Reconciling the Muon $g - 2$ and Dark Matter Relic Density with the LHC Results in Nonuniversal Gaugino Mass Models

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Abstract: Relatively light electroweak superparticle masses are required to satisfy the bulk annihilation region of dark matter relic density and account for the observed excess of muon $g - 2$, while TeV scale squark and gluino masses are required to account for the 125 GeV Higgs boson mass and the negative SUSY search results from 7 TeV LHC in most SUSY models. These two sets of requirements can be reconciled in a simple nonuniversal gaugino mass model, which assumes SUSY breaking via a combination of two superfields belonging to the singlet and the 200-plet representations of the GUT group SU(5). The model can be probed via squark/gluon search with the present and future LHC data. In a more general nonuniversal gaugino mass model the squark and gluino masses can be raised to the edge of the discovery limit of 14 TeV LHC or beyond. This model can be probed, however, through the search for electroweak pair production of the relatively light sleptons and winos with the 14 TeV LHC data in future.
1 Introduction

The minimal supergravity or the so called constrained minimal supersymmetric standard model (CMSSM) has universal gaugino and scalar masses $m_{1/2}$ and $m_0$ at the GUT scale, along with a universal trilinear coupling parameter $A_0$. Together with the ratio of the two Higgs vacuum expectation values ($\tan \beta$) and the sign of the higgsino mass parameter ($\mu$), one has four and half parameters in this model, while the magnitude of $\mu$ is determined by the radiative electroweak symmetry breaking condition \cite{1}. A large part of the SUSY phenomenology over the years has been based on this model because of its simplicity and the predictive value. Here the lightest superparticle (LSP), i.e. the dark matter, is dominantly a bino over the bulk of the model parameter space. Since the bino does not carry any gauge charge, its natural annihilation process is via sfermion exchange. And the cosmologically compatible dark matter relic density requires rather small bino and sfermion masses $\sim 100$ GeV. This is the so called bulk annihilation region. Unfortunately the LEP constraint on the light Higgs boson mass ($m_h > 114$ GeV) practically rules out the bulk annihilation region of the CMSSM parameter space \cite{2}. The remaining cosmologically compatible dark matter relic density regions of this model like the stau co-annihilation region, the resonant annihilation region and the focus point region, all require some amount of fine-tuning between independent SUSY mass parameters.

The reported discovery of Higgs boson at LHC by the ATLAS and CMS experiments \cite{3} at

$$m_h \simeq 125 \text{ GeV} \quad (1.1)$$
have stretched the above mentioned LEP constraint to significantly higher values of $m_0$ and $m_{1/2}$ in the CMSSM parameter space \cite{4}. It now rules out the lower mass parts of the stau co-annihilation, the resonant annihilation and the focus point regions. The remaining parts of these cosmologically compatible dark matter relic density regions correspond to $m_0 \gtrsim 1$ TeV, which imply TeV scale masses of the 1st and 2nd generation sfermions. Consequently the CMSSM contribution to the muon $g-2$ is much too small to explain the anomalous excess observed by the BNL experiment \cite{5}, i.e.

$$\Delta a_\mu = (28.7 \pm 8.0) \times 10^{-10},$$  \hspace{1cm} (1.2)$$

where $a_\mu \equiv (g - 2)_\mu / 2$ \cite{6}. The detailed analysis of ref.\cite{4} have also found very similar results for the nonuniversal Higgs mass models (NUHM) \cite{7}. More recently Buchmueller et al \cite{8} have supplemented the constraints on the CMSSM and NUHM parameter spaces coming from the 125 GeV Higgs boson mass \cite{3}, with those coming from the latest ATLAS results on direct SUSY search with 5 fb$^{-1}$ LHC data at 7 TeV \cite{9}, and the $B_s \rightarrow \mu^+\mu^-$ results of ATLAS, CDF, CMS and LHCb experiments \cite{10} along with the latest direct dark matter detection experiment result of the XENON100 experiment \cite{11}. The ATLAS result on direct SUSY search \cite{9} reinforces the exclusion of the low mass part of the stau co-annihilation region. The $B_s \rightarrow \mu^+\mu^-$ results \cite{10} are effective in the large $\tan\beta$ ($\gtrsim 30$) region, where the resonant annihilation region of the SUSY dark matter relic density is also effective. It reinforces the exclusion of the low mass part of the latter. Finally, the latest XENON100 experiment result \cite{11} enhances the exclusion of the low mass part of the focus point region \cite{12}. Thus these experiments strengthen the above mentioned incompatibility between the SUSY explanations of the observed muon $g-2$ anomaly \cite{5,6} and dark matter relic density with the 125 GeV Higgs boson mass result from LHC \cite{3} in both CMSSM and NUHM. This has led to a wide perception that there may be an inherent tension between the two sets of results in any simple SUSY model. For the parameter scan in a phenomenological MSSM see e.g. ref.\cite{13}.

