Sparticle Masses in Deflected Mirage Mediation

KC, Jeong, Nakamura, Okumura, Yamaguchi
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Flavor and CP conserving mediation of SUSY breaking

A. Dilaton or volume modulus mediation:

$$\int d^2\theta \, \frac{1}{4} T W^{a\alpha} W^a_\alpha + \int d^4\theta \, (T + T^*)^{n_i} Q_i^* Q_i \qquad (T = T_0 + F^T \theta^2)$$

$$M_a = \frac{F^T}{T_0 + T_0^*}, \quad m_i^2 = n_i \left| \frac{F^T}{T_0 + T_0^*} \right|^2, \quad A_{ijk} = (n_i + n_j + n_k) \frac{F^T}{T_0 + T_0^*}$$

($\ni$ Scherk-Schwarz breaking or radion mediation,
No-scale model or Gaugino mediation: $n_i = 0$)

- Flavor conserving as the moduli weights n_i are flavor-universal rational numbers.

- CP conserving due to the axionic shift symmetry of T.

In flux compactification, other moduli, e.g. complex structure moduli having flavor-non-universal couplings, can be naturally decoupled from SUSY breaking.

B. Gauge mediation:

$$\int d^2\theta \, \lambda \, X \, \Phi^c \Phi$$

$$(\, \Phi, \Phi^c = \text{Gauge-charged messenger}, \quad X = X_0 + F^X \theta^2 \,)$$

$$M_a \;\sim\; m_i \;\sim\; \frac{1}{8\pi^2} \frac{F^X}{X_0}$$

C. Anomaly mediation:

$$C \;\equiv\; \text{SUGRA Compensator} \;=\; C_0 + F^C$$

$$M_a \;\sim\; m_i \;\sim\; A_{ijk} \;\sim\; \frac{1}{8\pi^2} \frac{F^C}{C_0}$$

So far, phenomenological studies of low energy SUSY have focused mostly on the case that one of these mediations dominate others.

However, it is a plausible possibility that all (or two of) three mediations give comparable contributions to the MSSM soft masses, while preserving flavor and CP:

$$\int d^4\theta\, CC^* \left[(T+T^*)^{n_C} + (T+T^*)^{n_X} XX^* + (T+T^*)^{n_Z} ZZ^* \right]$$

$$+ \int d^2\theta\, C^3 \left[A_1 M_{Pl}^3 e^{-8\pi^2 T/N_1} + A_2 \frac{X^{N_2}}{M_{Pl}^{N_2-3}} + \Delta W(Z) \right] \quad (N_2 > 3)$$

($\Delta W(Z)$ provides SUSY breaking and nearly vanishing C.C.)

- For generic $A_{1,2}$ of $\mathcal{O}(1)$, and ΔW giving $m_{3/2} \ll M_{Pl}$,

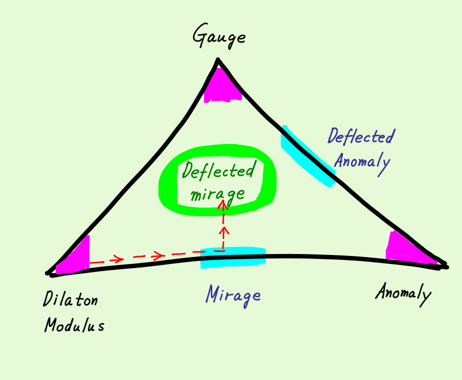
$$8\pi^2 \frac{F^T}{T_0 + T_0^*} \sim \frac{F^X}{X_0} \sim \frac{F^C}{C_0}$$

- The phases of F^T, F^C and F^X are dynamically aligned as

$$\mathrm{Arg}\left(\frac{F^C}{C_0}\right) = \mathrm{Arg}\left(\frac{F^T}{T_0 + T_0^*}\right) = \mathrm{Arg}\left(\frac{F^X}{X_0}\right) \; : \; \text{axion mechanism}$$

Sparticle Masses in Deflected Mirage Mediation

Deflected mirage mediation, being a general mixed gravity-gauge-anomaly mediation, provides a framework for more general but still theoretically well-motivated pattern of the MSSM soft parameters, which might be useful for the interpretation of experimentally measured sparticle masses.



