

Degenerate neutrinos from a supersymmetric A_4 model

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ABSTRACT: We investigate the supersymmetric A_4 model recently proposed by Babu, Ma and Valle [1]. The model naturally gives quasi-degenerate neutrinos that are bi-largely mixed, in agreement with observations. Furthermore, the mixings in the quark sector are constrained to be small, making it a complete model of the flavor structure. Moreover, it has the interesting property that CP-violation in the leptonic sector is maximal (unless vanishing). The model exhibit a close relation between the slepton and lepton sectors and we derive the slepton spectra that are compatible with neutrino data and the present bounds on flavor-violating charged lepton decays. The prediction for the branching ratio of the decay $\tau \rightarrow \mu\gamma$ has a lower limit of 10^{-9} . In addition, the overall neutrino mass scale is constrained to be larger than 0.3 eV. Thus, the model will be tested in the very near future.

1. Introduction

Thanks to the tremendous experimental progress in neutrino physics [2, 3, 4, 5, 6, 7] the main features of the mixing matrix in the leptonic sector have now been established. Especially, it is evident that the leptonic and the quark mixing matrices are rather different. The rough structure of the mixings being two large and one small mixing angle in the leptonic sector as opposed to three small mixings in the quarks sector. This calls for further studies of possible origins of the flavor structure.

Building attractive models which incorporates the structure of both the quark and lepton mixing matrices is a major challenge. In this work [8] we will examine a model that achieves this in a rather simple way. The main ingredients in the model, which was put

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forward in Ref.[1], are; (I) A_4 family symmetry, where A_4 is the symmetry group of the tetrahedron. (II) Heavy singlet lepton, quark and Higgs fields. (III) Low energy supersymmetry. (IV) Flavor violating soft SUSY breaking terms. The philosophy is to generate the mixing matrices through radiative corrections, starting from different boundary condition in the quark and the leptonic sector. These boundary conditions are provided by the family symmetry, which fix the value of the mixing matrices at some high energy scale, M_N , where the family symmetry is spontaneously broken. The quark mass matrices are aligned at M_N and therefore the mixing angles vanish at the high energy scale. Due to the hierarchical structure of the quark mass, the small radiative corrections naturally give small mixing angles. The observed low energy V_{CKM} can indeed be achieved, starting from the identity matrix at some high energy scale [9]. The neutrino masses are on the other hand fixed to be degenerate at M_N , thereby large mixings are easily obtained through quantum corrections. In this way the solar angle is naturally large, whereas the two other angles are restricted by the family symmetry. Also, the model has the interesting qualities of maximal CP-violation (unless zero) in the leptonic sector and exact atmospheric mixing.

Let us look at the sources of the radiative corrections to the mass matrices. Using the standard MSSM renormalization group equations (RGE's) and degenerate neutrinos at some high energy scale, it is not possible to obtain a suitable neutrino spectrum [10]. Nonetheless, allowing for threshold corrections from non-standard flavor violating (FV) interactions this is no longer true [11]. We explicitly show that including the radiative corrections coming from FV scalar lepton (slepton) interactions, a realistic low energy neutrino mass matrix can be obtained. This implies that both the atmospheric and the solar mass squared differences are generated by the radiative corrections.

A crucial ingredient in the model is therefore the flavor-non-blindness of the soft SUSY breaking terms, thus potentially large SUSY contribution to lepton flavor violation (LFV) may arise. However, the experimental bounds on FV in the lepton sector are less severe than in the quark sector. Especially, the bounds on the second and third generations are quite weak. The mechanism responsible for splitting the neutrino masses and the bounds on LFV push the off-diagonal elements of the slepton mass matrix in different directions.

We derive the possible low energy slepton masses and mixings by using the present knowledge of the neutrino mass matrix and the constraints from lepton flavor violation. We show that the model is indeed viable, although it is severely constrained. We give the predictions for lepton flavor violations processes, such as $\tau \rightarrow \mu\gamma$ and the overall neutrino mass scale. These are within experimental reach in the very near future.

