The Particle Spectrum Predicted by TGD and TGD Based SUSY

M. Pitkänen
Email: matpitka@luukku.com.
http://tgdtheory.com/public_html/.

April 3, 2012

Contents

1 Introduction

The detailed model of elementary particles has evolved slowly during more than 15 years and is still in progress. What SUSY means in TGD framework is second difficult question. In this problem text books provide no help since the SUSY differs in several respects from the standard SUSY.

1.1 The general TGD based view about elementary particles

A rough overall view about the particle spectrum predicted by TGD has remained rather stable since 1995 when I performed first p-adic mass calculations but several important ideas have emerged allowing to make the vision more detailed.

1. The discovery of bosonic emergence [7] had far reaching implications for both the formulation and interpretation of TGD. Bosonic emergence means that the basic building bricks of bosons are identifiable as wormhole contacts with throats carrying fermion and anti-fermion quantum numbers.

2. A big step was the realization wormhole throats carry Kähler magnetic charge [4]. This forces to assume that observed elementary particles are string like objects carrying opposite magnetic charges at the wormhole ends of magnetic flux tubes. The obvious idea is that weak massivation corresponds to the screening of weak charges by neutrino pairs at the second end of the flux tube.

   At least for weak gauge bosons this would fix the length of the flux tube to be given by weak length scale. For fermions and gluons the length of flux tube could also correspond to Compton length: the second end would be invisible since it would contain only neutrino pair. In the case of quarks an attractive idea is that flux tubes carry color magnetic fluxes and connect valence quarks and have hadronic size scale.

There are thus several stringy length scales present. The most fundamental corresponds to wormhole contacts and to CP_2 length scale appearing in p-adic mass calculations and is analogous to the Planck scale characterizing string models. String like objects indeed appear at all levels in TGD Universe: one can say that strings emerge. The assumption that strings are fundamental objects would be a fatal error.

3. p-Adic massivation does not involve Higgs mechanism [5]. The idea that Higgs provides longitudinal polarizations for gauge bosons is attractive, and its TGD based variant was that *all* Higgs components become longitudinal polarizations so that also photon has a small mass. The recent formulation of gauge conditions as $p_{M^2} \cdot \epsilon = 0$, where p_{M^2} is a projection of the momentum to to a preferred plane $M^2 \subset M^4$ assignable to a given CD and defining rest system and spin quantization axis, allows three polarizations automatically. Also the construction of gauge bosons as wormhole contacts with fermion and anti-fermion at the ends of throat massless on mass-shell states implies that all gauge bosons must be massive. Therefore Higgs does not seem to serve its original purposes in TGD.

4. This does not however mean that Higgs like states - or more generally spin 0 particles, could not exist. Here one encounters the problem of formulating what the notions like "scalar" and "pseudo-scalar" defined in M^4 field theory mean when M^4 is replaced with $M^4 \times CP_2$. The reason is that genuine scalars and pseudo-scalars in $M^4 \times CP_2$ would correspond to lepto-quark states and chiral invariance implying separate conservation of quark and lepton numbers denies their existence.

   These problems are highly non-trivial, and depending on what one is willing to assume, one can have spin 0 particles which however need not have anything to do with Higgs.

   (a) For a subset of these spin 0 particles the interpretation as 4 polarizations of gauge bosons in CP_2 direction is highly suggestive: the polarizations can be regarded as doublets $2 \oplus +\overline{2}$ defining representations of $u(2) \subset su(3)$ in its complement and therefore being rather "Higgsy". Another subset consists of triplet and singlet representations for $u(2) \subset u(3)$ allowing interpretation as the analog of strong isospin symmetry in CP_2 scale for the analogs of hadrons defined by wormhole contacts.

   (b) $3 \oplus 1$ representation of $u(2) \subset su(3)$ acting on $u(2)$ is highly analogous to (π, η) system and $2 \oplus \overline{2}$ representation assignable naturally to the complement of $u(2)$ is analogous to kaon system. Exactly the same representations are obtained from the model of hadrons as string like objects and the two representations explain the difference between (π, η) like and $(K, \overline{K}$ systems in terms of SU(3) Lie-algebra. Also the vector bosons associated with pseudo-scalar mesons identified as string like objects have counterparts at the level of wormhole contacts. A surprisingly precise analogy between hadronic spectrum and the spectrum of elementary particle states emerges and could help to understand the details of elementary particle spectrum in TGD Universe.

