A three generation supersymmetric composite model of particles with frugal extra dimensions

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Abstract

A previous supersymmetric preon scenario for the first generation particles is extended to include three generations and presumable T-duality.

Keywords: Standard Model, Composite models, Supersymmetry, T-duality

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1 Introduction

We investigate the possibility that at high enough energy the elementary particles may not be the standard model (SM) particles. We have proposed instead a supersymmetric preon scenario and engineer it here further to include three generations of fermions, emerging strong interactions and suggest T-duality.

Preons, called here chernons, are free particles above an energy scale Λ_{cr}. This scale Λ_{cr} is estimated to be close to the reheating temperature of standard cosmology in the early universe, about $T_R \sim 10^{10} - 10^{16}$ GeV. It is also close to the grand unified theory (GUT) scale.

Below Λ_{cr} preons make a phase transition, by an attractive CS model interaction, into composite states of standard model quarks and leptons. At laboratory energies the composite states are well described by point-like particles.

This short note is organized as follows. In section 2 we extend our previous preon model to include all three generations of the SM. Section 3 recaps the binding chernon-chernon interaction. The symmetries of the extended model are discussed in section 4. Conclusions are given in section 5. Appendix A is provided to visualize the difference between the standard model supesymmetry and ours.

This note contains new material in sections 2 and 4. Section 3 describes briefly reuse of a dense matter model adapted to chernons, which we have presented earlier. The genre of this note is exploratory: to search for simple ideas and concepts which define a consistent model beyond the standard model.

2 Extending the Wess-Zumino action

The divisive point of the chernon model for visible and dark matter is that supersymmetry must be implemented so that particles of the model are written together with their superpartners in the supermultiplets (as in table 1) and the Lagrangian ((2.1) - (2.3)) of the model, without doubling each known particle with its (unobserved) sparticle. This method was introduced in [1, 2]. The result turned out to have close resemblance to the Wess-Zumino (WZ) model [3], which contains three neutral fields: a Majorana spinor m, the real fields s and p with $J^P = \frac{1}{2}^+, 0^+$, and 0^-, respectively. The kinetic Lagrangian is

$$\mathcal{L}_{\text{WZ}} = -\frac{1}{2}\bar{m}\partial\!\!\!/ m - \frac{1}{2}(\partial s)^2 - \frac{1}{2}(\partial p)^2 \tag{2.1}$$

where m and s form the chiral multiplet. We assume that the pseudoscalar p is the axion [4], and denote it below as a. It has a fermionic superparther, the axino n, a candidate for dark matter but not discussed further here.

In order to include charged matter we define the following charged chiral field Lagrangian for fermion m^-, complex scalar s^- and the electromagnetic field tensor $F_{\mu\nu}$

$$\mathcal{L}_{\text{WZ}_{\text{Charge}}} = -\frac{1}{2}m^-\partial\!\!\!/ m^- - \frac{1}{2}(\partial s^-)^2 - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} \tag{2.2}$$

We next arrange color to the neutral fermion $m \to m_i^0$ $(i = R, G, B)$ in (2.1). The field s in (2.2) we replace by a triplet complex scalar s_r^0 and add a global SU(3) color singlet m_s^0 to (2.2). The color sector Lagrangian is then

$$\mathcal{L}_{\text{WZ}_{\text{Color}}} = -\frac{1}{2}\sum_{i=R,G,B,s\ r=1,2,3}\left[\bar{m}_i^0\partial\!\!\!/ m_i^0 - \frac{1}{2}(\partial s_r^0)^2\right] \tag{2.3}$$

To make a connection to string theory possible, s_r^0 is assumed near string scale to be a closed string, 2-brane or other such object, which looks like a point particle below Λ_{cr}. The scalar color triplet s_r^0 (r = 1, 2, 3) may form an observable spectroscopy of its own, which is not considered here.

Now we have the following supermultiplets shown in table 1.

Multiplet	Particle, Sparticle
chiral multiplets spins 0, 1/2	s_r^0, m_r^0; s^-, m^-; a, n
vector multiplets spins 1/2, 1	m_s^0, γ

Table 1: The particles m^-, m_i^0 (i = R, G, B, singlet) are Weyl spinors and s_r^0 is a triplet particle. γ is the photon. a is the axion and n axino.