In this work we shall try to reconcile the SUSY explanations of observed muon $g-2$ anomaly \cite{5,6} and dark matter relic density \cite{14} with the 125 GeV Higgs boson mass reported from LHC \cite{3} along with the results of ref.\cite{9–11} in some simple and predictive nonuniversal gaugino mass models \cite{15}. It was shown in \cite{16} that the most natural SUSY explanation of the observed dark matter relic density (in terms of fine-tuning) via the bulk annihilation region can be reconciled with the above mentioned Higgs mass bound from LEP \cite{2} in a set of such nonuniversal gaugino mass models. In a recent update of this analysis \cite{17} we have shown that the bulk annihilation region of dark matter relic density can also be reconciled with the 125 GeV Higgs boson mass in these models. The present work is mainly devoted to the analysis of the SUSY contribution to the muon $g-2$ anomaly \cite{5}, while we continue focus on a Higgs boson mass of 125 GeV. We shall see that one of these models can indeed
account for the observed muon $g - 2$ anomaly [5]. We also investigate this issue in a more general nonuniversal gaugino mass model, where we shall find even a closer agreement with the observed muon $g - 2$ anomaly of eq.(1.2) without any conflict with the Higgs mass or the direct SUSY search results from LHC. In view of the high precision of the dark matter relic density data [15] we shall consider solutions lying within $3\sigma$ of its central value (see eq (11) below). For muon $g - 2$ anomaly, with a relatively large error bar [5], we shall consider solutions lying within $2\sigma$ of the central value (1.2). Finally, for the putative Higgs boson mass of 125 GeV [3], there is a spread of about 3 GeV between the two important decay channels and the two experiments. Besides there is a theoretical uncertainty of 2-3 GeV in the prediction of this mass as discussed below. Therefore we shall consider solutions with the predicted Higgs mass agreeing with the putative value of 125 GeV within 3 GeV. Since the three observables have very different levels of theoretical and experimental errors, we shall not attempt to evaluate any overall chi-square for fitting these three experimental observables.

In section 2, we summarize the essential ingredients of the model. In section 3, we present the results for a specific choice of the nonuniversal gaugino mass model, which can account for the observed muon $g - 2$ anomaly. Then in section 4, we present the results for a more general nonuniversal gaugino mass model. We conclude with a brief summary of our results in section 5.

2 Nonuniversality of Gaugino Masses in SU(5) GUT

The gauge kinetic function responsible for the GUT scale gaugino masses originates from the vacuum expectation value of the F term of a chiral superfield $\Omega$ responsible for SUSY breaking,

$$\frac{\langle F_{\Omega} \rangle_{ij}}{M_{\text{Planck}}} \lambda_i \lambda_j, \quad (2.1)$$

where $\lambda_{1,2,3}$ are the U(1), SU(2), SU(3) gaugino fields - bino, wino and gluino. Since gauginos belong to the adjoint representation of the GUT group, $\Omega$ and $F_{\Omega}$ can belong to any of the irreducible representations appearing in their symmetric product, i.e.

