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SO(10) GUT's, Neutrinos and LFV

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A model based on $SO(10) \times SU(2)_F$ having symmetric mass textures with 5 zeros is constructed. The symmetric mass textures arising from the left-right symmetry breaking chain of SO(10) give rise to good predictions for the masses, mixing angles and CP violation measures in the quark and lepton sectors, all in agreement with the most up-to-date experimental data within 1 σ. Various lepton flavor violating decays in our model are also investigated. Unlike in models with lop-sided textures, our prediction for the decay rate of $\mu \to e\gamma$ is much suppressed and yet it is large enough to be probed by the next generation of experiments. The observed baryonic asymmetry in the Universe can be accommodated utilizing soft leptogenesis

SO(10) has long been thought to be an attractive candidate for a grand unified theory (GUT) for a number of reasons: First of all, it unifies all the 15 known fermions with the right-handed neutrino for each family into one 16-dimensional spinor representation. The seesaw mechanism then arises very naturally, and the small yet non-zero neutrino masses can thus be explained. Since a complete quark-lepton symmetry is achieved, it has the promise for explaining the pattern of fermion masses and mixing. Recent atmospheric neutrino oscillation data from Super-Kamiokande indicates non-zero neutrino masses. This in turn gives very strong support to the viability of SO(10) as a GUT group. Models based on SO(10) combined with discrete or continuous family symmetry have been constructed to understand the flavor problem [1]. Most of the models utilize "lopsided" mass textures which usually require more parameters and therefore are less constrained. The right-handed neutrino Majorana mass operators in most of these models are made out of $16_H \times 16_H$ which breaks the R-parity at a very high scale. The aim of this talk, based on Ref. [2,3], is to present a realistic model based on supersymmetric SO(10) combined with SU(2) family symmetry which successfully predicts the low energy fermion masses and mixings. Since we utilize *symmetric* mass textures and $\overline{126}$-dimensional Higgs representations for the right-handed neutrino Majorana mass operator, our model is more constrained in addition to having R-parity conserved. The set of up- and down-quark mass matrix combination is given by, at the GUT scale,

$$M_u=\begin{pmatrix} 0 & 0 & ae^{i\gamma_a} \\ 0 & be^{i\gamma_b} & ce^{i\gamma_c} \\ ae^{i\gamma_a} & ce^{i\gamma_c} & e^{i\gamma_d} \end{pmatrix} dv_u, \qquad M_d=\begin{pmatrix} 0 & ee^{i\gamma_e} & 0 \\ ee^{i\gamma_e} & fe^{i\gamma_f} & 0 \\ 0 & 0 & e^{i\gamma_h} \end{pmatrix} hv_d \; . \tag{1}$$

Symmetric mass textures arise naturally if SO(10) breaks down to the SM through the left-right symmetric breaking chain $SU(4)\times SU(2)_L\times SU(2)_R$. SO(10) relates the up-quark mass matrix to the Dirac neutrino mass matrix, and the down-quark mass matrix to the charged lepton mass matrix. To achieve the Georgi-Jarlskog relations, a factor of -3 is needed in the (2,2) entry of the charged lepton mass matrix,

$$M_e=\begin{pmatrix} 0 & ee^{i\gamma_e} & 0 \\ ee^{i\gamma_e} & -3fe^{i\gamma_f} & 0 \\ 0 & 0 & e^{i\gamma_h} \end{pmatrix} hv_d \; . \tag{2}$$

This factor of -3 can be accounted for by the SO(10) CG coefficients associated with $\overline{126}$-dimensional Higgs representations. The Dirac neutrino mass matrix is identical to the mass matrix of the up-quarks in the framework of SO(10)

$$M_{\nu_{LR}}=\begin{pmatrix} 0 & 0 & ae^{i\gamma_a} \\ 0 & be^{i\gamma_b} & ce^{i\gamma_c} \\ ae^{i\gamma_a} & ce^{i\gamma_c} & e^{i\gamma_d} \end{pmatrix} dv_u \; . \tag{3}$$

We consider an effective neutrino mass matrix of the form

$$M_{\nu_{LL}}=M_{\nu_{LR}}^T M_{\nu_{RR}}^{-1} M_{\nu_{LR}}=\begin{pmatrix} 0 & 0 & t \\ 0 & 1 & 1+t^n \\ t & 1+t^n & 1 \end{pmatrix} \frac{d^2 v_u^2}{M_R} \; , \tag{4}$$

with $n=1.15$. This form is obtained if the right-handed neutrino mass matrix has the same texture as that of the Dirac neutrino mass matrix,

$$M_{\nu_{RR}}=\begin{pmatrix} 0 & 0 & \delta_1 \\ 0 & \delta_2 & \delta_3 \\ \delta_1 & \delta_3 & 1 \end{pmatrix} M_R \tag{5}$$

