The R-Parity Violating Minimal Supersymmetric Standard Model

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We present a minimal version of supergravity with broken R-parity. We discuss the origins of lepton number violation in supersymmetry. We have computed the full set of coupled one-loop renormalization group equations for the gauge couplings, the superpotential parameters and for all the soft supersymmetry breaking parameters. After making an explicit choice of basis which we propose as a convention, we compute the low-energy spectrum of the superparticles and the neutrinos as a function of the small set of parameters at the unification scale. We use the neutrino masses to set new bounds on the R-parity violating couplings at the unification scale. We investigate the nature of the lightest supersymmetric particle and find extensive regions in parameter space, where it is *not* the neutralino. This leads to a novel set of supersymmetric signatures, which we classify.

I. MOTIVATION : WHY BROKEN R-PARITY?

Theorem : "There are only two generalized parities which are discrete anomaly free with the minimal particle content of the Supersymmetric Stabdard Model. One is the Standard Z_2-parity (commonly called R-parity) and the other is the Z_3 symmetry (commonly called Baryon-parity) which allows for lepton number violation and not for Baryon number violation (up to dimension-5 operators) [1]". Since, is almost confirmed that neutrinos have masses this is probably a good omen for lepton number violation. On the other hand, the proton is more stable than we expected within the Minimal SUSY SU(5) Model to be. The later forced us to forbid non-renormalizable B-number violating operators up to dimension 5. The MSSM with baryon parity explains both these observations for free. There is no reason to extend the particle content of the theory, as opposed to the R-parity conserving MSSM with the see-saw mechanism.

II. THE MINIMAL R-PARITY VIOLATING SUPERSYMMETRIC STANDARD MODEL

We start at some high scale M_X with the superpotential,

$$
\begin{aligned}
W \;=\; & \epsilon_{ab}\left[(\mathbf{Y}_E)_{ij}L_i^a H_1^b \bar{E}_j + (\mathbf{Y}_D)_{ij}Q_i^{ax}H_1^b\bar{D}_{jx} + (\mathbf{Y}_U)_{ij}Q_i^{ax}H_2^b\bar{U}_{jx}\right] \\
& +\epsilon_{ab}\left[\frac{1}{2}\lambda_{ijk}L_i^aL_j^b\bar{E}_k + \lambda'_{ijk}L_i^aQ_j^{xb}\bar{D}_{kx}\right] + \frac{1}{2}\epsilon_{xyz}\lambda''_{ijk}\bar{U}_i^x\bar{D}_j^y\bar{D}_k^z \\
& -\epsilon_{ab}\left[\mu H_1^aH_2^b + \kappa^i L_i^a H_2^b\right].
\end{aligned}
\tag{1}
$$

We denote an $SU(3)$ colour index of the fundamental representation by $x, y, z = 1, 2, 3$. The $SU(2)_L$ fundamental representation indices are denoted by $a, b, c = 1, 2$ and the generation indices by $i, j, k = 1, 2, 3$. In the basis where the sneutrino vevs are zero (see below) the κ_i term in the vector μ_α should be small and of order of MeV in order to agree with the neutrino mass limits. But what makes this parameter small? The natural solution one can think is that this parameter is zero at some high scale and is generated radiatively as we run down to low energies. This is a solution we present here and seems to work only in the minimal Supergravity scenario as we will see below. In any case, the κ_i term in (1) can always be rotated away in the Supersymmetric limit. One can shift the superfields by an orthogonal transformation[8]

$$
\mathcal{L}_\alpha = \mathcal{O}_{\alpha\beta}\mathcal{L}'_\beta \Rightarrow \begin{pmatrix} H_1 \\ L_1 \\ L_2 \\ L_3 \end{pmatrix} = \begin{pmatrix} c_3 & -s_3 & 0 & 0 \\ c_2 s_3 & c_2 c_3 & -s_2 & 0 \\ c_1 s_2 s_3 & c_1 s_2 c_3 & c_1 c_2 & -s_1 \\ s_1 s_2 s_3 & s_1 s_2 c_3 & s_1 c_2 & c_1 \end{pmatrix} \begin{pmatrix} \mathcal{L}'_0 \\ \mathcal{L}'_1 \\ \mathcal{L}'_2 \\ \mathcal{L}'_3 \end{pmatrix}, \tag{2}
$$

where $c_i = \cos\theta_i$ and $s_i = \theta_i$ are rotation angles. They are given explicitly by

$$
\begin{aligned}
c_1 &= \frac{\kappa_2}{\sqrt{\kappa_2^2+\kappa_3^2}}, \quad s_1 = \frac{\kappa_3}{\sqrt{\kappa_2^2+\kappa_3^2}} \\
c_2 &= \frac{\kappa_1}{\sqrt{\vec{\kappa}^2}}, \qquad s_2 = \frac{\sqrt{\kappa_2^2+\kappa_3^2}}{\sqrt{\vec{\kappa}^2}} \\
c_3 &= \frac{\mu}{\sqrt{\mu^2+\vec{\kappa}^2}}, \quad s_3 = \frac{\sqrt{\vec{\kappa}^2}}{\sqrt{\mu^2+\vec{\kappa}^2}}
\end{aligned} \tag{3}
$$

where we have introduced the notation $\vec{\kappa}^2 = \kappa_1^2 + \kappa_2^2 + \kappa_3^2$. After the above field redefinition the only remaining superfield bi-linear term is

$$\mu'' H_1' H_2 \tag{4}$$

with $\mu'' = \sqrt{\mu^2 + \vec{\kappa}^2}$ and $H_1' \equiv \mathcal{L}_0'$. It is well known [2, 3] that even if we set the billinear κ-term equal to zero this will be generated from loop corrections due to the appearence of the non-zero anomalous dimensions $\gamma_{H_1}^{L_i}$. The same also will happens for vanishing (at tree level) Yukawa couplings-this time due to the non-vanishing anomalous dimension, $\gamma_{L_i}^{L_j}, i \neq j$ in addition to $\gamma_{H_1}^{L_i}$. Thus at low energies the most general superpotential we can write down is (we drop the primes from the lepton fields)

$$W = \epsilon_{ab}\left[(\mathbf{Y}_U)_{ij} Q_i^a H_2^b \bar{U}_j + \frac{1}{2}\lambda_{\alpha\beta k}\mathcal{L}_\alpha^a \mathcal{L}_\beta^b \bar{E}_k + \lambda'_{\alpha jk}\mathcal{L}_\alpha^a Q_j^b \bar{D}_k - \mu_\alpha \mathcal{L}_\alpha^a H_2^b\right] + \frac{1}{2}\epsilon_{xyz}\lambda''_{ijk}\bar{U}_i^x \bar{D}_j^y \bar{D}_k^z \tag{5}$$

where we have exploited the four vector notation $\mathcal{L}_\alpha = (H_1, L_i)$ and $\mu_\alpha = (\mu, \kappa_i)$. It is also, $\lambda_{0jk} \equiv (\mathbf{Y}_E)_{jk}$ and $\lambda'_{0jk} \equiv (\mathbf{Y}_D)_{jk}$.

III. MINIMAL LOW ENERGY R-PARITY VIOLATING SUPERGRAVITY MODEL

The soft supersymmetry breaking Lagrangian obatined at low energies (of the order of the Electroweak scale)

$$
\begin{aligned}
-\mathcal{L}_{\rm SOFT} &= (m^2_{\tilde{\mathcal{L}}})_{\alpha\beta}\tilde{\mathcal{L}}^\dagger_\alpha \tilde{\mathcal{L}}_\beta + m^2_{H_2} H_2^\dagger H_2 + \widetilde{Q}^\dagger(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)\widetilde{Q} + \widetilde{\bar{E}}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)\widetilde{\bar{E}}^\dagger + \widetilde{\bar{D}}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)\widetilde{\bar{D}}^\dagger + \widetilde{\bar{U}}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)\widetilde{\bar{U}}^\dagger \\
&+ \epsilon_{ab}\left[(\mathbf{h}_U)_{ij} Q_i^a H_2^b \bar{U}_j + \frac{1}{2}h_{\alpha\beta k}\tilde{\mathcal{L}}_\alpha^a \tilde{\mathcal{L}}_\beta^b \bar{E}_k + h'_{\alpha jk}\tilde{\mathcal{L}}_\alpha^a Q_j^b \bar{D}_k - b_\alpha \tilde{\mathcal{L}}_\alpha^a H_2^b \ + \ \text{H.c}\right] + \frac{1}{2}\epsilon_{xyz}h''_{ijk}\bar{U}_i^x \bar{D}_j^y \bar{D}_k^z \ + \ \text{H.c} \\
&+ \left[\frac{1}{2}M_1 \widetilde{\mathcal{B}}\widetilde{\mathcal{B}} + \frac{1}{2}M_2 \widetilde{\mathcal{W}}^{(\Gamma)}\widetilde{\mathcal{W}}^{(\Gamma)} + \frac{1}{2}M_3 \widetilde{\mathcal{G}}^{(R)}\widetilde{\mathcal{G}}^{(R)} \ + \ \text{H.c}\right],
\end{aligned} \tag{6}
$$

where $b_\alpha = (\widetilde{B}, \widetilde{D}_i)$ is the bilinear SUSY soft breaking term, and $(\mathbf{h}_U)_{ij}, h_{\alpha\beta k}, h'_{\alpha jk}, h''_{ijk}$ the soft breaking trilinear couplings.

IV. RADIATIVE ELECTROWEAK SYMMETRY BREAKING

The full scalar potential can be derived from

$$\mathcal{V}_{\rm SCALAR} = \mathcal{V}_{\rm SUSY} + \mathcal{V}_{\rm SOFT}\ , \tag{7}$$

with

$$\mathcal{V}_{\rm SUSY} \ = \ \mathcal{V}_{\rm F} + \mathcal{V}_{\rm D} =$$

TABLE I: The particle content of the Minimal Supergravity R-Parity violating Model in terms of Superfields and their decomposition into components with their $SU(3)_c \times SU(2)_L \times U(1)_Y$ quantum numbers. x, R are SU(3) representation and generator indices, a, Γ are SU(2) representation and generator indices. $\alpha = 0,..,3$ is the family index of the Lepton superfield, and $i = 1,..3$ the usual family index of quarks, leptons and their superpartners. The fermionic components of superfields are Weyl two component spinors.

Chiral Superfields	$SU(3)_c \times SU(2)_L \times U(1)_Y$	Components
$Q_i^{a,x}$	$(\mathbf{3}, \mathbf{2}, \frac{1}{6})$	$\begin{pmatrix} \tilde{u}_L \\ \tilde{d}_L \end{pmatrix}$, $\begin{pmatrix} u_L \\ d_L \end{pmatrix}$
$\bar{D}_i^x$	$(\bar{\mathbf{3}}, \mathbf{1}, \frac{1}{3})$	$\tilde{d}_R^*$, d_R
$\bar{U}_i^x$	$(\bar{\mathbf{3}}, \mathbf{1}, -\frac{2}{3})$	$\tilde{u}_R^*$, u_R
$\mathcal{L}_\alpha^a = \{H_1^a, L_i^a\}$	$(1, \mathbf{2}, -\frac{1}{2})$	$\begin{pmatrix} \tilde{\nu}_\alpha \\ \tilde{e}_{L\alpha} \end{pmatrix} = \left\{ \begin{pmatrix} h_1^0 \\ h_1^- \end{pmatrix}, \begin{pmatrix} \tilde{\nu}_i \\ \tilde{e}_{Li} \end{pmatrix} \right\}$, $\begin{pmatrix} \nu_\alpha \\ e_{L\alpha} \end{pmatrix} = \left\{ \begin{pmatrix} \tilde{h}_1^0 \\ \tilde{h}_1^- \end{pmatrix}, \begin{pmatrix} \nu_i \\ e_{Li} \end{pmatrix} \right\}$
$\bar{E}_i$	$(\mathbf{1}, \mathbf{1}, \mathbf{1})$	$\tilde{e}_R^*$, e_R
h_2^a	$(\mathbf{1}, \mathbf{2}, \frac{1}{2})$	$\begin{pmatrix} h_2^+ \\ h_2^0 \end{pmatrix}$, $\begin{pmatrix} \tilde{h}_2^+ \\ \tilde{h}_2^0 \end{pmatrix}$
Vector Superfields	$SU(3)_c \times SU(2)_L \times U(1)_Y$	Components
V_1	$(\mathbf{1}, \mathbf{1}, \mathbf{0})$	$\widetilde{\mathcal{B}}$, B_μ
V_2	$(\mathbf{1}, \mathbf{3}, \mathbf{0})$	$\widetilde{\mathcal{W}}^{(\Gamma)}$, $W_\mu^{(\Gamma)}$
V_3	$(\mathbf{8}, \mathbf{1}, \mathbf{0})$	$\widetilde{\mathcal{G}}^{(R)}$, $G_\mu^{(R)}$

$$\sum_\Phi |\frac{dW}{d\Phi}|^2 + \sum_l \frac{g_l^2}{2} \sum_A \left(\sum_{\alpha,\beta} \Phi_\alpha^* T_{l,A}^{\alpha\beta} \Phi_\beta \right)^2 \quad (8)$$

and $\mathcal{V}_{\rm SOFT} = -\mathcal{L}_{\rm SOFT}$. In Eq.(8) Φ's are the scalar fields, g_l are the gauge couplings with g for the $U(1)_{EM}$, g_2 for the $SU(2)_L$ and g_3 for the $SU(3)$, α, β.. and A, B... representation and generator indices respectively. The expressions for $\mathcal{V}_{\rm F}$ and $\mathcal{V}_{\rm D}$ can be found in [4].

The scalar potential of the neutral scalar fields is

$$\begin{aligned}
\mathcal{V}_{\rm Neutral} &= (m_{H_2}^2 + |\mu_\alpha|^2)|h_2^0|^2 + \left[(m_{\tilde{\mathcal{L}}}^2)_{\alpha\beta} + \mu_\alpha^* \mu_\beta \right] \tilde{\nu}_\alpha^* \tilde{\nu}_\beta - (b_\alpha \tilde{\nu}_\alpha h_2^0 + b_\alpha^* \tilde{\nu}_\alpha^* h_2^{0*}) \\
&+ \frac{1}{8}(g^2 + g_2^2) \left(|h_2^0|^2 - |\tilde{\nu}_\alpha|^2 \right)^2 + \mathcal{V}_{\rm 1loop} \ . \qquad (9)
\end{aligned}$$

Expanding the scalar fields $h_2^0 = x_2 + i y_2$, $\tilde{\nu}_\alpha = x_\alpha + i y_\alpha$ and assuming that only the neutral scalar fields acquire a vacuum expectation values[9], $< x_2 >= v_2$, $< \tilde{x}_\alpha >= v_\alpha$ and $< y_2 >=< y_\alpha >= 0$ the following minimization conditions can be derived from (9)

$$\begin{aligned}
\Re \left[(m_{\tilde{\mathcal{L}}}^2)_{\alpha\beta} + \mu_\alpha^* \mu_\beta \right] v_\alpha - \Re(b_\beta) v_2 - \frac{1}{4}(g^2 + g_2^2) \left(|v_2|^2 - |v_\alpha|^2 \right) v_\beta + \frac{1}{2} \frac{\partial \mathcal{V}_{\rm 1loop}}{\partial v_\beta} &= 0 \\
(m_{H_2}^2 + |\mu_\alpha|^2) v_2 - \Re(b_\beta) v_\beta + \frac{1}{4}(g^2 + g_2^2) \left(|v_2|^2 - |v_\alpha|^2 \right) v_2 + \frac{1}{2} \frac{\partial \mathcal{V}_{\rm 1loop}}{\partial v_2} &= 0 \ , \qquad (10)
\end{aligned}$$

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We want to solve the system of these five minimization conditions. We start by defining

$$\tan\beta \;=\; \frac{v_u}{v_d}\;, \qquad (11)$$

and

$$v^2 = v_u^2 + v_d^2 + \sum_i v_i^2 = \frac{2M_W^2}{g_2^2}\;. \qquad (12)$$

Then the vev's v_u and v_d (I have diverted from the notation of v_1 (now v_d) and v_2 (noe v_u) for obvious reason) can be written

$$v_d^2 \;=\; \cos^2\beta\left(v^2 - \sum_i v_i^2\right)\;, \qquad (13)$$

$$v_u^2 \;=\; \sin^2\beta\left(v^2 - \sum_i v_i^2\right)\;, \qquad (14)$$

The big advantage of using the definition (11,12) is that $\tan\beta$ remains invariant in the R-parity conserved (RPC) and violating (RPV) model. This helps with the direct comparison of the two models.

