A MINIMAL PREON MNEMONIC AND NONSTANDARD BOSONS

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On the base of a minimal preon mnemonic operating with spin-$\frac{1}{2}$ and spin-0 subconstituents of lepton and quarks as well as of $W^{\pm}$ and Z^0, we predict some nonstandard bosons. One of them, being a colour octet (though no quark-antiquark pair), can decay into two or three gluons and so might be relevant for recent CERN collider experiments in progress.

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From the viewpoint of the historical development of atomic search since Democritos till the present, the idea that leptons and quarks are composites of some more elementary constituents (usually called preons) appears as the most traditional approach to the problem of experimental abundance of lepton and quark species. It was the reason why extensive theoretical studies in this direction were developed in the last decade [1], despite the lack of experimental evidence for the composite structure of leptons and quarks. Though these studies did not bring us to a convincing preon model, they helped us to see some points crucial for the preon idea. Let us mention two which seem especially important. The first point can be very adequately expressed by W. Pauli's words taken from his famous (second) letter to V. F. Weisskopf (dated January 27, 1957): "what shocks me is not the fact that God is left-handed but the fact that in spite of this He exhibits Himself as left-right symmetric when He expresses Himself strongly" [2]. On the level of composite leptons and quarks this sentence becomes particularly pertinent as new left-right symmetric super-strong binding forces seem to be necessary for preons. The second point concerns the question why lepton and quark masses are so small in comparison with the mass scale corresponding to the inverse of their radii, in contrast to the situation observed for all known composite states as atoms, nuclei and hadrons [3]. While the first point still remains a great challenge for theoreticians, the explanation of the second may be connected with such theoretical concepts as the anomaly matching mechanism necessary for preserving

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global chiral symmetries [3, 4] or/and the supersymmetric analogue of the Nambu--Goldstone mechanism in theories with spontaneously broken global symmetries [5, 6, 7].

In this note we assume the attitude that in its present stage the preon idea may give us at most a *mnemonic scheme* rather than a dynamical model, much as it was the case with the Gell-Mann and Zweig quark idea before QCD was developed. As is well known, the original quark idea with three flavours gave a clue (even before QCD was developed) to the understanding of some serious questions in the low-energy hadron physics: why hadrons appeared only in octets and decuplets and why flavour SU(3) worked. Similarly, the preon idea may give a clue (even before its dynamics is developed in detail) to understanding why leptons and quarks (at least the left-handed ones) appear only in doublets and why Weinberg-Salam $SU(2)\times U(1)$ works. However, our main point of interest in such an approach is that discussing (on the algebraic level) composite states of preons we *may* correctly predict some new nonstandard particles, e.g. nonstandard bosons, whose discovery may guide us beyond the familiar standard model.

Following this program let us consider two spin-$\frac{1}{2}$ preons L and Q and two spin-0 preons: one scalar S and one pseudoscalar P, all of which being doublets of a vector-like hypercolour gauge symmetry $SU_{HC}(2)$ and having the colour, charge and $B-L$ signature as given below:

	hypercolour	colour	charge	B−L
L	$\underline{2}$	$\underline{1}$	−1/2	−1
Q	$\underline{2}$	$\underline{3}$	1/6	1/3
S	$\underline{2}$	$\underline{1}$	−1/2	0
P	$\underline{2}$	$\underline{1}$	−1/2	0

(1)

Then the leptons and quarks of the first generation can be identified with the following nonexotic, hypercolour-singlet, ground bound states:

$$\nu_{eL,R} = \left(L_A \frac{\bar{S}_A \mp \bar{P}_A}{\sqrt{2}}\right), \quad e^-_{L,R} = \left(\varepsilon_{AB} L_A \frac{S_B \mp P_B}{\sqrt{2}}\right),$$

$$u_{L,R} = \left(Q_A \frac{\bar{S}_A \mp \bar{P}_A}{\sqrt{2}}\right), \quad d_{L,R} = \left(\varepsilon_{AB} Q_A \frac{S_B \mp P_B}{\sqrt{2}}\right), \tag{2}$$

