Supersymmetry Breaking Warped Throats and the Weak Gravity Conjecture

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

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Motivation: non susy AdS and the Swampland

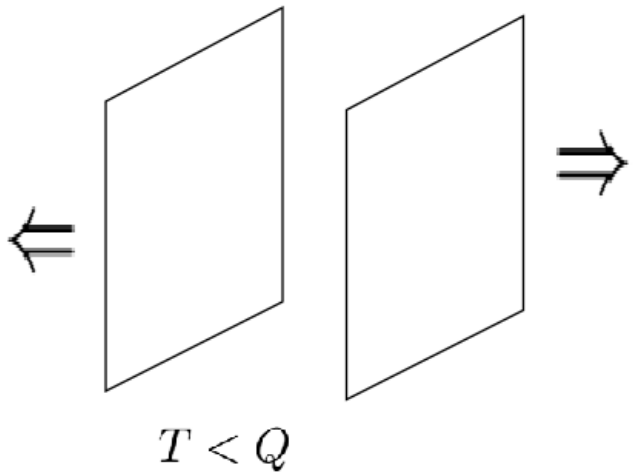
"Gravity is the weakest force" [Arkani-Hamed Motl Nicolis Vafa 2007]

WGC: given a $(p+1)$-form gauge potential, there exists a p-brane with tension

$$T \leq Q$$

[Ooguri Vafa 2017]

refined WGC: $T = Q \Leftrightarrow$ BPS states in a susy theory



Since AdS can be oobtained as near horizon limit of a configuration of branes, this motivates the

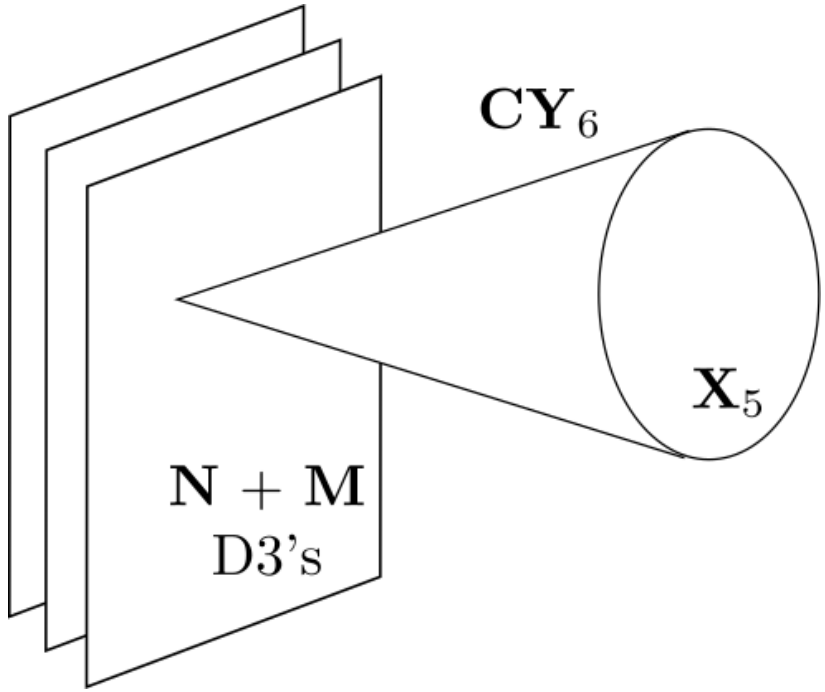
AdS-WGC: all non susy AdS vacua must be **unstable**

Still true for **local** AdS backgrounds?

Warped throats

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

$$ds^2_{\mathbf{CY}_6} = dr^2 + r^2 ds^2_{\mathbf{X}_5}$$



- For $M = 0$, the gauge theory is **conformal**.

