Anti-brane polarization and giant tachyons

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Anti-branes in flux backgrounds: references

1410.7776, 1402.2294 Bena, Graña, Kuperstein, SM

1407.6007 SM, Pasini, Puhm

1310.0015 Dymarksy, SM

1504.00656 Bena, Kuperstein

1502.07627 Bergshoeff, Dasgupta, Kallosh, Van Proyen, Wrase

1502.01234 Danielsson

1502.00927 Gautason, Truijen, Van Riet

1501.06568 Hartnett

1412.5702 Michel, Mintun, Polchinski, Puhm, Saad

1409.0534 Blåbäck, Danielsson, Junghans, Van Riet, Vargas

1402.6040 Junghans, Schmidt, Zagermann

Previous works:

Bena, Graña, Giecold, Halmagyi, Kuperstein, SM 12-13

Blåbäck, Danielsson, Junghans, Van Riet, Wrase, Zagermann 11-14

Bena, Buchel, Dias 12 Dymarsky, 11 McGuirk,Shiu, Sumitomo 09

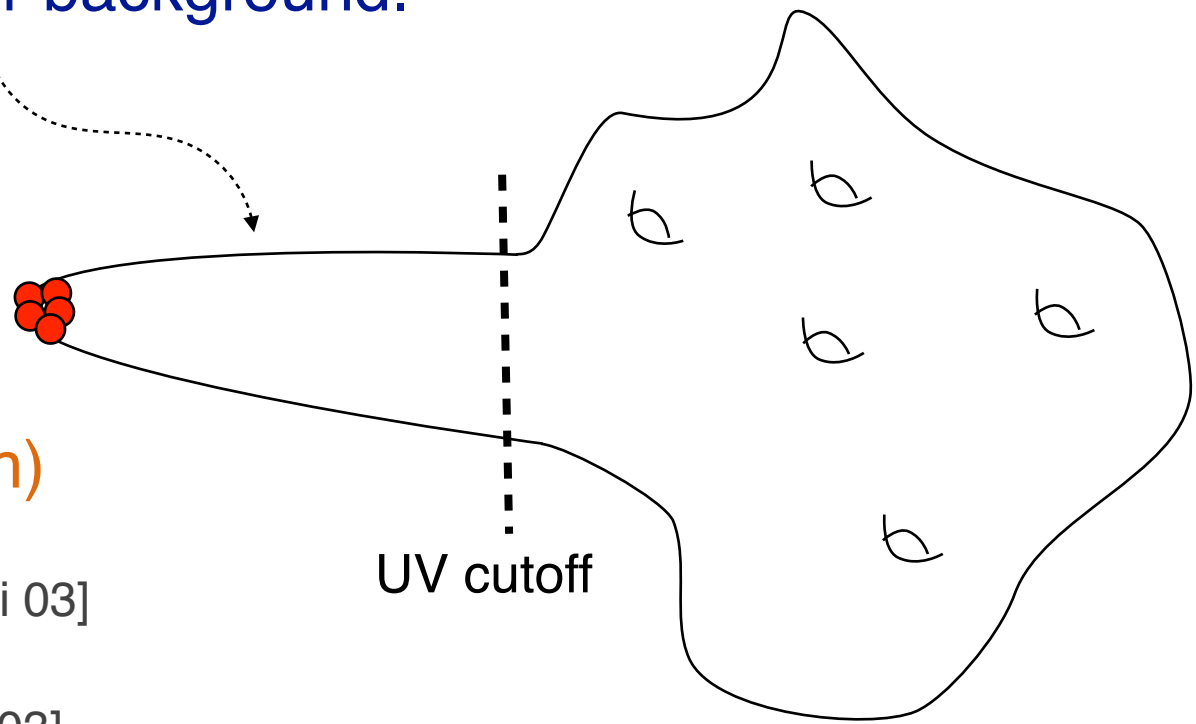
Bena, Graña, Halmagyi 09 + many others

Motivations

De Sitter vacua

• Anti-D3 branes at the tip of a warped throat: generic way to *uplift* an AdS vacuum (previously stabilized) to a dS one with small cosmological constant.

Local non-compact model:
Klebanov-Strassler background.



