Metastable time-dependent solution in M-theory

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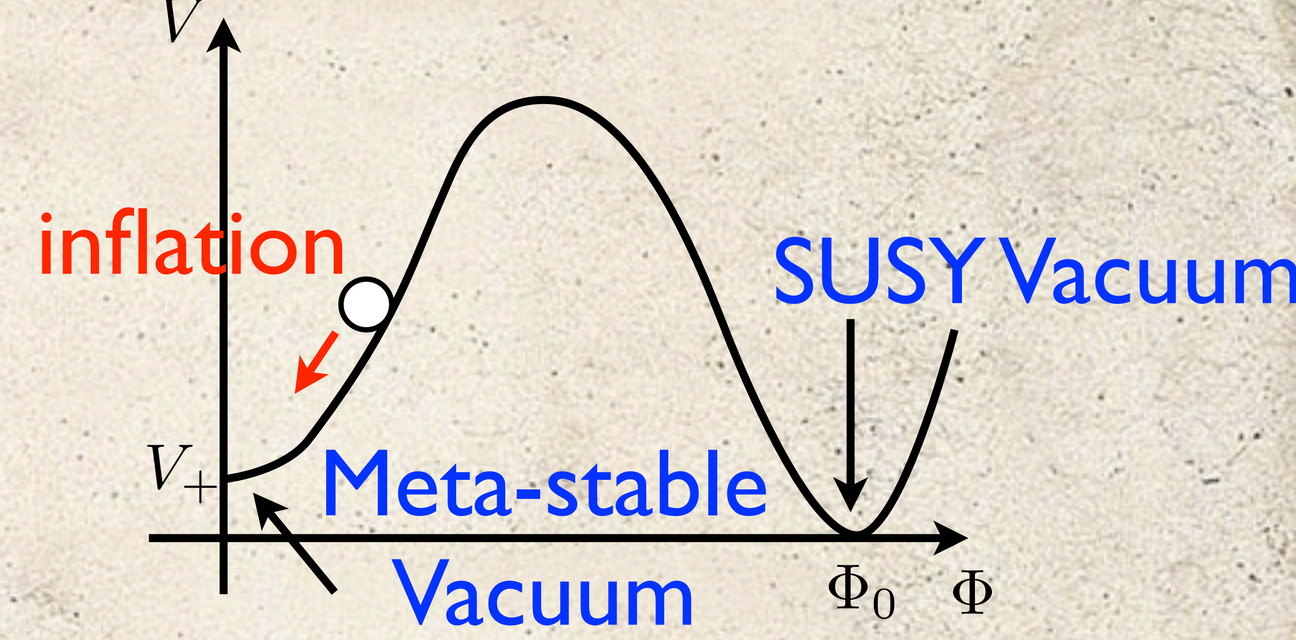
ISS meta-stable vacua

$\mathcal{N}=1$ SQCD

Intriligator, Seiberg & Shih hep-th/0602239

$W = h\mathrm{Tr}\varphi\Phi\tilde{\varphi} - h\mu^2\mathrm{Tr}\Phi$ @ tree

	$SU(N)$	$SU(N_f)$	$SU(N_f)$	$U(1)_B$	$U(1)'$	$U(1)_R$
Φ	1	$\square$	$\overline{\square}$	0	-2	2
φ	$\square$	$\overline{\square}$	1	1	1	0
$\tilde{\varphi}$	$\overline{\square}$	1	$\square$	-1	1	0



ISS-flation hybrid Inflation driven by superfield Φ

slow-roll parameter $x = \mu^{-1}\Phi$ $(x<1)$ Craig arXiv:0801.2157

$$\epsilon \approx x^2\left[(x^2-1)\log(1-x^{-2})+(x^2+1)\log(1+x^{-2})\right]^2 \ll 1$$

$$\eta \approx \left[(3x^2-1)\log(1-x^{-2})+(3x^2+1)\log(1+x^{-2})\right]^2 \ll 1$$

