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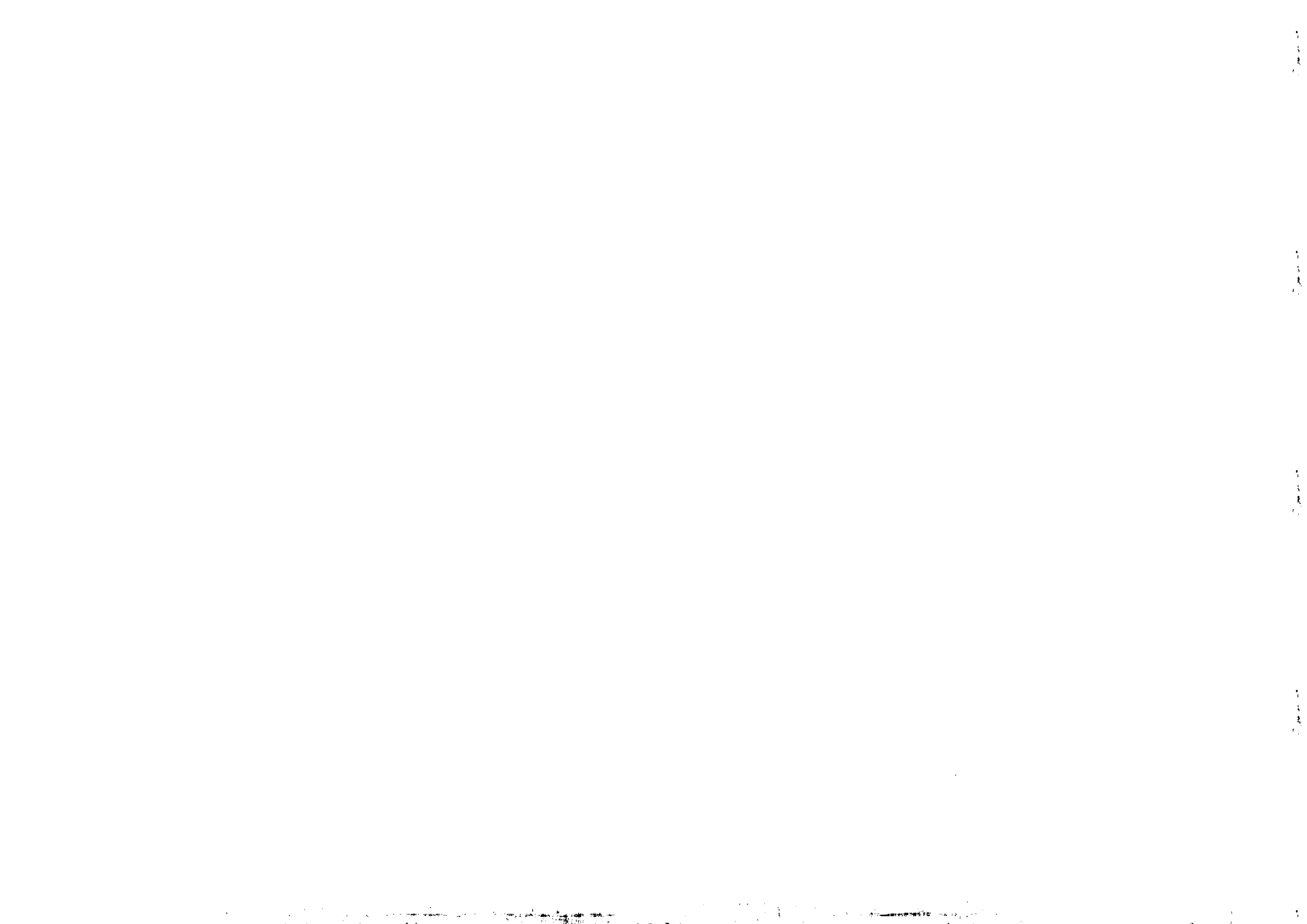


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A PREON MODEL WITH HIDDEN ELECTRIC AND MAGNETIC TYPE CHARGES \*

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1. The proliferation exhibited by three families of quarks and leptons and the associated spin-1 gauge and the spin-0 Higgs particles strengthens the need for a more elementary and more economical set of objects, of which these may be regarded as composites <sup>1),2)</sup>. In 1974 and 1975 a class of composite models of quarks and leptons was proposed <sup>1)</sup> whose salient features are the following.

i) Quarks and leptons are composites of three sets of elementary entities: the flavons <sup>\*)</sup>  $f_i = (u,d,c,s)$ , the chromons <sup>\*\*)</sup>  $C_\alpha = (r,y,b,t)$  and a third set of entities  $S_k$  <sup>\*\*\*)</sup>.

Each set is characterized by specific values of the binding charges stated below. The third set  $S_k$  may contain as few as a single member. <sup>\*)</sup> Collectively the entities  $\{f,C,S\}$  are named "preons". It is to be noted that the flavons and chromons directly define flavour and colour attributes of quarks and leptons <sup>\*\*\*\*)</sup>.

ii) The forces responsible for binding preons to make quarks and leptons are assumed to arise through two vectorial abelian symmetries  $U(1)_A \times U(1)_B$  generating two spin-1 gauge particles. The assigned charges  $(Q_A, Q_B)$  for the sets of  $f, C$  and  $S$  are  $(g,0)$ ,  $(0,h)$  and  $(-g,-h)$ , respectively. Quarks and leptons are assumed to be  $fCS$  composites. These are the only three-particle composites neutral with respect to both  $Q_A$  and  $Q_B$ .