  $AdS_5 \times \mathbf{X}_5$ gravity dual $\Rightarrow$ usual AdS-WGC

- For $M \neq 0$, the gauge theory has a non trivial RG flow (**duality cascade**). The gravity dual is a **local** AdS solution

- RR 3-form flux $\int_{\Sigma_3} F_3 = M$ constant
- NSNS 3-form flux $H_3 = dB_2$ $\int_{\Sigma_2} B_2 \sim g_s M \ln r$
- RR 5-form flux $\int_{\mathbf{X}_5} F_5 = N(r) \sim g_s M^2 \ln r$
- warped metric

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

with $Z(r) = \dfrac{L^4}{r^4}\,\ln\left(\dfrac{r}{r_s}\right)$ $L^2 \sim g_s M$ r_s naked singularity

The local AdS-WGC

[GB García-Valdecasas Uranga 2018]

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

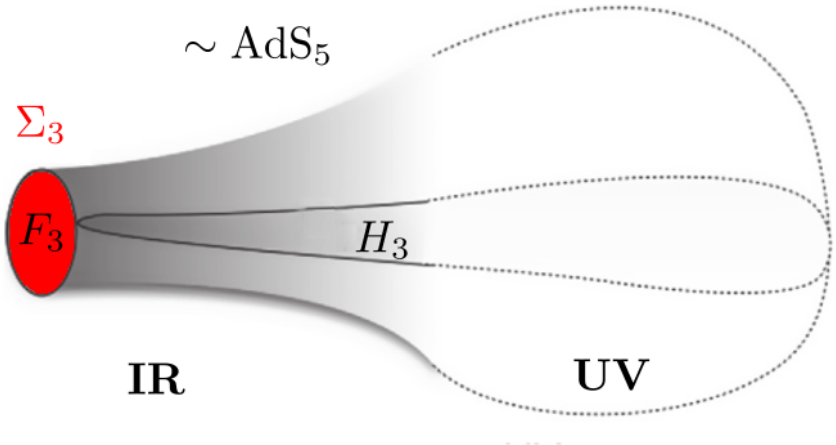
- warped throats with asymptotics modified by ingredients in the bulk

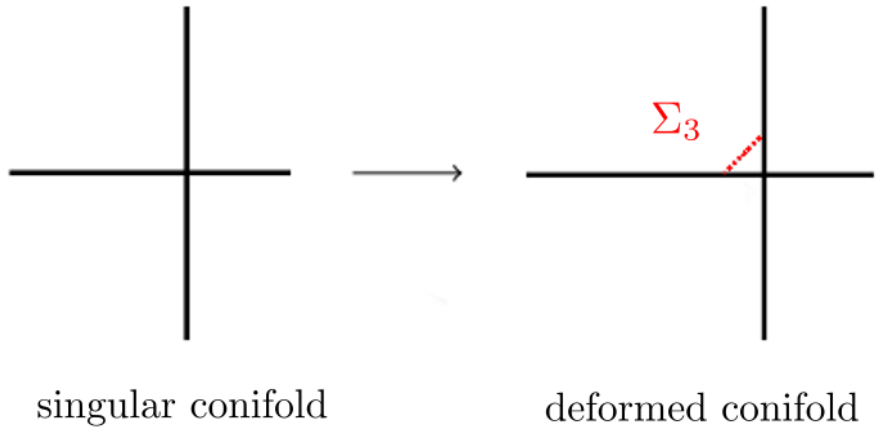
Evidence from deformation branes

Different classes of fractional branes, in particular:

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

[Klebanov Strassler 2000]



