Blonic membranes and AdS instabilities

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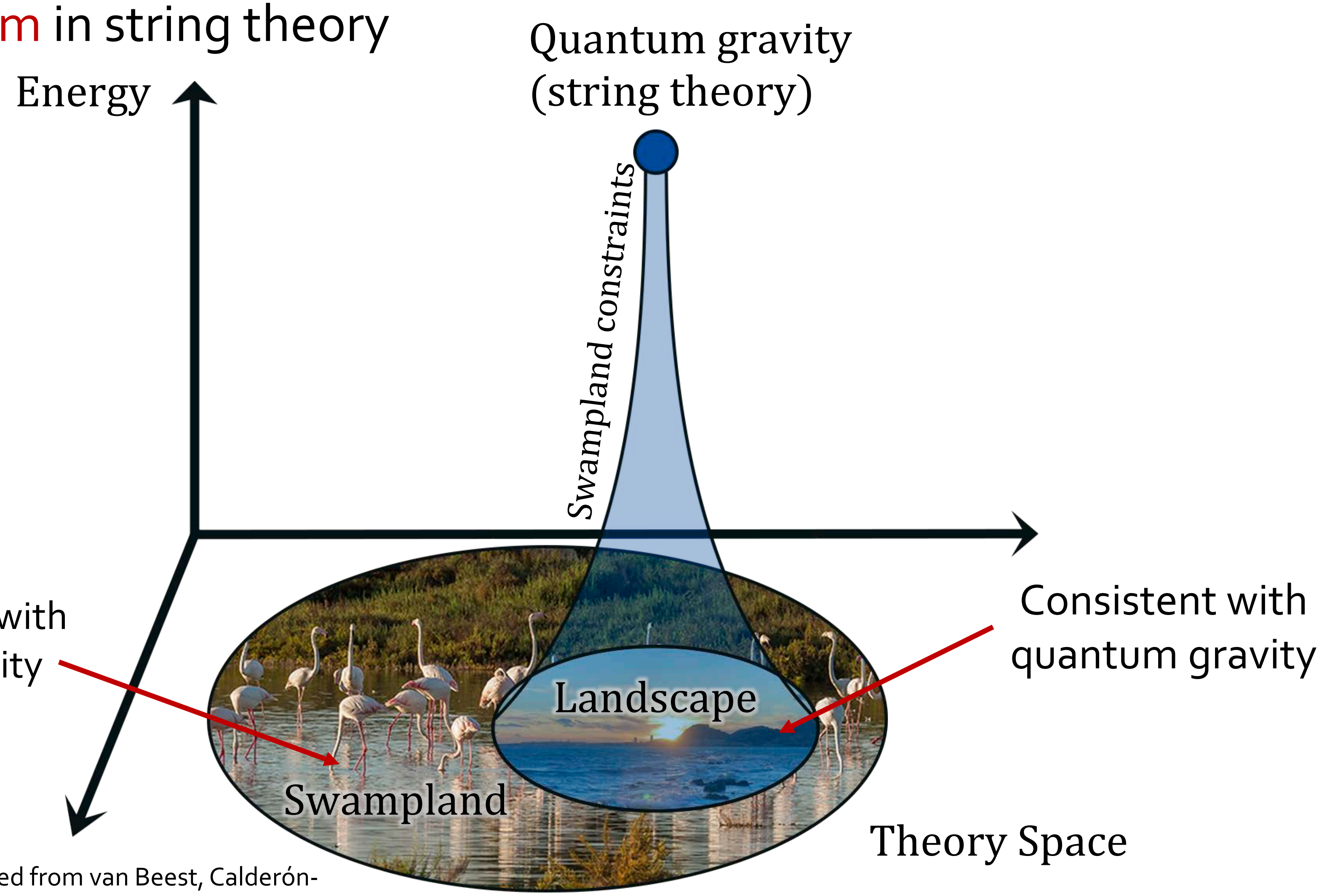
Based on: 2110.11370. with F.Marchesano and D.Prieto