#### ABSTRACT

The  $U(1) \times U(1)$  binding forces in an earlier preonic composite model of quarks and leptons are interpreted as arising from hidden electric and magnetic type charges. The preons may possess intrinsic spin zero; the half-integer spins of the composites being contributed by the force field. The quark-lepton gauge symmetry is interpreted as an effective low-energy symmetry arising at the composite level. Some remarks are made regarding the possible composite nature of the graviton.

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<sup>\*)</sup> Four flavons were introduced in 1974 and 1975 (Ref.1); at that time four quark flavours were known. Now with the possible existence of six flavours, it is attractive to treat two flavons  $(u,d)$  as basic and to generate three families dynamically, or alternatively, let  $S_k$ 's play the role of family quantum numbers (see text).

<sup>\*\*)</sup> Four chromons are chosen to go with the idea of lepton number as the fourth colour. However, in general, using preon ideas, one can consider leptons to differ from quarks by more than one attribute.

<sup>\*\*\*)</sup> The  $S$  particles in the original formulation carried spin  $\frac{1}{2}$  (assuming that chromons and flavons carry the same unit of spin). Thus they were named "spinons". In this note we consider situations where  $S$ -particle spin may be zero. A

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humble suggestion for the  $S$  particles is call them "essons"; a name more in keeping with "flavons" and "chromons" is "somons" - for the nectar of the Gods in Sanskrit (soma-ras).

<sup>\*\*\*\*)</sup> "Charges" or "attributes" may in general arise in two alternative ways. Either (i) each charge is associated with one elementary entity as for flavons and chromons or (ii) charges are generated (at least for some) dynamically at the composite level. An example of (ii) is the dynamical generation of "family" charge (see text).

iii) Low energy electroweak and strong interactions are generated in the model by postulating a local symmetry  $\mathcal{G} = SU(2)_L \times SU(2)_R \times SU(4)_{L+R}^C$  for the preonic Lagrangian and introducing the required spin-1 gauge as well as the spin-0 Higgs particles as elementary. This was in addition to the  $U(1)_A \times U(1)_B$  symmetry generating the preon binding forces, which commutes with  $\mathcal{G}$ .

The purpose of this note is to propose certain elaborations of this model, motivated by our desire to retain non-proliferation of fundamental coupling constants and of preons. In the new scheme we obtain (i) a new interpretation for the origin and the link between the binding charges  $Q_A$  and  $Q_B$ , (ii) a raison for spin  $\frac{1}{2}$  for quarks and leptons starting with just spin-0 preons and (iii) a plausible raison for the existence of families of quarks and leptons. The electroweak strong gauge symmetry such as  $SU(2)_L \times SU(2)_R \times SU(4)_{L+R}$  or its extension for example to  $SU(16)$ , is viewed as an effective low energy symmetry valid at energies below the inverse size of the composites. Certain possible experimental consequences of this class of preonic model are noted at the end.

2. We preserve the central feature of the old scheme that quarks and leptons are composites of three sets of preons  $f_i, C_j$  and  $S_k$  as well as the assignment of binding charges <sup>\*)</sup>  $(g,0), (0,h)$  and  $(-g,-h)$  to these sets. We modify the scheme in the following respects:

(1) It has recently been observed <sup>3)</sup> that ordinary "electric" type forces <sup>\*\*)</sup> (abelian or non-abelian) arising within a simple or semi-simple grand unifying symmetry are inadequate to bind preons to make quarks and leptons of small size  $r_0$  ( $< 10^{-16}$  cm) without proliferating preons unduly. Following the spirit of a suggestion made in Ref.3, we propose that the two primordial charges  $Q_A$  and  $Q_B$  (or rather  $g$  and  $h$ ) are not unrelated. They are reciprocal charges analogous to (but not identical with) the fundamental electric and magnetic charges. Thus they satisfy Dirac-like quantization condition <sup>4)</sup>

$$gh/4\pi = \frac{1}{2} N \quad (N = 1,2,3,\dots) \quad (1)$$

<sup>\*)</sup> Other charge assignments are in general permissible (see for example Ref.3), though in this note we shall restrict ourselves to this particular assignment.

<sup>\*\*)</sup> By "electric" type forces arising within a grand unifying symmetry, we mean forces whose effective strength is of order  $10^{-2}$  at the grand unifying mass  $M$ .

The two charges  $Q_A$  and  $Q_B$  may correspond to a  $U(1)_A \times U(1)_B$  gauge symmetry subject to a subsidiary condition <sup>5) \*)</sup> such that there exists only one primordial spin-1 gauge boson ( $A'_\mu$ ) (rather than two) coupled to both  $Q_A$  and  $Q_B$ . The integer  $N$  for the specific model introduced here must be unity (see below). Thus the two coupling constants  $g$  and  $h$  related by e.g. (1) represent just one fundamental parameter.

We assume that  $h$  is of order unity or larger ( $h^2/4\pi \gtrsim \frac{1}{2}$  to 1) at short distances  $r_0 \lesssim 10^{-17}$  or  $10^{-18}$  cm or equivalently at running momenta  $M_0 = 1/r_0 \gtrsim 1$  or 10 TeV, so that it may bind preons to make composites of small size  $r_0$ . Together with the constraint  $N = 1$  this would imply that  $g^2(M_0)/4\pi < (\frac{1}{2} \text{ to } \frac{1}{4})$ .

