \frac{1}{4}\Delta \ , \ m_\rho^2 = M_+^2 + \frac{3}{4}\Delta \\ m^2_{\pi_{ex}} &= M_-^2 - \frac{1}{4}\Delta \ , \ m^2_{\rho_{ex}} = M_-^2 + \frac{3}{4}\Delta \ , \\ M_+^2 &= \frac{M_1^2+M_2^2}{2} + \sqrt{(\frac{M_1^2+M_2^2)}{2})^2 + M_{12}^4} = \frac{m_\rho^2 + 3m_\pi^2}{2} \ , \\ M_-^2 &= \frac{M_1^2+M_2^2}{2} - \sqrt{\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4} = M_+^2 - 2\sqrt{(\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4} \ . \end{aligned} \tag{4.24}$$

2. The condition that ρ_{ex} is tachyonic gives

$$m^2_{\rho_{ex}} = M_-^2 + \frac{3}{4}\Delta < 0 \ , \tag{4.25}$$

giving

$$\begin{aligned} m_\rho^2 &< 2\sqrt{(\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4} \ , \\ M_+^2 &= \frac{M_1^2+M_2^2}{2} + \sqrt{(\frac{M_1^2+M_2^2}{2})^2 + M_{12}^4} = \frac{m_\rho^2 + 3m_\pi^2}{2} \ , \end{aligned} \tag{4.26}$$

3. In the parameterization $(m_1^2, m_2^2, M_{12}^2) = (x,y,z)m_\rho^2$ one obtains the conditions

$$\begin{aligned} D \equiv \sqrt{(x+y)^2 + z^2} &> 1/2 \ , \\ \frac{x+y}{2} + D = \frac{1}{2} + \frac{3}{2}\frac{m_\pi^2}{m_\rho^2} & \ . \end{aligned} \tag{4.27}$$

4. These equations imply the conditions

$$\begin{aligned} x+y &< 3\frac{m_\pi^2}{m_\rho^2} \simeq .099 \ , \\ .490 &< z < .599 \ . \end{aligned} \tag{4.28}$$

The first condition implies $\sqrt{m_1^2+m^2} < 242.7$ MeV. Second condition gives $339 < M_{12}/MeV < 595.9$ so that rather stringent bounds on the parameters are obtained. The simplest solution to the conditions corresponds to $x = y = 0$ and $z = .599$. This solution would mean vanishing masses in the absence of mixing and spin-spin splitting and could be defended by the Golstone boson property of pions mass degenerate with ρ mesons.

This little calculation encourages to consider the possibility that all exotic counterparts of light mesons are tachyonic and that this due the very large mixing induced by gluon exchange (gluino exchange squark option) at low energies. It would be nice if also mesons containing only single heavy quark were tachyonic and this could be the case if the p-adic length scale defining the strength of color interactions corresponds to that of the light quark so that the mass matrix has large enough non-diagonal component. Here one must be however very cautious since experimental situation is far from clear.

The model suggests that ordinary charmonium states and their exotic partners are in 1-1 correspondence. If so then many new exotic states are waiting to be discovered.

4.3.6 The option based on heavy color excitations/spartners of light quarks

An alternative option is that color excitations/spartners of light quarks have large mass: this mass should not be however larger than the mass of c quarks if we want to explain X: s and Y: s as pairs of color excitations of light quarks. Suppose that the p-adic mass scale is same as that for c quarks or near it (not that the scales come as powers of $\sqrt{2}$). This raises the question whether exotic $c\overline{c}$ mesons really consist of exotic c and $\overline{c}$: why not color excitations of u, d, s and their antiquarks? As a matter fact, we cannot be sure about the quark content of X and Y mesons. Could these states be $d\overline{d}$ and $u\overline{u}$ states for their color excitations? It however seems that the presence of two W exchanges makes the decay rate quite too low so that this option seems to be out of question.

One can however consider the option in which the squarks associated with light quarks are heavy. This option is indeed realized in standard SUSY were the mass scales of particles families are inverted so that stop and sbottom are the lightest squarks and super-partners of u and d the heaviest ones. This would would predict that the smesons associated with $\overline{t}$ and $b\overline{b}$ are lighter than X and Y (s)mesons. This option does not look at all natural in TGD but of course deserves experimential checking.

4.3.7 How to test the dark squark option?

The identification of X and Y as dark smesons looks like a viable option and explains the failure to find SUSY at LHC if shadronization is a fast process as compared to the selectro-weak decays. The option certainly deserves an experimental testing. One could learn a lot about SUSY in TGD sense (or maybe in some other sense!) by just carefully scanning the existing data at lower energies. For instance, one could try to answer the following questions by analyzing the already existing experimental data.

1. Are X and Y type mesons indeed in 1-1 correspondence with charmonium states? One could develop numerical models allowing to predict the precise masses of scharmonium states and their decay rates to various final states and test the predictions experimentally.

2. Do $b\overline{b}$ mesons have smesonic counterparts with the same mass scale? What about B_c type smesons containing two heavy squarks?

3. Do the mesons containing one heavy quark and one light quark have smesonic counterparts? My light-hearted guess that this is not the case is based on the assumption that the general mass scale of the mass squared matrix is defined by the p-adic mass scale of the heavy quark and the non-diagonal elements are proportional to the color coupling strength at p-adic length scale associated with the light quark and therefore very large: as a consequence the second mass eigenstate would be tachyonic.

4. What implications the strong mixing of light mesons and smesons would have for CP breaking? CP breaking amplitudes would be superpositions of diagrams representing CP breaking for mesons *resp.* smesons. Could the presence of smesonic contributions perhaps shed light on the poorly understood aspects of CP breaking?

4.3.8 Objection against covariantly constant neutrinos as SUSY generators

TGD SUSY in its simplest form assumes that covariantly constant right-handed neutrino generates SUSY. The second purely TGD based element is that squarks would correspond to the same p-adic mass scale as partners.

This looks nice but there are objections.

1. The first objection relates to the tachyonicity needed to get rid of double degeneracy of light mesons consisting of u, d, and s quarks. Mesons and smesons consisting of squark pair mix and for large α_s the mixing is large and can indeed make second eigenvalue of the mass squared matrix negative. If so, these states disappears from spectrum. At least to me this looks however somewhat unaesthetic.

   Luckily, the transformation of second pion-like state to tachyon and disappearance from spectrum is not the only possibility. After a painful search I found experimental work (see `http://tinyurl.com/ybq323yy`) [C31] claiming the existence of states analogous to ordinary pion with masses 60, 80, 100, 140, ... MeV. Also nucleons have this kind of satellite states. Could it be that one of these states is spion predicted by TGD SUSY for ordinary hadrons? But what about other states? They are not spartners: what are they?

2. The second objection relates to the missing energy. SUSY signatures involving missing energy have not been observed at LHC. This excludes standard SUSY candidates and could do the same in the case of TGD. In TGD framework the missing energy would be eventually right handed neutrinos resulting from the decays of sfermions to fermion and sneutrino in turn decaying to neutrino and right handed neutrino. The naive argument is that shadronization would be much faster process than the decay of squarks to quarks and spartners of electro-weak gauge bosons and missing energy so that these events would not be observed. Shadrons would in turn decay to hadrons by gluino exchanges. The problem with this argument is that the weak decays of squarks producing right handed neutrinos as missing energy are still there!

   This objection forces to consider the possibility that covariantly constant right handed neutrino which generates SUSY is replaced with a color octet. Color excitations of leptons of lepto-hadron hypothesis [K13] would be sleptons which are color octets so that SUSY for leptons would have been seen already at seventies in the case of electron. The whole picture would be nicely unified. Sleptons and squark states would contain color octet right handed neutrino the same wormhole throats as their em charge resides. In the case of squarks the tensor product $3 \otimes 8 = 3 + \overline{6} + 15$ would give several colored exotics. Triplet squark would be like ordinary quark with respect to color.

   Covariantly constant right-handed neutrino as such would represent pure gauge symmetry, a super-generator annihilating the physical states. Something very similar can occur in the reduction of ordinary SUSY algebra to sub-algebra familiar in string model context. By color confinement missing energy realized as a color octet right handed neutrino could not be produced and one could overcome the basic objections against SUSY by LHC.

What about the claimed anomalous trilepton events at LHC interpreted in terms of SUSY, which however breaks either the conservation of lepton or baryon number. I have proposed TGD based interpretation [K9] is in terms of the decays of W to $\tilde{W}$ and $\tilde{Z}$, which in turn decay and produce the three lepton signature. Suppose that $\tilde{W}$ and $\tilde{Z}$ are color octets and that sleptons replace the color octet excitations of leptons responsible for lepto-hadron physics [K13]. One possible decay chain would involve the decays $\tilde{W}^+ \to \tilde{L}^+ + \overline{\nu}_L$ and $\tilde{Z} \to L^+ + \tilde{L}^-$. Color octet sleptons pair combine to form lepto-pion which decays to lepton pair. This decay cascade would produce missing energy as neutrino and this seems to be the case for other options too.e could overcome the basic objections against SUSY by LHC.

This view about TGD SUSY clearly represents a hybrid of the two alternative views about X and Y bosons as composites of either color excitations of quarks or of squarks and is just one possibility. The situation is not completely settled and one must keep mind open.

4.3.9 Does one really obtain pseudo-scalar smesons?

The critical question is whether one obtains pseudo-scalar states as meson-like bound states of squarks. This depends on what one means with squarks. Also the notion of pseudo-scalar is not the same for $M^4 \times CP_2$ and M^4. In TGD framework M^4 (pseudo–)scalars constructed from fermions and anti-fermions are replaced by CP_2 (pseudo–)vectors since the chiral symmetry for $M^4 \times CP_2$ implying separate conservation of lepton and baryon numbers implies that genuine fermionic H-scalars and pseudo-scalars would have quantum numbers of leptoquark.

1. The first question is what one means with ordinary pseudo-scalar mesons in TGD framework. These mesons should be characterized by a bi-local quantity which behaves like a preferred CP_2 pseudo-vector and therefore like M^4 pseudo-scalar. One should identify a unique direction of CP_2 polarization mathematically analogous to Higgs vacuum expectation value and construct a bilinear in quark wave functions associated with the partonic 2-surfaces assigned to the quarks. The problem is however that CP_2 is not a flat space. Also non-locality is a problem. Somehow one should be able to construct general coordinate invariant quantities with well-defined transformation properties under discrete symmetries.