   In both cases charge matrices are expressible in terms of Killing vector fields of color isometries and gamma matrices or sigma matrices acting however on electroweak spin degrees of freedom so that a close connection between color and strong isospin is suggestive. This connection is empirically suggested also by the conserved vector current hypothesis and and partially conserved vector current hypothesis allowing to express strong interaction observables in terms of weak currents. In TGD framework color and electro-weak quantum numbers are therefore not totally unrelated as they are in standard model and it would be interesting to see whether this could allow to distinguish between TGD and standard model.

The detailed model for elementary particles involves still many un-certainties and in the following some suggestions allowing more detailed view are considered.

1.2 What SUSY means in TGD framework

What SUSY means in TGD framework is second long-standing problem. In TGD framework SUSY is inherited from super-conformal symmetry at the level of WCW [1, 3]. The SUSY differs from $\mathcal{N} = 1$ SUSY of the MSSM and from the SUSY predicted by its generalization and by string models. One obtains the analog of the $\mathcal{N} = 4$ SUSY in bosonic sector but there are profound differences in the physical interpretation.

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 [7] means the construction of bosons as bound states of fermions and antifermions at opposite throats of wormhole contact. This reduces TGD SUSY to that for fermions. This difference is fundamental and means deviation from the SUSY of $\mathcal{N} = 4$ SUSY, where SUSY acts on gauge boson states. Bosonic representations are obtained as tensor products of representation assigned to the opposite throats of wormhole contacts. 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. 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 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.

5. 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.

2 Construction of elementary particles in TGD framework

In the following the recent view about the construction of elementary particles is discussed. By bosonic emergence the construction reduces to the construction of the fermionic states associated with wormhole throats. Bosonic states are obtained as tensor products of states associated with the opposite throats of wormhole contact.

2.1 Construction of single fermion states

The general prediction of TGD is that particles correspond to partonic 2-surfaces, which can carry arbitrary high fermion number. The question is why only wormhole throats seem to carry fermion number 1 or 0 and why higher fermion numbers can be only assigned to the possibly existing super-partners.

1. p-Adic calculations assume that fermions correspond at imbedding space level to color partial waves assignable to the CP_2 cm degrees of freedom of partonic 2-surface. The challenge is to give a precise mathematical content to the statement that partonic 2-surface moves in color partial wave. Color partial wave for the generic partonic 2-surface in general varies along the surface. One must either identify a special point of the surface as cm or assume that color partial wave is constant at the partonic 2-surface.

2. The first option looks artificial. Constancy condition is however very attractive since it would correlate the geometry of partonic 2-surface with the geometry of color partial wave and therefore code color quantum numbers to the geometry of space-time surface. This quantum classical correlation cannot hold true generally but could be true for the maxima of Kähler function.

3. Similar condition can be posed in M^4 degrees of freedom and would state that the plane wave representing momentum eigenstate is constant at the partonic 2-surface.

For momentum eigenstates one obtains only one condition stating

$$p_{M^4} \cdot m = constant = C$$

at the partonic 2-surface located at the light-like boundary of CD. Here p_{M^4} denotes the M^2 projection of the four-momentum. CD projection is at most 2-dimensional and at the surface of ellipsoid of form

$$x^2 + y^2 + k^2(z - z_0)^2 = R^2 \ ,$$

where the parameters are expressible in terms of the momentum components p_0, p_3 parameter C. In this case, the assumption that fermions have collinear M^2 momentum projection allows to add several fermions to the state provided the conditions in CP_2 degrees of freedom allow this. In particular, covariantly constant right-handed neutrino must be collinear with the other fermions possibly present in the state.

For color partial waves the condition says that color partial wave is complex constant at partonic 2-surface $\Psi = C$.

1. The condition implies that the CP_2 projection of the color partial wave is 2-dimensional so that one obtains a family of 2-surfaces Y^2 labelled by complex parameter C. Color transformations act in this space of 2-surfaces. In general Y^2 is not holomorphic since only the lowest representations (1,0) and (0,1) of $SU(3)$ correspond to holomorphic color partial waves. What is highly satisfying is that the condition allows CP_2 projection with maximal possible dimension.