For the specific assignment of the binding charges  $(Q_A, Q_B)$  - namely  $(g,0), (0,h)$  and  $(-g,-h)$  for  $f, C$  and  $S$ , both  $Q_A$  and  $Q_B$  are zero for quark and lepton composites (fCS). Since ordinary electric charge is non-vanishing on quarks and leptons, we see that we cannot identify either  $Q_A$  or  $Q_B$  with ordinary electric charge. We therefore interpret both  $Q_A$  and  $Q_B$  to be new conserved charges which are operative only at the preon level, but are hidden at the quark lepton level. They are analogous to electric and magnetic charges in being reciprocals of each other; however, clearly, they have to be distinct from them. The associated primordial gauge particle  $A'_\mu$  is thus distinct from the ordinary photon. <sup>\*\*\*)</sup> In the present model, the ordinary photon must be regarded as composite like the gluons, the W's and the Z (see remarks below). This is to be contrasted from the specific model presented in the text of Ref.3, where one of the two reciprocal charges was identified with ordinary electric and the other with magnetic charge; and the primordial gauge particle was the known photon. These two alternatives, while sharing many common features, can be distinguished experimentally.

<sup>\*)</sup> While we provisionally follow the formalism in the first paper of Ref.5, a field theory of electric and magnetic type charges with manifest Lorentz invariance still needs elaboration. In this note we do not consider the 't Hooft-Polyakov type of magnetic monopoles nor their non-abelian extensions.

<sup>\*\*\*)</sup> We provisionally leave the question of masslessness of  $A'$  open.

We note that even with a massless  $A'$  there is no conflict with the limits from Eötvös type experiments, since quarks and leptons are neutral with regard to  $Q_A$  and  $Q_B$  and have small sizes  $r_0$ . The Van-der-Waals force between neutral matter is proportional to  $\sim \alpha_h^2 (r_0/R)^6$ . For  $r_0 \lesssim 10^{-17}$  cm, this force is very much smaller than the gravitational even if  $R$  is atomic  $\sim 10^{-8}$  cms.

(2) The second new feature in this note concerns the generation of spin  $\frac{1}{2}$  for quarks and leptons. We consider the possibility here that the flavons, chromons and S-particles may all be scalar particles. Quarks and leptons, which are fCS composites nevertheless possess spin  $\frac{1}{2}$  due to half-integral angular momentum associated with the field created by the two reciprocal charges (g and h). This is entirely analogous to the case of angular momentum possessed by the electromagnetic field of an electric charge in the presence of a magnetic monopole. <sup>6) \*</sup>

To obtain precisely half-integer angular momentum from the field as opposed to higher values, we set

$$gh/4\pi = \frac{1}{2} \quad (2)$$

This is the reason for choosing  $N = 1$  in Eq.(1). The problem of making three-body composites allowing for angular momentum of the field is discussed later.

(3) We propose <sup>3)</sup> that the abelian force generated by the charges ( $Q_A, Q_B$ ) is the only primordial force, and all other forces including the non-abelian electroweak <sup>and</sup> strong forces (leaving out gravity for the present, on which we comment later) are derived effectively only at the composite level. We adopt this point of view in the interests of non-proliferation of fundamental coupling constants and non-proliferation of preons. <sup>\*\*)</sup>

The primordial force being strong at very short distances ( $r \lesssim 10^{-17} - 10^{-18}$  cm) binds three preons (fCS) to make spin  $\frac{1}{2}$  quarks and leptons of small size <sup>\*\*\*)</sup>  $r_0 \lesssim 10^{-17}$  to  $10^{-18}$  cm; it can also bind even numbers of preons including anti-preons to make a host of spin-1 and spin-0 composites, which are neutral <sup>\*\*\*\*)</sup> with respect to the binding charges  $Q_A$  and  $Q_B$ . We assume that these spin-0 and spin-1 composites also possess small sizes  $\sim r_0$ , with the masses of the composites being much smaller than their inverse size  $M_0 \equiv \frac{1}{r_0}$ . Note that  $M_0$  exceeds 10 TeV for  $r_0 < 10^{-18}$  cm, and may be as large as Planck mass if  $r_0 \sim 10^{-33}$  cm.

<sup>\*</sup>) We are aware that the usual treatment (see Ref.6) is non-relativistic and that it would need further elaboration for application to the present situation.

<sup>\*\*)</sup> Note that had we introduced  $G_K \times U(1)_A \times U(1)_B$  as a fundamental symmetry (subject to  $h^2(M_0)/4\pi \gtrsim 1$ ) where  $G_K$  contains the familiar  $SU(2) \times U(1) \times SU(3)^C$  symmetry we would not be in a position to embed such a symmetry into a simple or semisimple group larger than  $G_K \times U(1) \times U(1)$  without proliferating preons. <sup>3)</sup>

<sup>\*\*\*)</sup> The size  $r_0$  of the composites is perhaps as large as  $\sim 10^{-17} \sim 10^{-18}$  cm; it may even be as small as  $1/M_{\text{Planck}} \sim 10^{-33}$  cm. In general, if preons are composites of prepreons and pre-pre-preons (see Ref.7), there may be a hierarchy of sizes of these composites ranging from  $10^{-17}$  cm down to gravitational length  $1/M_{\text{Planck}} \sim 10^{-33}$  cm.