⇒ large num of flavors $m \ll \mu \ll \Lambda \leq M_P$

end of the slow-roll = global SUSY braeking

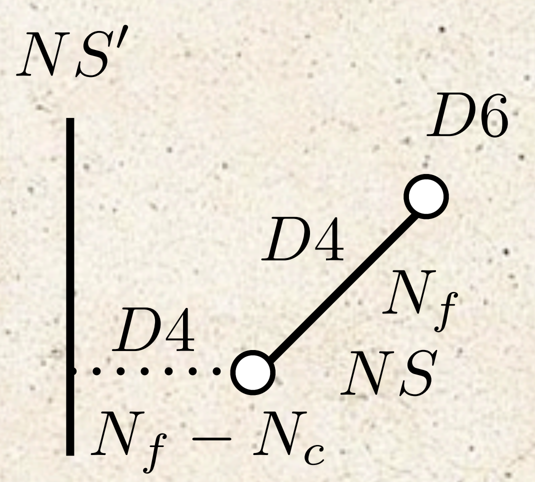
ISS vacua in type IIA

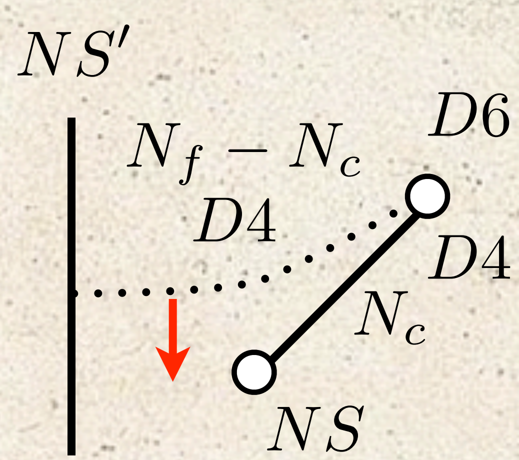
Brane configuration of SQCD

Ooguri & Ookouchi hep-th/0607183

	t	x^1	x^2	x^3	y^1	y^2	z^1	z^2	w	r
NS	○	○	○	○	○	○				
NS'	○	○	○	○			○	○		
$D4$	○	○	○	○					○	
$D6$	○	○	○	○	○	○				○

SUSY Vacuum ⇨ Meta-stable Vacuum





$(N_f - N_c)$ D4-brane's length increase dynamically

M5-M5-M5 brane

	t	x^1	x^2	x^3	y^1	y^2	z^1	z^2	v^1	v^2	r
H_A	○	○	○	○	○	○					
H_B	○	○	○	○			○	○			
H_C	○	○	○	○					○	○	

static supersymmetrical solution

$$ds^2 = (H_A H_B H_C)^{2/3} \left[(H_A H_B H_C)^{-1} \sum_{i=0}^{3} dx_i^2 + dr^2 + \sum_{\alpha=1}^{2} H_A^{-1} dy_\alpha^2 + \sum_{\rho=1}^{2} H_B^{-1} dz_\rho^2 + \sum_{\mu=1}^{2} H_C^{-1} dv_\mu^2 \right]$$

$$C_A = H_A^{-1}(r) dt \wedge dx_1 \wedge dx_2 \wedge dx_3 \wedge dy_\alpha \wedge dy_\beta$$
$$C_B = H_B^{-1}(r) dt \wedge dx_1 \wedge dx_2 \wedge dx_3 \wedge dz_\rho \wedge dz_\sigma$$
$$C_C = H_C^{-1}(r) dt \wedge dx_1 \wedge dx_2 \wedge dx_3 \wedge dv_\mu \wedge dv_\nu$$

$$\Gamma^{x_0 x_1 x_2 x_3 y_1 y_2} = -1$$
$$\Gamma^{x_0 x_1 x_2 x_3 z_1 z_2} = -1$$
$$\Gamma^{x_0 x_1 x_2 x_3 v_1 v_2} = -1$$