Dark world to swampland 2021

Contents

A bit of context: motivating the problem

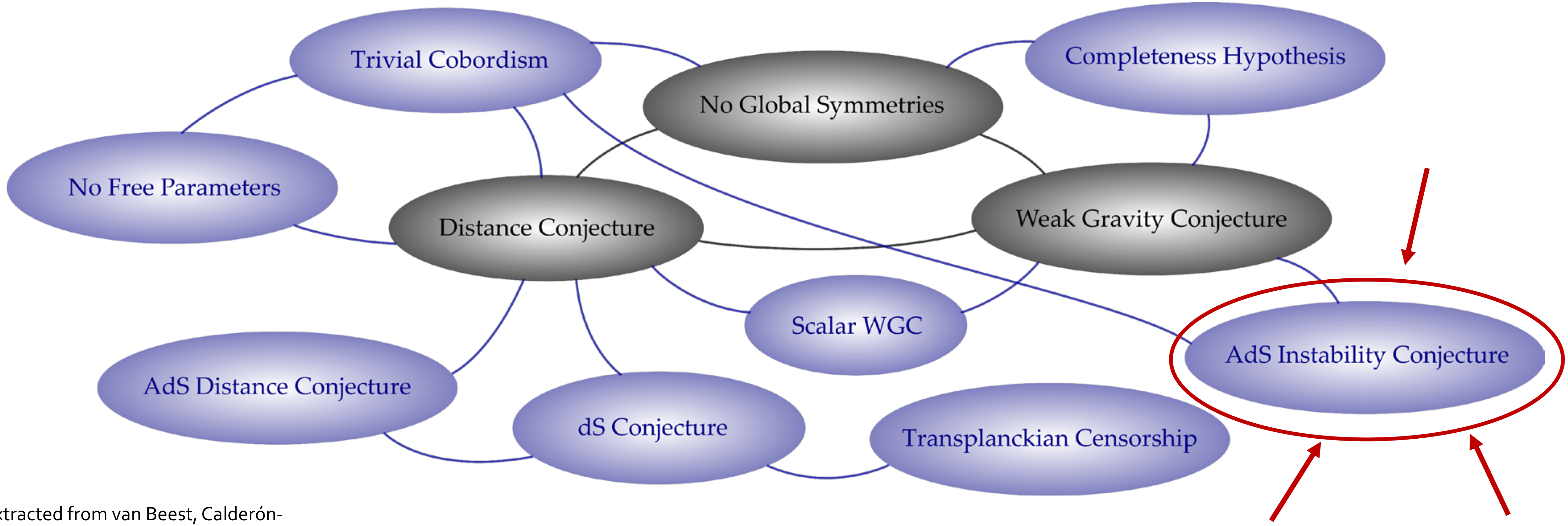
- Swampland program in string theory



Adapted from van Beest, Calderón-Infante, Mirfendereski, Valenzuela '21

A bit of context: motivating the problem

- Swampland program in string theory
- Web of conjectures



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A bit of context: motivating the problem

Ooguiri, Vafa '16

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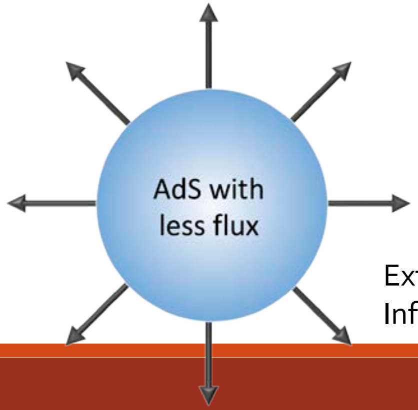
Maldacena, Michelson, Strominger '99

  - Consequence II: this brane corresponds to an instability. Any non-SUSY AdS supported by fluxes is at best metastable.



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- Shown to be satisfied in many examples

Apruzzi, Bruno De Luca, Gnecchi, Lo Monaco, A. Tomasiello '19; Bena, Pilch, Warner '20; Suh '20; Apruzzi, Bruno De Luca, Lo Monaco, Uhlemann '21; Bomans, Cassani, Dibitetto, Petri '21...

Compactifications of the form $AdS_4 \times X_6$, with X_6 admitting a CY metric, remain elusive (perturbatively stable)

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  - Obtained using directly the 4d effective theory and not solving the 10d EOM

  - Intersecting orientifold planes: no uplift was known so far (only if the sources are smeared* Acharya, Benini, Valandro '07)

  - Phenomenologically interesting : scale separation at large volume and small string coupling.

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- First order uplift computed recently in Junghans '20, Marchesano, Palti, Tomassiello, JQ '20

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  - Perturbative stability studied. Some of the non-SUSY vacua were shown to be perturbatively stable.

