Deflected Mirage Mediation

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Based on:
L.E., I.-W. Kim, P. Ouyang, K. Zurek, 0804.0592, 0806.2330
B. Altunkaynak, L.E., I.-W. Kim, B. Nelson, Y. Rao, in progress
Many benefits/features:

(i) Hierarchy problem

(ii) Gauge coupling unification

(iii) Higgs sector/radiative EW breaking

(iv) Dark matter candidate

...
SUSY Breaking

As we all know, SUSY must be a broken symmetry.

Why not just parametrize?

Impractically vast number of parameters even in MSSM (~100 masses, CKM-like angles, and CP phases)

no cartography of full viable parameter space exists

need theory of SUSY breaking!
Hidden sector paradigm:

mediation mechanisms:
gravity mediation, gauge mediation, anomaly mediation
Mediators side-by-side

Gravity:

\[ m_{\text{SUSY}} \sim \frac{F}{M_{\text{Pl}}} \]
\[ m_{3/2} \sim \frac{F}{M_{\text{Pl}}} \]

Gauge:

\[ m_{\text{SUSY}} \sim \frac{1}{16\pi^2} \frac{F^X}{X} \]
\[ m_{3/2} \sim \frac{F^X}{M_{\text{Pl}}} \]

Anomaly:

\[ m_{\text{SUSY}} \sim \frac{1}{16\pi^2} \frac{F^C}{C} \]
\[ m_{3/2} \sim \frac{F^C}{C} \]
Mediators side-by-side (II)

Gravity:

\[ m_{\text{SUSY}} \sim \frac{F}{M_{\text{Pl}}} \]

Gauge:

\[ m_{\text{SUSY}} \sim \frac{1}{16\pi^2} \frac{F^X}{X} \]

Anomaly:

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Lightest sparticle (LSP):

- \( U(1)_Y \) gaugino/higgsino
- gravitino
- \( SU(2)_L \) gaugino

Solves:

- higgsino mass problem
- flavor problem
- flavor problem (?)

Distinctive features:

- often unified gauginos
- variable spectrum
- long lived NLSP
- stretched spectrum
- long lived chargino spectrum: DOA
  needs extra pieces...
Generalized (Mixed) SUSY Breaking

Minimal models:

- single mediation mechanism assumed to dominate

Useful, but too restrictive!

- e.g. CMSSM: 100+ → 5 (4+sign)

bottom-up approach: perturb about CMSSM or other scenarios

Here, a complementary approach: (“deflected mirage mediation”)

Generalized (Mixed) SUSY Breaking (II)

Lesson from recent progress from top-down approach:

(moduli stabilization in string theory)

All 3 mediation mechanisms can be present, effects comparable!

“deflected mirage mediation”
Background: Mirage Mediation

KKLT scenario (Type IIB string theory)  
Kachru, Kallosh, Linde, Trivedi ’03

“Mirage mediation:”  
gridadity and anomaly mediation comparable

\[
\frac{F^T}{T + T} \sim \frac{1}{\log(M_{Pl}/m_{3/2})} \frac{F^C}{C} \sim \frac{1}{4\pi^2} \frac{F^C}{C}
\]

Choi et al. ’05, Endo et al. ’05,...
Deflected Mirage Mediation

Observable sector (SM)

Hidden sector (SUSY broken)

stabilization of $T,X$ moduli

$X$, messengers: give comparable gauge-mediated terms!

heuristically:

$$F^X \simeq -e^{K/2} K^{XX} (\partial_X \overline{W} + (\partial_X K) \overline{W})$$

$$\simeq -e^{K/2} \overline{W} (T + \overline{T})^{nx} (T + \overline{T})^{-nx} X = -m_{3/2} X$$

$$\frac{F^X}{X} \sim -m_{3/2} \sim -\frac{F^C}{C}$$

LE, Kim, Ouyang, Zurek ’08
Moral: if include $X$, messengers (generic):

gravity, anomaly, gauge mediation all comparable!

$$
\begin{align*}
\frac{F_T}{T + \bar{T}} & \sim \frac{1}{\log(M_{Pl}/m_{3/2})} \frac{F_C}{C} \\
\frac{F_X}{X} & \sim - \frac{2}{n - 1} \frac{F_C}{C}
\end{align*}
$$

More generally:

$$
\begin{align*}
\frac{F_T}{T + \bar{T}} &= m_0 \\
\frac{F_C}{C} &= \alpha_m \log(M_{Pl}/m_{3/2}) m_0 \\
\frac{F_X}{X} &= \alpha_g \frac{F_C}{C}
\end{align*}
$$

Parameters: $m_0, \alpha_m, \alpha_g, \tan \beta, \langle X \rangle, N, \{n_i\}, \text{sign} \mu$

LE, Kim, Ouyang, Zurek ’08
Deflected Mirage Mediation

Anomaly Mediation

deflected anomaly mediation

mirage mediation

Gravity Mediation

Gauge Mediation

“dial” between scenarios with tunable $\alpha_m, \alpha_g$
Superpartner Mass Spectrum

Mirage mediation result: unification at “mirage scale”

\[ M_{\text{mirage}} = M_G \left( \frac{m_3/2}{M_{P1}} \right)^{\frac{\alpha m}{2}} \]

Choi et al., ’05
“Deflected” mirage unification scale for gauginos:

\[ M_{\text{mirage}} = M_G \left( \frac{m_3/2}{M_P} \right)^{\alpha_m \rho/2} \]

\[ \rho = \frac{1 + \frac{2N g_0^2}{16\pi^2} \ln \frac{M_{\text{GUT}}}{M_{\text{mess}}}}{1 - \frac{\alpha_m \alpha_g N g_0^2}{16\pi^2} \ln \frac{M_P}{m_3/2}} \]

\[ m_0 = 2 \text{ TeV}, N = 3, \alpha_g = 1 \]

can be useful for DM constraints, fine-tuning,...

LE, Kim, Ouyang, Zurek ’08
Deflected Mirage Mediation
Collider+Dark Matter Phenomenology

$m_0 = 1 \text{ TeV}, N = 1, \alpha_g = 0.5$

K. Choi et al., 0901.0052
M. Holmes and B. Nelson, 0905.0674

Altunkaynak, LE, Kim, Nelson, Rao, in progress
Upshot

CMSSM: \(~100\)  
4 continuous, 1 discrete

DMM: \(~100\)  
5 continuous, 3+ discrete

(more general, plus connection to top-down)
Summary and Outlook

- Model-building question for **low energy SUSY**: SUSY breaking
- Deflected mirage mediation:
  - string-motivated framework for SUSY breaking
  - comparable contributions from anomaly, gravity, and gauge mediation
- **Simple framework w/ distinctive phenomenology**
  -- useful for tests of SUSY at LHC!