$$(24 \times 24)_{\text{sym}} = 1 + 24 + 75 + 200 \quad (2.2)$$

for the simplest GUT group SU(5). Thus, the GUT scale gaugino masses for a given representation of the SUSY breaking superfield are determined in terms of one parameter as

$$M_{1,2,3}^G = C^n_{1,2,3} m_{1/2}^n \quad (2.3)$$

where [15]

$$C^n_{1,2,3} = (1, 1, 1), \quad C^{24}_{1,2,3} = (-1, -3, 2), \quad C^{75}_{1,2,3} = (-5, 3, 1), \quad C^{200}_{1,2,3} = (10, 2, 1). \quad (2.4)$$
The CMSSM assumes $\Omega$ to be a singlet leading to universal gaugino masses at the GUT scale. On the other hand, any of the nonsinglet representations of $\Omega$ would imply nonuniversal masses via eqs. (2.3) and (2.4). These nonuniversal gaugino mass models are known to be consistent with the universality of gauge couplings at the GUT scale [15, 19], with $\alpha_G \simeq 1/25$. The phenomenology of nonuniversal gauginos arising from nonsinglet $\Omega$ have been widely studied [20].

It was assumed in [16] that SUSY is broken by a combination of a singlet and a nonsinglet superfields belonging to the $1 + 24, 1 + 75$ or $1+200$ representations of SU(5). Then the GUT scale gaugino masses are given in terms of two mass parameters,

$$M^G_{1,2,3} = C^l_{1,2,3} m_{1/2}^l + C^l_{1,2,3} m_{1/2}^l \quad \text{with} \quad l = 24, 75 \text{ or } 200. \quad (2.5)$$

It is evident from the above equation that these NUGM models have an extra gaugino mass parameter than in the CMSSM. The corresponding weak scale superparticle and Higgs boson masses are given in terms of these gaugino masses and the universal scalar mass parameter $m_0$ via the RGE. It was shown that in these models one can access the bulk annihilation region of dark matter relic density, while keeping the light Higgs boson mass above the LEP limit of 114 GeV [2]. In order to understand this, one can equivalently consider the two independent gaugino mass parameters of eq.(2.5) in any one of these models to be $M^{G1}$ and $M^{G3}$. The corresponding weak scale bino LSP mass is given to a good approximation by the one-loop RGE,

$$M_1 = \left( \frac{\alpha_1}{\alpha_G} \right) M^G_1 \simeq \left( \frac{25}{60} \right) M^G_1. \quad (2.6)$$

Thus one can choose a relatively small $M^G_1 \sim 200$ GeV along with a small $m_0 \sim 80$ GeV to ensure a small weak scale bino mass $M_1 \sim 80$ GeV along with right slepton masses of $\sim 100$ GeV. Then the annihilation of the bino LSP pair via right slepton exchange

$$\chi\chi \overset{\text{IR}}{\rightarrow} \bar{l}l \quad (2.7)$$

gives the desired dark matter relic density [14]. The other mass parameter $M^G_3$ can then be raised to an appropriate level to raise the Higgs boson mass above the LEP limit with relatively heavy squarks and gluino. In our update of ref.[17] the Higgs boson mass was further raised close to the reported value from LHC [3] with the help of a large negative $A_0$ term.

It may be noted here that with given $M^G_1$ and $M^G_3$ inputs, each of the three models makes a definitive prediction for $M^G_3$. It can be shown from eqs.(2.4) and (2.5) that the $1 + 200$ model predicts a smaller $M^G_3$ and hence smaller weak scale wino and left slepton masses compared to the other two models. Hence it offers the best chance of accounting for a significant SUSY contribution to the muon $g - 2$. Therefore we shall pursue this issue in detail in the next section using the $1 + 200$ model.
Figure 1. Parameter space for $1+200$ model compatible with the WMAP relic density result and with the predicted $a_\mu$ agreeing with the observed excess $\Delta a_\mu$ (2) within $2\sigma$ in the $M_1 - M_2$ plane. The colour code for $\delta a_\mu = \Delta a_\mu - a_\mu$ is shown on the right. Here we take $m_0 = 80$ GeV, $\tan \beta = 10$, trilinear couplings $A_{t0} = A_{b0} = -2.1$ TeV, varying $M_1^G$ between 200 – 240 GeV and $M_3^G$ between 600 and 900 GeV.

