Moduli stabilization and new low-energy spectra

Alberto Romagnoni

Laboratoire de Physique Théorique, Université Orsay-Paris Sud
Centre de Physique Théorique, École Polytechnique

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E. Dudas, Y. Mambrini, S. Pokorski, A.R. *To appear*

Motivations and Ingredients

MSSM embedded in String theory, Extra-Dimensions Models, … but new things appear:

Moduli

- they parametrize "flat directions"
- they have to be taken into account and stabilized (typically by nonperturbative effects)

New Symmetries

In particular new $U(1)_X$ gauge symmetries and new charged fields Φ_i

$\hookrightarrow$ Spontaneous SUSY breaking in a new hidden sector

$\hookrightarrow$ Communicate it to the MSSM

Charged Moduli

Consider the modulus T parametrizing the volume of the compact space.

T can carry $\mathrm{U}(1)_X$ charge $\Rightarrow$ it transforms as a Goldstone boson

- mass to $\mathrm{U}(1)_X$ gauge boson
- anomalies

Gauge invariance + SUSY

- Fayet-Iliopoulos term depending on T
- constraints for terms in the superpotential

The model

General Framework

Type IIB compactified on orientifold $\rightarrow$ Supergravity in 4D (KKLT-like model)

Two main ingredients:

- Kahler potential:
  $K = -3\ln(T+\overline{T}) + |\Phi_-|^2 + |\Phi_+|^2 + K_{MSSM}$
- Superpotential: $W = W_0 + e^{-bT}\Phi_-^q + m\,\Phi_+\Phi_-$

The scalar potential is
$V = e^K(|F_T|^2 + |F_+|^2 + |F_-|^2 - 3|W|^2) + g_T^2\, D^2$

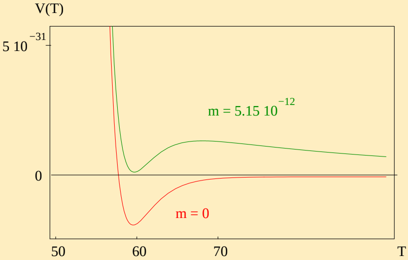
FI mechanism $\rightarrow$ spontaneous SUSY Breaking: $D, F_i \neq 0$

First Phenomenological Results

Uplift

Parameters in the superpotential fixed by some phenomenological requirements:

- $m_{3/2} \sim \frac{W}{M_P^2} \Rightarrow$ fix W_0
- Imposing $\Lambda_{cosm} = 0$ $\Rightarrow$ fix m



Soft terms by gravitational effects:

$$m_{1/2} \sim \frac{F_T}{T} \qquad m_0 \sim m_{3/2}$$

Usually F_T small.....here:

$m_{1/2} \lesssim m_0 \sim m_{3/2} \sim \text{TeV} \qquad D \sim (100\ \text{TeV})^2$

Anomalies & Gauge Messengers

If T couples to the SM gauge fields, since it is charged under $\mathrm{U}(1)_X$, its shift generates mixed $\mathrm{U}(1)_X - G_a^2$ anomalies

(G_a =SU(3), $\mathrm{SU}(2)_L$, $\mathrm{U}(1)_Y$)

$$\int d^2\theta \; T \; W_a^\alpha \; W_{\alpha\ a} \;\rightarrow\; \# \; F_a^{\mu\nu} \; \widetilde{F}_{\mu\nu\ a}$$

Possibilities :

- MSSM fields charged under $\mathrm{U}(1)_X \Rightarrow$
  problems: large masses for squarks and sleptons $\sim \sqrt{D}$, tachyonic directions,...
- MSSM fields uncharged but additional fields $M, \widetilde{M}$

$M, \widetilde{M}$ "Messengers" fields introduced in Gauge Mediated Supersymmetry Breaking

Perturbative gauge coupling unification $\rightarrow$ $M, \widetilde{M} \in \mathrm{SU}(5)$

Gauge Mediation & Soft masses

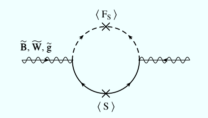
GMSB: Messengers $M, \widetilde{M}$ couple to Susy Breaking hidden sector (superfield S)

$$\lambda \int d^4\theta \, S \, M \, \widetilde{M}$$

$\hookrightarrow$ mediation of Susy Breaking at perturbative level

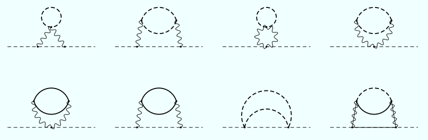
Gauginos masses

$$m_{1/2}^{GMSB} \sim \frac{g_a^2}{8\pi^2} \frac{F_S}{S}$$



Scalars masses

$$(m_0^{GMSB})^2 \sim \frac{g_a^4}{128\pi^4} \left(\frac{F_S}{S}\right)^2$$



Gauge Mediation & Uplift + D-term

If $D = \mathrm{STr}\, M^2_{Mess} \neq 0 \quad \Rightarrow$ different GMSB result for scalars

[Poppitz, Trivedi, Phys.Lett. B 401(1997)38]

$$(\widetilde{m}_0^{GMSB})^2 \sim (...) + \frac{g_a^4}{128\pi^4} D \left[c - \ln\left(\frac{\Lambda_{UV}^2}{m^2_{Mess}} \right) \right]$$

for D and $\frac{\Lambda^2_{UV}}{m^2_{Mess}}$ big enough $\rightarrow (\widetilde{m}_0^{GMSB})^2$ negative

Our model: $(\widetilde{m}_0^{GMSB})^2 < 0$ and $|(\widetilde{m}_0^{GMSB})^2| \sim m^2_{3/2} \sim (\mathrm{TeV})^2$

Nontrivial interplay:

- Gravity contribution is universal
- $(\widetilde{m}_0^{GMSB})^2$ depends on couplings between scalars and gauge vectors

$\Rightarrow$ Squarks can be lighter than sleptons at high energy
$\hookrightarrow$ measurable effects at low energy after RG flow

Conclusions & Outlooks

Results

- Example of a **non-decoupled** uplift: modulus contribution F_T to SUSY Breaking is not negligible
  $\Rightarrow$ gauginos masses **comparable** to the scalars and gravitino masses
- Natural mixing between **gauge** & **gravity** mediation mechanisms
- Original phenomenological signature testable at LHC: **spectrum "compressed"**, squarks **lighter** than sleptons (H.E.)

Work in progress

- Can F_T be increased?
- Systematic study of the phenomenology of the model