Gravity in gauge mediated supersymmetry breaking

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Introduction: R symmetry and supersymmetry breaking

$$K = \bar{X}X + s\frac{(\bar{X}X)^2}{\Lambda^2} + \sum_i (\bar{q}_i q_i + \bar{Q}_i Q_i) + \ldots$$

$$W = fX + \sum_{i,j} Q_i \mathcal{M}(X)_{ij} q_j + c$$

Nelson-Seiberg theorem:

(i) SUSY breaking

□

R symmetry

(ii) Spontaneous R symmetry breaking

□

SUSY breaking

s	M_P	$\mathcal{M}(X)$	SUSY minimum	~~SUSY~~ minimum
-1	∞	(hX)	$\langle X\rangle = 0$ $\langle Q\rangle \neq 0 \neq \langle q\rangle$	
$+1$	∞	(hX)	$\langle X\rangle = 0$ $\langle Q\rangle \neq 0 \neq \langle q\rangle$	depends on $\mathcal{O}(\lvert X\rvert^6)$ terms in K
-1	1	(hX)	-ǁ-	$\langle X\rangle \sim \frac{\Lambda^2}{M_P}\frac{c}{fM_P}$
$+1$	1	(hX)	-ǁ-	depends on $\mathcal{O}(\lvert X\rvert^6)$ terms in K

Kitano 2006, Shih 2007, …

The role of gravity – a simple criterion

$$W_1 = \sum_{i=1}^{N}\sum_{j=1}^{N} \tilde{\phi}_i \underbrace{(m_{ij} + \lambda_{ij} X)}_{\mathcal{M}_{ij}} \phi_j$$

In the leading order in $f/\bar{m}^2$ the effective potential can be described by:

$$\delta K = -\frac{1}{16\pi^2}\mathrm{Tr}\left[\mathcal{M}^\dagger\mathcal{M}\ln\left(\frac{\mathcal{M}^\dagger\mathcal{M}}{Q^2}\right)\right] = -\frac{n_\phi \bar{m}^2}{16\pi^2}\sum_{\ell=0}^{\infty} f_{2\ell}\cdot\left(\frac{\bar{\lambda}|X|}{\bar{m}}\right)^{2\ell}$$

Intriligator, Seiberg & Shih 2006

dimensionless functions of $\lambda_{ij}/\bar{\lambda}$ and $R_i \equiv m_i/\bar{m}$

$f_4 < 0$	$f_4 > 0$
susy breaking related to spontaneous *R* symmetry breaking	susy breaking related to soft *R* symmetry breaking transmitted through gravity

A few examples

EXAMPLE 1

- $N = 2$
- $\mathcal{M}(X) = \begin{pmatrix} \bar{m} & \bar{\lambda} X \\ 0 & R\bar{m} \end{pmatrix}$

$$f_4 = \frac{1+R^2}{2(R^2-1)^2} - \frac{R^2}{(R^2-1)^3} \ln R^2$$

EXAMPLE 2

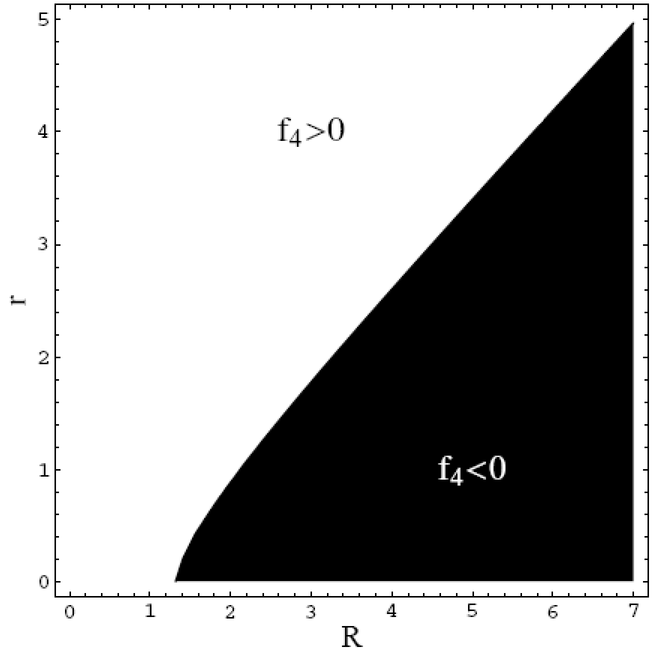
- N large
- $R_k^2 = 1 + k\delta \quad , \quad \delta \to 0$

$$f_4 \cong \sum_k q_k^2 \left(\frac{1}{6} q_k^2 + q_{k-1}^2 \left(k^2 - \frac{1}{6} \right) \right)$$