3 The Weak Scale SUSY spectra and Muon $g - 2$ Prediction of the $1 + 200$ Model

We have used the two-loop RGE code SuSpect [21] to generate the weak scale SUSY spectra. The resulting dark matter relic density and muon anomalous magnetic moment ($g - 2$) were computed using the micrOMEGAs code [22]. The sign of the $\mu$ parameter was chosen to be positive for getting a positive SUSY contribution to the muon anomalous magnetic moment,

$$a_\mu = \frac{(g - 2)_{\mu}}{2}. \quad (3.1)$$

To ensure the bulk annihilation region of the dark matter relic density, we chose a small $m_0 = 80$ GeV, and varied $M_1^G$ upwards starting at 200 GeV. The second gaugino mass parameter $M_3^G$ was varied upwards starting from 600 GeV, to ensure squark and gluino mass range of interest to LHC. The $A_0$ parameter was set at $-2.1$ GeV to get the desired Higgs mass. We required the dark matter relic density to lie within $3\sigma$ range of WMAP data [14] i.e.

$$0.102 < \Omega h^2 < 0.123. \quad (3.2)$$
It effectively limited the $M_1^G$ scan to the $200 - 240$ GeV range. Requiring the SUSY contribution to $a_\mu$ (3.1) to be within $2\sigma$ of the observed excess of eq.(1.2), restricted the $M_3^G$ scan to the $600 - 900$ GeV range.

The main SUSY contributions to the muon anomalous magnetic moment $a_\mu$ come from the bino-right slepton ($\tilde{B} - \tilde{\mu}_R$) and wino-left slepton ($\tilde{W}^0 - \tilde{\mu}_L, \tilde{W}^- - \tilde{\nu}_L$) loops, which mainly depend on the weak scale gaugino masses $M_1$ and $M_2$ respectively. Figure 1 compares the predicted SUSY contribution to $a_\mu$ with the observed excess $\Delta a_\mu$ of eq(1.2), in the $M_1 - M_2$ plane at $\tan \beta = 10$, where

$$\delta a_\mu = \Delta a_\mu - a_\mu.$$  \hfill (3.3)

Figure 2 shows a similar comparison for $\tan \beta = 15$ and a larger $m_0$ to compensate for the lowering of $\tilde{\tau}_1$ at a larger $\tan \beta$. One sees a little better agreement in Fig. 2 relative to Fig. 1, resulting from a small rise of the SUSY contribution with $\tan \beta$. With further rise of $\tan \beta$, however, one has to choose a still larger $m_0$ to compensate for the faster drop of the $\tilde{\tau}_1$ mass. The resulting increase in the slepton masses compensate the linear rise of $a_\mu$ with $\tan \beta$ at constant SUSY masses. Thus one gets a broad peak for the predicted $a_\mu$ at $\tan \beta \simeq 15$. Explicit formulae for the SUSY contributions to $a_\mu$ can be found for example in [23].

For better insight into the underlying physics, we list the weak scale superparticle and Higgs boson masses along with the resulting $a_\mu$ (3.1) and $\delta a_\mu$ (3.3) for $\tan \beta = 10$ and 15 in Tables 1 and 2 respectively. As in ref. [17], the Higgs boson mass
All masses in GeV