where $\bar{S}$ and $\bar{P}$ are antiparticles and $A, B = 1, 2$ denote hypercolour doublet indices (while all other indices are suppressed). In Eq. (2) we *require* that $(L_A\bar{S}_A) = \gamma_5(L_A\bar{P}_A)$, etc. Note that *no other* nonexotic hypercolour-singlet, composite fermions can be constructed from preons (1) in ground bound states. If SU_{HC} (2) were a chiral left-handed symmetry and P were absent, our mnemonic scheme would be the Abbott-Farhi model [8], where right--handed composite leptons and quarks can hardly be constructed.

Looking at the structure (2) of composite leptons and quarks we come to the conclusion that the nonexotic, hypercolour-singlet *P*-wave bound states

$$W^+_{L,R} = \left(\varepsilon_{AB} \frac{\bar{S}_A \mp \bar{P}_A}{\sqrt{2}} \frac{\bar{S}_B \mp \bar{P}_B}{\sqrt{2}}\right)_P, \quad Z^0_{L,R} = \left(\frac{\bar{S}_A \mp \bar{P}_A}{\sqrt{2}} \frac{S_A \mp P_A}{\sqrt{2}}\right)_P \tag{3}$$

describe in our mnemonic scheme the left and right weak spin-1 bosons (the latter of which should be somehow much heavier than the former). We can see that $W^{\pm}_{L,R}$ are ground states due to Bose statistics obeyed by S and P, while $Z^0_{L,R}$ are orbitally excited states and so may decay *radiatively* into the corresponding spin-0 bosons (cf. e.g. [9]) represented through the S-wave bound states

$$H^0_{L,R} = \left(\frac{\bar{S}_A \mp \bar{P}_A}{\sqrt{2}}\ \frac{S_A \mp P_A}{\sqrt{2}}\right)_S. \tag{4}$$

Beside the composite bosons $W^{\pm}_{L,R}$, $Z^0_{L,R}$ and $H^0_{L,R}$ built from spin-0 preons, there exist in our mnemonic scheme some composite bosons built from spin-$\frac{1}{2}$ preons, which are all entirely *nonstandard*. They are represented by the following nonexotic, hypercolour--singlet, bound states:

(*i*) colour singlets (with charge 0, −1, 0, respectively)

$$(\bar{L}L), \quad (LL)_{^3S} \quad \text{or} \quad (LL)_{^1P}, \quad (\bar{Q}Q)_{\underline{1}}, \tag{5}$$

(*ii*) colour triplets (with charge −1/3, 2/3, −1/3, respectively)

$$(\bar{Q}\bar{Q})_{\underline{3}^1S} \quad \text{or} \quad (\bar{Q}\bar{Q})_{\underline{3}^3P}, \quad (\bar{L}Q), \quad (LQ), \tag{6}$$

(*iii*) colour antisextet (with charge −1/3)

$$(\bar{Q}\bar{Q})_{\underline{6}^{*3}S} \quad \text{or} \quad (\bar{Q}\bar{Q})_{\underline{6}^{*1}P} \tag{7}$$

and (*iv*) colour octet (with charge 0):

$$(\bar{Q}Q)_{\underline{8}}. \tag{8}$$

Here, $\bar{L}$ and $\bar{Q}$ denote antiparticles. The bosons of the type $(\bar{L}L)$ and $(\bar{Q}Q)$ can be pseudoscalars as well as vectors (i.e., para- as well as ortho-states), where vectors are presumably heavier. Similarly, the bosons $(\bar{L}Q)$ and (LQ) can appear as para- and ortho-states.