2. If one requires covariant constancy of fermionic spinors, only vanishing induced spinor curvature is possible and CP_2 projection is 1-dimensional, which does not conform with the assumption that elementary particles correspond to Kähler magnetic monopoles.

3. There is an objection against this picture. The topology of CP_2 projection must be consistent with the genus of the partonic 2-surface [2]. The conditions that plane waves and color partial waves are constant at the partonic 2-surface means that one can regard partonic 2-surfaces as sub-manifolds in 4-dimensional sub-manifold of $A \times B \subset \delta CD \times CP_2$. The topologies of $AandB$ pose no conditions on the genus of partonic 2-surface locally. Therefore the objection does not bite.

One can consider also partonic 2-surfaces containing several fermions. In the case of covariantly constant right-handed neutrino this gives no additional conditions in CP_2 degrees of freedom if the right handed neutrino has M^2 momentum projection collinear with the already existing fermion. Therefore $\Psi = C$ constraint is consistent with SUSY in TGD sense. For other fermions N-fermion state gives $2N$ conditions in CP_2 degrees of freedom. Already for $N = 2$ the solutions consist of discrete points of CP_2. Physical intuition suggests that the states with higher fermion number are not realized as maxima of Kähler function and are effectively absent unlike the observed states and their spartners.

2.2 About the construction of mesons and elementary bosons in TGD Universe

It looks somewhat strange to talk about the construction of mesons and elementary bosons in the same sentence. The construction recipes are however structurally identical so that it is perhaps sensible to proceed from mesons to elementary bosons. Therefore I will first consider the construction of meson like states relevant for the TGD based model of hadrons, in particular for the model of the pion of M_{89} hadron physics possibly explaining the 125 GeV state for which LHC finds evidence. The more standard interpretation is as elementary spin 0 boson, which need not however have anything to do with Higgs. Amusingly, the two alternatives obey very similar mathematics.

2.2.1 Construction of meson like states in TGD framework

The challenge is how translate attributes like scalar and pseudo-scalar making sense at M^4 level to statements making sense at the level of $M^4 \times CP_2$.

In QCD the view about construction of pseudo-scalar mesons is roughly that one has string like object having quark and antiquark at its ends, call them A and B. The parallel translation of the antiquark spinor from A to B is needed in order to construct gauge invariant object of type $\overline{\Psi} O \Psi$, where O characterizes the meson. The parallel translation implies stringy non-locality. In lattice QCD this string correspond to the edge of lattice cell. For a general meson O is "charge matrix" obtained as a combination of gamma matrices (γ_5 matrix for pseudo-scalar), polarization vectors, and isospin matrices.

This procedure must be generalized to TGD context. In fact a similar procedure applies also in the construction of gauge bosons possible Higgs like states since also in this case one must have general coordinate invariance and gauge invariance. Consider as an example pseudo-scalars.

1. Pseudo-scalars in M^4 are replaced with axial vectors in $M^4 \times CP_2$ with components in CP_2 direction. One can say that these pseudo-scalars have CP_2 polarization representing the charge of the pseudo-scalar meson. One replaces γ_5 with $\gamma_5 \times O_a$ where $O_a = O_a^k \gamma_k$ is the analog of $\epsilon^k \gamma_k$ for gauge boson. Now however the gamma matrices are CP_2 gamma matrices and O_a^k is some vector field in CP_2. The index a labels the isospin components of the meson.

2. What can one assume about O_a at the partonic 2-surfaces? In the case of pseudo-scalars pion and η (or vector mesons ρ and ω with nearly the same masses) one should have four such fields forming isospin triplet and singlet with large mass splitting. In the case of kaon would should have also 4 such fields but with almost degenerate masses. Why such a large difference between kaon and (π, η) system? A plausible explanation is in terms of mixing of neutral pseudo-scalar mesons with vanishing weak isospin mesons raising the mass of η but one might dream of alternative explanations too.