| Particle          | $M_1^G = 220$ | $M_3^G = 600$ | $M_1^G = 200$ | $M_3^G = 700$ | $M_1^G = 200$ | $M_3^G = 800$ | $M_1^G = 200$ | $M_3^G = 900$ |
|-------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| $\tilde{\chi}^0_1$ (bino) | 89.2          | 80.7          | 80.3          | 80.0          | 79.5          |
| $\tilde{\chi}^0_2$ (wino) | 447           | 445           | 518           | 591           | 664           |
| $\tilde{\chi}^0_3$ (higgsino) | 1227          | 1226          | 1320          | 1415          | 1511          |
| $\tilde{\chi}^0_4$ (higgsino) | 1230          | 1230          | 1324          | 1419          | 1515          |
| $\tilde{\chi}^+_1$ (wino) | 447           | 445           | 518           | 591           | 664           |
| $\tilde{\chi}^+_2$ (higgsino) | 1231          | 1230          | 1324          | 1419          | 1515          |
| $M_1$             | 90.3          | 81.7          | 81.5          | 81.2          | 80.3          |
| $M_2$             | 437           | 435           | 506           | 577           | 648           |
| $M_3$             | 1343          | 1343          | 1542          | 1742          | 1933          |
| $\mu$             | 1233          | 1232          | 1326          | 1421          | 1341          |
| $\tilde{g}$       | 1354          | 1354          | 1561          | 1766          | 1969          |
| $\tilde{t}_1$     | 101           | 94.8          | 95.3          | 94.8          | 93.5          |
| $\tilde{t}_2$     | 374           | 373           | 424           | 476           | 529           |
| $\tilde{\ell}_R, \tilde{\mu}_R$ | 122           | 118           | 117           | 117           | 117           |
| $\tilde{\ell}_L, \tilde{\mu}_L$ | 370           | 368           | 421           | 474           | 527           |
| $\tilde{b}_1$     | 507           | 508           | 729           | 919           | 1094          |
| $\tilde{b}_2$     | 1049          | 1049          | 1224          | 1395          | 1565          |
| $\tilde{b}_1$     | 995           | 995           | 1179          | 1358          | 1533          |
| $\tilde{b}_2$     | 1168          | 1168          | 1345          | 1519          | 1692          |
| $\tilde{q}_{1,2,R}$ | \sim 1188     | \sim 1188     | \sim 1364     | \sim 1538     | \sim 1710     |
| $\tilde{q}_{1,2,L}$ | \sim 1234     | \sim 1233     | \sim 1417     | \sim 1598     | \sim 1778     |
| $h$               | 122           | 122           | 123           | 123           | 124           |

Table 1. The SUSY mass spectrum for the (1+200) model for a $\sim 80$ GeV LSP and the corresponding $g - 2$ contribution from SUSY. We take $m_0 = 80$ GeV, $\tan\beta = 10$, $A_{t0} = A_{b0} = -2.1$ TeV with $A_{\tau 0} = 0$ TeV.

has been raised by a few GeV via stop mixing by using a moderately large and negative GUT scale trilinear coupling parameter $A_0$ for the squark sector. The only phenomenologically relevant GUT scale A parameters ($A_0$) are $A_{0t} = A_{0b}$ and $A_{0\tau}$,
All masses in GeV

| Particle          | $M^G_1 = 220$ | $M^G_2 = 600$ | $M^G_3 = 700$ | $M^G_3 = 800$ | $M^G_3 = 900$ |
|-------------------|---------------|---------------|---------------|---------------|---------------|
| $\tilde{\chi}_1^0$ (bino) | 88.8          | 80.2          | 79.9          | 79.6          | 79.1          |
| $\tilde{\chi}_2^0$ (wino)   | 445           | 443           | 516           | 589           | 662           |
| $\tilde{\chi}_3^0$ (higgsino) | 1032         | 1031          | 1132          | 1233          | 1333          |
| $\tilde{\chi}_4^0$ (higgsino) | 1036         | 1036          | 1137          | 1237          | 1337          |
| $\tilde{\chi}_1^+$ (wino)    | 445           | 443           | 516           | 589           | 662           |
| $\tilde{\chi}_2^+$ (higgsino) | 1036         | 1037          | 1137          | 1237          | 1337          |
| $M_1$              | 90.1          | 81.4          | 81.1          | 80.8          | 80.4          |
| $M_2$              | 437           | 435           | 506           | 577           | 648           |
| $M_3$              | 1331          | 1331          | 1533          | 1734          | 1933          |
| $\mu$              | 1034          | 1033          | 1133          | 1233          | 1332          |
| $\tilde{g}$        | 1354          | 1354          | 1561          | 1766          | 1969          |
| $\tilde{\tau}_1$   | 103           | 97.4          | 96.2          | 93.6          | 89.8          |
| $\tilde{\tau}_2$   | 381           | 379           | 429           | 480           | 532           |
| $\tilde{e}_R, \tilde{\mu}_R$| 138          | 134           | 133           | 133           | 132           |
| $\tilde{e}_L, \tilde{\mu}_L$| 374          | 373           | 425           | 477           | 530           |
| $\tilde{t}_1$      | 748           | 749           | 920           | 1082          | 1240          |
| $\tilde{\tau}_2$   | 1107          | 1107          | 1275          | 1441          | 1607          |
| $\tilde{b}_1$      | 1056          | 1055          | 1232          | 1405          | 1576          |
| $\tilde{b}_2$      | 1161          | 1161          | 1336          | 1509          | 1681          |
| $\tilde{q}_{1,2,R}$| $\sim 1188$  | $\sim 1188$  | $\sim 1364$  | $\sim 1538$  | $\sim 1710$  |
| $\tilde{q}_{1,2,L}$| $\sim 1233$  | $\sim 1233$  | $\sim 1417$  | $\sim 1598$  | $\sim 1778$  |
| $h$                | 122           | 122           | 122           | 122           | 123           |

