Backreacting Flavors in the Klebanov-Witten Model via D7-branes

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Gauge/Gravity with Flavors

- Different large N_c expansions:

t'Hooft limit

$$N_c \to \infty$$

$$g_{YM}^2 N_c, \quad N_f \quad \text{fixed}$$

Planar diagrams *without* quark loops

Topological expansion in *closed* Riemann surfaces

Gauge/Gravity framework:

Karch,Katz 02, Kruczenski et al. 03, ...

Veneziano limit

$$N_c \to \infty$$

$$g_{YM}^2 N_c, \quad \frac{N_f}{N_c} \quad \text{fixed}$$

Planar diagrams *with* quark loops

Topological expansion in surfaces with *boundaries*

Graña,Polchinski 01,

Bertolini et al. 01, ...

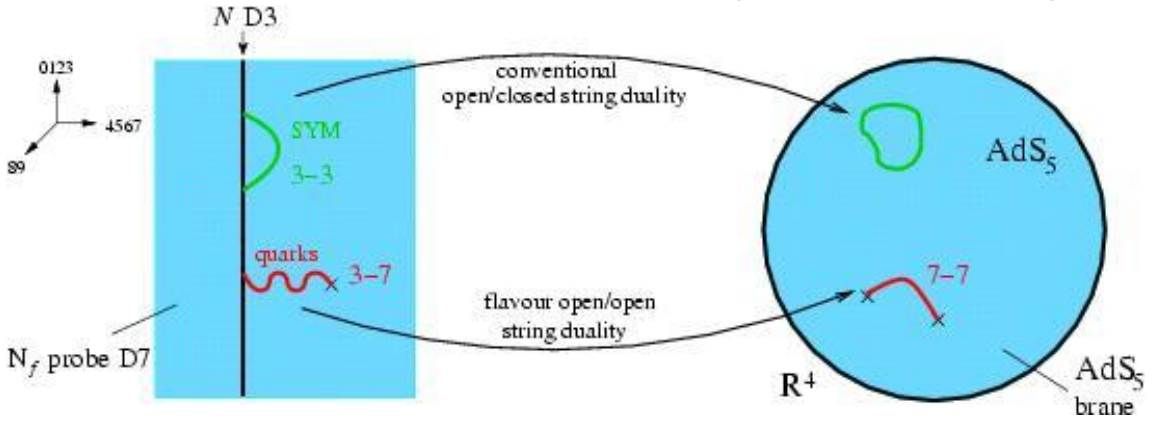
Some phenomena visible with fundamentals:

- screening of color charges, breaking of flux tubes
- Seiberg duality
- meta-stable SUSY breaking vacua

non-AdS/non-CFT with Flavors

Add flavors to the Gauge/Gravity correspondence as *higher dimensional flavor branes*: D7-branes Karch,Katz 02

Field Theory side: $g_s N_c \ll 1$ Gravity side: (near horizon) $g_s N_c \gg 1$



D7-branes are *not* replaced by flux:

Flavor symm in Field Theory $\longleftrightarrow$ Gauge symm on D7-branes

t'Hooft limit: N_f fixed $g_s N_f \to 0$

Veneziano limit: N_f / N_c fixed $g_s N_f \gg 1$ fixed

Backreacting flavors on the KW background

Outline:

- D3-branes on a *conifold* geometry
- Procedure for adding *backreacting* D7-branes
- The supergravity solution
- Comparison with field theory
- Addition of *fractional branes*
- Conclusions

D3-branes on the Conifold

Gravity side:

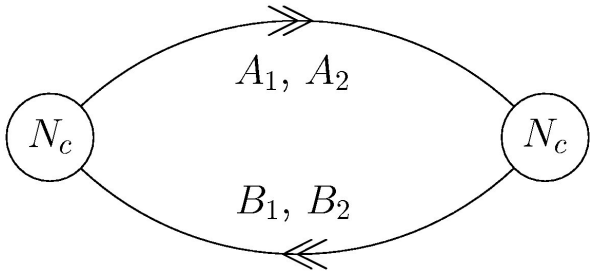
N_c D3-branes at the tip (near horizon) $\Rightarrow$

- $AdS_5 \times T^{1,1}$
- N_c units of RR 5-form flux on both factors
- constant dilaton

Field Theory side:

Gauge theory: $SU(N_c) \times SU(N_c)$ $\mathcal{N} = 1$ Superconformal

Matter: bifundamental $A_{1,2}$ and $B_{1,2}$



Superpotential:

$$W = A_1 B_1 A_2 B_2 - A_1 B_2 A_2 B_1$$

Flavor symmetries:

$$SU(2)_\ell \times SU(2)_r \times U(1)_R \times U(1)_B$$

We are going to add *flavor D7-branes* to this background

D7-branes: Computation of the Backreaction

Procedure:

Casero,Nunez,Paredes 05

- Find SUSY D7 probes

  The background is $\mathcal{N} = 1$ superconformal: 8 supercharges

  The D7's preserve only 4 supercharges

- Compute the backreaction of the D7's

  D7-branes provide energy (Einstein and dilaton eqns)

  and F_1 flux (also EOMs for fluxes)