   (a) Obviously O_a:s should form strong isospin triplets and singlets in case of (π, η) system. In the case of kaon system they should form strong isospin doublets. The group in question should be identifiable as strong isospin group. One can formally identify the subgroup $U(2) \subset SU(3)$ as a counterpart of strong isospin group. The group $SO(3) \subset SU(3)$ defines second candidate of this kind. These subgroups correspond to two different geodesic spheres of S^2. The first gives rise to vacuum extremals of Kähler action and second one to non-vacuum extremals carrying magnetic charge at the partonic 2-surface. Cosmic strings as vacuum extremals and cosmic strings as magnetically charged objects are basic examples of what one obtains. The fact that partonic 2-surfaces carry Kähler magnetic charge strongly suggests that $U(2)$ option is the only sensible one but one must avoid too strong conclusions.

   (b) Could one identify O_a as Killing vector fields for $u(2) \subset su(3)$ or for its complement and in this manner obtain two kinds of meson states directly from the basic Lie algebra structure of color algebra? For $u(2)$ one would obtain 3+1 vector fields forming a representation of $u(2)$ decomposing to a direct sum of representations 3 and 1 of $U(2)$ having interpretation in terms of π and η the symmetry breaking is expected to be small between these representations. For the complement of $u(2)$ one would obtain doublet and its conjugate corresponding to kaon like states. Mesons states are constructed from the four states $U_i\overline{D}_j$, $\overline{U}_iD_j$, $U_i\overline{U}_j$, $D_i\overline{D}_j$. For $i=j$ one would have $u(2)$ and for $i\neq j$ its complement.

(c) One would obtain a connection between color group and strong isospin group at the level of meson states and one could say that mesons states are not color invariants in the strict sense of the world since color would act on electroweak spin degrees of freedom non-trivially. This could relate naturally to the possibility to characterize hadrons at the low energy limit of theory in terms of electroweak quantum numbers. Strong force at low energies could be described as color force but acting only on the electroweak spin degrees of freedom. This is certainly something new not predicted by the standard model.

3. Covariant constancy of O_a at the entire partonic 2-surface is perhaps too strong a constraint. One can however assume this condition only at the the braid ends.

(a) The holonomy algebra of the partonic 2-surface is Abelian and reduces to a direct sum of left and right handed parts. For both left- and right-handed parts it reduces to a direct sum of two algebras. Covariant constancy requires that the induced spinor curvature defining classical electroweak gauge field commutes with O_a. The physical interpretation is that electrowak symmetries commute with strong symmetries defined by O_a. There would be at least two conditions depending only on the CP_2 projection of the partonic 2-surface.

(b) The conditions have the form

$$F^{AB}j^a_B = 0 \ ,$$

where a is color index for the sub-algebra in question and A,B are electroweak indices. The conditions are quadratic in the gradients of CP_2 coordinates. One can interpret F^{AB} as components of gauge field in CP_2 with Abelian holonomy and j^a as electroweak current. The condition would say that the electroweak Lorentz force acting on j^a vanishes at the partonic 2-surface projected to CP_2. This interpretation looks natural classically. The conditions are trivially satisfied at points, where one has $j^a_B=0$, that is at the fixed points of the one-parameter subgroups of isometries in question. O_a would however vanish identically in this case.

(c) The condition $F^{AB}j^a_B=0$ at all points of the partonic 2-surface looks un-necessary strong and might fail to have solution. The reason is that quantum classical correspondence strongly suggests that the color partial waves of fermions and planewaves associated with 4-momentum are constant along the partonic surface. The additional condition $F^{AB}j^a_B=0$ allows only a discrete set of solutions.

A weaker form of these conditions would hold true for the braid ends only and could be used to identify them. This conforms with the notion of finite measurement resolution and looks rather natural from the point of view of quantum classical correspondence. Both forms of the conditions allows SUSY in the sense that one can add to the fermionic state at partonic 2-surface a covariantly constant right-handed neutrino spinor with opposite fermionic helicity.

(d) These conditions would be satisfied only for the operators O_a characterizing the meson state and this would give rise to symmetry breaking relating to the mass splittings. Physical intuition suggests that the constraint on the partonic 2-surface should select or at least pose constraints on the maximum of Kähler function. This would give the desired quantum classical correlation between the quantum numbers of meson and space-time surface.