(see talk by R. Kallosh)

[Kachru, Kallosh, Linde, Trivedi 03]

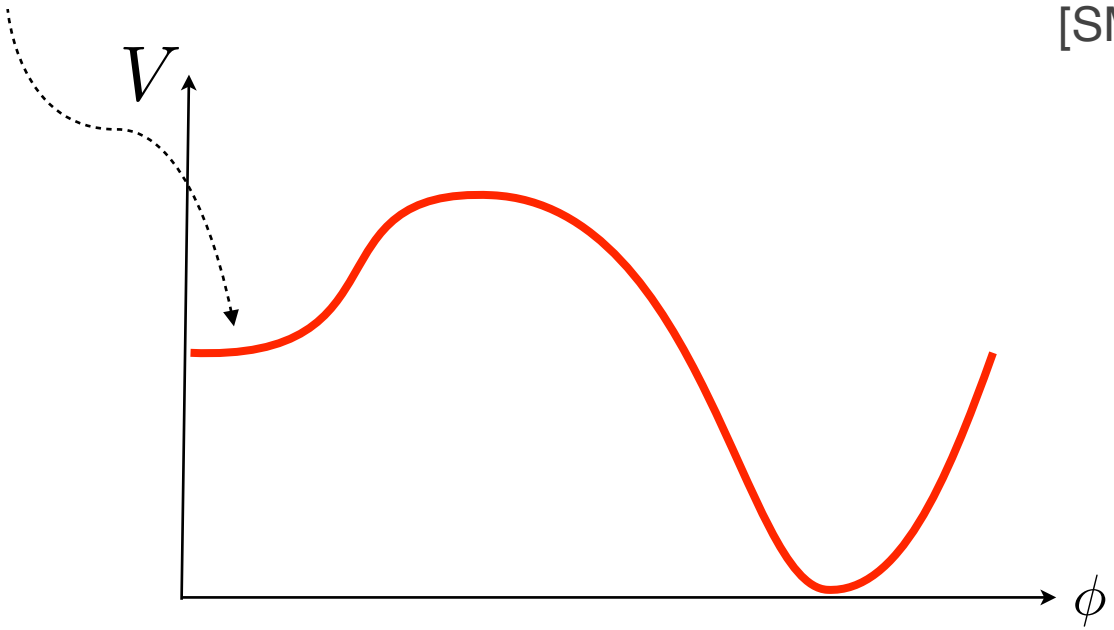
[Kachru, Kallosh, Linde, Maldacena, McAllister, Trivedi 03]

Non-SUSY holography

- Flux backgrounds dual to interesting N=1 theories.
- Non-BPS branes:
  dynamical SUSY breaking in metastable states.

Hard due to strong coupling:
ideal problem for holography.

[Maldacena, Nastase 01]
[Kachru, Pearson, Verlinde 01]
[Intriligator, Seiberg, Shih 06]
[SM, Pasini, Puhm 14]
[…]



Non-extremal BH microstates

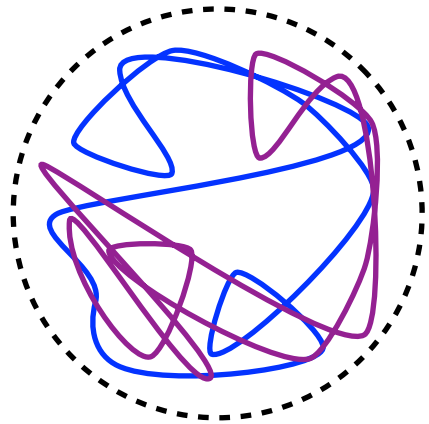
• Bubbles with fluxes: mechanisms to resolve SUGRA singularities up to horizon scale. Works well for extremal BHs.

Fuzzball proposal: O(1) corrections at horizon.

Add metastable supertubes in bubbling backgrounds
→ near-extremal black hole microstates.

[Bena, Puhm, Vercnocke 12]

• Useful for de Sitter microstates?



