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Hybrid Models of Supersymmetry Breaking

- S. Lavignac,J. Parmentier, E.D, in progress

Outline

- Gravity and gauge mediation: advantages/problems
- Hybrid models and metastability
- Hybrid models with GUT induced doublet-triplet messenger splitting
- Prospects

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Sergiev Posad

1. Gravity and gauge mediation : advantages/problems

- Gravity mediation

SUSY broken in a "hidden" sector which communicates with our sector via (super)gravitational interactions

MSSM $\leftrightarrow$ Hidden Sector

nonren.int. $T_i, \langle F_i \rangle \neq 0$

Define $F^2 = \sum_i |F_i|^2$, then

$$M_{SUGRA} \sim m_{3/2} \quad , \quad m_{3/2} = \frac{F}{\sqrt{3} M_P}$$

Ex : $(G = K + \ln |W|^2,\ F^\alpha = m_{3/2} G^\alpha)$

$$m^2_{i\bar{j}} = m^2_{3/2}\ (G_{i\bar{j}} - R_{i\bar{j}\alpha\bar{\beta}} G^\alpha G^{\bar{\beta}}\ )$$

Advantages:

• Natural solution for the μ-problem via Giudice-Masiero mechanism

$$\mu \sim m_{3/2} \quad , \quad B\mu \sim m_{3/2}^2$$

where

$$L_{MSSM} = (\int d^2\theta \ \mu H_1 H_2) + B\mu h_1 h_2 + c.c. + \cdots$$

• Easy to construct explicit models, natural in string theory (moduli fields)

Problems

• FCNC effects are generically problematic in SUGRA theories (GIM not enough)

Solutions for FCNC problem :

i) flavor universality : $(m_0^2)_{ij} = (m_0^2)\delta_{ij}$

ii) alignement : $(m_0^2)_{ij}$ are aligned to Yuk. Y_{ij}

(diagonalized in the same basis)

If not squark, slepton masses > 50 TeV or so !

• Universality/alignment are not generic in gravity mediation.

- Gauge mediation

Transmission of SUSY breaking through SM gauge loops

= gauge mediation

SUSY breaking sector	$\leftrightarrow$	Messenger sector	$\leftrightarrow$	MSSM
$X = \langle X \rangle + \theta^2 F_X$	$\rightarrow$	$X \Phi \tilde{\Phi}$	$\rightarrow$	soft terms

Messengers are typically :

- vector-like, charged under SM gauge group.

- If $SU(5)$ complete multiplets (say N pairs $5 + \bar{5}$), they preserve MSSM gauge coupling unification.

• MSSM soft terms, minimal gauge mediation:

- gaugino masses $\rightarrow$ 1-loop

$$M_{1/2} \sim N_m \frac{g^2}{16\pi^2} \left(\frac{F_X}{\langle X \rangle}\right) \sim N_m M_{GMSB}$$

- scalar (squarks,sleptons) masses : two-loops

$$m_0^2 \sim N_m \left(\frac{g^2}{16\pi^2}\right)^2 \left(\frac{F_X}{\langle X \rangle}\right)^2 \sim N_m M_{GMSB}^2$$

Typically $M_{GMSB} \gg m_{3/2}$, gravitino very light (LSP)

Minimal gauge mediation has

- $StrM^2 = 0$ in the messenger sector.

- $SU(5)$ symmetric messenger masses.

Advantages :

- Gauge mediation solves the flavor problem
- In its minimum version, highly predictive spectrum.

Problems :

- Very difficult to generate μ, $B\mu$ of correct size.
- Complicated explicit models (vacuum metastability) .

2. Hybrid models

(Poppitz-Trivedi,..., Mambrini,Pokorski,Romagnoni,E.D. ; Feng, Lester and Nir ; Lavignac, Parmentier and E.D.)

In recent works messengers are taken to be very heavy

$$\mathcal{M}_m \sim 10^{13} - 10^{16} GeV$$

Then $m_{3/2} \sim M_{GMSB}$ is possible and the SUGRA and GMSB contributions can be comparable.

$$m_0^2 \sim m_{3/2}^2 + N_m M_{GMSB}^2 \ ,$$
$$M_{1/2} \sim m_{3/2} + N_m M_{GMSB}$$

Couplings of messengers to SUSY breaking sector:

$$W_m = \Phi(\lambda_X X \ + \mathcal{M})\tilde{\Phi}$$

where X is the SUSY breaking field(s).