Dilaton/Modulus (mSUGRA) $\longrightarrow$ Mirage $\longrightarrow$ Deflected Mirage

Gaugino masses and light generation sfermion masses

- Gaugino mass ratios are the least sensitive to the other details of the model such as extra matters and/or extra interactions.
- 3rd generation sfermion masses and Higgs masses might severely depend on how μ and B are generated.

mSUGRA (Dilaton/Modulus Domination)

At M_{GUT},

$$M_a = M_0, \quad m_i^2 = m_0^2 = n_0 M_0^2 \quad \left(M_0 \equiv \frac{F^T}{T_0 + T_0^*} \right)$$

At TeV,

- $M_{\tilde{B}} : M_{\tilde{W}} : M_{\tilde{g}} \simeq 1 : 2 : 6$.
- $m^2_{\tilde{q}_L} : m^2_{\tilde{u}_R} : m^2_{\tilde{d}_R} : m^2_{\tilde{\ell}_L} : m^2_{\tilde{e}_R}$

$$\simeq (n_0 + 5.0) : (n_0 + 4.6) : (n_0 + 4.5) : (n_0 + 0.5) : (n_0 + 0.15)$$

Mirage $\equiv$ Dilaton/Modulus + Anomaly

KC, Falkowski, Nilles, Olechowski, Pokorski

$$\alpha \equiv \frac{F^C/C_0}{F^T/(T_0+T_0^*)}\frac{1}{\ln(M_{Pl}/m_{3/2})}$$

$$\left(\alpha \simeq 1 \quad \text{for} \quad W = A_1 e^{-8\pi^2 T/N_1} \ : \ \text{KKLT}\right)$$

At TeV,

- $M_{\tilde{B}} : M_{\tilde{W}} : M_{\tilde{g}} \ \simeq \ (1+0.66\alpha) : (2+0.2\alpha) : (6-1.8\alpha)$

- $m^2_{\tilde{q}_L} \ : m^2_{\tilde{u}_R} \ : m^2_{\tilde{d}_R} \ : m^2_{\tilde{\ell}_L} \ : m^2_{\tilde{e}_R}$

$$\begin{aligned}\simeq \ & (n_0+5.0-3.5\alpha+0.5\alpha^2) : (n_0+4.6-3.3\alpha+0.5\alpha^2) : \\ & (n_0+4.5-3.3\alpha+0.5\alpha^2) : (n_0+0.5-0.2\alpha-0.01\alpha^2) : \\ & (n_0+0.15-0.05\alpha-0.01\alpha^2)\end{aligned}$$

Mirage unification of soft masses

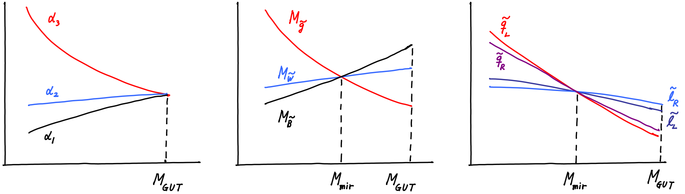
KC, Jeong, Okumura

$$\frac{1}{g_a^2(\mu)} = \frac{1}{g_{GUT}^2} - \frac{b_a}{8\pi^2}\ln\left(\frac{\mu}{M_{GUT}}\right)$$

$$M_a(\mu) = M_0 + \frac{b_a}{8\pi^2}M_0 g_a^2(\mu)\ln\left(\frac{\mu}{M_{\rm mir}}\right)$$

$$m_i^2(\mu) = m_0^2 - \frac{1}{4\pi^2}\gamma_i(\mu)M_0^2\ln\left(\frac{\mu}{M_{\rm mir}}\right) - \frac{1}{8\pi^2}\dot{\gamma}_i(\mu)M_0^2\left[\ln\left(\frac{\mu}{M_{\rm mir}}\right)\right]^2$$

$$\left(M_{\rm mir} = M_{GUT}\left(\frac{m_{3/2}}{M_{Pl}}\right)^{\alpha/2}\right)$$