| Muon $g - 2$       |               |               |               |               |               |
|--------------------|---------------|---------------|---------------|---------------|---------------|
| $a_\mu$            | $2.22 \times 10^{-9}$ | $2.28 \times 10^{-9}$ | $1.89 \times 10^{-9}$ | $1.59 \times 10^{-9}$ | $1.37 \times 10^{-9}$ |
| $(\delta a_\mu)$   | (0.83σ)      | (0.75σ)      | (1.24σ)      | (1.61σ)      | (1.89σ)      |

Table 2. Same as Table 1, but with $\tan \beta = 15$, $m_0 = 103$ GeV and $A_{t0} = A_{b0} = -1.4$ TeV.

where the first two are relevant for the Higgs mass. Since in a nonuniversal model the GUT scale $A$ parameter for the lepton sector need not be the same as that for quarks, we have kept the $A_t = 0$ for simplicity. It should be noted here that the MS renormalization scheme used in the SuSpect RGE code [21] is known to predict a
lower Higgs boson mass than the on-shell renormalization scheme used in FeynHiggs [24] by $2 - 3$ GeV[25]. Therefore a predicted Higgs boson mass $\geq 122$ GeV in these tables is compatible with the reported mass of 125 GeV [3] within this theoretical uncertainty. Coming to the SUSY masses, one sees that the bino LSP and the right slepton masses are only $\sim 100$ GeV as expected for the bulk annihilation region. The wino is at least 5 times heavier than bino, while the left sleptons are at least $3 - 4$ times heavier than the right ones. The low value of $m_0$ ensures that the left sleptons are always lighter than wino, so that one expects SUSY cascade decay to result in relatively large LHC signals in the leptonic channels. There is also an inverted hierarchy of squark masses suggesting large number of b-tags in the SUSY signal. The first two generation squarks are roughly degenerate with gluinos. The SUSY search result of the 5 fb$^{-1}$ data at 7 TeV in the CMSSM shows a discovery limit of 1100 -- 1200 GeV for degenerate squarks and gluons, while the claimed limit of 1360 GeV may have questionable physical significance [9]. With the 20 fb$^{-1}$ data available at 8 TeV one expects this discovery limit to go up to $\sim 1500$ GeV. If one assumes a similar discovery limit for degenerate squarks and gluinos in the present model as well, then one would be able to probe the SUSY spectra shown in the first three columns of tables 1 and 2. It is evidently imperative to do a dedicated SUSY search with the accumulated data in this simple nonuniversal gaugino mass model.

In closing this section it should be noted that our results are immune to the $B_s \to \mu^+\mu^-$ constraints [10], which are effective only in the large $\tan\beta \ (\gtrsim 30)$ region. They are also immune to the direct detection limit from the XENON 100 experiment [11], since the predicted cross-section is very small for a bino dominated dark matter. Detailed account of this comparison is given in ref.[17]. And finally for the preferred sign of $\mu$, we find that the branching fraction $B(b \to s\gamma)$ for our chosen benchmark points falls within $2\sigma$ of the experimental world average $B(b \to s\gamma) = (3.55 \pm 0.25) \times 10^{-4}$ [18].

