

# Moduli Stabilization in Stringy ISS Models

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## Summary

1. We present stringy realization of the ISS metastable SUSY breaking model with **moduli stabilization**.
2. The mass moduli of ISS model is fixed by gauging of a U(1) symmetry and its **D-term** potential.

## 1. Introduction

We want to construct ISS models from string theory!

### ISS Model

ISS model ('06): metastable SUSY breaking  
Realistic model building made easy, generic

String Theory

Q. Already many works?

A. But all of these works are done **in the global SUSY limit**, where gravity decouples and parameters put in by hand.

## 2. ISS Model

Here we consider **compact** Calabi-Yau with SUGRA and string theory with **moduli stabilization**

### Electric Theory

$SU(N_c)$  SQCD with  $N_f$  fundamentals  $\varphi_i$  and antifundamentals  $\bar{\varphi}_i$  with mass term

$$W_{\text{electric}} = m\varphi_i\bar{\varphi}^i,$$

### Magnetic Theory

$SU(N_f - N_c)$  SQCD with  $N_f$  quarks  $q_i, \bar{q}_i$  and mesons  $M_{ij}$

$$W_{\text{magnetic}} = m\text{Tr}M + \frac{1}{\mu}q^i M_{ij}\bar{q}^j + \text{nonperturbative term}.$$

Seiberg duality

SUSY broken by rank condition

$$\underbrace{m\delta_{ij}}_{\text{rank}=N_f} + \frac{1}{\mu}\underbrace{q_i\bar{q}_j}_{\text{rank}=N_c} \neq 0$$

Potential at metastable vacuum

$$V = N_c|m|^2|\Lambda|^2$$

$$V = N_c|\rho|^2|\Lambda|^2$$

## 3. Moduli Stabilization in Global SUSY Limit

Introduce **anomalous U(1)** symmetry

$\rho$	$\varphi, \bar{\varphi}$	$M$	$\Lambda^{3N_c-2N_f}$	$q, \bar{q}$	$\tilde{\Lambda}^{2N_f-3N_c}$
-2	+1	+2	$2N_f$	-1	$-2N_f$

$$\Lambda^{3N_c-N_f}\tilde{\Lambda}^{2N_f-3N_c} = (-1)^{N_f-N_c}\mu^{N_f}$$

$$V_D = \frac{g^2}{2} \left( \xi - |q|^2 - |\bar{q}|^2 - 2|\rho|^2 + 2\frac{|M|^2}{|\tilde{\Lambda}|^2} \right)^2 + (\text{higher Kahler corrections}).$$

The value of  $\rho$  now fixed?

When  $m$  becomes dynamical variable  $\rho$ ,  
 $\rho=0$  and SUSY restored!

$$V = V_D + V_F$$

### Problem

1. We need stabilization of FI parameter?
2. U(1) symmetry anomalous?

Natural solution

String Theory

# 4. Moduli Stabilization in Stringy ISS Models

Consider type IIB moduli stabilization on CY with one Kahler modulus + O7-plane and D7-branes

Brane configuration

### 1. Matter contents

$$G = U(1) \times SU(N_c)$$

	U(1)	SU(N <sub>c</sub> )
$\varphi$	+1	N <sub>c</sub>
$\tilde{\varphi}$	+1	$\tilde{N}_c$
$\rho$	-2	