Maxwell equations : $\partial_r^2 H_i = 0$

Chiral condition

→ D=11 N=1/8 SUGRA ≈ D=4 N=1 SYM

Smearing Sol

Compactification on conifold = monopole in M-theory

smearing : $dv_2 \;\Rightarrow\; d\tilde{w}_2 = dw_2 + \mathcal{A} \qquad dv_1 \;\Rightarrow\; dw_1$

$$ds^2 = (H_A H_B H_C)^{2/3}\left[(H_A H_B H_C)^{-1}\gamma_{ij}dx^i dx^j + dr^2 + H_A^{-1}(dy_1^2 + dy_2^2)\right.$$
$$\left. + (H_B/H_D)^{-1}(dz_1^2 + dz_2^2) + (H_C/H_D)^{-1}dw_1^2 + (H_C H_D)^{-1}d\tilde{w}_2^2\right]$$

smeared term : $\mathcal{A} = A_1^\nu(z^2)dz^1 + A_2^\nu(z^1)dz^2 \qquad R_4(\gamma) = 0$

gauge field :

$$C_A = H_A^{-1}(r)dt \wedge dx^1 \wedge dx^2 \wedge dx^3 \wedge dy^1 \wedge dy^2$$
$$C_B = H_B^{-1}(r)H_D(w^1)dt \wedge dx^1 \wedge dx^2 \wedge dx^3 \wedge dz^1 \wedge dz^2$$
$$C_C = H_C^{-1}(r)dt \wedge dx^1 \wedge dx^2 \wedge dx^3 \wedge dw^1 \wedge d\tilde{w}^2$$

monopole condition :

$$d\mathcal{A} = *d\log H_D \;\Leftrightarrow\; \frac{1}{2}\partial_{[a}A_{b]}^\nu = \frac{H_C H_D}{H_B}\frac{\partial_\mu H_D}{H_D} \;\Rightarrow\; H_C = Q_D H_B$$

Still conserving 1/8 SUSY in M-theory

Compactify on w_ν direction ⇨ SQCD in type IIA

time-dep dipole charge

Maeda, Ohta & Uzawa arXiv:0903.5483

time-dependence $H_i(r) \ \Rightarrow \ H_i(t,r)$

crossing rule : $\#(M2 \perp M2) = 1, \ \#(M2 \perp M5) = 2, \ \#(M5 \perp M5) = 4$

this configuration is only possible to satisfy crossing rule

	t	x^1	x^2	x^3	y^1	y^2	z^1	z^2	v^1	v^2	r
Q_A	○	○	○	○	○	○					
Q_B	○	○	○	○			○	○			
Q_C	○	○	○	○					○	○	
q_A					○	○					○
q_B							○	○			○
q_C									○	○	○

conserved charge : Q_A, Q_B, Q_C dipole charge : q_A, q_B, q_C

Brane World Solution

Maxwell eqs : $\partial_t^2 H_i = 0,\ \partial_r^2 H_i = 0,\ \partial_t \partial_r H_i = 0$

Harmonic function : $H_A = Q_A r + \epsilon_{ABC} q^B q^C t$

dipole charge Constraint : $q_A q_B q_C = 0$

dipole charge brakes SUSY in dynamically

Compactify six extra dimension $(y_1, y_2, z_1, z_2, w_1, w_2)$

Einstein flame : $ds_5^2 = \Xi^{-1}(-dt^2 + dx_1^2 + dx_2^2 + dx_3^2) + dr^2$

conformal factor : $\Xi = H_A H_B H_C$

ex. $q_A = 0$ case (D4 & NS'-brane moving in type IIA)

brane cosmology $(r = 0)$ $ds_4^2 \sim \frac{1}{t}(-dt^2 + dx_1^2 + dx_2^2 + dx_3^2)$

asymptotically AdS $(r \to \infty)$ $ds_5^2 \sim \frac{1}{r^2}(-dt^2 + dx_1^2 + dx_2^2 + dx_3^2) + dr^2$

Future Works

The scale factor in not de Sitter or inflationary solution

time-dependence for monopole $H_D(z^1) \;\Rightarrow\; H_D(t, z^1)$

monopole condition : $d\mathcal{A} = *d\mathcal{B} \qquad \mathcal{B} = \log H_D(dt + dz^1)$

⇨ self-dual field : $\mathcal{C} = \mathcal{A} + \mathcal{B},\ \ d\mathcal{C} = *d\mathcal{C}$

Einstein equation : $\mathcal{R}(\gamma) \sim dC \wedge *dC$

induced metric : $\gamma_{ij}dx^i dx^j = a(t)^2(-dt^2 + dx_1^2 + dx_2^2 + dx_3^2)$

⇨ dynamically compactification

We must confirm moduli stabilization for metric function

1-loop correction derive effective cosmological constant

We must check end of inflation = fixed point at extra dim