Supersymmetric Preons Peeking Superstrings

Risto Raitio*
02230 Espoo, Finland

February 12, 2019

Abstract

Consenting to negative results in standard model superpartner search at the LHC and elsewhere an alternative point of view has been proposed, a preon model with unbroken supersymmetry. It offers a natural basis for constructing the standard model and going beyond it. Significance of the supersymmetric particle model to superstring theory is discussed briefly on the basis of Weinberg rationale.

PACS 12.60.Rc

Keywords: Preons, Supersymmetry, Supergravity, Standard Model

---

*E-mail: risto.raitio@gmail.com

1 Introduction

It is commonly stated that the CERN LHC has 'failed' to discover supersymmetry (SUSY). But on the other hand, LHC has perhaps only indicated where supersymmetry is not to be found. In addition, LHC has given strong support for the standard model (SM) of particles. Accordingly, I have proposed that the SM quarks and leptons can be represented as three supersymmetric preon states, and supersymmetry is unbroken, or at most softly broken [1]. Therefore all fields have zero, or very small mass.

The supersymmetric preon model contains all the fields and their superpartner fields in its basic supermultiplets. Therefore no new superpartners need to be found experimentally. By embedding this model into the Weinberg rationale [2], defined in section 3, preons may gain a position in phenomenology development.

The article is organized as follows. The supersymmetric preon model is rehearsed and completed with the graviton supermultiplet in section 2. In section 3 a brief recap of general relativity is done. This section is of general nature but it emphasizes particle picture of gravity rather than traditional Riemannian geometry. Conclusions are given in the final section 4.

2 Supersymmetric Preon Model

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

$$G = \begin{pmatrix} \rightarrow \\ \leftarrow \end{pmatrix} \text{ and } \tilde{\mathrm{G}} = \begin{pmatrix} \rightarrow \\ \leftarrow \end{pmatrix} \tag{2.1}$$

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:

$$\gamma = \begin{pmatrix} \rightarrow \\ \leftarrow \end{pmatrix} \text{ and } \tilde{\mathrm{m}}^0 = \begin{pmatrix} \uparrow \\ \downarrow \end{pmatrix}, \ \mathrm{m}^+ = \begin{pmatrix} \uparrow \\ \downarrow \end{pmatrix} \text{ and } \tilde{\mathrm{s}}^+_{1,2} \tag{2.2}$$

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 $\tilde{\mathrm{s}}^+_{1,2}$ form the chiral supermultiplet. The R-parity for fields in (2.2) 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 [3]. 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)

$$\begin{aligned} u_k &= \epsilon_{ijk} m_i^+ m_j^+ m^0 \\ \bar{d}_k &= \epsilon_{ijk} m^+ m_i^0 m_j^0 \\ e &= \epsilon_{ijk} m_i^- m_j^- m_k^- \\ \bar{\nu} &= \epsilon_{ijk} \bar{m}_i^0 \bar{m}_j^0 \bar{m}_k^0 \end{aligned} \tag{2.3}$$

Above the energy of the order $\Lambda_{cr} \sim 10^{16 \pm 1}$ 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 global supersymmetric preon model on par with the early quark model, with the u and d quarks but without gluons. The model does not allow large SUSY breaking, or any high mass superpartners because $\tilde{m}^0$ is the partner of the photon and a constituent of the neutrino and the quarks.

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

$$a_i^0 = \tilde{s}_i^+ \ \tilde{s}_i^- , \quad i = 1, 2 \tag{2.4}$$

Scalar bound states can also be formed from the fermions

$$\begin{aligned} b^0 &= m^+ m^- \\ c^0 &= m^0 m^0 \\ h^\pm &= m^\pm m^0 \end{aligned} \tag{2.5}$$

The states (2.4) and (2.5) (and other possible states including mixtures) are candidates for the axion and the Higgs (the latter more precisely a $3m^\pm m^0$ state). Finally, the model allows an unbound scalar charge $\frac{1}{3}$ field.

3 Brief Recap of Particle Based Gravity Theories

3.1 Graviton and Diffeomorphism Invariance

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 [4, 5]. Further, helicity two implies the equivalence principle [5].

It is often said that Poincaré group is the gauge symmetry of gravity. 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 [6]. 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.