Deflection from mirage unification due to gauge mediation

Everett, Kim, Ouyang, Zurek

Add "gauge mediation" with

$$\frac{F^X}{X_0} \sim \frac{F^C}{C_0} \sim \frac{1}{8\pi^2}\frac{F^T}{T_0+T_0^*}, \quad N_\Phi \equiv \#\text{ of } \Phi(5)+\Phi^c(\bar{5})$$

Effects of gauge mediation on sparticle masses at TeV:

KC, Jeong, Nakamura, Okumura, Yamaguchi

1) Renormalize the mirage parameters α and $n_0 = m_i^2(M_{\rm mir})/M_a^2(M_{\rm mir})$:

$$\alpha \;\to\; \alpha_{\rm eff} \equiv \frac{\alpha}{(1+\epsilon)}, \quad n_0 \;\to\; n_0^{\rm eff} \equiv \frac{n_0}{(1+\epsilon)^2}$$

$$\epsilon = \frac{N_\Phi}{4}\left[\frac{-F^X/X_0}{8\pi^2 F^T/(T_0+T_0^*)} - \frac{1}{4\pi^2}\ln\left(\frac{M_{GUT}}{X_0}\right)\right]$$

$$M_{\rm mir}^{\rm eff} = M_{GUT}\left(\frac{m_{3/2}}{M_{Pl}}\right)^{\alpha_{\rm eff}/2}$$

2) Deflection of sfermion masses from the mirage pattern:

- $M_{\tilde{B}} : M_{\tilde{W}} : M_{\tilde{g}} \simeq (1 + 0.66\alpha_{\rm eff}) : (2 + 0.2\alpha_{\rm eff}) : (6 - 1.8\alpha_{\rm eff})$
- $m^2_{\tilde{q}_L} : m^2_{\tilde{u}_R} : m^2_{\tilde{d}_R} : m^2_{\tilde{\ell}_L} : m^2_{\tilde{e}_R}$

$$\begin{aligned}
\simeq\ & (n_0^{\rm eff} + 5.0 - 3.5\alpha_{\rm eff} + 0.5\alpha^2_{\rm eff} + \delta_{\tilde{q}_L}) : \\
& (n_0^{\rm eff} + 4.6 - 3.3\alpha_{\rm eff} + 0.5\alpha^2_{\rm eff} + \delta_{\tilde{u}_R}) : \\
& (n_0^{\rm eff} + 4.5 - 3.3\alpha_{\rm eff} + 0.5\alpha^2_{\rm eff} + \delta_{\tilde{d}_R}) : \\
& (n_0^{\rm eff} + 0.5 - 0.2\alpha_{\rm eff} - 0.01\alpha^2_{\rm eff} + \delta_{\tilde{\ell}_L}) : \\
& (n_0^{\rm eff} + 0.15 - 0.05\alpha_{\rm eff} - 0.01\alpha^2_{\rm eff} + \delta_{\tilde{e}_R})
\end{aligned}$$

$$\delta_i = \frac{2\epsilon^2}{(1+\epsilon)^2} \sum_a C_2^a(\Phi_i) \left[\frac{4 g_a^4(X_0)}{N_\Phi} - \frac{g_a^2(X_0)}{4\pi^2} \left(\frac{1+2\epsilon}{2\epsilon} + g_a^2(X_0) \right) \ln\left(\frac{M_{GUT}}{X_0} \right) \right]$$

$\delta_i - \delta_j$ represent the true deflection from the mirage pattern, and their relative importance depends on the sign of F^X/F^T.

For $F^X/X_0 F^T < 0$, which is when X is stabilized by $X^{N_2}/M_{Pl}^{N_2-3}$, the deflection is not significant:

$$|\delta_{\tilde{q}_L} - \delta_{\tilde{e}_R}| \lesssim 0.02 N_\Phi, \quad |\delta_{\tilde{d}_R} - \delta_{\tilde{\ell}_L}| \lesssim 0.01 N_\Phi \quad \text{for } \alpha \simeq 1,\ 4 \le N_2 \le 6$$

Conclusion

Deflected mirage mediation provides a framework for quite general but still theoretically well-motivated pattern of the MSSM soft parameters, which might be useful for the interpretation of experimentally measured sparticle masses.