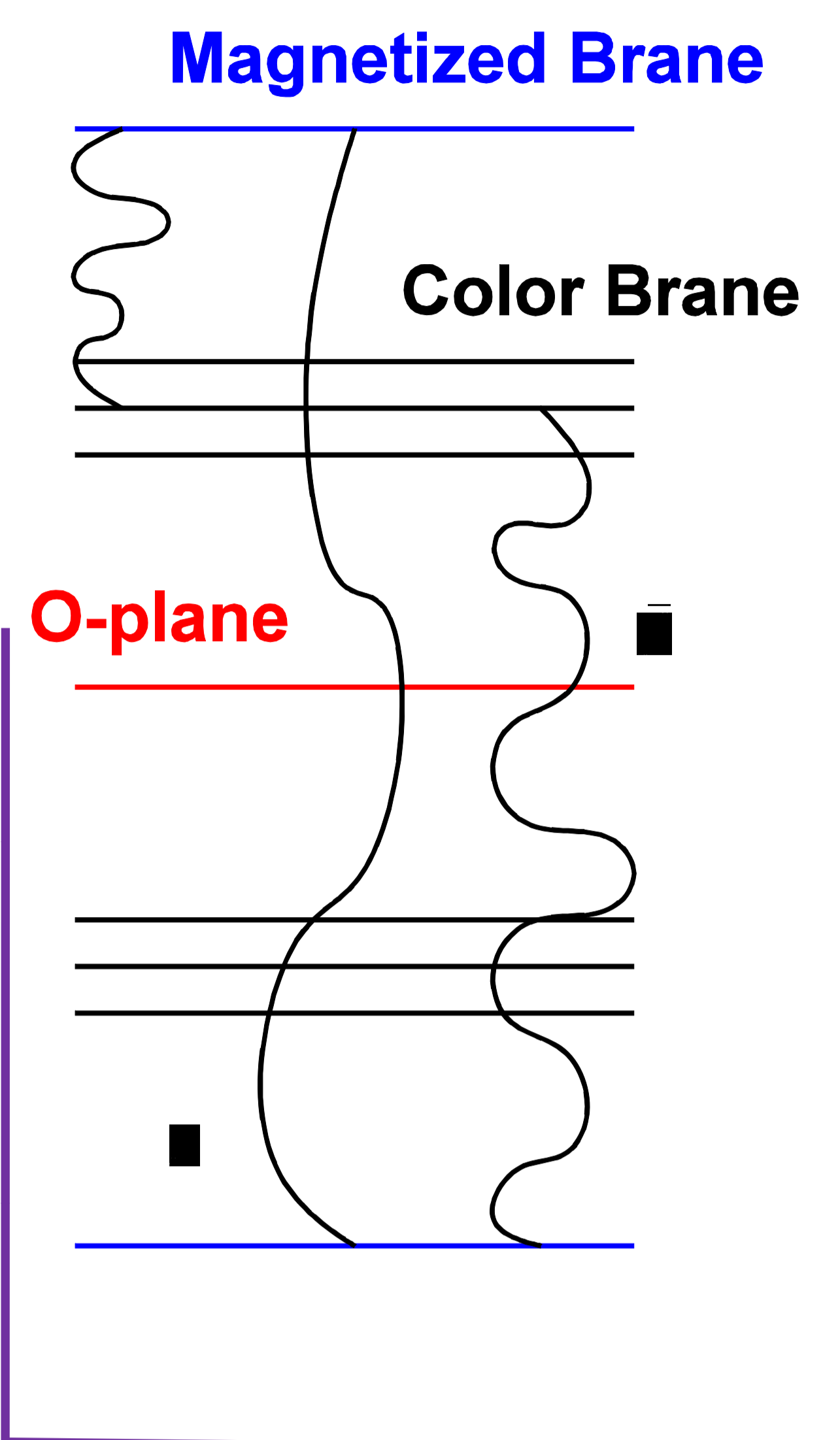
### 2. Superpotential (mass term for quarks)

$$W = \rho \varphi_i \tilde{\varphi}^i,$$

### 3. FI parameter comes from Chern-Simons coupling

$$\int_{D7} C_4 \wedge F \wedge F \quad \rightarrow \quad \int_{\Sigma} \omega \wedge f \int_{\mathbb{R}^4} D_2 \wedge F$$

$$\int_{\mathbb{R}^4} \partial_\mu \phi A_\mu$$



$$T(x; \theta) = \frac{1}{g^2}(x) + \frac{i}{8\pi^2}\phi(x) + O(\theta)$$

gauge invariant combination:  $T + T^\dagger - \frac{N_f}{4\pi^2}V$

$$\int d^4\theta K(T + T^\dagger - \frac{N_f}{4\pi^2}V) = \left(\frac{\partial K}{\partial V}\right)_{V=0} V|_{\theta^4} + \frac{1}{2} \left(\frac{\partial^2 K}{\partial V^2}\right)_{V=0} \left(\frac{\partial_\mu \phi}{2N_f} + A_\mu\right)^2 + \dots$$

FI parameter!

Super/Kahler potentials determined by construction

$$W = W_0 + \rho \text{Tr} M + \frac{1}{\mu} q^i M_{ij} \tilde{q}^j$$

$$K = -2 \log(\tau^{3/2} + \zeta) + \frac{|\rho|^2}{\tau^n} + \frac{|q|^2 + |\tilde{q}|^2}{\tau^n} + \frac{|M|^2}{\tau^n} e^{\frac{8\pi^2 \tau}{3N_c - 2N_f}}$$