<sup>\*\*\*\*)</sup> The spin-0, spin-1 composites, neutral with regard to  $(Q_A, Q_B)$  are of the form  $r_{1j} \bar{F}_j, C_{\alpha\beta}, S_k, \bar{S}_k, \dots$

Starting with the observation that quarks and leptons possess small sizes, compared to which inverse masses of these objects are irrelevant and that an effective field theory of these composites <sup>\*</sup>) should be expressible as a series of terms in powers of the size parameter, it has been conjectured <sup>\*\*)</sup> (we believe plausibly and agreeably) that the effective field-theoretic interactions of these composites of spins 0,  $\frac{1}{2}$  and 1 at momenta  $\ll M_0 = \frac{1}{r_0}$  must be renormalizable at least for a perturbative approach. Adopting this philosophy, non-renormalizable interactions (which incidentally are the only ones available for composites of spins <sup>\*\*\*)</sup>  $\frac{3}{2}, 2, \frac{5}{2}, \dots$ , etc.) will be damped out at low energies by powers of the size,  $1/M_0$ .

Since the only renormalizable theory of interacting "charged" spin-1 fields is a Yang-Mills theory based on a spontaneously broken non-abelian local symmetry, it follows from the above remark that the effective interactions of the composites <sup>\*\*\*\*)</sup> of spins 0,  $\frac{1}{2}$  and 1 of small size must be generated by a non-abelian spontaneously broken gauge theory upto energies  $< M_0 \equiv \frac{1}{r_0}$ . The spin-0 composites can now play the role of the Higgs fields.

The economy of this picture is appealing. The basic theory, as in Ref.3, involves a single gauge coupling constant  $g$ , a single primordial spin-1 particle  $A'_\mu$ , and a reasonably small number (less than at most nine) of preons. The proliferated quark-lepton gauge structure,  $SU(16)$  or bigger, with the associated proliferated spin  $\frac{1}{2}$ , spin-1 as well as spin-0 quanta (quarks, leptons, Higgs, etc.) derives its origin only at the composite level. All of its parameters should be computable in principle in terms of the basic theory. The renormalizable Yang-Mills theory is a consequence of the small size of the composites and applies only at low energies  $\ll \frac{1}{r_0}$ .

<sup>\*</sup>) Composites possessing non-zero values of  $Q_A$  and/or  $Q_B$  can also form. They may possess higher masses. Such composites can effectively play the role of technifermions <sup>3), 8)</sup>.

<sup>\*\*)</sup> Unpublished remarks due to M. Veltman, G. 't Hooft, M. Parisi and K. Wilson. In the present context this conjecture is stressed in Ref.3. We are of course assuming that preon masses (evaluated at  $M_0$ ) are also very much smaller than  $M_0$ . Any departure in this respect from experience with QCD may have its origin in the abelian (rather than non-abelian) preon dynamics.

<sup>\*\*\*)</sup> This may provide a reason for the absence of spin  $\frac{3}{2}$  and higher spin composite quarks and leptons with noticeable strong interaction at low energies.

<sup>\*\*\*\*)</sup> This idea of composite spin-1 gauge fields was proposed in a general context in Ref.9.

3. We now wish to discuss three-body composites. One naive picture is of "shell structure" where a two-body composite of smaller size is formed first, to which the third entity binds. Consider the pair CS, which can form two-body composites  $X_1 \equiv (CS)_{(-g,0)}$  with charges indicated by a subscript. Here the pair can bind both through  $Q_B \cdot Q_B$  coupling as well as through  $Q_A \cdot Q_B$  coupling. With C and S carrying charges (0,h) and (-g,-h), the field of the (CS) pair has an angular momentum  $-gh/4\pi = \frac{1}{2}$  (see Eq.(2)). Thus  $X_1$  made of two spin-0 components has halfinteger spin. Now the third entity f binds to  $X_1$  to make composites  $(fCS) \sim (fX_1)_{(0,0)}$ . Since both f and  $X_1$  carry only  $Q_A$  charge, the field of the  $(fX_1)$  system carries zero angular momentum. With  $X_1$  of spin  $\frac{1}{2}$  and f of spin-0, the  $(fX_1)$  composite has spin  $\frac{1}{2}$ , if  $X_1$  and f bind in S wave. Hence spin  $\frac{1}{2}$  for quarks and leptons.

Pursuing the picture of forming two-body composites first, two other such "composites" may be possible:  $X_2 \equiv (fS)_{(0,-h)}$  and  $X_3 \equiv (fC)_{(g,h)}$ , each of which possesses spin  $\frac{1}{2}$  for reasons mentioned above. These quasi-two-body composites may then form the cores to which C and S may, respectively, bind. These could provide two additional spin  $\frac{1}{2}$  (fCS) composites which may be viewed approximately as  $(CX_2)$  and  $(SX_3)$  composites. We would then have three sets of fCS composites, possibly distinguished from each other by the sizes of the inner cores and the outer radii, representing three distinct families. \*\*)

