$N=2$ Gauge-Gravity Duals

Gauge-gravity duals with reduced supersymmetry and no conformal invariance—

- General remarks

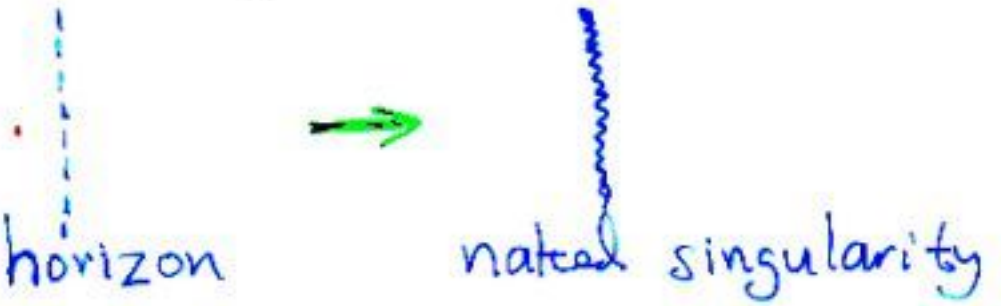
  Johnson, Peet, JP hep-th/9911161

  JP, Strassler hep-th/0003136

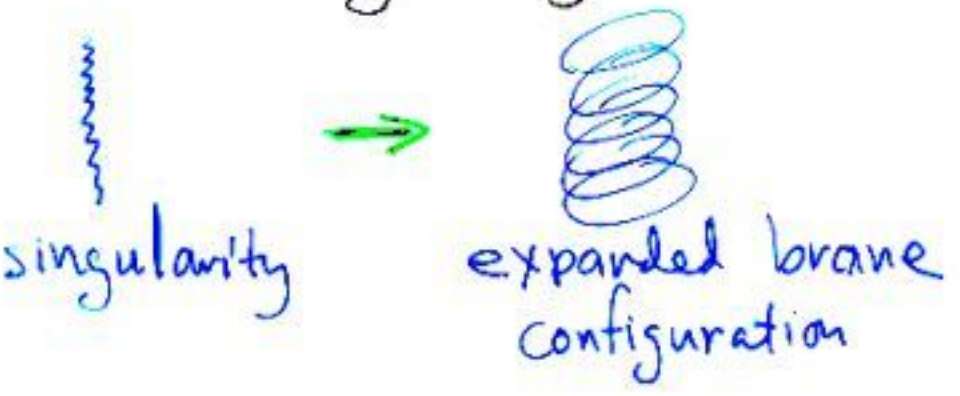
- Recent work
  - in part with Buchel, Peet

Gauge theory ➡ Gravity

When conformal symmetry of AdS is broken, generally in supergravity



but in full string theory



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Mechanisms –

- brane polarization (Myers effect)
  (e.g. $N=4 \to N=1$)

JP + Strassler; talks by Myers, Strassler

- branes "melting" into field theory soliton

Johnson, Peet + JP; talk by Johnson
= "enhançon"

How general? Conjecture: for any singularity with large brane charge N (or: approximate SUSY + sugra description).

Note – in Randall-Sundrum, expanded branes = low energy branes = our world

Gauge Theory ⟵ Gravity

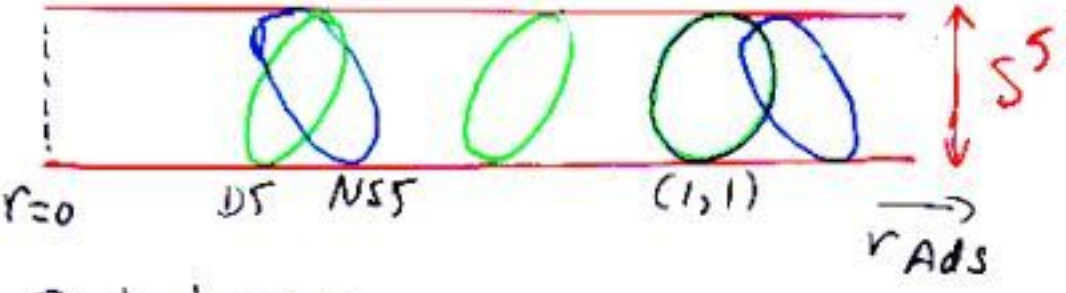
- Now have a string theory solution to a 4-d confining gauge theory (Strassler talk)

Long term goal: solve large-N QCD.

