Resurrecting Supersymmetry

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Abstract

Consenting to negative results in standard model superpartner search at the LHC and elsewhere I propose an alternative point of view, a preon model with unbroken supersymmetry. It offers a natural basis for constructing the standard model and going beyond it. Pivotal significance of preon supersymmetry to superstring theory is discussed briefly.

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1 Introduction

It is commonly stated that the CERN LHC has 'failed' to discover supersymmetry (SUSY). But in fact, LHC has only indicated where supersymmetry is not to be found. At the same time LHC has given strong support for the standard model of particles (SM). Consequently, I have proposed that supersymmetry functions on preon level and it is unbroken, or at most softly broken [1]. The SUSY preon model contains all the fields and their superpartner fields in its supermultiplets. Therefore no new superpartners need to be found experimentally. Quarks and leptons are represented as three preons states. By Weinberg reasoning [2] this supersymmetric model is of pivotal significance for supergravity and superstring theory development.

The article is organized as follows. In section 2 I give motivation for the preon model. The construction of scalars, quarks and leptons as composite states of supersymmetric preons is presented in section 3. In section 4 fundamentals of gravity are examined. Short discussion of supergravity is given in section 5. Conclusions are given in the final section 6.

2 Why Preons?

When one wants to go beyond the standard model one has to consider what is the most important element missing from the SM. Here I assume it is gravity. Admittedly, it is also the most difficult problem in theoretical physics. Therefore it is reasonable to start with something simple and generally accepted like global symmetries are forbidden by quantum gravity [3]. In such a scheme the SM particles, quarks and leptons, carrying baryon and lepton number, may not be the best particles for supersymmetric model building. One must play with fewer quantum numbers. Such a model was introduced in [4, 5, 6, 1]. I considered the supersymmetric[1] preon model scheme with these properties

- the quantum numbers of basic objects must be those available for vacuum solutions of Einstein equations: mass, spin and charge (no-hair),
- supersymmetry is unbroken and valid for preons,
- the basic fields are members of a supermultiplet which includes the graviton, photon, a light spin $\frac{1}{2}$ preon of charge $\frac{1}{3}$, and their superpartners, and
- scalar particles, preons, quarks and leptons are classified using the quantum group SLq(2) representations [7, 8].

It is supposed that quantum gravity, when available, will organize the preons in bound states in three generations. A tentative preon binding mechanism will be described elsewhere. Alternatively, there may be a new very strong gauge interaction between the preons.

[1] Supersymmetry was anticipated in passing in [4].

3 Supersymmetric Preon Model

In the present supersymmetric preon model we have, starting with the highest spin states, the graviton G and its spin $\frac{3}{2}$ superpartner gravitino $\tilde{G}$

$$G = \begin{pmatrix} \rightarrow \\ \leftarrow \end{pmatrix} \text{ and } \tilde{\mathrm{G}} = \begin{pmatrix} \rightarrow \\ \leftarrow \end{pmatrix} \tag{3.1}$$

This the graviton supermultiplet.

On the next level down in spin there are the photon γ and its neutral spin $\frac{1}{2}$ superpartner, the photino, denoted $\tilde{m}^0$. The third superpair is the spin $\frac{1}{2}$, charge $\frac{1}{3}$ preon m^+ and two scalar superpartners $\tilde{s}_i^+$, i = 1, 2. All fields γ, $\tilde{m}^0$, m^+ and $\tilde{s}_i^+$ have two degrees of freedom:

$$\gamma = \begin{pmatrix} \rightarrow \\ \leftarrow \end{pmatrix} \text{ and } \tilde{\mathrm{m}}^0 = \begin{pmatrix} \uparrow \\ \downarrow \end{pmatrix}, \ \mathrm{m}^+ = \begin{pmatrix} \uparrow \\ \downarrow \end{pmatrix} \text{ and } \tilde{\mathrm{s}}_{1,2}^+ \tag{3.2}$$

where the horizontal and vertical arrows refer to helicity and spin, respectively, and + and 0 refer to charge in units of $\frac{1}{3}$ electron charge. The $\tilde{m}^0$ is a Majorana fermion. The γ and the $\tilde{m}^0$ form the gauge supermultiplet and the m^+ and the $\tilde{s}_{1,2}^+$ form the chiral supermultiplet. The R-parity for fields in (3.2) is simply $P_R = (-1)^{2(spin)}$. All fields are assumed to be massless or to have light mass, of the order of the first generation quark and lepton mass scale.

