Horizontal Gauge Symmetry and Masses of Neutrinos

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Recently several authors have studied a possible unification of electronic and muonic matter by adding the horizontal local-symmetry, $SU_F(2)$,[1)∿3)] to the weak and electromagnetic $SU(2)\times U(1)$.[4)] As a consequence of gauging the symmetry, the conservation of muon number is violated. The exchange of horizontal gauge bosons, S_μ^a, also induce the superweak type of CP-nonconservation.[1)] From the data on CP-violation in $K_L^0 \to 2\pi$ decay, the effective coupling constant, G_S, of S_μ^a with leptons and quarks is determined as $G_S \sim 10^{-15}$ GeV^{-2} unless the accidental cancellation occurs.[1)] The strength is enough weak to avoid unwanted flavour-changing transitions.

If there exist six leptons and six quarks, we extend the horizontal $SU_F(2)$ to $SU_F(3)$. The weak-SU(2) doublet-and singlet-fermions transform as triplets under the horizontal $SU_F(3)$. The triangle anomalies[5)] appearing in the lepton sector can be removed by assuming right-handed neutrinos.[*)]

The purpose of this short note is to point out the possibility that the spontaneous breakdown of the symmetry generates the masses of right-handed and left-handed neutrinos and each neutrino becomes a massive Majorana particle. The mass of each particle may be $m_\xi \sim 10^5$ GeV and $m_\zeta \sim 10 \sim 10^4$ eV, respectively.

The assignment for leptons is the following:

$$\underset{\updownarrow}{SU(2)} \quad \psi_L = \begin{pmatrix} \nu_e & \nu_\mu & \nu_\tau \\ e & \mu & \tau \end{pmatrix}_L , \quad \begin{array}{l} \nu_R = [\nu_e \quad \nu_\mu \quad \nu_\tau]_R \; , \\ \qquad (3, \; 1, \; 0) \\ \ell_R = [e \quad \mu \quad \tau]_R \; . \\ \qquad (3, \; 1, \; -2) \end{array} \tag{1}$$

$$(3, \; 2, \; -1)$$

$$\leftarrow SU_F(3) \rightarrow \qquad\qquad \leftarrow SU_F(3) \rightarrow$$

Here the first two values in each parenthesis denote the representation dimensions of $SU_F(3) \times SU(2)$ and the last one the U(1) hypercharge.

In order to make the horizontal gauge bosons, S^a_μ $(a = 1 \sim 8)$, heavy sufficiently we introduce a Higgs scalar, $\chi_{ij} = (6, 1, 0)$. Another Higgs scalar, $\phi^a = (8, 2, -1)$ is also assumed to break the symmetry $SU(2) \times U(1)$ surviving down to the electromagnetic one.

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*) It is possible to assign fermions as triplets of $SU_F(2)$. In this case the anomalies are not generated without right-handed neutrinos (see Ref.2)).

The general form of the neutrino's mass term is given by

$$\mathcal{L}^{\nu}_{mass} = \frac{1}{2}G^{\nu}_{\chi}\,\overline{(\nu^{i}_{R})^{c}}\,\langle x_{ij}\rangle\,\nu^{i}_{R} + G^{\nu}_{\phi}\,\bar{\psi}_{L}\langle\phi^{a}\rangle\lambda^{a}\nu_{R} + \text{h.c}, \tag{2}$$

where $(\nu^{i}_{R})^{c}$ denotes the charge-conjugated field of ν^{i}_{R} and $(\nu^{1}\ \nu^{2}\ \nu^{3})_{R}$ corresponds $(\nu_{e}\ \nu_{\mu}\ \nu_{\tau})_{R}$. Eq(1) represents a 6×6 mass matrix among six Majorana particles, $\xi^{i} = \nu^{i}_{R} + (\nu^{i}_{R})^{c}$ and $\zeta^{i} = \nu^{i}_{L} + (\nu^{i}_{L})^{c}$ $(i = 1\sim 3)$. The masses of these neutrinos are roughly obtained as

$$m_{\xi} \sim G^{\nu}_{\chi}\langle\chi\rangle \quad , \tag{3}$$

$$m_{\zeta} \sim \frac{G^{\nu}_{\phi}\langle\phi\rangle}{G^{\nu}_{\chi}\langle\chi\rangle}\cdot G^{\nu}_{\phi}\langle\phi\rangle \quad , \tag{4}$$

where $\langle\chi\rangle$ and $\langle\phi\rangle$ are vacuum-expectation values averaged and $\langle\phi\rangle/\langle\chi\rangle \sim 10^{-5}$.[1] To estimate magnitudes of these masses we tentatively assume that all Yukawa coupling constants are same order, $G^{\nu}_{\chi} \sim G^{\nu}_{\phi} \sim G^{\ell}_{\phi}$, where G^{ℓ}_{ϕ} is the coupling constant for leptons, $\ell = (e\ \mu\ \tau)$. Then we find $m_{\xi} \sim 10^{5}$ GeV and $m_{\zeta} \sim 10 \sim 10^{4}$ eV. Neutrino oscillations are also expected, but the oscillation length depends on the details of the mass matrix.

Finally we stress that the present scheme of the symmetry breaking is a realistic one in the sense that the Higgs scalars ϕ^{a} and χ_{ij} can be considered as bound states of fermion-antifermion $(\bar{\nu}_{R}\psi_{L}+\bar{\ell}_{R}\psi_{L}+\cdots)$ and fermion-fermion $(\nu_{R}\nu_{R})$, respectively.[6] It is, therefore, due to the large violation of the horizontal symmetry that right-handed neutrinos disappear at low energy regions.

References

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