Gauge / SUGRA contributions to MSSM soft terms

$$\frac{M_{GMSB}}{m_{3/2}} \ \sim \ N_m \frac{g^2}{16\pi^2}\lambda_X \frac{M_P}{\mathcal{M}}$$

can be comparable for very heavy messengers.

Most models are metastable (lower vacuum with messenger vev's); lifetime of our vacuum

$$\tau \ \sim \ e^{\frac{1}{\lambda_X^2}}$$

- Stability prefers gravity mediation.

• Hybrid models could combine advantages of both SUSY breaking mechanisms if

$$M_{GMSB} \sim TeV \sim 30 - 100\ m_{3/2} \qquad (1)$$

We use ISS (Intriligator-Seiberg-Shih) model as sector that breaks SUSY (other DSB models similar results).

$$\begin{aligned} W &= W_{ISS} + W_m + W_\mu + W_{MSSM} \\ W_{ISS} &= hqX\tilde{q} - hf^2 TrX \\ W_\mu &= \lambda \frac{q\tilde{q}}{M_P} H_1 H_2 \end{aligned}$$

where $f^2 = m\Lambda \sim (10^{10} GeV)^2$.

• $\lambda_X \sim \Lambda/M_P \ll 1 \rightarrow$ large lifetime.

At tree-level there are pseudo-moduli in X. At one-loop, effective potential generates a vev $\langle X \rangle \sim (\lambda_X^3/h^2)(f^2/\mathcal{M})$.

$$m_{3/2} \sim \frac{F_X}{M_P}$$

$$\mu \sim \frac{N}{h} m_{3/2} \quad , \quad B = \frac{F_q}{q} \sim h\langle X \rangle$$

We need $N/h \gg 1$. μ and B are similar (TeV).

3. Hybrid models with GUT induced doublet-triplet messenger splitting

Messengers are naturally very heavy if they couple to $SU(5)$ GUT adjoint ($\mathbf{5} \times \bar{\mathbf{5}} = \mathbf{1} + \mathbf{24}$). The messenger mass matrix is

$$\mathcal{M} = \lambda_\Sigma \Sigma + \lambda'_\Sigma \frac{\Sigma^2}{M_P}$$

where Σ is the $SU(5)$ GUT adjoint breaking $SU(5) \to$ SM. If $\langle X \rangle \ll \langle \Sigma \rangle \sim M_{GUT} \times diag\ (2, 2, 2, -3, -3)$, then doublet and triplet messengers are split

$$\mathcal{M}_{3m} \simeq 2\lambda_\Sigma M_{GUT} \quad , \quad \mathcal{M}_{2m} \simeq -3\lambda_\Sigma M_{GUT}$$

Messengers are very heavy; it is easy to obtain (1).

Since $\langle\Sigma\rangle \sim VY$, we get a peculiar spectrum at high energy :

(Ex: $M_a^2 \sim$ (one $-$ loop) $Tr(Q_a^2/\langle\Sigma\rangle)$

$$M_3 = -\frac{3}{2}M_2 \sim TeV \ , \ M_1 \sim 100GeV$$

$$m_{q_L}^2 \simeq \frac{5}{4}m_{u_R}^2 \ , \ m_{d_R}^2 \simeq m_{u_R}^2$$

$$m_{e_L}^2 \simeq \frac{5}{6}m_{e_R}^2 \ , \ m_{u_R}^2 \simeq 4m_{e_L}^2 \ , \ \text{etc}$$

$$\mu \ , \ B \sim TeV$$

- Bino gets GMSB mass only from $\lambda'_\Sigma \rightarrow$ bino and the gravitinos are the lightest.
- The other superpartner masses are 300 GeV - 1 TeV.

Prospects

• LHC will start in 2008 the hunt for physics BSM and particularly low-energy SUSY.

• There are generically three possibilities :

- generic SUGRA mediation $\rightarrow$ all soft terms of the same order $m_{soft} \sim m_{3/2}$, but numerically different.

- gauge mediation $\rightarrow$ flavor universality and some correlation between the different soft terms. Very likely that this will be a metastable vacuum, in which case "There are reasons of anxiety" (Coleman, 1977).

- hybrid models : they can combine advantages and eliminate problems of gauge / gravity mediations

• For GUT induced doublet-triplet messenger splitting, predictive spectrum related to existence of $SU(5)$ GUT.

• Under investigation : comparison of the low-energy spectrum with minimal gauge mediation and mSUGRA.

• More general cases deserve attention : LHC predictions important !