4 The Weak SUSY spectra and Muon $g - 2$ Prediction of a General Nonuniversal Gaugino Mass Model

Finally we shall extend the above analysis to a general nonuniversal gaugino mass model, where all the three GUT scale gaugino masses $M_1^G$, $M_2^G$ and $M_3^G$ are independent parameters. This means that there are now two more gaugino mass parameters than in the CMSSM. This model can be realized in a scenario of SUSY breaking by three superfields, belonging to different adjoint representations of the GUT group e.g. a $(1 + 75 + 200)$ model. One can equivalently choose the $M_1^G$, $M_2^G$ and $M_3^G$ as the three input parameters.

As in the previous section the $M_1^G$ and $m_0$ parameters are chosen to ensure adherence to the bulk annihilation region of dark matter relic density. The $M_2^G$
Table 3. The SUSY mass spectrum for a general non-universal model for a \( \sim 80 \) GeV LSP with increasing \( \tan \beta \) and the corresponding \( g - 2 \) contribution from SUSY. We take \( A_{t0} = A_{b0} = -1.4 \) TeV with \( A_{\tau 0} = 0 \), while \( m_0 \) is chosen to ensure the correct relic density in each case.
parameter can now be chosen to obtain a SUSY contribution to $a_\mu$ very close to the observed excess of eq. (1.2). Then the remaining parameter $M_3^G$ can be chosen to be in the TeV scale so that one can account for the reported Higgs mass of 125 GeV [3] with an $A_0$ parameter of similar size as $M_3^G$.

Table 3 lists the weak scale superparticle and Higgs boson masses for such a model along with resulting $a_\mu$ predictions for $\tan \beta = 10, 15$ and 20. The $M_1^G$ value is chosen as in the last section to ensure adherence to the bulk annihilation region. In this case one requires a somewhat larger value of $m_0$ to ensure $\tilde{\tau}_1$ mass to remain $\sim 20\%$ above the bino LSP mass to avoid copious co-annihilation, so that the dark matter relic density remains in the desired range of eq. (3.2). Note that the $m_0$ value goes up with $\tan \beta$ to compensate for the decrease of $\tilde{\tau}_1$ mass from RGE, as mentioned in the last section. The value of $M_2^G = 575$ GeV is chosen to account for the observed $a_\mu$ excess to within a quarter $\sigma$. The value of $M_3^G = 1200$ GeV is chosen to account for the reported Higgs boson mass [3] with a similar size of $A_0 = -1400$ GeV. The resulting degenerate squark-gluino masses are in the range of 2300 – 2600 GeV, which can be probed only by the 14 TeV LHC experiments. Finally table 4 shows the corresponding weak scale superparticle and Higgs boson masses along with the $a_\mu$ predictions for a higher $M_3^G = 1500$ GeV. The results are very similar to those of table 3, except for rise of the degenerate squark-gluino masses to the range of 2800-3200 GeV. This may be at the edge of the discovery limit of 14 TeV LHC run. The squark-gluino masses can be pushed up still higher with a higher value of $M_3^G$. Note however, that one can search for the pair production of relatively light sleptons and also winos via the Drell-Yan process with the 14 TeV LHC data. Indeed this provides a direct LHC test for the SUSY explanation of the observed excess of $a_\mu$ (1.2) via relatively low mass sleptons and wino. The discovery limit with 5 fb$^{-1}$ of 7 TeV LHC data by the ATLAS collaboration [26] falls short of the slepton and wino mass ranges of our interest. It is imperative to make a dedicated search for the electroweak production of such superparticle pairs in this model with the available LHC data, of about 5 and 20 fb$^{-1}$ at 7 and 8 TeV respectively.

5 Conclusion

The relatively low SUSY masses favoured by the observed dark matter relic density [14] and especially the observed excess of muon $g - 2$ [5] are incompatible with the reported Higgs boson mass of 125 GeV [3] and the direct SUSY search results [9] from 7 TeV LHC in the CMSSM as well as the NUHM [4, 8]. However, these two sets of results can be reconciled in a simple and predictive nonuniversal gaugino mass model, based on the SUSY GUT group SU(5) [15]. It assumes SUSY breaking by a combination of a singlet and a non singlet superfields belonging to the symmetric product of two adjoint representations of the GUT group, i.e. $1+24, 1+75$ or $1+200$ representations [16]. In each case one can satisfy the bulk annihilation region of dark
All masses in GeV