Anti-D3 branes dynamics

Klebanov-Strassler (KS) geometry

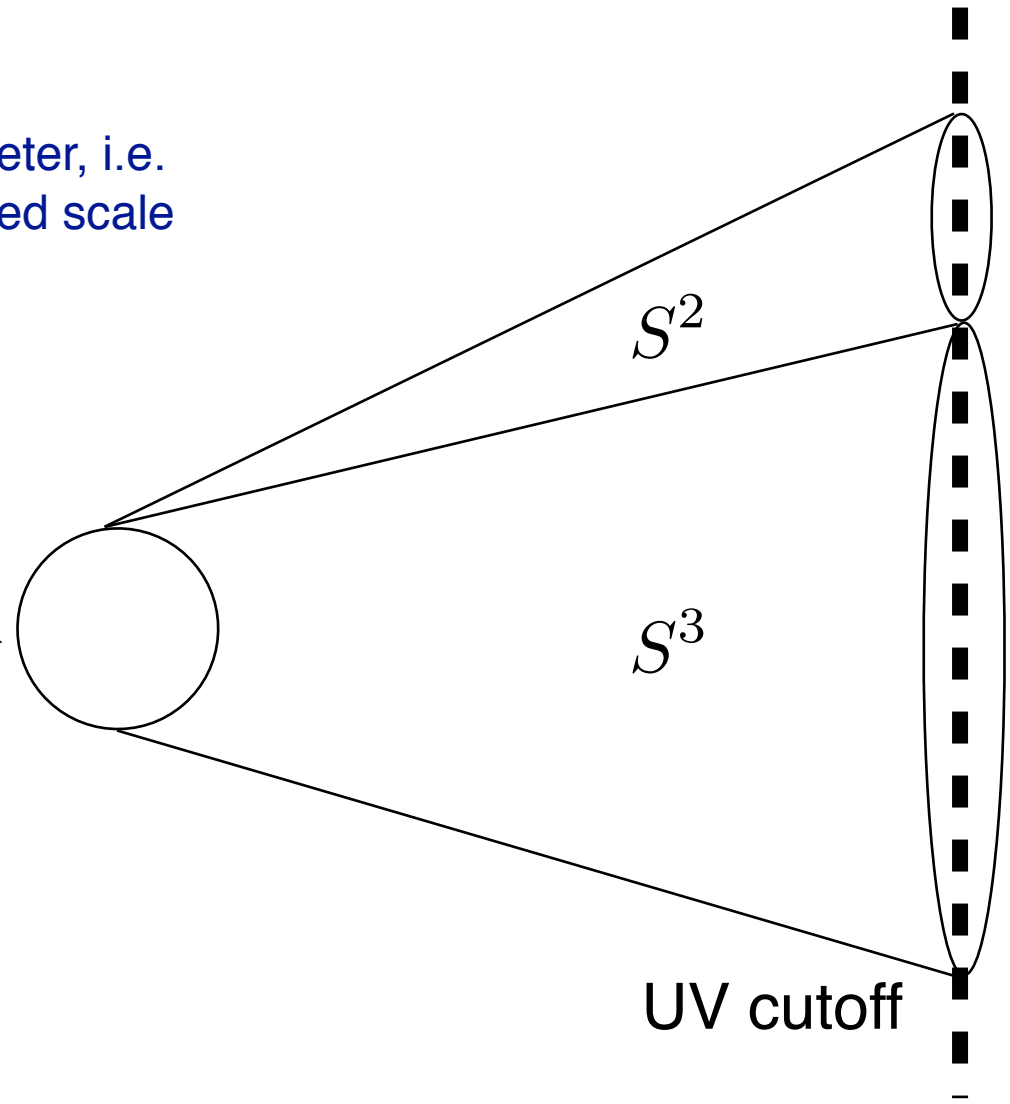
KS geometry: local model of a warped throat

$$\sum_{i=1}^{4} z_i^2 = \epsilon^2$$

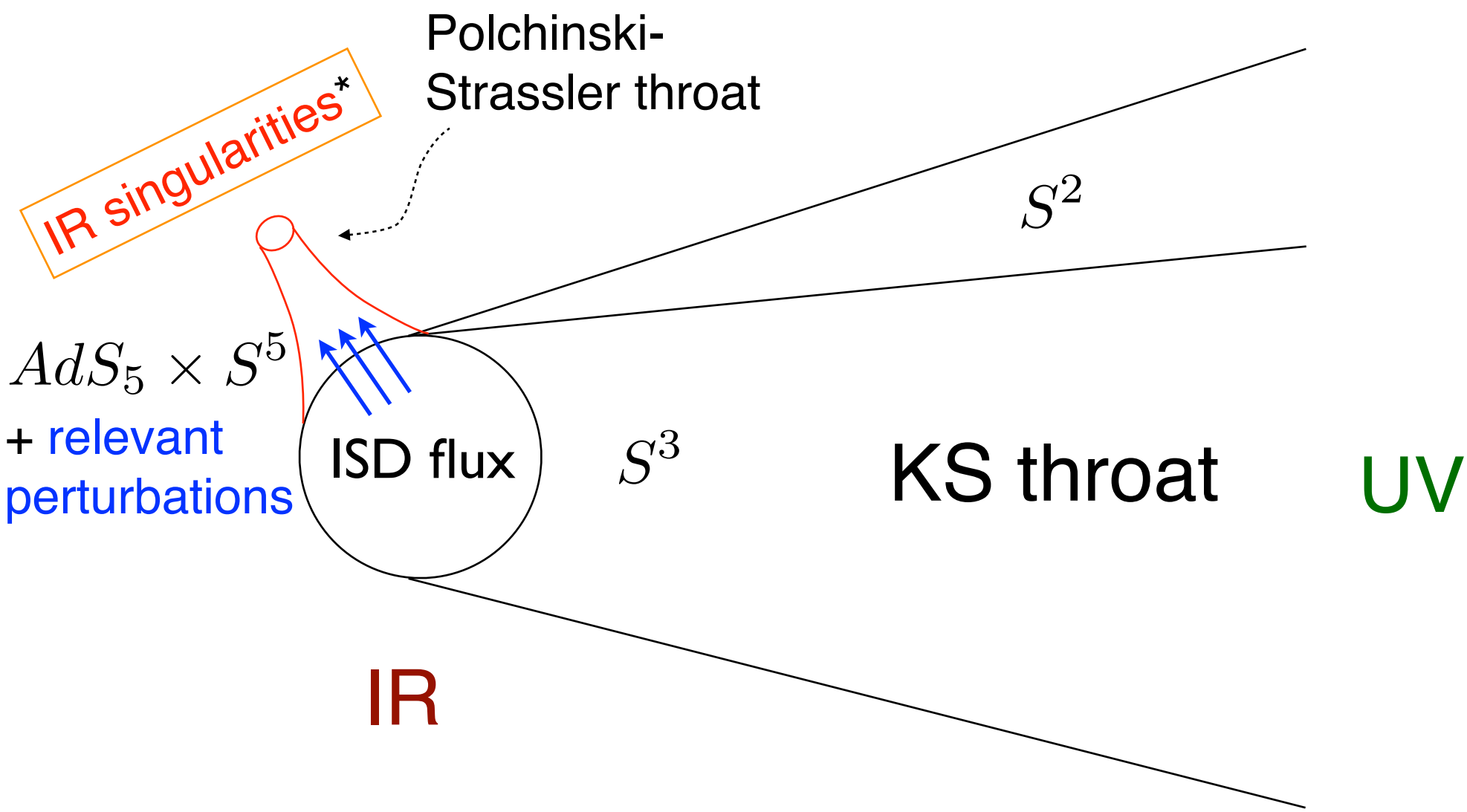
Dimensionful parameter, i.e. dynamically generated scale