4. The parallel translation between the ends connecting the partonic 2-surfaces at which quark and antiquark reside at braid ends is along braid strand defining the state of string like object at the boundary of CD. These stringy world sheets are fundamental structures in quantum TGD and a possible interpretation is as singularity of the effective covering of the imbedding space associated with the hierarchy of Planck constans and due to the vacuum degeneracy of

Kähler action implying that canonical momentum densities correspond to several values for the gradients of imbedding space coordinates. The parallel translation is therefore unique once the partonic 2-surface is fixed. This is of outmost importance for the well-definedness of quantum states. Obviously this state of affairs gives an additional "must" for braids.

The construction recipe generalizes trivially to scalars. There is however a delicate issue associated with the construction of spin 1 partners of the pseudo-scalar mesons. One must assign to a spin 1 meson polarization vector using $\epsilon^k\gamma_k$ as an additional factor in the "charge matrix" slashed between fermion and antifermion. If the charge matrix is taken to be $Q_a = \epsilon^k\gamma_k j^a_k\Gamma^k$, it has matrix elements only between quark and lepton spinors. The solution of the problem is simple. The triplet of charge matrices defined as $Q_a = \epsilon^k\gamma_k D_k j^a_l\Sigma^{kl}$ transforms in the same manner as the original triplet under $U(2)$ rotations and can be used in the construction of spin 1 vector mesons.

2.2.2 Generalization to the construction of gauge bosons and spin 0 bosons

The above developed argument generalizes with trivial modifications to the construction of the gauge bosons and possible Higgs like states as well as their super-partners.

1. Now one must form bi-linears from fermion and anti-fermion at the opposite throats of the wormhole contact rather than at the ends of magnetic flux tube. This requires braid strands along the wormhole contact and parallel translation of the spinors along them. Hadronic strings are replaced with the TGD counterparts of fundamental strings.

2. For electro-weak gauge bosons O corresponds to the product $\epsilon_k\gamma^k Q_i$, where Q_i is the charge matrix associated with gauge bosons contracted between both leptonic and quark like states. For gluons the charge matrix is of form $Q_A = \epsilon_k\gamma^k H_A$, where H_A is the Hamiltonian of the corresponding color isometry.

3. One can also consider the possibility of charge matrices of form $Q_A = \epsilon^k\gamma_k D_k j^A_l\Sigma^{kl}$, where j^A is the Killing vector field of color isometry. These states would compose to representations of $u(2) \subset u(3)$ to form the analogs of (ρ,ω) and $(K^*,\overline{K}^*)$ system in CP_2 scale. This is definitely something new.

4. In the case of spin zero states polarization vector is replaced with polarization in CP_2 degrees of freedom represented by one of the operators O_a already discussed. One would obtain the analogs of (π,η) and $(K,\overline{K})$ systems at the level of wormhole contacts. Higgs mechanism for these does not explain fermionic masses since p-adic thermodynamics gives the dominant contributions to them. It is also difficult to imagine how gauge bosons could eat these states and what the generation of vacuum expectation value could mean mathematically. Higgs mechanism is essentially 4-D concept and now the situation is 8-dimensional.

5. At least part of spin zero states corresponds to polarizations in CP_2 directions for the electroweak gauge bosons. This would mean that one replaces $\epsilon_k\gamma^k$ with $j^k_a\Gamma_k$, where j_a is Killing vector field of color isometry in the complement of $u(2) \subset su(3)$. This would give four additional polarization states. One would have 4+2=6 polarization just as one for a gauge field in 8-D Minkowski space. What about the polarization directions defined by $u(2)$ itself? For the Kähler part of electroweak gauge field this part would give just the (ρ,ω) like states already mentioned. Internal consistency might force to drop these states from consideration.

The nice aspect of p-adic mass calculations is that they are so general: only super-conformal invariance and p-adic thermodynamics and p-adic length scale hypothesis are assumed. The drawback is that this leaves a lot of room for the detailed modeling of elementary particles.

1. Lightest mesons are lowest states at Regge trajectories and also p-adic mass calculations assign Regge trajectories in CP_2 scale to both fermions and bosons.

2. It would be natural to assign the string tension with the wormhole contact in the case of bosons and identifiable in terms of the Kähler action assignable to the wormhole contact modelable as piece of CP_2 type vacuum extremal and having interpretation in terms of the action of Kähler magnetic fields.

