

Polarisation everywhere

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String Swampology 2019, Geneva



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Article

Talk

Polarization

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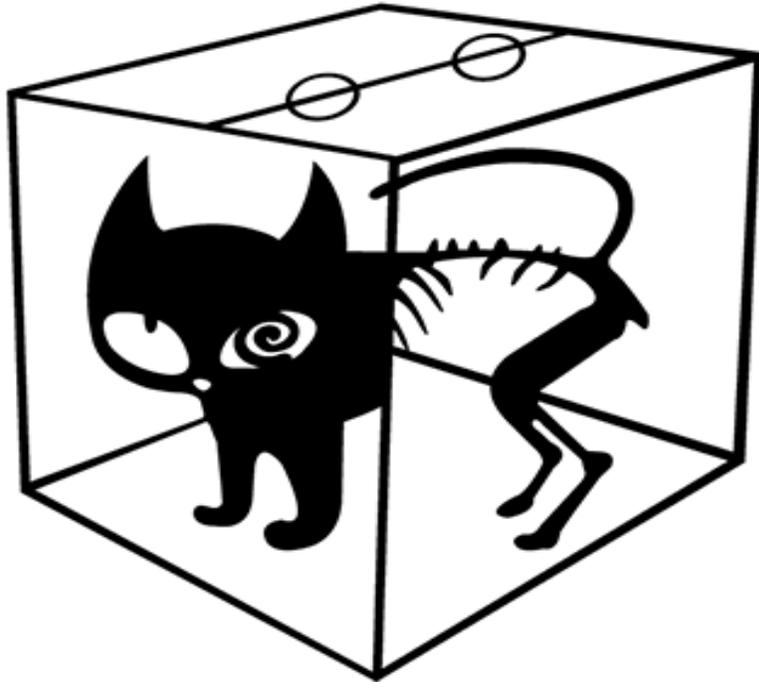
- [Vacuum polarization](#), a process in which a background electromagnetic field produces virtual electron-positron pairs
- [Political polarization](#), the process by which the public opinion divides and goes to the extremes

A de Sitter-exit?

[Brennan, Carta, Vafa] [Danielsson, VR] [Obied, Ooguri,
Spodyneiko, Vafa] [Ooguri, Palti, Shiu, Vafa] [...]

De Sitter space is

ALEA VIE



Counter examples? more than 10^{500} :
[KKLT, 2003, LVS 2005 & many follow-ups]