Short term goal: go beyond approximation that D3-branes dominate dynamics, to full sugra solution.

Needed to understand:

- phase with many branes



- $r \to 0$ behavior

* transitions

For $N = pq$, p D5-branes of radius q and q NS5-branes of radius p describe the same phase (p electric charges or q magnetic charges are screened).

$$g < \frac{q}{p} \Rightarrow \text{D5 description}$$

$$g > \frac{q}{p} \Rightarrow \text{NS5 description}$$

Approximations break down at $g \sim q/p$ - how to describe transition?

- within sugra?
- via 7-branes?
- something more exotic?

Some recent results —

Can break to $N=2$ via

(1) orbifolding (w/ fractional branes)

... Klebanov + { Nekrasov, Tseytlin, Strassler } $N=1$

(2) mass perturbation

NOTE:

(1) $N=2$ matter (2) light $N=4$ matter

—

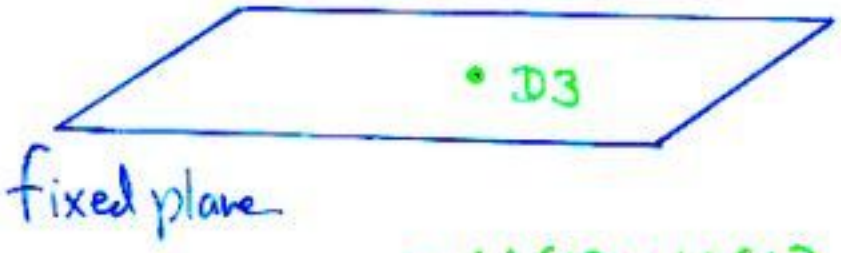
Outline:

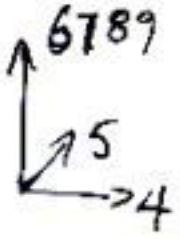
- General sugra solution and singularity resolution (via enhançon) for (1)

- Analysis of a solution of Pilch+Warner in case (2) w/ Buchel, Peet

"Fractional Branes".

Orbifold IIB by $\mathbb{Z}_2$ reflection of $X^{6,7,8,9}$:





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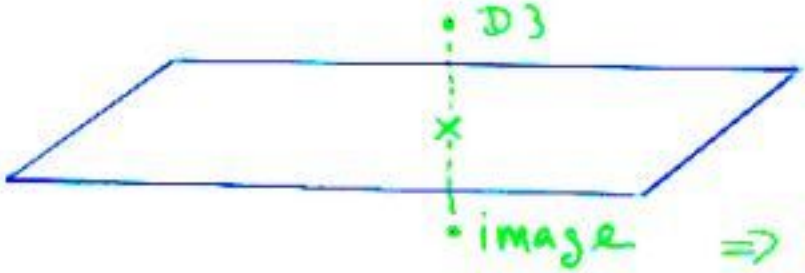
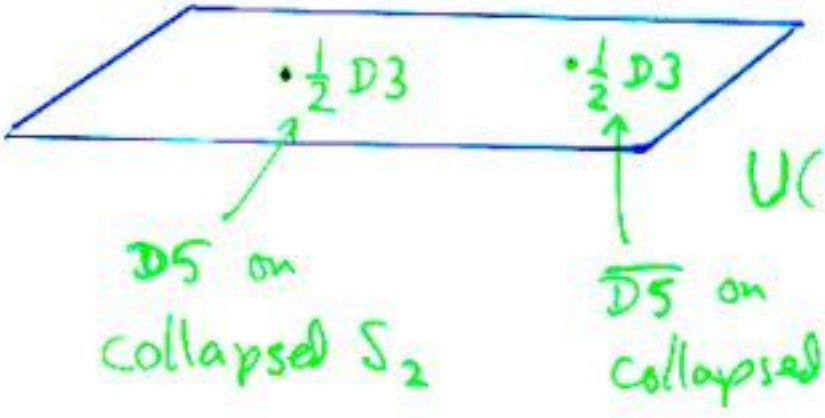
$\Rightarrow U(1) \times U(1)$

