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## 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,  $SU_F(2),^{1)\sim 3)}$  to the weak and electromagnetic  $SU(2)\times U(1).$ <sup>4)</sup> As a consequence of gauging the symmetry, the conservation of muon number is violated. The exchange of horizontal gauge bosons,  $S_\mu^a$ , also induce the superweak type of CP-nonconservation.<sup>1)</sup> From the data on CP-violation in  $K_L^0 \rightarrow 2\pi$  decay, the effective coupling constant,  $G_S$ , of  $S_\mu^a$  with leptons and quarks is determined as  $G_S \sim 10^{-15} \text{ GeV}^{-2}$  unless the accidental cancellation occurs.<sup>1)</sup> 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<sup>5)</sup> 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:

$$\begin{array}{ccc}
 \begin{array}{c} \uparrow \\ SU(2) \\ \downarrow \end{array} & \psi_L = \begin{pmatrix} \nu_e & \nu_\mu & \nu_\tau \\ e & \mu & \tau \end{pmatrix}_L & , \quad \begin{array}{l} \nu_R = [\nu_e \quad \nu_\mu \quad \nu_\tau]_R \\ (3, \quad 1, \quad 0) \end{array} \\
 & & \begin{array}{l} \ell_R = [e \quad \mu \quad \tau]_R \\ (3, \quad 1, \quad -2) \end{array} \\
 & (3, \quad 2, \quad -1) & (3, \quad 1, \quad -2) \\
 & \leftarrow SU_F(3) \rightarrow & \leftarrow SU_F(3) \rightarrow
 \end{array} \quad (1)$$

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,  $S_\mu^a$  ( $a = 1 \sim 8$ ), 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

$$\mathcal{L}_{\text{mass}}^{\nu} = \frac{1}{2} G_{\chi}^{\nu} \overline{(\nu_R^i)^c} \langle \chi_{ij} \rangle \nu_R^i + G_{\phi}^{\nu} \bar{\psi}_L \langle \phi^a \rangle \lambda^a \nu_R + \text{h.c.}, \quad (2)$$

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

$$m_{\xi} \sim G_{\chi}^{\nu} \langle \chi \rangle, \quad (3)$$

$$m_{\zeta} \sim \frac{G_{\phi}^{\nu} \langle \phi \rangle}{G_{\chi}^{\nu} \langle \chi \rangle} \cdot G_{\phi}^{\nu} \langle \phi \rangle, \quad (4)$$

where  $\langle \chi \rangle$  and  $\langle \phi \rangle$  are vacuum-expectation values averaged and  $\langle \phi \rangle / \langle \chi \rangle \sim 10^{-5}$ .<sup>1)</sup> To estimate magnitudes of these masses we tentatively assume that all Yukawa coupling constants are same order,  $G_{\chi}^{\nu} \sim G_{\phi}^{\nu} \sim G_{\phi}^{\ell}$ , where  $G_{\phi}^{\ell}$  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  $\phi^a$  and  $\chi_{ij}$  can be considered as bound states of fermion-antifermion  $(\bar{\nu}_R \psi_L + \bar{\ell}_R \psi_L + \dots)$  and fermion-fermion  $(\nu_R \nu_R)$ , respectively.<sup>6)</sup> It is, therefore, due to the large violation of the horizontal symmetry that right-handed neutrinos disappear at low energy regions.

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