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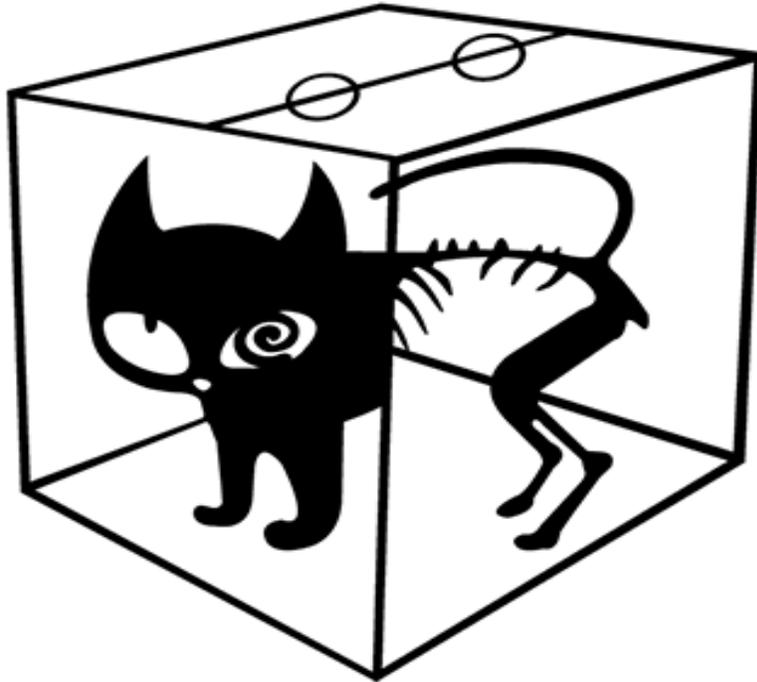
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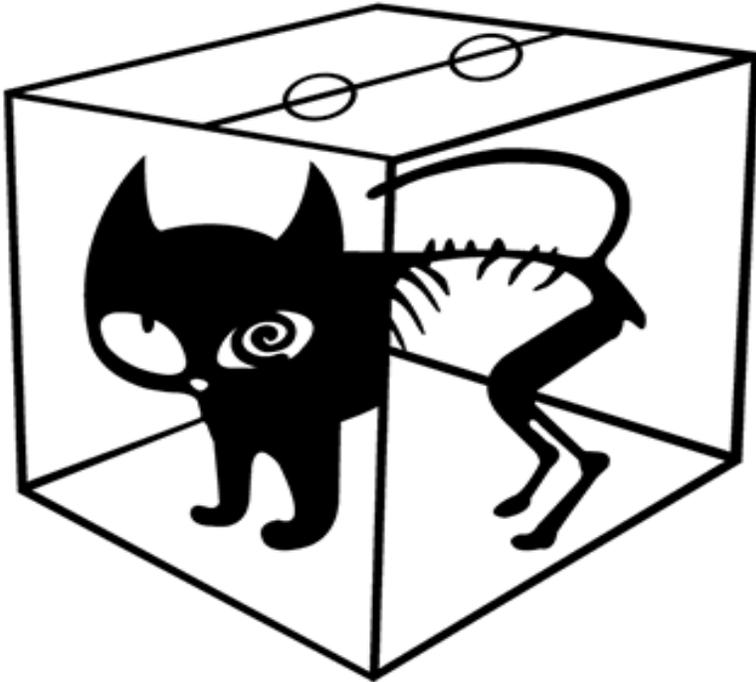
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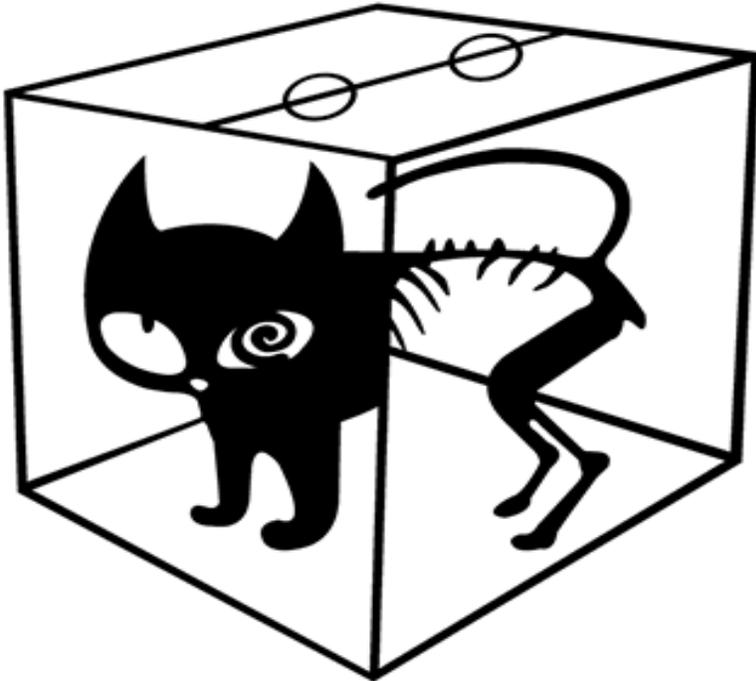