A few examples

EXAMPLE 3

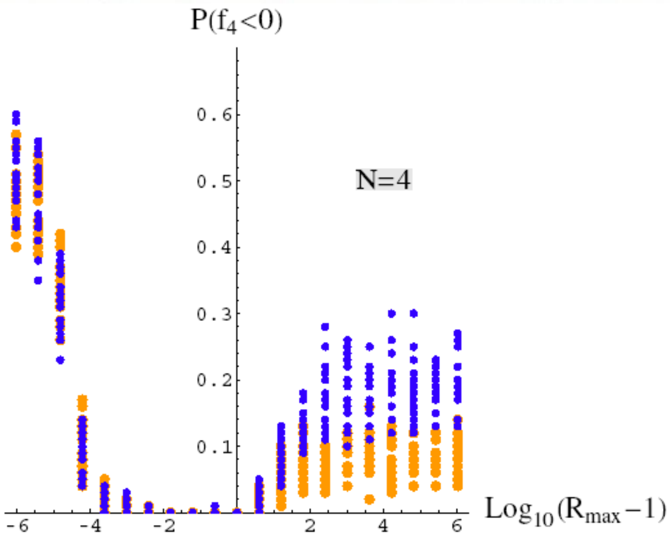
- $N = 3$
- $\mathcal{M}(X) = \begin{pmatrix} \bar{m} & \bar{\lambda}X & 0 \\ 0 & R\bar{m} & \bar{\lambda}X \\ 0 & 0 & r\bar{m} \end{pmatrix}$

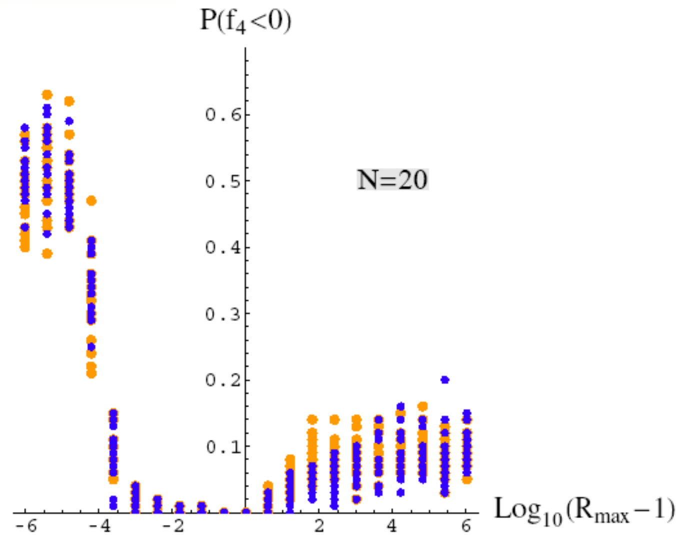


A few examples

EXAMPLE 4

- $N = 4$ or $N = 20$
- $\mathcal{M}(X)_{ij} = \bar{m} R_i \delta_{ij} + \bar{\lambda} q_i \delta_{i,j-1} X$
- $q_i \in [1,2]$, $\varrho(q_i) = const$
- $R_i \in [1, R_{max}]$
  - $\varrho(R_i) = const$
  - $\varrho(\ln R_i) = const$





The role of gravity – full supergravity potential

$$V(X) = f^2 n_\phi \left(\sum_{i=0}^{4} V_i X^i + \mathcal{O}(X^5) \right) \qquad \Lambda = 4\pi \bar{m} / (\bar{\lambda}^2 n_\phi^{1/2} |f_4|^{1/2})$$

$$V_1 = -\frac{4}{\sqrt{3} M_P}, \quad V_2 \approx \pm \frac{4}{\Lambda^2}, \quad V_3 \approx \pm \frac{4}{\sqrt{3}\Lambda^2 M_P}, \quad V_4 \approx \frac{144\pi^2 n_\phi}{\Lambda^4 \bar{\lambda}^2} \frac{f_6}{f_4^2}$$

