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O(18) REVIVED*

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ABSTRACT

We present an O(18) theory which is pertubatively unifiable and which accounts for the absence of right-handed families in the low-energy world. The model gives rise to dramatic predictions for proton decay and for the Z° width.

Many of the outstanding questions of particle physics concern the question of families. We do not know why quarks and leptons come in families, nor why the families repeat. Furthermore, we do not even know why the weak interactions are purely V-A. We still cannot tell Rabi who ordered the muon.

The most appealing theories of family unification are based on the group O(18). There are many reasons for this. All the known families fit into just one representation, the 256-dimensional spinor. This spinor is complex, so superheavy masses for ordinary families are forbidden. In addition, the group O(18) is automatically anomaly-free.

Previous attempts to construct realistic theories based on O(18) were plagued by serious difficulties.[1] These stem from the fact that the 256-dimensional spinor contains too many families. This can be seen by decomposing the 256 under O(10) $\times$ O(8), $256 \rightarrow (16,8') + (\overline{16},8'')$. Here O(10) is the usual grand unified group and O(8) is a horizontal family symmetry. Under O(10) $\times$ O(8), the O(18) spinor splits into eight left- and eight right-handed families. With 16 light families, perturbative unification is lost.

Thus, it is necessary to split the O(18) spinor,[2,3] and leave some families behind at the grand unified scale M_{GUT}. We have split the spinor by finding all continous symmetries $H \subseteq$ O(8) under which the 256 contains a complex representation of $G = SU(3) \times SU(2) \times U(1) \times H$. We assume that fermions in real representations of G get masses of order M_{GUT}, and that fermions in complex representations remain massless down to the weak scale M_W. To ensure perturbative unification, we must choose H so that at least four left- and four right-handed families get mass at the grand unified scale. We have shown that there are only two possibilities for H. Both are abelian and both leave four light left-handed families and four light right-handed families.

Having split the heavy families from the light families, we must now explain why the light right-handed families are heavier than their left-handed counterparts. This is easy to do via O(8) group theory. The crucial point is that the left- and right-handed families transform under *different* representations of O(8). The O(8) multiplication laws ensure that if the Weinberg-Salam Higgs ϕ is contained in a 35'' of O(8), it couples directly to right-handed families, but only radiatively to left-handed families.

The experimental implications of O(18) are dramatic, and the model will be tested very soon. Some of the predictions depend on exactly which version of the theory is being discussed. Others are more robust, and are the implications on which we shall concentrate here.

The most striking prediction of our O(18) theory is that eight light neutrinos should contribute to the Z° width.[2] Their precise masses depend on the model under discussion, but in all cases the masses are less than half that of the Z°.

A second prediction is that four right-handed families should live near the weak scale. They are heavy enough that the quark masses should be governed by an infrared fixed point.[2] This leads to a mass sum rule for the right-handed quarks: $\frac{1}{8}\sum m_Q^2 \lesssim (125\ \mathrm{GeV})^2$. The masses of the right-handed charged leptons are not governed by any fixed point. Nevertheless, our numerical studies indicate that they also obey a sum rule, $\frac{1}{4}\sum m_L^2 \lesssim (50\ \mathrm{GeV})^2$. It is quite likely that some of the right-handed charged leptons should contribute to the Z° width.

A third prediction is that there should be a fourth left-handed family. The exact mass of this family depends on the details of the left-handed mass matrix, but it should be lighter than the right-handed families.

A final consequence of O(18) is that it postpones proton decay.[2] By now, proton decay experiments exclude not only minimal SU(5), but a host of other models as well. O(18) escapes this fate because it contains eight light families. For eight families, and only for eight families, the color beta function is dominated by its two-loop contribution. This increases the unification mass from its minimal SU(5) value. Since our theory at M_{GUT} is an effective SU(5) theory, we expect to find the same decay modes. For $\Lambda_{\overline{MS}} = 100$ MeV, we find $\tau(p \rightarrow e^+\pi^\circ) = 5.9 \times 10^{31\pm1}$ years, and $\sin^2\theta = .214$. These are our favored values. The error in the exponent comes from uncertainties in the hadronic matrix element. Since experiment now places a limit $\tau(p \rightarrow e^+\pi^\circ) \gtrsim 2 \times 10^{32}$ years, we predict that proton decay should be seen very soon.

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2. J. Bagger and S. Dimopoulos, Nucl. Phys. B244, 247 (1984); J. Bagger, S. Dimopoulos and E. Massó, Phys. Lett. B (in press); SLAC-PUB-3437; 3441 (1984).
3. Another scenario is discussed in G. Senjanović, F. Wilczek and A. Zee, Phys. Lett. 141B, 389 (1984).

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