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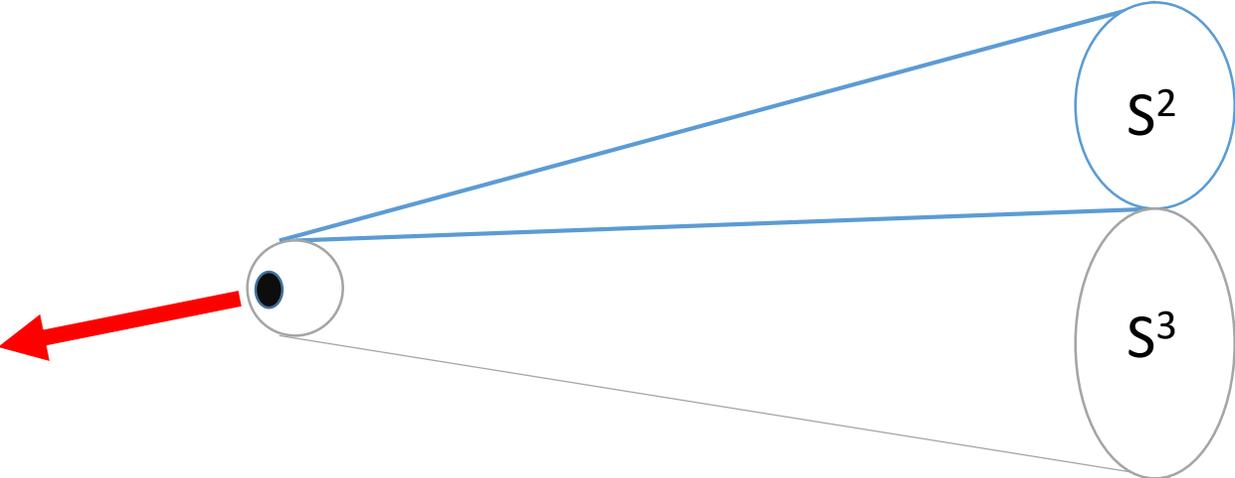
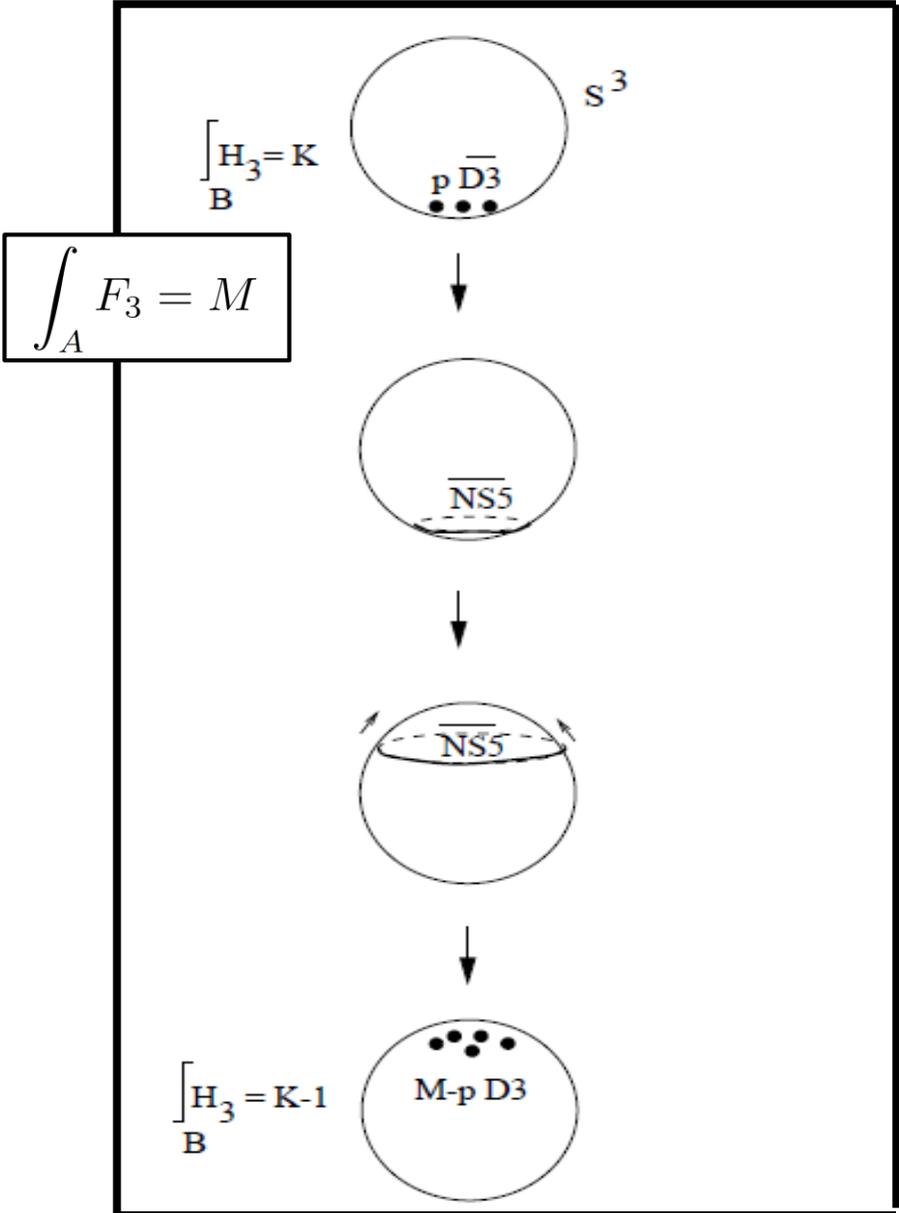
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SUSY breaking anti-branes in warped throats:

$$M_p^2 = \text{Vol}_6 g_s^{-2} \ell_s^{-2} = \infty$$

$$M_p^2 = \text{Vol}_6 g_s^{-2} \ell_s^{-2} < \infty$$

Kachru, Pearson, Verlinde (KPV) 2001



Holographic dual to dynamical SUSY breaking in the Klebanov Strassler gauge theory

Locally confined backreaction & meta-stability if :

$$p/M \ll 1$$

KPV computation: no backreaction



Flux attracted towards anti-branes
gravitationally *and* magnetically

With backreaction



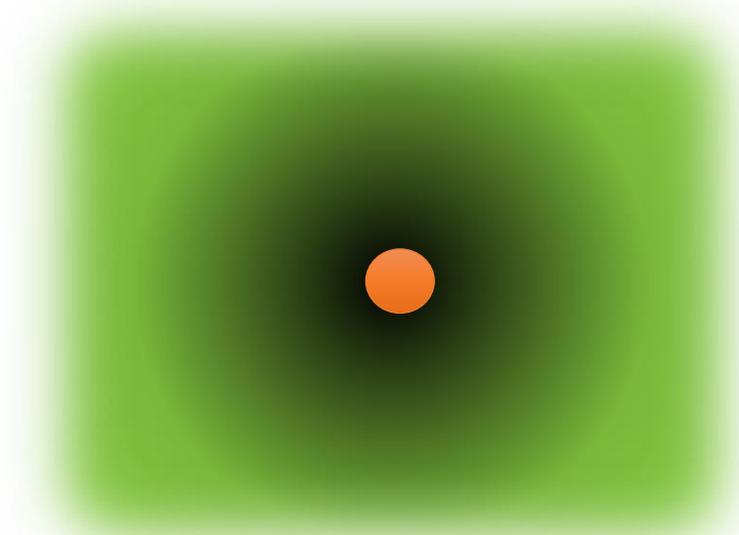
Can a probe approximation fail (in the probe limit) ?

KPV computation: no backreaction



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Can a probe approximation fail (in the probe limit) ?

6D backreaction = infinite fluxclumping

$$e^{-\phi} H^2 \rightarrow \infty$$

If correct, direct brane-flux decay [Blaback, Danielsson, VR, 2012].

(**Bena**, Blaback, **Grana**, Giecold, Puhm, Orsi, Massai, Kuperstein, Zagermann, Junghans, Wrase, Danielsson, Gautason, Vercoocke, Diaz, Truijen, Cohen-Maldonado, Hashimoto, Cottrell, VR, Vargas, **Halmagyi**, Kutasov, Wisanji, McGuirk, Massai, Shiu, Sumitomo, Galante, Buchel, Hartnett, Dymarsky, Polchinski, Saad, Mintun, Michel,)

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- Define charges: $Q_3 = \int_{S^5} F_5$, $Q_5 = \int_{S^3} H_3$

and the gauge potentials near the source: $C_4 = \alpha_H \tilde{\star}_4 1$, $B_6 = b_H \tilde{\star}_4 1 \wedge \epsilon_2$

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- From the Ansatz (...) one can easily show that absence of infinite flux clumping implies $\alpha_{H=0}$.
- ***Only when Ansatz allows spherical NS5 branes one can take $\alpha_{H=0}$. All claims of singularities in the literature can be explained this way: a too restrictive Ansatz (conflicting KPV).***

See [C.-Maldonado, Diaz, Gautason, 1603.05678] for a significant extension and formalization of this.

- Note that we do not prove existence of solutions. We prove when they cannot exist. Existence is instead argued from probe computations (KPV).

