Supersymmetry Breaking Warped Throats and the Weak Gravity Conjecture

GB, E. García-Valdecasas, A. Uranga [arXiv:1810.07673]

cf. talk by Eduardo

String Phenomenology, Geneva, 27th June 2019
Gravity as the weakest force

WGC: given an abelian gauge field, there exists a charged particle with mass

\[ M \leq Q \quad \text{(in units where } M_{Pl} = 1) \]

Motivated by the need for extremal black holes to decay

Also, given a \((p + 1)\)-form gauge potential, there exists a \(p\)-brane with tension

\[ T \leq Q \]
Refined WGC: \( T = Q \iff \) BPS states in a susy theory

AdS is typically obtained in holography from the near-horizon limit of a configuration of branes.

A possible decay channel for non susy AdS supported by flux is through brane nucleation.

AdS-WGC: all non susy AdS vacua must be unstable.
Still true for “locally” AdS backgrounds?
Warped throats

- $N$ regular + $M$ fractional D3’s probing a CY singularity

$$ds^2_{Y_6} = dr^2 + r^2 ds^2_{X_5}$$

- For $M = 0$, the gauge theory is *conformal*.
  
  $AdS_5 \times X_5$ gravity dual with constant RR 5-form flux $N$ over $X_5$

  $$\Rightarrow \text{usual AdS-WGC}$$

- For $M \neq 0$, the gauge theory is no more conformal and undergoes a non trivial RG flow.

  The gravity dual is a *local* AdS solution
Warped throats

- RR 3-form flux
  \[ \int_{\Sigma_3} F_3 = M \]  
  constant

- NSNS 3-form flux
  \[ \int_{\Sigma_2} B_2 \sim g_s M \ln r \quad H_3 = dB_2 \]

- RR 5-form flux
  \[ \int_{X_5} F_5 = N(r) \sim g_s M^2 \ln r \]

\[ ds^2 = Z(r)^{-1/2} \eta_{\mu\nu} \, dx^\mu \, dx^\nu + Z(r)^{1/2} \left[ dr^2 + r^2 ds_{X_5}^2 \right] \]

with
\[ Z(r) = \frac{L^4}{r^4} \ln \left( \frac{r}{r_s} \right) \quad L^2 \sim g_s M \quad r_s \text{ naked singularity} \]
In a consistent theory of quantum gravity, there are no stable non-supersymmetric solutions with asymptotics given by local AdS backgrounds.

We do not rule out:

- metastable throats (no infinite volume factor multiplying the decay probability, in contrast with the usual AdS-WGC) 
  \[ \Rightarrow \] no direct contradiction with dS uplift

- warped throats with asymptotics modified by ingredients in the bulk
Evidence from deformation branes

Different classes of fractional branes, in particular:

- deformation branes, associated to complex deformations of the singular manifold

\[ \text{[Klebanov Strassler 2000]} + \ldots \]

The naked singularity can be smoothed out by giving $\Sigma_3$ a finite size, while preserving supersymmetry

$\Rightarrow$ The local AdS-WGC is satisfied
Evidence from DSB branes

- DSB branes, not associated to complex deformations

\[ \Sigma_3 \] cannot be given a finite size, while preserving supersymmetry

If one could smooth out the IR region to an alternative susy breaking stable configuration, this would contradict the local AdS-WGC...

But we argue that this is not possible  

\[ \text{cf. Eduardo’s talk} \]
The $dP_1$ runaway

simplest example of a duality cascade triggered by DSB branes

[Berenstein Herzog Ouyang Pinansky 2005] [Bertolini Bigazzi Crotone 2005] [Franco Hanany Saad Uranga 2005]

The gravity dual is not known, but the field theory analysis suggests that smoothing of the singularity would break susy and involve some instability.

- no susy minimum
- runaway behaviour

The gravity dual is not known, but the field theory analysis suggests that smoothing of the singularity would break susy and involve some instability.
Introducing orientifold planes

- Large number $N$ of regular D3’s, possibly with extra $M$ deformation branes, on top of an anti-O3 plane.

- The corresponding AdS or local AdS backgrounds feel the absence of susy at 1-loop.

- If **fully** stable, they would contradict both the AdS-WGC and the local AdS-WGC.
Dynamics of D3’s and anti-O3’s

[Witten 1998] [Uranga 2000]

Four possible kinds of anti-O3 planes:

| D-brane description | $(\theta_{NS}, \theta_{RR})$ | Tension | RR charge |
|---------------------|----------------------------|---------|-----------|
| anti-(O3$^-$)       | $(0, 0)$                   | $-1/2$  | $+1/2$    |
| anti-(O3$^-$) + 1 D3| $(0, 1/2)$                 | $+1/2$  | $-1/2$    |
| anti- O3$^+$        | $(1/2, 0)$                 | $+1/2$  | $-1/2$    |
| anti- $\tilde{O}3^+$| $(1/2, 1/2)$              | $+1/2$  | $-1/2$    |

in D3 units

Under type IIB $SL(2, \mathbb{Z})$, the anti-(O3$^-$) is a singlet and the other three transform into each other.

Now introduce $N$ D3’s
| D-brane description | $(\theta_{NS}, \theta_{RR})$ | Tension | RR charge |
|---------------------|-----------------------------|---------|-----------|
| anti-(O3$^-$)       | (0, 0)                      | $-1/2$  | $+1/2$    |

- The gravitational and gauge interactions are both repulsive and the D3’s are repelled

| D-brane description | $(\theta_{NS}, \theta_{RR})$ | Tension | RR charge |
|---------------------|-----------------------------|---------|-----------|
| anti-(O3$^-$) + 1 D3 | (0, 1/2)                    | $+1/2$  | $-1/2$    |

- The D3’s are attracted, but when reaching stringy distances a single D3 can annihilate with the stuck $\overline{D3}$, which is replaced by another D3. In the final configuration, the gauge repulsion overcomes the gravitational attraction and the D3’s are repelled
The gravitational and gauge interactions are both attractive, so there is no obvious instability at weak coupling. However, strong-weak type IIB duality relates the anti-(O3\(^+\)) at strong coupling to the anti-(O3\(^-\)) + 1 \(\overline{D3}\) at weak coupling, thus implying that the system is unstable at strong coupling.

As in the previous case, an instability is expected because the system is related to the anti-(O3\(^-\)) + 1 \(\overline{D3}\) via an \(SL(2, \mathbb{Z})\) transformation.
Conclusions

- We propose a new swampland conjecture generalizing the AdS-WGC to locally AdS backgrounds and forbidding stable non susy warped throats with local AdS asymptotics.

- Its application allows to reinterpret known results about warped throats from fractional branes.

- We also derived new results on the (in)stability properties of large classes of non susy warped throats, providing further evidence for both the AdS-WGC and the local AdS-WGC.

Thank you!