| Particle       | \(M_1^G = 200\), \(M_2^G = 575\) and \(M_3^G = 1500\) |
|----------------|--------------------------------------------------|
|                | \(m_0 = 117\) | \(m_0 = 160\) | \(m_0 = 201\) |
| \(\tan \beta = 10\) | \(\tan \beta = 15\) | \(\tan \beta = 20\) |
| \(\tilde{\chi}_1^0\) (bino) | 74.8 | 75.0 | 75.2 |
| \(\tilde{\chi}_2^0\) (wino) | 455 | 456 | 457 |
| \(\tilde{\chi}_3^0\) (higgsino) | 1976 | 1965 | 1959 |
| \(\tilde{\chi}_4^0\) (higgsino) | 1977 | 1967 | 1961 |
| \(\tilde{\chi}_1^+\) (wino) | 455 | 456 | 457 |
| \(\tilde{\chi}_2^+\) (higgsino) | 1978 | 1967 | 1961 |
| \(M_1\) | 76.7 | 76.7 | 76.8 |
| \(M_2\) | 437 | 437 | 438 |
| \(M_3\) | 3125 | 3126 | 3128 |
| \(\mu\) | 1970 | 1960 | 1954 |
| \(\tilde{g}\) | 3178 | 3179 | 3180 |
| \(\tilde{\tau}_1\) | 93.9 | 97.7 | 104 |
| \(\tilde{\tau}_2\) | 375 | 402 | 434 |
| \(\tilde{e}_R, \tilde{\mu}_R\) | 139 | 176 | 214 |
| \(\tilde{e}_L, \tilde{\mu}_L\) | 363 | 379 | 398 |
| \(\tilde{t}_1\) | 2207 | 2212 | 2216 |
| \(\tilde{t}_2\) | 2535 | 2529 | 2520 |
| \(\tilde{b}_1\) | 2517 | 2510 | 2499 |
| \(\tilde{b}_2\) | 2724 | 2709 | 2689 |
| \(\tilde{q}_{1,2,R}\) | \(\sim 2738\) | \(\sim 2741\) | \(\sim 2745\) |
| \(\tilde{q}_{1,2,L}\) | \(\sim 2748\) | \(\sim 2751\) | \(\sim 2754\) |
| \(h\) | 123 | 123 | 122 |

Table 4. The SUSY mass spectrum for a general non-universal model for a \(\sim 80\) GeV LSP with increasing \(\tan \beta\) and the corresponding \(g-2\) contribution from SUSY. We take \(A_t = A_b = -1.4\) TeV with \(A_{\tau} = 0\) TeV as before, while \(m_0\) is chosen such that the correct relic density is obtained in each case.

Muon \(g - 2\)

| \(a_\mu\) | \(2.67 \times 10^{-9}\) | \(2.7 \times 10^{-9}\) | \(2.54 \times 10^{-9}\) |
| \(\delta a_\mu\) | \(0.26\sigma\) | \(0.23\sigma\) | \(0.43\sigma\) |
matter relic density with relatively small bino and right slepton masses $\sim 100$ GeV, while having TeV scale squark/gluino masses and $A_0$ parameter to satisfy the Higgs mass and direct SUSY search results from 7 TeV LHC [17]. We show here that the 1+200 model predicts a relatively modest mass range for wino and left slepton masses, which can also account for the observed excess of the muon $\mu - 2$. Part of this model parameter space can be probed via squark/gluino search with the available LHC data, while the remainder can be probed with the 14 TeV LHC data. We then present a more general model of nonuniversal gaugino masses, where one can account for the bulk annihilation region of dark matter relic density and the observed excess of muon $\mu - 2$, while pushing up the squark/gluino masses beyond the reach of the available 7 and 8 TeV LHC data and in fact to the edge of the discovery limit of the 14 TeV data or beyond. However, the model can be probed via SUSY search for electroweak production of the relatively light wino and slepton pairs at least with the 14 TeV LHC data. We conclude with the hope that the ATLAS and CMS collaborations will start dedicated search for wino and sleptons in these simple models via squark/gluino cascade decay as well as electroweak pair production.

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