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- “Increasing temperature” makes meta-stable vacuum disappear. This happens exactly when [Armas, Nguyen, Niarchos, Obers, VR,2018]



META-STABLE



HEAT UP



UNSTABLE

More involved and rich structure for anti-M2 branes and finite T [Armas, Nguyen, Niarchos, Obers 2019]

No clash between SUGRA and probe actions? → Anti-D6 branes in massive IIA an exception
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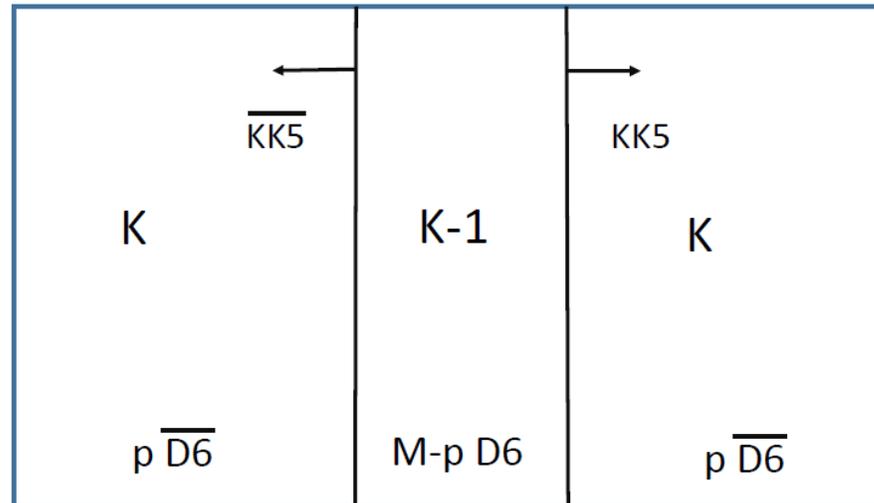
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→ Direct brane flux decay [Blaback, Danielsson, VR 2012], happens via KK5 dipoles [Danielsson, Gautason, VR 2016]



.....BUT

Anti-brane singularities as red herrings

J. Blåbäck^a, F. F. Gautason^b, A. Ruipérez^{bc}, T. Van Riet^b

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- Good news for classical IIA dS constructions? [Kallosh-Wrase 2018]

Excursion: WGC and cosmic censorship [\[Crisford, Horowitz, Santos\]](#)

4D Einstein Maxwell theory in AdS.

$$S = \frac{1}{16\pi} \int d^4x \sqrt{-g} \left[R - 2\Lambda - F^2 - 4D_\mu \Psi (D^\mu \Psi)^\dagger - 4m^2 \Psi \Psi^\dagger \right]$$

Ansatz:

$$ds^2 = -e^{2f(x)} dt^2 + \gamma_{ij} dx^i dx^j$$

$$A = \Phi(x) dt$$

Boundary condition for gauge field:

$$A_\partial = \frac{a dt}{\left(1 + \frac{r^2}{\ell^2}\right)^{\frac{n}{2}}}$$

- For $a < a_{\max}$ bulk is a self gravitating lump of electric fields with a Poincare horizon in IR.
- When $a > a_{\max}$ there is a naked singularity .
- Start with small a and then increase adiabatically \rightarrow *breaking of Cosmic Censorship*.

Numerical Observation: this does not happen when a charged scalar is added that obeys WGC!

Polarization of scalar makes that F^2 cannot grow unboundedly towards horizon. WGC crucial

Towards an analytic derivation? [De Smet, , Ruiperez, Van Hemelryck, VR, unpublished]

Smarr relation (.....):

$$8\pi M + \frac{1}{2}a^2\mathcal{I} + 16\pi PV = - \int_{t=\text{cst}} |\psi|^2 e^f m_{\text{eff}}^2 \star_3 1$$

$$a^2\mathcal{I} = - \int_{z=0} e^{-f} \Phi \star_3 d\Phi \quad m_{\text{eff}}^2 = m^2 - q^2 \Phi^2 e^{-2f}$$

Assume: no-singularity means $M > 0$.

In absence of scalar, $M > 0$ becomes:

$$\frac{-32\pi PV}{\mathcal{I}} > a^2$$

So we get a bound on a^2 ! Is this a_{max} ?