and if the elements δ_i are of the right orders of magnitudes, determined by $\delta_i=f_i(a,b,c,t,\theta)$. The mass matrix given in Eq.(4) give rise to bi-large mixing pattern. The ratio of $\Delta m^2_{\odot}$ to Δm^2_{atm} is proportional to $|U_{e3}|^2$. The SU(2) family symmetry is implemented *á la* the Froggatt-Nielsen mechanism. The heaviness of the top quark and to suppress the SUSY FCNC together suggest that the third family of matter fields transform as a singlet and the lighter two families of matter fields transform as a doublet under SU(2), which breaks down in two steps: $SU(2)\xrightarrow{\epsilon M}U(1)\xrightarrow{\epsilon' M}nothing$, where $\epsilon'\ll\epsilon\ll 1$ and M is the family symmetry scale. The superpotential of our model which generates fermion masses is given by $W=W_{D(irac)}+W_{M(ajorana)}$, where $W_D=\psi_3\psi_3 T_1+\frac{1}{M}\psi_3\psi_a\left(T_2\phi_{(1)}+T_3\phi_{(2)}\right)+\frac{1}{M}\psi_a\psi_b\left(T_4+\overline{C}\right)S_{(2)}+\frac{1}{M}\psi_a\psi_b T_5 S_{(1)}$ and $W_M=\psi_3\psi_3\overline{C}_1+\frac{1}{M}\psi_3\psi_a\Phi\overline{C}_2+\frac{1}{M}\psi_a\psi_b\Sigma\overline{C}_2$. Here T_i's and $\overline{C}_i$'s are the 10 and $\overline{126}$ dimensional Higgs representations of SO(10) respectively, and Φ and Σ are the doublet and triplet of SU(2), respectively. Detailed quantum number assignment and the VEVs acquired by various scalar fields are given in Ref. [2]. This superpotential gives rise to the mass textures given in Eq.(1)-(5). The input parameters at the GUT scale are determined using the values of $m_f,(f{=}u,c,t,e,\mu,\tau)$ and $|V_{us,ub,cb}|$ at the weak scale [3]. The predictions at M_Z including 2-loop RGE effects are in good agreements with the experimental values: $\frac{m_s}{m_d}{=}25$, $m_s{=}86.0MeV$, $m_b{=}3.03GeV$, $|V_{ud}|{=}0.974$, $|V_{cd}|{=}0.225$, $|V_{cs}|{=}0.973$, $|V_{td}|{=}0.00801$, $|V_{ts}|{=}0.0386$, $|V_{tb}|{=}0.999$, $J^q_{CP}{=}2.87{\times}10^{-5}$, $\sin 2\alpha{=}{-}0.048$, $\sin 2\beta{=}0.740$, $\gamma{=}64^0$. Using $\Delta m^2_{atm}{=}2.33{\times}10^{-3}\ eV^2$ and $\Delta m^2_{\odot}{=}8.14{\times}10^{-5}\ eV^2$ for the LMA solution as input parameters, we determine $t{=}0.344$ and $M_R{=}6.97{\times}10^{12}GeV$, which yields $(\delta_1,\delta_2,\delta_3){=}(0.00120,0.000703e^{i\ (1.47)},0.0210e^{i\ (0.175)})$. The three mass eigenvalues are predicted to be $(m_{\nu_1},m_{\nu_2},m_{\nu_3}){=}(0.00262,0.00939,0.0492)\ eV$, and the mixing angles are predicted to be $\sin^2 2\theta_{atm}{=}1$, $\tan^2\theta_{\odot}{=}0.36$, $\sin^2\theta_{13}{=}0.0134$. These predictions agree with current bounds from experiments within 1 σ. The strengths of CP violation in the lepton sector are $(J^l_{CP},\alpha_{31},\alpha_{21}){=}({-}0.00941,0.934,{-}1.49)$, and the matrix element for the neutrinoless double β decay is given by $|{<}m{>}|{=}3.1{\times}10^{-3}\ eV$. We consider LFV decays resulting from the non-vanishing off-diagonal matrix elements in the slepton mass matrix $(m^2_{\tilde{L}})_{ij}$, induced by the RG corrections between M_{GUT} and M_R, $\delta(m^2_{\tilde{L}})_{ij}{=}{-}\frac{1}{8\pi}(3m_0^2{+}A_0^2)\sum_{k=1,2,3}(\mathcal{Y}^\dagger_\nu)_{ik}(\mathcal{Y}_\nu)_{kj}\ln(\frac{M_{GUT}}{M_{R_k}})$. Our prediction for $\mu\rightarrow e\gamma$ is given in Fig. 1 [3]. Our predictions for the decay rates of $\ell_i\rightarrow\ell_j\gamma$, $\mu-e$ conversion as well as $\mu\rightarrow 3e$ are well below the most stringent bounds up-to-date [3] and yet many of them are within the reach of the next generation of LFV searches. This is especially true for $\mu-e$ conversion and $\mu\rightarrow e\gamma$. The observed baryonic asymmetry in the Universe can be accommodated utilizing soft leptogenesis [3].

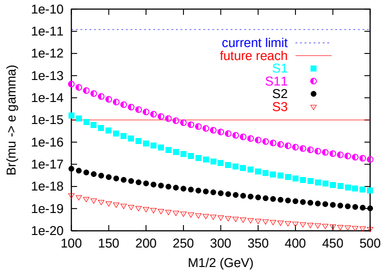

Fig. 1. The branching ratio of the decay $\mu\rightarrow e\gamma$ as a function of the universal gaugino mass $M_{1/2}$ for various scalar masses A_0 and m_0. (S1): $m_0 = A_0 = 100\ GeV$; (S11): $m_0 = 100\ GeV, A_0 = 1\ TeV$; (S2): $m_0 = A_0 = 500\ GeV$; (S3): $m_0 = A_0 = 1\ TeV$.

References

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