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  - ➢ Stability already studied in Aharony, Antebi, Berkooz '08; Narayan, Trivedi '10 using D4, D6 and D2 DW. At most marginal decays
- We will focus on the D8s. Results Junghans '20, Marchesano, Palti, Tomassiello, Quirant '20 will be important.

NEW

Membranes in AdS_4

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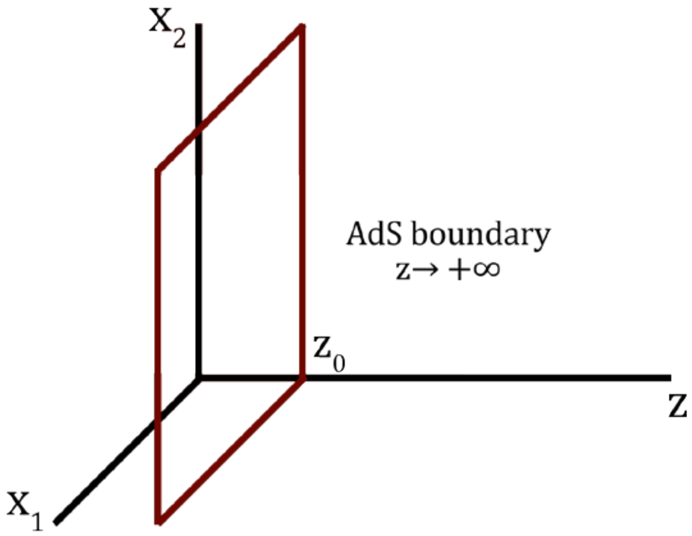

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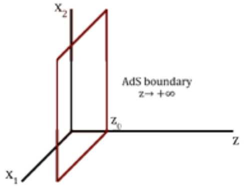

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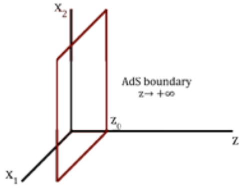

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- Study the spectrum of membranes with $z = z_0$. If $T \geq Q$ → decays are marginal or forbidden. If $T < Q$ potential non-perturbative instability.

AdS_4 orientifold. Smearing. SUSY

- Massive IIA on a CY orientifold with H flux and RR *internal* fluxes:

$$\widehat{G_0} = \frac{1}{l_S} m, \qquad \widehat{G_2} = 0, \qquad \widehat{G_4} = \frac{3G_0}{10} J_{CY}^2, \qquad \widehat{G_6} = 0$$

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C_9 ↓ $\qquad$ C_5 ↓

Couplings for D(2p)-branes wrapping (2p-2) cycles

$$Q_{D8} = -\frac{5}{3} e^{K/2} V_{CY} \qquad Q_{D4} = e^{K/2} \int_\Sigma J_{CY}$$

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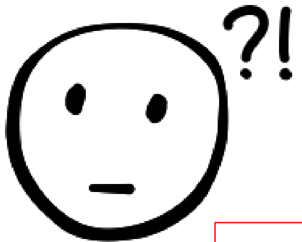

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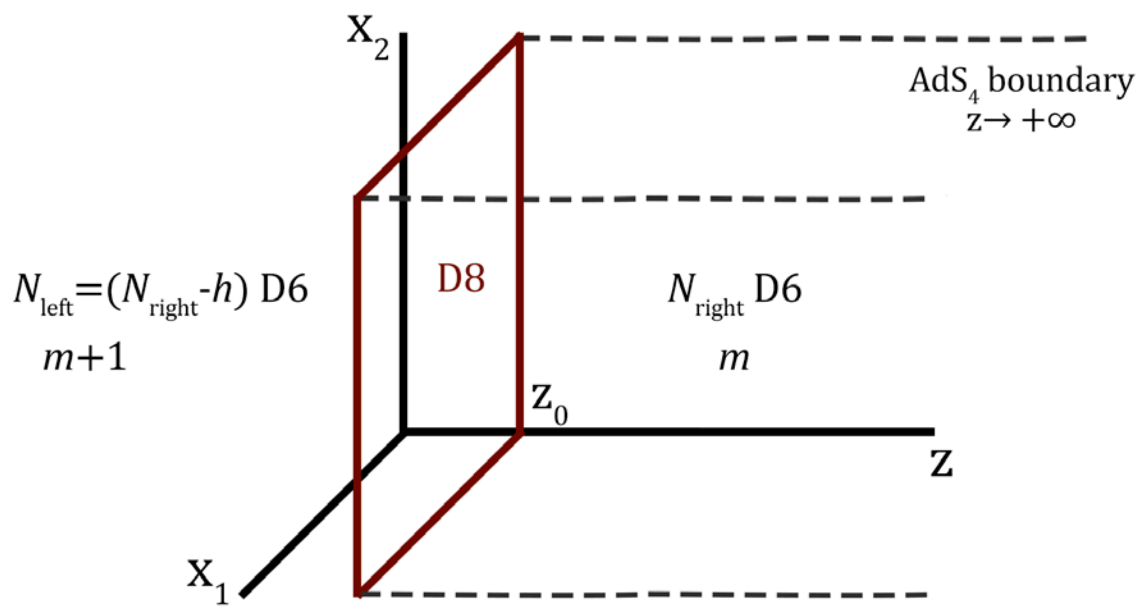
- Need an excess of N space filling D6 branes on the interval $[z_0, \infty)$ satisfying $N_{right} - N_{left} = |h|$, $[l_s^{-2} H] = |h| [\Pi_{O6}]$