2. The effective 2-dimensionality implying the notions of partonic 2-surfaces and string world sheets suggests a solution to the non-locality problem. Also the experience with QCD suggests that bilinear expression contains a non-integrable phase factor U connecting quark and anti-quark ad defined by the classical color gauge potentials which are just projections of SU(4) Killing vector fields to the space-time surface. The curve would be analogous to a string connecting the partonic 2-surfaces and fixed uniquely by the strong form of holography in turn reducing to the strong form of general coordinate invariance. TGD indeed predicts the existence of string world sheets and thus strings at the 3-D ends of space-time sheets defined by causal diamond.

3. What about the preferred CP_2 vector?
   (a) The first candidate is the quantity $X = I_3 j_3^{Ak}\Gamma_k + Y j_Y^{Ak}\Gamma_k$ where I_3 and Y denote color isospin and hyper-charge of the quark and j_i^{Ak} corresponding Killing vectors. The preferred vector would be due to the choice of quantization axes. This option is natural for in the case of quark bilinears but fails for a bilinear constructed from covariantly constant right handed neutrino.
   (b) Second candidate would the CP_2 part for the trace of the second fundamental form contracted with CP_2 gamma matrices -denote it by $X = H^k\Gamma_k$ -at the either end of the string connecting fermion and anti-fermion at partonic 2-surfaces. This option would be natural for the right-handed neutrino. Bi-local super-generators would vanish when the partonic 2-surface is minimal surface. This would be analogous to the representations of SUSY for which $2^{-k}\mathcal{N}$ generators annihilate the physical states and act as pure gauge symmetries.

4. This would suggest that the basic invariants in the construction is the quantity $\overline{\Psi}_1 UXO\Psi_2$. Sub-script $i = 1, 2$ refers to the partonic 2-surface, X can occur at both ends and γ_5 guarantees pseudo-scalar property. O is $1 \pm \gamma_5$ for right- *resp.* left-handed quarks. The recipe would apply also to the bilinears formed right-handed neutrinos: now only the projector $(1 + \gamma_5)$ to right-handed neutrino appears so that only single state is obtained.

Most of the options that one can imagine give something else that pseudo-scalar smeson.

1. Assuming that $\mathcal{N} = 2$ symmetry is not too badly broken, one can add to the partonic 2-surface carrying quark either right-handed neutrino or anti-neutrino or both so that one obtains a 4-plet containing two quark states, spin zero squark and and spin 1 squark. From these states one can construct meson like states.
   (a) The first implication is degeneracy of quark like states because of the presence of neutrino pair. TGD however predicts large breaking of SUSY. According to the arguments of [K6] the state containing right handed neutrino pair has propagator behaving like $1/p^3$ and

does not correspond to ordinary particle. It is not at all clear whether this kind squarks can give rise to meson like states. Also the R-parity of these squarks would be +1 and the model requires negative R-parity.

   (b) For spin one squarks one obtains pseudo-vector state with spin 1: the smeson state would transform like the cross product of the vectors characterizing spin 1 squarks. These states could be also present in the spectrum although they do not correspond to pseudo-scalars.

   This suggests that $\mathcal{N}=2$ SUSY is badly broken and one must restrict the consideration to $\mathcal{N}=1$ option.

2. For $\mathcal{N}=1$ option both squarks are scalars (quark plus anti-neutrino option).

   (a) Forgetting the non-locality and regarding partonic 2-surfaces as basic objects as a whole, one has bound state of scalar squarks and the possible meson-like state is most naturally a scalar rather than pseudo-scalar.

   (b) Non-locality brought in by strings however changes the situation. One could construct a pseudo-scalar by starting from pseudo-scalar meson constructed by using the non-local recipe. To add neutrino and anti-neutrino at the partonic 2-surfaces one could use the bilinears $\overline{\nu}_{R,1}H^k\Gamma_k\nu_{R,2}$ and $\overline{\nu}_{R,2}H^k\Gamma_k\nu_{R,1}$ to obtain the needed right-handed CP_2 current, which is neither scalar nor pseudo-scalar. The stringy picture (braids as representation of many fermion states) forced by the strong from of general coordinate invariance (or strong form of holography or effective two-dimensonality) would be absolutely essential for this picture to work.

To sum up, it is not completely clear whether the squark option really gives pseudo-scalar smesons. One cannot exclude additional pseudo-vector states and scalars unless $\mathcal{N}=2$ SUSY is badly broken. The option based on color excitations in turn predicts only pseudo-scalar smesons but also for this option a non-local state construction is needed.

4.3.10 What are the implications for M_{89} hadron physics?

Lubos Motl (see `http://tinyurl.com/yc8xgorx`) told about the latest information concerning Higgs search. It is not clear how much these data reflect actual situation [C1]. Certainly the mass values must correspond to observed bumps. The statistical significances are *expected* statistical significances, not based on real data. Hence a special caution is required. At 4.5/fb of data one has following bumps together with their expected statistical significance:

- 119 GeV: 3 sigma
- 144 Gev: 6 sigma(!)
- 240 GeV: 4.5 sigma
- 500 GeV: 4 sigma

It is interesting to try to interpret these numbers in TGD framework. The first thing to observe is that weak boson decay widths do not pose any constraints on the model and one could assume that M_{89} squarks are not dark.

1. The interpretation of 144 GeV bump

Consider first the 144 GeV state 6 sigma expected significance, which is usually regarded as a criterion for discovery. Of course this is only expected statistical significance, which cannot be taken seriously.

1. 144 GeV is exactly the predicted mass of the pion of M_{89} hadron physics which was first observed by CDF and then decided to be a statistical fluctuation. I found myself rather alone while defending the interpretation as M_{89} pion in viXra log and trying to warn that one should not throw baby with the bath water.

2. From an earlier posting of Lubos Motl one learns that 244 GeV state must be CP odd -just like neutral pion- and should correspond to A_0 Higgs of SUSY. Probably this conclusion as well as the claimed CP even property of 119 GeV state follow both from the assumption that these states correspond to SUSY Higgses so that one must not take them seriously.

3. The next step before TGD will be accepted is to discover that this state cannot be Higgs of any kind.

2. Possible identification of the remaining bumps

Could the other bumps correspond to the pseudo-scalar mesons of M_{89} hadron physics? For only a week ago I would have answered "Definitely not" ! Could the claimed bumps explained by assuming that also M_{89} quarks have either color excitations or super partners with the same mass scale and the same mechanism is at work for M_{89} mesons as for ordinary mesons. The same question can be made for the option based on color excitations of quarks in $\overline{6}$ or 15.

Consider now the possible identification of the remaining Higgs candidates concentrating for definiteness to the squark option.

1. In the earlier framework there was no identification for meson like states below 144 GeV. The discovery of this week was however that squarks could have the same p-adic mass scale as quarks and that one has besides mesons also smesons consisting of squark pair as a consequence. Every meson would be accompanied by a smeson. Gluino exchange however mixes mesons and smesons so that mass eigenstates are mixtures of these states. At low energies however the very large non-diagonal element of mass squared matrix can make second mass eigenstate tachyonic. This must happen for mesons consisting of light quarks. This of course for the M_{107} hadron physics familiar to us.

2. Does same happen in M_{89} hadron physics? Or is the non-diagonal element of mass squared matric so small that both states remain in the spectrum? Could 119 GeV state and 144 GeV state correspond to the mass eigenstates of supersymmetric M_{89} hadron physics? If this is the case one could understand also this state.

3. What about 240 GeV state? The proposal has been that selectron corresponds to M_{89}. This would give it the mass 262.14 GeV by direct scaling; $m(selectron) = 2^{(127-89)/2}m(electron)$. This is somewhat larger than 240 GeV.

   Could this state correspond to spartner of the ρ_{89} consisting of M_{89} squarks. There is already earlier evidence for bumps at 325 GeV interpreted in terms of ρ_{89} and ω_{89}. The mass squared difference should be same for pionic mass eigenstates and ρ_{89} like mass eigenstates. This would predict that the mass of the second ρ like eigenstate is 259 GeV, which is not too far from 240 GeV.

   Tommaso Dorigo's newest posting "The Plot Of The Week - The 327 GeV ZZ Anomaly" (see `http://tinyurl.com/3t3ym3q`) [C8] tells about further support about ZZ anomaly at 327 GeV, which in TGD framework could be interpreted in terms of decays of the neutral member of ρ_{89} isospin triplet or ω_{89}, which is isospin singlet. A small splitting in mass found earlier is expected unless this decay corresponds to ω_{89}. Also WZ anomaly is predicted.

4. What about the interpretation of 500 GeV state? The η' meson of M_{107} hadron physics has mass 957.66 MeV. The scaling by 512 gives 490.3 GeV- not too far from 500 GeV!

The alternative option replaces squarks with their color excitations. The arguments are identical in this case. Many other pseudo-scalar mesons states are predicted if either of these options is correct. In the case of squark option one could say that also SUSY in TGD sense has been discovered and has been discovered in ordinary hadron physics for 8 years ago! SUSY would not reveal itself via the usual signatures since shadronization would be faster process than the decay of squarks via emission of selectro-weak bosons.

All these looks too good to be true. I do not know how the *expected* significances are estimated and how precisely the mass values correspond to experimental data. In any case, if these states turn out to be pseudo-scalars, one can say that this is a triump for TGD. Combining this with the neutrino super-luminality which can be explained easily in terms of sub-manifold gravitation, the prospects for TGD to become the next TOE are brighter than ever.

4.4 Strange Trilepton Events At CMS

Lubos Motl reports that CMS sees SUSY-like trilepton excesses (see `http://tinyurl.com/y8mr4vm5`). Also Matt Strassler tells about indications that something curious has been detected at the Large Hadron Collider (see `http://tinyurl.com/y9hhd69g`) [C29]. Probably a statistical fluctuation is in questions as so many times earlier. The dream to discover SUSY ieasily leads to misinterpretations. Trilepton events however provide an excellent opportunity to learn about SUSY in TGD framework.

4.4.1 The recent view about TGD SUSY briefly

Before continuing it is good to say something about what SUSY in TGD Universe might mean and also about expected masses of squarks and sleptons as well as intermediate gauge bosons in TGD Universe. The picture is of course preliminary and developing all the time in strong interaction with experimental input from LHC so that there is no guarantee that I agree with this view for the rest of my life.

