Backreaction of SUSY-breaking branes

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arXiv: 1009.1877, 1105.4879, 1111.2605
Outline

Introduction

A simple non-BPS example

The problematic backreaction

Conclusion
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Localised sources

- Localised sources (D-branes, O-planes) are important ingredients in string theory/supergravity compactifications:
  SUSY breaking, tadpole cancelation, dS uplifts, ...

  e.g. Kachru, Kallosh, Line, Trivedi 03; Douglas, Kallosh 10
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![Diagram of D-branes and O-planes with a point indicating a localised source]

- Equations of motion (Einstein, dilaton, RR fields) include delta functions:

  \[ S_{\text{loc}} = \mu_p e^{\frac{p-3}{4} \phi} \int d^{10}x \sqrt{g} \delta^{(9-p)}(x) - \mu_p \int C_{p+1} \wedge \delta^{(9-p)} \]
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Usually hard to solve!
Smearing

- Common trick: take 'smeared limit' as approximation, i.e. simplify computations by assuming

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Easier!
Does this make any sense?

- Compare smeared and localised solutions to find out!
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- Localised solutions known for a few *BPS examples* (GKP & T-duals), effects of backreaction *explicitly computable*

  Giddings, Kachru, Polchinski 01
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- BPS: objects that are mutually BPS do not exert any force on each other, since interactions cancel out
- Example: compactifications down to $p+1$ dimensions with spacetime-filling (anti-) $O_p$-planes, fluxes and Ricci-flat internal space
Setup has smeared solution with

\[ \phi, F_{6-p} = \text{const.}, \quad H = \pm e^{\frac{p+1}{4} \phi} \star_{9-p} F_{6-p} \]
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Find that incorporating backreaction does not change relevant properties of solution (moduli, curvature, ...)

Smearing is good approximation in GKP-like setups. Naive argument: no force between sources and flux that are mutually BPS!
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Smearing justified in non-BPS setups?
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- Idea: explicitly address this question in a simple setup!

Blåbäck, Danielsson, DJ, Van Riet, Wrase, Zagermann 11
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which is stable and satisfies all eoms with

$$\phi, F_0 = \text{const.}, \quad H = \pm \frac{5}{2} F_0 e^{7/4\phi} \star_3 1$$
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Is there also a localised solution?
Ansatz

- Now consider our setup with **localised sources**

\[ ds^2 = e^{2A} ds^2_{7} + e^{2B} ds^2_{3} , \]

and (a priori) arbitrary $\phi$, $F_0$, $F_2$, $H$. 

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Blåbäck, Danielsson, DJ, Van Riet, Wrase, Zagermann 10
Ansatz

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- Most general ansatz compatible with symmetries: warped AdS times a conformal sphere, i.e.

\[ ds^2 = e^{2A} ds_7^2 + e^{2B} ds_3^2, \]

and (a priori) arbitrary

\[ \phi, F_0, F_2, H \]
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Problem reduced to solving 4 ODEs for 4 functions $A, B, \phi, \alpha$!
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Seems tractable...
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Warmup: regularised sources

- Assume *smooth* source profile of any shape:

  Can approximate delta source profile with arbitrary precision!
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- **Solve eoms locally** using a Taylor expansion of $A, B, \phi, \alpha$ around some arbitrary point on the 3-sphere
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  ![Profile](image)

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- Surprisingly strong constraints: smeared profile is the **only profile** allowed (up to coordinate transformations)!
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**Last resort: genuine delta profiles...**
Fully localised solution?

- Finally: check whether is there a **fully localised** solution!
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- Need to solve bulk eoms, but what are the correct boundary conditions for $A, B, \phi, \alpha$ in the near-source region?

- Expand (possibly divergent) functions around the source and solve eoms locally to find strong restriction:

  1. standard 'flat space' bc: flux/source are BPS near source
     
     cf. Janssen, Meessen, Ortín 99

  2. 'unusual' bc: flux/source not BPS, $H$ has divergent energy density
A topological no-go

- Do these bc allow a **global solution**? Use **topological constraints** from eoms to decide!
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- \( F_2 \) Bianchi and \( H \) eom yield strong constraint for global behavior of \( \alpha \):
  \[ \text{sgn} \, \alpha = \text{sgn} \, \alpha'' \text{ at every extremum } \alpha' = 0 \]
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- We also need to satisfy the tadpole condition for (anti-) D6-branes:
  \[ \int F_0 H = F_0^2 \int \alpha e^{\phi - 7A} \star_3 1 \overset{\leq}{\gtrless} 0 \]
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  - 'flat space' bc: $\alpha = 0, \alpha' \begin{cases} < 0 \end{cases}$
  - 'unusual' bc: $\alpha$ finite, $\alpha' \begin{cases} > 0 \end{cases}$
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- **Topological no-go** rules out 'flat space' bc:

  ![Diagram](image)

  - 'flat space' bc: $\alpha = 0$, $\alpha'_{(\geq)} 0$
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- ‘Unusual’ bc is **not ruled out** by topological argument, global solution may exist
- However: no obvious **interpretation** of $H$-singularity! Can this be resolved in full string theory? Or is solution **unphysical**?
- Closely related problem debated in the literature: put anti-D3-branes into Klebanov-Strassler throats (KKLT!), **same singularity** will show up

Klebanov, Strassler 00; Kachru, Pearson, Verlinde 02
Kachru, Kallosh, Line, Trivedi 03
Bena, Graña, Halmagyi 09
Bena, Giecold, Graña, Halmagyi, Massai 11
Several suggestions...

- Singularity is due to *partial smearing* of the branes (excluded in our analysis!)

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Fate of backreacted solution unclear...
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- Warping effects cancel out in BPS setups so that smeared solution stays a solution when localised.

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