2. Outline of the model

We present a schematic overview of the model, for further detail we refer to Refs.[1, 8, 12]. Let us briefly discuss the A_4 group as it is not widely known. It is the symmetry group of even permutations of four elements and has four irreducible representation; three independent singlet, which we denote as $\underline{1}$, $\underline{1}'$ and $\underline{1}''$ and one triplet $\underline{3}$. The decomposition of the product of two triplets is

$$\underline{3} \times \underline{3} = \underline{1} + \underline{1}' + \underline{1}'' + \underline{3} + \underline{3}. \quad (2.1)$$

Defining $\underline{3}_i = (a_i, b_i, c_i)$, $i = 1, 2$ we have e.g. the following rules

$$\begin{aligned}\underline{1} &= a_1 a_2 + b_1 b_2 + c_1 c_2, \\ \underline{1}' &= a_1 a_2 + \omega^2 b_1 b_2 + \omega c_1 c_2, \\ \underline{1}'' &= a_1 a_2 + \omega b_1 b_2 + \omega^2 c_1 c_2.\end{aligned}\tag{2.2}$$

The usual MSSM fields are assigned the following transformation properties under A_4 ,

$$\hat{Q}_i = (\hat{u}_i, \hat{d}_i), \quad \hat{L}_i = (\hat{\nu}_i, \hat{e}_i) \sim \underline{3}, \quad \hat{\phi}_{1,2} \sim \underline{1}\tag{2.3}$$

$$\hat{u}_1^c, \hat{d}_1^c, \hat{e}_1^c \sim \underline{1}, \quad \hat{u}_2^c, \hat{d}_2^c, \hat{e}_2^c \sim \underline{1}', \quad \hat{u}_3^c, \hat{d}_3^c, \hat{e}_3^c \sim \underline{1}''.\tag{2.4}$$

We add heavy quark, lepton and Higgs superfields as follows

$$\hat{U}_i, \hat{U}_i^c, \hat{D}_i, \hat{D}_i^c, \hat{E}_i, \hat{E}_i^c, \hat{N}_i^c, \hat{\chi}_i \sim \underline{3}\tag{2.5}$$

all are $SU(2)$ singlets. The superpotential is then given by

$$\begin{aligned}\hat{W} &= M_U \hat{U}_i \hat{U}_i^c + f_u \hat{Q}_i \hat{U}_i^c \hat{\phi}_2 + h_{ijk}^u \hat{U}_i \hat{u}_j^c \hat{\chi}_k \\ &+ M_D \hat{D}_i \hat{D}_i^c + f_d \hat{Q}_i \hat{D}_i^c \hat{\phi}_1 + h_{ijk}^d \hat{D}_i \hat{d}_j^c \hat{\chi}_k \\ &+ M_E \hat{E}_i \hat{E}_i^c + f_e \hat{L}_i \hat{E}_i^c \hat{\phi}_1 + h_{ijk}^e \hat{E}_i \hat{e}_j^c \hat{\chi}_k \\ &+ \frac{1}{2} M_N \hat{N}_i^c \hat{N}_i^c + f_N \hat{L}_i \hat{N}_i^c \hat{\phi}_2 + \mu \hat{\phi}_1 \hat{\phi}_2 \\ &+ \frac{1}{2} M_\chi \hat{\chi}_i \hat{\chi}_i + h_\chi \hat{\chi}_1 \hat{\chi}_2 \hat{\chi}_3,\end{aligned}\tag{2.6}$$

where an extra Z_3 symmetry, softly broken by M_χ , has been implemented in order to restrict further the superpotential. The A_4 symmetry is spontaneously broken at the high scale by the vev's $\langle \chi_i \rangle = u = -M_\chi/h_\chi$, $i = 1, 2, 3$. This is a F-flat direction and therefore it preserves SUSY, which is only broken at the TeV energy scale. The low energy effective theory of the model is in fact the MSSM. The electroweak symmetry is broken by the vev's, $\langle \phi_i^0 \rangle = v_i$ of the two Higgs doublet. We define as usual $\tan(\beta) = v_2/v_1$.

The charged lepton mass matrix is given by the simple form

$$M_{eE} = \begin{pmatrix} 0 & 0 & 0 & f_e v_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & f_e v_1 & 0 \\ 0 & 0 & 0 & 0 & 0 & f_e v_1 \\ h_1^e u & h_2^e u & h_3^e u & M_E & 0 & 0 \\ h_1^e u & h_2^e \omega u & h_3^e \omega^2 u & 0 & M_E & 0 \\ h_1^e u & h_2^e \omega^2 u & h_3^e \omega u & 0 & 0 & M_E \end{pmatrix},\tag{2.7}$$

in the basis (e_i, E_i) . Note that the factors of ω arise from forming A_4 invariant products (see Eq.2.2). This mass matrix is of see-saw type, and the effective 3×3 low energy mass matrix, M_ℓ^{eff} , can be diagonalized by $M_\ell^{\text{diag.}} = U_L M_\ell^{\text{eff}} I$, where the left diagonalization matrix reads

$$U_L = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 1 & 1 \\ 1 & \omega & \omega^2 \\ 1 & \omega^2 & \omega \end{pmatrix}.\tag{2.8}$$