Higgs branch:



$\Rightarrow U(1)$

Coulomb branch:



$U(1) \times U(1)$

- $D5/\overline{D5}$ mutually BPS (no force)
  because S_2 has zero size
- correct coupling to twisted states
- $$Q_3 = Q_5 \times \frac{\theta}{2\pi} + n$$
  $\frac{\theta}{2\pi}$: $B \wedge C_{(4)}$; n: $F \wedge C_{(4)}$

  and $\theta = \pi$ for orbifold.
- $T \propto |Q_3|$, $T \to 0$ as $Q_3 \to 0$
- Must restrict to $Q_3 \geq 0$ (BPS).

Let $0 < \theta < 2\pi$.

A. $D5 + \frac{\theta}{2\pi} D3$: $U(1)$

B. $\overline{D5} + \left(1 - \frac{\theta}{2\pi}\right) D3$: $U(1)$

C. $D5 + \left(N + \frac{\theta}{2\pi}\right) D3$: $U(N+1) \times U(N)$

$C \sim (N+1)A + NB$

- as θ varies, D3 flows to sugra fields (~ Taylor)
- as θ passes through $2\pi \times$ integer, gauge group jumps (note: tensionless string phase)

D. $K\,D5 + \left(N + K\frac{\theta}{2\pi}\right) D3$: $U(N+K) \times U(N)$

$K << N \Rightarrow$ small β-function

Want sugra for D.

Klebanov, Strassler, Nekrasov

linearized solution, first order in K/N:

