# A light neutralino in hybrid models of supersymmetry breaking

E. Dudas[1], S. Lavignac[2] and J. Parmentier[1,2]

[1]Centre de Physique Théorique
Ecole Polytechnique, France

[2]Institut de Physique Théorique
CEA Saclay, France

GDR SUSY

# Outline



This talk is based on 0808.0562[hep-ph], to appear in Nucl. Phys. B.

# SQCD and SUSY breaking

## Duality

quarks Q and anti-quarks $\widetilde{Q}$
with $N_c$ colors, $N_f$ flavors
For $N_c < N_f < 3/2 N_c$

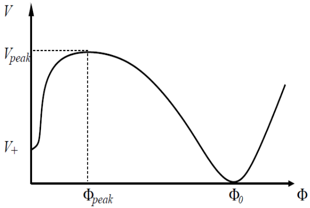
$$\Updownarrow$$

$N_f$ flavors, N= $N_f - N_c$ colors
quarks q, antiquarks $\widetilde{q}$ and
meson X

## Superpotential

$$W = hqX\widetilde{q} - h\mu^2 \, \mathrm{TrX}$$

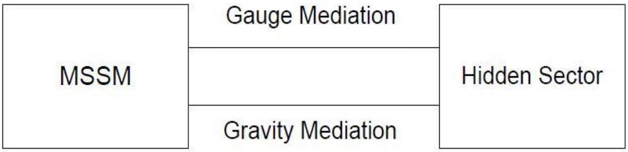
Intriligator, Seiberg and Shih, hep-th/0602239




## Why SUSY is broken

$$F_{X_j^i} = hq_i^a \widetilde{q}_a^j - h\mu^2 1\!\mathrm{I}$$

# Mediation of SUSY breaking : General Scheme




## Gravity Mediation

- Natural $\mu$, B$\mu$
- Generates Flavor Changing Neutral Currents
- LSP neutralino

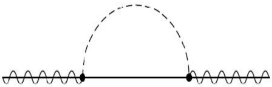
## Gauge Mediation

- Have to find a mechanism to generate $\mu$, B$\mu$
- Flavor Blind process
- LSP gravitino

# Having both mediations

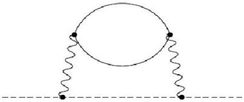
## Order of magnitude

- Gauge mediation
  $\Lambda_{GM} \sim \frac{\alpha}{4\pi}\frac{F}{M}$
- Gravity mediation
  $m_{3_2} \sim \frac{F}{M_{Pl}}$



## Heavy messengers

$m_{3/2} \sim (0.01 - 0.1)\Lambda_{GM}$
$\rightarrow M \sim 10^{13} - 10^{14}$ GeV



Do messengers interact with the GUT sector ?

# Model : coupling messengers to the GUT sector

## Our Model

Lets consider

- ISS as a hidden sector
- Messengers coupled to the other fields by $\phi(\lambda_X X + \lambda_\Sigma \Sigma)\widetilde{\phi}$, with Σ = diag(2,2,2,-3,-3)v that breaks SU(5)

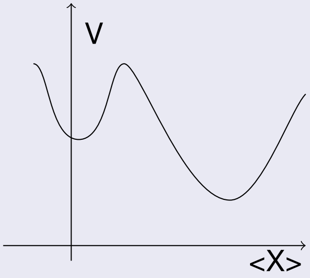
## Model bulding characteristics

Why studying this coupling ?

- Gravitational effects : $m_{3/2} \sim (0.1 - 0.01)\Lambda_{GM}$
- One free parameter $\lambda_\Sigma$
- Doublet and triplet messengers have different masses $M = \lambda_\Sigma 6vY$

# Shape of potentials

## Quantum Corrections at one loop for ISS + messengers




We can explicitely compute the Coleman-Weinberg potential and we find

- Metastability for $\lambda_X < 10^{-2}$
- $< X > \neq 0$

## Mass term for the Higgs

Non-renormalisable term ... but non negligeable !