The Yukawa couplings h_i^e , $i = 1, 2, 3$, are chosen such that the three eigenvalues of M_ℓ^{eff} , agree with the measured masses of the electron, muon and tau particles. As also the up-type and down-type quark mass matrices have the same structure as in Eq.(2.7), they will be simultaneously diagonalized, enforcing $V_{\text{CKM}} = I$ at the high scale. The observed low-energy V_{CKM} can be obtained from non-standard radiative corrections [9]. In the numerical study, however, we only consider the leptonic sector.

The Majorana neutrino mass matrix in the flavor basis $(\nu_e, \nu_\mu, \nu_\tau, N_1^c, N_2^c, N_3^c)$, may be written as

$$\begin{pmatrix} 0 & U_L f_N v_2 \\ U_L^T f_N v_2 & M_N \end{pmatrix}, \quad (2.9)$$

where M_N is proportional to the identity matrix. This is the usual see-saw form, and the effective low-energy neutrino mass matrix, is given by

$$M_\nu^0 = \frac{f_N^2 v_2^2}{M_N} U_L^T U_L = \frac{f_N^2 v_2^2}{M_N} \lambda_0, \quad \lambda_0 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}. \quad (2.10)$$

Therefore, a very attractive tree-level neutrino mass matrix has been obtained. It has degenerate neutrinos, $m_1 = m_2 = m_3$, and exact maximal atmospheric mixing. Also the tree-level value of the 'reactor' angle, s_{13} , is vanishing¹. Here, we use the standard parametrization of the neutrino mixing matrix as in Ref.[13].

Consider now the quantum corrections to the tree-level matrix in Eq.(2.10) written at the scale M_N . In general there are two kinds of corrections; the standard MSSM renormalization group equation (RGE) effects and the low-energy threshold corrections. The RGE effects, accounting for the running from M_N to the SUSY scale M_S , can in the flavor basis be approximated by [14]

$$M_{\alpha\beta}(M_S) \simeq \left[1 - \frac{m_\alpha^2 + m_\beta^2}{16\pi^2 v^2 \cos^2(\beta)} \log(M_N/M_S) \right] M_{\alpha\beta}(M_N). \quad (2.11)$$

These effects can not produce corrections to the texture zeros in M_ν^0 , as they are proportional to the original mass element. Nonetheless, it is clear that small corrections to the tree-level texture zeros are necessary in order to obtain a realistic mass matrix and that these must originate from flavor-changing interactions. Therefore, we invoke flavor-changing soft SUSY breaking terms and indeed in this case the threshold corrections can give the desired effect. In fact, in SUSY theories the threshold corrections can dominate over the RGE effects.

The one-loop (threshold) contributions to the neutrino mass renormalization are given by the diagrams shown in Fig.1. For the evaluation we make the following approximations:

- We consider only the 3×3 left-left, $M_{LL,\ell}$, part of the charged slepton mass matrix.
- We assume $M_{LL,\tilde{\ell}}^2 = M_{LL,\tilde{\nu}}^2 = M_{LL}^2$, thereby neglecting the, usually much smaller, D-term contributions.

¹We define the most split neutrino mass as m_3 and require $m_2 > m_1$, therefore the 'reactor' angle is always given by s_{13}