With f containing two flavons (u,d), C containing four chromons (r,y,b,l) and S being a single member set, there would be exactly eight members ( $2 \times 4 \times 1$ ) in each of the three sets  $\{f_i C S\}$ . Each of the eight members having spin  $\frac{1}{2}$  can appear with either left or right helicity depending upon the orientation of the field spin relative to the direction of motion of the composite. The eight members in each set match by construction the flavour

\*) In 1948 Harish Chandra (Ref.10), on the basis of a classical calculation showed that an electric charge cannot bind with a magnetic monopole. This result has been questioned by A.S. Goldhaber <sup>10)</sup> who shows that both zero and non-zero mass composites can form classically. (The former may possibly represent neutrinos.) In this context R. Jackiw has shown <sup>10)</sup> that the dynamics of the monopole charge system possesses a hidden  $O(2,1)$  symmetry and that it is characterized by a simple irreducible, unitary (hence infinite dimensional) representation of this group. One wonders whether this could have any relevance to the number of families and whether this number is infinite; see also A. Barut, Ref.10, for the question of binding in dyonium systems based on classical considerations.

\*\*) We observe that this mechanism is not applicable to three-body composites of "identical" objects like the three-quark composites. The preons f, C and S do differ from each other in respect of their binding charges.

and colour quantum numbers of the six quarks plus two leptons in each family. In view of the naivety of the dynamical picture outlined above, one may entertain the alternative possibility that the origin of families lies at a more basic level. Thus one may postulate that there may for example be three S-particles ( $S_e, S_\mu, S_\tau$ ) and identify the e,  $\mu$  and  $\tau$  families as the ground states of  $fCS_e$ ,  $fCS_\mu$  and  $fCS_\tau$  composites. Within this picture, the  $S_k$ 's may appropriately be named "famillions".

The effective gauge symmetry

We shall assume that the effective gauge symmetry at low energies ( $E \lesssim 1$  TeV) is determined by those spin-1 preonic composites which are neutral with respect to the binding charges  $(Q_A, Q_B)$ . The two-body composites neutral with regard to  $(Q_A, Q_B)$  are  $\bar{f}_i f_j$ ,  $\bar{C}_a C_b$  and  $\bar{S}S$ . If the preons have indeed spin-0 rather than spin  $-\frac{1}{2}$ , it is clear that the corresponding currents  $(\bar{p}_i \gamma^\mu p_j)$  would be purely vectorial at the preonic level. The six-body spin-1 composites  $(fCS \bar{fCS})$  on the other hand can couple to chiral currents (L and R) if spin  $\frac{1}{2}$  is generated at the level of three-body composites like fCS (corresponding to quarks and leptons). Allowing for all six-body composites of the above sort (neutral with regard to  $Q_A, Q_B$ ) and allowing for the chiral nature of the associated quark and lepton currents, one may obtain the maximal gauge symmetry  $U(16)$  or  $SU(16)$  in the space of one family <sup>\*\*\*)</sup> of composite eight left-handed fermions  $f_L$  (comprising six left-handed quarks and two left-handed leptons) and their antiparticles  $f_L^C$ . The corresponding composite gauge particles will couple to the fermionic currents  $\bar{f}_L \gamma^\mu f_L$  and  $\bar{f}_L^C \gamma^\mu f_L^C$  for energies  $< M_0$ .

One word of qualification is in order. The symmetry  $U(16)$  or  $SU(16)$  generating chiral currents possesses triangle anomalies, which spoil renormalizability. Thus subject to the renormalizability conjecture mentioned before, we expect that either the specific dynamics of preon

\*) For spin  $\frac{1}{2}$  preons, there is a related mechanism, which together with different helicity configurations for the preons, generates three families of quarks and leptons as well as three mirror families <sup>8)</sup>.

\*\*) For binding purposes, these six-body composites cannot be regarded as  $q\bar{q}$  composites, since the latter have "big" sizes  $\sim 10^{-13}$  cm. Even though q and  $\bar{q}$  are shielded from the primordial binding force, the components within  $(fCS \bar{fCS})$  are not. Once the six-body composites form with small sizes, the effective coupling would be to currents  $\bar{q}_L \gamma^\mu q_L$  and  $\bar{q}_R \gamma^\mu q_R$  at the quark level.

\*\*\*) In principle the symmetry may encompass all families and may be as large as  $[U(16)]^3$  or even  $U(48)$ .



binding generates additional multiplets of composite fermions \*) with masses  $\ll M_0$  so as to cancel the anomalies, or else the effective gauge symmetry at low energies ( $E < M_0$ ) is restricted \*\*) to an appropriate anomaly-free subgroup H of U(16) or SU(16). The two most obvious anomaly-free subgroups are SO(10) or the still smaller  $SU(2)_L \times SU(2)_R \times SU(4)_{L+R}^C$ , both of which are left-right symmetric and treat lepton number as the fourth colour. As stated before, since the photon is a composite field, the electric charge itself is defined by this effective gauge symmetry; in particular <sup>1)</sup>  $Q_{em} = I_{3L} + I_{3R} + \sqrt{2/3} F_{15} = I_{3L} + I_{3R} + (B-L)/2$ .