$$C_{(2)} + \tau B_{(2)} = 2\pi\alpha' \omega_{(2)} \gamma(z)$$

$\omega_{(2)}$: 2-form on collapsed cycle

$\gamma(z)$: holomorphic in $z = x^4 + i x^5$

Klebanov + Nekrasov

$\gamma \sim \gamma + 2\pi \sim \gamma + 2\pi\tau$, so

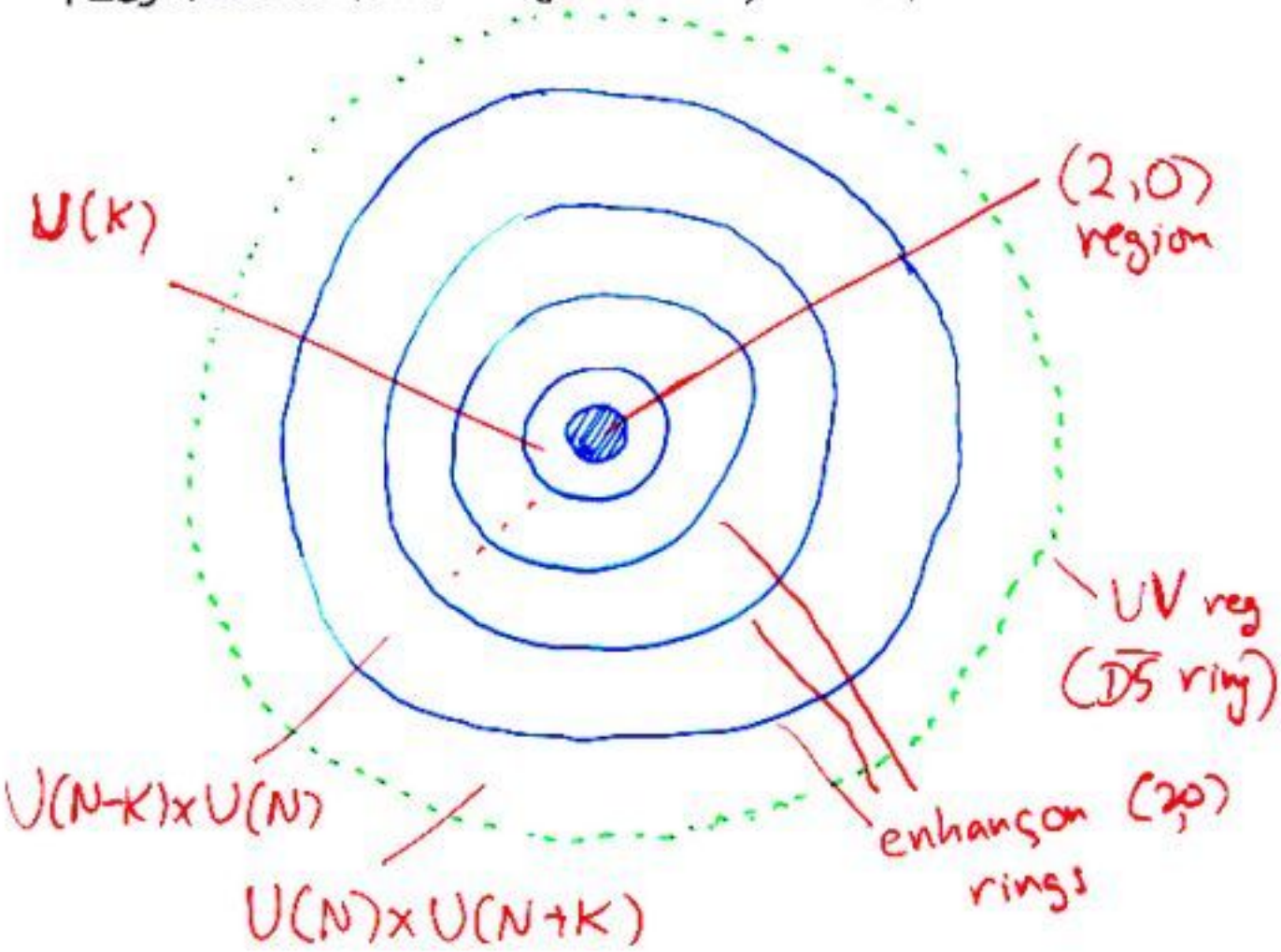
$$\gamma(z) = -iK \ln z \approx K \text{ D5's.}$$

Backreaction on other fields: $F_{(3)}$, $H_{(3)}$ enter precisely like D3 density, so we use black p-brane Ansatz with

$$\nabla^2 H = |\partial_z \gamma|^2 \delta^4(x^{6,7,8,9}) + \text{explicit D3 sources}$$

Repulson singularity ($G_{uv} \to \infty$) near $z = 0$: must repair as in Johnson, Peet, JP

Resolved solution (x^4-x^5 plane):



$\theta = \text{Im}\,\tau = \frac{1}{2}$ at ∞, decreases through integers on enhancon rings

# of rings $\approx N/K$ / moduli space validity

A puzzle: $U(1) \times U(1)$ Coulomb branch

Save —

What is

?