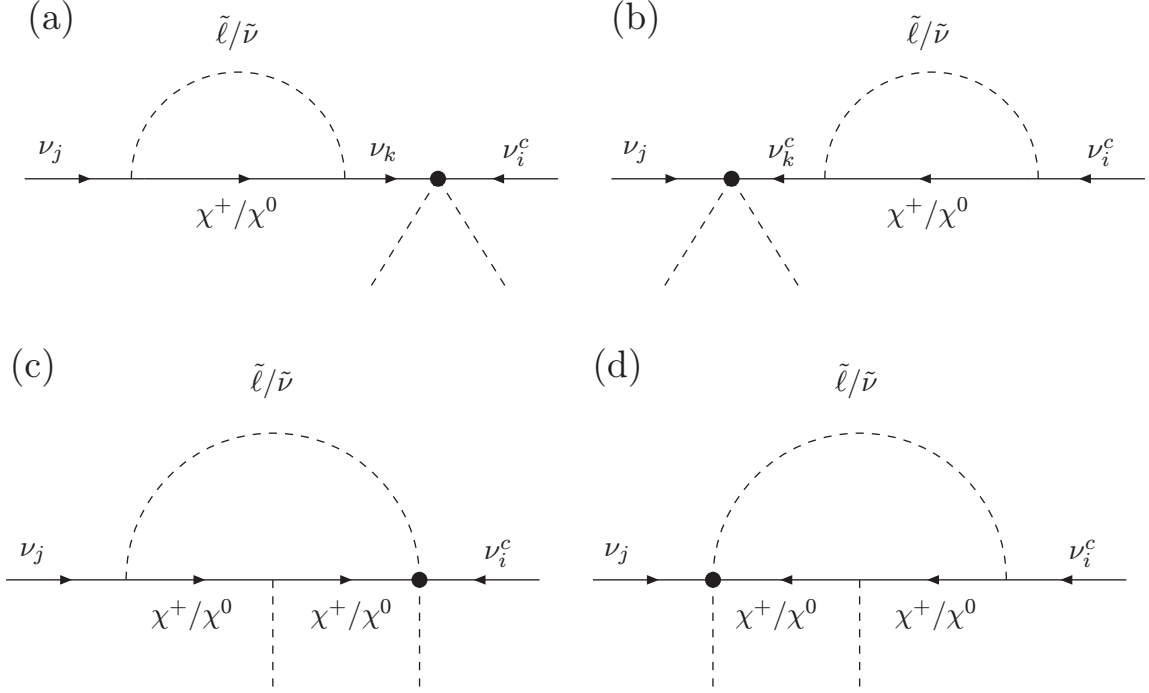


Figure 1: Feynman diagrams responsible for the radiative corrections to mass of the neutrino. The fat vertex indicates an effective Lagrangian term obtained from integrating out the heavy right-handed neutrinos.

Consequently, the sleptons and sneutrinos have identical masses and mixings. The contribution from the $\chi^+/\tilde{\ell}_R$ loop in the diagrams in Fig.1 are suppressed with the Yukawa couplings squared. Hence, for the first two generations and also the third generation for small $\tan(\beta)$ the above approximation is reasonable. As we will discuss below, the viable solutions have indeed small $\tan(\beta)$. It is easily realized that the one-loop corrections to the neutrino mass matrix have the structure

$$\lambda^{1\text{-loop}} = \lambda^0 \hat{\delta} + (\hat{\delta})^T \lambda^0, \quad \hat{\delta} = \begin{pmatrix} \delta_{ee} & \delta_{e\mu}^* & \delta_{e\tau}^* \\ \delta_{e\mu} & \delta_{\mu\mu} & \delta_{\mu\tau}^* \\ \delta_{e\tau} & \delta_{\mu\tau} & \delta_{\tau\tau} \end{pmatrix}. \quad (2.12)$$

The analytic expression for $\hat{\delta}$ may be found in Ref.[8]. The leading effect from the RGE running, originating from the tau Yukawa coupling, is taken into account. However, the arguments below are valid considering the full RGE contribution. The form of the neutrino mass matrix may be written as

$$M_\nu^{1\text{-loop}} = m_0 \begin{pmatrix} 1 + \delta_0 + 2\delta + 2\delta' & \delta'' & \delta''^* \\ \delta'' & \delta & 1 + \delta_0 + \delta - 2\delta_\tau \\ \delta''^* & 1 + \delta_0 + \delta - 2\delta_\tau & \delta \end{pmatrix}, \quad (2.13)$$

where m_0 is the overall neutrino mass scale. All parameters except δ'' may be taken real².

²The phase of the δ ($\delta_{\mu\tau}$) parameter can be rotated away, even though the neutrinos are Majorana particles, due to the special form of $M_\nu^{1\text{-loop}}$.