We have above extended the first generation model to three generations by adding the broken global SU(3) scalar chernon s_r^0 (r = 1, 2, 3) to each generation r [5][1] The matter-chernon correspondence is indicated in table 2.

[1]In [5] the group is SU(4). We get the dark sector from (2.3).

SM Matter i=1,2,3	Chernon state
ν_e	$m_R^0 m_G^0 m_B^0 s_r^0$
u_R	$m^+ m^+ m_R^0 s_r^0$
u_G	$m^+ m^+ m_G^0 s_r^0$
u_B	$m^+ m^+ m_B^0 s_r^0$
e^-	$m^- m^- m^- s_r^0$
d_R	$m^- m_G^0 m_B^0 s_r^0$
d_G	$m^- m_B^0 m_R^0 s_r^0$
d_B	$m^- m_R^0 m_G^0 s_r^0$
W-Z Dark Matter	Particle
boson (or BC)	s_r^0, axion(s)
e'	axino n
meson, baryon o	$n\bar{n}, 3n$
nuclei (atoms with γ')	multi n
celestial bodies	any dark stuff
black holes	anything (neutral)

Table 2: Visible and Dark Matter with corresponding particles and chernon composites. m_i^0 (i = R, G, B) is color triplet, $m^\pm$ are color singlets. s_r^0 is a closed loop or 2-brane. The subscript r (= 1, 2, 3) is the generation number. e' and γ' refer to dark electron and dark photon, respectively. BC stands for Bose condensate. Chernons obey anyon statistics. The binding of chernon composites is described in section 3.

Color was introduced in the Lagrangian $\mathcal{L}_{\mathrm{WZ}_{\mathrm{Color}}}$ in (2.3). It would be natural to couple the colored triplet of m_i^0 (i = R, G, B) to the octet of gluons, as is done in the standard model. But there are no gluons in table 1. That is, we do not want to introduce the unobserved gluon superpartners and their spectroscopy. There is, however, another way to introduce gluons.

After quarks have been formed gluons must emerge since it is known that fractional charge quark states have not been observed in nature. To make observable color neutral, integer charge states possible we proceed as follows. The local $SU(3)_{color}$ group structure of the eight gluons is formed by quark-antiquark pairs as follows (with only color charge indicated):

$$\text{Gluons}: \mathrm{R\bar{G}, R\bar{B}, G\bar{R}, G\bar{B}, B\bar{R}, B\bar{G}}, \frac{1}{\sqrt{2}}(\mathrm{R\bar{R} - G\bar{G}}), \frac{1}{\sqrt{6}}(\mathrm{R\bar{R} + G\bar{G} - 2B\bar{B}}) \qquad (2.4)$$

Finally, we introduce the weak interaction. After the SM quarks, gluons and leptons have been formed there is no more supersymmetry in nature. Therefore we introduce the standard model electroweak interaction in our model. The Higgs boson, however, may have composite structure. Within our scheme there are many possibilities to form scalars from table 1. Now the standard model has been heuristically derived.

We note that in our approach, at present, there is no gravity. In Kaluza-Klein (KK) model the situation is the other way around, 5D gravity is the starting point. Therefore we think that also five dimensional models are an interesting area of detailed study.

3 Chernon-chernon interaction

This section is covered fully in [8, 9] with references to original papers. The chernon-chernon scattering amplitude in the non-relativistic approximation is obtained by calculating the t-channel exchange diagrams of the Higgs scalar and the massive gauge field. The propagators of the two exchanged particles and the vertex factors are calculated from the action [10].

The gauge invariant effective potential for the scattering considered is obtained in [11, 12]

$$V_{\rm CS}(r) = \frac{e^2}{2\pi}\left[1 - \frac{\theta}{m_e}\right] K_0(\theta r) + \frac{1}{m_e r^2}\left\{l - \frac{e^2}{2\pi\theta}[1 - \theta r K_1(\theta r)]\right\}^2 \tag{3.1}$$

where $K_0(x)$ and $K_1(x)$ are the modified Bessel functions and l is the angular momentum ($l = 0$ in this note). In (3.1) the first term [ ] corresponds to the electromagnetic potential, but it now behaves like a Yukawa potential, the second one $\{\ \}^2$ contains the centrifugal barrier $\left(l/mr^2\right)$, the Aharonov-Bohm term and the two photon exchange term.