In addition to the gauge particles of the electroweak (EW) gauge symmetry  $G_{EW} = (SU(2)_L \times SU(2)_R \times SU(4)_{L+R}^C \text{ or } SO(10))$ , we expect <sup>3)</sup> (in fact for any preon model based on three sets of preons) that three strongly bound spin-1 composites  $Z_F, Z_C$  and  $Z_S$  coupled, respectively, to the currents  $\text{Tr } \bar{\psi}_L \gamma_\mu \psi_L, \text{Tr } \bar{\psi}_R \gamma_\mu \psi_R$  and  $\text{Tr } S^{\dagger} \gamma_\mu S$ , should form. These define the vectorial <sup>\*\*\*)</sup> abelian symmetry  $G = U(1)_F \times U(1)_C \times U(1)_S$ ; the charges defined by these currents being just the flavon, the chromon and the S numbers  $N_F, N_C$  and  $N_S$ . The net local symmetry <sup>\*\*\*\*)</sup> at the composite level is thus of the form  $G_{EW} \times U(1)_F \times U(1)_C \times U(1)_S$ .

We expect  $Z_F, Z_C$  and  $Z_S$  to acquire masses dynamically. These gauge particles have the remarkable feature that each one of them couples universally to all quarks and leptons. This is because each quark (or lepton) possesses  $N_F = N_C = N_S = 1$ . The existence of three or more such gauge particles is peculiar to preonic models. If quarks and leptons are assumed to be elementary and if we assume a grand unifying non-abelian symmetry for the

\*) One example of such fermions are the mirror fermions. With spin  $\frac{1}{2}$  preons, there exists a simple mechanism to generate three families plus their mirror sets <sup>8)</sup>.

\*\*\*) This amounts to saying that the spin-1 gauge particles within the coset spaces  $SU(16)/H$  must effectively be superheavy  $> M_0$ , if they form as composites at all.

\*\*\*\*) For the case of spin- $\frac{1}{2}$  preons the abelian symmetry can be chiral unless anomaly constraint restricts it to be vectorial. Note that the composite gauge particles  $Z_{F,C,S}$  are distinct from the primordial gauge particle  $A'_\mu$ .

\*\*\*\*\*) It is worth noting that the symmetry of the preonic Lagrangian was just  $[U(1)_A \times U(1)_B]_{\text{local}} \times [U(2)_F \times U(4)_C \times U(1)_S]_{\text{global}}$ , where the hat A signifies that the two U(1)'s (of electric and magnetic character) are inter-related.

This symmetry translates into  $G_{EW} \times [U(1)]^3_{\text{local}}$  at the quark lepton level in accordance with the renormalizability conjecture. Why we started with two flavons, four chromons and one S - or rather why the global preonic symmetry is  $U_F(2) \times U_C(4) \times U_S(1)$  - can only be answered at the level of pre-preons

quark-lepton Lagrangian, it would be possible to generate one such gauge particle coupled to a fermion number \*) as in the SU(16) model, but not three.

This opens the possibility for a clear experimental signal for preonic models. If the masses of  $Z_F, Z_C$  and  $Z_S$  are in the range of a few hundred GeV, their presence can be felt in  $e^+e^- + \mu^+\mu^-$  and  $e^+e^- \rightarrow q\bar{q}$  forward-backward asymmetry measurements even at LEP energies and similar measurements in  $pp + \bar{p}\bar{p}$  and  $\bar{p}p + \bar{p}\bar{p}$  at Isabelle and the new CERN  $\bar{p}p$  accelerator. Evidence for three such gauge particles coupling universally to all quarks and leptons, if found, would call for a preonic basis. We see that such evidence could come (depending upon the masses of the Z's) even before one may reach the energy scale  $M_0 \approx \frac{1}{r_0}$ , where quarks and leptons would begin showing form factors, or even dissociating.

This preon model (with both binding charges  $Q_A$  and  $Q_B$  "hidden") can be distinguished from those <sup>\*\*)</sup> in which one of the "binding" charges is ordinary electric and the other charge is magnetic. For the latter, collisions of ordinary matter (carrying electric charge) can lead to emission of virtual high-energy photons, which through the large magnetic coupling can convert to a preon-antipreon pair at short distances. The latter in turn can generate more preon pairs; these could recombine to give large multiplicity events <sup>11)</sup> of  $q\bar{q}$  and  $l\bar{l}$  type in comparable numbers and perhaps also photons. These processes would take place as long as centre-of-mass energies exceed twice the effective mass of preons at short distances, which need not be much greater than 200 GeV <sup>\*\*\*)</sup>. Such a threshold may thus be much lower than the inverse size  $M_0 = \frac{1}{r_0} > 1$  to 10 TeV. For the present model with both  $Q_A$  and  $Q_B$  "hidden", such a dramatic signal would appear only at an energy scale  $\lambda M_0$ , where simultaneously quarks and leptons would begin showing form factors.

We end this note with a few remarks which are more general than the specific model proposed here.

(1) To pursue the point of economy one may regard the graviton as a composite of the primordial spin-1 quanta  $A'$  and of the preons. A composite picture for the graviton has been considered by several authors <sup>12)</sup>. It has also been noted <sup>13)</sup> in a general context that a spin-2 particle treated in the

\*) The fermion number symmetry may be identified with the diagonal sum of the three symmetries  $U(1)_F, U(1)_C$  and  $U(1)_S$ .

\*\*\*) See Ref. 3.