The minimization conditions (10) can be written as

$$(m_{H_d}^2+\mu^2)v_d + \left[(\mathbf{m}^2_{\tilde{L}_iH_1}) + \kappa_i^*\mu\right]v_i - \widetilde{B}v_u + \frac{1}{2}M_Z^2\cos 2\beta v_d + \frac{1}{2}(g^2+g_2^2)\sin^2\beta v_d\sum_i v_i^2 + \frac{1}{2}\frac{\partial\mathcal{V}_{1\text{loop}}}{\partial v_d} \;=\; 0\;, \qquad (15)$$

$$\left[(\mathbf{m}^2_{H_1\tilde{L}_i}) + \mu^*\kappa_i\right]v_d + \left[(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{ji} + \kappa_j^*\kappa_i\right]v_j - \widetilde{D}_iv_u + \frac{1}{2}M_Z^2\cos 2\beta v_i + \frac{1}{2}(g^2+g_2^2)\sin^2\beta v_i\sum_j v_j^2 + \frac{1}{2}\frac{\partial\mathcal{V}_{1\text{loop}}}{\partial v_i} \;=\; 0\;, \qquad (16)$$

$$(m_{H_u}^2+\mu^2+|\kappa_i|^2)v_u - \widetilde{B}v_d - \widetilde{D}_iv_i - \frac{1}{2}M_Z^2\cos 2\beta v_u - \frac{1}{2}(g^2+g_2^2)\sin^2\beta v_u\sum_i v_i^2 + \frac{1}{2}\frac{\partial\mathcal{V}_{1\text{loop}}}{\partial v_u} \;=\; 0\;, \qquad (17)$$

We first derive μ and $\widetilde{B}$ from (15) and (17). The μ-parameter is obtained after solving the quadratic equation

$$A\mu^2 + B\mu + \Gamma = 0\;, \qquad (18)$$

with

$$A \;\equiv\; \tan^2\beta - 1\;, \qquad (19)$$

$$B \;\equiv\; -\kappa_i^*\frac{v_i}{v_d}\;, \qquad (20)$$

$$\Gamma \;\equiv\; \left\{\left[\bar{m}^2_{H_u} + |\kappa_i|^2 - (g^2+g_2^2)\sum_i v_i^2 - \widetilde{D}_i\frac{v_i}{v_u}\right]\tan^2\beta - \left[\bar{m}^2_{H_d} + (\mathbf{m}^2_{\tilde{L}_iH_1})\frac{v_i}{v_d}\right]\right\} + \frac{1}{2}M_Z^2\;,. \qquad (21)$$

$\widetilde{B}$ takes a simple form

$$\widetilde{B} \;=\; \frac{\sin 2\beta}{2}\left\{\left[\bar{m}^2_{H_d} + \bar{m}^2_{H_u} + 2|\mu|^2 + |\kappa_i|^2\right] + \left[(\mathbf{m}^2_{\tilde{L}_iH_1}) + \kappa_i^*\mu\right]\frac{v_i}{v_d} - \widetilde{D}_i\frac{v_i}{v_u}\right\}\;, \qquad (22)$$

where in both (21) and (22) is

$$\bar{m}^2_{H_{u,d}} \;\equiv\; m^2_{H_{u,d}} + \frac{1}{2}\frac{1}{v_{u,d}}\frac{\partial\mathcal{V}_{1\text{loop}}}{\partial v_{u,d}}\;. \qquad (23)$$

Now Eq.(16) can be cast in a form,

$$(M^2_{\tilde{\nu}})_{ij}v_j = -\left[(\mathbf{m}^2_{H_1\tilde{L}_i}) + \mu^*\kappa_i\right]v_d + \widetilde{D}_iv_u - \frac{1}{2}\frac{\partial\mathcal{V}_{1\text{loop}}}{\partial v_i} \qquad (24)$$

where

$$(M^2_{\tilde{\nu}})_{ij} \;=\; (\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{ji} + \kappa_i\kappa_j^* + \frac{1}{2}M_Z^2\cos 2\beta\delta_{ij} + \frac{1}{2}(g^2+g_2^2)\sin^2\beta(v^2-v_u^2-v_d^2)\delta_{ij}\;. \qquad (25)$$

Now the numerical procedure is the following : i) We solve (21) and (22) first in the RPC limit $v_i = 0, \kappa = \widetilde{D} = 0$ and we define initial values for μ and $\widetilde{B}$. ii) We pass μ into the system (22) and we solve with respect to v_i by treating v_u and v_d as constants (then the system (22) is linear and even analytically you can find solution). iii) We correct the vevs v_u and v_d from Eqs.(13,14). iv) We iterate the procedure until convergence of $\mu, \widetilde{B}, v_u, v_d, v_i$ is reached. I tryed extreme values of lambdas and kapas and I saw that the system is always convergent apart from cases it simply does not have a solution. So we achieved what we wanted : We start by giving as input $\tan\beta$ as in the MSSM, we define μ and $\widetilde{B}$ from the mins and we have the sneutrino vevs. Now we do not have to rotate to any basis. Just plug in those values to the basis independent mass matrices below and find the spectrum.

V. PARTICLE AND SUPERPARTICLE MASSES

The mass matrices for particle and superparticles are given in both basis independent and basis dependent Eq.(??) choice below. Note that we strictly follow the conventions of Haber and Grossman [4] which in the R-parity conserved limit coincide with those of Haber and Kane [5].

A. CP-Even Higgs-Sneutrino masses

Sneutrinos mix with Higgs bosons. If CP is conserved we can separate them in CP-even and CP-odd types. Following Grossman and Haber [4] let us denote with $\tilde{\nu}_+$ ($\tilde{\nu}_-$) the CP-even(CP-odd) sneutrinos. If R-parity is broken the mass of $\tilde{\nu}_+$ is in general different than the mass of $\tilde{\nu}_-$ i.e., there is a sneutrino anti-sneutrino mass spliting. The CP-even Higgs-sneutrinos $h, H, \tilde{\nu}_+^i$ are obtained in a basis independent form after the diagonalization of a 5×5 matrix

$$\mathcal{L} = -\frac{1}{2}(x_2, x_\gamma)\mathcal{M}^2_{\mathrm{CP-even}} \begin{pmatrix} x_2 \\ x_\delta \end{pmatrix} \tag{26}$$

where

$$\mathcal{M}^2_{\mathrm{CP-even}} = \begin{pmatrix} \frac{b_\alpha v_\alpha}{v_2} + \frac{1}{2}(g^2+g_2^2)v_2^2 & -b_\delta - \frac{1}{2}(g^2+g_2^2)v_2 v_\delta \\ -b_\gamma - \frac{1}{2}(g^2+g_2^2)v_2 v_\gamma & (m^2_{\tilde{\nu}})_{\gamma\delta} + \frac{1}{2}(g^2+g_2^2)v_\gamma v_\delta \end{pmatrix}, \tag{27}$$

with

$$(m^2_{\tilde{\nu}})_{\alpha\beta} = [(m^2_{\tilde{L}})_{\alpha\beta} + \mu^*_\alpha \mu_\beta] - \frac{1}{4}(g^2+g_2^2)(v_2^2 - v_\gamma^2)\delta_{\alpha\beta} \tag{28}$$

where $v_\gamma^2 \equiv \sum_\gamma v_\gamma^2$. In the basis choice Eq.(**??**), the CP-even squared mass matrix is written

$$\mathcal{M}^2_{\mathrm{CP-even}} = \begin{pmatrix} \widetilde{B}\cot\beta + M_Z^2 \sin^2\beta & -\widetilde{B} - \frac{1}{2}M_Z^2 \sin 2\beta & -\widetilde{D}_1 & -\widetilde{D}_2 & -\widetilde{D}_3 \\ -\widetilde{B} - \frac{1}{2}M_Z^2 \sin 2\beta & \widetilde{B}\tan\beta + M_Z^2\cos^2\beta & \widetilde{D}_1\tan\beta & \widetilde{D}_2\tan\beta & \widetilde{D}_3\tan\beta \\ -\widetilde{D}_1 & \widetilde{D}_1\tan\beta & & & \\ -\widetilde{D}_2 & \widetilde{D}_2\tan\beta & & (m^2_{\tilde{\nu}})_{ij} & \\ -\widetilde{D}_3 & \widetilde{D}_3\tan\beta & & & \end{pmatrix}, \tag{29}$$

In deriving (29), we have made use of the minimization conditions Eqs(**??**) and

$$(m^2_{\tilde{\nu}})_{ij} = [(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{ij} + \kappa_i\kappa_j] + \frac{1}{2}M_Z^2\cos 2\beta\,\delta_{ij}\ . \tag{30}$$

B. CP-Odd Higgs-Antisneutrino masses

The CP-odd Higgs-sneutrinos $A, \tilde{\nu}_-^i$ (and the massless Goldstone boson in unitary gauge) are obtained in a basis independent form after the diagonalization of a 5×5 matrix

$$\mathcal{L} = -\frac{1}{2}(y_2, y_\gamma)\mathcal{M}^2_{\mathrm{CP-odd}} \begin{pmatrix} y_2 \\ y_\delta \end{pmatrix} \tag{31}$$

where

$$\mathcal{M}^2_{\mathrm{CP-odd}} = \begin{pmatrix} \frac{b_\alpha v_\alpha}{v_2} & b_\delta \\ b_\gamma & (m^2_{\tilde{\nu}})_{\gamma\delta} \end{pmatrix}. \tag{32}$$

In the basis choice Eq.(**??**), the CP-odd squared mass matrix is written

$$\mathcal{M}^2_{\mathrm{CP-even}} = \begin{pmatrix} \widetilde{B}\cot\beta & \widetilde{B} & \widetilde{D}_1 & \widetilde{D}_2 & \widetilde{D}_3 \\ \widetilde{B} & \widetilde{B}\tan\beta & \widetilde{D}_1\tan\beta & \widetilde{D}_2\tan\beta & \widetilde{D}_3\tan\beta \\ \widetilde{D}_1 & \widetilde{D}_1\tan\beta & & & \\ \widetilde{D}_2 & \widetilde{D}_2\tan\beta & & (m^2_{\tilde{\nu}})_{ij} & \\ \widetilde{D}_3 & \widetilde{D}_3\tan\beta & & & \end{pmatrix} \tag{33}$$

where again we made use of Eqs.(**??**). For one generation we obtain two nonzero eigenvalues identified as the CP-odd Higgs and the sneutrino,

$$\begin{aligned} m^2_{\tilde{\nu}_-} &= \frac{1}{2}\left[m^2_{\tilde{\nu}} + \frac{2\tilde{B}}{\sin 2\beta} + \sqrt{\left(m^2_{\tilde{\nu}} - \frac{2B}{\sin 2\beta}\right)^2 + 4\tilde{D}_1^2\left(1+\tan^2\beta\right)}\right] \\ m^2_A &= \frac{1}{2}\left[m^2_{\tilde{\nu}} + \frac{2\tilde{B}}{\sin 2\beta} - \sqrt{\left(m^2_{\tilde{\nu}} - \frac{2B}{\sin 2\beta}\right)^2 + 4\tilde{D}_1^2\left(1+\tan^2\beta\right)}\right] \end{aligned} \tag{34}$$

Notice the $\tan\beta$ enhancement(reduction) of the sneutrino(higgs) is due exclusively to a R-parity violating contribution. In order not to have negative CP-odd Higgs mass it must be $m_{\tilde\nu}^2 > \frac{\tilde{D}_1^2 \tan\beta}{\tilde{B}}$ which says that $\tilde{D}_1 << \tilde{B}$. For $\tilde{D}_1 \to 0$ we have $m_{\tilde\nu_-} = m_{\tilde\nu}$ and $m_A^2 = \frac{2\tilde{B}}{\sin 2\beta}$ as it should be.

C. Charged Higgs Bosons-Sleptons

Charged Higgs Bosons mix with sleptons. In a basis independent way we find the 8×8 mass matrix which upon diagonilization gives the masse eigenstates : $G^{\pm}, H^{\pm}, \tilde{e}_{i=1,\dots 6}$.

$$\mathcal{L} = -(h_2^-, \tilde{e}_{L_\gamma}, \tilde{e}_{R_k})\mathcal{M}^2_{\text{Charged}} \begin{pmatrix} h_2^+ \\ \tilde{e}^*_{L_\delta} \\ \tilde{e}^*_{R_l} \end{pmatrix} \tag{35}$$

where

$$\mathcal{M}^2_{\text{Charged}} = \begin{pmatrix} (m^2)_{11} + D & b^*_\delta + D_\delta & \lambda_{\beta\alpha l}\mu^*_\alpha v_\beta \\ b_\gamma + D^*_\gamma & (m^2)_{\delta\gamma} + \lambda_{\alpha\gamma l}\lambda_{\beta\delta l} v_\alpha v_\beta + D_{\gamma\delta} & h_{\alpha\gamma l} v_\alpha - \lambda_{\alpha\gamma l}\mu^*_\alpha v_2 \\ \lambda^*_{\beta\alpha k}\mu_\alpha v_\beta & h^*_{\alpha\delta k} v_\alpha - \lambda_{\alpha\delta k}\mu_\alpha v_2 & (\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{lk} + \lambda_{\alpha\beta k}\lambda_{\alpha\gamma l} v_\beta v_\gamma + D_{lk} \end{pmatrix} . \tag{36}$$

with (38)

$$\begin{aligned} (m^2)_{11} &= m^2_{H_2} + |\mu_\alpha|^2 \ , \\ D &= \frac{1}{4}(g_2^2 + g^2)(v_2^2 - |v_\alpha|^2) + \frac{1}{2} g_2^2 |v_\alpha|^2 \ , \\ D_\delta &= \frac{1}{2} g_2^2 v_2 v_\delta \ , \\ (m^2)_{\gamma\delta} &= (m^2_{\tilde{\mathcal{L}}})_{\delta\gamma} + \mu_\gamma \mu^*_\delta \ , \\ D_{\gamma\delta} &= \frac{1}{4}(g_2^2 - g^2)(v_2^2 - v_\alpha^2)\delta_{\delta\gamma} + \frac{1}{2} g_2^2 v_\gamma v_\delta \ , \\ (D)_{lk} &= \frac{1}{2} g^2 (v_2^2 - v_\alpha^2)\delta_{lk} \ . \end{aligned} \tag{37}$$

In the basis choice Eq.(**??**), the Charged Higgs Boson-Slepton squared mass matrix is written

$$\mathcal{L} = -(h_2^-, h_1^-, \tilde{e}_{L_i}, \tilde{e}_{R_l})\mathcal{M}^2_{\text{Charged}} \begin{pmatrix} h_2^+ \\ h_1^+ \\ \tilde{e}^*_{L_m} \\ \tilde{e}^*_{R_k} \end{pmatrix} \tag{39}$$

with

$$\mathcal{M}^2_{\text{Charged}} = \begin{pmatrix} \tilde{B}\cot\beta + M_W^2\cos^2\beta & \tilde{B} + \frac{1}{2}M_W^2 \sin 2\beta & \tilde{D}_m & (\mathbf{Y}_E)_{jk}\kappa^*_j v_1 \\ * & \tilde{B}\tan\beta + M_W^2 \sin^2\beta & \tilde{D}^*_m \tan\beta & (\mathbf{Y}_E)_{jk}\kappa^*_j v_2 \\ * & * & (\Omega^2_{LL})_{im} & (\Omega^2_{LR})_{ik} \\ * & * & * & (\Omega^2_{RR})_{lk} \end{pmatrix} , \tag{40}$$

where with "*" we denote the complex conjugate element and

$$\begin{aligned} (\Omega^2_{LL})_{im} &= \left[(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{im} + \mu_i \mu^*_m\right] + (\mathbf{Y}_E \mathbf{Y}_E^\dagger)_{im} v_1^2 + \left(\frac{1}{2}M_Z^2 - M_W^2\right)\cos 2\beta\,\delta_{im} \ , \\ (\Omega^2_{LR})_{ik} &= (\mathbf{h}_E)_{ik} v_1 - \left[(\mathbf{Y}_E)_{ik}\mu^* + \lambda_{lik}\kappa^*_l\right] v_2 \qquad (41) \\ (\Omega^2_{RR})_{lk} &= (\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{lk} + (\mathbf{Y}_E^\dagger \mathbf{Y}_E)_{kl} v_1^2 + (M_W^2 - M_Z^2)\cos 2\beta\,\delta_{lk} \ . \qquad (42) \end{aligned}$$

In deriving (40) we have made use of the minimization conditions (**??**). It is not hard to prove that the determinant of (36) or (40) is zero and Goldstone boson corresponds to the eigenvector $(-v_2, v_\alpha, 0)$.