Here, we have defined

$$\delta = 2\delta_{\mu\tau}, \quad \delta_0 = \delta_{\mu\mu} + \delta_{\tau\tau} - 2\delta_{\mu\tau} \quad (2.14)$$

$$\delta' = \delta_{ee} - \delta_{\mu\mu}/2 - \delta_{\tau\tau}/2 - \delta_{\mu\tau} \quad (2.15)$$

$$\delta'' = \delta_{e\mu}^* + \delta_{e\tau} \quad (2.16)$$

$$\delta_\tau \equiv \frac{m_\tau^2}{8\pi^2 v^2 \cos^2(\beta)} \log(M_N/M_S) \quad (2.17)$$

The effect of δ_0 can be absorbed into m_0 , as its value does not affect the mixing angles. In the numerical analysis we assume that δ'' is real, in which case the neutrino mass matrix can be diagonalized analytically. The eigenvalues are

$$\begin{aligned} m_1 &= m_0 \left(1 + 2\delta + \delta' - \delta_\tau - \sqrt{\delta'^2 + 2\delta''^2 + 2\delta'\delta_\tau + \delta_\tau^2} \right) \\ m_2 &= m_0 \left(1 + 2\delta + \delta' - \delta_\tau + \sqrt{\delta'^2 + 2\delta''^2 + 2\delta'\delta_\tau + \delta_\tau^2} \right) \\ m_3 &= m_0(-1 + 2\delta_\tau) \end{aligned} \quad (2.18)$$

Hence, the mass squared differences can be approximated by

$$\Delta m_{\text{atm}}^2 \simeq 4m_0^2 \delta \quad (2.19)$$

$$\Delta m_{\text{sol}}^2 \simeq 4m_0^2 \sqrt{\delta'^2 + 2\delta''^2 + 2\delta'\delta_\tau + \delta_\tau^2} \quad (2.20)$$

Although the neutrinos are quasi-degenerate, we will refer to the case of $\delta < 0$ as normal hierarchy and of $\delta > 0$ as inverted hierarchy. The solar angle is given by

$$\tan^2(\theta_{\text{sol}}) = \frac{2\delta''^2}{(\delta' + \delta_\tau - \sqrt{\delta'^2 + 2\delta''^2 + 2\delta'\delta_\tau + \delta_\tau^2})^2} \quad (2.21)$$

and is independent of both δ and δ_0 .

The form of M_ν in Eq.(2.13) implies that the mixing matrix satisfies $|U_{\mu i}| = |U_{\tau i}|$, $i = 1, 2, 3$ [15]. From this it is easily seen that the atmospheric mixing angle is *maximal*, and thus not affected by the radiative corrections [1]. The relation also implies that $s_{13} \cos(\delta_{\text{CP}}) = 0$, where δ_{CP} is the Dirac CP-phase. Therefore, unavoidably along with a non-zero value of s_{13} is maximal CP-violation in the leptonic sector [1]. The Majorana phases are constrained to be 1 or i , and will not give rise to CP-violation [15]. The property of maximal CP-violation gives interesting perspectives for discovery of leptonic CP-violation in future long-baseline experiments.

In Eq.(2.13) the neutrino mass matrix is written in the tree-level flavor basis. The radiative corrections to the charged lepton mass matrix will therefore result in small corrections to the leptonic mixing angles. These corrections, albeit very small, will result in deviation from maximal atmospheric mixing and also maximal CP-violation.

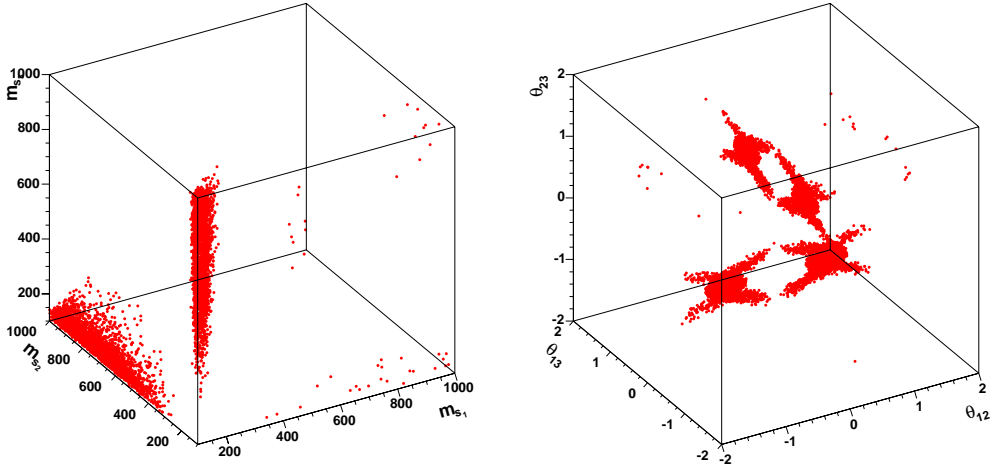


Figure 2: The allowed range for the slepton masses and mixings for $\delta < 0$.