$$W_1 = \lambda_1 \frac{q\tilde{q}}{M_{Pl}} H_u H_d \rightarrow \boxed{\mu}$$

$$W_2 = \lambda_2 \frac{X^2}{M_{Pl}} H_u H_d \rightarrow \boxed{\mathrm{B}\mu}$$

# UV spectrum

## 5-$\bar{5}$

$$M_3 = \frac{1}{2} N_m \frac{\alpha_3}{4\pi} \frac{\lambda_X F_X}{\lambda_\Sigma v}$$
$$M_2 = -\frac{1}{3} N_m \frac{\alpha_2}{4\pi} \frac{\lambda_X F_X}{\lambda_\Sigma v}$$
$$m^2_Q : m^2_{U^c} : m^2_{D^c} : m^2_L : m^2_{E^c}$$
$$\approx 0.79 : 0.70 : 0.68 : 0.14 : 0.08$$

## 10-$\overline{10}$

$$M_3 = \frac{7}{4} N_m \frac{\alpha_3}{4\pi} \frac{\lambda_X F_X}{\lambda_\Sigma v}$$
$$M_2 = 3\, N_m \frac{\alpha_2}{4\pi} \frac{\lambda_X F_X}{\lambda_\Sigma v}$$
$$m^2_Q : m^2_{U^c} : m^2_{D^c} : m^2_L : m^2_{E^c}$$
$$\approx 8.8 : 5.6 : 5.5 : 3.3 : 0.17$$

## Commun feature

$$M_{1,1-loop,GM} \sim \mathrm{Tr}(Y^2/M)$$
$$M_{1,1-loop,GM} \sim \mathrm{Tr}(Y) = 0\,!$$
$$\boxed{M_1 \sim m_{3/2}}$$
$$\neq$$

Universality for gauginos

$$M_1 : M_2 : M_3 = \alpha_1 : \alpha_2 : \alpha_3$$

## How far can we go in the hierarchy ?

Limits come from

- Heavy masses for the messengers
- Gravitational effects interesting
- Neutralino LSP

# IR spectrum

## Constraint by Dark Matter

What are the bounds on $m_{\chi_1^0}$ ?

- No bound from colliders !
- bound from dark matter constraint (relic density)

What is the ligthest neutralino that we can build in this model ?

- $m_{\chi_1^0} \leq 40$ GeV would need R-parity violation
- $m_{\chi_1^0} \sim 40$ GeV with light sleptons
- $m_{\chi_1^0} \geq 40$ GeV but less interesting for the moment...

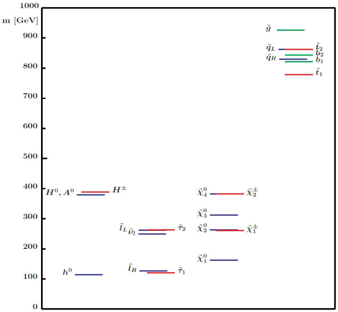
## FCNC

Light Sleptons $\longrightarrow$ FCNC in the lepton sector
Difficult to avoid because of the very few parameters of the model

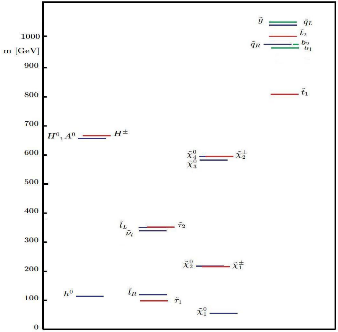
# GMSB vs hybrid mediation

From B.C. Allanach et al., hep-ph/0202233

SPS 7: GMSB scenario with $\tilde{\tau}$ NLSP

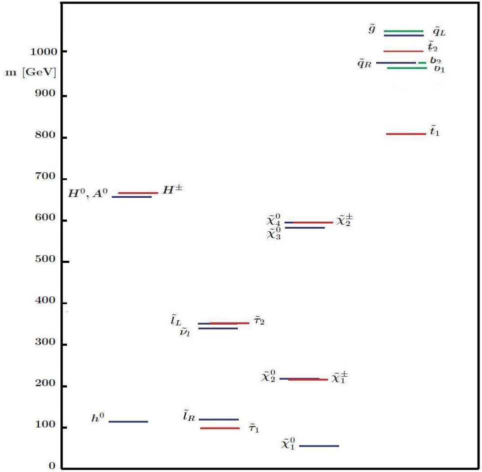



$\Lambda = 40\,\mathrm{TeV}, \quad M_{\mathrm{mes}} = 80\,\mathrm{TeV}, \quad N_{\mathrm{mes}} = 3, \quad \tan\beta = 15, \quad \mu > 0.$