D. Squarks

1. Down Squarks

The down squark mass eigenstates $\tilde{d}_i, i = 1,...6$ are given by diagonalizing the following mass matrix written here on a basis independent form

$$\mathcal{L} = -(\tilde{d}^*_{L_i}, \tilde{d}^*_{R_{i+3}})\mathcal{M}^2_{\rm Down} \begin{pmatrix} \tilde{d}_{L_j} \\ \tilde{d}_{R_{j+3}} \end{pmatrix} , \qquad (43)$$

where

$$\mathcal{M}^2_{\rm Down} = \begin{pmatrix} ({\mathbf{m}_{\tilde{\mathbf{Q}}}}^2)_{ij} + \lambda'^*_{\alpha il}\lambda'_{\gamma jl}v_\alpha v_\gamma + \left(\frac{1}{4}g_2^2 + \frac{1}{12}g^2\right)(v_2^2 - v_\alpha^2)\delta_{ij} & h'^*_{\alpha ij}v_\alpha - \lambda'^*_{\alpha ij}\mu_\alpha v_2 \\ * & ({\mathbf{m}_{\tilde{\mathbf{D}}}}^2)_{ij} + \lambda'^*_{\alpha lj}\lambda'_{\beta li}v_\alpha v_\beta + \frac{1}{6}g^2(v_2^2 - v_\alpha^2)\delta_{ij} \end{pmatrix} , \qquad (44)$$

and in the basis choice (**??**)

$$\mathcal{M}^2_{\rm Down} = \begin{pmatrix} ({\mathbf{m}_{\tilde{\mathbf{Q}}}}^2)_{ij} + (\mathbf{Y}_D\mathbf{Y}_D^\dagger)_{ji}v_1^2 + D^d_{L_{ij}} & (\mathbf{h}^*_D)_{ij}v_1 - [(\mathbf{Y}^*_D)_{ij}\mu + \lambda'^*_{mij}\kappa_m]v_2 \\ * & ({\mathbf{m}_{\tilde{\mathbf{D}}}}^2)_{ij} + (\mathbf{Y}_D^\dagger\mathbf{Y}_D)_{ji}v_1^2 + D^d_{R_{ij}} \end{pmatrix} , \qquad (45)$$

where

$$\begin{aligned} D^d_{L_{ij}} &= -\frac{1}{3}\left(M_W^2 + \frac{1}{2}M_Z^2\right)\cos 2\beta\delta_{ij} , \\ D^d_{R_{ij}} &= \frac{1}{3}\left(M_W^2 - M_Z^2\right)\cos 2\beta\delta_{ij} , \end{aligned} \qquad (46)$$

are the D-term contributions.

2. Up Squarks

The up squark mass eigenstates $\tilde{u}_i, i = 1,...6$ are given by diagonalizing the following mass matrix written here on a basis independent form

$$\mathcal{L} = -(\tilde{u}^*_{L_i}, \tilde{u}^*_{R_{i+3}})\mathcal{M}^2_{\rm Up} \begin{pmatrix} \tilde{u}_{L_j} \\ \tilde{u}_{R_{j+3}} \end{pmatrix} , \qquad (47)$$

where

$$\mathcal{M}^2_{\rm Up} = \begin{pmatrix} ({\mathbf{m}_{\tilde{\mathbf{Q}}}}^2)_{ij} + (\mathbf{Y}_U\mathbf{Y}_U^\dagger)_{ji}v_2^2 - \frac{1}{4}\left(g_2^2 - \frac{1}{3}g^2\right)(v_2^2 - v_\alpha^2)\delta_{ij} & (\mathbf{h}^*_U)_{ij}v_2 - (\mathbf{Y}^*_U)_{ij}\mu_\alpha v_1 \\ * & ({\mathbf{m}_{\tilde{\mathbf{U}}}}^2)_{ij} + (\mathbf{Y}_U^\dagger\mathbf{Y}_U)_{ji}v_2^2 - \frac{1}{3}g^2(v_2^2 - v_\alpha^2)\delta_{ij} \end{pmatrix} ,$$

(48)

and in the basis choice (??)

$$\mathcal{M}^2_{\rm Up} = \begin{pmatrix} (\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{ij} + (\mathbf{Y}_U\mathbf{Y}_U^\dagger)_{ji}v_2^2 + D^u_{L_ij} & (\mathbf{h}_U^*)_{ij}v_2 - (\mathbf{Y}_U^*)_{ij}\mu v_\alpha \\ * & (\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{ij} + (\mathbf{Y}_U^\dagger\mathbf{Y}_U)_{ji}v_2^2 + D^u_{R_ij} \end{pmatrix} , \tag{49}$$

where

$$\begin{aligned} D^u_{L_ij} &= \left(\frac{2}{3}M_W^2 - \frac{1}{6}M_Z^2\right)\cos 2\beta\delta_{ij} , \\ D^u_{R_ij} &= \frac{2}{3}\left(M_Z^2 - M_W^2\right)\cos 2\beta\delta_{ij} , \end{aligned} \tag{50}$$

are the D-term contributions. Notice that the form of the Up Squark mass matrix does remains as in the R-parity conserved case in the basis (??).

E. Quarks

The Down quark masses are ,

$$(m_d)_{ij} = \lambda'_{\alpha ij}v_\alpha , \tag{51}$$

and in basis (??)

$$(m_d)_{ij} = (\mathbf{Y}_D)_{ij}v_1 . \tag{52}$$

The Up quark masses are always

$$(m_u)_{ij} = (\mathbf{Y}_U)_{ij}v_2 . \tag{53}$$

F. Neutrinos-Neutralinos

Neutrinos mix with neutralinos resulting one massive neutrino at tree level and four massive neutralinos. The Lagrangian contains the (7×7 for three generations of neutrinos) neutrino-neutralino mass matrix as

$$\mathcal{L} = -\frac{1}{2}(-i\widetilde{\mathcal{B}}, -i\widetilde{\mathcal{W}}^{(3)}, \tilde{h}_2^0, \nu_\alpha)\mathcal{M}_{\rm N}\begin{pmatrix} -i\widetilde{\mathcal{B}} \\ -i\widetilde{\mathcal{W}}^{(3)} \\ \tilde{h}_2^0 \\ \nu_\beta \end{pmatrix} , \tag{54}$$

where the eigenvalues $\tilde{\chi}^0_{1,\ldots 4}, \nu_{i=1,\ldots 3}$ are given upon the diagonalization of the matrix[10]

$$\mathcal{M}_{\rm N} = \begin{pmatrix} M_1 & 0 & M_Z s_w\frac{v_2}{\sqrt{v_\gamma^2}} & -M_Z s_w\frac{v_\beta}{\sqrt{v_\gamma^2}} \\ 0 & M_2 & -M_Z c_w\frac{v_2}{\sqrt{v_\gamma^2}} & M_Z c_w\frac{v_\beta}{\sqrt{v_\gamma^2}} \\ M_Z s_w\frac{v_2}{\sqrt{v_\gamma^2}} & -M_Z c_w\frac{v_2}{\sqrt{v_\gamma^2}} & 0 & -\mu_\beta \\ -M_Z s_w\frac{v_\alpha}{\sqrt{v_\gamma^2}} & M_Z c_w\frac{v_\alpha}{\sqrt{v_\gamma^2}} & -\mu_\alpha & 0_{\alpha\beta} \end{pmatrix} , \tag{55}$$

with $M_Z^2 = \frac{1}{2}(g^2+g_2^2)(v_2^2+v_\alpha^2)$, $M_W^2 = \frac{1}{2}g_2^2(v_2^2+v_\alpha^2)$ and $s_W = \sin\theta_W$ the weak mixing angle. In the basis (??) the above matrix is written

$$\mathcal{L} = -\frac{1}{2}(-i\widetilde{\mathcal{B}}, -i\widetilde{\mathcal{W}}^{(3)}, \tilde{h}_2^0, \tilde{h}_1^0, \nu_i)\mathcal{M}_{\rm N}\begin{pmatrix} -i\widetilde{\mathcal{B}} \\ -i\widetilde{\mathcal{W}}^{(3)} \\ \tilde{h}_2^0 \\ \tilde{h}_1^0 \\ \nu_j \end{pmatrix} \tag{56}$$

with

$$\mathcal{M}_{\rm N} = \begin{pmatrix} M_1 & 0 & M_Z s_w \sin\beta & -M_Z s_w \cos\beta & 0_j \\ 0 & M_2 & -M_Z c_w \sin\beta & M_Z c_w \cos\beta & 0_j \\ M_Z s_w \sin\beta & -M_Z c_w \sin\beta & 0 & -\mu & -\kappa_j \\ -M_Z s_w \cos\beta & M_Z c_w \cos\beta & -\mu & 0 & 0_j \\ 0_i & 0_i & -\kappa_i & 0_i & 0 \end{pmatrix} . \tag{57}$$

The matrices (55,57) have five non-zero eigenvalues, i.e., 4 neutralinos + 1 neutrino.

G. Leptons-Charginos

Leptons mix with charginos. The Lagrangian contains the (5×5 for three generations of leptons) lepton-chargino mass matrix as[11]

$$\mathcal{L} = -(-i\widetilde{\mathcal{W}}^-, e^-_{L_\alpha})\mathcal{M}_{\rm C} \begin{pmatrix} -i\widetilde{\mathcal{W}}^+ \\ \tilde{h}_2^+ \\ e^+_{R_k} \end{pmatrix} + {\rm H.c} \tag{58}$$

where the eigenvalues $\tilde{\chi}^{\pm}_{1,\ldots,2}, l = (e,\mu,\tau)$ are given upon the diagonalization of the matrix

$$\mathcal{M}_{\rm C} = \begin{pmatrix} M_2 & g_2 v_2 & 0_k \\ g_2 v_\alpha & \mu_\alpha & \lambda_{\beta\alpha k} v_\beta \end{pmatrix} , \tag{59}$$

whereas in basis (**??**)

$$\mathcal{L} = -(-i\widetilde{\mathcal{W}}^-, \tilde{h}_1^-, e^-_{L_i})\mathcal{M}_{\rm C} \begin{pmatrix} -i\widetilde{\mathcal{W}}^+ \\ \tilde{h}_2^+ \\ e^+_{R_j} \end{pmatrix} + {\rm H.c} \tag{60}$$

$$\mathcal{M}_{\rm C} = \begin{pmatrix} M_2 & \sqrt{2} M_W \sin\beta & 0 & 0 & 0 \\ \sqrt{2} M_W cos\beta & \mu & 0 & 0 & 0 \\ 0 & \kappa_1 & & & \\ 0 & \kappa_2 & & (\mathbf{Y}_E)_{ij} v_1 & \\ 0 & \kappa_3 & & & \end{pmatrix} \tag{61}$$

VI. BOUNDARY CONDITIONS AT M_X

VII. RESULTS

A. No-Scale case

B. General Case

VIII. CONCLUSIONS

The ultimate paper!

APPENDIX A: NOTATION AND ANOMALOUS DIMENSIONS

The chiral superfields of the R_p-MSSM and the $\not{R}_p$-MSSM have the following $G_{SM} = SU(3)_c \times SU(2)_L \times U(1)_Y$ quantum numbers

$$\begin{aligned} L: &\quad (1,2,-\tfrac{1}{2}), \quad \bar{E}: \quad (1,1,1), \qquad Q: (3,2,\frac{1}{6}), \quad \bar{U}: (3,1,\frac{2}{3}), \\ \bar{D}: &\quad (3,1,-\tfrac{1}{3}), \quad H_1: (1,2,-\frac{1}{2}), \quad H_2: (1,2,\frac{1}{2}). \end{aligned} \tag{A1}$$

The $\not{R}_p$-MSSM superpotential is then given by

$$W = \epsilon_{ab} \left[(\mathbf{Y}_E)_{ij} L_i^a H_1^b \bar{E}_j + (\mathbf{Y}_D)_{ij} Q_i^{ax} H_1^b \bar{D}_{jx} + (\mathbf{Y}_U)_{ij} Q_i^{ax} H_2^b \bar{U}_{jx} \right]$$

$$+\epsilon_{ab}\left[\frac{1}{2}(\mathbf{\Lambda}_{E^k})_{ij}L_i^aL_j^b\bar{E}_k+(\mathbf{\Lambda}_{D^k})_{ij}L_i^aQ_j^{xb}\bar{D}_{kx}\right]+\frac{1}{2}\epsilon_{xyz}(\mathbf{\Lambda}_{U^i})_{jk}\bar{U}_i^x\bar{D}_j^y\bar{D}_k^z$$
$$-\epsilon_{ab}\left[\mu H_1^aH_2^b+\kappa^iL_i^aH_2^b\right]. \qquad (A2)$$

We denote an $SU(3)$ colour index of the fundamental representation by $x,y,z=1,2,3$. The $SU(2)_L$ fundamental representation indices are denoted by $a,b,c=1,2$ and the generation indices by $i,j,k=1,2,3$. We have introduced the twelve 3×3 matrices

$$\mathbf{Y}_E,\quad \mathbf{Y}_D,\quad \mathbf{Y}_U,\quad \mathbf{\Lambda}_{E^k},\quad \mathbf{\Lambda}_{D^k},\quad \mathbf{\Lambda}_{U^i}, \qquad (A3)$$

for all the Yukawa couplings. This implies the following conventions in the Martin and Vaughn [6] notation

$$\begin{aligned}
Y^{L_i^aQ_j^{bx}\bar{D}_{ky}} &= Y^{L_i^a\bar{D}_{ky}Q_j^{bx}}=Y^{\bar{D}_{ky}L_i^aQ_j^{bx}}=Y^{Q_j^{bx}L_i^a\bar{D}_{ky}}\\
&= Y^{Q_j^{bx}\bar{D}_{ky}L_i^a}=Y^{\bar{D}_{ky}Q_j^{bx}L_i^a}=(\mathbf{\Lambda}_{D^k})_{ij}\epsilon_{ab}\delta_x^y, && (A4)\\
Y^{L_i^aL_j^b\bar{E}_k} &= Y^{L_i^a\bar{E}_kL_j^b}=Y^{\bar{E}_kL_i^aL_j^b}=(\mathbf{\Lambda}_{E^k})_{ij}\epsilon_{ab}=-(\mathbf{\Lambda}_{E^k})_{ji}\epsilon_{ab}, && (A5)\\
Y^{\bar{U}_{ix}\bar{D}_{jy}\bar{D}_{kz}} &= Y^{\bar{D}_{jy}\bar{U}_{ix}\bar{D}_{kz}}=Y^{\bar{D}_{jy}\bar{D}_{kz}\bar{U}_{ix}}=\epsilon_{xyz}\left(\mathbf{\Lambda}_{U^i}\right)_{jk}=-\epsilon_{xyz}\left(\mathbf{\Lambda}_{U^i}\right)_{kj}, && (A6)
\end{aligned}$$

