On the Stability of non-SUSY Warped Throats

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An special room

Motivation

- We all love the Swampland.
- A sharpening of WGC leads to the conjecture that **non-SUSY AdS** is **unstable** (AdS-WGC).
- This idea can be used to put constraints on extensions of SM (Ibanez *et al.*, 2017; Gonzalo *et al.*, 2018; Gonzalo & Ibanez, 2018).
- Construction of deSitter in String Theory typically uses warped throats with SUSY breaking at its bottom to tune cosmological constant.
  $\Rightarrow$ Interesting to consider such throats and their stability.
- We propose a *local AdS-WGC* forbidding stable non-SUSY locally AdS warped throats.

The AdS-WGC

- Non-Supersymmetric AdS vacua have been conjectured to be unstable in (Ooguri & Vafa, 2017; Freivogel & Kleban, 2016). Arguments:
  1. **Sharpened WGC**: $\boxed{Q = T \text{ only for BPS states}} \Rightarrow$ non-SUSY: $Q > T$. Flux supported non-SUSY AdS backgrounds may be unstable under **nucleation of branes** discharging the flux. In D-brane picture, **branes repel.**
  2. Bubble of nothing solutions exist in some cases (Ooguri & Spodyneiko, 2017).
  3. Some AdS spacetimes arise as near-horizon geometry of black objects that should decay (WGC).
- Non-SUSY AdS could be metastable, but decay probability multiplied by infinite volume.

The *local* AdS-WGC

- Consider system of N regular and M fractional branes at a CY singularity with metric,

$$ds^2_{\mathbf{Y_6}} = dr^2 + r^2 ds^2_{\mathbf{X_5}} \tag{1}$$

$\Rightarrow$ The SUGRA solution for this setup is,

$$ds^2 \;=\; Z(r)^{-1/2}\,\eta_{\mu\nu}\,dx^\mu\,dx^\nu \;+\; Z(r)^{1/2}\,[\,dr^2 \;+\; r^2 ds^2_{\mathbf{X}_5}\,], \tag{2}$$

With near-horizon geometry,

$$ds^2 = \frac{r^2}{L(r)^2}\,\eta_{\mu\nu}\,dx^\mu\,dx^\nu \;+\; \frac{L(r)^2}{r^2}\,dr^2 \;+\; L(r)^2 ds^2_{\mathbf{X}_5} \tag{3}$$

There is a *local* AdS_5 with curvature changing in r as a result of the flux:

$$H_3 \;=\; \frac{3\,g_s\,M\,\alpha'}{2}\,\frac{dr}{r}\,\wedge\omega_2(\Sigma_3) \quad\rightarrow\quad N_{eff} \sim g_s\,M^2\ln(r/r_s) \tag{4}$$

The *local* AdS-WGC

In a consistent theory of Quantum Gravity, there are no stable non-supersymmetric solutions with asymptotics given by local AdS backgrounds.

- A **meta-stable** disclaimer:
  1. The conjecture has no bearing with *metastable* throats. No infinite volume multiplying decay probability.
  2. Anti-D3 branes are (possibly) metastable excited states.
  3. In global compactifications bulk ingredients may modify asymptotics, evading the conjecture. For example, euclidean D3 instantons (Florea *et al.*, 2007). Also D7-branes realizing metastable ISS vacua (Franco & Uranga, 2006).

Literature on fractional branes

Three kinds of fractional branes.

1. Deformation fractional branes: Singularity smoothed in the IR, supersymmetry preserved. ✔
2. DSB fractional branes: SUSY broken in the IR by strong effects ✗.
   - e.g (Franco *et al.*, 2006). dP1 DSB fractional brane gives F-term potential:

     $$V_F = |M|^2 + |Z + \Lambda^4 M^{-3/2}|^2 \tag{5}$$

     With runaway $M \to 0, \quad Z \to \infty$. But $V_D = |Z|^4$ prevents it.
     Allowing for dynamical FI terms $\to V_D = (|Z|^2 - \xi^2)^2 \Rightarrow Z$ is free to run towards SUSY vacuum $\to$ Singularity is **blown up**.
     $\Rightarrow$ **Cured by dynamical FI terms!**
   - Indeed FI terms must always be present and dynamical in String Theory (Komargodski & Seiberg, 2009).
3. $\mathcal{N} = 2$ fractional branes.