$$Q^{\text{eff}}_{D8/D6} = Q_{D8} + Q^{\text{eff}}_{D6} = e^{K/2} V_{CY}$$

Coming from the DBI of the D6

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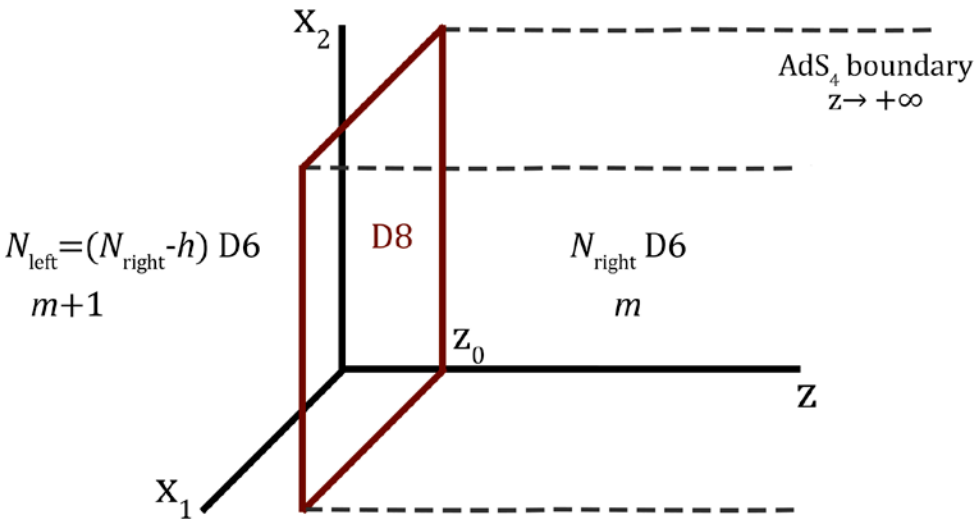
- Bound state of D8+D6s is BPS: $Q^{\rm eff}_{D8/D6} = Q_{D8} + Q^{\rm eff}_{D6} = e^{K/2} V_{CY} = T_{D8}$



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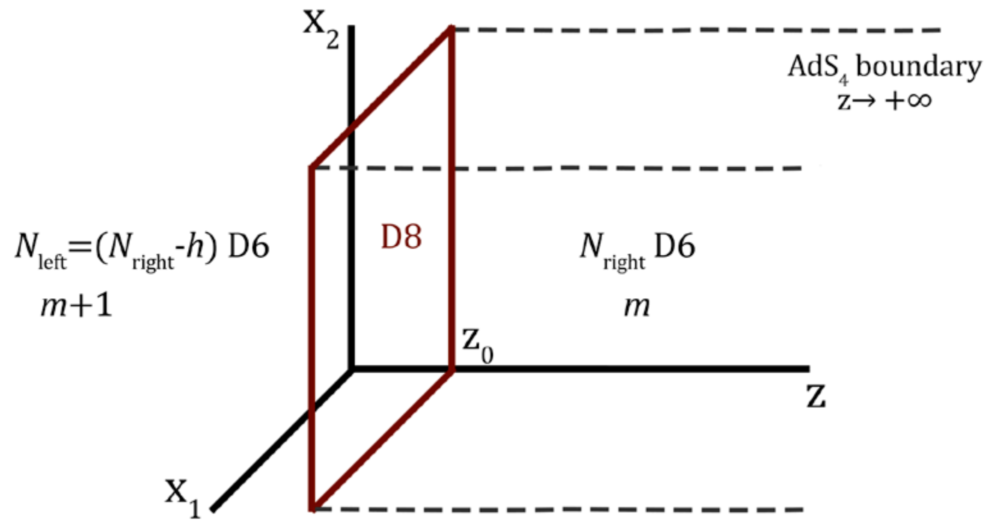