The soft SUSY breaking Lagrangian is given by,

$$\begin{aligned}
-\mathcal{L} &= m_{H_1}^2H_1^\dagger H_1+m_{H_2}^2H_2^\dagger H_2+\widetilde{L}^\dagger(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)\widetilde{L}+\widetilde{L_i}^\dagger(\mathbf{m}^2_{\tilde{L}_iH_1})H_1+H_1^\dagger(\mathbf{m}^2_{H_1\tilde{L}_i})\widetilde{L}\\
&+ \widetilde{Q}^\dagger(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)\widetilde{Q}+\widetilde{\bar{E}}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)\widetilde{\bar{E}}^\dagger+\widetilde{\bar{D}}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)\widetilde{\bar{D}}^\dagger+\widetilde{\bar{U}}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)\widetilde{\bar{U}}^\dagger\\
&+ \Big[(\mathbf{h}_E)_{ij}\widetilde{L_i}H_1\widetilde{\bar{E}_j}+(\mathbf{h}_D)_{ij}\widetilde{Q_i}H_1\widetilde{\bar{D}_j}+(\mathbf{h}_U)_{ij}\widetilde{Q_i}H_2\widetilde{\bar{U}_j}\\
&+ (\mathbf{h}_{E^k})_{ij}\widetilde{L_i}\widetilde{L_j}\widetilde{\bar{E}_k}+(\mathbf{h}_{D^k})_{ij}\widetilde{L_i}\widetilde{Q_j}\widetilde{\bar{D}_k}+(\mathbf{h}_{U^i})_{jk}\widetilde{\bar{U}_i}\widetilde{\bar{D}_j}\widetilde{\bar{D}_k}+\ \mathrm{H.c}\Big]\\
&- \left[\widetilde{B}H_1H_2+\widetilde{D_i}\widetilde{L_i}H_2\ \ +\mathrm{H.c}\right], && (A7)
\end{aligned}$$

where we have introduce the soft SUSY breaking trilinear couplings

$$\mathbf{h}_E,\quad \mathbf{h}_D,\quad \mathbf{h}_U,\quad \mathbf{h}_{E^k},\quad \mathbf{h}_{D^k},\quad \mathbf{h}_{U^i}, \qquad (A8)$$

defined analogously as the Yukawa couplings in (A4-A6).

In general the one-loop renormalisation group equations for the Yukawa couplings are given by [6]

$$\frac{d}{dt}Y^{ijk}=Y^{ijp}\left[\frac{1}{16\pi^2}\gamma_p^k\right]+(k\leftrightarrow i)+(k\leftrightarrow j), \qquad (A9)$$

and the anomalous dimensions are

$$\gamma_i^j = \frac{1}{2}Y_{ipq}Y^{jpq}-2\delta_i^j\sum_a g_a^2C_a(i), \qquad (A10)$$

$$(A11)$$

We have denoted by $C_a(f)$ the quadratic Casimir of the representation f of the gauge group G_a. For details see the Appendix A of [3].

The one-loop anomalous dimensions are given by [3][12]

$$\begin{aligned}
\gamma_{L_j}^{L_i} &= \left(\mathbf{Y}_E\mathbf{Y}_E^\dagger\right)_{ij}+(\mathbf{\Lambda}_{E^q}\mathbf{\Lambda}_{E^q}^\dagger)_{ij}+3(\mathbf{\Lambda}_{D^q}\mathbf{\Lambda}_{D^q}^\dagger)_{ij}-\delta_j^i(\frac{3}{10}g_1^2+\frac{3}{2}g_2^2), && (A12)\\
\gamma_{E_j}^{E_i} &= 2\left(\mathbf{Y}_E^\dagger\mathbf{Y}_E\right)_{ji}+\mathrm{Tr}(\mathbf{\Lambda}_{E^i}\mathbf{\Lambda}_{E^j}^\dagger)-\delta_j^i(\frac{6}{5}g_1^2), && (A13)\\
\gamma_{Q_j}^{Q_i} &= \left(\mathbf{Y}_D\mathbf{Y}_D^\dagger\right)_{ij}+\left(\mathbf{Y}_U\mathbf{Y}_U^\dagger\right)_{ij}+(\mathbf{\Lambda}_{D^q}^\dagger\mathbf{\Lambda}_{D^q})_{ji}-\delta_j^i(\frac{1}{30}g_1^2+\frac{3}{2}g_2^2+\frac{8}{3}g_3^2), && (A14)\\
\gamma_{D_j}^{D_i} &= 2\left(\mathbf{Y}_D^\dagger\mathbf{Y}_D\right)_{ji}+2\mathrm{Tr}(\mathbf{\Lambda}_{D^j}^\dagger\mathbf{\Lambda}_{D^i})+2(\mathbf{\Lambda}_{U^q}\mathbf{\Lambda}_{U^q}^\dagger)_{ij}-\delta_j^i(\frac{2}{15}g_1^2+\frac{8}{3}g_3^2), && (A15)
\end{aligned}$$

$$\gamma_{U_j}^{U_i} = 2\left(\mathbf{Y}_U^\dagger \mathbf{Y}_U\right)_{ji} + \mathrm{Tr}(\mathbf{\Lambda}_{U^i}\mathbf{\Lambda}_{U^j}^\dagger) - \delta_j^i(\frac{8}{15}g_1^2 + \frac{8}{3}g_3^2), \tag{A16}$$

$$\gamma_{H_1}^{H_1} = \mathrm{Tr}\left(3\mathbf{Y}_D\mathbf{Y}_D^\dagger + \mathbf{Y}_E\mathbf{Y}_E^\dagger\right) - (\frac{3}{10}g_1^2 + \frac{3}{2}g_2^2), \tag{A17}$$

$$\gamma_{H_2}^{H_2} = 3\mathrm{Tr}\left(\mathbf{Y}_U\mathbf{Y}_U^\dagger\right) - (\frac{3}{10}g_1^2 + \frac{3}{2}g_2^2), \tag{A18}$$

$$\gamma_{L_i}^{H_1} = \gamma_{H_1}^{(1)L_i\,*} = -3(\mathbf{\Lambda}_{D^q}^*\mathbf{Y}_D)_{iq} - (\mathbf{\Lambda}_{E^q}^*\mathbf{Y}_E)_{iq}. \tag{A19}$$

Note that here, $H_{1,2}, L, Q$ represent the fields $H_{1,2}^a$, L^a, Q^a where a is the index of the fundamental representation of $SU(2)$ (i.e. no factors of ϵ_{ab} are factored in). The β-functions for the Yukawa couplings [3] as well for the billinear superpotential couplings are just combinations of the above anomalous dimensions (A12-A19). The two loop anomalous dimensions in the $R\!\!\!/_p$-MSSM can be found in [3]. We present the one-loop beta functions for the superpotential couplings and masses for complemetarity reasons.

The RGEs for the Yukawa couplings (including full family dependence) are given by

$$16\pi^2\frac{d}{dt}(\mathbf{Y}_E)_{ij} = (\mathbf{Y}_E)_{ik}\gamma_{E_k}^{E_j} + (\mathbf{Y}_E)_{ij}\gamma_{H_1}^{H_1} - (\mathbf{\Lambda}_{E^j})_{ki}\gamma_{L_k}^{H_1} + (\mathbf{Y}_E)_{kj}\gamma_{L_k}^{L_i}, \tag{A20}$$

$$16\pi^2\frac{d}{dt}(\mathbf{Y}_D)_{ij} = (\mathbf{Y}_D)_{ik}\gamma_{D_k}^{D_j} + (\mathbf{Y}_D)_{ij}\gamma_{H_1}^{H_1} - (\mathbf{\Lambda}_{D^j})_{ki}\gamma_{L_k}^{H_1} + (\mathbf{Y}_D)_{kj}\gamma_{Q_k}^{Q_i}, \tag{A21}$$

$$16\pi^2\frac{d}{dt}(\mathbf{Y}_U)_{ij} = (\mathbf{Y}_U)_{ik}\gamma_{U_k}^{U_j} + (\mathbf{Y}_U)_{ij}\gamma_{H_2}^{H_2} + (\mathbf{Y}_U)_{kj}\gamma_{Q_k}^{Q_i}, \tag{A22}$$

$$16\pi^2\frac{d}{dt}(\mathbf{\Lambda}_{E^k})_{ij} = (\mathbf{\Lambda}_{E^l})_{ij}\gamma_{E_l}^{E_k} + (\mathbf{\Lambda}_{E^k})_{il}\gamma_{L_l}^{L_j} + (\mathbf{Y}_E)_{ik}\gamma_{H_1}^{L_j} - (\mathbf{\Lambda}_{E^k})_{jl}\gamma_{L_l}^{L_i} - (\mathbf{Y}_E)_{jk}\gamma_{H_1}^{L_i}, \tag{A23}$$

$$16\pi^2\frac{d}{dt}(\mathbf{\Lambda}_{D^k})_{ij} = (\mathbf{\Lambda}_{D^l})_{ij}\gamma_{D_l}^{D_k} + (\mathbf{\Lambda}_{D^k})_{il}\gamma_{Q_l}^{Q_j} + (\mathbf{\Lambda}_{D^k})_{lj}\gamma_{L_l}^{L_i} - (\mathbf{Y}_D)_{jk}\gamma_{H_1}^{L_i}, \tag{A24}$$

$$16\pi^2\frac{d}{dt}(\mathbf{\Lambda}_{U^i})_{jk} = (\mathbf{\Lambda}_{U^i})_{jl}\gamma_{D_l}^{D_k} + (\mathbf{\Lambda}_{U^i})_{lk}\gamma_{D_l}^{D_j} + (\mathbf{\Lambda}_{U^l})_{jk}\gamma_{U_l}^{U_i}. \tag{A25}$$

The RGE's for the bilinear terms are

$$16\pi^2\frac{d}{dt}\mu = \mu\left\{\gamma_{H_1}^{H_1} + \gamma_{H_2}^{H_2}\right\} + \kappa^i\gamma_{L_i}^{H_1}, \tag{A26}$$

$$16\pi^2\frac{d}{dt}\kappa^i = \kappa^i\gamma_{H_2}^{H_2} + \kappa^p\gamma_{L_p}^{L_i} + \mu\gamma_{H_1}^{L_i}. \tag{A27}$$

APPENDIX B: A METHOD TO DERIVE THE SOFT SUSY BREAKING RGE'S

A straightforword way to derive the RGEs for the soft SUSY breaking couplings and masses is by a direct use of the explict formulae at 1-loop given in [6]. This is a somehow tedious job. A very elegant method which is also very helpful for numerical calculations is that described in [7]. All the soft SUSY RGE's can be derived by the knoweldge of just the anomalous dimensions (A12-A19) when usually an action of an operator on them is taking place[13]. The method not only works at one loop but it has been proven to all orders in perturbation theory [7]. Thus the soft β-functions for the bilinear $\mathbf{b}^{ij}$, trilinear $\mathbf{h}^{ijk}$ and scalar masses $(\mathbf{m}^2)^i_j$ soft SUSY breaking terms can be read from

$$16\pi^2\frac{d\mathbf{b}^{ij}}{dt} = \gamma_l^i\mathbf{b}^{jl} + \gamma_l^j\mathbf{b}^{il} - 2(\gamma_1)_l^i\mu^{jl} - 2(\gamma_1)_l^j\mu^{il}\ , \tag{B1}$$

$$16\pi^2\frac{d\mathbf{h}^{ijk}}{dt} = \gamma_l^i\mathbf{h}^{jkl} + \gamma_l^j\mathbf{h}^{ikl} + \gamma_l^k\mathbf{h}^{jil} - 2(\gamma_1)_l^i\mathbf{Y}^{jkl} - 2(\gamma_1)_l^j\mathbf{Y}^{ikl} - 2(\gamma_1)_l^k\mathbf{Y}^{jil}\ , \tag{B2}$$

$$16\pi^2\frac{d(\mathbf{m}^2)_j^i}{dt} = \left(2\mathcal{O}\mathcal{O}^* + 2MM^*g_a^2\frac{\partial}{\partial g_a^2} + \widetilde{\mathbf{Y}}_{lmn}\frac{\partial}{\partial\mathbf{Y}_{lmn}} + \widetilde{\mathbf{Y}}^{lmn}\frac{\partial}{\partial\mathbf{Y}^{lmn}} + X_a\frac{\partial}{\partial g_a}\right)\gamma_j^i\ , \tag{B3}$$

where

$$(\gamma_1)_j^i = \mathcal{O}\gamma_j^i\ , \tag{B4}$$

$$\mathcal{O} = \left(M_a g_a^2\frac{\partial}{\partial g_a^2} - \mathbf{h}^{lmn}\frac{\partial}{\partial\mathbf{Y}^{lmn}}\right)\ , \tag{B5}$$

$$\widetilde{\mathbf{Y}}^{ijk} \;=\; \mathbf{Y}^{ljk}(\mathbf{m}^2)^i_l + \mathbf{Y}^{lik}(\mathbf{m}^2)^j_l + \mathbf{Y}^{lji}(\mathbf{m}^2)^k_l \;, \tag{B6}$$

and repeated indices are summed over and $t = \ln(Q)$, Q is the renormalization scale. At one loop the last term in (B3) is irrelevant, see [7] for details. The Renormalization Group Equations (B1-B3) valid as long as we do not eliminate the U(1) Fayet-Iliopoulos D-term. In the case we do so an extra term proportional to the U(1) gauge coupling appears (see the $\mathcal{S}$-term in the RGEs of the Appendix C.).