$$\frac{1}{4\pi^2\alpha'}\int_{S^3} F_3 = M$$

M = # fractional D3 branes



[Klebanov, Strassler 00]



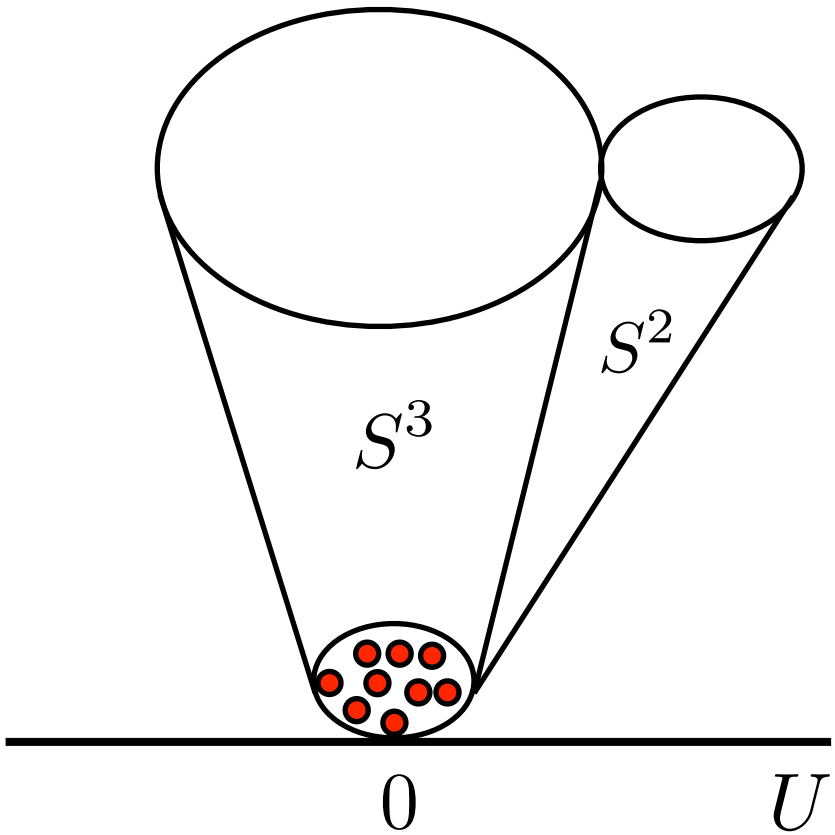
* [Bena, Graña, Halmagyi 09]
[McGuirk,Shiu, Sumitomo 09]

