Lepton flavor violation in lopsided models and a new neutrino mass model

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1, There are two exotic while interesting features of the neutrino parameters:

- Extremely *small* neutrino masses

- *Large* neutrino mixing angles

2, Correspondingly, there are two elegant ideas to explain the two features:

- See-saw mechanism, which requires supersymmetry to avoid hierarchy problem.

- lopsided charged lepton mass matrix, where the maximal $\nu_\mu - \nu_\tau$ mixing is mainly from the charged lepton sector.

$$(M_L)_{23} \sim \begin{pmatrix} 0 & \sigma \\ \epsilon & 1 \end{pmatrix},$$

with $\sigma \sim 1$ while $\epsilon \ll 1$.

3, Many SUSY-GUT models have been built based on the above two elements in the literature.

4, These models can account for the neutrino properties very well. At the same time there is a definite prediction for this kind of models — the lepton flavor violating processes, which can be used to test this kind of models.

5, The branching ratio of LFV radiative decay can be approximately expressed as,

$$Br(l_i \rightarrow l_j \gamma) \sim \frac{\alpha^3}{G_F^2} \frac{[(\delta m_{\tilde{L}}^2)_{ij}]^2}{m_s^8} \tan^2 \beta \quad,$$

m_s represents the common slepton mass. $\delta m_{\tilde{L}}^2$'s are the non-diagonal terms of the slepton mass matrix. So, arbitrary slepton mass matrix is forbidden by experiments. The soft SUSY breaking terms are assumed flavor independent at the GUT (Plank) scale in the supergravity models to avoid the SUSY flavor problem.

6, However, we will show that the supersymmetric see-saw models based on lopsided charged lepton mass matrix can induce big flavor mixing terms $(\delta m_{\tilde{L}}^2)$ at low energy, even they are flavor blind at the GUT scale.

7, Above the scale of the RH neutrino masses, the superpotential of lepton sector is

$$W = Y_N^{ij} \hat{H}_2 \hat{L}_i \hat{N}_j + Y_L^{ij} \hat{H}_1 \hat{L}_i \hat{E}_j + \frac{1}{2} M_R^{ij} \hat{N}_i \hat{N}_j + \mu \hat{H}_1 \hat{H}_2 \ .$$

Y_N and Y_L can not be diagonalized simultaneously. LFV is then induced.

8, The running of RGE for the slepton mass matrix between M_{GUT} (universal here) and M_R (ν_R decouple here) leads to flavor mixing terms,

$$\begin{aligned}
\left(\delta m_{\tilde{L}}^2 \right)_{ij} &\propto (Y_N Y_N^\dagger)_{ij} \log \frac{M_{GUT}}{M_R} \\
&\approx V_{i3} V_{j3}^* \cdot Y_{N_3}^2 \log \frac{M_{GUT}}{M_R} \ ,
\end{aligned}$$

where only the third generation Yukawa coupling is kept, and

$$V = U_L^\dagger V_L \ ,$$

U_L and V_L are the left-handed mixing matrices for Y_L and Y_N.

In the lopsided models, there is large mixing in U_L, which leads to large $\delta m_{\tilde{L}}^2$ — finally leads to observable LFV effects.

9, $Br(\tau \to \mu\gamma) \propto V_{23}V_{33}$, with $V_{23} \sim V_{33} \sim \frac{1}{\sqrt{2}}$ in the lopsided models. We thus have definite prediction for this process.

10, $Br(\mu \to e\gamma) \propto V_{13}V_{23}$, where V_{13} seems quite model-dependent. However, under the follow observation and assumption, we find a general prediction of V_{13} in this kind of models.

1. $Y_N \sim Y_U$,
2. $\sin\theta_{12} \sim \sqrt{m_e/m_\mu} \cong 0.07$

we get

$$
\begin{aligned}
V_{13} &\approx \sin\theta_{12}\sin\theta_{23} \sim 0.05 \quad , \\
V_{23} &\approx -\sin\theta_{23} \approx -0.707 \quad .
\end{aligned}
$$

θ's are mixing angles in U_L. We then have $Br(\mu \to e\gamma) \sim 10^{-9} - 10^{-7}$ ($\tan\beta = 10$, $m_s < 1TeV$), far larger than the present experimental limit 1.2×10^{-11}. The large mixing angle θ_{23} (features the lopsided model) enhances both V_{13} and V_{23}.

11, Here we give a new structure of charged lepton mass matrix. On the basis where Y_N is diagonal, the charged lepton mass matrix is

$$M_L \sim \begin{pmatrix} 0 & \delta & \sigma' \\ -\delta & 0 & 1-\epsilon \\ 0 & \epsilon & 1 \end{pmatrix} ,$$

with $\delta = 0.00075$, $\epsilon = 0.12$ and $\sigma' = 0.6$. The notable feature of M_L is a large σ'. Here, ϵ is chosen to fit m_μ/m_τ and δ to fit m_e/m_μ. With a large σ' we get $\tan^2 \theta_{12} = 0.45$, $\sin^2 2\theta_{23} = 0.997$ and $V_{13} = 0.0052$. The very small V_{13} leads to small $Br(\mu \to e\gamma)$.

The amazing feature for this structure is that it can naturally lead to large 1-2 mixing, which motivates the LMA solution for solar neutrinos, and maximal 2-3 mixing.

Conclusions

- *The process $\tau \to \mu\gamma$ is quite promising to test whether there is a large mixing in the charged lepton sector, as predicted by lopsided models.*

- *In general, the lopsided models predict a large Br($\mu \to e\gamma$) exceeding the present experimental limit.*

- A new form of charged lepton mass matrix is found to produce maximal 2-3 mixing, large $1-2$ mixing while very small $1-3$ mixing in the lepton sector, which can give $Br(\mu \to e\gamma)$ below the present experimental limit and lead to LMA solution for solar neutrinos.