Analysis of Chiral Extensions of the MSSM with Gauge Mediated SUSY Breaking

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Content

General structure of supersymmetric models

$$\mathcal{L} = \mathcal{L}_{gauge} + \mathcal{L}_{matter} - \sqrt{2}g(\Phi^* T^a \psi)\lambda^a - \sqrt{2}g(\psi^* T^a \Phi)\lambda^a + \mathcal{L}_{soft}$$

- Gauge part of the lagrangian:

$$\mathcal{L}_{gauge} = -\frac{1}{4}F^a_{\mu\nu}F^{a\,\mu\nu} + i\lambda^{\dagger a}\bar{\sigma}^\mu \nabla_\mu \lambda^a$$

- Part of lagrangian with matter:

$$\mathcal{L}_{matter} = i\psi^{\dagger i}\bar{\sigma}^\mu D_\mu \psi_i - D^\mu \Phi^{*i} D_\mu \Phi_i - \frac{1}{2}M^{ij}\psi_i\psi_j - \frac{1}{2}M^*_{ij}\psi^{\dagger i}\psi^{\dagger j} - \\ - \frac{1}{2}y^{ijk}\Phi_i\psi_j\psi_k - \frac{1}{2}y^*_{ijk}\Phi^{\dagger i}\psi^{\dagger j}\psi^{\dagger k} - V(\Phi, \Phi^\dagger)$$

- Superpotential:

$$W = L^i\Phi_i + \frac{1}{2}M^{ij}\Phi_i\Phi_j + \frac{1}{6}y^{ijk}\Phi_i\Phi_j\Phi_k$$

- Scalar potential:

$$V = V_F + V_D = W^k W^*_k + \frac{1}{2}g^2(\Phi^\dagger T^a \Phi)^2$$

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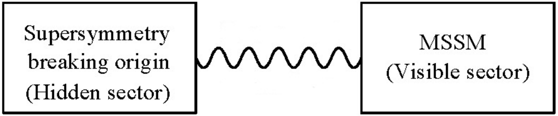
SUSY Breaking

- Soft SUSY breaking

$$\mathcal{L}_{soft} = -(\frac{1}{2}M_a\lambda^a\lambda^a + \frac{1}{6}a^{ijk}\Phi_i\Phi_j\Phi_k + \frac{1}{2}b^{ij}\Phi_i\Phi_j + t^i\Phi_i) + cc - (m^2)^i_j\Phi^{j*}\Phi_i$$

- Gauge mediated SUSY breaking



MSSM Content

	SU(3)	SU(2)	U(1)
Q	$\square$	$\square$	$\frac{1}{6}$
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$\bar{d}$	$\bar{\square}$	-	$\frac{1}{3}$
L	-	$\square$	$-\frac{1}{2}$
$\bar{\nu}$	-	-	-
$\bar{e}$	-	-	1
H_u	-	$\square$	$\frac{1}{2}$
H_d	-	$\square$	$-\frac{1}{2}$

$$W_{MSSM} = Y_u^{ij}\bar{u}_i Q_j H_u - Y_d^{ij}\bar{d}_i Q_j H_d - Y_e^{ij}\bar{e}_i L_j H_d + \mu H_u H_d$$

- $$W_{\Delta L=1} = \frac{1}{2}\lambda^{ijk} L_i L_j \bar{e}_k + \frac{1}{2}\lambda'^{ijk} L_i Q_j \bar{d}_k + \mu'^{i} L_i H_u$$
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Content of Chiral EMSSM

	SU(3)	SU(2)	U(1)	$U'(1)$
Q	$\square$	$\square$	$\frac{1}{6}$	q_{1i}
$\bar{u}$	$\bar{\square}$	-	$-\frac{2}{3}$	q_{2i}
$\bar{d}$	$\bar{\square}$	-	$\frac{1}{3}$	q_{3i}
L	-	$\square$	$-\frac{1}{2}$	q_{4i}
$\bar{\nu}$	-	-	-	q_{5i}
$\bar{e}$	-	-	1	q_{6i}
H_u	-	$\square$	$\frac{1}{2}$	q_{7i}
H_d	-	$\square$	$-\frac{1}{2}$	q_{8i}
S	-	-	-	q_{9i}

$$W_{EMSSM} = \sum_i^3 \sum_j^3 [Y_u^{ij} \bar{u}_j Q_i H_u^j - Y_d^{ij} \bar{d}_j Q_i H_d^j + Y_\nu^{ij} \bar{\nu}_j L_i H_u^j -$$

$$- Y_e^{ij} \bar{e}_j L_i H_d^j] + \sum_i^3 (\kappa_i S_i H_u^i H_d^i) + \lambda S_1 S_2 S_3$$