Hybrid Mediation

# GMSB vs hybrid mediation




**Hybrid Mediation**

# Conclusions

From the model building point of view

- Explicit models of supersymmetry breaking
- Quite constrained model
- Correct EWSB
- Correct relic abundance
- Still FCNC

Even if gauge mediation, light neutralino as a signature

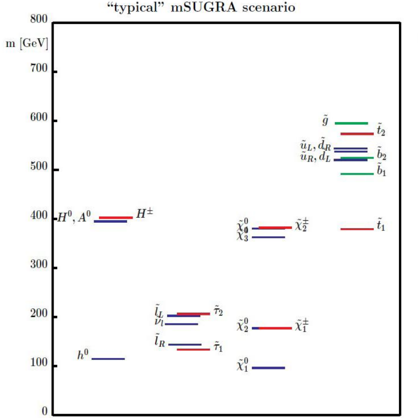
Waiting for the LHC ...

# Datas

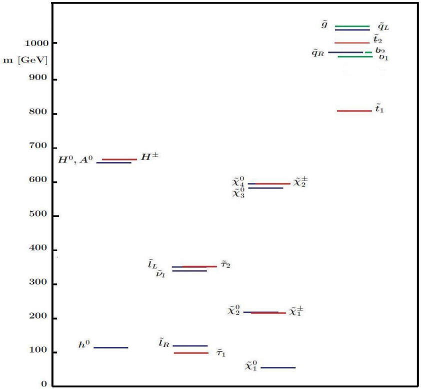
| model | 1 | 2 | 3 | 3 bis | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| $N_{(5,\bar{5})}$ | 1 | 6 | 0 | 0 | 0 | 1 | 3 |
| $N_{(10,\overline{10})}$ | 0 | 0 | 1 | 1 | 4 | 1 | 1 |
| $M_{GM}$ | 1000 | 200 | 300 | 300 | 110 | 220 | 160 |
| $M_1$ | 50 | 50 | 50 | 85 | 80 | 85 | 85 |
| $\tan\beta$ | 30 | 24 | 15 | 15 | 9 | 15 | 15 |
| sign$(\mu)$ | + | + | + | + | + | + | + |
| $h$ | 114.7 | 115.0 | 115.2 | 115.2 | 116.5 | 114.6 | 114.8 |
| $A$ | 779.2 | 645.4 | 892.2 | 892.4 | 1015 | 735.8 | 662.7 |
| $H^0$ | 779.2 | 645.5 | 892.4 | 892.6 | 1015 | 735.9 | 662.8 |
| $H^\pm$ | 783.3 | 650.3 | 895.7 | 895.9 | 1018 | 740.1 | 667.5 |
| $\tilde{\chi}_1^\pm$ | 259.4 | 305.0 | 560.2 | 560.3 | 676.7 | 408.0 | 223.9 |
| $\tilde{\chi}_2^\pm$ | 747.8 | 636.8 | 693.9 | 694.0 | 970.4 | 590.4 | 597.5 |
| $\tilde{\chi}_1^0$ | 24.5 | 23.5 | 23.2 | 42.9 | 38.1 | 43.0 | 42.9 |
| $\tilde{\chi}_2^0$ | 259.4 | 305.0 | 560.1 | 560.3 | 677.1 | 408.0 | 223.9 |
| $\tilde{\chi}_3^0$ | 743.3 | 629.8 | 596.9 | 597.1 | 691.0 | 570.8 | 589.2 |
| $\tilde{\chi}_4^0$ | 745.7 | 634.7 | 693.8 | 693.9 | 970.4 | 590.4 | 596.3 |
| $\lvert Z_{11}\rvert$ | 0.9982 | 0.9975 | 0.9971 | 0.9971 | 0.9978 | 0.9968 | 0.9969 |
| $\lvert Z_{13}\rvert$ | 0.0599 | 0.0708 | 0.0750 | 0.0755 | 0.0648 | 0.0792 | 0.0772 |
| $\tilde{g}$ | 1064 | 1207 | 1097 | 1097 | 1527 | 1028 | 1063 |
| $\tilde{t}_1$ | 984.6 | 927.3 | 861.7 | 861.6 | 1080 | 795.7 | 809.5 |
| $\tilde{t}_2$ | 1156 | 1074 | 1240 | 1240 | 1468 | 1058 | 1002 |
| $\tilde{u}_1, \tilde{c}_1$ | 1195 | 1087 | 1135 | 1135 | 1361 | 1006 | 987.9 |
| $\tilde{u}_2, \tilde{c}_2$ | 1240 | 1115 | 1327 | 1327 | 1555 | 1118 | 1043 |
| $\tilde{b}_1$ | 1128 | 1040 | 1123 | 1123 | 1356 | 995.4 | 966.2 |
| $\tilde{b}_2$ | 1169 | 1079 | 1224 | 1224 | 1451 | 1038 | 987.1 |
| $\tilde{d}_1, \tilde{s}_1$ | 1184 | 1085 | 1134 | 1134 | 1360 | 1005 | 987.1 |
| $\tilde{d}_2, \tilde{s}_2$ | 1243 | 1117 | 1329 | 1329 | 1557 | 1121 | 1046 |
| $\tilde{\tau}_1$ | 242.2 | 99.0 | 86.3 | 89.3 | 87.0 | 96.7 | 95.2 |
| $\tilde{\tau}_2$ | 420.3 | 289.4 | 696.2 | 696.3 | 753.1 | 498.6 | 349.8 |
| $\tilde{e}_1, \tilde{\mu}_1$ | 294.4 | 150.6 | 131.5 | 133.6 | 105.4 | 123.6 | 117.4 |
| $\tilde{e}_2, \tilde{\mu}_2$ | 413.4 | 275.1 | 699.1 | 699.2 | 754.1 | 500.1 | 348.5 |
| $\tilde{\nu}_\tau$ | 396.6 | 260.5 | 691.4 | 691.5 | 749.0 | 491.4 | 337.6 |
| $\tilde{\nu}_e, \tilde{\nu}_\mu$ | 405.8 | 263.6 | 694.8 | 694.9 | 750.1 | 493.9 | 339.5 |
| $\Omega_{\tilde{\chi}_1^0} h^2$ | 6.40 | 0.428 | 0.279 | 0.122 | 0.124 | 0.118 | 0.116 |