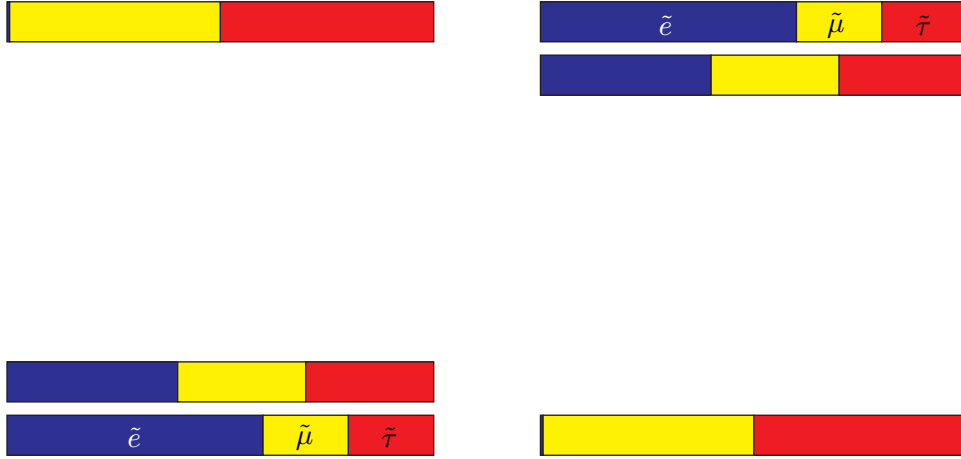


Figure 3: The rough form of the slepton and sneutrino spectrum in the case of normal hierarchy (left) or inverted hierarchy (right). The dark shaded area represent the amount of selectron in the slepton mass-eigenstate (U_{ej}^2), the light shaded the amount of smuon and finally the medium shaded the amount of stau.

3. Analysis

We carry out a detailed numerical analysis, using constraints from neutrino data and LFV. The allowed parameter space is determined by a random search through the 10 dimensional parameter space, keeping all SUSY masses real and in the range 100 GeV to 1000 GeV. For the neutrino parameters we use the 3σ allowed ranges [16]. The strongest bounds on LFV comes from $\ell_j \rightarrow \ell_i \gamma$ and explicitly formulas for the SUSY contributions can be found in Ref.[17]. We have compared our numerical programs for the branching ratios against the ones in Ref.[18] and found agreement. The present bounds are [13]

$$BR(\mu \rightarrow e \gamma) < 1.2 \times 10^{-11} ,$$

$$\begin{aligned} BR(\tau \rightarrow \mu\gamma) &< 1.1 \times 10^{-6}, \\ BR(\tau \rightarrow e\gamma) &< 2.7 \times 10^{-6}. \end{aligned} \quad (3.1)$$

The overall neutrino mass scale m_0 for the degenerate neutrinos is constrained by $(\beta\beta)_{0\nu}$ experiments and cosmology. The bound from neutrinoless double beta decay is less restrictive considering the uncertainties in the nuclear matrix element. Here we will apply the cosmological bound of 0.6 eV derived in Ref.[19].

It turns out difficult to get the neutrino mass splittings large enough. The mass splittings are related to the parameters δ, δ' and δ'' in Eqs. 2.14, 2.15, 2.16, and these are increasing functions of the slepton mixings and also mass splittings. This is potentially in conflict with the restrictions on LFV which will push the spectrum toward mass degeneracy and small mixings. Therefore it is a non-trivial task to show that a viable spectrum exist.

Indeed, the allowed range for the charged slepton parameters, identical to that of the sneutrinos, is quite restricted. The spectra fall into two different groups. The normal hierarchy having two low mass sleptons (~ 150 GeV) and one heavy (above ~ 500 GeV), and the inverted hierarchy case having two heavy sleptons and one light. In both cases at least one slepton mass is below about 200 GeV, which is detectable at the LHC. Most points fall into the case of normal hierarchy, which often corresponds to a normal hierarchy for the neutrinos

as well. In Fig.2 the slepton masses and mixings are shown for the case of $\delta < 0$. The typical case has one small and two large mixing angles. This structure is also found for $\delta > 0$. Evidently the small mixing angle is needed to suppress the decay $\mu \rightarrow e\gamma$. Also the degeneracy of two of the sleptons helps to minimize the LFV. As a rule of thumb there is at least one pair of sleptons with a mass splitting of less than 40 GeV. The rough spectrum needed is schematized in Fig.3, although there is room for substantial deviations from the shown spectrum. The similarity with the neutrino spectrum is quite striking and is related to the necessary relation $\delta \gg \delta', \delta''$.