1. Super-partner of the particle is obtained by adding a the partonic 2-surface a parallelly moving right-handed neutrino or antineutrino so that one has $\mathcal{N} = 1$ SUSY. It must be emphasized that one has higher SUSYs but they are badly broken. Allowing both right-handed neutrino and antineutrino one obtains $\mathcal{N} = 2$ SUSY and interpreting all fermionic oscillator operators as generators of SUSY one obtains badly broken SUSY with rather large $\mathcal{N}$, which is however finite by finite measurement resolution inducing a cutoff on the number of fermionic oscillator operators.

2. R-parity is broken in TGD SUSY since sparticle can decay to particle and neutrino. Therefore all neutral sparticles manifesting themselves as missing energy in TGD framework eventually decay and produce neutrinos as the eventual missing energy. The decay rates to particles and neutrinos can however be so slow that photino and sneutrinos leave the reactor volume before decaying.

3. The basic assumption is that particle and sparticle obey the same mass formula apart from p-adic mass scale that can be different. For instance, the masses of sleptons are half-octaves of lepton masses. This breaking of SUSY is extremely elegant and is absolutely essential part of ordinary particle massivation too explaining the enormous mass scale differences between neutrinos and top quark in a natural manner.

4. I have proposed that the super-partners of M_{107} quarks (ordinary quarks) and gluon could have the same mass scale but be dark in TGD sense, in other words have Planck constant which is integer multiple of the ordinary Planck constant. This is required by the fact that intermediate gauge boson decay widths do not allow light exotic particles. This hypothesis could allow to understand the exotic X and Y mesons and also the absence of smesons containing light squarks could be understood. Since shadronization is expected to proceed much faster than selectro-weak decays of squarks, the squarks of M_{89} hadron physics need not be dark and M_{89} shadrons might be there. The fruitless search for squarks would be based on wrong signatures if this the case and already now we would have direct evidence for the squarks of M_{89} hadron physics.

5. Only the decays of electro-weak gauginos and sleptons would produce the standard signatures.

    (a) Charged sleptons must have large p-adic scales in TGD Universe. Ordinary leptons correspond to Mersenne prime (see `http://tinyurl.com/p8e7n5c`) M_{127}, Gaussian Mersenne (see `http://tinyurl.com/ydcqo3av`) $M_{G,113}$, and Mersenne prime M_{107}. If also sleptons obey this rule, they would correspond to the Mersenne primes M_{89} and Gaussian Mersennes $M_{G,n}$, $n = 79, 73$. Assuming that particle and sparticle obey the same mass formula apart from different p-adic mass scale, the masses of selectron, smuon, and stau would be about 267 GeV, 13.9 TeV, and 164.6 TeV. Only selectron is expected to be visible at LHC.

   (b) About the mass scales of sneutrinos it is difficult to say anything definite. A natural guess is that sneutrinos are relatively light so that they would be produced in the decays of sleptons and electro-weak gauginos. Same applies to photino. These particles are good candidates to missing energy unless their decay to particle plus neutrino is fast enough.

   (c) There seems to be no strong constraints to the mass scales of $\tilde{W}$ and $\tilde{Z}$. The mass scale could be even M_{89} characterizing W and Z. p-Adic length scale hypothesis predicts that the p-adic mass scale is half octave of intermediate boson mass scale and if the Weinberg angle is same the masses are half octaves of W/Z masses.

6. The most general option inspired by twistorial considerations (absence of IR divergences) and zero energy ontology is that both Higgs like states and Higgsinos and their higher spin generalizations are eaten so that the outcome is spectrum of massive states. This might have something do with the phenomenon in which some supersymmetry generators annihilate physical states. In any case the fermions at wormhole throats are always massless- even the virtual particles identified in terms of wormhole contacts consist of massless wormhole throats which can have also negative energy.

It is important to notice that trilepton events as signals for SUSY have nothing to do with squarks and gluinos for which I have proposed a non-standard interpretation in the article [L1].

4.4.2 How to interpret the trilepton events in TGD framework?

Trilepton events (see `http://tinyurl.com/y8zhxzpy`) [C27] represent the simplest SUSY signal and would be created in the decays $W \to \tilde{W} + \tilde{Z}$. The decays $Z \to \tilde{W}^+ + \tilde{W}^-$ would give rise to dilepton events. Electro-weak gauginos would in turn decay and yield multi-lepton events. Neither W/Z boson nor the gauginos need to be on mass shell.

In the following I will discuss these decays taking seriously the above listed conjectures about SUSY a la TGD.

1. Obviously the situation reduces to the study of the decays of $\tilde{W}$ and $\tilde{Z}$.

   (a) For $\tilde{W}$ the decay channels are $\tilde{W} \to W + \tilde{\gamma}$ and $\tilde{W} \to L + \tilde{\overline{\nu}}_L$. W would decay to charged lepton-neutrino pair. One charged lepton would result in both cases.

   (b) For $\tilde{Z}$ the decay channels are $\tilde{Z} \to \nu + \tilde{\overline{\nu}}_L$, $\tilde{Z} \to \tilde{W}^+ + W^-$, and $\tilde{Z} \to \tilde{L} + \overline{L}$ and charge conjugates of these. For the second decay mode the decays of W^+ and $\tilde{W}^-$ produce lepton antilepton pair. For the third decay mode selectron is the most plausible slepton candidate and is expected to have rather large masses in TGD Universe (about 267 GeV and thus off mass-shell). $\tilde{L} \to L + \tilde{\gamma}$ is the most natural decay for slepton.

2. The decay cascade beginning with $Z \to \tilde{W}^+ + \tilde{W}^-$ would produce 2 charged leptons (more generally even number of charged leptons) plus missing energy. Charged leptons would have opposite charges. No sleptons would be needed as intermediate states and all lepton families would be democratically represented as final states.

3. The decay cascade beginning with $W \to \tilde{W} + \tilde{Z}$ would produce 2 or 3 charged leptons plus missing energy.

   (a) For $\tilde{Z} \to \tilde{W}^+ + W^-$ option 3 charged leptons would result and there would be a complete family democracy. For this option the rate is expected to be largest.

   (b) For the option having slepton as intermediate state, the large masses for smuon and stau would favor selectron for 3 lepton events. 3-lepton events would have charge signatures –+ or ++- following from charge conservation alone. The suggested large mass for selectron would however reduce also the rate of 3 lepton events considerably. Note that the reported events (see `http://tinyurl.com/y9hhd69g`) have total transversal energy larger than 200 GeV.

4. In MSSM also $sZ \rightarrow \tilde{\chi}_1^0 + Z$ followed by $Z \rightarrow L^+ + L^-$ is possible so that trilepton state results. Here $\tilde{\chi}_1^0$ denotes the lightest neutral sboson and is a mixture of $\tilde{h}, \tilde{Z}$, and $\tilde{\gamma}$. If $\tilde{h}$ is not in the spectrum, then $\tilde{\gamma}$ is an excellent candidate for the lightest neutral gaugino. If the Weinberg angle is SUSY invariant the decay producing three charged leptons in this manner is not possible.
5. Photinos would decay to photons and neutrinos producing photons and missing energy. It is not clear whether this decay is fast enough to take place in the reactor volume.

To sum up, the trilepton events are possible and would be produced in the decays $\tilde{Z} \rightarrow \tilde{W} + W$ and $\tilde{W} \rightarrow e + \tilde{\gamma}$. The trilepton events involving selectron as intermediate state do not look highly plausible in TGD framework if one takes seriously the guess for the slepton mass scales.

4.4.3 More about strange trilepton events

I already told about indications for strange charged tri-lepton events at CMS. The inspiration came from a posting "CMS sees SUSY-like tri-lepton excesses" (see `http://tinyurl.com/y8mr4vm5`) of Lubos Motl.

Only a few days later both Tommaso Dorigo (see `http://tinyurl.com/yc8jqu4k`) and Lubos Motl (see `http://tinyurl.com/ybfup7cj`) discussed a quite recent paper telling about charged tri-lepton events observed at CMS (see `http://tinyurl.com/ycfa9ctx`).

1. From Tommaso Dorigo's posting one learns that three charged leptons with total mass near to Z mass have been observed. Charge conservation of course requires fourth charged lepton if the particles originate in the decay of Z as assumed and Tommaso Dorigo argues that this lepton has so low energy that it is not detected. This kind of lepton could results in an energy asymmetric decay of photon. The assumption that Z is the decaying particle might be however un-necessarily strong: it could be quite well W with almost the same mass. In this case charge conservation allows genuine charged tri-lepton event. The above discussion suggests the decay $W \rightarrow \tilde{W} + \tilde{Z}$ to be the source of charged tri-lepton events.
2. The authors of the paper (see `http://tinyurl.com/ycfa9ctx`) propose that the reaction could be initiated by a decay of squark or gluino and necessarily involving R-parity breaking. There are two possibile options for R-parity breaking allowed by proton stability depending on whether it conserves lepton or baryon number. For lepton number violating option intermediate particle is neutralino (lightest sparticle which is stable in R-parity breaking scenarios) and for baryon number violating scenatior bino or higgsino. The R-parity violating decay of lightest spartner (neutral) would yield slepton-lepton pair and the R-parity violating decay of slepton a lepton pair plus neutrino. This would produce instead single observed lepton charged tri-lepton state. The authors do not give enough details to make possible for a non-professional to deduce what the detailed model for the process really is.

It is interesting to consider the situation in TGD framework in light of the crucial additional data (the three charged leptons have mass rather near to that of Z and therefore to that of$W$).

1. The decay of $W \rightarrow \tilde{W} + \tilde{Z}$ with the decays $\tilde{W}$ and $\tilde{Z}$ proceeding in either of the two manners discussed above would predict that the *total mass of all particles produced* is near to W mass (and therefore Z mass) and also why one obtains genuine charged tri-lepton states. The problem is that missing energy in the form of neutrinos and neutral sparticles is present and it is not at all clear why this energy should be small.
2. An option not discussed discussed above is the decay $W \rightarrow \tilde{\nu} + L$ followed by the decay $\tilde{\nu} \rightarrow L + \tilde{W}$ followed by $\tilde{W} \rightarrow L + \tilde{\nu}$ would not break R-parity and would produce $\tilde{\nu}$. Total energy would correspond to W mass but it is not clear why the missing energy assigned with $\tilde{\nu}$ should be small.
3. R-parity violation predicted by TGD however allows also to consider the direct decay $\tilde{\nu} \rightarrow L^+ + L^-$ so that there would be no missing energy. One could say that the decay is the reversal of a process in which $L^+ + L^-$ annihilates to a $\tilde{\nu}$ identifiable as a pair of neutrino and right-handed neutrino at microscopic level. All standard model quantum numbers would be conserved.