# mSUGRA vs hybrid mediation

From B.C. Allanach et al., hep-ph/0202233

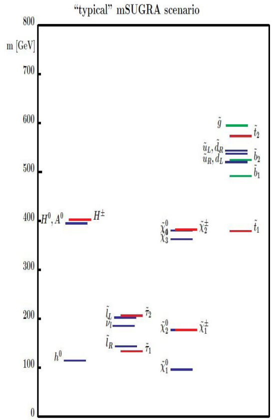



$m_0 = 100\,\text{GeV}, \quad m_{1/2} = 250\,\text{GeV}, \quad A_0 = -100\,\text{GeV}, \quad \tan\beta = 10, \quad \mu > 0.$




**Hybrid Mediation**

# Comparisons

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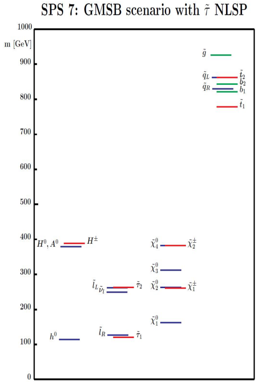


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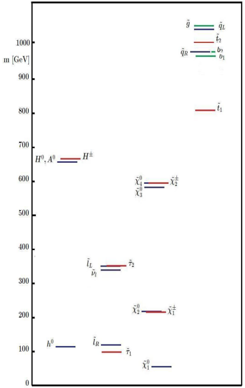


Hybrid Mediation