The preons combine freely, modulo three, without extra assumptions into standard model fermion composite states. They form a three member combinatorial system [5]. For the same charge preons fermionic permutation antisymmetry factor ϵ_{ijk} must be included. These arguments lead heuristically to four bound states made of preons, which form the first generation quarks (q) and leptons (l) (dropping the tildes)

$$\begin{aligned} u_k &= \epsilon_{ijk} m_i^+ m_j^+ m^0 \\ \bar{d}_k &= \epsilon_{ijk} m^+ m_i^0 m_j^0 \\ e &= \epsilon_{ijk} m_i^- m_j^- m_k^- \\ \bar{\nu} &= \epsilon_{ijk} \bar{m}_i^0 \bar{m}_j^0 \bar{m}_k^0 \end{aligned} \tag{3.3}$$

Above the energy of the order $\Lambda_{cr} \sim 10^{16\pm1}$ GeV quarks and leptons ionize, or make a phase transition, into their constituents, preons. Below this critical point, I consider the standard model a well behaving renormalizable theory with a UV momentum cutoff Λ_{cr}. Above this transition energy unbroken supersymmetry enters the scene: it is defined for preons, which are now unbound and massless.

I consider this preon model on par with the early quark model, with the u, d and s quarks but without gluons. This circumstance is utilized in section 5.

Bound states of scalar constituents do not make a spectrum like fermions. A neutral, very light two body bound state is expected to exist

$$a_i^0 = \tilde{s}_i^+ \ \tilde{s}_i^-, \quad i = 1, 2 \tag{3.4}$$

Scalar bound states can also be formed from the fermions

$$\begin{aligned} b^0 &= m^+ m^- \\ c^0 &= m^0 m^0 \\ h^\pm &= m^\pm m^0 \end{aligned} \tag{3.5}$$

The states (3.4) and (3.5) (and other possible states including mixtures) are candidates for the Higgs and the axion. Finally, the model allows an unbound scalar charge $\frac{1}{3}$ field.

4 Fundamentals of General Relativity

Let us consider gravity from the point of view of symmetry and helicity states. The needed gauge symmetry is linearized general coordinate invariance. The helicity of the graviton is two. Demanding consistent graviton self-interactions leads to general relativity with full general coordinate invariance [9, 10]. Further, helicity two implies the equivalence principle [10].

Strictly speaking, gauge symmetries are redundancies of description rather than fundamental properties. One can always fix the gauge and eliminate the gauge symmetry, without changing the physics of the system. If a system does not have gauge invariance it is always possible to introduce redundant variables and restore gauge symmetry. This procedure is called Stueckelberg trick [11]. Using it one can make any Lagrangian invariant under general coordinate diffeomorphism. Therefore this symmetry is not adequate for defining general relativity. The principle of equivalence is in a similar position in general relativity. It can be satisfied even in scalar theories by defining the interaction in a proper way.

Let us now consider briefly local supersymmetry following [12]. Let the supersymmetry parameter depend on spacetime coordinate

$$\begin{aligned} \delta_\epsilon B &= \bar{\epsilon}(x) F \\ \delta_\epsilon F &= \epsilon(x) \partial B \end{aligned} \tag{4.1}$$

The commutator of two infinitesimal transformations δ_ϵ yields

$$[\delta_{\epsilon_1}, \delta_{\epsilon_2}] B \propto (\bar{\epsilon_1} \gamma^\mu \epsilon_2)(x) \partial B \tag{4.2}$$

The factor $(\bar{\epsilon_1} \gamma^\mu \epsilon_2)(x)$ is an element of the infinitesimal version of the group of local diffeomorphism on spacetime. Therefore locally supersymmetric theory is necessarily diffeomorphism invariant. The best known diffeomorphism invariant theory is, of course, general relativity.

