Deflected Mirage Mediation

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Outline of Talk

KKLT and Mirage Mediation – Mixed Gravity/Anomaly

Kachru et al proposed a scenario for stabilizing string theory moduli:

- Fix complex structure moduli with $W = \int G \wedge \Omega \to w_0$.
- Add nonperturbative dynamics to stabilize the volume modulus T

$$W = w_0 + Ae^{-aT}$$

- Break susy with an anti-D3-brane $V_{\bar{D}3} = \frac{\Delta}{(T+\bar{T})^2}$

This proposal has interesting consequences for phenomenology if one considers the soft terms induced in the MSSM (Choi et al):

- $\frac{F^T}{T+\bar{T}} \sim \frac{1}{a\langle T \rangle} \frac{F^C}{C}$; gravity contribution suppressed so that anomaly mediation is comparable.
- "mirage" unification of gauginos at an intermediate scale

What if there are additional vector-like states?

Deflected Anomaly Mediation – Mixed Anomaly/Gauge.

The problem of mixed anomaly/gauge mediation has already been treated and we can simply borrow results. (Pomarol, Rattazzi,...) Consider messengers $\psi, \tilde{\psi}$ with SM charge coupled to a SM singlet X:

$$W = \lambda X \psi \tilde{\psi}, K = X \bar{X} + \dots$$

- With no additional superpotential, X receives a soft mass on SUSY breaking. Allows Coleman-Weinberg stabilization of X. Interestingly, $F^X/X = -F^C/C$.
- With nonrenormalizable superpotential $W = X^n/\Lambda^{n-3}$,

$$\frac{F^X}{X} = -\frac{2}{n-1}\frac{F^C}{C}.$$

- Lesson: F^X/X and F^C/C can give comparable contributions to soft terms.

Our Model

Following this motivation, we propose a model with moduli/gravity mediation, anomaly mediation, and gauge mediation all active.

- N_{mess} messenger fields (assume $SU(5)$)
- Superpotential
  $W = w_0 + Ae^{-aT} + \lambda X \psi \tilde{\psi} + W_g(X) + W_{MSSM}$
- Kahler potential ("modular weights" n_i)

$$K = K_0 - 3\ln(T+\overline{T}) + (T+\overline{T})^{-n_X} X\overline{X} + (T+\overline{T})^{-n_{\Phi_i}} \Phi_i \overline{\Phi_i} + \dots$$

- Gauge kinetic functions $f_a \propto T^{l_a}$
- Uplifting term as in KKLT.

A very similar model has been studied in the context of axions in cosmology (Yamaguchi et al, this conference.)

Our Model

- Parametrize F-terms as (3 parameters m_0, α_m, α_g):

$$\frac{F^T}{T+\bar{T}} = m_0$$
$$\frac{F^C}{C} = \alpha_m \ln(m_P/m_{3/2}) m_0$$
$$\frac{F^X}{X} = \alpha_g \frac{F^C}{C}$$

- 2 additional continuous parameters: M_{mess}, $\tan\beta$.
- Discrete parameters – fix modular weights $n_{matter} = 1/2, n_{Higgs} = 1$ In gauge kinetic terms, $l_a = 1$. We also take $sign(\mu) > 0$.

Computation of Soft Terms

The soft terms induced by susy breaking can be computed from the wavefunction renormalizations and (one loop) gauge couplings:

$$
\begin{aligned}
M_a &= F^n \partial_n \log Re(\alpha_a^{-1}(\mu)) \\
A_i &= F^n \partial_n \log e^{-K_0/3} Z_i \\
m_i^2 &= -F^m F^{\bar{n}} \partial_m \partial_{\bar{n}} \log e^{-K_0/3} Z_i
\end{aligned}
$$

where

$$
Z_i(\mu) = Z_i(\Lambda_{UV}) \prod_a \left(\frac{\alpha_a(\Lambda_{UV})}{\alpha_a(X)} \right)^{\frac{2c_a}{b_a - N}} \left(\frac{\alpha_a(X)}{\alpha_a(\mu)} \right)^{\frac{2c_a}{b_a}} .
$$

- Compute UV boundary conditions
- Run RG to intermediate scale, compute threshold effects due to integrating out messengers
- Run to TeV scale

Example – Gaugino Masses

As an illustration, these are the induced contributions to the gaugino masses:

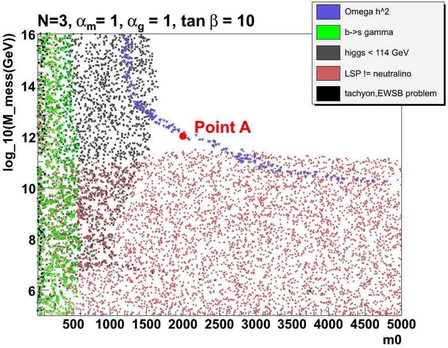
$$\begin{aligned} M_a(\mu = M_{\rm GUT}) &= \frac{F^T}{T+\bar{T}} + \frac{\alpha_{\rm GUT}}{4\pi} b'_a \frac{F^C}{C} \\ M_a(\mu = M_{\rm mess} - \epsilon) &= M_a(\mu = M_{\rm mess} + \epsilon) + \Delta M_a, \end{aligned}$$