3. Free fermion has only single wormhole throat. The action of the piece of CP_2 type vacuum extremal could give rise to the string tension also now. One would have something analogous to a string with only one end, and one can worry whether this is enough. The magnetic flux of the fermion however enters to the Minkowskian region and ends up eventually to a wormhole throat with opposite magnetic charge. This contribution to the string tension is however expected to be small being proportional to $1/S$, where S is the thickness of the magnetic flux tube connecting the throats. Only if the magnetic flux tube remains narrow, does one obtain the needed string tension from the Minkowskian contribution. This is the case if the flux tube is very short. It seem that the dominant contribution to the string tension must come from the wormhole throat.

4. The explanation of family replication phenomenon [2] based on the genus of wormhole throat works for fermions if the the genus is same for the two throats associated with the fermion. In case of bosons the possibility of different genera leads to a prediction of dynamical SU(3) group assignable to genus degree of freedom and gauge bosons should appear also in octets besides singlets corresponding to ordinary elementary particles. For the option assuming identical genera also for bosons only the singlets are possible.

5. Regge trajectories in CP_2 scale indeed absolutely essential in p-adic thermodynamics in which massless states generate thermal mass in p-adic sense. This makes sense in zero energy ontology without breaking of Poincare invariance if CD corresponds to the rest system of the massive particle. An alternative way to achieve Lorentz invariance is to assume that observed mass squared equals to the thermal expectation value of thermal weight rather than being thermal expectation for mass squared.

It must be emphasized that spin 0 states and exotic spin 1 states togetherwith their super-partners might be excluded by some general arguments. Induced gauge fields have only two polarization states, and one might argue that that same reduction takes place at the quantum level for the number of polarization states which would mean the elimination of $F_L\overline{F}_R$ type states having interpretation as CP_2 type polarizations for gauge bosons. One could also argue that only gauge bosons with charge matrices corresponding to induced spinor connection and gluons are realized. The situation remains open in this respect.

3 Construction of fermionic and bosonic super-multiplets

The missing energy predicted standard SUSY is absent at LHC. The easy explanation would be that the mass scale of SUSY is unexpectedly high, of order 1 TeV. This would however destroy the original motivations for SUSY.

In TGD framework the first guess is that the missing energy corresponds to covariantly constant right-handed neutrinos carrying four-momentum. The objection is that covariantly constant right-handed neutrinos cannot appear in asymptotic states because one cannot assign a super-multiplet to right-handed neutrinos consistently. Covariantly constant right-handed neutrinos can however generate SUSY.

This alone would explain the missing missing momentum at LHC predicted by standard SUSY. 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. So called leptohadrons could correspond to bound states of colored sleptons and have same p-adic mass scale as leptons have [8]. Even in the case of quarks the situation could be the same.

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

3.1 Fermionic super-multiplets

The construction of fermionic multiplets is based on the identification of SUSY generators as covariantly constant right handed neutrinos.

1. Right-handed neutrinos carry momenta momenta for which $M^2 \subset M^4$ projections are collinear with those for the basic fermion but are covariantly constant spinors in CP_2 degrees of freedom.

2. For all quarks and leptons except right handed neutrino one obtains for a given helicity 4 states so that one has $\mathcal{N} = 2$ multiplet containing four particles with helicities 0,1/2,1. Multiplets contain fermion number 2 state which for Majorana SUSY would correspond to boson with vanishing fermion number. In the case of leptons one has states with $L = 2$, and in case of quarks states having $(L, q) = (1, 1)$.

3. Right-handed neutrino is an exception. Pauli Principle does not allow to assign with it a $\mathcal{N} = 2$ multiplet. Also the assignment of $\mathcal{N} = 1$ multiplet fails since $\nu_R\overline{\nu}_R$ state would be associated with both ν_R and $\overline{\nu}_R$. The condition that asymptotic states correspond to full super-multiplets implies that covariantly constant neutrino cannot appear as asymptotic state.

   (a) Higher color partial waves of right handed neutrino can however appear as asymptotic states, and in decays of sfermions these states must be produced in pairs and combine to form color singlets transforming to ordinary fermions by exchange of gluons. This would explain why the missing energy due to the decay to light superpartners has not been detected at LHC.