The parameter δ is bounded from above which, through the relation to Δm_{atm}^2 in Eq.2.19, imposes a minimum value for m_0 . In Fig.4 the maximum achievable value of Δm_{atm}^2 is plotted against the value of m_0 . The lower bound

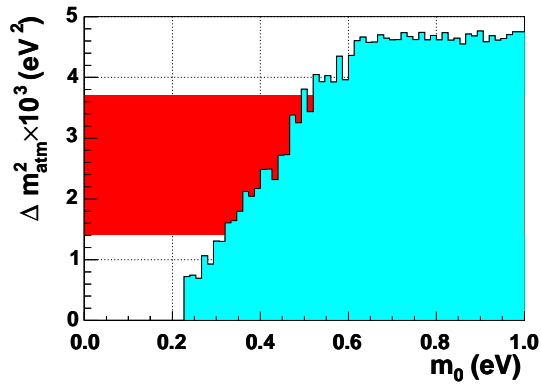


Figure 4: The light shaded histogram shows the maximum possible value of the atmospheric mass squared difference as a function of m_0 . The dark shaded region is the current 3σ allowed region for Δm_{atm}^2 .

$$m_0 > 0.3 \text{ eV} \quad (3.2)$$

is derived, leaving only little room for the value of m_0 .

We obtain a lower bound on the value of the μ parameter of about 500 GeV, although there are a few points, having inverse slepton hierarchy, with $\mu \sim 200$ GeV as seen in Fig.5. The second chargino, which is almost pure Higgsino is therefore rather heavy.

As there is at least one low mass slepton present in the model, one could suspect that a large contribution to the anomalous magnetic moment of the muon will result. We have explicitly calculated the magnitude, using the formulas in Ref.[20]. The rough order of magnitude is 10×10^{-10} , which is too small to explain the BNL result [21]. As is well-known the contribution to $g - 2$ has the same sign as the μ -term, thereby disfavoring negative values for the μ parameter.

An important outcome of this study is the prediction for the charged lepton decays $\ell_i \rightarrow \ell_j \gamma$. As seen in Fig.6 a lower bound of 10^{-9} for $\text{BR}(\tau \rightarrow \mu \gamma)$ is found. This is within reach of the future BaBar and Belle searches. Also, $\text{BR}(\mu \rightarrow e \gamma)$ is constrained to be larger than about 10^{-15} and therefore stands good chance of being observed in the near future at PSI.

The value of $\tan(\beta)$, also plotted in Fig.6, is constrained to be small. For large $\tan(\beta)$ the RGE effect destroys the agreement with the solar data. The numerical value of δ_τ can not be much bigger than the solar mass scale, as seen from Eq.2.20. A rough estimate gives $\delta_\tau \lesssim 5 \times 10^{-4}$, corresponding to the bound $\tan(\beta) < 10$. This agrees with the precise bound found in Fig.6. For small values of $\tan(\beta)$ the threshold corrections dominate and the strongest constraint comes from the bound on $\text{BR}(\mu \rightarrow e \gamma)$.

4. Concluding remarks

The supersymmetric A_4 model can account for the known flavor structure and has, at leading order, the interesting features

- Maximal CP-violation in the leptonic sector (unless $U_{e3} = 0$).
- Maximal atmospheric mixing.

The mixing matrices are generated by quantum corrections, starting from a fixed value at the high energy scale. The mechanism requires flavor-changing soft supersymmetry terms, and a close relation between the slepton and lepton sectors is obtained. To get sufficient suppression of LFV is a general problem in SUSY models. Nevertheless, as the A_4 model is relying on flavor violation in the slepton sector, the problem is more acute. In fact, in order to get sufficient splitting of the degenerate neutrinos, large mixings and large mass

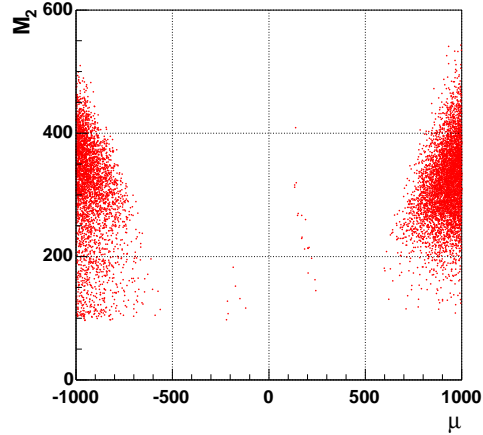


Figure 5: The allowed range for SU(2) gaugino soft breaking mass M_2 and the μ -parameter for $\delta < 0$. All points are in agreement with present bounds on LFV as well as the neutrino data.