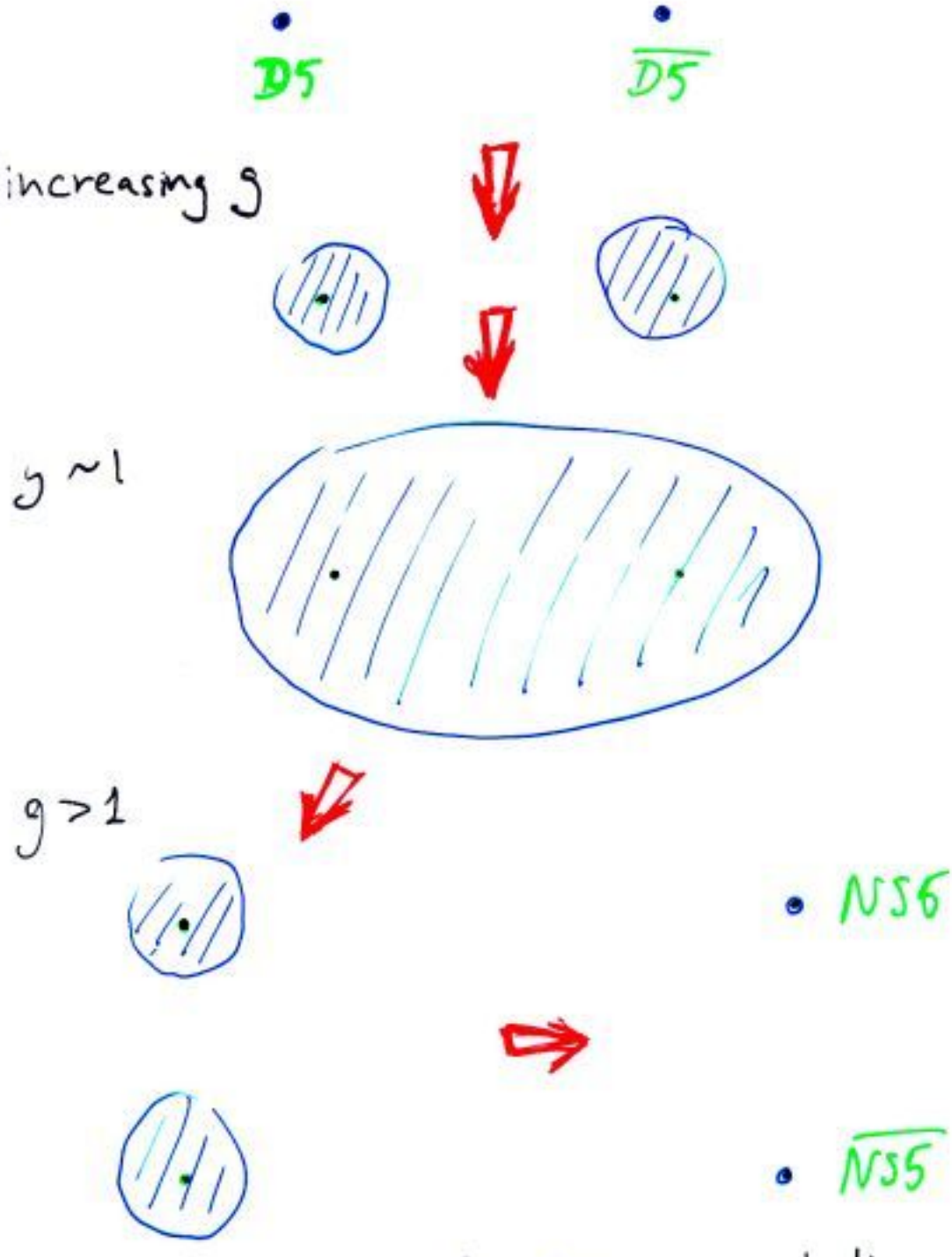
Coulomb branch is self-$\hat{S}$-dual

so these are the same?

Yes! One is small g, one large g.

How?

$g << 1$



cf Potsdam '99 talk

$\mathcal{N}=4 \Rightarrow \mathcal{N}=2$ by mass perturbation.

So far, harder - solution known only at one point of moduli space (Pilch + Warner, hep-th/0004063),

by lifting $d=5$ solution.

- Investigate physics of $D3$-brane probe (with Buchel, Peet):

  * Potential vanishes only in X^4-X^7 plane (expected moduli space)

  * Gauge + kinetic terms can be put in $\mathcal{N}=2$ form.

  * Enhançon (where $\Phi \to \infty$, $D1$ tension $\to 0$) is a line: ("$X^4 + iX^7$")

    (not limit of PS).

** One loop metric on moduli space is exact where it is positive — cut off by enhancon where it vanishes.

DETERMINES PART OF SUGRA, ANYWHERE ON MODULI SPACE

** Splittings due to $N=4$ breaking << splitting due to gauge symmetry breaking:

$$\frac{1}{g} \sim N \ln \frac{\phi^2+m^2}{\phi^2} \Rightarrow$$

$$\frac{m^2}{\phi^2} \approx \frac{1}{gN}$$

** Can turn on $B_{\mu\nu}$, study interplay between noncommutativity and symmetry breaking.

Conclusion –

- Still some interesting puzzles and systems.
- May be possible to get a much more complete description of perturbed $d = 10$ theories.