Now from (B1) the RGEs for the bilinear soft SUSY breaking masses in the $\not{R}_p$-MSSM are

$$16\pi^2\frac{d\widetilde{B}}{dt} \;=\; \widetilde{B}\left[\gamma^{H_1}_{H_1} + \gamma^{H_2}_{H_2}\right] + \widetilde{D}_i\gamma^{H_1}_{L_i} - 2\mu\left[(\gamma_1)^{H_1}_{H_1} + (\gamma_1)^{H_2}_{H_2}\right] - 2\kappa_i(\gamma_1)^{H_1}_{L_i} \;, \tag{B7}$$

$$16\pi^2\frac{d\widetilde{D}_i}{dt} \;=\; \left[\gamma^{L_i}_{L_l}\widetilde{D}^l + \gamma^{H_2}_{H_2}\widetilde{D}^i\right] + \widetilde{B}\gamma^{L_i}_{H_1} - 2\left[(\gamma_1)^{L_i}_{L_l}\kappa^l + (\gamma_1)^{H_2}_{H_2}\kappa^i\right] - 2\mu(\gamma_1)^{L_i}_{H_1} \;. \tag{B8}$$

The RGEs for the trilinear soft SUSY breaking masses in the $\not{R}_p$-MSSM can be read from (B2)

$$\begin{aligned}16\pi^2\frac{d(\mathbf{h}_E)_{ik}}{dt} &= \gamma^{L_i}_{L_l}(\mathbf{h}_E)_{lk} + \gamma^{H_1}_{H_1}(\mathbf{h}_E)_{ik} + \gamma^{H_1}_{L_l}(\mathbf{h}_{E^k})_{il} + \gamma^{E_k}_{E_l}(\mathbf{h}_E)_{il}\\ &- 2(\gamma_1)^{L_i}_{L_l}(\mathbf{Y}_E)_{lk} - 2(\gamma_1)^{H_1}_{H_1}(\mathbf{Y}_E)_{ik} - 2(\gamma_1)^{H_1}_{L_l}(\mathbf{\Lambda}_{E^k})_{il} - 2(\gamma_1)^{E_k}_{E_l}(\mathbf{Y}_E)_{il} \;,\end{aligned} \tag{B9}$$

$$\begin{aligned}16\pi^2\frac{d(\mathbf{h}_D)_{ik}}{dt} &= \gamma^{Q_i}_{Q_l}(\mathbf{h}_D)_{lk} + \gamma^{H_1}_{H_1}(\mathbf{h}_D)_{ik} - \gamma^{H_1}_{L_l}(\mathbf{h}_{D^k})_{li} + \gamma^{D_k}_{D_l}(\mathbf{h}_D)_{il}\\ &- 2(\gamma_1)^{Q_i}_{Q_l}(\mathbf{Y}_D)_{lk} - 2(\gamma_1)^{H_1}_{H_1}(\mathbf{Y}_D)_{ik} + 2(\gamma_1)^{H_1}_{L_l}(\mathbf{\Lambda}_{D^k})_{li} - 2(\gamma_1)^{D_k}_{D_l}(\mathbf{Y}_D)_{il} \;,\end{aligned} \tag{B10}$$

$$\begin{aligned}16\pi^2\frac{d(\mathbf{h}_U)_{ik}}{dt} &= \gamma^{Q_i}_{Q_l}(\mathbf{h}_U)_{lk} + \gamma^{H_2}_{H_2}(\mathbf{h}_U)_{ik} + \gamma^{U_k}_{U_l}(\mathbf{h}_U)_{il}\\ &- 2(\gamma_1)^{Q_i}_{Q_l}(\mathbf{Y}_U)_{lk} - 2(\gamma_1)^{H_2}_{H_2}(\mathbf{Y}_U)_{ik} - 2(\gamma_1)^{U_k}_{U_l}(\mathbf{Y}_U)_{il} \;,\end{aligned} \tag{B11}$$

$$\begin{aligned}16\pi^2\frac{d(\mathbf{h}_{E^k})_{ij}}{dt} &= \gamma^{L_i}_{L_l}(\mathbf{h}_{E^k})_{lj} - \gamma^{L_i}_{H_1}(\mathbf{h}_E)_{jk} + \gamma^{L_j}_{L_l}(\mathbf{h}_{E^k})_{il} + \gamma^{L_j}_{H_1}(\mathbf{h}_E)_{ik} + \gamma^{E_k}_{E_l}(\mathbf{h}_{E^l})_{ij}\\ &- 2(\gamma_1)^{L_i}_{L_l}(\mathbf{\Lambda}_{E^k})_{lj} + 2(\gamma_1)^{L_i}_{H_1}(\mathbf{Y}_E)_{jk} - 2(\gamma_1)^{L_j}_{L_l}(\mathbf{\Lambda}_{E^k})_{il} - 2(\gamma_1)^{L_j}_{H_1}(\mathbf{Y}_E)_{ik} - 2(\gamma_1)^{E_k}_{E_l}(\mathbf{\Lambda}_{E^l})_{ij} \;,\end{aligned} \tag{B12}$$

$$\begin{aligned}16\pi^2\frac{d(\mathbf{h}_{D^k})_{ij}}{dt} &= \gamma^{L_i}_{L_l}(\mathbf{h}_{D^k})_{lj} - \gamma^{L_i}_{H_1}(\mathbf{h}_D)_{jk} + \gamma^{Q_j}_{Q_l}(\mathbf{h}_{D^k})_{il} + \gamma^{D_k}_{D_l}(\mathbf{h}_{D^l})_{ij}\\ &- 2(\gamma_1)^{L_i}_{L_l}(\mathbf{\Lambda}_{D^k})_{lj} + 2(\gamma_1)^{L_i}_{H_1}(\mathbf{Y}_D)_{jk} - 2(\gamma_1)^{Q_j}_{Q_l}(\mathbf{\Lambda}_{D^k})_{il} - 2(\gamma_1)^{D_k}_{D_l}(\mathbf{\Lambda}_{D^l})_{ij} \;,\end{aligned} \tag{B13}$$

$$\begin{aligned}16\pi^2\frac{d(\mathbf{h}_{U^i})_{jk}}{dt} &= \gamma^{U_i}_{U_l}(\mathbf{h}_{U^l})_{jk} + \gamma^{D_j}_{D_l}(\mathbf{h}_{U^i})_{lk} + \gamma^{D_k}_{D_l}(\mathbf{h}_{U^i})_{jl}\\ &- 2(\gamma_1)^{U_i}_{U_l}(\mathbf{\Lambda}_{U^l})_{jk} - 2(\gamma_1)^{D_j}_{D_l}(\mathbf{\Lambda}_{U^i})_{lk} - 2(\gamma_1)^{D_k}_{D_l}(\mathbf{\Lambda}_{U^i})_{jl} \;.\end{aligned} \tag{B14}$$

The RGEs for the soft SUSY breaking masses in the $\not{R}_p$-MSSM can be written from (B3)

$$\begin{aligned}16\pi^2\frac{d(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)^{E_i}_{E_j}}{dt} \equiv 16\pi^2\frac{d(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{ji}}{dt} &= 4(\mathbf{h}^\dagger_E\mathbf{h}_E)_{ji} + 2\;\mathrm{Tr}(\mathbf{h}_{E^i}\mathbf{h}^\dagger_{E^j}) - \delta_{ij}\left(\frac{24}{5}g_1^2|M_1|^2\right)\\ &+ 2(\mathbf{Y}^\dagger_E\widetilde{\mathbf{Y}_E})_{ji} + \;\mathrm{Tr}(\widetilde{\mathbf{\Lambda}_{E^i}}\mathbf{\Lambda}^\dagger_{E^j}) + 2(\widetilde{\mathbf{Y}^\dagger_E}\mathbf{Y}_E)_{ji} + \;\mathrm{Tr}(\mathbf{\Lambda}_{E^i}\widetilde{\mathbf{\Lambda}^\dagger_{E^j}}) \;,\end{aligned} \tag{B15}$$

$$\begin{aligned}16\pi^2\frac{d(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)^{L_i}_{L_j}}{dt} \equiv 16\pi^2\frac{d(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{ij}}{dt} &= 2(\mathbf{h}_E\mathbf{h}^\dagger_E + \mathbf{h}_{E^q}\mathbf{h}^\dagger_{E^q} + 3\mathbf{h}_{D^q}\mathbf{h}^\dagger_{D^q})_{ij} - \delta_{ij}\left(\frac{6}{5}g_1^2|M_1|^2 + 6g_2^2|M_2|^2\right)\\ &+ (\widetilde{\mathbf{Y}_E\mathbf{Y}^\dagger_E})_{ij} + (\widetilde{\mathbf{\Lambda}_{E^q}}\mathbf{\Lambda}^\dagger_{E^q})_{ij} + 3(\widetilde{\mathbf{\Lambda}_{D^q}}\mathbf{\Lambda}^\dagger_{D^q})_{ij}\\ &+ (\mathbf{Y}_E\widetilde{\mathbf{Y}^\dagger_E})_{ij} + (\mathbf{\Lambda}_{E^q}\widetilde{\mathbf{\Lambda}^\dagger_{E^q}})_{ij} + 3(\mathbf{\Lambda}_{D^q}\widetilde{\mathbf{\Lambda}^\dagger_{D^q}})_{ij}\end{aligned} \tag{B16}$$

$$16\pi^2\frac{d(\mathbf{m^2})^{H_1}_{L_i}}{dt} \equiv 16\pi^2\frac{d(\mathbf{m}^2_{H_1\tilde{L}_i})}{dt} \;=\; -6(\mathbf{h}^*_{D^q}\mathbf{h}_D)_{iq} - 2(\mathbf{h}^*_{E^q}\mathbf{h}_E)_{iq}$$

$$- \; 3(\mathbf{\Lambda}^*_{D^q}\widetilde{\mathbf{Y}_D})_{iq} - (\mathbf{\Lambda}^*_{E^q}\widetilde{\mathbf{Y}_E})_{iq} - 3(\widetilde{\mathbf{\Lambda}^*_{D^q}}\mathbf{Y}_D)_{iq} - (\widetilde{\mathbf{\Lambda}^*_{E^q}}\mathbf{Y}_E)_{iq} \tag{B17}$$

$$\begin{aligned}16\pi^2\frac{d({\mathbf{m}_{\tilde{\mathbf{Q}}}}^2)^{Q_i}_{Q_j}}{dt} \equiv 16\pi^2\frac{d({\mathbf{m}_{\tilde{\mathbf{Q}}}}^2)_{ij}}{dt} &= 2(\mathbf{h}_D\mathbf{h}_D^\dagger + \mathbf{h}_U\mathbf{h}_U^\dagger)_{ij} + 2(\mathbf{h}^\dagger_{D^q}\mathbf{h}_{D^q})_{ji} - \delta_{ij}\left(\frac{2}{15}g_1^2|M_1|^2 + 6g_2^2|M_2|^2 + \frac{32}{3}g_3^2|M_3|^2\right)\\ &+ (\widetilde{\mathbf{Y}_D}\mathbf{Y}_D^\dagger)_{ij} + (\widetilde{\mathbf{Y}_U}\mathbf{Y}_U^\dagger)_{ij} + (\mathbf{\Lambda}^\dagger_{D^q}\widetilde{\mathbf{\Lambda}_{D^q}})_{ji}\\ &+ (\mathbf{Y}_D\widetilde{\mathbf{Y}_D^\dagger})_{ij} + (\mathbf{Y}_U\widetilde{\mathbf{Y}_U^\dagger})_{ij} + (\widetilde{\mathbf{\Lambda}^\dagger_{D^q}}\mathbf{\Lambda}_{D^q})_{ji}\ ,\end{aligned} \tag{B18}$$

$$\begin{aligned}16\pi^2\frac{d({\mathbf{m}_{\tilde{\mathbf{D}}}}^2)^{D_i}_{D_j}}{dt} \equiv 16\pi^2\frac{d({\mathbf{m}_{\tilde{\mathbf{D}}}}^2)_{ji}}{dt} &= 4(\mathbf{h}_D^\dagger\mathbf{h}_D)_{ji} + 4\ \mathrm{Tr}(\mathbf{h}^\dagger_{D^j}\mathbf{h}_{D^i}) + 4(\mathbf{h}_{U^q}\mathbf{h}^\dagger_{U^q})_{ij}\\ &- \delta_{ij}\left(\frac{8}{15}g_1^2|M_1|^2 + \frac{32}{3}g_3^2|M_3|^2\right)\\ &+ 2(\mathbf{Y}_D^\dagger\widetilde{\mathbf{Y}_D})_{ji} + 2\ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{D^j}\widetilde{\mathbf{\Lambda}_{D^i}}) + 2(\widetilde{\mathbf{\Lambda}_{U^q}}\mathbf{\Lambda}^\dagger_{U^q})_{ij}\\ &+ 2(\widetilde{\mathbf{Y}_D^\dagger}\mathbf{Y}_D)_{ji} + 2\ \mathrm{Tr}(\widetilde{\mathbf{\Lambda}^\dagger_{D^j}}\mathbf{\Lambda}_{D^i}) + 2(\mathbf{\Lambda}_{U^q}\widetilde{\mathbf{\Lambda}^\dagger_{U^q}})_{ij}\ ,\end{aligned} \tag{B19}$$

$$\begin{aligned}16\pi^2\frac{d({\mathbf{m}_{\tilde{\mathbf{U}}}}^2)^{U_i}_{U_j}}{dt} \equiv 16\pi^2\frac{d({\mathbf{m}_{\tilde{\mathbf{U}}}}^2)_{ji}}{dt} &= 4(\mathbf{h}_U^\dagger\mathbf{h}_U)_{ji} + 2\ \mathrm{Tr}(\mathbf{h}_{U^i}\mathbf{h}^\dagger_{U^j}) - \delta_{ij}\left(\frac{32}{15}g_1^2|M_1|^2 + \frac{32}{3}g_3^2|M_3|^2\right)\\ &+ 2(\mathbf{Y}_U^\dagger\widetilde{\mathbf{Y}_U})_{ji} + \ \mathrm{Tr}(\widetilde{\mathbf{\Lambda}_{U^i}}\mathbf{\Lambda}^\dagger_{U^j}) + 2(\widetilde{\mathbf{Y}_U^\dagger}\mathbf{Y}_U)_{ji} + \ \mathrm{Tr}(\mathbf{\Lambda}_{U^i}\widetilde{\mathbf{\Lambda}^\dagger_{U^j}})\ ,\end{aligned} \tag{B20}$$

$$\begin{aligned}16\pi^2\frac{dm^2_{H_1}}{dt} &= \ \mathrm{Tr}(6\mathbf{h}_D\mathbf{h}_D^\dagger + 2\mathbf{h}_E\mathbf{h}_E^\dagger) - \left(\frac{6}{5}g_1^2|M_1|^2 + 6g_2^2|M_2|^2\right)\\ &+ 3\ \mathrm{Tr}(\widetilde{\mathbf{Y}_D}\mathbf{Y}_D^\dagger) + \ \mathrm{Tr}(\widetilde{\mathbf{Y}_E}\mathbf{Y}_E^\dagger) + 3\ \mathrm{Tr}(\mathbf{Y}_D\widetilde{\mathbf{Y}_D^\dagger}) + \ \mathrm{Tr}(\mathbf{Y}_E\widetilde{\mathbf{Y}_E^\dagger})\ ,\end{aligned} \tag{B21}$$

$$\begin{aligned}16\pi^2\frac{dm^2_{H_2}}{dt} &= 6\ \mathrm{Tr}(\mathbf{h}_U\mathbf{h}_U^\dagger) - \left(\frac{6}{5}g_1^2|M_1|^2 + 6g_2^2|M_2|^2\right)\\ &+ 3\ \mathrm{Tr}(\widetilde{\mathbf{Y}_U}\mathbf{Y}_U^\dagger) + 3\ \mathrm{Tr}(\mathbf{Y}_U\widetilde{\mathbf{Y}_U^\dagger})\ ,\end{aligned} \tag{B22}$$

where from (B4-B5)

$$(\gamma_1)^{L_i}_{L_j} = -\left(\mathbf{h}_E\mathbf{Y}_E^\dagger\right)_{ij} - (\mathbf{h}_{E^q}\mathbf{\Lambda}^\dagger_{E^q})_{ij} - 3(\mathbf{h}_{D^q}\mathbf{\Lambda}^\dagger_{D^q})_{ij} - \delta^i_j(\frac{3}{10}M_1g_1^2 + \frac{3}{2}M_2g_2^2), \tag{B23}$$

$$(\gamma_1)^{E_i}_{E_j} = -2\left(\mathbf{Y}_E^\dagger\mathbf{h}_E\right)_{ji} - \mathrm{Tr}(\mathbf{h}_{E^i}\mathbf{\Lambda}^\dagger_{E^j}) - \delta^i_j(\frac{6}{5}M_1g_1^2), \tag{B24}$$