- Including α' curvature corrections (important for the non-SUSY case):

$$T^{\text{total}}_{D8} = T_{D8} + \left(K_a^{F_{D8}} - K_a^{2}\right) T^a_{D4} = Q^{total}_{D8}$$

$$K_a^{F_{D8}} = \frac{1}{2}\int_{X_6} F_{D8} \wedge F_{D8} \wedge \omega_a, \qquad K_a^{(2)} = \frac{1}{24}\int_{X_6} c_2(X_6) \wedge \omega_a, \qquad T^a_{D4} = e^{K/2} t^a$$

Recap

- Massive IIA with RR and NSNS fluxes on an orientifold CY. Smearing uplift

→ Branes spanning $(t, x_1 x_2)$ at $z = z_0$

→ SUSY case.

- D4 wrapping 2-cycle [J], $T = Q$
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Non-SUSY case $G_4 \to -G_4$

- D4 ?
- D8?

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Agreement with Narayan, Trivedi '10

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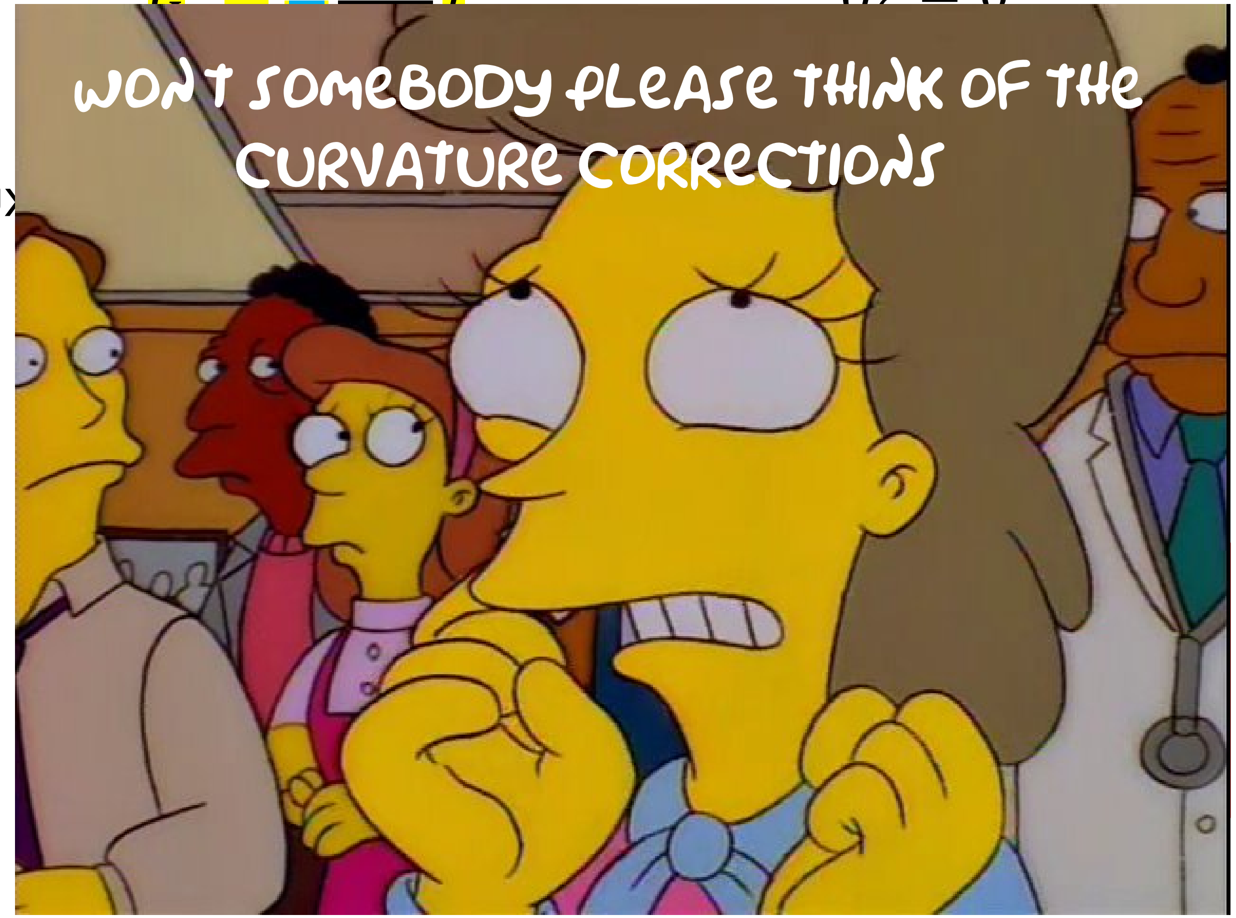