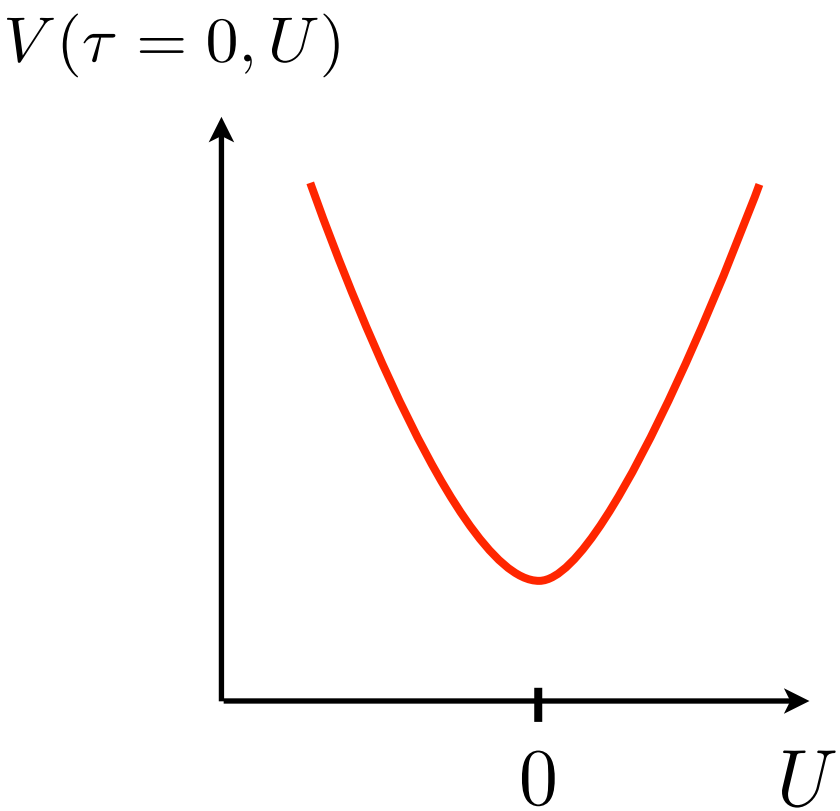
Uplifting the baryonic branch

• Despite the IR singularity, holographic computations done with the (perturbative) smeared anti-D3 solution give accurate predictions.

• Uplift of baryonic branch mode by anti-D3: full agreement between SUGRA and probe computations.

[SM, Dymarsky 13]





Relevant perturbations in holography

Scale in the QFT: $r = z_{AdS}^{-1}$

Local operator of dim Δ ⬌ 2 linearized solutions in gravity:

$$r \to \infty$$

$$\phi \to a\, r^{\Delta - d} + b\, r^{-\Delta}$$

Non-normalizable (coupling)

$$H = H_0 + a\,\mathcal{O}$$

Normalizable (vev)

$$\langle 0|\mathcal{O}|0\rangle = b$$

Relevant perturbations: Δ < *d*. Unimportant in the UV, large in the IR.

Example: *N=4* → *N=1** [Girardello, Petrini, Porrati, Zaffaroni 99]

Mass perturbation = 3-form flux perturbation of $AdS_5 \times S^5$.

[e.g. Graña, Polchinski 00]

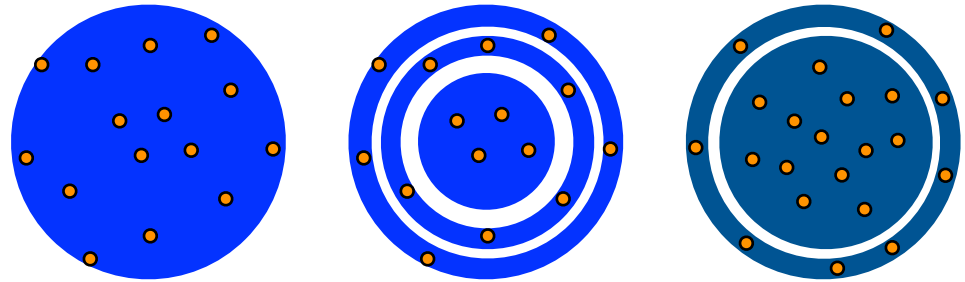
Gravity dual of N=1* SYM

D3 → D5 + S-dual (p,q) 5-branes + concentric shells

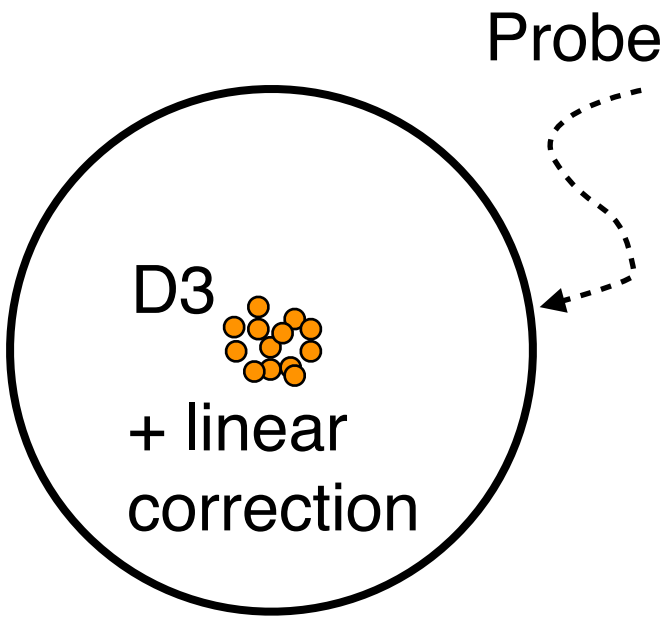
[Polchinski, Strassler 00]