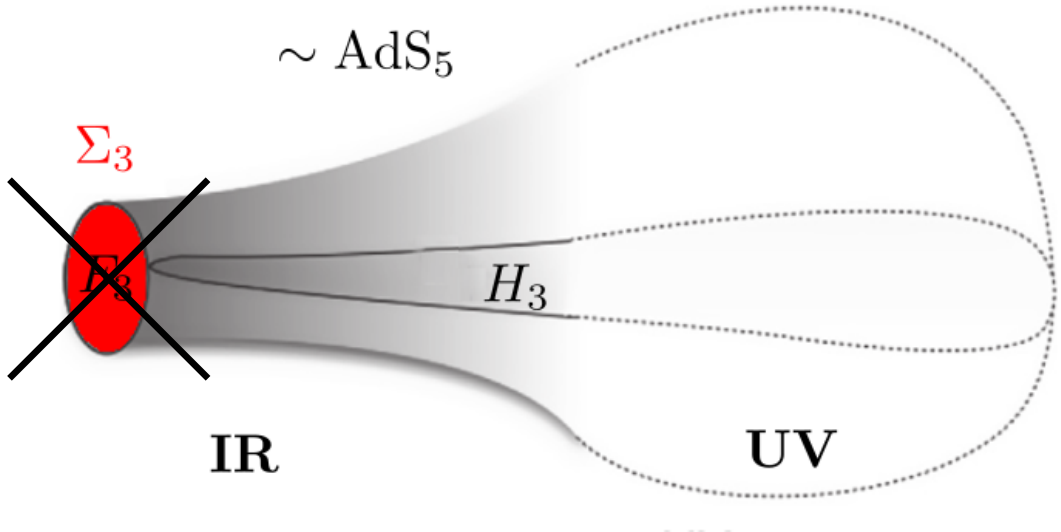


The naked singularity can be smoothed out by giving the 3-cycle a finite size, while preserving supersymmetry

$\Rightarrow$ The local AdS-WGC is **satisfied**

Evidence from DSB branes

- DSB branes, not associated to complex deformations



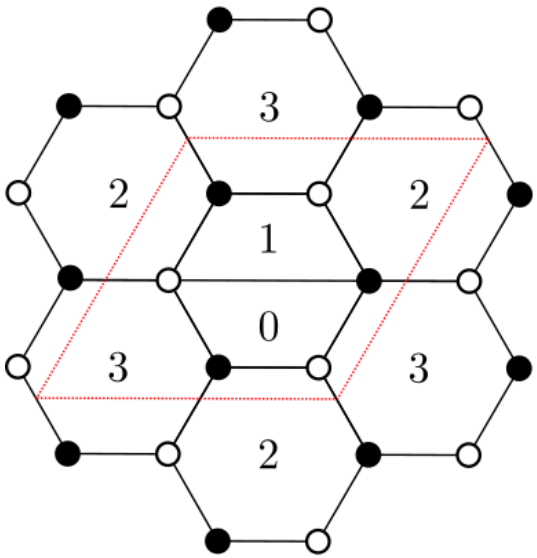
If one could smooth out the IR region to an alternative susy breaking **stable** configuration, this would contradict the local AdS-WGC...

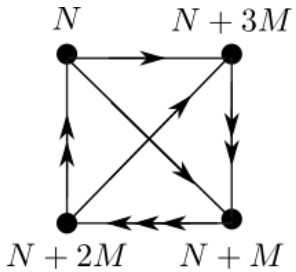
But we argue that this is **not** possible.

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]





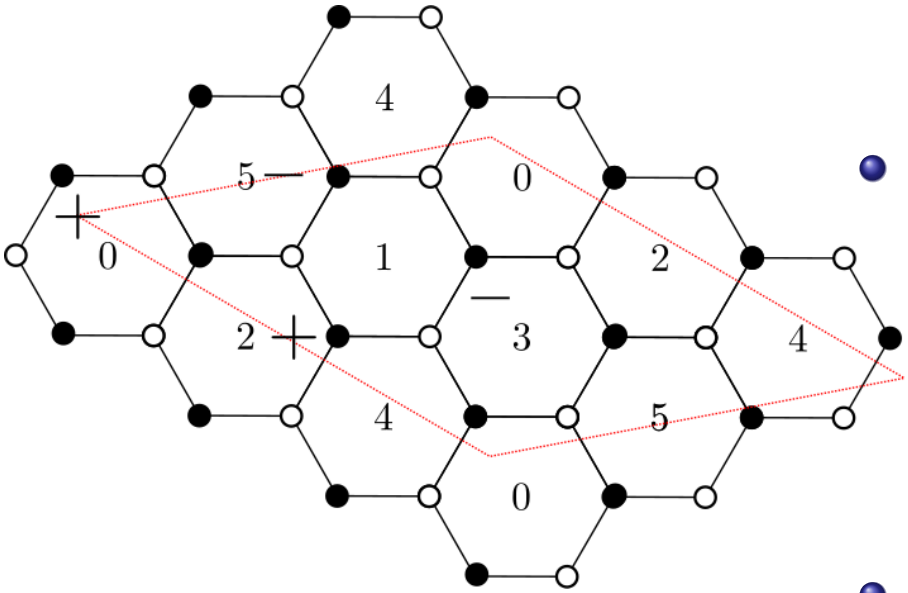
- no susy minimum
- **runaway** behaviour