- The solution would have a non-trivial angular profile

- Smearing

  Distribute the D7's along the angular directions (N_f large)

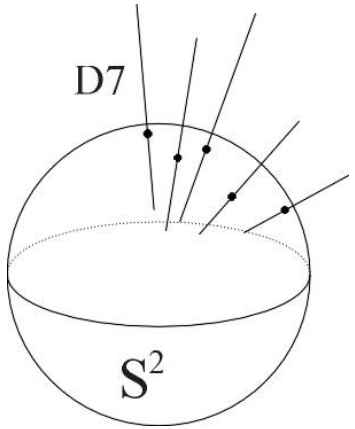
  Kill the angular dependency

  $\Rightarrow$ Ansatz with *only radial functions*

- Solve the SUSY equations and check the EOMs

The Smearing Procedure

With (magnetic) sources
Bianchi identities are violated:



$$dF_1 = -\sum_{i=1}^{N_f} \delta^{(2)}(\mathrm{D7}_{(i)})$$

Homogeneous angular distribution (at large N_f):

$$dF_1 = -\sum_{i=1}^{N_f} \delta^{(2)}(\mathrm{D7}_{(i)}) \quad \rightarrow \quad -\Omega_2$$

This comes from the DBI and WZ actions:

$$S_{WZ} = \sum_{i=1}^{N_f} \int_{D7_{(i)}} C_8 \qquad \rightarrow \int C_8 \wedge \Omega_2$$

$$S_{DBI} = \sum_{i=1}^{N_f} \int_{D7_{(i)}} e^{\phi} \sqrt{-\hat{g}}\, d^8\xi \quad \rightarrow \quad \dots$$

Ansatz for the Backreacted Solution

In our setup, Ω_2 is computed to be:

$$\Omega_2 = \frac{N_f}{4\pi}\left(\sin\theta_1\, d\theta_1 \wedge d\varphi_1 + \sin\theta_1\, d\theta_1 \wedge d\varphi_1\right)$$

Ansatz: $SU(2)_\ell \times SU(2)_r \times U(1)_R$ isometry

$$ds_{10}^2 = h^{-\frac{1}{2}}\, dx_{1,3}^2 + h^{\frac{1}{2}}\, ds_6^2$$

$$ds_6^2 = dr^2 + \frac{e^{2g}}{6}\sum_{i=1,2}(d\theta_i^2 + \sin^2\theta_i\, d\varphi_i^2) + \frac{e^{2f}}{9}(d\psi + \sum_{i=1,2}\cos\theta_i\, d\varphi_i)^2$$

$$e^{\phi} = e^{\phi(r)}$$

$$F_5 = (1 + *)\, d^4x \wedge dh^{-1}$$

$$F_1 = \frac{N_f}{4\pi}(d\psi + \sum_{i=1,2}\cos\theta_i\, d\varphi_i)$$

Unknow functions: $h(r)$, $g(r)$, $f(r)$, $\phi(r)$.

The Supergravity Solution

The system can be analytically integrated (many integr consts)

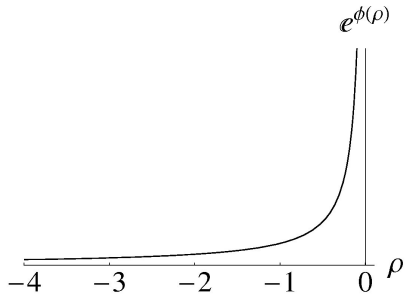
Change radial variable $r \to \rho$: $e^{-f} dr = d\rho$

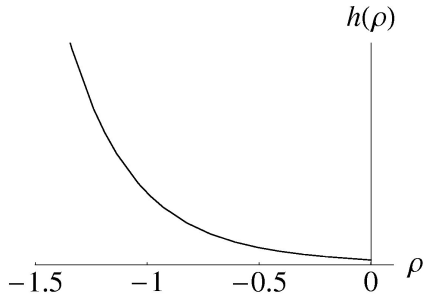
$$e^{\phi} = \frac{4\pi}{3N_f} \frac{1}{(-\rho)}$$

$$e^{g} = (1-6\rho)^{1/6} e^{\rho}$$

$$e^{f} = (-6\rho)^{1/2} (1-6\rho)^{-1/3} e^{\rho}$$

$$h = -27\pi N_c \int_0^{\rho} e^{-4g} + c_2$$





- The warp factor $h(\rho)$ can be analytically integrated
- The solution is defined in: $-\infty < \rho < 0$
- $\rho = 0$ (UV): the dilaton blows up – Landau pole
- $\rho \to -\infty$ (IR): up to logarithmic correction of order $1/|\log(r)|$ the geometry approaches $AdS_5 \times T^{1,1}$ with $e^{\phi}(r) \to 0$
  The Einstein frame curvature is finite