Account for vacua of the theory:

[Vafa, Witten 94] [Donagi, Witten 95]

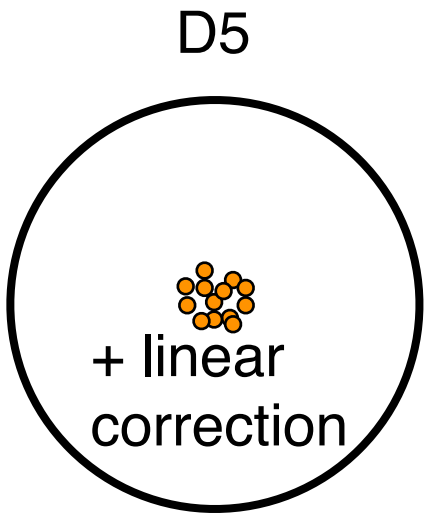


How could we possibly compute all that?



Polchinski-Strassler: just do a probe computation, with all the D3s at the origin.

D5-brane probe action



n = # D3 inside D5

$$V_{D5} \approx \frac{r^4}{2n} - m\, r^3 + \frac{n\, m^2\, r^2}{2} = \frac{r^2}{2n}(r - mn)^2$$

Metric of wrapped S^2

Linear G_3 perturbation:

$$\omega = h^{-1}(\star_6 G_3 - i G_3)$$
$$d\omega = d \star_6 \omega = 0$$

Imperfect cancellation between DBI and WZ: *force on probe branes*.

All terms fixed only by UV boundary conditions!

Explicit check in fully backreacted solution (LLM): [SM, Pasini, Puhm 14]

Anti-D3 and the N=0* throat

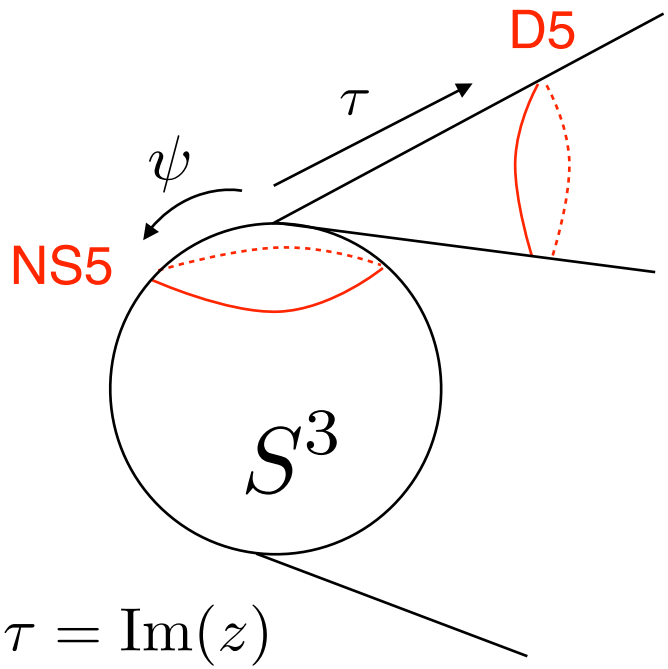
We reduce a complicated problem to the study of phases of N=0* theory. Probe (p,q) 5-brane potential:

$$V_{(p,q)}(z) = \frac{1}{n}\cdot|\mathcal{M}|^2|z|^4 + \frac{1}{3\sqrt{2}}\mathrm{Im}\left[3m\overline{\mathcal{M}}z\bar{z}^2 + m'\overline{\mathcal{M}}z^3\right]$$
$$+ n\cdot\frac{1}{8}\left[\left(|m|^2 + \frac{|m'|^2}{3}\right)|z|^2 + \mathrm{Re}\left(\mu^2 z^2\right)\right]$$