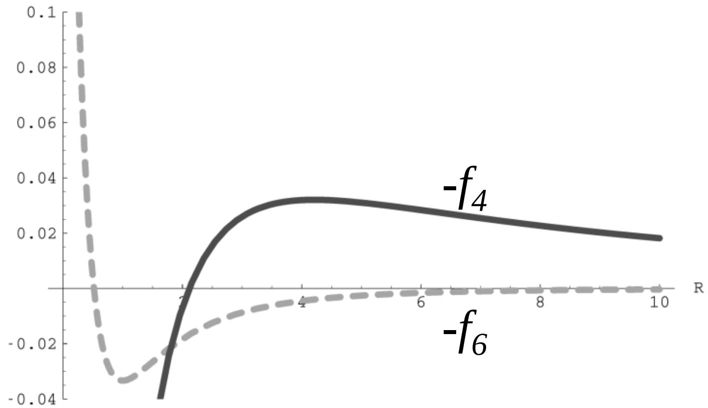
$$X \approx \frac{\Lambda^2}{\sqrt{12} M_P}$$

$$X^2 = \frac{8|f_4|}{9 f_6} \frac{\bar{m}^2}{\bar{\lambda}^2}$$

$$X^3 = -\frac{16\pi^2}{9\sqrt{3} n_\phi f_6} \frac{\bar{m}^4}{\bar{\lambda}^6 M_P}$$

$$W = m\phi_1\phi_3 + \frac{R}{2} m \phi_2^2 + \lambda \phi_1 \phi_2$$

Shih 2007



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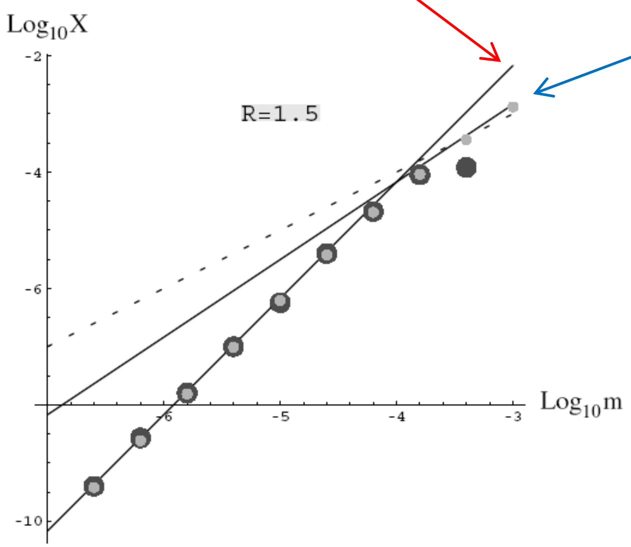

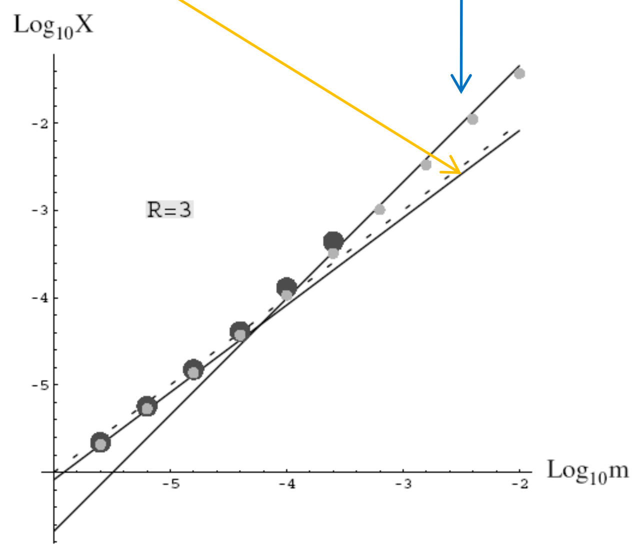

- **very often:**
supersymmetry breaking metastable minimum
related to soft R symmetry breaking
(cosmological constant cancellation)
transmitted through gravity

- **supergravity corrections constrain the scale of generalized O'Raifeartaigh models**