One sees from (3.1) the first term may be positive or negative while the second term is always positive. The function $K_0(x)$ diverges as $x \to 0$ and approaches zero for $x \to \infty$ and $K_1(x)$ has qualitatively similar behavior. For our scenario we need negative potential between all, including equal charge chernons. Having no data points for several parameters in (3.1) we can give one relation between these parameter values for a negative potential. We must have the $K_0(\theta r)$ dominating by the condition[2]

$$\theta \gg m_e \tag{3.2}$$

The potential (3.1) also depends on v^2, the vacuum expectation value, and on y, the parameter that measures the coupling between fermions and Higgs scalar. Being a free parameter, v^2 indicates the energy scale of the spontaneous breakdown of the $U(1)$ local symmetry.

4 T-duality

A closed string, like the suggested s_r^0 above Λ_{cr}, can be wound around like thread on a cylinder. This yields the winding number w. Between string theories

[2] For applications to condensed matter physics, one must require $\theta \ll m_e$, and the scattering potential given by (3.1) then comes out positive [10].

of types IIA and IIB and between heterotic SO(32) and $E_8 \times E_8$ there is a symmetry. Namely, if one wraps a string around a cylindrical space of radius R and the other around a cylindrical space of radius 1/R, then the winding number of one theory matches the quantized momentum number of the other theory. This is T-duality.

We propose that the scalar particle s_r^0 may at string scale be a 2-brane or a torus. These objects may be thought to be the end points to the fermions of the model, now elevated to stringy objects. But there are a lot of other possibilities in superstring theory, which should be the starting point for the low energy limit calculation. This is beyond the scope of this note.

This scenario with the winding number is consistent with the Big Bang model presented in [13]. This model is singularity-free due to the near Hagedorn temperature thermal string condensate initial state.

5 Conclusions

The main results of this work are

- new fundamental, topological level of matter in three generations and the dark sector. The number of SM generations is equal to the number of colors, i.e. flavor is color twice,
- WZ supersymmetric Lagrangian is extended to charged and colored particles and to include Chern-Simons binding interaction. The octet of gluons emerges from fractionally charged chernons as seen in (2.4). Our stringent implementation of supersymmetry is expected to reward in the calculations,
- new light scalar particles are predicted, and
- a window to little strings may be open above Λ_{cr} by postulating stringy properties to s.

Earlier results of this scenario include (i) reason why supersymmetry is hidden below Λ_{cr} [14], (ii) inevitable quantum statistical mechanism for baryon asymmetry [8, 9] with $\frac{n_B}{n_\gamma} \ll 1$, (iii) the scenario economically unifies matter and interactions based on few supermultiplets, rather than large GUT internal symmetries, and (iv) a brief discussion on string and preon symmetries is in [15].

In the absence of MSSM superpartners the present model is a noteworthy candidate for BSM physics.

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A The basic idea of the model

We attempt to visualize the basic idea behind the model in figure 1.

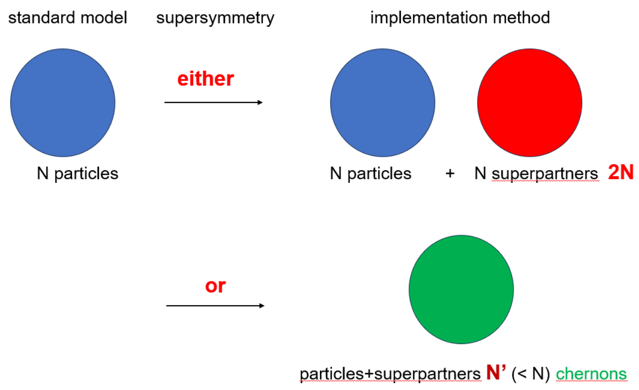

Figure 1: On the right (top) is the standard minimal supersymmetric model logical structure with the number of SM particles doubled by introducing the superpartners, disclosing a risk for double counting. Furthermore, the SM superpartners (red) have not been observed in nature. Bottom picture (green) indicates that by splitting quarks and leptons into three m fermions plus a scalar s our scenario has fewer elementary particles organized in supermultiplets.

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