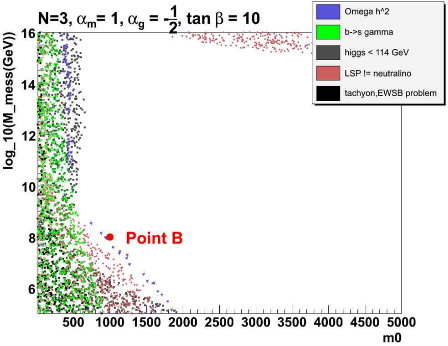
where b' is the β-function coefficient above the threshold. At the threshold,

$$\Delta M_a = -\frac{\alpha_a(M_{\rm mess})}{4\pi} N_{mess} \left(\frac{F^C}{C} + \frac{F^X}{M_{\rm mess}} \right).$$

Parameter Scan

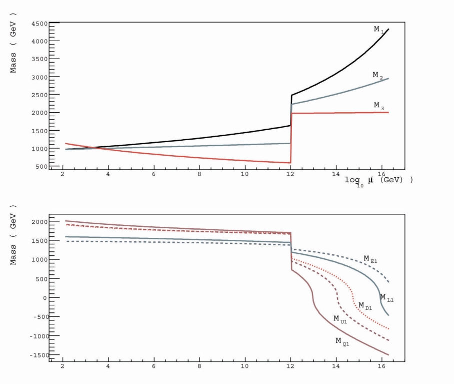
We have scanned the parameter space for interesting points subject to standard experimental constraints (here the chargino, Higgs, and dark matter relic density are most relevant.)





Let's examine these two points in detail.

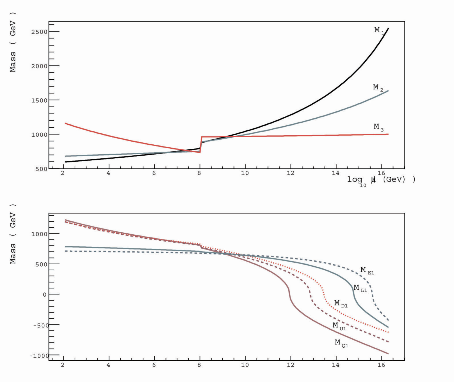
Point A



Highlights:

- Gaugino unification scale is very low; nearly unified at TeV scale with ratios $\sim 1 : 1 : 1.2$. The light gluino may be distinctive at LHC.
- LSP is mixed bino/wino (well-tempered)
- nearly conformal behavior for scalars (RG with light gluino)

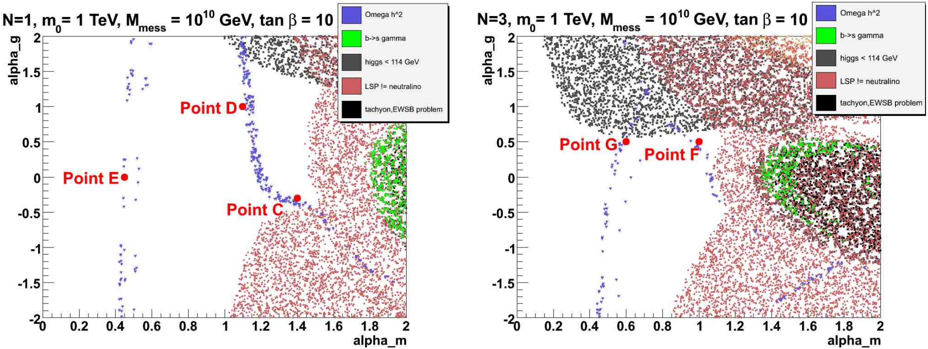
Point B



Highlights

- Higher gaugino unification scale; gaugino mass ratio at TeV is $\sim 1 : 1.1 : 2$.
- Scalars can be light; gluino is still fairly light
- Stop coannihilation gives correct DM relic density

Different Slices of the Parameter Space



- Points E and G are funnel-type
- Point C has stau coannhilation
- Points D and F are mixed coannihilation and bino/wino/Higgsino mixing

Prospects

- Rich new framework for exploring signatures of SUSY with potentially distinctive phenomenology
- Scan of parameter space in progress
- Detailed analysis of collider spectrum (footprints?)
- Could vary modular weights to generate new models (deflected gaugino mediation,...)
- Would be interesting to understand embedding of gauge mediation in a UV theory