   (b) Right handed neutrinos would be eaten by left handed neutrinos as they become massive. Right-handed neutrinos pair $\nu_R\overline{\nu}_R$ would be eaten by Z^0 boson. I have earlier proposed a variant of this mechanism assuming that colored right-handed neutrino appears as SUSY generator. This mechanism is however un-necessarily complicated and not consistent with the proposed partonic description. This modified rather dramatically the standard vision about SUSY.

   (c) Sparticles could even correspond to the same p-adic mass scale as sparticles. In particular, leptohadrons for which there is considerable evidence, could correspond to pairs of slepton and its antiparticle: they must however have non-standard value of Planck constant possible in TGD framework [6]. Also in the case of hadrons smesons consisting of squark pairs are predicted and there is some evidence that pions and also other mesons such as charmonium possess states having no interpretation in the standard QCD framework [6].

The tables 1 and 2 summarize the contents of left and right handed multiplets for leptons and quarks.

3.2 Gauge boson and spin 0 super-multiplets

Overall view about gauge boson super-multiplets is following.

1. The simplest model assumes only spin 1 gauge bosons and their spartners. This means that only spin 1-type multiplets are assumed as ground states. From the fermion and antifermion defining the ground state one builds super-multiplets. This gives $4 \times 4 = 16$ gauge boson states for a given helicity (left handed or right handed boson of given helicity which is of form $F_L\overline{F}_L$ or $F_R\overline{F}_R$. Physical states are massive and superposition of left and right handed parts in general. This is not the most general option but conforms with the minimal vision that TGD predicts no Higgs.

2. The condition that both fermion and antifermion are on mass shell states with positive sign of energy requires that the 3-momenta are opposite or at least non-parallel. This forces massivation of gauge bosons.

3. For the antifermion at second throat fermion number changes sign but helicity remains same in the above tables: $(q, L) \to -(q, L)$, $h \to h$. In terms of above tables the quantum numbers of the gauge boson like state are $F = F_1 + F_2$ and $h = h_1 + h_2$.

4. The resulting gauge boson multiplets correspond to multiplets of $\mathcal{N} = 4$ SUSY as one sees from the tables below: the total numbers of fermionic and bosonic states are indeed 8 for a given helicity. In the fermionic case one has $\mathcal{N} = 2$. The analogy is so called short representations for $\mathcal{N} = 4$ SUSY for which one half of SUSY generators annihilate the state. For $\mathcal{N} = 4$ SYM the

super generators have same helicity and and the gauge boson multiplets with opposite helicities define one and same multiplet. Now the multiplets are different.

Table 3 gives the lepton pair projections of W bosons which contain only left handed lepton pairs, that is $e_L\overline{\nu}_L$ and superpartners appearing as building blocks of W multiplet. Table 4 gives the lepton pair projections for $e_R\overline{e}_R$ and its superpartners appearing in Z^0 and γ multiplet. Quark pair projections are obtained in obvious manner and have same total quantum numbers.

Also spin 0 particles has super-partners. The construction of the spin 0 particles has been already discussed. Fermionic representations of SUSY induces the super-multiplets assignable to spin zero states as their tensor products. $\mathcal{N} = 4$ SUSY is obtained also now but with charge assignments different from the standard SUSY. The table 5 gives and example of the predicted supermultiplet.

3.3 Tables

state	(h,L)
$e_L\nu_R$	(0,2)
$e_L, e_L\nu_R\overline{\nu}_R$	(-1/2,1)
$e_L\overline{\nu}_R$	(1,0)
$e_R\nu_R$	(1,2)
$e_R, e_R\nu_R\overline{\nu}_R$	(1/2,1)
$e_R\overline{\nu}_R$	(0,0)

Table 1: The super-multiplet associated with e_L and e_R together with helicity and lepton number assignments. Note that for e_L scalar state has lepton number 2 and spin 1 state lepton number 0. For e_R scalar has lepton number 0 and spin 1 state lepton number 2. This means parity breaking at the level of multiplets induced by the fact that super-generator is always right-handed fermion.

state	(h,q,L)
$q_L\nu_R$	(0,1,1)
$q_L, q_L\nu_R\overline{\nu}_R$	(-1/2,1,0)
$q_L\overline{\nu}_R$	(-1,1,-1)
$q_R\nu_R$	(1,1,1)
$q_R, q_L\nu_R\overline{\nu}_R$	(1/2,1,0)
$q_R\overline{\nu}_R$	(0,1,-1)

Table 2: The super-multiplet associated with quarks together with helicity and quark and lepton number assignments.