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- Curvature corrections in this case do have something to say

$$Q_{D8}^{total} = T_{D8} - (K_a^F - K_a^2)T_{D4}^a \qquad T_{D8}^{\text{total}} = T_{D8} + (K_a^F - K_a^2)T_{D4}^a$$

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- ➢ Internal fluxes ($K_a^{F_{D8}}$) can be taken to zero and so $Q_{D8}^{total} - T_{D8}^{\text{total}} > 0$

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- Sharpened WGC satisfied. Possible instability sourced by the curvature corrections.
- Only applies to vacua containing D6s.

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SUSY

$$H = \frac{2}{5}\frac{m}{l_s} g_s(\mathrm{Re}\Omega_{\mathrm{CY}} + g_s K) - \frac{1}{2} d\mathrm{Re}(\bar{v}\cdot\Omega_{\mathrm{CY}}) + O(g_s^3)$$

$$\widehat{G_2} = d_{\mathrm{CY}}^{\dagger} K + O(g_s)$$

$$\widehat{G_4} = \frac{m}{l_s} J_{\mathrm{CY}} \wedge J_{\mathrm{CY}} \left(\frac{3}{10} - \frac{4}{5} g_s \varphi\right) + J_{\mathrm{CY}} \wedge g_s^{-1} d\mathrm{Im}\, \mathrm{v} + \mathrm{O}(\mathrm{g}_s^2)$$

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Non-SUSY NEW

$$H = \frac{2}{5}\frac{m}{l_s} g_s(\mathrm{Re}\Omega_{\mathrm{CY}} - 2 g_s K) + \frac{1}{10} d\mathrm{Re}(\bar{v}\cdot\Omega_{\mathrm{CY}}) + O(g_s^3)$$

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$$\widehat{G_6} = 0$$

- We can repeat the previous section with this more accurate solution. Notice that now $\widehat{G_2} \neq 0$

Beyond the smearing. D4s

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- The new $G_6 = d\text{vol}_4 \wedge -\lambda(\star_6 \hat{G}_4)$ is:

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- Remarkably for both the SUSY and the non-SUSY cases, correction are exact forms→ not contribute to the CS $Q_{D4}^{\text{smearing}} = Q_{D4}^{\text{beyond smearing}}$ → results of Smearing approximation hold

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Beyond the smearing. Bionic D8s

- Consider again a D8 wrapping X_6 and extended along $z = z_0$. BI for the D8 worldvolume $F_{D8} = B + \frac{l_s}{2\pi} F$ is

$$dF_{D8} = H - \frac{1}{l_s} \delta(\Pi_{O6})$$

- In the smearing approximation the RHS vanishes and F_{D8} is closed (actually a harmonic (1,1) form)

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- Going beyond the smearing approximations means that now:

$$F_{D8} = \frac{G_2}{G_0} = \frac{l_s}{m} d^{\dagger}_{\mathrm{CY}} K + O(g_s)$$

- Compatible with a BPS configuration if the D8-brane transverse field Z develops a non-trivial profile (Bion-like solution)

$$\star_{CY}\, dZ = \mathrm{Im}\Omega_{CY} \wedge F_{D8} + O(g_s) \longrightarrow \Delta_{CY} Z = l_s \left(\delta_{\Pi_{O6}} - \frac{V_{\Pi_{O6}}}{V_{CY}} \right) \qquad Z \sim \frac{l_s}{r} \text{ near } \Pi_{O6}$$