In TGD framework R-parity violation is a prediction of the theory and it would not violate either baryon or lepton number conservation. There is no need to assume undetected charged lepton since charge conservation allows charged tri-lepton final state as such without any missing energy. Obviously the TGD based model is by several orders of magnitude simpler than the model based on standard SUSY.

4.5 CMS Observes Large Diphoton Excess

LHC has started to produce data indicating that the new physics required by very general arguments indeed is there. Lubos Motl (`http://tinyurl.com/yd3h8dghl`) told today about a preprint by CMS collaboration [C15] showing a very large excess of di-photons in proto-proton collisions. This excess is so large that only a rough systematic error can threat its status.

4.5.1 What has been observed?

The following two data bits give strong hints about what might be involved.

1. From the figure (see `http://tinyurl.com/pfj74yu`) in the posting of Lubos Motl (see `http://tinyurl.com/y7n4vzco`) one learns that the distribution for the difference $\Delta\phi$ for the difference of the azimutal angles with respect to the beam direction covers rather evenly the span $\Delta\phi < 2.80$ and the production rate is considerably higher than predicted by QCD calculations except near π where the production rate is smaller than the prediction. From momentum conservation one would expect $\Delta\phi \sim \pi$ in a good approximation in the cm frame of photons. Unless the resonance does not move with a very high velocity, the photons $\Delta\phi \simeq \pi$ should hold true quite generally. This gives hints about the production mechanism.

2. Figure 3 of the CMS preprint (see `http://tinyurl.com/3u4vzlk`) [C15] gives the differential cross section with respect to diphoton invariant mass $m_{\gamma\gamma}$ as a function of $m_{\gamma\gamma}$. The distribution has a sharp knee between 45-55 GeV. One might be able to see double peak at invariant masses about 50 GeV and 75 GeV and even third peak around 175 GeV. The differential cross section is however anomalous already around 20 GeV which serves as transverse momentum cutoff for photons

   The naive question by a non-professional is whether there could be resonance decaying to two photons with mass in this range. $\Delta\phi \sim \pi$ would be however required if the resonance does not move very fast in the cm frame of colliding protons. The cut on transversal momenta is 20 GeV making 40 GeV transversal energy and I am not absolutely sure whether this could cause the shoulder. The experimenters however speak about shoulder and certainly they would not do this if it were due to the cufoff. Therefore I will assume that the shoulder is genuine.

3. If the shoulder located roughly between 45 GeV and 75 GeV is real, it would seem that the two-photon state must be accompanied by a state with opposite momentum and roughly the same energy and thus moving in opposite direction. This suggests two states with mass(es) in the range [90, 150] GeV.

4.5.2 What could it be?

The speculation of Lubos Motl is that the decay of Higgs like state with mass around 119 GeV might explain the finding but admits that standard model Higgs should not produce any visible effect. Even worse, the so called little Higgs alternative would predict a reduction of diphoton production rate. There are also exotic explanations involving large dimensions and exotic gravitons but to my opininion these alternatives belong to the realm of bad science fiction and can be safely forgotten.

In my naive mind frame the strong knee around 55 GeV is something which I find very difficult to not interpret as a bump suggesting the presence of a meson like state. On the other hand, the distribution for $\Delta\phi$; does not fit with this simplistic picture.

What about the TGD inspired interpretation? The first interpretation that comes into mind relies on the TGD based view about SUSY, which differs considerably from the standard view.

1. As explained in [K9], TGD could allow the realization of SUSY in which quarks and squarks have same p-adic mass scale- perhaps even masses- before the mixing of hadrons and shadrons allowed by R-parity conservation. The mechanism explaining the experimental absence of squarks would be shadronization proceeding faster than the decay of squarks to quark and electroweak gaugino.

    (a) In this framework the mysterious X and Y mesons accompanying charmonium states would be their super partners in a good approximation since the mixing would be small. The mixing of mesons and smesons would be however very large near confinement mass scale and make the other mixed state (identified as eigen state of mass squared matrix) tachyonic and eliminate it from the spectrum. The companion of pion would be tachyonic and excluded from spectrum: this would hold true for all smesons containing light quarks and perhaps also those containing only single light squark if the mass scale of the mass squared matrix is determined by the heavier quark and α_s by the lighter quark so that mixing is very large.

    (b) A crucial assumption is that the squarks are dark in the sense of having a non-standard value of Planck constant: otherwise the decay widths of electro-weak gauge bosons would be too large. The phase transition changing the value of $\hbar$ and having a purely geometric (topological) meaning in TGD framework would accompany also the mixing process being analogous to mass insertions in the lines of Feynman graph.

2. In TGD framework the proposed view about squarks as particles having common p-adic mass scale with quark is suggested to hold true in both the ordinary M_{107}- and M_{89} hadron physics. There is however no need to assume that M_{89} squarks are dark. The pion of M_{89} hadron physics could identified as the earlier 144 GeV Higgs candidate, forgotten but mentioned again by Lubos Motl (`http://tinyurl.com/yc8xgorx`), would have 119 GeV bump as a lighter companion. The two states would be mixtures of pion and spion. The mass values for the bumps assigned to ρ_{89} and ω_{89} and to their spartner candidates allow to estimate the mass of the partner of π_{89}. The mass would be near to 119 GeV for which there are slight indications [K9].

How the shoulder around 45-55 GeV could be created from the decays of the partner of π_{89}- a (probably strong) mixture of pion and spion (no breaking of R-symmetry). Could the two mixtures of M_{89} pion and its spartner with masses (say) 119 GeV and 144 GeV (one should not take these number too literally) be responsible for the effect as the indications about two peaked structure suggest? Could the spionic parts of the states produce the events diphoton events.

1. The simplest Feynman diagram for the decay of the pion-like state would describe the turn around of squark backwards in time via the emission of two photons. This would produce onlty $\Delta\phi \sim \pi$ events and photons with energies around 60 GeV and 72 GeV for the proposed masses 119 GeV and 144 GeV.

    Comment: 144 GeV is the estimate for the mass of $\pi_{89}^{\pm}$, one obtains 138 GeV for π_{89}^{0}: I have earlier neglected electromagnetic mass splitting of pions and approximated pion masses with charged pion mass 140 MeV. This scales the second mass to 69 GeV.

2. For a more complex Feynman diagram exchanged squark turning around in time would emit quark and antiquark transforming in this manner to gluino and back to squark. Another possibility is emission of two gluons. This would give photon pair and something which could be just two hadron jets if the emitted quarks and gluons transform to ordinary quarks.

3. The objection is that this model need not explain the strong concentration of diphoton invariant mass to the range 45-75 GeV since in principle 4-particle final states are in question and phase space distribution does not predict anything like this. p-Adic length scale hypothesis however suggests that the resulting quark pairs actually form a p-adically scaled down variant of the pion like state and have therefore mass, which is half of its mass. This would give rise to a resonance like behavior and impy a strong concentration of the events to the invariant masses which are one half of the mass of the mother particle.

The p-adically scaled up quarks appear even in the TGD based model of light hadrons and produce mass formula replacing Gell-Mann-Nishijina mass formula [K11]. As a matter fact, the naive prediction for the mass of M_{89} pion is just 512 times the mass of the ordinary neutral pion and gives 69.1 GeV!

4. One must also worry about overall parity conservation required if only strong and electromagnetic interactions are involved with the decay process. Pion is pseudo-scalar and the decay of pion to two pions with scaled down mass requires parity breaking in the effective action involving the pion fields only unless the vertex contains derivatives but one cannot build a Lorentz invariant involving 4-D permutation symbol from three pion fields. Should one assume that the process breaks parity conservation and involves therefore weak interactions? Or should one assume that second scaled down pion is replaced with two pions with mass equal 1/4 the mass of the decaying pion to give parity invariant effective interaction Lagrangian as assumed in the model of CDF anomaly [K13]. This would predict also diphoton pairs with invariant masses scaled down to 22.5-40 GeV. The differential cross section is anomalous down to the 20 GeV cutoff. One should be able to resolve this issue before one can take the model seriously.

4.5.3 A connection with Aleph anomaly?

There is an old anomaly known as Aleph anomaly [C10] producing 4-jets states with *jet-jet* invariant mass of 55 GeV. According to the reference, the anomaly did not survive improved statistics. Delphi and L3 also observed 4-jet anomaly with dijet invariant mass about 68 GeV: this not too far from the mass for p-adically scaled down mass of π_{89} equal to 69.1 GeV! Remarkably, according to the above reference L3 observation survived the improvement of the statistics!

1. For more than decade ago I proposed an explanation of Aleph anomaly in terms of a meson-like state formed by p-adically scaled up variants of b quark and its antiquark [K11]. The mass of the resonance was predicted correctly using p-adic length scale hypothesis predicting that the mass of scaled up b quark is half octave of the mass of b quark.

2. The model could be generalized by replacing b quark with its super-partner if one assumes that SUSY breaking means only different p-adic mass scale. There is however an aesthetic problem (I take aesthetic arguments very seriously). The model for X and Y mesons assumed that the p-adic mass scale is same: now one should give up this assumption for b quark. The reader has probably already asked whether Aleph anomaly and the recent CMS anomaly could correspond to the same meson like state. 4-jets could be produced when $\tilde{b}$ and $\tilde{b}^*$ decay to bb^* pair by emission of gluinos which then exchange quark to produce quark pair or gluon pair. In the decays of X and Y mesons the resulting quark pair would form pion or some other meson. Now two quark or gluon jets by exchanged gluinos would be produced giving altogether four jets.

3. CMS anomaly suggests a different interpretation. Perhaps the 4-jets with di-jet energies around 55 GeV and 68 GeV are produced by the decays of the mixtures of M_{89} pion and spion (identified as squark pair) with masses around 110 GeV and 144 GeV producing as intermediate state the 2-adically scaled down pions with half of their original masses.

   The same mechanism is assumed also in themodel of CDF anomaly discovered for three years ago but already forgotten [K13]. Political memory is short! The mechanism would be a modification of that producing the diphoton excess. Squark and anti-squark would transform to quark-antiquark pair giving rise to intermediate scaled down pionlike state decaying to two jets with invariant mass concentrated around the mass of pion-like state. The exchanged gluino emits quark and antiquark or two gluons. Quark antiquark state could also form a scaled down M_{89} pion before the decay to two jets. The outcome would be four jets with concentration to preferred invariant masses.