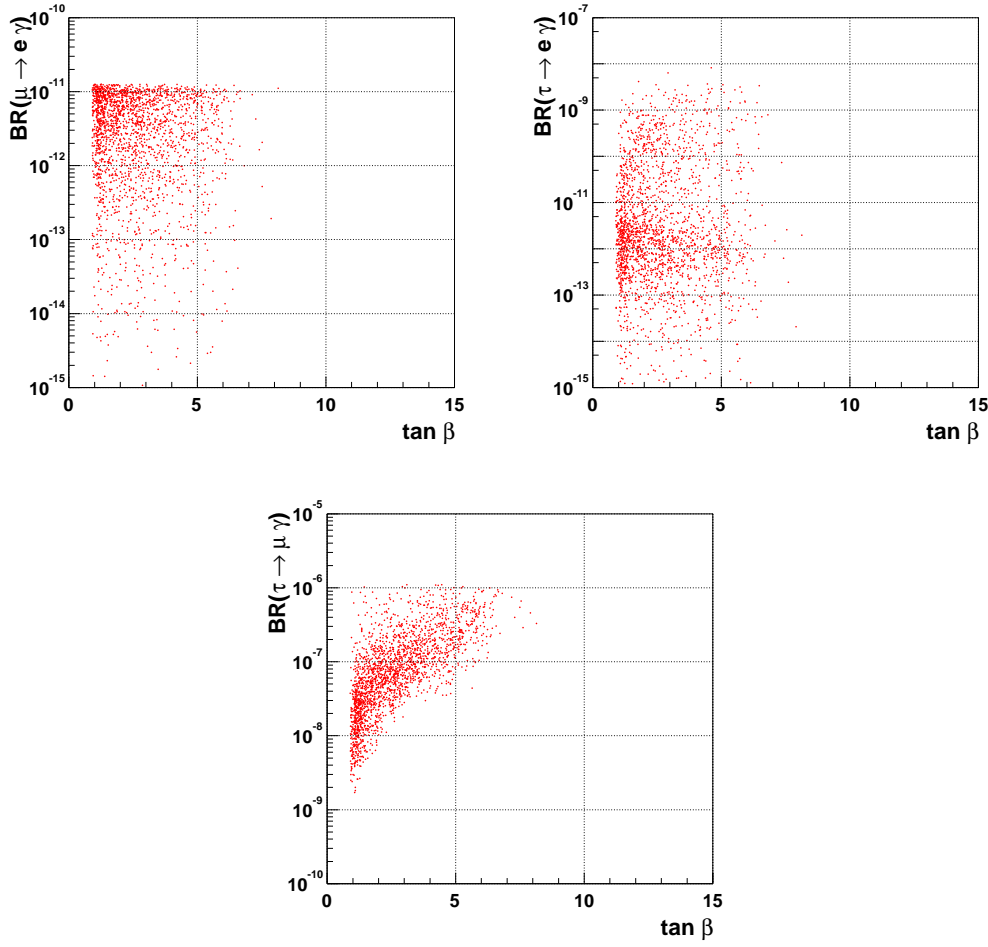


Figure 6: The predictions for the branching ratios for the processes $\ell_i \rightarrow \ell_j \gamma$ as a function of $\tan(\beta)$.

splittings in the slepton sector are required. We derive the flavor structure of the charged slepton and sneutrinos sectors, using neutrino data and the bounds on flavor-violating charged lepton decays. We find that the rough structure of the slepton spectrum is one almost degenerate pair along with one split state. Furthermore, the sleptons are bi-largely mixed, as are the neutrinos, with large mixing between $\tilde{\mu} - \tilde{\tau}$ and small mixing between \tilde{e} and the split state. Therefore, the model predicts large branching ratio for the decay $\tau \rightarrow \mu \gamma$. In addition, at least one charged slepton is below 200 GeV and the overall neutrino mass scale is constrained to be larger than 0.3 eV.

In conclusion the analysis shows that, although a functioning area of the SUSY parameter space exist, it is rather strongly restricted. If the model is realized in nature it should give rise to interesting experimental discoveries in the very near future.

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