WGC triggers the holographic superconducting phase: $m_{\text{eff}}^2 < 0$. There is no bound on a^2

End of excursion.

$$M_p^2 = \text{Vol}_6 g_s^{-2} \ell_s^{-2} = \infty \quad \longrightarrow \quad \text{Seems OK}$$

$$M_p^2 = \text{Vol}_6 g_s^{-2} \ell_s^{-2} < \infty \quad \longrightarrow \quad \text{Worried!}$$

Controlled SUSY breaking & uplifting:

If there exist SUSY AdS vacua for which

$$\boxed{mR = \kappa \gg 1} \quad (m \text{ is mass of lightest modulus.})$$

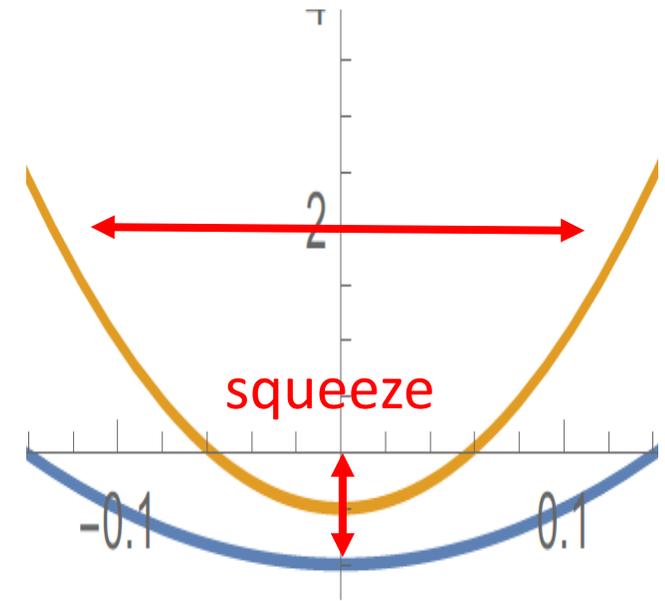
Then any form of SUSY breaking leads to controlled dS vacua!

Conjecture: *such AdS vacua are in the Swampland*: [1810.08518, F. Gautason, V. Van Hemelryck, VR]

- Is conjecture on **SUSY AdS vacua** motivated from the more speculative dS conjecture.
- A stronger version was motivated differently in [Lust, Palti, Vafa 2019], see talk Vafa, Palti.
- Is conjecture on 3D N=1 CFTs. They have not a single low-lying operator!

$$\Delta = \frac{3}{2} + \frac{1}{2}\sqrt{9 + 4\kappa^2} \gg 1$$

“Dead End CFTs”. Do we know such CFTs?



Let us for a moment *assume* we can obtain AdS vacua (KKLT, LVS,...) that obey

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→ See however [\[Sethi 2017\]](#), and Sethi's talk this conference