From the viewpoint of collider experiments being actually in progress at CERN [10, 11], the most interesting of bosons (5)–(8) should be the strongly interacting neutral colour octet $(\bar{Q}Q)_{\underline{8}}$ (both in its para- and ortho-state). It may be produced in $\bar{q}q$ collisions: (1) alone (or jointly with a photon or with Z^0_L or H^0_L) if $\bar{q}q = \bar{u}u$ and $\bar{d}d$, or (2) jointly with $W^+_L \to e^+\nu_e$ or $W^-_L \to e^-\bar{\nu}_e$ if $\bar{q}q = \bar{d}u$ or $\bar{u}d$, respectively. Then it can decay *strongly* into two or three coloured gluons, or into a neutral colour singlet $(\bar{Q}Q)_{\underline{1}}$ (in its para- or ortho-state) plus one or two coloured gluons. The gluons produce jets, while $(\bar{Q}Q)_{\underline{1}}$ can escape observation or give a 2γ- or 3γ-cluster when $(\bar{Q}Q)_{\underline{1}}$ is para or ortho, respectively (of course, in a $\bar{p}p$ collision colour of all fragments must be neutralized separately before the system dissociates). Thus, we should get finally

$$\bar{u}+u \quad \text{or} \quad \bar{d}+d \to \text{jet(s)} + \{(\bar{Q}Q)_{\underline{1}}\} + \{\gamma, Z^0_L, H^0_L\} \tag{9}$$

and

$$\bar{u}+d \to \text{jet(s)} + \{(\bar{Q}Q)_{\underline{1}}\} + e^-\bar{\nu}_e, \tag{10}$$

where {} indicates that $(\bar{Q}Q)_{\underline{1}}$ and the single γ or Z_L^0 or H_L^0 may or may not appear. We can see that the jet(s) in processes (9) and (10) can display (apparently) unbalanced large transverse momentum (provided $(\bar{Q}Q)_{\underline{8}}$ is appropriately heavy, while $(\bar{Q}Q)_{\underline{1}}$ escapes observation being light enough). Then, the signature of processes (9) and (10) might correspond to some UA1 and UA2 events, respectively (cf. Ref. [10] and [11]).

In conclusion, we would like to add a few comments on the theoretical aspect of our mnemonic scheme. First of all, let us note that Eq. (2) establishes an isomorphy between eight composite fermions ν_e, e^-, u, d and eight fundamental fermions L, Q. Thus, our mnemonic belongs to such a class of preon schemes (operating with spin-$\frac{1}{2}$ as well as spin-0 subconstituents [12, 13, 14]), where the so-called "complementarity" [15, 16] holds and, therefore, the 't Hooft anomaly matching conditions [3, 4] are automatically satisfied. It is, in fact, the *minimal* of such schemes: the isomorphy is here realized by means of four (complex) spin-0 preons only, while e.g. in Refs. [16] and [17] it requires 12 and 16 spin-0 preons, respectively (note that the haplon model [18] containing $6n$ spin $\frac{1}{2}$ preons and $6n$ spin-0 preons with $n = 1, 2, 3, \ldots$ is not self-"complementary"). Our mnemonic is also more economical than the composite schemes based on spin-$\frac{1}{2}$ preons, as e.g. the rishon model [19] involving 18 spin-$\frac{1}{2}$ preons.

With P absent, our mnemonic scheme would be even more economical [20], but (with the vectorlike $SU_{HC}(2)$) its connection to the effective Weinberg-Salam symmetry $SU(2)_L \times U_Y(1)$) would become quite obscure. With P present and with the weak spin-1 bosons described as in Eq. (3) this connection seems to be much closer and can be discussed along the lines of Ref. [8] (if $W_R^\pm$ and Z_R^0 are much heavier than $W_L^\pm$ and Z_L^0 and if, as in Refs [8] and [21], an effective $Z_L^0-\gamma$ interaction is invoked to contribute to the effective neutral current coupled to Z_L^0).

However, according to the attitude assumed in this paper it is not our aim here to discuss the relation between the effective standard model and the preon hypothesis [22]. We believe that not all ends of this problem are gathered in our hands yet (cf. e.g. Refs [10] and [11]). Our main point in this note was to emphasize that even the minimal preon mnemonic predicts the existence of some *nonstandard* bosons (cf. Eqs. (5)–(8)), while fermions remain such as in the standard model (cf. Eq. (2)).

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