THREE STERILE NEUTRINOS IN E_6

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Possible inconsistencies in the three-family picture of neutrino masses and mixings can be alleviated by additional "sterile" neutrinos mixing weakly with the ordinary ones. A possible source of these neutrinos is the grand unified group E_6. The 27-dimensional fundamental representation of E_6 contains exotic fermions, including weak isosinglet quarks of charge –1/3, vector-like weak isodoublet leptons, and neutral leptons which are singlets under both left-handed and right-handed SU(2). These last ar candidates for light sterile neutrinos, hinted at by various short-baseline neutrino experiments. To accommodate three families of quarks and charged leptons, an E_6 model must contain three 27-plets, each of which contains a sterile neutrino candidate n. The mixing pattern within a 27-plet was described, and experimental consequences discussed, in Ref. [1]. It is proposed for Snowmass 2021 to update these analyses and to describe the prospects for gaining further information about this possibility.

The standard model group $SU(3)_{color} \times SU(2)_L \times U(1)$ can be incorporated into a grand unified group. Candidates include SU(5), SO(10), and E_6 [2]. Each quark and lepton family consists of a $5^* + 10$ representation of SU(5). Adding a right-handed neutrino N [an SU(5) singlet] to each such hypermultiplet, one gets a spinor 16-plet of SO(10). A right-handed neutrino can pair with a left-handed one to generate a Dirac mass m_D as occurs for charged leptons and quarks. However, the neutrality of the right-handed neutrino under the standard model group allows it to have a large Majorana mass M, leading via the seesaw mechanism [3] to light-neutrino masses $m_\nu = m_D^2/M$. At this stage there are three light neutrinos (mostly electroweak doublets) and three heavy ones (mostly electroweak singlets).

In addition to the "active" light neutrinos ν_e, ν_μ, ν_τ, some short-baseline neutrino experiments hint at the existence of one or more light "sterile" neutrinos, participating in the weak interactions only via mixing with the active ones. Schemes exist, not discussed here, in which one or more right-handed neutrinos plays the role of a light sterile neutrino. For Snowmass 2021 we pursue instead a scenario for sterile neutrinos based on E_6. This would be especially timely if the exotic states predicted in E_6 were to show up in forthcoming experiments at the CERN Large Hadron Collider. A 10-plet of SO(10) [a $5 + 5^*$ of SU(5)] can be added to each quark and lepton family. It consists of quarks $h + h^c$ which are singlets under $SU(2)_L$ and $SU(2)_R$, and leptons $E^\pm$ and their neutral counterparts which are doublets under both. The smallest E_6 representation, a 27-plet, is formed by adding another singlet n of SO(10). The n has neither L nor R isospin. We propose to explore the scenario in which the three n states are candidates for light sterile neutrinos, leaving all three right-handed neutrinos unconstrained and potentially very heavy.

The proposed analysis is meant to tell what it takes for E_6 to be a satisfactory framework for treating sterile neutrinos. The following conditions have been found sufficient:

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- The standard seesaw mechanism accounts for all three (light) active neutrino masses, entailing three very heavy right-handed neutrinos which are left-handed SU(2) singlets and right-handed SU(2) doublets.

- Fermion masses arise from the lowest-dimension (27^*) Higgs representation in E_6, aside from a mechanism permitting right-handed neutrinos to acquire large Majorana masses.

- This is achieved by breaking E_6 down to $SU(5) \times U(1)_N$, where $U(1)_N$ is a symmetry under which right-handed neutrinos are neutral. Q_N is the corresponding charge. The gauge boson carrying U(1) charge could be light enough to be seen at the LHC.

- Exotic isodoublet leptons ν_E, E and isosinglet quarks h should acquire large Dirac masses and mix weakly with lighter states.

- A term M_{14} in the 5×5 neutrino mass matrix is taken to be small despite carrying zero weak (left-handed) isospin. This fine-tuning, possibly achieved via a Z_2 symmetry, seems needed to describe the observed spectrum.

The grand unified group E_6 provides candidates for three light sterile neutrinos. The extended Higgs and gauge structure of E_6 permits new mechanisms for production of these candidates in the early universe. Conclusive evidence for three sterile neutrinos, if interpreted within the framework of E_6, would entail also isovector charged leptons and isosinglet quarks h with charge –1/3. These would then be prime targets for higher-energy searches at the CERN Large Hadron Collider.

References

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