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

Brane engineering the $SU(5)$ model

$SU(5)$ with $\square\!\square + \overline{\square}$, no superpotential and **stable** isolated DSB vacuum

[Affleck Dine Seiberg 1984]



$0 \Leftrightarrow 0 \quad 1 \Leftrightarrow 5 \quad 2 \Leftrightarrow 4 \quad 3 \Leftrightarrow 3$

- fixed point orientifold of $\mathbb{C}^3/\mathbb{Z}_6'$ orbifold

$$\theta : z_i \to e^{2\pi i v_i} z_i, \quad v_i = (1, 2, -3)/6$$

- $SO(n_0) \times U(n_1) \times U(n_2) \times USp(n_3)$

$$(\square_0, \overline{\square}_1) + (\square_1, \overline{\square}_2) + (\square_2, \overline{\square}_3) +$$
$$+ (\square_0, \overline{\square}_2) + (\square_1, \square_3) + \square\!\square_2 + \overline{\square\!\square}_1 +$$
$$+ (\square_0, \square_3) + (\square_1, \square_2) + (\overline{\square}_1, \overline{\square}_2)$$

- anomaly-free choice of ranks $(n_0, n_2 = 1, 5)$

Embedding in a throath

[GB García-Valdecasas Uranga 2018]

- Add a large number N of regular D3's

$$SO(N+1) \times U(N) \times U(N+5) \times USp(N),$$

- Due to the DSB sector, the gravity dual is non susy

Where is the instability?

- The D3's are **not** repelled, as can be seen from **Higgsing** and **scale matching**,

$$SU(N+5) \xrightarrow{\Phi} SU(5), \qquad \Lambda = \Lambda_{UV}$$

- Each regular D3 can **split** into $\mathcal{N}=2$ fractional branes that can move along the corresponding complex plane of singularities. The Higgsing pattern is

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

with scale matching $\Lambda = \left(\frac{v'}{v}\right)^{2N} \Lambda_{UV}$,

describing a **runaway** towards a susy vacuum with zero energy

[GB García-Valdecasas Uranga 2018]

- This instability is always present for singularities admitting fractional branes of the $\mathcal{N}=2$ type

[Argurio Bertolini Meynet Pasternak 2019]

Introducing orientifold planes

- Large number N of regular D3's, possibly with extra M fractional branes, on top of an anti-O3 plane
- The corresponding AdS or local AdS backgrounds feel the absence of susy at 1-loop
- If 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-($\mathrm{O3}^-$)	$(0,0)$	$-1/2$	$+1/2$
anti-($\mathrm{O3}^-$) + 1 $\overline{\mathrm{D3}}$	$(0,1/2)$	$+1/2$	$-1/2$
anti- $\mathrm{O3}^+$	$(1/2,0)$	$+1/2$	$-1/2$
anti- $\widetilde{\mathrm{O3}}^+$	$(1/2,1/2)$	$+1/2$	$-1/2$

in D3 units

Under type IIB $SL(2,\mathbf{Z})$, the anti-($\mathrm{O3}^-$) 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 $\overline{\text{D3}}$	$(0,1/2)$	$+1/2$	$-1/2$

- The D3's are attracted, but when reaching stringy distances a single D3 can annihilate with the stuck $\overline{\text{D3}}$, which is replaced by another D3. In the final configuration, the gauge repulsion overcomes the gravitational attraction and the D3's are repelled

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

- 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 $\overline{\mathrm{D3}}$ at weak coupling, thus impling that the system is unstable at strong coupling

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

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

Conclusions

- We propose a new swampland conjecture generalizing the AdS-WGC to local AdS backgrounds
- Its application allows to reinterpret known results about warped throats from fractional branes
- We also derive 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

Conclusions

- We propose a new swampland conjecture generalizing the AdS-WGC to local AdS backgrounds
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Thank you!