$$\tau = T + T^\dagger = \frac{2}{g^2} + \text{small dilaton correction}$$

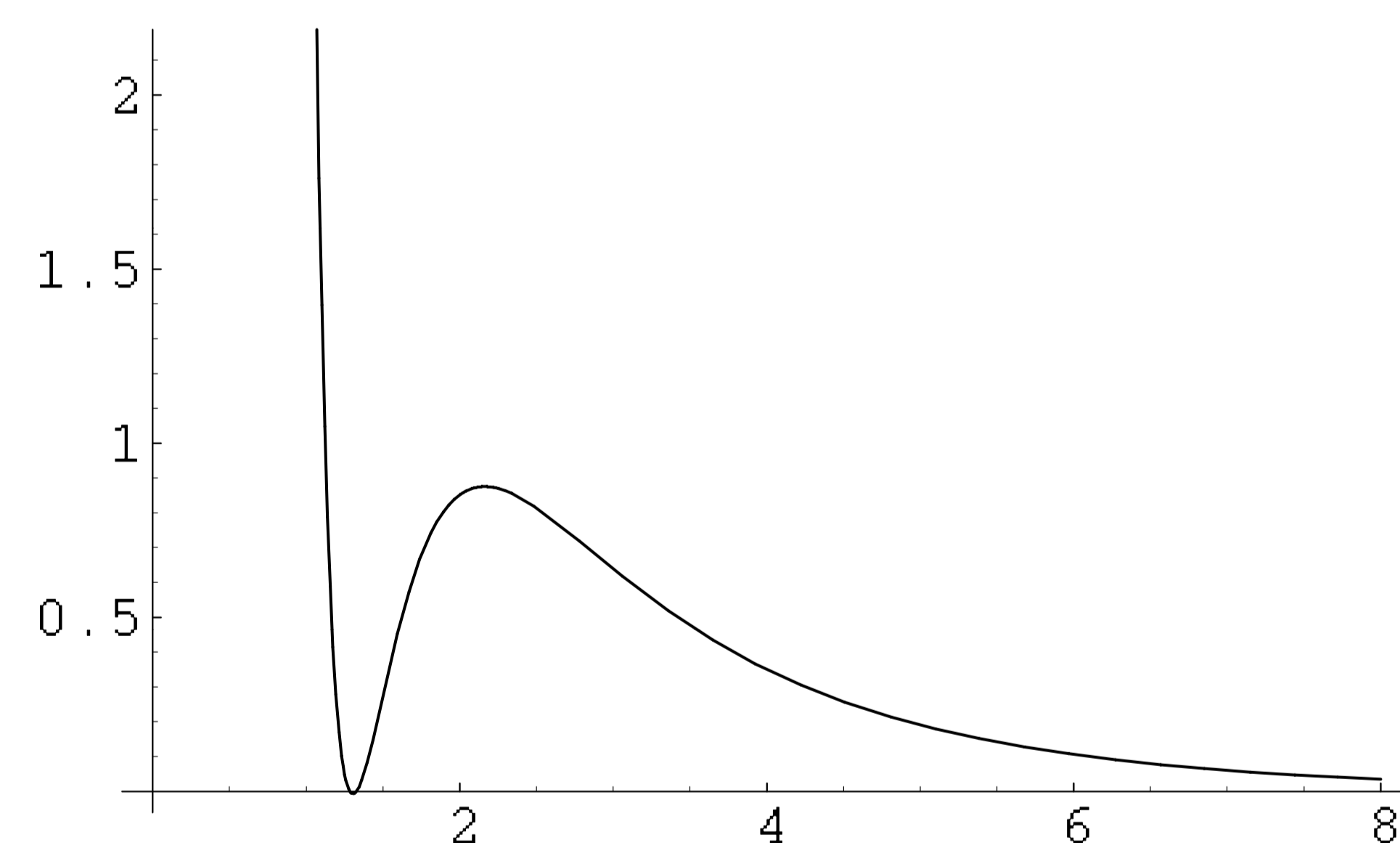
$\zeta$ :  $\alpha'$ -correction (Euler number of CY)  
n: modular weight

$$V = V_F + V_D,$$

$$V_F = e^K (K^{i\bar{j}} D_i W \bar{D}_{\bar{j}} \bar{W} - 3|W|^2),$$

$$V_D = \frac{g^2}{2} \left( \frac{-N_f}{4\pi^2} \partial_T K + \sum_i q_i \phi_i \partial_{\phi_i} K \right)^2,$$

Stabilization of moduli can be checked using SUGRA



## 5. Summary and Discussions

### Summary

- We have presented stringy realization of ISS metastable dynamical SUSY breaking vacua with **moduli stabilization**
- Mass moduli of ISS model fixed by gauging of **anomalous U(1) and its D-term**
- SUSY broken both by **D-term** and F-term
- Possible to obtain de Sitter vacua with vanishingly small cosmological constant

### Future Problem

- SUSY breaking scale  $\sim$  Planck scale  $\leftarrow$  Nakayama-Yamazaki-Yanagida, in progress
- Application to D-term gauge mediation  $\leftarrow$  Nakayama-Taki-Watari-Yanagida, ('07)