A genuine DSB throat

DSB D-brane sector embedded in a warped throat in (Retolaza & Uranga, 2016). The setup is:

- D-branes in orientifold of $\mathbb{C}^3/\mathbb{Z}_6'$. With appropriate choice of orbifold and orientifold planes, field theory:

$$
\begin{gathered}
SO(n_0) \times U(n_1) \times U(n_2) \times USp(n_3) \\
(\square_0, \overline{\square}_1) + (\square_1, \overline{\square}_2) + (\square_2, \overline{\square}_3) + \\
+(\square_0, \overline{\square}_2) + (\square_1, \square_3) + \begin{array}{|c|}\hline \\ \hline \\ \hline \end{array}_2 + \overline{\square\square}_1 + \\
+[(\square_0, \square_3) + (\square_1, \square_2) + (\overline{\square}_1, \overline{\square}_2)]
\end{gathered} \tag{6}
$$

- Take $n_0 = 1$, $n_2 = 5$ and $n_1 = n_3 = 0$. This is $SU(5)$ theory with $\begin{array}{|c|}\hline \\ \hline \\ \hline \end{array}$, $\overline{\square}$ $\Rightarrow$ **DSB**.
- This theory may be embedded in a **parent** throat whose complex deformation cascade has the DSB theory at the bottom. *Counterexample?*

The DSB AdS throat.

Analizing full throat is messy. We can add $N \gg 1$ D3-branes to DSB sector:

$$n_0 = N + 1 \quad , \quad n_1 = n_3 = N \quad , \quad n_2 = N + 5 \tag{7}$$

The near-horizon geometry is $\mathbf{AdS_5 \times X_5}$ for large N.

$\Rightarrow$ If stable, counterexample to AdS-WGC.

$\Rightarrow$ Maybe the system is unstable and repels the D3-branes?

- Repel D3-branes $\rightarrow$ Higgsing by vev of mesonic operator $\langle \mathcal{O} \rangle$:

$SU(N+5)$ w. flavors $(3N+1)\,\overline{\square} + 2N\,\square + \begin{array}{|c|}\hline\\\hline\\\hline\end{array}$ $\rightarrow$ $SU(5)$ w. flavors $\begin{array}{|c|}\hline\\\hline\\\hline\end{array}$, $\overline{\square}$ (8)

$\Rightarrow$ Matching condition is:

$$\Lambda_{IR} = \Lambda_{UV} \times \langle \mathcal{O} \rangle^0 \quad \Rightarrow \quad \boxed{\textbf{D3-branes not repelled.}} \tag{9}$$

A novel decay

- $\mathbb{C}^3/\mathbb{Z}_6'$ orientifold **not isolated singularity.** There are lines of $\mathbb{C}^2/\mathbb{Z}_2$ and $\mathbb{C}^2/\mathbb{Z}_3$ singularities.
- These directions correspond to $\mathcal{N}=2$ fractional branes. Maybe runaway directions?

$\Rightarrow$ Consider meson operators v, v' parametrizing motion of fractional branes along $\mathbb{C}^2/\mathbb{Z}_2$ singularity. Give them vev $\langle v\rangle \gg \langle v'\rangle$:

$$SO(N+1)\times SU(N)\times SU(N+5)\times USp(N) \xrightarrow{v} \tag{10}$$
$$\xrightarrow{v} SO(1)\times SU(N)\times SU(5)\times USp(N) \xrightarrow{v'} SO(1)\times SU(5)$$

And scale matching is,

$$\Lambda_{IR}^{13} = \Lambda_{UV}^{13}\langle v'\rangle^{2N}\langle v\rangle^{-2N} \quad \Rightarrow \quad \boxed{v \textbf{ runs away to infinity!}} \tag{11}$$

Interpretation of the decay

- Dynamical D3-branes split in two kinds of fractional branes.
- v fractional branes run to ∞, while v' ones remain at the origin.
- The field theory is $SO(1) \times SU(N) \times SU(5) \times USp(N)$ with additional flavors. It has SUSY vacua.
- In gravity picture, **bubbles of fractional branes**. No bubble of nothing. No discharge 5-form flux completely.
- The gravity dual is locally AdS with the singularity resolved by a **enhançon** configuration supported by the N fractional branes at the origin.
- Embedding the DSB sector in warped throat does not alleviate the instability.

Conclusions

- We argue that **In a consistent theory of Quantum Gravity, there are no stable non-supersymmetric solutions with asymptotics given by local AdS backgrounds.**
- There is evidence in the literature: Deformation fractional branes and dP1 DSB fractional branes reinterpreted.
- DSB D-brane sectors can't be given a gravity dual with AdS asymptotics.
- A particular example is unstable under **nucleation of fractional D3-branes** giving rise to $N = 2$ dynamics.
- No direct relation to metastable states.
- Check out **Ginevra Buratti's** talk for more awesome instabilities.

Merci!

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