4.6 No SUSY Dark Matter And Too Small Electron Dipole Moment For Standard SUSY

LUX group has reported that one leading dark matter candidate has disappeared (see `http://tinyurl.com/njrmdhb`). [C16] Lubos Motl (see `http://tinyurl.com/yc4tkbwb`) tells more about this. The candidate is light fermion - so called neutralino predicted by SUSY models as a candidate for dark matter. What makes it a candidate is that it stable against decays if R-parity is conserved: this implies that neutralino can disappear only via pair annihilation. This is also a further blow against $\mathcal{N} = 1$ SUSY paradigm in its standard form implying among other things the non-conservation of baryon and lepton number or both.

The result of course does not mean that there would be no dark matter. It only says that the main stream of particle physics community has been at completely wrong track concerning the nature of dark matter. As I have patiently explained year after year in this blog, dark matter is not some exotic particle this or that. Dark matter is something much deeper and its understanding requires a generalization of quantum theory to include hierarchy of Planck constants. This requires also a profound generalization of the notion of space-time time.

In particular, all standard particles can be in dark phase characterized by the value of Planck constant, and the main applications are TGD inspired quantum biology and consciousness theory since dark matter with large value of Planck constant can form macroscopic quantum phases. Also dark energy in TGD sense is something very different from the standard dark energy. Dark energy in TGD Universe corresponds to Kähler magnetic energy assignable to magnetic flux tubes carrying monopole flux. These magnetic fields need no currents to generate them, which explains why cosmos can full of magnetic fields. Superconductors at the verge of breakdown of superconductivity and even ordinary ferromagnets might carry these Kähler monopole fluxes although monopoles themselves do not exist.

The result of LUX was expected from TGD point of view and does not exclude particles dark in TGD sense. Even dark particles at the mass scale of tau lepton and even at mass scale of 7-8 GeV can be considered and the CDF anomaly reported few years ago could have explanation in terms of dark variant of tau-pion identifiable as pion like bound state of colored tau leptons: also for other leptons analogous states have been reported [K13]. The experimental signatures of this kind of particles are however very different from the dark particles that LUX was searching for and could explain some reports about evidence for dark matter in ordinary sense.

The lesson to learn is that one can find only what one is searching for in recent day particle physics. Particle phenomenologists should return to the roots. Challenging the cherished beliefs - even the beliefs about what QCD color is - is painful but is the only way to make progress.

A further blow against standard SUSY came few weeks after dark matter results. ACME collaboration has deduced a new upper boundon the electric dipole moment of electron, which is by order of magnitude smaller than the previous one (`http://tinyurl.com/k7ybs6j`) [C14]. Jester (see `http://tinyurl.com/y8afqeqk`) and Lubos Motl (see `http://tinyurl.com/y9ftnva2`) have more detailed commentaries.

The measurement of the dipole moment relies on a simple idea: electric dipole moment gives rise to additional precession if one has parallel magnetic and electric fields. The additional electric field is now that associated with the molecule containing electrons plus strong molecular electric field in the direction of spin quantization axes. One puts the molecules containing the electrons into magnetic field and measurex the precession of spins by detecting the photons produced in the process. The deviation of the precession frequency from its value in magnetic field only should allow to deduce the upper bound for the dipole moment.

Semiclassically the non-vanishing dipole moment means asymmetric charge distribution with respect to the spin quantization axis. The electric dipole coupling term for Dirac spinors comes to effective action from radiative corrections and has the same form as magnetic dipole coupling involving sigma matrices except that one has an additional γ_5 matrix bringing in CP breaking. The standard model prediction is of order $d_e \simeq 10^{-40} e \times m_e$: this is by a factor 10^{-5} smaller than Planck length!

The new upper bound is $d_e \simeq .87 \times 10^{-32} e \times m_e$ and still much larger than standard model prediction. Standard SUSY predicts typically non-vanishing dipole moment for electron. The estimate for the electron dipole moment coming from SUSYs and is by dimensional considerations of form $d_e = c\hbar; e \times m_e/16\pi^2 M^2$, where c is of order unity and M is the mass scale for the new physics. The Feynman diagram in question involves the decay of electron to virtual neutrino and virtual chargino and the coupling of the latter to photon before absoption.

This upper bound provides a strong restriction on “garden variety” SUSY models (involving no fine tuning to make dipole moment smaller) and the scale at which SUSY could show itself becomes of order 10 TeV at least so that hopes for detecting SUSY at LHC should be rather meager. One can of course do fine tuning. “Naturality” idea does not favor fine tunings but is not in fashion nowadays: the existing theoretical models do not simply allow such luxury. The huge differences between elementary particle mass scales and quite “too long” proton lifetime represent basic example about “non-naturality” in the GUT framework. For an outsider like me this strongly suggests that although Higgs exist, Higgs mechanism provides only a parameterization of particle masses - maybe the only possible theoretical description in quantum field theory framework treating particles as point like - and must be eventually replaced with a genuine theory. For instance, Lubos Motl does not see this fine tuning is not seen as reason for worrying too much. Personally I however feel worried since my old-fashioned view is that theoretical physicists must be able to make predictions rather than only run away the nasty data by repeated updating of the models so that they become more and more complicated.

4.7 Leptoquarks As First Piece Of Evidence For TGD Based View About SUSY?

The basic problem of TGD inspired SUSY has been the lack of experimental information allowing to guess what might be the p-adic length scale associated with sparticles. The massivation as such is not a problem in TGD: the same mass formula would be obeyed by particles and sparticles and SUSY breaking would mean only different p-adic mass scales for stable particle states. One can even consider the possibility that particles and sparticles have identical masses but sparticles have non-standard value of h_{eff} behaving therefore like dark matter.

The solution of the problem could emerge from experiments in totally unexpected manner. Indications for the existence of leptoquarks have been accumulating gradually from LHC. Leptoquarks should have same quantum numbers as pairs of quark and right-handed neutrino and would thus correspond to squarks in $\mathcal{N} = 2$ SUSY of TGD.

I have written about leptoquarks as an explanation for the breaking of leptonic universality for which indications have emerged from B meson decays [K9] [L4].

Leptoquarks have received considerable attention in blogs. Both Jester (see `http://tinyurl.com/yd6jksu3`) and Lubos (see `http://tinyurl.com/ybosxc93`) have written about the topic. Jester lists 3 B-meson potential anomalies, which leptoquarks could resolve:

- A few sigma deviation in differential distribution of $B \to K^* \mu^+ \mu^-$ decays.
- 2.6 sigma violation of lepton flavor universality in $B \to D \mu^+ \mu^-$ *vs.* $K \to D e^+ e^-$ decays.
- 3.5 sigma violation of lepton flavor universality, but this time in $B \to D \tau \nu$ *vs.* $B \to D \mu \nu$ decays.

There is also a 3 sigma discrepancy of the experimentally measured muon magnetic moment, one of the victories of QED. And old explanation has been in terms of radiative corrections brought in by SUSY. In TGD framework one can consider an explanation in terms of $\mathcal{N} = 2$ SUSY generated by right-handed neutrino. It has been claimed (see `http://tinyurl.com/ychg6wjh`) that leptoquark with quantum numbers of $D\nu_R$, where D denotes D type quark actually s quark, which in TGD framework corresponds to genus $g = 1$ for the corresponding partonic 2-surface, could explain all these anomalies.

An alternative model would explain the breaking of lepton universality in terms of bosonic analogs of higher fermion generations. The charge matrix of ordinary gauge boson is unit matrix in the 3-D state space assignable with the three generations representing various fermion families. Gauge bosons correspond to charge 3×3 matrices, which must be orthogonal with respect to the inner product defined by trace. Hence fermion universality is broken for the 2 higher gauge boson generations. The first guess is that the mass scale of the second boson generation corresponds to Gaussian Mersenne $M_{G,79}$ [K9] [L5].

The model for the breaking of universality in lepton pair production is in terms of $M_{G,79}$ bosons. In standard model the production of charged lepton pairs would be due to the decay of virtual W bosons appearing in self-energy loop of penguin diagram. W emits Z^0 or γ decaying to a charged lepton pair. If a virtual higher generation W_{79} boson appears in self energy loop, it can transform to W by emitting Z^0_{79} or γ_{79} decaying to lepton pair and inducing a breaking of lepton universality. Direct decays of W_{79} to $l\overline{\nu}_L$ pairs imply a breaking of lepton universality in lepton-neutrino pair production. TGD as squark.

The breaking of the universality is characterized by charge matrices of weak bosons for the dynamical SU(3) assignable with family replication. The first generation corresponds to unit matrix whereas higher generation charge matrices can be expressed as orthogonal combinations of isospin and hypercharge matrices I_3 and Y. I_3 distinguishes between tau and lower generations (third experiment) but not between the lowest two generations. There is however evidence for this (the first two experiments above). Therefore a mixing the I_3 and Y should occur.

Recently additional evidence for the existence of this kind of weak boson has emerged (see `http://tinyurl.com/gqrg9zt`). If I understood correctly, the average angle between the decay products of B meson is not quite what it is predicted to be. This is interpreted as an indication that Z′ type boson appears as an intermediate state in the decay.

Does the breaking of universality occurs also for color interactions? If so, the predicted M_{89} and $M_{G,79}$ hadron physics would break universality in the sense that the couplings of their gluons to quark generations would not be universal. This also forces to consider to the possibility that there are new quark families associated with these hadron physics but only new gluons with couplings breaking lepton universality. This looks somewhat boring at first.

On the other hand, there exist evidence for bumps at masses of M_{89} hadron physics predicted by scaling to be 512 time heavier than the mesons of the ordinary M_{107} hadron physics. According to the prevailing wisdom coming from QCD, the meson and hadron masses are however known to be mostly due to gluonic energy and current quarks give only a minor contribution. In TGD one would say that color magnetic body gives most of the meson mass. Thus the hypothesis would make sense. One can also talk about constituent quark masses if one includes the mass of corresponding portion of color magnetic body to quark mass. These masses are much higher than current quark masses and it would make sense to speak about constituent quarks for M_{89} hadron physics. Constituent quarks of the new hadron physics would be different from those of the standard hadron physics.

With a lot of good luck both mechanisms are involved and leptoquarks are squarks in TGD sense. If also M_{89} and M_{79} hadron make themselves visible at LCH (there are several pieces of evidence for this), a breakthrough of TGD would be unavoidable. Or is it too optimistic to hope that the power of truth could overcome academic stupidity, which is after all the strongest force of Nature?

4.8 SUSY after LHC

As we now know, SUSY was not found at LHC and the basic motivation for SUSY at LHC energies has disappeared. The popular article "Where Are All the 'Sparticles' That Could Explain What's Wrong with the Universe?" (see `http://tinyurl.com/y6n5cjhv`) tells about the situation. The title is however strange. There is nothing wrong with the Universe. Theoreticians stubbornly sticking to a wrong theory are the problem.