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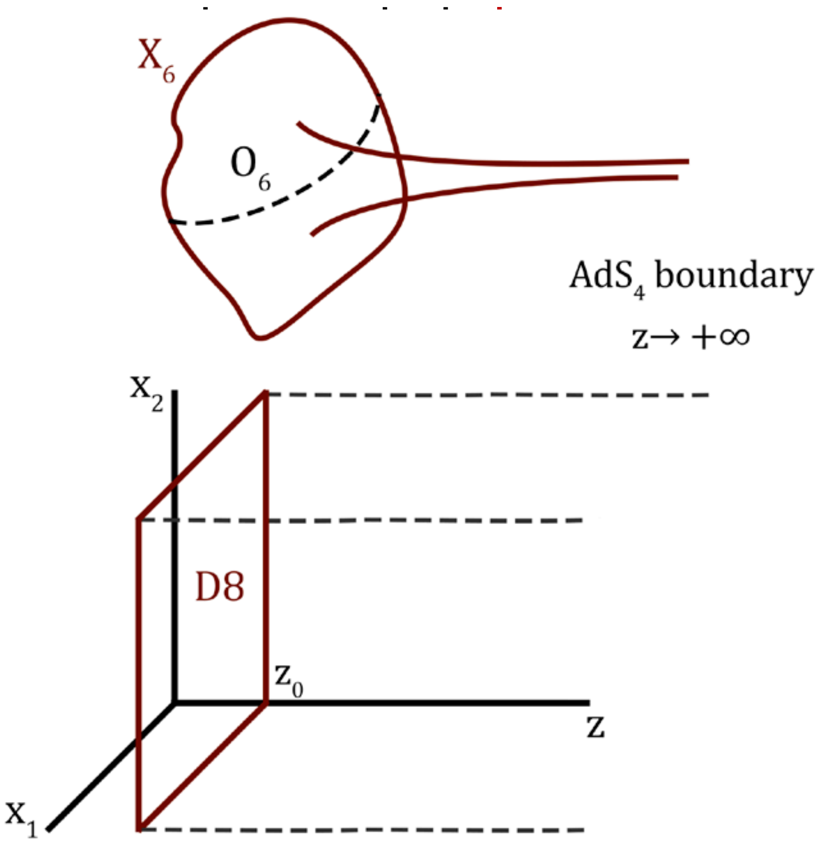

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- With this result one can compute the T and the Q of the system

- For the SUSY solution:

  - $T_{D8}^{BIon} = Q_{D8}^{BIon}$

$*dF = H + \delta$ → Smearing approximation: $\delta = -H$

Beyond the smearing. Bionic D8s

- With this result one can compute the T and the Q of the system

- For the non-SUSY solution we obtain:
  - $Q_{D8}^{BIon} - T_{D8}^{BIon} = 2\left(K_a^2 - K_a^{F_{D8}}\right)T_{D4}^a$

$$K_a^{(2)} = \frac{1}{24}\int_{X_6} c_2(X_6) \wedge \omega_a,$$

$$K_a^{F_{D8}} = \frac{1}{2}\int_{X_6} F_{D8} \wedge F_{D8} \wedge \omega_a,$$

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  - Big difference: now the sources are not smeared and F_{D8} always must have a non-harmonic part.

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  - For more complicated geometries we expect $K_a^{F_{D8}}\, T_{D4}^a < 0$ to hold.

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Only applies to vacua containing D6s.

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- D4 wrapping 2-cycle -[J] , $T = Q$
- Blonic D8-D6s and curvature corrections $T \neq Q$.

Conclusions

- Studied non-perturbative stability of IIA $N = 0 \text{ AdS}_4 \times X_6$ orientifold (X_6 admitting a CY metric) vacua using D4 and D8 membranes with $G_4^{\text{non-SUSY}} = -G_4^{\text{SUSY}}$.

- Potential decay channel via D8 $Q > T$ branes. Curvature corrections and Bion profile, which is only seen beyond the smearing uplift, equally important.

    - Explicitly computed for toroidal models. More complicated CYs geometries to be studied

- Only apply to vacua with space-time filling D6s. Not in the original setup of DGKT… Other decay channels? More corrections needed?

- Further study deserved: more detailed 4d analysis, generalise it to other string theory settings…

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Thank you for your attention! 🙂