\*\*\*\*\*) See Ref. 8. For a thorough discussion of related points for energies  $E \gtrsim \frac{1}{r_0}$ , see Ref. 11. We note that photons of energies higher than

inverse size will exhibit circular polarization revealing parity violation if photons couple to electric and magnetic charge. Parity violation for such energies is truly characteristic of all theories based on dual charges, whether hidden or manifest.

framework of a local field theory \*) must be massless and must uniquely couple in a generally covariant manner to the energy momentum tensor  $T_{\mu\nu}$  in order that the theory may be ghost-free \*\*). Since

positive definiteness (guaranteeing conservation of probabilities) is the minimal requirement even for an effective field theory of composites, this result serves to provide credence to a composite picture of the graviton in the sense that the unique emergence of the Einstein Lagrangian at the composite level is not an accident; it is guaranteed on more general grounds regardless of the details of the binding dynamics.

One may furthermore observe that the renormalizability conjecture stated before implies - since gravitational interaction is perturbatively non-renormalizable - that this interaction must be damped by the small size  $R \approx \frac{1}{M}$  of the composites at energies much smaller than  $M$ . (Here  $R$  may in general be much smaller than the size  $r_0$  of quarks and leptons - see remarks below.) This would say that the weakness of the gravitational coupling constant is related to another known fact - the smallness of the size of quarks and leptons (or of their constituents) and thus to the dynamics of the primordial binding force.

To identify  $R$  with  $\frac{1}{M_{\text{Planck}}}$  where  $M_{\text{Planck}} \approx 2 \times 10^{19}$  GeV, we find it

\*) We are assuming here that the composites including graviton have sufficiently small size  $\sim 1/M_{\text{Planck}}$ , so that they may be encompassed within a local field theory for energy ranges  $\ll M_{\text{Planck}}$ . We remark that the above statement does not of course preclude the existence of massive spin-2 composites like the f graviton <sup>14)</sup> composite perhaps of two gluons, with masses  $M_c \ll M_{\text{Planck}}$  but inverse sizes  $\ll M_c$ . These can also be described by effective local field theories for energies less than their inverse size.

\*\*\*) It is noteworthy that no spin  $\frac{2}{2}$  or spin 3 interacting theories which are field theoretically satisfactory have yet been discovered.

natural to envision several layers \*) of increasing elementarity - preons, pre-preons, pre-pre-preons... within quarks and leptons with their sizes decreasing progressively from say  $10^{-17}$ - $10^{-18}$  cm to  $10^{-33}$  cm - the size of the last but one layer which includes the graviton (if it is composite) being of order  $1/M_{\text{Planck}}$ . Within this picture the gravitational interaction would be damped by form factors at momenta approaching Planck mass scale thus rendering the theory well behaved for these energies. Unfortunately the differences from the conventional picture where gravitation is included as a fundamental interaction would manifest themselves only at and beyond Planck energies if one may be so daring as to contemplate this regime where the graviton may have dissociated into its more elementary constituents. In such a theory the perspective of unification of gravity with the other forces takes a new form: the effective Yang-Mills constant of the present gauge theories as well as the Newtonian constant would be computable, in principle, in terms of the primordial  $[U(1) \times U(1)]$  constant (suitably dimensionally transmuted). Compare this with the picture presented for example by supergravity theories at Planck energies and beyond, where gravity plus some form of matter - possibly with a fundamental Yang-Mills interaction - would survive and the eventual theory may contain two constants (Newtonian and Yang Mills or equivalently Newtonian and a cosmological constant).

(2) One may choose to assign spin  $\frac{1}{2}$  to the preons f, C and S rather than spin 0, while assigning them the same binding charges  $(Q_A, Q_B)$  as in the text. In this case one must choose  $(gh/4\pi) = (\frac{1}{2})(2) = 1$ , so that the field generated by each pair would contribute one unit of angular momentum rather than half a unit and the composites fCS can still have spin  $\frac{1}{2}$ . Here, for  $h^2/4\pi = 1$ , we would have  $g^2/4\pi = gh/4\pi = 1$ . Thus both  $Q_A \cdot Q_A$  and  $Q_B \cdot Q_B$  couplings can be of the same order.\*\*) This case will share most of the consequences of the model presented above except that spin  $\frac{1}{2}$  will not have its origin in the force field and that spin 1  $\bar{P}P$  composites can couple to chiral rather than purely vectorial currents.

(3) We see that the effective gauge symmetry at the quark lepton level need not be simple or semisimple; it may in general have a form  $\mathcal{G}_{\text{EN}} \times U(1)$ -factors, which cannot be embedded into a simple or semisimple group for reasons

\*) This would correspond to having no long extending "desert" or grand plateau in physics.

\*\*\*) Note that in this case, all three families (arising through three different two-body cores in the manner discussed in the text) would have similar binding energies.

discussed above. This however does not run counter to the spirit of grand unification, since the primordial force is governed by one coupling constant.

(4) Proton decay into leptons (with composite quarks, leptons, gauge and Higgs particles) will occur and provide an upper limit to the scale of the inverse size  $1/r_0 = M_0$ . This is because the masses of the composites (including the gauge and Higgs particles) are, within the picture presented here, bounded above by  $M_0$ .