(h,L)	(0,-2)	(-1/2,-1)	(1,0)
(0,2)	(0,0)	$2\times(-1/2,1)$	(1,2)
$2\times(-1/2,1)$	$2\times(-1/2,-1)$	$4\times(-1,0)$	$2\times(1/2,1)$
(1,0)	(1,-2)	$2\times(1/2,-1)$	(2,0)

Table 3: $e_L\overline{\nu}_L$ and superpartners appearing as lepton pair building blocks of W super-multiplet. The elements of the table give the total helicity and lepton number given by $(h, L) = (h_1 + h_2, F_1 + F_2)$, where h_i and F_i are helicities and lepton numbers associated with the multiplets at the two wormhole throats carrying opposite three-momenta and opposite fermion numbers.

(h,L)	(1,-2)	(1/2,-1)	(0,0)
(1,2)	(2,0)	$2 \times (3/2, 1)$	(1,2)
$2 \times (1/2, 1)$	$2 \times (3/2, -1)$	$4 \times (1, 0)$	$2 \times (1/2, 1)$
(0,0)	(1,-2)	$2 \times (1/2, -1)$	(0,0)

Table 4: $e_R\overline{e}_R$ and superpartners appearing as building blocks of Z and photon super-multiplet. The elements of the table give the total helicity and lepton number given as $(h, L) = (h1 + h_2, F_1 + F_2)$, where h_i and F_i are helicities and lepton numbers associated with the multiplets at the two wormhole throats carrying opposite three-momenta (change in the sign of helicity) and opposite fermion numbers.

(h,L)	(1,-2)	(1/2,-1)	(0,0)
(0,2)	(1,0)	$2 \times (1/2, 1)$	(0,2)
$2 \times (-1/2, 1)$	$2 \times (1/2, -1)$	$4 \times (0, 0)$	$2 \times (-1/2, 1)$
(1,0)	(2,-2)	$2 \times (3/2, -1)$	(1,0)

Table 5: $e_L\overline{e}_R$ and superpartners appearing as building blocks of possible Higgs-like super-multiplet. The elements of the table give the total helicity and lepton number given as $(h, L) = (h1+h_2, F_1+F_2)$, where h_i and F_i are helicities and lepton numbers associated with the multiplets at the two wormhole throats carrying opposite three-momenta (change in the sign of helicity) and opposite fermion numbers.

Books related to TGD

[1] M. Pitkänen. Construction of Configuration Space Kähler Geometry from Symmetry Principles. In *Quantum Physics as Infinite-Dimensional Geometry*. Onlinebook. http://tgdtheory.com/public_html/tgdgeom/tgdgeom.html#compl1, 2006.

[2] M. Pitkänen. Construction of elementary particle vacuum functionals. In *p-Adic length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#elvafu, 2006.

[3] M. Pitkänen. Construction of Quantum Theory: Symmetries. In *Towards M-Matrix*. Onlinebook. http://tgdtheory.com/public_html/tgdquant/tgdquant.html#quthe, 2006.

[4] M. Pitkänen. Does the Modified Dirac Equation Define the Fundamental Action Principle? In *Quantum Physics as Infinite-Dimensional Geometry*. Onlinebook. http://tgdtheory.com/public_html/tgdgeom/tgdgeom.html#Dirac, 2006.

[5] M. Pitkänen. Massless states and particle massivation. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#mless, 2006.

[6] M. Pitkänen. New Particle Physics Predicted by TGD: Part I. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#mass4, 2006.

[7] M. Pitkänen. Quantum Field Theory Limit of TGD from Bosonic Emergence. In *Towards M-Matrix*. Onlinebook. http://tgdtheory.com/public_html/tgdquant/tgdquant.html#emergence, 2006.

[8] M. Pitkänen. The Recent Status of Lepto-hadron Hypothesis. In *p-Adic Length Scale Hypothesis and Dark Matter Hierarchy*. Onlinebook. http://tgdtheory.com/public_html/paddark/paddark.html#leptc, 2006.