Discuss now briefly local supersymmetry following [7]. Let the supersymmetry parameter depend on spacetime coordinate

$$\begin{aligned} \delta_\epsilon B &= \bar{\epsilon}(x)F \\ \delta_\epsilon F &= \epsilon(x)\partial B \end{aligned} \tag{3.1}$$

The commutator of two infinitesimal transformations δ_ϵ yields

$$[\delta_{\epsilon_1}, \delta_{\epsilon_2}]B \propto (\bar{\epsilon_1}\gamma^\mu\epsilon_2)(x)\partial B \tag{3.2}$$

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.

Instead of coordinate invariance, equivalence principle or geometry the basic principle of general relativity may be taken this statement [4]:

"... 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".

3.2 Weinberg Rationale

One may perceive the action for any locally supersymmetric model as follows

$$\mathcal{L} = \mathcal{L}_G + \mathcal{L}_g + \mathcal{L}_c + \mathcal{L}_i \tag{3.3}$$

where the terms are for gravity, gauge field, chiral fields and interactions, respectively. The gravity term is written using supergravity fields (2.1). 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 (3.3) 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 (3.3). All the terms are now of the same field theory origin, supergravity.

The model of section 2 is intended to serve as a guide to defining mathematical expressions for the next, or beyond standard model level particle description.

Any realistic theory of quantum gravity may differ from the present model but it is hoped that the present definition of supersymmetry in section 2 may give, if properly understood, a useful clue on the road forward. Fair enough, there seems to be a goal indicated by Weinberg [2], call it the Weinberg rationale:

"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.",

In the first sentence of the above quotation, the leap from gravity to supergravity is too long. Gravity is basically neither supersymmetric nor microscopic. Therefore one has to define microscopic matter fields to which the graviton (2.1) is coupled. Altogether, preons of section 2 build the standard model with the minimum number of elementary fields and, as an agreeable bonus, supergravity can be formulated. 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 to make superstrings and -branes compatible with preons and the standard model. The string theory brane structure would seem to be simpler with the present model, having two abelian gauge groups, than with the standard model, having in addition two non-abelian gauge groups. Interesting enough, the Weinberg enlargement arguments do not include the SM. Therefore I am lead to the following scheme of supersymmetry breaking within the preon model in the next section.

4 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. The advantage is that both the particles and the superpartners are in the basic supermultiplets (2.1) and (2.2). 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,
- forms a natural base for unbroken global supersymmetry,

- gives a step to higher level constructions, like supergravity and superstring theory, by the Weinberg enlargement rationale.

I believe this setup of the preons brings clarity and beauty as compared to the traditional approach to supersymmetry and unification. A distinctive feature of the model is that at energies above $\Lambda_{cr} \sim 10^{16}$ GeV there are only two interactions, gravity and electromagnetism.[1]

Despite the apparent fluency of this schematic model nothing is done yet. The supersymmetry phenomenology is to be recalculated and extended to local supersymmetry [8]. A world without supersymmetry is not an option.

References

[1] Risto Raitio, Supersymmetric preons and the standard model, Nuclear Physics B931 (2018) 283–290. doi:10.1016/j.nuclphysb.2018.04.021 `arXiv:1805.03013`
Risto Raitio, A Model of Lepton and Quark Structure. Physica Scripta, 22, 197 (1980). `PS 22, 197` [2]

[2] Steven Weinberg, The Quantum Theory of Fields, Volume III, Supersymmetry, Cambridge University Press (2005).

[3] Risto Raitio, Combinatorial Preon Model for Matter and Unification, Open Access Library Journal, 3: e3032 (2016). `OALibJ 3:e3032`

[4] Kurt Hinterbichler, Theoretical Aspects of Massive Gravity, Rev. Mod. Phys. 84, 671-710 (2012). `arXiv:1105.3735`

[5] S. Weinberg, Quantum Theory of Fields, Vol. 1 Foundations, (Ch. 13) Cambridge Univ. Press (1995).

[6] H. Ruegg and M. Ruiz-Altaba, The Stueckelberg Field, Int.J.Mod.Phys. A19:3265-3348, 2004. `arXiv:hep-th/0304245`

[7] Timo Weigand, Loretta Cerbas, Basics of Supergravity (unpublished Heidelberg lectures).

[8] M. Duff, Erice lectures The status of local supersymmetry, International School of Subnuclear Physics, Erice, August 2003. `arXiv:hep-th/0403160`

---

[1] Because of asymptotic freedom of quantum chromodynamics this may be considered as an approximation to a traditional grand unified theory.

[2] The model was conceived in November 1974 at SLAC to propose that the c-quark would be a gravitational excitation of the u-quark. The idea was opposed by the community and was therefore not written down until five years later.