Could it be that the interpretation of SUSY has been wrong? For instance, the minimal $\mathcal{N} = 1$ SUSY predicts typically Majorana neutrinos and non-conservation of fermion number. This does not conform with my own physical intuition. Perhaps we should seriously reconsider the notion of supersymmetry itself and ask what goes wrong with it.

Can TGD framework provide any new insights?

1. TGD can be seen as a generalization of superstring models, which emerged years before superstring models came in fashion. In superstring models supersymmetry is extended to superconformal invariance and could give badly broken SUSY as space-time symmetry. SUSY in standard QFT framework requires massless particles and this requires generalization of the Higgs mechanism. The proposals are not beautiful - this is most diplomatic manner to state it.

In TGD framework super-conformal symmetries generalize dramatically since light-like 3-D surfaces - in particular light-cone boundary and boundaries of causal diamond (CD) have one light-like direction and are metrically 2-D albeit topologically 3-D. One outcome is modification of AdS/CFT duality - which turned out to be a disappointment - to a more realistic duality in which 2-D surfaces of space-time regarded itself as surface in $H = M^4 \times CP_2$ are basic objects. The holography in question is very much like strong form of ordinary holography and is akin to the holography assigned with blackhole horizons.

2. The generators of supersymmetries are fermionic oscillator operators and the Fock states can be regarded as members of SUSY multiplets but having totally different physical interpretation. At elementary particle level these many fermion states are realized at partonic 2-surfaces carrying point-like fermions assignable to lepton and quark like spinors associated with single fermion generations. There is infinite number of modes and most of them are massive.

   This gives rise to infinite super-conformal multiplets in TGD sense. Ordinary light elementary particles could correspond to partonic 2-surfaces carrying only fermion number at most ±1.

3. By looking the situation from the perspective of 8-D imbedding space $M^4 \times CP_2$ situation gets really elegant and simple.

   8-D twistorialization [L12] requires massless states in 8-D sense and these can be massive in 4-D sense. Super-conformal invariance for 8-D masslessness is infinite-D variant of SUSY: all modes of fundamental fermions generate supersymmetries. The counterpart SUSY algebra is generated by the fermionic oscillator operators for induced spinor fields. All modes independently of their 4-D mass are generators of supersymmetries. M^4 chirality conservation of 4-D SUSY requiring 4-D masslessness is replaced by 8-D chirality conservation implying a separate conservation of baryon and lepton numbers. Quark-lepton symmetry is possible since color quantum numbers are not spin-like but realized as color partial waves in cm degrees of freedom of particle like geometric object.

   No breaking of superconformal symmetry in the sense of ordinary SUSYs is needed. p-Adic thermodynamics causes massivation of massless (in 4-D sense) states of spectrum via mixing with very heavy excitations having mass scale determined by CP_2 mass.

   One could say that the basic mistake of colleagues - who have been receiving prizes for impressively many breakthroughs during last years - is the failure to realize that 4-D spinors must be replaced with 8-D ones. This however requires 8-D imbedding space and space-time surfaces and one ends up to TGD by requiring standard models symmetries or just the existence of twistor lift of TGD. All attempts to overcome the problems lead to TGD. Colleagues do not seem like this at all so that they prefer to continue as hitherto. And certainly this strategy has been an amazing professional success.

What about the counterpart of space-time supersymmetry - SUSY - in TGD framework? The question whether TGD allows space-time SUSY or not has bothered me for a long time, and I have considered SUSY from TGD point of view in [K6, K17, K4]. In the following I summarize my recent views, which reflect the increased understanding of twistor lift and cosmological constant and of preferred extremals as minimal surfaces having 2-D string world sheets as singularities analogous to edges [L11, L13, L14] [L12].

1. The analog of SUSY would be generated by massless or light modes of induced spinor fields. Space-time SUSY would correspond to the lightest slowly varying modes for the induced spinor fields being in 1-1-correspondence with the components of H-spinors. The number $\mathcal{N}$ associated with SUSY is quite large as the number of components of H-spinors. The corresponding fermionic oscillator operators generate repsesentations of Clifford algebra and SUSY multiplets are indeed such.

   If space-time surface is canonically imbedded Minkowski space M^4, no SUSY breaking occurs. This is however an unrealistic situation. For general preferred extremal right- and left handed components of spinors mix, which causes in turn massivation and breaking of SUSY in 4-D sense.

Could right-handed neutrino be an exception. It does not couple to electroweak and color gauge potentials. Does this mean that ν_R and its antiparticle generate exact $\mathcal{N}=2$ SUSY? No: ν_R has small coupling to CP_2 parts of induced gamma matrices mixing neutrino chiralities and this coupling causes also SUSY breaking. This coupling is completely new and not present in standard QFTs since they do not introduce induced spinor structure forced by the notion of sub-manifold gemetry.

Even worse, one can argue that right-handed neutrino is "eaten" as right- and left-handed massless neutrinos combine to massive neutrino unless one has canonically imbedded M^4. There fate resembles that of charge Higgs components. One could still however say that one has an analog of broken SUSY generated by massive lepton and quark modes. But it would be better to talk about 8-D supersymmetry.

2. The situation is now however so simple as this. TGD space-time is many-sheeted and one has a hierarchy of space-time sheets in various scales labelled by p-adic primes labelling also particles and by the value of Planck constant $h_{eff} = n \times h_0$.

   Furthermore, spinors can be assigned to 4-D space-time interiors, to 2-D string world sheets, to their light-like 1-D boundaries at 3-D light-like orbits of partonic 2-surfaces, or even with the partonic orbits. 2-D string world sheets are analogous to edges of 3-D object and action receives "stringy" singular contribution from them because of edge property. Same applies to the boundaries of string world sheets location at the light-like orbits of partonic 2-surfaces. Think of a cloth, which has folds which move along it as an analog. Space-time interior is a minimal surface in 4-D sense except at 2-D folds and string world sheets and their boundaries are also minimal surfaces.

   Therefore one has many kinds of fermions: 4-D space-time fermions, 2-D string world sheet fermions possibly associated with hadrons (there presence might provide new insights to the spin puzzle of proton), and 1-D boundary fermions for these as point-like particles and naturally identifiable as basic building bricks of ordinary elementary particles. Perhaps even 3-D fermions associated with light-like partonic orbits can be considered. All these belong to the spectrum and the situation is very much like in condensed matter physics, where people talk fluently about edge states.

3. In TGD framework ordinary elementary particles are assigned with the light-like boundaries of string world sheets. Right-handed neutrino and antineutrino generate $\mathcal{N}=2$ SUSY for massless states assignable as light-like curves at light-like orbits of partonic 2-surfaces. This implies badly broken SUSY and it seems that one cannot talk about SUSY at all in the conventional sense. These states are however massless in 8-D sense, not in 4-D sense!

   In TGD framework one can however consider an analogy of SUSY for which massless ν_R modes in 4-D space-time interior - rather than at orbits of partonic 2-surfaces - generate supersymmetry. One could say that the many particle state, rather than particle has a spartner. Think of any system - it can contain larger number of ordinary particles forming a single quantum coherent entity to which one an assign space-time sheet. One can assign to this system space-time shet a right-handed neutrino, antineutrino, or both. This gives the superpartner of the system. The presence of ν_R is not seen in the same manner in interactions as in SUSY theories.

This picture [L11, L13, L14] is an outcome of a work lasted for decades, not any ad hoc model. One can say that classical aspects of TGD (exact part of quantum theory in TGD framework) are now well understood. To sum up, the simplest realizations of SUSY in TGD sense are following and the best manner to look at them is from the perspective 8-D masslessness.

1. Massless 4-D supersymmetry generated by ν_R. Other fermions which are massive because of their electroweak and color interactions not possessed by ν_R. Also ν_R generates small mass. These spartners are not however visible in elementary particle physics but belong to condensed matter physics.

2. Massive neutrino and other fermions but no supersymmetry generatig ν_R anymore since it is “eaten”. This would be realized as very badly broken SUSY in 4-D sense and the

spartners would be very massive. At the partonic 2-surfaces, this option forced by Uncertainty Principle.

5 SUSY in TGD Universe

What SUSY is in TGD framework is a longstanding question which found a rather convincing answer rather recently. In twistor Grassmannian approach to $\mathcal{N} = 4$ SYM [B6, B3, B4, B5, B9, B7, B2] 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 realizes 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 [L15] throws also light to the problem whether SUSY is realized in TGD [L16] 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. Super-octonion components of polynomials have different orders so that also the extension of rational assignable to them is different and therefore also the ramified primes so that p-adic prime as one them can be different for the members of SUSY multiplet and mass splitting is obtained.

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).

One ends up with the precise understanding of quantum criticality and the relation between its descriptions at M^8 level and H-level. Polynomials describing a hierarchy of dark matters describe also a hierarchy of criticalities and one can identify inclusion hierarchies as sub-hierarchies formed by functional composition of polynomials. The Wick contractions of quark-antiquark monomials appearing in the expansion of super-coordinate of H define the analog of radiative corrections. $M^8 - H$ duality and number theoretic vision require that the number of non-vanishing Wick contractions is finite. This condition gives rise to conserved currents having an identification in terms of symmetries. The number of contractions increases with the degree of the octonionic polynomial and gives rise to a discrete coupling constant evolution parameterized by the extensions of rationals. The polynomial composition hierarchies correspond to inclusion hierarchies for isomorphic sub-algebras of super-symplectic algebra having interpretation in terms of inclusions of hyper-finite factors of type II_1.

One also ends up to the first completely concerete proposal for how to construct S-matrix directly from the solutions of super-Dirac equations and super-field equations for space-time super-surfaces.

5.1 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.

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

5.1.1 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 electroweak 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 electroweak 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 [L9].

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 [L9]. 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 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 electroweak 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.

5.1.2 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 rearrangement 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.

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.

5.2 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.

5.2.1 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 [L12] 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:

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

$n-1$-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 [L12].

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.

5.2.2 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 $\Psi = \Psi_N O_N(\theta,\overline{\theta})$ 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. Super-Dirac spinor is expanded in monomials $O_N(\theta,\overline{\theta})$ of θ and its conjugate $\overline{\theta}$, whose anti-commutator is non-trivial. One can equally well talk about quark like oscillator operators. The 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. Quark oscillator operators are same as appearing in the imbedding space super-coordinates. Only monomials O_N having odd quark number are allowed. Super-spinor field however contains terms involving quark pairs giving rise to spartners of multiquark states with fixed quark number. The conjugate of super-spinor is defined in an obvious manner.