- m : mass for the 3 chiral multiplets
- m' : gaugino mass (in the vector multiplet).
- μ : L=2 harmonic in the 20 of SO(6)

$$\mathcal{M} = p\left(C_0 + e^{-\phi}\right)i + q$$

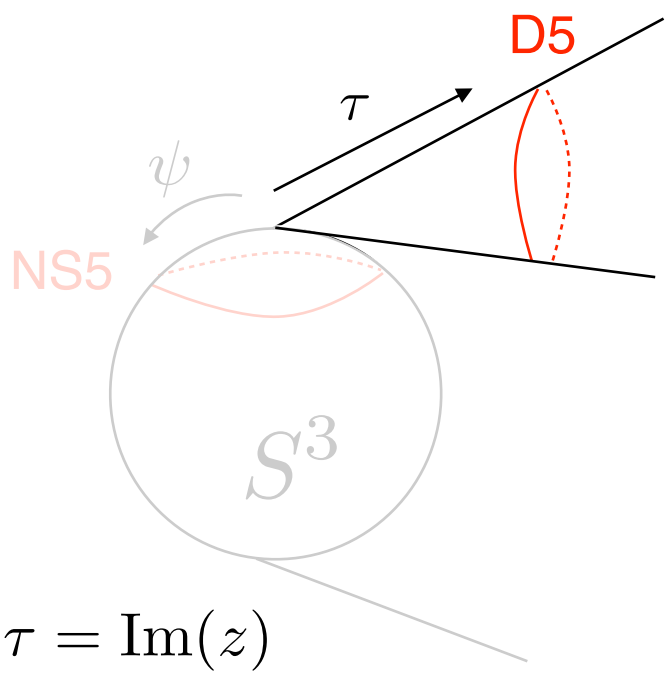
n = # of D3s inside the 5-brane



$\tau = \mathrm{Im}(z)$

$\psi = \mathrm{Re}(z)$

D5 channel



$\tau = \mathrm{Im}(z)$

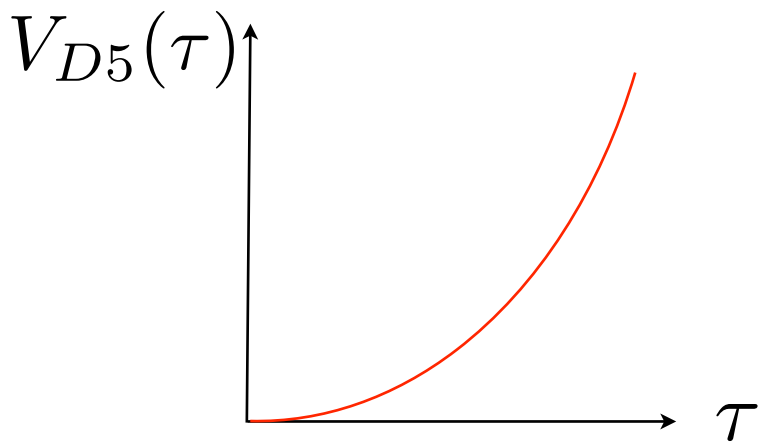
$\psi = \mathrm{Re}(z)$

- Unaffected by smearing*: can be computed by solving EOM in the IR

$$V_{D5}(\tau) = \frac{n}{3}(\alpha^2 + 48\beta^2)\tau^2 - \frac{1}{3}\alpha\tau^3 + \frac{1}{8n}\tau^4$$

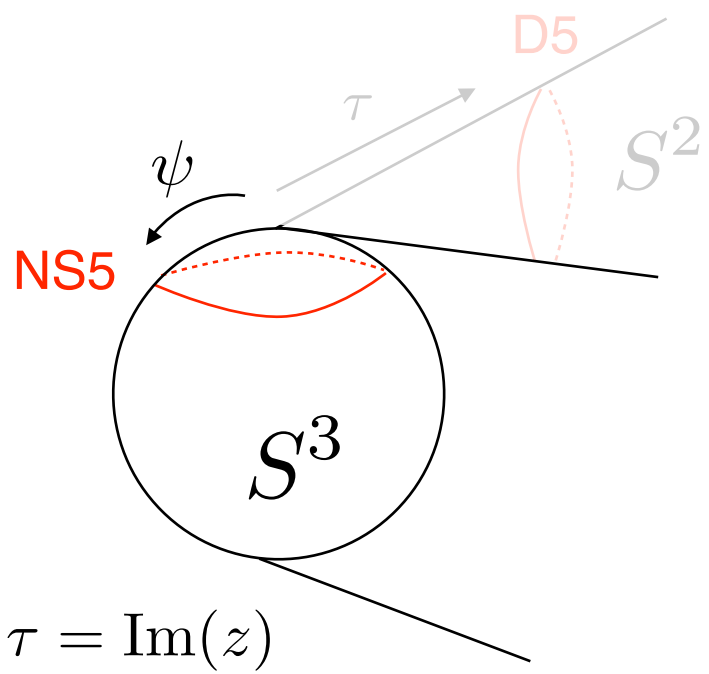
α, β: UV parameters, functions of *m, m', μ*

D5 is lifted:



* True only in some regime of parameters.