In summary, coordinate invariance, equivalence principle or geometry are not the basic principles of general relativity. Rather it is the statement [9]:
"... general relativity is the theory of a non-trivially interacting massless helicity two particle. The other properties are consequences of this statement, and the implication cannot be reversed".

5 Supergravity

Having established supersymmetry in the preon model, one may perceive the action for the model as follows

$$\mathcal{L} = \mathcal{L}_G + \mathcal{L}_g + \mathcal{L}_c + \mathcal{L}_i \tag{5.1}$$

where the terms are for gravity, gauge field, chiral fields and interactions, respectively. The gravity term is written using supergravity fields (3.1). The gauge term includes the photon and its superpartner. The matter term contains the chiral supermultiplet and the potential term that the the preons undergo (at this tender stage one may restrain writing all terms explicitly). In (5.1) the 4D electromagnetic gauge theory is added to gravity, unlike in the gauge/gravity duality.

The supergravity equation, equivalent to the Einstein equation, is derived from the variation of (5.1). All the terms are now of the same field theory origin, supergravity.

This model is intended to serve as a guide to defining mathematical expressions for the next level particle description. Any realistic theory of quantum gravity is expected to differ from the present model but it is hoped that the present definition of supersymmetry in section 3 may give, if properly understood, a pivotal clue on the road forward. Fair enough, there seems to be a goal indicated by Weinberg [2]:
"Gravity exists, so if there is any truth to supersymmetry then any realistic supersymmetry theory must eventually be enlarged to a supersymmetric theory of matter and gravitation, known as supergravity. Supersymmetry without supergravity is not an option, though it may be a good approximation at energies below the Planck Scale.",

secondly, superstrings are hinted
"Supergravity is itself only an effective nonrenormalizable theory which breaks down at the Planck energies. So if there is any truth to supersymmetry then any realistic theory must eventually be enlarged to superstrings which are ultraviolet finite. Supersymmetry without superstrings is not an option.",

and finally the non-perturbative M-theory looms to us
"Superstring theory is itself only a perturbative theory which breaks down at strong coupling. So if there is any truth to supersymmetry then any realistic theory must eventually be enlarged to the non-perturbative M-theory, a theory involving higher dimensional extended objects: the super p-branes. Supersymmetry without M-theory is not an option.".

The question now is what can be done for superstrings and -branes to conform to preons and the standard model?

6 Summary and Outlook

The present supersymmetric preon model is based on the proposal that the physical domain of supersymmetry is the preon level instead of quark and lepton level. Consequently, both the particles/fields and the superpartners are in the basic supermultiplets. Supersymmetric models possess diffeomorphism invariance and they are (in D=10) low energy limits of superstring theory. Therefore the model has rich enough structure for quantitative study on the way towards quantum gravity. Summarizing, the model

- is an economic way to build the standard model fermions,
- has no SM-like superpartner issue, and
- gives a basis to higher level constructions, like superstring theory, by the Weinberg enlargement principle.

Compared to the early version of the preon model the new fields are the two scalar spreons $\tilde{s}$ having charge $\frac{1}{3}$. Consequently, there must be in nature two three spreon scalar boson bound states with charge one. Preon-antipreon and spreon-antispreon pairs may make two neutral observable scalar bosons. It is tempting to associate both the charged bound states and the neutral preon-antipreon pair with the Higgs bosons [21]. Even charge $\frac{1}{3}$ scalar bosons must exist, which would be a clear signal for the model. The supersymmetry phenomenology is to be recalculated and extended to local supersymmetry [22].

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