$$(\gamma_1)^{Q_i}_{Q_j} = -\left(\mathbf{h}_D\mathbf{Y}_D^\dagger\right)_{ij} - \left(\mathbf{h}_U\mathbf{Y}_U^\dagger\right)_{ij} - (\mathbf{\Lambda}^\dagger_{D^q}\mathbf{h}_{D^q})_{ji} - \delta^i_j(\frac{1}{30}M_1g_1^2 + \frac{3}{2}M_2g_2^2 + \frac{8}{3}M_3g_3^2), \tag{B25}$$

$$(\gamma_1)^{D_i}_{D_j} = -2\left(\mathbf{Y}_D^\dagger\mathbf{h}_D\right)_{ji} - 2\mathrm{Tr}(\mathbf{\Lambda}^\dagger_{D^j}\mathbf{h}_{D^i}) - 2(\mathbf{h}_{U^q}\mathbf{\Lambda}^\dagger_{U^q})_{ij} - \delta^i_j(\frac{2}{15}M_1g_1^2 + \frac{8}{3}M_3g_3^2), \tag{B26}$$

$$(\gamma_1)^{U_i}_{U_j} = -2\left(\mathbf{Y}_U^\dagger\mathbf{h}_U\right)_{ji} - \mathrm{Tr}(\mathbf{h}_{U^i}\mathbf{\Lambda}^\dagger_{U^j}) - \delta^i_j(\frac{8}{15}M_1g_1^2 + \frac{8}{3}M_3g_3^2), \tag{B27}$$

$$(\gamma_1)^{H_1}_{H_1} = -\mathrm{Tr}\left(3\mathbf{h}_D\mathbf{Y}_D^\dagger + \mathbf{h}_E\mathbf{Y}_E^\dagger\right) - (\frac{3}{10}M_1g_1^2 + \frac{3}{2}M_2g_2^2), \tag{B28}$$

$$(\gamma_1)^{H_2}_{H_2} = -3\mathrm{Tr}\left(\mathbf{h}_U\mathbf{Y}_U^\dagger\right) - (\frac{3}{10}M_1g_1^2 + \frac{3}{2}M_2g_2^2), \tag{B29}$$

$$(\gamma_1)^{H_1}_{L_i} = {(\gamma_1)^{L_i}_{H_1}}^* = 3(\mathbf{\Lambda}^*_{D^q}\mathbf{h}_D)_{iq} + (\mathbf{\Lambda}^*_{E^q}\mathbf{h}_E)_{iq}\ , \tag{B30}$$

and from (B6)

$$(\widetilde{\mathbf{Y}_E})_{ik} = (\mathbf{Y}_E)_{lk}({\mathbf{m}_{\tilde{\mathbf{L}}}}^2)_{il} + (\mathbf{Y}_E)_{ik}m^2_{H_1} + (\mathbf{\Lambda}_{E^k})_{il}(\mathbf{m}^2_{H_1\tilde{L}_l}) + (\mathbf{Y}_E)_{il}({\mathbf{m}_{\tilde{\mathbf{E}}}}^2)_{lk}\ , \tag{B31}$$

$$(\widetilde{\mathbf{Y}_D})_{ik} = (\mathbf{Y}_D)_{lk}({\mathbf{m}_{\tilde{\mathbf{Q}}}}^2)_{il} - (\mathbf{\Lambda}_{D^k})_{li}(\mathbf{m}^2_{H_1\tilde{L}_l}) + (\mathbf{Y}_D)_{ik}m^2_{H_1} + (\mathbf{Y}_D)_{il}({\mathbf{m}_{\tilde{\mathbf{D}}}}^2)_{lk}\ , \tag{B32}$$

$$(\widetilde{\mathbf{Y}_U})_{ik} = (\mathbf{Y}_U)_{lk}({\mathbf{m}_{\tilde{\mathbf{Q}}}}^2)_{il} + (\mathbf{Y}_U)_{ik}m^2_{H_2} + (\mathbf{Y}_U)_{il}({\mathbf{m}_{\tilde{\mathbf{U}}}}^2)_{lk}\ , \tag{B33}$$

$$(\widetilde{\mathbf{\Lambda}_{E^k}})_{ij} = (\mathbf{\Lambda}_{E^k})_{lj}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{il} - (\mathbf{Y}_E)_{jk}(\mathbf{m}^2_{\tilde{L}_iH_1}) + (\mathbf{\Lambda}_{E^k})_{il}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{jl} + (\mathbf{Y}_E)_{ik}(\mathbf{m}^2_{\tilde{L}_jH_1}) + (\mathbf{\Lambda}_{E^l})_{ij}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{lk}\,, \quad \text{(B34)}$$

$$(\widetilde{\mathbf{\Lambda}_{D^k}})_{ij} = (\mathbf{\Lambda}_{D^k})_{lj}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{il} - (\mathbf{Y}_D)_{jk}(\mathbf{m}^2_{\tilde{L}_iH_1}) + (\mathbf{\Lambda}_{D^k})_{il}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{jl} + (\mathbf{\Lambda}_{D^l})_{ij}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{lk}\,, \quad \text{(B35)}$$

$$(\widetilde{\mathbf{\Lambda}_{U^i}})_{jk} = (\mathbf{\Lambda}_{U^l})_{jk}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{li} + (\mathbf{\Lambda}_{U^i})_{lk}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{lj} + (\mathbf{\Lambda}_{U^i})_{jl}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{lk}\,. \quad \text{(B36)}$$

Numericaly we would like to follow the following procedure :
a) Define the anomalous dimensions (A12-A19)
b) Define $(\gamma_1)^i_j$ from (B23-B30)
c) Define (B31-B36).
d) Plug (a,b,c) into (B7-B22).
This is much simbler from putting the explicit formulae of the Appendix C below.

APPENDIX C: EXPLICIT RGE'S FOR THE SOFT SUPERSYMMETRIC BREAKING TERMS

We arrange here the explicit formulae of the RGEs. As a cross check we have calculated them by first using the explicit formulae of the Ref. [6] and second by using the method described in Appendix B. We found agreement using both methods.

Thus the RGE for the bilinear μ and κ_i terms of the superpotential parameters is given by

$$\begin{aligned} 16\pi^2\frac{d\mu}{dt} &= \mu\Big[3\ \mathrm{Tr}(\mathbf{Y}_U\mathbf{Y}_U^\dagger) + \ \mathrm{Tr}(3\mathbf{Y}_D\mathbf{Y}_D^\dagger + \mathbf{Y}_E\mathbf{Y}_E^\dagger) - \frac{3}{5}g_1^2 - 3g_2^2\Big] \\ &- \kappa_p\Big[\mathbf{\Lambda}^*_{E^n}\mathbf{Y}_E + 3\mathbf{\Lambda}^*_{D^n}\mathbf{Y}_D\Big]_{pn}\,, \end{aligned} \quad \text{(C1)}$$

$$\begin{aligned} 16\pi^2\frac{d\kappa_i}{dt} &= \kappa_i\Big[3\ \mathrm{Tr}(\mathbf{Y}_U\mathbf{Y}_U^\dagger) - \frac{3}{5}g_1^2 - 3g_2^2\Big] \\ &+ \kappa_p\Big[\mathbf{Y}_E\mathbf{Y}_E^\dagger + \mathbf{\Lambda}_{E^n}\mathbf{\Lambda}^\dagger_{E^n} + 3\mathbf{\Lambda}_{D^n}\mathbf{\Lambda}^\dagger_{D^n}\Big]_{ip} - \mu\Big[\mathbf{\Lambda}_{E^n}\mathbf{Y}^*_E + 3\mathbf{\Lambda}_{D^n}\mathbf{Y}^*_D\Big]_{in}\,. \end{aligned} \quad \text{(C2)}$$

Similar, the RGE's for the soft SUSY breaking bilinear terms can be read from,

$$\begin{aligned} 16\pi^2\frac{d\widetilde{B}}{dt} &= \widetilde{B}\Big[3\ \mathrm{Tr}(\mathbf{Y}_U^\dagger\mathbf{Y}_U) + 3\ \mathrm{Tr}(\mathbf{Y}_D^\dagger\mathbf{Y}_D) + \ \mathrm{Tr}(\mathbf{Y}_E^\dagger\mathbf{Y}_E) - \frac{3}{5}g_1^2 - 3g_2^2\Big] \\ &+ \mu\Big[6\ \mathrm{Tr}(\mathbf{Y}_U^\dagger\mathbf{h}_U) + 6\ \mathrm{Tr}(\mathbf{Y}_D^\dagger\mathbf{h}_D) + 2\ \mathrm{Tr}(\mathbf{Y}_E^\dagger\mathbf{h}_E) + \frac{6}{5}g_1^2M_1 + 6g_2^2M_2\Big] \\ &- \widetilde{D}_l\Big[\mathbf{\Lambda}^*_{E^n}\mathbf{Y}_E + 3\mathbf{\Lambda}^*_{D^n}\mathbf{Y}_D\Big]_{ln} - \kappa_l\Big[2\mathbf{\Lambda}^*_{E^n}\mathbf{h}_E + 6\mathbf{\Lambda}^*_{D^n}\mathbf{h}_D\Big]_{ln}\,, \end{aligned} \quad \text{(C3)}$$

$$\begin{aligned} 16\pi^2\frac{d\widetilde{D}_i}{dt} &= \widetilde{D}_i\Big[3\ \mathrm{Tr}(\mathbf{Y}_U\mathbf{Y}_U^\dagger) - \frac{3}{5}g_1^2 - 3g_2^2\Big] + \kappa_i\Big[6\ \mathrm{Tr}(\mathbf{h}_U\mathbf{Y}_U^\dagger) + \frac{6}{5}g_1^2M_1 + 6g_2^2M_2\Big] \\ &+ \widetilde{D}_l\Big[\mathbf{Y}_E\mathbf{Y}_E^\dagger + \mathbf{\Lambda}_{E^n}\mathbf{\Lambda}^\dagger_{E^n} + 3\mathbf{\Lambda}_{D^n}\mathbf{\Lambda}_{D^n}\Big]_{il} + 2\kappa_l\Big[\mathbf{h}_E\mathbf{Y}_E^\dagger + \mathbf{h}_{E^n}\mathbf{\Lambda}^\dagger_{E^n} + 3\mathbf{h}_{D^n}\mathbf{\Lambda}^\dagger_{D^n}\Big]_{il} \\ &- 2\mu\Big[\mathbf{h}_{E^n}\mathbf{Y}^*_E + 3\mathbf{h}_{D^n}\mathbf{Y}^*_D\Big]_{in} - \widetilde{B}\Big[\mathbf{\Lambda}_{E^n}\mathbf{Y}^*_E + 3\mathbf{\Lambda}_{D^n}\mathbf{Y}^*_D\Big]_{in}\,. \end{aligned} \quad \text{(C4)}$$

The RGE's for the soft SUSY trilinear couplings are given by

$$\begin{aligned} 16\pi^2\frac{d(\mathbf{h}_E)_{ij}}{dt} &= (\mathbf{h}_E)_{il}\Big[2(\mathbf{Y}_E^\dagger\mathbf{Y}_E)_{lj} + \ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{E^l}\mathbf{\Lambda}_{E^j})\Big] \\ &+ (\mathbf{h}_E)_{lj}\Big[\mathbf{Y}_E\mathbf{Y}_E^\dagger + \mathbf{\Lambda}_{E^n}\mathbf{\Lambda}^\dagger_{E^n} + 3\mathbf{\Lambda}_{D^n}\mathbf{\Lambda}^\dagger_{D^n}\Big]_{il} \\ &+ (\mathbf{h}_E)_{ij}\Big[\ \mathrm{Tr}(\mathbf{Y}_E^\dagger\mathbf{Y}_E) + 3\ \mathrm{Tr}(\mathbf{Y}_D^\dagger\mathbf{Y}_D) - \frac{9}{5}g_1^2 - 3g_2^2\Big] \end{aligned}$$

$$
\begin{aligned}
&+ \ (\mathbf{h}_{E^j})_{il}\Big[-\mathbf{\Lambda}^*_{E^n}\mathbf{Y}_E - 3\mathbf{\Lambda}^*_{D^n}\mathbf{Y}_D\Big]_{ln} \\
&+ \ (\mathbf{Y}_E)_{il}\Big[4(\mathbf{Y}^\dagger_E\mathbf{h}_E)_{lj} + 2\ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{E^l}\mathbf{h}_{E^j})\Big] \\
&+ \ (\mathbf{Y}_E)_{lj}\Big[2\mathbf{h}_E\mathbf{Y}^\dagger_E + 2\mathbf{h}_{E^n}\mathbf{\Lambda}^\dagger_{E^n} + 6\mathbf{h}_{D^n}\mathbf{\Lambda}^\dagger_{D^n}\Big]_{il} \\
&+ \ (\mathbf{Y}_E)_{ij}\Big[2\ \mathrm{Tr}(\mathbf{Y}^\dagger_E\mathbf{h}_E) + 6\ \mathrm{Tr}(\mathbf{Y}^\dagger_D\mathbf{h}_D) + \frac{18}{5}g_1^2M_1 + 6g_2^2M_2\Big] \\
&+ \ (\mathbf{\Lambda}_{E^j})_{il}\Big[-2(\mathbf{\Lambda}^*_{E^n}\mathbf{h}_E) - 6(\mathbf{\Lambda}^*_{D^n}\mathbf{h}_D)\Big]_{ln}\ ,
\end{aligned}
\tag{C5}
$$

$$
\begin{aligned}
16\pi^2\frac{d(\mathbf{h}_D)_{ij}}{dt} &= (\mathbf{h}_D)_{il}\Big[2(\mathbf{Y}^\dagger_D\mathbf{Y}_D)_{lj} + 2\ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{D^l}\mathbf{\Lambda}_{D^j}) + 2(\mathbf{\Lambda}_{U^n}\mathbf{\Lambda}^\dagger_{U^n})_{jl}\Big] \\
&+ \ (\mathbf{h}_D)_{lj}\Big[\mathbf{Y}_D\mathbf{Y}^\dagger_D + \mathbf{Y}_U\mathbf{Y}^\dagger_U\Big]_{il} + (\mathbf{h}_D)_{lj}\Big[\mathbf{\Lambda}^\dagger_{D^n}\mathbf{\Lambda}_{D^n}\Big]_{li} \\
&+ \ (\mathbf{h}_D)_{ij}\Big[\ \mathrm{Tr}(\mathbf{Y}^\dagger_E\mathbf{Y}_E) + 3\ \mathrm{Tr}(\mathbf{Y}^\dagger_D\mathbf{Y}_D) - \frac{7}{15}g_1^2 - 3g_2^2 - \frac{16}{3}g_3^2\Big] \\
&+ \ (\mathbf{h}_{D^j})_{li}\Big[(\mathbf{\Lambda}^*_{E^n}\mathbf{Y}_E) + 3(\mathbf{\Lambda}^*_{D^n}\mathbf{Y}_D)\Big]_{ln} \\
&+ \ (\mathbf{Y}_D)_{il}\Big[4(\mathbf{Y}^\dagger_D\mathbf{h}_D)_{lj} + 4\ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{D^l}\mathbf{h}_{D^j}) + 4(\mathbf{h}_{U^n}\mathbf{\Lambda}^\dagger_{U^n})_{jl}\Big] \\
&+ \ (\mathbf{Y}_D)_{lj}\Big[2\mathbf{h}_D\mathbf{Y}^\dagger_D + 2\mathbf{h}_U\mathbf{Y}^\dagger_U\Big]_{il} + (\mathbf{Y}_D)_{lj}\Big[2\mathbf{\Lambda}^\dagger_{D^n}\mathbf{h}_{D^n}\Big]_{li} \\
&+ \ (\mathbf{Y}_D)_{ij}\Big[2\ \mathrm{Tr}(\mathbf{Y}^\dagger_E\mathbf{h}_E) + 6\ \mathrm{Tr}(\mathbf{Y}^\dagger_D\mathbf{h}_D) + \frac{14}{15}g_1^2M_1 + 6g_2^2M_2 + \frac{32}{3}g_3^2M_3\Big] \\
&+ \ (\mathbf{\Lambda}_{D^j})_{li}\Big[2(\mathbf{\Lambda}^*_{E^n}\mathbf{h}_E) + 6(\mathbf{\Lambda}^*_{D^n}\mathbf{h}_D)\Big]_{ln}\ ,
\end{aligned}
\tag{C6}
$$