Within the standard approach the (B-L) conserving proton decay (e.g.  $p \rightarrow e^+ + \pi^0$ ) is mediated by diquark and lepto-antiquark type of gauge particles, which for a preonic theory of the type presented here are to be interpreted as six rather than two preonic composites. The masses of these gauge particles are estimated to exceed around  $10^{14}$  GeV to account for the known lower limit on proton lifetime. For this picture to be consistent with our approach the sizes of quarks and leptons and the superheavy gauge particles would have to be less than  $(10^{14} \text{ GeV})^{-1}$ . There is an alternative scenario which would arise if the dynamics of preon binding does not favour the formation of six preonic spin-1 composites<sup>\*</sup>). In this case, proton decay into  $e^+ + \pi^0$  may occur through<sup>a</sup> third order in the effective four preonic transition  $(P_1 + P_2 \rightarrow \bar{P}_3 + \bar{P}_4 + \phi_a + \langle \phi_b \rangle)$  followed by an effective quartic  $\lambda \phi^4$  coupling (subject to one component of  $\phi$  having non-zero VEV.<sup>\*\*</sup>) The four preonic transitions of the above sort can be mediated (for the case of spin- $\frac{1}{2}$  preons) by dipreonic gauge composites with for example the compositions (cf), (fs) and (sc). The emitted Higgs ( $\phi_a$ ) may have the same composition or may contain four preons. The amusing feature of such a mechanism is that the characteristic mass scale for this process (yielding  $\Delta F = -4, p \rightarrow e^+ + \pi^0$ ) is only of the order of  $10^3 - 10^4$  GeV in contrast to  $10^{14}$  GeV for the SU(6) or SO(10) models. The  $\Delta F = 0$  proton decay mediated by leptoquark X of mass  $10^4$  GeV would be comparable in strength with similar remarks<sup>applying</sup> for  $\Delta F = -2, -6$ . Within this picture quarks and leptons need have sizes no smaller than  $\approx (10 \text{ TeV})^{-1}$ . A choice between the two scenarios would need direct experiments with high-energy probes from the region of energies of order 10 TeV.

<sup>\*</sup>) Unfortunately the question of binding for such systems of charges and monopoles is very little understood.

<sup>\*\*</sup>) This mechanism is analogous to that of the  $\Delta F = 0$  proton decay ( $p \rightarrow 3\pi + \text{mesons}$ ) for the standard case (see Ref. 1).

(5) Finally we have taken a fairly conservative attitude towards the physics of preons. If we are to entertain the notion of layers of compositeness and elementarity, we should be prepared for new physics, relevant at very small distances. Ideally we shall be looking for the preon, pre-preon, pre-pre-preon... sequence to end with one single (monotheistic) entity<sup>\*\*\*</sup> endowed perhaps with properties of topological nature<sup>\*\*\*</sup>},

Note added: After completing this note, we came across a paper of Weinberg and Witten<sup>20</sup> in which restrictions on spins of composites are derived, under certain assumptions, among which Lorentz invariance plays an important role. If our preons carrying dual charges are described by a theory like that of Zwanziger<sup>5</sup>, Lorentz invariance emerges only non-perturbatively, and it is not clear to us if the considerations of Weinberg and Witten should apply to this case.

<sup>\*</sup>) See remarks in the last reference of Ref. 1.

<sup>\*\*</sup>) We observe that of the three sets of preons (f,C,S), one set can be considered as composite of the other two so far as their charge assignment is concerned, e.g. f $\rightarrow$ CS. Alternatively, and perhaps more attractively, one may introduce just two preons, e.g.  $\alpha$  with charge (g,0) and  $\beta$  with charge (0,h). Identify S of charge (-g,-h) with  $(\alpha\beta)$  and its mirror S' of charge (g,-h) with  $\alpha\bar{\beta}$ . The two flavons (f's) may be identified with  $\alpha$  and  $\bar{\beta}\bar{\beta} = \bar{\beta}(\alpha\beta)$  or (and, for 2 families) with  $\alpha(\bar{\alpha}\alpha)$  and  $\beta(\alpha\bar{\beta})$ . Likewise one can specify composite constructions for four or more C's. One ~~criteria~~ for choosing a particular set could be the emergence of appropriate commutation relations for the composite currents from the canonical commutation relations<sup>19</sup> in the approximation when composite size is neglected. With just two fundamental entities  $\alpha$  and  $\beta$ , related by duality, one might already be approaching a monotheistic view, but such a model, as it stands, yields integer spin for quarks and leptons, when viewed as fCS composites. This is true for either spin assignment (0 or  $\frac{1}{2}$ ) for ( $\alpha,\beta$ ) and either field-spin ( $gh/4\pi = \frac{1}{2}$  or 1). This difficulty can of course be removed by introducing, in addition, supersymmetric partners of (spin  $\frac{1}{2}$ )  $\alpha$ 's and  $\beta$ 's or alternatively a fundamental spinon with charges (g,h); however we would like to believe that there is yet another source for spin  $\frac{1}{2}$  which will obviate the need for introducing these extra entities.

<sup>\*\*\*</sup>) We have in mind the possible use of the theory of knots built on a fundamental substructure<sup>16</sup>, or the use of higher<sup>17</sup> dimensions where dual charges can be topologically defined<sup>18</sup>. In this latter context W. Nahm (in a private discussion) has emphasised that the N = 4 Yang-Mills supersymmetric theory which can be formulated in ten dimensions is a good candidate for a fundamental local theory of dual charges. The  $\beta$  function vanishes (upto three loops) in the theory implying lack of need for perturbative renormalizability for either charge (electric g or magnetic  $h = \frac{2\pi \times \text{integer}}{g}$ ).

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