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.

   There are also couplings to gauge potentials defined by the spinor connection of CP_2 and the expansion of them with respect to the imbedding space coordinates gives at the first step rise covariant derivatives of gauge potentials giving spinor curvature. At next steps one obtains covariant derivatives of spinor curvature, which however vanish so that the number of terms coming from the dependence of spinor connection on CP_2 coordinates is expected to be finite. Constant curvature property of CP_2 is therefore be essential (not that also M^4 would have covariantly constant spinor curvature in twistor lift and give rise to CP breaking).

   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 $L_{k_1\alpha_1 \ldots k_n 1 \alpha_n}$ 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.

5.2.3 Feedback to M^8 level

Super-symmetrization of bosonic action identified as sum of Kähler action and volume term plus super-Dirac action [L12] 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. The original speculations related to [L8] super-octonions were too naive and is not consistent with the picture at H level.

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.

So: what super-octonions could be?

1. The key idea is that the powers o^n of octonion appearing are associative. If the coefficients of $P(o)$ are real or possibly even complex rationals $m + in$ commuting with octonions, associativity is not lost. Octonion o would be multiplied by a super-polynomial p_s with (possibly complex-) rational coefficients to get super-octonion $o_s = op_s$. The conjugate octonion $\overline{s}$ would be treated analogously. The terms in o_s would be proportional to super-monomials $O_N(\theta,\overline{\theta})$. One would have $o_s^n = o^n p_s^n$ so that associativity would be preserved.

   θ *resp.* $\overline{\theta}$ would transform like components of 8-D spinor *resp.* its conjugate and have interpretation as quark *resp.* anti-quark like spinors. $SO(1,7)$ triality allows only leptonic or quark-like spinors and quark-like spinors are the only physical choice. $O_N(\theta,\overline{\theta})$ would behave like quark multi-spinors.

2. Super-polynomial $P_s(o)$ would be defined by super-analytic continuation as $P(o_s)$ by Taylor expanding it with respect to the super-part of o_s. The outcome is super-polynomial with coefficients of monomials O_N given by ordinary octonionic polonomials P_N. Each P_N would define 4-surface by requiring that the imaginary or real part of P_N (in quaternionic sense) vanishes. The polynomials P_N are expressible in terms of P and its derivatives.

3. The geometric description of SUSY would be in terms of super-octonions and their super-polynomials and the 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.

4. $SO(1,7)$ triality implies that 8-spinors, their conjugates, and 8-vector form a triplet. Super-field formalism in $M^4 \times CP_2$ suggests that there bosonic action defining space-time surface and super-Dirac action are fundamental. This should have analog at M^8 level. This would suggest that super-variants of ordinary octonions serve as arguments of octonion valued super-fields having interpretation as quarks and antiquarks. Θ parameters are same in all cases.

   The bosonic super-monomials in o_s would be of form $O_N(\theta,\overline{\theta})$ with vanishing quark number and monomial and its conjugate would appear as sum: the interpretation would be in terms of local bosonic states with vanishing quark number. Quark-like octonionic super-field q_s would be odd polynomial of θ with coefficients polynomials of o_s. For antiquark-like super-field $\overline{q}_s$ θ would be replaced with its conjugate. The interpretation would be in terms of states with odd quark or anti-quark number. Also in this interpretation the vanishing of the real or imaginary part of the quark- or antiquark-like polynomial would define a space-time surface in M^8 and one would have bosonic, quark-like, and antiquark-like space-time surfaces.

5.3 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.

5.3.1 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 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 [K16] 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 [K8] 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 [K1]: 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 [C24] [L7] 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.

5.3.2 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.

5.3.3 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 [K12]. 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 [K13] 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.

The life-time for the decay modes predicted by GUTs is extremely long - longer than 1.67×10^{34} years (see `http://tinyurl.com/nqco2j7`). This fact provides a killer test for the proposal.

One should estimate the life-time of proton in number theoretic approach. The corresponding SUSY vertex corresponds to a Wick contraction involving 4 terms in super-Dirac action: the trilinear term for quarks and 3 linear terms.

1. The vertex would associated with a partonic 2-surface at which 3 incoming quark space-time sheets and outgoing electron space-time sheet meet. At quark level the vertex means an emanation of 3 quark lines from single 3-quark line at a point of partonic 2-surface in the intersection of the ends of 4 space-time surfaces with 6-sphere $t = r_n$ defining a universal root of octononic polynomial $P(o)$. t is M^4 time coordinate [L15]. The vertex itself does not seem to be small.

2. A fusion of 3 homologically non-trivial partonic 2-surfaces to single partonic 2-surface with trivial homology charge cannot occur since partonic 2-surfaces with different homology charge cannot co-incide.

   The reaction $p \rightarrow e^+ + ..$ can occur only if the quark-like partonic 2-surface fuse first to single homologically trivial partonic 2-surface: this would correspond to de-confinement phase transition for quarks. After that the 3 quark lines would fuse to single e^+ line.

   (a) To gain some intuition consider two oppositely oriented circles around a puncture of a plane with opposite homology charges. The circles can reconnect to homologically trivial circle. Instead of circles one would now have 3 homologically trivial quark-like 2-surfaces at three light-like boundaries between Minkowskian and Euclidian regions of the space-time surface representing proton. First 2 quark-like 2-surfaces would touch and develop a wormhole contact connecting them. After that the resulting di-quark 2-surface and third quark 2-surface would fuse. The 3 quarks would be now analogous to de-confined quarks.

   (b) At the next step the 3 separate quark lines would fuse to single one. This process must occur in single step since di-quark cannot correspond to single point because the Dirac super-polynomial is odd in θ parameters. The fusion point would correspond to 3 degenerate roots of the octonionic polynomial associated with the partonic 2-surface. This partonic 2-surface would be associated with $t = r_n$ hyperplane of M^4 and it would become leptonic 3-surface.

   (c) 3 4-D sheets defined by the roots of the octonionic polynomial should meet at the vertex assignable to $t = r_n$ hyper-plane. This gives 2 additional conditions besides the conditions defining space-time sheets. This for both the protonic and positronic space-time sheets. One would have double quantum criticality. The tip of a cusp catastrophe serves as an analog. Since the coefficients of the octonionic polynomial are rational numbers, it might be possible to estimate the probability for this to occur: the probability could be proportional to the ratio N_2/N_0 of the number N_2 of doubly critical points to the number N_0 of all points with coordinates in the extension. This could make the process very rare.

5.3.4 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).

(a) 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 $(1, 4^2 = 16, 6^2 = 36, 4^2 = 16, 1)$.

(b) 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.

(c) 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 [C12, C13, C18] (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.

(a) 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.

(b) 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).

(a) 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.

(b) 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.

(a) In bi-local model gauge bosons would correspond to representations of a dynamical symmetry group $SU(3)_g$ associated with the 3 genera [K1]. 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 [K9].

(b) 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.

(c) 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 [K1] (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 antiquark 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.

5.3.5 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.

5.4 Finiteness for the number of non-vanishing Wick contractions, quantum criticality, and coupling constant evolution

The consistency with number theoretic vision requires that the number of terms in the super-Taylor expansion of action is finite - otherwise one is led out from the extension: this applies both to the action determining space-time surfaces and to the corresponding modified Dirac action. There are several options that one can consider.

(a) Normal ordering of the fermionic oscillator operators would be a straightforward manner to handle the situation. One would obtain finite number of terms since the number of quark oscillator operators is $d = 4+4 = 8$. The maximal degree m_{max} of multiple partial derivative of action with respect to gradient of H-coordinate h would be $m_{max} = d = 8$ and correspond to monomial with 4+4 quark oscillator operators. Note that the normal ordering of this term gives rise to c-number.

It however seems that the natural solution of the problem must involve cancellation of the Wick contractions when the degree m of the multiple partial derivative satisfies $m > m_{max}$. Some cancellation mechanism for $m \geq m_{max}$ should guarantee that Wick-contractions give in this case a vanishing contribution to each of the $d = 8$ monomials in the super-action.

(b) The strongest condition would be that all Wick contraction terms coming from the normal ordering vanish. The contraction terms are expressible as divergences of currents and the interpretation would be in terms of Noether current associated with some symmetry. Super-symplectic symmetry is the best candidate in this respect. Note that besides these currents also the Noether currents coming from the super-symplectic variations should have a vanishing divergence.

One can argue that if continuum variant of this picture exists, all contractions must vanish since one would obtain powers of delta functions.

(c) One can consider also a weaker condition. Wick contractions vanish for $m > m_{max}$ such that $m_{max} > 8$ is possible. This would give rise to the analog of radiative corrections, and if m_{max} can vary, one obtains the analog coupling constant evolution and discrete coupling constant evolution corresponds to the variation of m_{max}.

How the value of m_{max} could be determined?

(a) $M^8 - H$ duality requires that M^8- and H-pictures are structurally similar. Octonionic polynomials are characterized by their order n and also the super-extremals should be characterized by n and even the individual terms of super-polynomial should have counterparts at H-level.

One can define super-octonionic polynomials at M^8-level and also for these normal ordering terms appear. Ordinary derivatives of $P(o)$ with respect to o replace those of the action with respect to the gradients of H coordinates, and one obtains only finite number of Wick contractions. There is no need to require their vanishing now, and the hierarchy of degrees $n = h_{eff}/h_0$ for P defines a discrete coupling constant evolution with each level corresponding to its own values of coupling constants differing by the number of Wick contractions. This gives a connection with the ordinary coupling constant evolution with Wick contractions taking the role of loops.

This picture should have direct image at H-side. In particular, one should have $m_{max} = n$.

(b) The cancellation of Wick contractions for the action containing both Kähler term and cosmological term probably happens only for critical values of cosmological constant determined dynamically from the mechanism of dimensional reduction reducing 6-D surface in the product of twistor spaces $T(M^4) = M^4 \times S^2$ and $T(CP_2) = SU(3)/U(1) \times U(1)$ to S^2 bundle over space-time surface representing induced twistor structure. The cancellation condition for the higher terms could fix the value of cosmological constant emerging from the mechanism.

(c) The picture could be interpreted in terms of quantum criticality. The polynomials $P(o)$ characterize quantum critical phases. Also Taylor series can be considered but they would not be critical and infinite amount of information would be required to specify them whereas the specification of critical dynamics requires by its universality only a finite number of parameters coded by the rational coefficients of polynomial.