$$
\begin{aligned}
16\pi^2\frac{d(\mathbf{h}_U)_{ij}}{dt} &= (\mathbf{h}_U)_{il}\Big[2(\mathbf{Y}^\dagger_U\mathbf{Y}_U)_{lj} + \ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{U^l}\mathbf{\Lambda}_{U^j}\Big] \\
&+ \ (\mathbf{h}_U)_{lj}\Big[(\mathbf{Y}_U\mathbf{Y}^\dagger_U)_{il} + (\mathbf{Y}_D\mathbf{Y}^\dagger_D)_{il} + (\mathbf{\Lambda}^\dagger_{D^n}\mathbf{\Lambda}_{D^n})_{li}\Big] \\
&+ \ (\mathbf{h}_U)_{ij}\Big[3\ \mathrm{Tr}(\mathbf{Y}^\dagger_U\mathbf{Y}_U) - \frac{13}{15}g_1^2 - 3g_2^2 - \frac{16}{3}g_3^2\Big] \\
&+ \ (\mathbf{Y}_U)_{il}\Big[4(\mathbf{Y}^\dagger_U\mathbf{h}_U)_{lj} + 2\ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{U^l}\mathbf{h}_{U^j})\Big] \\
&+ \ (\mathbf{Y}_U)_{lj}\Big[2(\mathbf{h}_U\mathbf{Y}^\dagger_U)_{il} + 2(\mathbf{h}_D\mathbf{Y}^\dagger_D)_{il} + 2(\mathbf{\Lambda}^\dagger_{D^n}\mathbf{h}_{D^n})_{li}\Big] \\
&+ \ (\mathbf{Y}_U)_{ij}\Big[6\ \mathrm{Tr}(\mathbf{Y}^\dagger_U\mathbf{h}_U) + \frac{26}{15}g_1^2M_1 + 6g_2^2M_2 + \frac{32}{3}g_3^2M_3\Big]\ ,
\end{aligned}
\tag{C7}
$$

$$
\begin{aligned}
16\pi^2\frac{d(\mathbf{h}_{E^k})_{ij}}{dt} &= (\mathbf{h}_{E^l})_{ij}\Big[2(\mathbf{Y}^\dagger_E\mathbf{Y}_E)_{lk} + \ \mathrm{Tr}(\mathbf{\Lambda}^\dagger_{E^l}\mathbf{\Lambda}_{E^k})\Big] \\
&+ \ (\mathbf{h}_E)_{jk}\Big[\mathbf{\Lambda}_{E^n}\mathbf{Y}^*_E + 3\mathbf{\Lambda}_{D^n}\mathbf{Y}^*_D\Big]_{in} \\
&+ \ (\mathbf{h}_{E^k})_{jl}\Big[-\mathbf{Y}_E\mathbf{Y}^\dagger_E - \mathbf{\Lambda}_{E^n}\mathbf{\Lambda}^\dagger_{E^n} - 3\mathbf{\Lambda}_{D^n}\mathbf{\Lambda}^\dagger_{D^n}\Big]_{il}
\end{aligned}
$$

$$
\begin{aligned}
&+ \;(\mathbf{h}_{E^k})_{il}\left[\mathbf{Y}_E\mathbf{Y}_E^\dagger + \mathbf{\Lambda}_{E^n}\mathbf{\Lambda}_{E^n}^\dagger + 3\mathbf{\Lambda}_{D^n}\mathbf{\Lambda}_{D^n}^\dagger\right]_{jl} \\
&+ \;(\mathbf{h}_E)_{ik}\left[-\mathbf{\Lambda}_{E^n}\mathbf{Y}_E^* - 3\mathbf{\Lambda}_{D^n}\mathbf{Y}_D^*\right]_{jn} \\
&+ \;(\mathbf{\Lambda}_{E^l})_{ij}\left[4(\mathbf{Y}_E^\dagger\mathbf{h}_E)_{lk} + 2\;\mathrm{Tr}(\mathbf{\Lambda}_{E^l}^\dagger\mathbf{h}_{E^k})\right] \\
&+ \;(\mathbf{Y}_E)_{jk}\left[2\mathbf{h}_{E^n}\mathbf{Y}_E^* + 6\mathbf{h}_{D^n}\mathbf{Y}_D^*\right]_{in} \\
&+ \;(\mathbf{\Lambda}_{E^k})_{jl}\left[-2\mathbf{h}_E\mathbf{Y}_E^\dagger - 2\mathbf{h}_{E^n}\mathbf{\Lambda}_{E^n}^\dagger - 6\mathbf{h}_{D^n}\mathbf{\Lambda}_{D^n}^\dagger\right]_{il} \\
&+ \;(\mathbf{\Lambda}_{E^k})_{il}\left[2\mathbf{h}_E\mathbf{Y}_E^\dagger + 2\mathbf{h}_{E^n}\mathbf{\Lambda}_{E^n}^\dagger + 6\mathbf{h}_{D^n}\mathbf{\Lambda}_{D^n}^\dagger\right]_{jl} \\
&+ \;(\mathbf{Y}_E)_{ik}\left[-2\mathbf{h}_{E^n}\mathbf{Y}_E^* - 6\mathbf{h}_{D^n}\mathbf{Y}_D^*\right]_{jn} \\
&- \;(\mathbf{h}_{E^k})_{ij}\left[\frac{9}{5}g_1^2 + 3g_2^2\right] + (\mathbf{\Lambda}_{E^k})_{ij}\left[\frac{18}{5}g_1^2M_1 + 6g_2^2M_2\right] ,
\end{aligned} \tag{C8}
$$

$$
\begin{aligned}
16\pi^2\frac{d(\mathbf{h}_{D^k})_{ij}}{dt} &= \;(\mathbf{h}_{D^l})_{ij}\left[2(\mathbf{Y}_D^\dagger\mathbf{Y}_D)_{lk} + 2\;\mathrm{Tr}(\mathbf{\Lambda}_{D^l}^\dagger\mathbf{\Lambda}_{D^k}) + 2(\mathbf{\Lambda}_{U^n}^\dagger\mathbf{\Lambda}_{U^n})_{lk}\right] \\
&+ \;(\mathbf{h}_{D^k})_{lj}\left[\mathbf{Y}_E\mathbf{Y}_E^\dagger + \mathbf{\Lambda}_{E^n}\mathbf{\Lambda}_{E^n}^\dagger + 3\mathbf{\Lambda}_{D^n}\mathbf{\Lambda}_{D^n}^\dagger\right]_{il} \\
&+ \;(\mathbf{h}_D)_{jk}\left[\mathbf{\Lambda}_{E^n}\mathbf{Y}_E^* + 3\mathbf{\Lambda}_{D^n}\mathbf{Y}_D^*\right]_{in} \\
&+ \;(\mathbf{h}_{D^k})_{il}\left[(\mathbf{Y}_D\mathbf{Y}_D^\dagger)_{jl} + (\mathbf{Y}_U\mathbf{Y}_U^\dagger)_{jl} + (\mathbf{\Lambda}_{D^n}^\dagger\mathbf{\Lambda}_{D^n})_{lj}\right] \\
&+ \;(\mathbf{\Lambda}_{D^l})_{ij}\left[4(\mathbf{Y}_D^\dagger\mathbf{h}_D)_{lk} + 4\;\mathrm{Tr}(\mathbf{\Lambda}_{D^l}^\dagger\mathbf{h}_{D^k}) + 4(\mathbf{\Lambda}_{U^n}^\dagger\mathbf{h}_{U^n})_{lk}\right] \\
&+ \;(\mathbf{\Lambda}_{D^k})_{lj}\left[2\mathbf{h}_E\mathbf{Y}_E^\dagger + 2\mathbf{h}_{E^n}\mathbf{\Lambda}_{E^n}^\dagger + 6\mathbf{h}_{D^n}\mathbf{\Lambda}_{D^n}^\dagger\right]_{il} \\
&+ \;(\mathbf{Y}_D)_{jk}\left[2\mathbf{h}_{E^n}\mathbf{Y}_E^* + 6\mathbf{h}_{D^n}\mathbf{Y}_D^*\right]_{in} \\
&+ \;(\mathbf{\Lambda}_{D^k})_{il}\left[2(\mathbf{h}_D\mathbf{Y}_D^\dagger)_{jl} + 2(\mathbf{h}_U\mathbf{Y}_U^\dagger)_{jl} + 2(\mathbf{\Lambda}_{D^n}^\dagger\mathbf{h}_{D^n})_{lj}\right] \\
&- \;(\mathbf{h}_{D^k})_{ij}\left[\frac{7}{15}g_1^2 + 3g_2^2 + \frac{16}{3}g_3^2\right] \\
&+ \;(\mathbf{\Lambda}_{D^k})_{ij}\left[\frac{14}{15}g_1^2M_1 + 6g_2^2M_2 + \frac{32}{3}g_3^2M_3\right] ,
\end{aligned} \tag{C9}
$$

$$
\begin{aligned}
16\pi^2\frac{d(\mathbf{h}_{U^i})_{jk}}{dt} &= \;(\mathbf{h}_{U^i})_{jl}\left[2(\mathbf{Y}_D^\dagger\mathbf{Y}_D)_{lk} + 2\;\mathrm{Tr}(\mathbf{\Lambda}_{D^l}^\dagger\mathbf{\Lambda}_{D^k}) + 2(\mathbf{\Lambda}_{U^m}^\dagger\mathbf{\Lambda}_{U^m})_{lk}\right] \\
&+ \;(\mathbf{h}_{U^l})_{jk}\left[2(\mathbf{Y}_U^\dagger\mathbf{Y}_U)_{li} + \;\mathrm{Tr}(\mathbf{\Lambda}_{U^l}^\dagger\mathbf{\Lambda}_{U^i})\right] \\
&+ \;(\mathbf{h}_{U^i})_{kl}\left[-2(\mathbf{Y}_D^\dagger\mathbf{Y}_D)_{lj} - 2\;\mathrm{Tr}(\mathbf{\Lambda}_{D^l}^\dagger\mathbf{\Lambda}_{D^j}) - 2(\mathbf{\Lambda}_{U^n}^\dagger\mathbf{\Lambda}_{U^n})_{lj}\right] \\
&+ \;(\mathbf{\Lambda}_{U^i})_{jl}\left[4(\mathbf{Y}_D^\dagger\mathbf{h}_D)_{lk} + 4\;\mathrm{Tr}(\mathbf{\Lambda}_{D^l}^\dagger\mathbf{h}_{D^k}) + 4(\mathbf{\Lambda}_{U^m}^\dagger\mathbf{h}_{U^m})_{lk}\right] \\
&+ \;(\mathbf{\Lambda}_{U^l})_{jk}\left[4(\mathbf{Y}_U^\dagger\mathbf{h}_U)_{li} + 2\;\mathrm{Tr}(\mathbf{\Lambda}_{U^l}^\dagger\mathbf{h}_{U^i})\right]
\end{aligned}
$$

$$
\begin{aligned}
&+ \ (\mathbf{\Lambda}_{U^i})_{kl}\left[-4(\mathbf{Y}_D^\dagger \mathbf{h}_D)_{lj} - 4 \ \mathrm{Tr}(\mathbf{\Lambda}_{D^l}^\dagger \mathbf{h}_{D^j}) - 4(\mathbf{\Lambda}_{U^n}^\dagger \mathbf{h}_{U^n})_{lj}\right] \\
&- \ (\mathbf{h}_{U^i})_{jk}\left[\frac{4}{5}g_1^2 + 8g_3^2\right] + (\mathbf{\Lambda}_{U^i})_{jk}\left[\frac{8}{5}g_1^2 M_1 + 16 g_3^2 M_3\right]. \qquad \text{(C10)}
\end{aligned}
$$

The RGE's for the gaugino masses are not affected by the R-parity violating couplings up to 1-loop. The RGE's for the SUSY soft breaking masses are given by,

$$
\begin{aligned}
16\pi^2 \frac{d(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{ij}}{dt} &= 2(\mathbf{Y}_E^\dagger \mathbf{Y}_E)_{in}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{nj} + \ \mathrm{Tr}(\mathbf{\Lambda}_{E^i}^\dagger \mathbf{\Lambda}_{E^n})(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{nj} \\
&+ \ 2(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{in}(\mathbf{Y}_E^\dagger \mathbf{Y}_E)_{nj} + (\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{in} \ \mathrm{Tr}(\mathbf{\Lambda}_{E^n}^\dagger \mathbf{\Lambda}_{E^j}) \\
&+ \ 4(\mathbf{Y}_E^\dagger \mathbf{Y}_E)_{ij} m_{H_1}^2 + 4(\mathbf{Y}_E^\dagger \mathbf{\Lambda}_{E^j})_{ir}(\mathbf{m}_{\tilde{L}_r H_1}^2) \\
&+ \ 4 \ \mathrm{Tr}[(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)\mathbf{\Lambda}_{E^j}^\dagger \mathbf{\Lambda}_{E^i}] + 4(\mathbf{m}_{\tilde{L}_q H_1}^2)(\mathbf{\Lambda}_{E^i}^\dagger \mathbf{Y}_E)_{qj} \\
&+ \ 4[\mathbf{Y}_E^\dagger(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)\mathbf{Y}_E]_{ij} + 4(\mathbf{h}_E^\dagger \mathbf{h}_E)_{ij} + 2 \ \mathrm{Tr}(\mathbf{h}_{E^i}^\dagger \mathbf{h}_{E^j}) \\
&- \ \left(\frac{24}{5}|M_1|^2 g_1^2 - \frac{6}{5}g_1^2 \mathcal{S}\right)\delta_{ij} \ , \qquad \text{(C11)}
\end{aligned}
$$

