SUSY after LHC: the TGD perspective

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Abstract

Contrary to the expectations, SUSY was not found at LHC and the basic motivations for SUSY were lost. This forces to ask whether there is something fundamentally wrong in the recent views about supersymmetry often identified as $\mathcal{N}=1$ SUSY predicting Majorana fermions.

In this article I will consider the problem from TGD perspective and discuss the recent TGD view about supersymmetry. There are several important new elements involved.

1. The identification of preferred extremals of the action principle as singular minimal surfaces forced by the twistor lift of TGD. These minimal surfaces have string world sheets as analogs of edges/folds.
2. The replacement of 4-D light-masslessness with its 8-D counterpart essential for the twistor lift and the extension of super-conformal invariance from 2-D surfaces to 3-D light-like surfaces. Superconformal multiplets are massless in 8-D sense and can contain also particles massless in 4-D sense. Superconformal symmetry in 8-D sense would be exact. Superconformal multiplets analogous to SUSY multiplets at large $\mathcal{N}$ limit.
3. The notion of induced spinor structure. Induced spinor modes can be assigned with the interior of space-time surface, with string world sheets at which the action has delta function like singularity, and with the light-like curves defining 1-D boundaries of string world sheets at the light-like 3-D orbits of partonic 2-surfaces. All these modes represent fermionic degrees of freedom.

The many fermion states at partonic 2-surfaces consisting of point-like fundamental fermions define superconformal multiplets. Fundamental fermions in turn serve as building bricks of ordinary elementary particles. These states are massless only in 8-D sense. Twistor lift actually suggests that all many-particle states can be regarded as resonances massless in 8-D sense. String world sheet fermions could be assignable to hadrons and weak bosons.

Induced spinor structure implies mixing of M^4 chiralities and massivation in 4-D sense. Right-handed neutrino generates the analog of $\mathcal{N}=2$ SUSY broken in 4-D sense by this mixing: one can also say right-handed neutrino is "eaten" by massive neutrino. By the small size of partonic 2-surfaces, 4-D SUSY is badly broken for elementary particles but stringy and interior modes of fermions, in particular right-handed neutrinos, could give rise to light excitations obeying weakly broken SUSY. They would not give to effects expected in standard SUSY, which would explain why SUSY has not been found in elementary particle physics. Interior excitations might be more natural in condensed matter context than in elementary particle physics.

1 Introduction

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 super-conformal 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 [K4] 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.

2 Space-time SUSY from TGD point of view

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 [K2, K3, K1]. 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 [L1, L2, L3] [K4].

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 [L1, L2, L3] 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.

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