Anomalies and Yukawa constraints

- There are $9 \cdot 3 = 27$ unknown charges.
- There are 4 linear equations coming from anomalies, like:

$$SU(3)SU(3)U'(1) \Rightarrow \sum_{i=1}^{3}(2q_{1i} + q_{2i} + q_{3i}) = 0,$$

- There 2 non-linear equations coming from anomalies, like:

$$U(1)U'(1)U'(1) \Rightarrow \sum_{i=1}^{3}(q_{1i}^2 - 2q_{2i}^2 + q_{3i}^2 - q_{4i}^2 + q_{6i}^2 + q_{7i}^2 - q_{8i}^2) = 0,$$

- Linear constraints from the form of superpotential, like:

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Chiral extension

One particular solution is present on the table.

q_{ai}	$i=1$	$i=2$	$i=3$
Q	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$
$\bar{u}$	$\frac{1}{3}-s$	$\frac{1}{3}+s$	$\frac{1}{3}$
$\bar{d}$	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{4}{3}$
L	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$
$\bar{\nu}$	$1-s$	$1+s$	1
$\bar{e}$	$\frac{1}{3}$	$\frac{1}{3}$	$-\frac{2}{3}$
H_u	$-\frac{1}{2}+s$	$-\frac{1}{2}-s$	$-\frac{1}{2}$
H_d	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{7}{6}$
S	$\frac{1}{3}-s$	$\frac{1}{3}+s$	$-\frac{2}{3}$

Table: $U'(1)$ charges of EMSSM for each family, where $s \equiv \frac{1}{\sqrt{3}}$.

EW Breaking

- Covariant derivative:

$$D_\mu = \partial_\mu - ig_2 A^a_\mu \tau^a - ig_1 Y B_\mu - ig'_1 q B'_\mu.$$

- Kinetic terms of Higgs fields and singlets:

$$(D_\mu \Phi^i)^\dagger D^\mu \Phi_i \rightarrow \frac{1}{2} g_2^2 v_1^2 W^+_\mu W^{-\mu} + \begin{pmatrix} A^3_\mu & B_\mu & B'_\mu \end{pmatrix} M^2 \begin{pmatrix} A^{3\mu} \\ B^\mu \\ B'^\mu \end{pmatrix}$$

- Eigenvalues of the mass matrix:

$$m_A^2 = 0, \;\; \frac{1}{2} m_Z^2 = \frac{1}{4} v_1^2 (g_1^2 + g_2^2)(1 + \tilde{g}_1'^2), \;\; \frac{1}{2} m_{Z'}^2 = g_1'^2 (v_3^2 - \frac{v_2^4}{v_1^2}).$$

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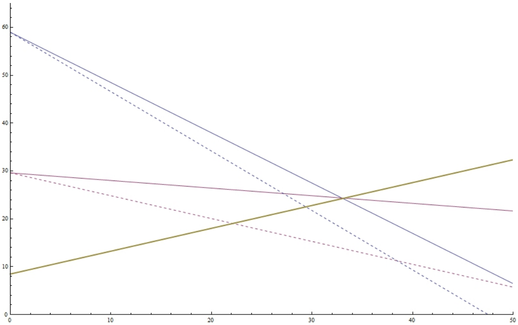
Running Coupling Constants

Running coupling constants g_i in terms of $\alpha_i \equiv \frac{g_i^2}{4\pi}$ up to one loop:

$$\alpha_i^{-1}(t) = \alpha_i^{-1}(EW) - \frac{b_i}{2\pi} t,$$

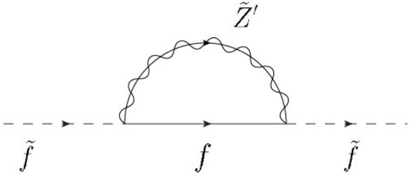
where $t = \ln \Lambda$, Λ-energy scale and b_i model dependent constants:

$$b_1 = 2n_g + \frac{3}{10} n_h, \; b_2 = -6 + 2n_g + \frac{1}{2} n_h, \; b_3 = -9 + 2n_g.$$



Radiative corrections of the masses

- Masses of the sfermions arise from the one-loop diagrams:



$$m_{\tilde{f}}^2 = \frac{g_{\tilde{Z}'}^2 m_{\tilde{Z}'}^2}{4\pi^2} \ln\left(\frac{\Lambda}{m_{\tilde{Z}'}}\right)$$

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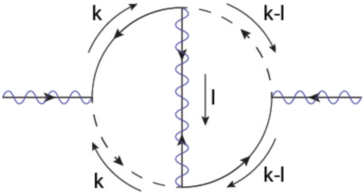

$$m_{\tilde{\lambda}} = \frac{m_{\tilde{Z}'} g_{\tilde{\lambda}}^2 g_{\tilde{Z}'}^2}{64\pi^4} \ln\left(\frac{\Lambda}{m_{\tilde{Z}'}}\right)$$

Forthcoming work

- Analysis of different sets of $U'(1)$ charges
- CP-violation from the Higgs sector

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