An Intriguing Multiplet for Left-Handed Quarks and Leptons, Which Suggests a Possible Composite Particle Structure

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It is shown how the internal flavor symmetries of left-handed chiral quarks and leptons within a single generation, form part of an adjoint representation of the simple local gauge group SU(4). This adjointness of representation suggests the possibility of decomposing quarks and leptons into a more basic set of preon fields, which form the fundamental representation of SU(4). While this decomposition properly accounts for the *internal* symmetries of quarks and leptons, it ignores their *spacetime* symmetries, particularly spin. To account for spin, one instead uses a 4x4 version of the gauge group SO(4), which reproduces all of the SU(4) internal symmetries, and also results in a more satisfactory spin content. The proposed decomposition of elementary particles may be compatible with the theory of open strings, with preons defining the "charges" at the string endpoints, and with open strings and their endpoints transforming together in an adjoint representation of SO(4).

1. An Intriguing Multiplet for Left Handed Quarks and Leptons

We begin discussion by examining the well-known quantum numbers for left-handed chiral projections of quarks, leptons and charged electroweak vector bosons, as follows:

	Spin	I^3	Y	B	Q	Qu	L
u_L	1/2	1/2	1/6	1/3	2/3	1	0
d_L	1/2	-1/2	1/6	1/3	-1/3	1	0
υ_L	1/2	1/2	-1/2	0	0	0	1
e_L	1/2	-1/2	-1/2	0	-1	0	1
W^{+u}	1	1	0	0	1	0	0
W^{-u}	1	-1	0	0	-1	0	0

Figure 1 - Left-Handed Quarks, Leptons, and Charged Electroweak Bosons

In the above, u and d denote the up and down quarks; υ and e the neutrino and electron leptons; and W^{+u} and W^{-u} the charge raising and lowering weak bosons. I^3, Y, B, Q, Qu and L denote, respectively, weak isospin, weak hypercharge, baryon, electrostatic Coulomb charge, quark and lepton numbers. We have confined consideration to the first fermion generation. If R, G, and B denote the red, green and blue quantum numbers associated with QCD color (distinguish B = blue from B = baryon number by context), then quark number may be related to these by Qu = R + G + B.

One gets right to the crux of the matter by plotting these particles and their antiparticles on a flavor "weight diagram" of Y vs. I^3 as follows, where we have set $Q = Y + I^3$ in the usual manner: (spins are in parentheses)

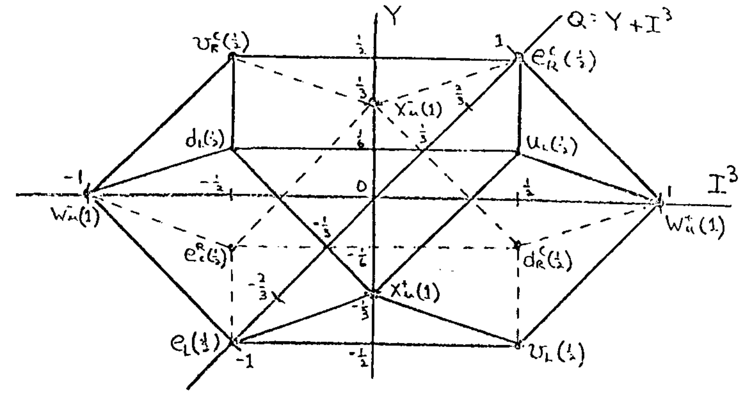

Figure 2 - Weight Diagram of Left-Handed Quarks, Leptons, and Charged Electroweak Bosons, Y vs I^3

Close examination of figure 2 reveals almost immediately that this looks just like a weight diagram for the adjoint $4 \otimes 4^*$ representation of the simple gauge group SU(4), where particle / antiparticle states labelled X^{+u} and X^{-u} have been added to complete the charged current sector of the representation, and where the neutral current sector has been omitted. The degrees of freedom displayed are those ordinarily associated with the SU(4) generators T^3 and T^8. By drawing a similar diagram of Y vs. B with I^3 suppressed, one arrives at the following:

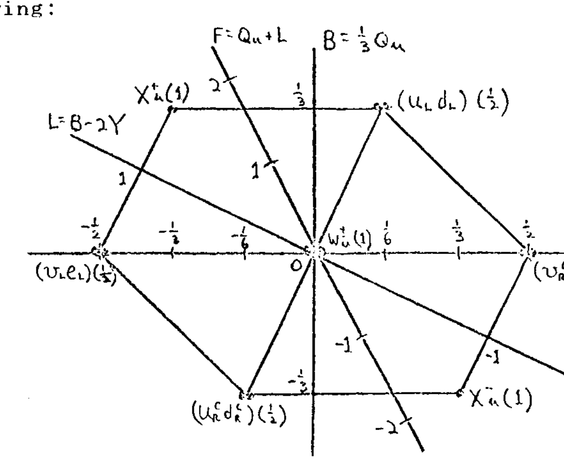

Figure 3 - Weight Diagram of Left-Handed Quarks, Leptons, and Charged Electroweak Bosons, B vs Y

Examination of the above reveals that this too looks like a weight diagram for the adjoint representation of SU(4), though the degrees of freedom displayed here are those ordinarily associated with the T^8 and T^{15} generators of SU(4). Thus, we may regard figure 3 as simply an orthogonal view of figure 2, with I^3 suppressed. One may also construct Qu and L for these left-handed chiral projections from linear combinations of B and Y, by setting Qu = 3B and L = B - 2Y. Similarly, fermion number F = Qu + L. We henceforth denote Y by Y^8 and B by B^{15}, to illustrate the above noted correspondences with the generators of SU(4).

Figures 2 and 3, which are constructed from well-established particle and interaction characteristics that are empirically based, have several intriguing aspects, including the following: 1) quarks and leptons appear in the same multiplet, which one ordinarily associates with grand unification; 2) particles and antiparticles appear in the same multiplet, which one also associates with grand unification; and 3) spin 1/2 fermions and spin 1 bosons appear in the same multiplet, which suggests the presence of some principle that connects the internal symmetries of these particles of differing spin. But what is most intriguing about these diagrams is the fact that they depict an *adjoint* representation of SU(4), rather than a *fundamental* representation. This leads one to consider the possibility that the quarks, leptons and vector bosons associated with this adjoint SU(4) representation may in fact be composite; with their elementary constituents transforming according to the fundamental representation of SU(4). The challenge is to develop a physically meaningful theory on the basis of such a decomposition.

From Adams, Mukhopadhyay, Stoler, ed., Excited Baryons 1988.
World Scientific (1988), pp. 492-494.