Criticality corresponds to the vanishing of not only function but also some of its derivatives at critical point. The criticality would be now infinite in the sense that all derivatives of $P(o)$ higher than n would vanish. This is indeed the view about quantum criticality that I ended up to long time ago. This implies that the parameter space for the functions describing criticality is finite-dimensional.

In Thom's catastrophe theory which essentially describes a hierarchy of criticalities concretely, the finite-dimension of the space of control parameters is essential. For cusp catastrophe this space is 2-dimensional and catastrophe graph is defined by a fourth order polynomial so that all higher order derivatives vanish identically also now.

(d) At the level of H criticality would mean that m-fold partial derivatives of action only up to $m = m_{max} = n$-fold partial derivatives contribute to the radiative corrections. The action would be polynomial of finite order in the multi-spinor components of super-coordinates and discrete coupling constant evolution would be realized. The ordinary variations of the action would be of course non-vanishing to arbitrary high order.

Coupling constant evolution would reduce to the hierarchy of extensions of rationals since the degree n of P determines the dimension of extension. Evolution in terms of the hierarchy of extensions of rationals would dictate also coupling constant evolution. This evolution would also dictate the preferred p-adic length scales if preferred p-adic primes are identifiable as ramified primes. Ramified primes at the lowest level of hierarchy are ramified primes at higher levels if $P(0) = 0$ condition is true for them. Evolutionary hierarchies correspond to functional composition hierarchies for polynomials with degrees n_i such that n_{i+1} is divisible with n_i that is $n_{i+1}/n_i = k_i$.

Remark: Functional composition occurs also in the construction of fractals like Mandelbrot fractal and as a special case one iterates single polynomial to get a hierarchy in powers of integers n_1. This interpretation would conform with the interpretation of the symmetries guaranteeing the cancellation of Wick terms as super-symplectic symmetries.

(e) A connection with the inclusion hierarchies for super-symplectic algebra is highly suggestive. The fractal hierarchy of super-symplectic sub-algebras (fractality and conformal symmetry - now in generalized sense - are essential for quantum criticality) with levels labelled by n would naturally give rise to counterparts of the functional composition hierarchies.

Inclusion hierarchies would correspond to sub-hierarchies of super-symplectic algebras formed by sequences of sub-algebras with weights divisible by integer n_i such that n_i divides n_{i+1}. n_i would correspond to a degree of polynomial in the hierarchy formed by their compositions in accordance with functional composition of polynomials.

(f) The inclusion hierarchies of super-symplectic algebras would have interpretation in terms of inclusions of hyper-finite factors of type II_1. The ratios $n_{i+1}/n_i = k_i$ appearing in the composition hierarchies would correspond to the integers labelling the inclusions of HFFs and defining quantum phases $U = exp(i\pi/k_i)$ characterizing quantum algebras and quantum spaces as analogs of state spaces modulo finite measurement resolution [K15, K7].

The interpretation of finite measurement resolution as an ability to detect only space-time sheets characterized by polynomials of order n below some fixed integer is natural. n would characterize the measurement resolution.

To sum up, this picture rather neatly fuses together several speculative visions about quantum TGD. The reduction of dynamics to polynomial dynamics at the level of M^8 has interpretation in terms of quantum criticality with finite-D space of control parameters implying universal dynamics involving very few coupling parameters, which are fixed points of coupling constant evolution for given value of n. M^8-H duality maps M^8 dynamics to the level of H, where it is realized in terms of a hierarchy of sub-algebras of super-symplectic algebra and sub-hierarchies correspond to sequences of integers n_i dividing n_{i+1}. A connection with the inclusions of HFFs and finite measurement resolution emerges. The notion of discrete coupling constant evolution finds a precise formulation, and the notion of radiation correction is realized in terms of Wick contractions.

5.4.1 How the earlier vision about coupling constant evolution would be modified?

In [L13, L11] I have considered a vision about coupling constant evolution assuming twistor space $T(M^4) = M^4 \times S^2$. In this model the interference of the Kähler form made possible by the same signature of $S^2(M^4)$ and $S^2(CP_2)$ gives rise to a length scale dependent cosmological constant appearing defining the running mass squared scale of coupling constant evolution.

For $T(M^4)$ identified as $CP_3(3,h)$ the signatures of twistor spheres are opposite and Kähler forms differ by factor i (imaginary unit commuting with octonion units) so that the induced Kähler forms do not interfere anymore. The evolution of cosmological constant must come from the evolution of the ratio of the radii of twistor spaces (twistor spheres). This forces to modify the earlier picture.

(a) M^8-H duality has two alternative forms with $H = CP_{2,h} \times CP_2$ or $H = M^4 \times CP_2$ depending on whether one projects the twistor spheres of $CP_{3,h}$ to $CP_{2,h}$ or M^4. Let us denote the twistor space $SU(3)/U(1) \times U(1)$ of CP_2 by F.

(b) The key idea is that the p-adic length scale hierarchy for the size of 8-D CDs and their 4-D counterparts is mapped to a corresponding hierarchy for the sizes of twistor spaces $CP_{3,h}$ assignable to M^4 by M^8-H-duality. By scaling invariance broken only by discrete size scales of CDs one can take the size scale of CP_2 as a unit so that $r = R^2(S^2(CP_{3,h})/R(S^2(F))$ becomes an evolution parameter.

   Coupling constant evolution must correspond to a variation for the ratio of $r = R^2(S^2(CP_{3,h})/R(S^2(F))$ and a reduction to p-adic length scale evolution is expected. A simple argument shows that is inversely proportional to constant magnetic energy assignable to $S^2(X^4)$ divided by $1/\sqrt{g_2(S^2)}$ in dimensional reduction needed to induce twistor structure. Thus one has $\Lambda \propto 1/r^2 \propto 1/L_p^2$. Preferred p-adic primes would be identified as ramified primes of extension of rationals defining the adele so that coupling constant evolution would reduce to number theory.

(c) The induced metric would vanish for $R(S^2(CP_{3,h}) = R(S^2(F))$. Λ would be infinite at this limit so that one must have $R(S^2(CP_{3,h}) \neq R(S^2(F))$. The most natural assumption is that one $R(S^2(CP_{3,h}) > R(S^2(F))$ but one cannot exclude the alternative option. Λ behaves like $1/L_p^2$. Inversions of CDs with respect to the values of the cosmological time parameter $a = L_p$ would produce hierarchies of length scales, in particular p-adic length scales coming as powers of $\sqrt{p}$. CP_2 scale and the scale assignable to cosmological constant could be seen as inversions of each other with respect to a scale which is of order 10^{-4} meters defined by the density of dark energy in the recent Universe and thus biological length scale.

(d) The original model for the length scale evolution of coupling parameters [L13] would reduce to that along paths at $S^2(CP_2)$ and would depend on the ends points of the path only. This picture survives as such. Also in the modified picture the zeros of Riemann zeta could naturally correspond to the quantum critical points as fixed points of evolution defining the coupling constants for a given extension of rationals.

    Space-time surfaces the level of M^8 would be determined by octonionic polynomials determined by real polynomials with rational coefficients. The non-critical values of couplings might correspond to the values of the couplings for space-time surfaces associated with octonion analytic functions determined by real analytic functions with rational Taylor coefficients.

5.5 S-matrix and SUSY

The construction of S-matrix has been one of the eternity projects of TGD. There are many proposals such as the construction based on the quaternionic generalization of twistor Grassmannian approach for cognitive representations involving huge simplification due to the vanishing of loop diagrams [L12, L18, L17] but also this approach is indirect. SUSY in TGD sense finally suggests a quite concrete fundamental approach.

(a) The construction would be based on the explicit solution of the super-symmetrized field equations. In principle everything reduces formally to classical partial differential equations for super-space-time surface and super-spinors. One solves preferred extremal as its super-variants which means solving the space-time evolution of multi-spinors defining super-coordinates and in this background one solves super-Dirac equation. This is highly non-trivial but in principle a well-defined procedure. If one gives initial values of various multi-spinor mods at the first light-like boundary of causal diamond (CD), one can deduce super-spinor field at opposite boundary of CD and express it as a superposition of its basic modes with well-defined quark number and other quantum numbers. This gives S-matrix.

(b) Situation simplifies dramatically for discrete cognitive representation replacing space-time surface with the set of points having imbedding space coordinates in extension of rationals defining the adele. Since finite set of points defining the preferred time scales $t = r_n$ as roots of a real polynomial determines the octonionic polynomia, $M^8 - H$ duality raises the hope that the discretization provided by cognitive representation is exact and improvement in UV/IR resolution means addition of new space-time sheets with smaller/bigger size.

(c) Partonic 2-surfaces define topological vertices. They are identified as intersections of incoming particle like 4-surfaces as roots of octonionic polynomials with 6-sphere defining analogs of branes in M^8 as universal roots of octonionic polynomials and having M^4 time $t = r_n$ hyperplanes of M^4 as their intersections.

    Multi-quark-antiquark vertices at partonic 2-surfaces are points of cognitive representation having H-coordinates in an extension of rationals (or at least their pre-images in M^8 have this property). Lines defining local multi-quark states fuse and split again into new states in quark number conserving manner. Vertices are super-symmetric in TGD sense and determined as vacuum expectations of the bosonic action and super-Dirac action and analogous to those defined by θ integration in SUSY.

(d) The counterparts of radiative corrections of QFTs are Wick contraction terms for the fermionic oscillator operators. $M^8 - H$ duality requires that their contribution from partial multi-derivatives of order higher than the order n of the octonionic polynomial are vanishing. This leads to the conditions having interpretation as conservation of Noether currents of symmetries. As n increases, the number of Wick contractions increases and this gives rise to discrete coupling constant evolution as function of the dimension of extension of rationals defined by the octonionic polynomial.

(e) No further quantization is needed since super-symmetrization corresponds to second quantization. This is part of the realization of the dream about geometrizing also quantum theory. This should have been realized long time ago also by colleagues since SUSY algebra is Clifford algebra like also oscillator operator algebra.

5.6 $M^8 - H$ duality and SUSY

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

(a) $h_{eff}/h_0 = n$ 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.

(b) 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.

(c) 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 [L6, L10] would allow the known elementary particles.

5.7 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.

(a) 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 $n = n(g)$.

(b) 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.

(c) 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 [L6, L10] led to the conclusion $h = 6h_0$. The condition is actually weaker: $h/h_0 \ mod \ 6 = 0$.

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