$$
\begin{aligned}
16\pi^2 \frac{d(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{ij}}{dt} &= (\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{in}(\mathbf{Y}_E \mathbf{Y}_E^\dagger)_{nj} - (\mathbf{m}_{\tilde{L}_i H_1}^2)(\mathbf{\Lambda}_{E^q}^* \mathbf{Y}_E)_{jq} \\
&+ \ (\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{in}(\mathbf{\Lambda}_{E^q}\mathbf{\Lambda}_{E^q}^\dagger)_{nj} + (\mathbf{Y}_E \mathbf{Y}_E^\dagger)_{in}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{nj} \\
&- \ (\mathbf{\Lambda}_{E^q}\mathbf{Y}_E^*)_{iq}(\mathbf{m}_{H_1 \tilde{L}_j}^2) + (\mathbf{\Lambda}_{E^q}\mathbf{\Lambda}_{E^q}^\dagger)_{in}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{nj} \\
&+ \ 2(\mathbf{Y}_E \mathbf{Y}_E^\dagger)_{ij} m_{H_1}^2 + 2(\mathbf{\Lambda}_{E^p})_{ir}(\mathbf{Y}_E^\dagger)_{pj}(\mathbf{m}_{H_1 \tilde{L}_r}^2) \\
&- \ 3(\mathbf{\Lambda}_{D^q}\mathbf{Y}_D^*)_{iq}(\mathbf{m}_{H_1 \tilde{L}_j}^2) + 3((\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)\mathbf{\Lambda}_{D^q}\mathbf{\Lambda}_{D^q}^\dagger)_{ij} \\
&- \ 3(\mathbf{\Lambda}_{D^q}^* \mathbf{Y}_D)_{jq}(\mathbf{m}_{\tilde{L}_i H_1}^2) + 3(\mathbf{\Lambda}_{D^q}\mathbf{\Lambda}_{D^q}^\dagger(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2))_{ij} \\
&+ \ 2(\mathbf{Y}_E)_{ip}(\mathbf{\Lambda}_{E^p}^\dagger)_{qj}(\mathbf{m}_{\tilde{L}_q H_1}^2) + 2(\mathbf{\Lambda}_{E^p})_{ir}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{qr}(\mathbf{\Lambda}_{E^p}^\dagger)_{qj} \\
&+ \ 2(\mathbf{Y}_E)_{ir}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{rq}(\mathbf{Y}_E^\dagger)_{qj} + 2(\mathbf{\Lambda}_{E^r})_{ip}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{rq}(\mathbf{\Lambda}_{E^q}^\dagger)_{pj} \\
&+ \ 6(\mathbf{\Lambda}_{D^r})_{ip}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{rq}(\mathbf{\Lambda}_{D^q}^\dagger)_{pj} + 6(\mathbf{\Lambda}_{D^p})_{ir}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{qr}(\mathbf{\Lambda}_{D^q}^\dagger)_{pj} \\
&+ \ 2(\mathbf{h}_E \mathbf{h}_E^\dagger)_{ij} + 2(\mathbf{h}_{E^q}\mathbf{h}_{E^q}^\dagger)_{ji} + 6(\mathbf{h}_{D^q}\mathbf{h}_{D^q}^\dagger)_{ij} \\
&- \ \left(\frac{6}{5}g_1^2|M_1|^2 + 6g_2^2|M_2|^2 + \frac{3}{5}g_1^2\mathcal{S}\right)\delta_{ij} \ , \qquad \text{(C12)}
\end{aligned}
$$

$$
\begin{aligned}
16\pi^2 \frac{d(\mathbf{m}_{\tilde{L}_i H_1}^2)}{dt} &= (\mathbf{\Lambda}_{E^q}^\dagger \mathbf{Y}_E)_{iq} m_{H_1}^2 + (\mathbf{\Lambda}_{E^q}^\dagger \mathbf{\Lambda}_{E^q})_{in}(\mathbf{m}_{H_1 \tilde{L}_n}^2) \\
&- \ (\mathbf{m}_{H_1 \tilde{L}_n}^2)(\mathbf{Y}_E \mathbf{Y}_E^\dagger)_{ni} - 3(\mathbf{\Lambda}_{D^q}^* \mathbf{Y}_D)_{iq} m_{H_1}^2 \\
&+ \ 3(\mathbf{\Lambda}_{D^q}\mathbf{\Lambda}_{D^q}^\dagger)_{ni}(\mathbf{m}_{H_1 \tilde{L}_n}^2) + [\ \mathrm{Tr}(\mathbf{Y}_E \mathbf{Y}_E^\dagger) + 3 \ \mathrm{Tr}(\mathbf{Y}_D^\dagger \mathbf{Y}_D)](\mathbf{m}_{H_1 \tilde{L}_i}^2) \\
&+ \ (\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{ni}(\mathbf{\Lambda}_{E^q}^\dagger \mathbf{Y}_E - 3\mathbf{\Lambda}_{D^q}^* \mathbf{Y}_D)_{nq} + 2(\mathbf{\Lambda}_{E^p}^\dagger)_{iq}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{qr}(\mathbf{Y}_E)_{rp} \\
&+ \ 2(\mathbf{\Lambda}_{E^q}^\dagger \mathbf{Y}_E)_{ir}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{rq} - 6(\mathbf{\Lambda}_{D^q}^* \mathbf{Y}_D)_{ir}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{rq} \\
&- \ 6(\mathbf{\Lambda}_{D^p}^*)_{iq}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{qr}(\mathbf{Y}_D)_{rp} - [2\mathbf{h}_{E^q}^* \mathbf{h}_E + 6\mathbf{h}_{D^q}^* \mathbf{h}_D]_{iq} \ , \qquad \text{(C13)}
\end{aligned}
$$

$$
\begin{aligned}
16\pi^2 \frac{d(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{ij}}{dt} &= [\mathbf{Y}_D \mathbf{Y}_D^\dagger + \mathbf{Y}_U \mathbf{Y}_U^\dagger]_{nj}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{in} + (\mathbf{\Lambda}_{D^q}^\dagger \mathbf{\Lambda}_{D^q})_{jn}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{in} \\
&+ \ [\mathbf{Y}_D \mathbf{Y}_D^\dagger + \mathbf{Y}_U \mathbf{Y}_U^\dagger]_{in}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{nj} + (\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{nj}(\mathbf{\Lambda}_{D^q}^\dagger \mathbf{\Lambda}_{D^q})_{ni} \\
&+ \ 2(\mathbf{Y}_D)_{ir}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{rq}(\mathbf{Y}_D^\dagger)_{qj} + 2(\mathbf{Y}_D \mathbf{Y}_D^\dagger)_{ij} m_{H_1}^2 \\
&+ \ 2(\mathbf{\Lambda}_{D^p}^\dagger)_{jq}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{qr}(\mathbf{\Lambda}_{D^p})_{ri} + 2(\mathbf{Y}_U)_{ir}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{rq}(\mathbf{Y}_U^\dagger)_{qj}
\end{aligned}
$$

$$
\begin{aligned}
&+\ 2(\mathbf{Y}_U\mathbf{Y}_U^\dagger)_{ij}m_{H_2}^2 + 2(\mathbf{\Lambda}_{D^q}^\dagger\mathbf{\Lambda}_{D^r})_{ji}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{rq} \\
&-\ 2(\mathbf{m}^2_{H_1\tilde{L}_l})(\mathbf{\Lambda}_{D^k})_{li}(\mathbf{Y}_D^\dagger)_{kj} - 2(\mathbf{Y}_D)_{iq}(\mathbf{\Lambda}_{D^q}^\dagger)_{jk}(\mathbf{m}^2_{\tilde{L}_k H_1}) \\
&+\ 2[\mathbf{h}_D\mathbf{h}_D^\dagger + \mathbf{h}_U\mathbf{h}_U^\dagger]_{ij} + 2(\mathbf{h}_{D^q}^\dagger\mathbf{h}_{D^q})_{ji} \\
&-\ \left(\frac{2}{15}g_1^2|M_1|^2 + 6g_2^2|M_2|^2 + \frac{32}{3}g_3^2|M_3|^2 - \frac{1}{5}g_1^2\mathcal{S}\right)\delta_{ij}\ ,
\end{aligned}
\tag{C14}
$$

$$
\begin{aligned}
16\pi^2\frac{d(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{ij}}{dt} &= 2(\mathbf{Y}_D^\dagger\mathbf{Y}_D)_{in}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{nj} + 2\ \mathrm{Tr}(\mathbf{\Lambda}_{D^i}^\dagger\mathbf{\Lambda}_{D^n})(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{nj} \\
&+\ 2(\mathbf{\Lambda}_{U^q}\mathbf{\Lambda}_{U^q}^\dagger)_{ni}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{nj} + 2(\mathbf{Y}_D^\dagger\mathbf{Y}_D)_{nj}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{in} \\
&+\ 2\ \mathrm{Tr}(\mathbf{\Lambda}_{D^j}\mathbf{\Lambda}_{D^n}^\dagger)(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{in} + 2(\mathbf{\Lambda}_{U^p}\mathbf{\Lambda}_{U^p}^\dagger)_{jn}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{in} \\
&+\ 4(\mathbf{Y}_D^\dagger)_{iq}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{qr}(\mathbf{Y}_D)_{rj} + 4(\mathbf{Y}_D^\dagger)_{ip}(\mathbf{Y}_D)_{pj}m_{H_1}^2 \\
&+\ 4(\mathbf{\Lambda}_{D^j}\mathbf{\Lambda}_{D^i}^\dagger)_{rq}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{qr} + 4(\mathbf{\Lambda}_{D^i}^\dagger\mathbf{\Lambda}_{D^j})_{qr}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{qr} \\
&+\ 4(\mathbf{\Lambda}_{U^p}^\dagger)_{qi}(\mathbf{\Lambda}_{U^p})_{jr}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{rq} + 4(\mathbf{\Lambda}_{U^l}\mathbf{\Lambda}_{U^q}^\dagger)_{ij}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{lq} \\
&+\ 4(\mathbf{h}_D^\dagger\mathbf{h}_D)_{ij} + 4\ \mathrm{Tr}(\mathbf{h}_{D^i}^\dagger\mathbf{h}_{D^j}) + 4(\mathbf{h}_{U^p}\mathbf{h}_{U^p}^\dagger)_{ji} \\
&-\ 4(\mathbf{\Lambda}_{D^i}\mathbf{Y}_D^*)_{lj}(\mathbf{m}^2_{H_1\tilde{L}_l}) - 4(\mathbf{\Lambda}_{D^j}^*\mathbf{Y}_D)_{li}(\mathbf{m}^2_{\tilde{L}_l H_1}) \\
&-\ \left(\frac{8}{15}g_1^2|M_1|^2 + \frac{32}{3}g_3^2|M_3|^2 - \frac{2}{5}g_1^2\mathcal{S}\right)\delta_{ij}\ ,
\end{aligned}
\tag{C15}
$$

$$
\begin{aligned}
16\pi^2\frac{d(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{ij}}{dt} &= 2(\mathbf{Y}_U^\dagger\mathbf{Y}_U)_{in}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{nj} + \mathrm{Tr}(\mathbf{\Lambda}_{U^i}^\dagger\mathbf{\Lambda}_{U^n})(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{nj} \\
&+\ 2(\mathbf{Y}_U^\dagger\mathbf{Y}_U)_{nj}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{in} + \mathrm{Tr}(\mathbf{\Lambda}_{U^j}\mathbf{\Lambda}_{U^n}^\dagger)(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{in} \\
&+\ 4(\mathbf{Y}_U^\dagger)_{iq}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{qr}(\mathbf{Y}_U)_{rj} + 4(\mathbf{Y}_U^\dagger\mathbf{Y}_U)_{ij}m_{H_2}^2 \\
&+\ 4(\mathbf{\Lambda}_{U^i}^\dagger\mathbf{\Lambda}_{U^j})_{qr}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{rq} + 4(\mathbf{h}_U^\dagger\mathbf{h}_U)_{ij} + 2\ \mathrm{Tr}(\mathbf{h}_{U^i}^\dagger\mathbf{h}_{U^j}) \\
&-\ \left(\frac{32}{15}g_1^2|M_1|^2 + \frac{32}{3}g_3^2|M_3|^2 + \frac{4}{5}g_1^2\mathcal{S}\right)\delta_{ij}\ ,
\end{aligned}
\tag{C16}
$$

$$
\begin{aligned}
16\pi^2\frac{dm_{H_1}^2}{dt} &= 2\ \mathrm{Tr}(\mathbf{Y}_E^\dagger\mathbf{Y}_E)m_{H_1}^2 + 6\ \mathrm{Tr}(\mathbf{Y}_D^\dagger\mathbf{Y}_D)m_{H_1}^2 + (\mathbf{Y}_E^\dagger\mathbf{\Lambda}_{E^q})_{qn}(\mathbf{m}^2_{H_1\tilde{L}_n}) \\
&+\ 3(\mathbf{Y}_D^\dagger\mathbf{\Lambda}_{D^q})_{qn}(\mathbf{m}^2_{H_1\tilde{L}_n}) + 3(\mathbf{\Lambda}_{D^q}^\dagger\mathbf{Y}_D)_{nq}(\mathbf{m}^2_{\tilde{L}_n H_1}) \\
&+\ (\mathbf{\Lambda}_{E^q}^\dagger\mathbf{Y}_E)_{nq}(\mathbf{m}^2_{\tilde{L}_n H_1}) + 2(\mathbf{Y}_E^\dagger\mathbf{Y}_E)_{qr}(\mathbf{m}_{\tilde{\mathbf{E}}}{}^2)_{rq} \\
&+\ 2(\mathbf{Y}_E\mathbf{Y}_E^\dagger)_{rq}(\mathbf{m}_{\tilde{\mathbf{L}}}{}^2)_{qr} + 6(\mathbf{Y}_D^\dagger\mathbf{Y}_D)_{qr}(\mathbf{m}_{\tilde{\mathbf{D}}}{}^2)_{rq} \\
&+\ 6(\mathbf{Y}_D\mathbf{Y}_D^\dagger)_{rq}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{qr} + 2\ \mathrm{Tr}(\mathbf{h}_E^\dagger\mathbf{h}_E) + 6\ \mathrm{Tr}(\mathbf{h}_D^\dagger\mathbf{h}_D) \\
&-\ \left(\frac{6}{5}g_1^2|M_1|^2 + 6g_2^2|M_2|^2 + \frac{3}{5}g_1^2\mathcal{S}\right)\delta_{ij}\ ,
\end{aligned}
\tag{C17}
$$

$$
\begin{aligned}
16\pi^2\frac{dm_{H_2}^2}{dt} &= 6\ \mathrm{Tr}(\mathbf{Y}_U^\dagger\mathbf{Y}_U)m_{H_2}^2 + 6(\mathbf{Y}_U^\dagger\mathbf{Y}_U)_{qr}(\mathbf{m}_{\tilde{\mathbf{U}}}{}^2)_{rq} \\
&+\ 6(\mathbf{Y}_U\mathbf{Y}_U^\dagger)_{rq}(\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2)_{qr} + 6\ \mathrm{Tr}(\mathbf{h}_U^\dagger\mathbf{h}_U) \\
&-\ \left(\frac{6}{5}g_1^2|M_1|^2 + 6g_2^2|M_2|^2 - \frac{3}{5}g_1^2\mathcal{S}\right)\delta_{ij}\ ,
\end{aligned}
\tag{C18}
$$

where

$$
(\mathbf{m}^2_{H_1\tilde{L}_i}) = (\mathbf{m}^2_{\tilde{L}_i H_1})^*\ , \tag{C19}
$$

and

$$
\mathcal{S} = m_{H_2}^2 - m_{H_1}^2 + \mathrm{Tr}[\mathbf{m}_{\tilde{\mathbf{Q}}}{}^2 - \mathbf{m}_{\tilde{\mathbf{L}}}{}^2 - 2\mathbf{m}_{\tilde{\mathbf{U}}}{}^2 + \mathbf{m}_{\tilde{\mathbf{D}}}{}^2 + \mathbf{m}_{\tilde{\mathbf{E}}}{}^2]\ . \tag{C20}
$$

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[8] It is not hard to generalize to a unitary transformation, Marc Thormeier, *unpublished*. In that case one can get rid of the phase of κ_i as well.
[9] Throught this paper we assume that the vacuum expectation values are real.
[10] We have corrected the sign error for the μ_α parameter in Eq.(3.2) of [4]. We would like to thank H. Haber for communication.
[11] We used the notation $(\widetilde{\mathcal{W}}^{\pm} = \frac{1}{\sqrt{2}}(\widetilde{\mathcal{W}}^{(1)} \mp i\widetilde{\mathcal{W}}^{(2)})$.
[12] A typo in $\gamma_{E_i}^{(1)E_j}$ of [3] has been corrected.
[13] For the gaugino masses a knowledge of the β-function of the gauge couplings is also neccecary. Since the $\not{R}_p$-couplings do not affect the gaugino masses at one loop one can use the gaugino RGEs directly from [6].