The Dual Field Theory

Gauge theory: $SU(N_c) \times SU(N_c)$ $\mathcal{N} = 1$

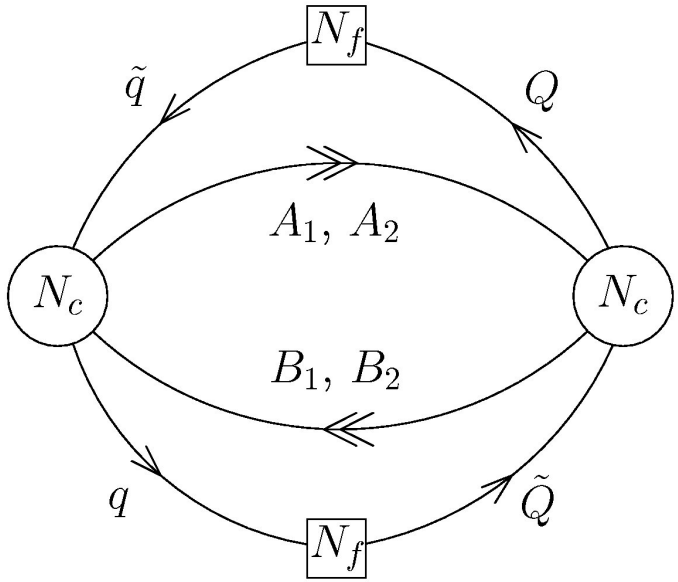
Flavor symmetry: $U(N_f) \times U(N_f)$ (partially anomalous)

Matter: $A_{1,2}$ and $B_{1,2}$ bifundamentals

D7 matter: q, $\tilde{q}$, Q, $\tilde{Q}$ fundamentals

Superpotential (localized D7's):

$$W = A_1 B_1 A_2 B_2 - A_1 B_2 A_2 B_2 + \tilde{q} A_1 Q + \tilde{Q} B_1 q$$



Smearing: only the superpotential (cubic coupling) is affected

Appears a linear combination of A_i and B_j

Having added flavors to a conformal theory, we expect *positive β-function*

Comparison with Field Theory and Extensions

- Matching of β-functions and $U(1)_R$ anomaly

Compute: gauge couplings g_i (from e^{ϕ})
YM theta angles θ_i^{YM} (from C_0)

β-functions: β_{g_i} are positive
Match γ_A and γ_q at almost conformal point

$U(1)_R$ anomaly: $U(1)_R \times U(1)_B \quad \rightarrow \quad \mathbb{Z}_{N_f} \times U(1)_B$

- Extensions:
  - Massive flavors: SUGRA solution for massive flavors
    Check of holomorphic decoupling
  - Generic Calabi-Yau singularities

    SUGRA solution with backreacting D7's
    for every $AdS_5 \times M_5$ (Sasaki-Einstein)

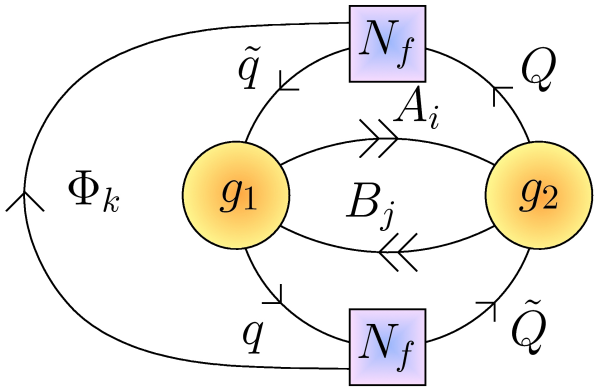
Addition of Fractional Branes

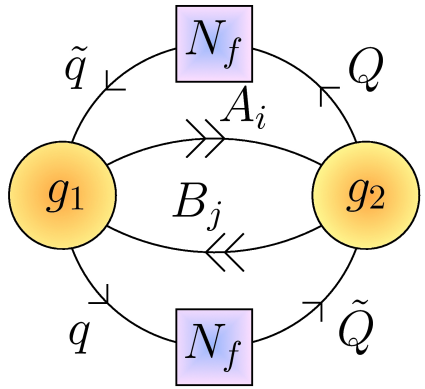
★ Field Theory side

Realize different gauge ranks: $G_1 > G_2$

RG flow: cascade of Seiberg dualities
both ranks and their difference reduce

Extra gauge singlet fields involved





★ Gravity side

Add 3-form flux: F_3 and H_3

$P_{D7}[H_3] \neq 0 \quad \Rightarrow \quad$ forced to put gauge flux $\mathcal{F}$ on the D7's

SUGRA solution with 3-form flux + backreacting D7's with $\mathcal{F}$

- Matching of the cascade:

  Page charges $\rightarrow$ mathing of gauge rank cascade

  Intersecting D7 with flux $\mathcal{F}$ $\rightarrow$ extra gauge singlets

Conclusions

- System of D3 + D7 backreacting branes on Conifold (*flavored* KW model)
- SUGRA solution (in terms of analytic functions)
- Dual field theory
- Perfect matching of:
  - gauge and flavor symmetries
  - β-functions
  - anomalies
- System of fractional D3 + D7 with flux $\mathcal{F}$ on Conifold (*chirally flavored* KT model)
- SUGRA solution (in terms of analytic functions) Matching with the field theory cascade