NS5 channel



- Localised anti-D3s: get the potential indirectly from the PS formula.
- Need one more relation between the integration constants and the masses:

$$\frac{m'}{m} = \frac{\omega_{(3,0)}}{\omega_{(1,2)}} \quad , \quad \text{with}$$

$$\omega = h^{-1}(\star G_3 + iG_3)$$
$$= (\alpha + 12\beta)\chi_{(3,0)} + (\alpha - 4\beta)\chi_{(2,1)}$$

- From this we determine the parameter μ and we compute:

$$V_{NS5}(\psi) = -\frac{1}{3}\alpha\,\psi^3 + \frac{1}{8n}\psi^4$$

NS5 has a minimum.

Oblique phases and giant tachyon

- Look at quadratic term for a general oblique channel:

$$V_{(p,q)} = \underbrace{-C\left[\mathrm{Im}\left(\mu^2\right)\mathrm{Re}(z) + \mathrm{Re}\left(\mu^2\right)\mathrm{Im}(z)\right]\mathrm{Im}(z)}\,\tau^2 + \ldots$$

$C > 0$

DBI + WZ:
force on probe branes.

- If $\mathrm{Im}(\mu^2) \neq 0$ the coefficient is negative for some directions.
- Anti-branes repel each other:

This tachyon can render the giant NS5 unstable: "giant tachyon".

[Bena, Kuperstein 15]

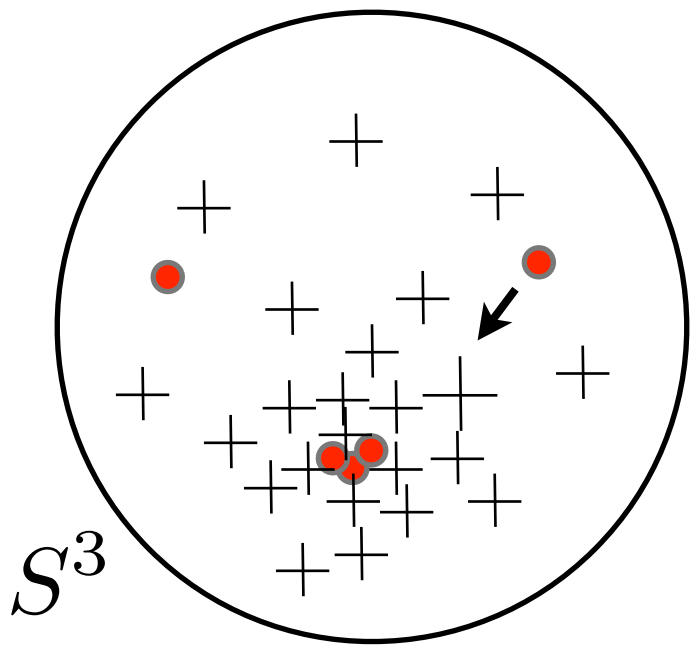
- Generic: tachyon along the sphere for anti-M2s in CGLP.

[Bena, Graña, Kuperstein, SM 14]

Anti-D3 dynamics

• Generically, we expect the anti-D3s to be expelled from the AdS throat. Their dynamics can be rather intricate due to screening effects.

• The dynamics of a single anti-D3 was considered in the previous talk from the EFT point of view. (see talk by A. Puhm)



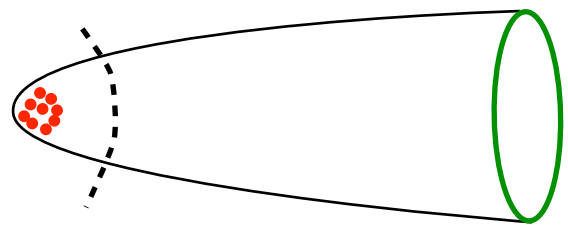
Finite temperature

Common lore: if the supergravity description supports finite T, i.e. a black hole horizon which "cloaks" the singularity, the singularity is physical. [Gubser 00]

Attempts to find such solutions in KS failed so far:

- Well understood for smeared anti-D3 [Bena, Buchel, Dias 12]
- No-go's for localized anti-D3 proposed [Blåbäck, Danielsson, Junghans, Van Riet, Vargas 14]
- Loophole found in toy model [Hartnett 15]

Probably new results will appear soon.



(see talk by T. Van Riet)

Conclusions

We understood the resolution of anti-brane infrared singularities via brane polarization or AdS throat fragmentation.

- Tachyon in supergravity regime: endpoint?
- Comparison with the $g_s p \ll 1$ regime?
- Finite T for localized solutions?

More ambitiously:

- Understand brane/flux annihilation from first principles (closed string field theory?)
- Hunt for metastable vacua in dual field theories.

Thank you!