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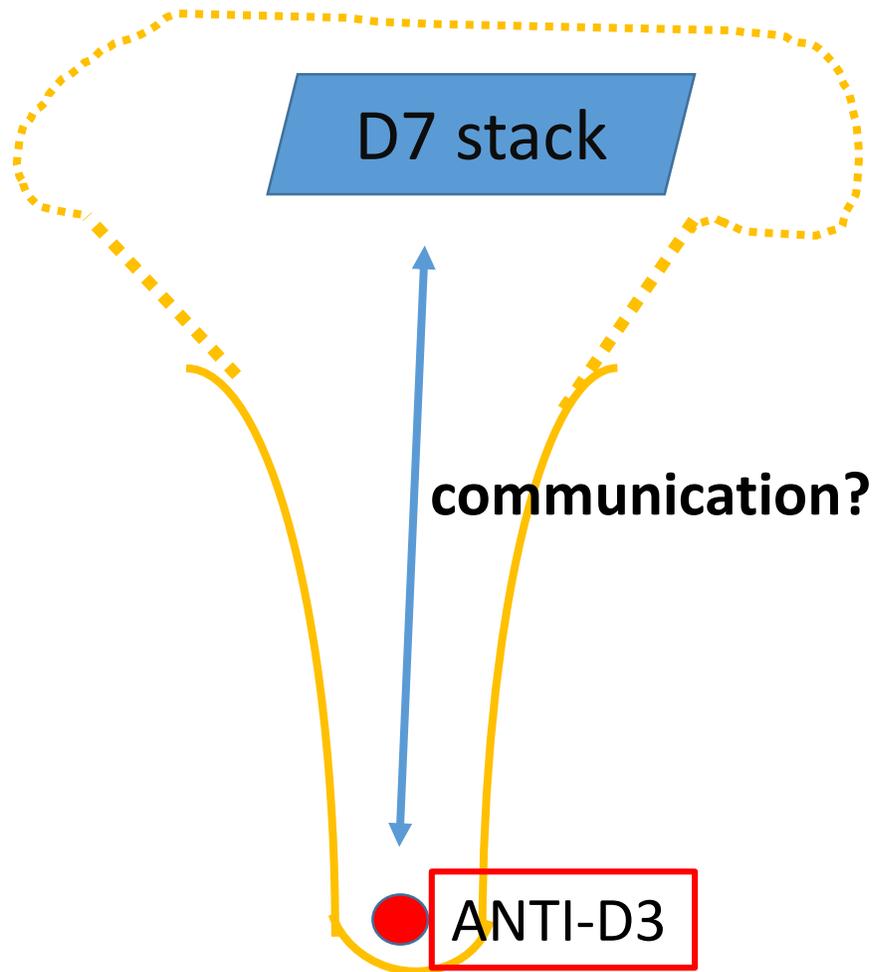
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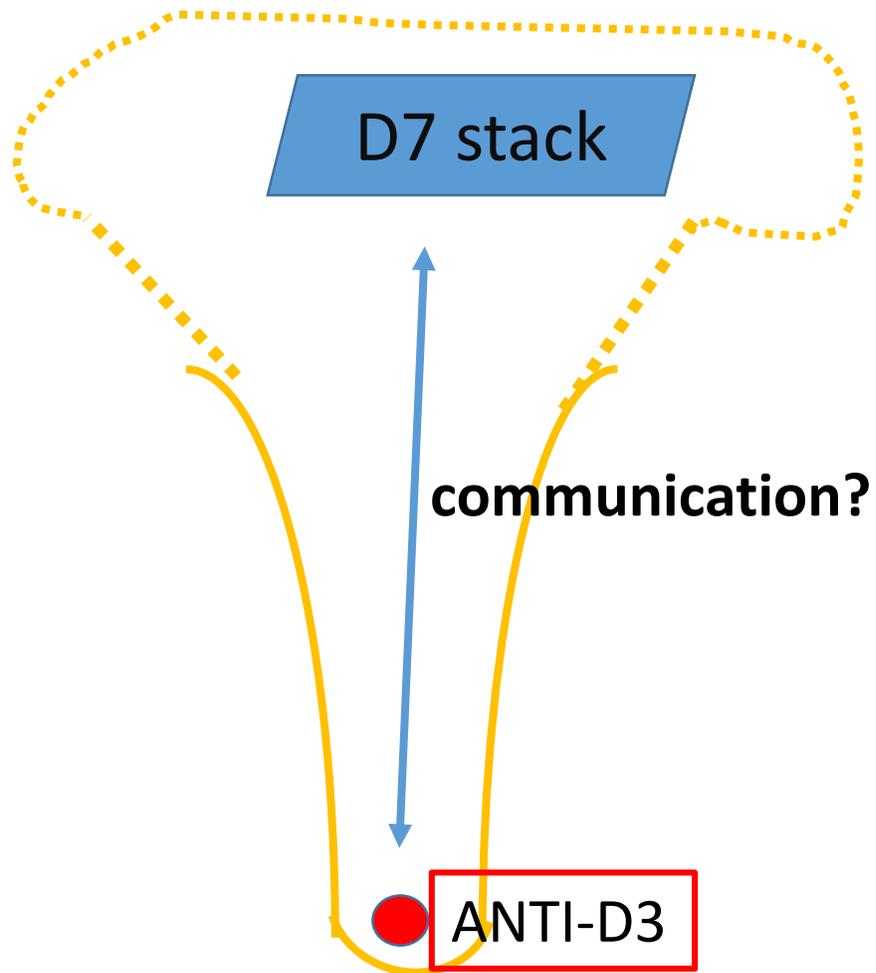
‘Anti-brane, do you even lift?’



Interplay gaugino condensation, SUSY-breaking? See talks McAllister, Grana, Hebecker, Westphal



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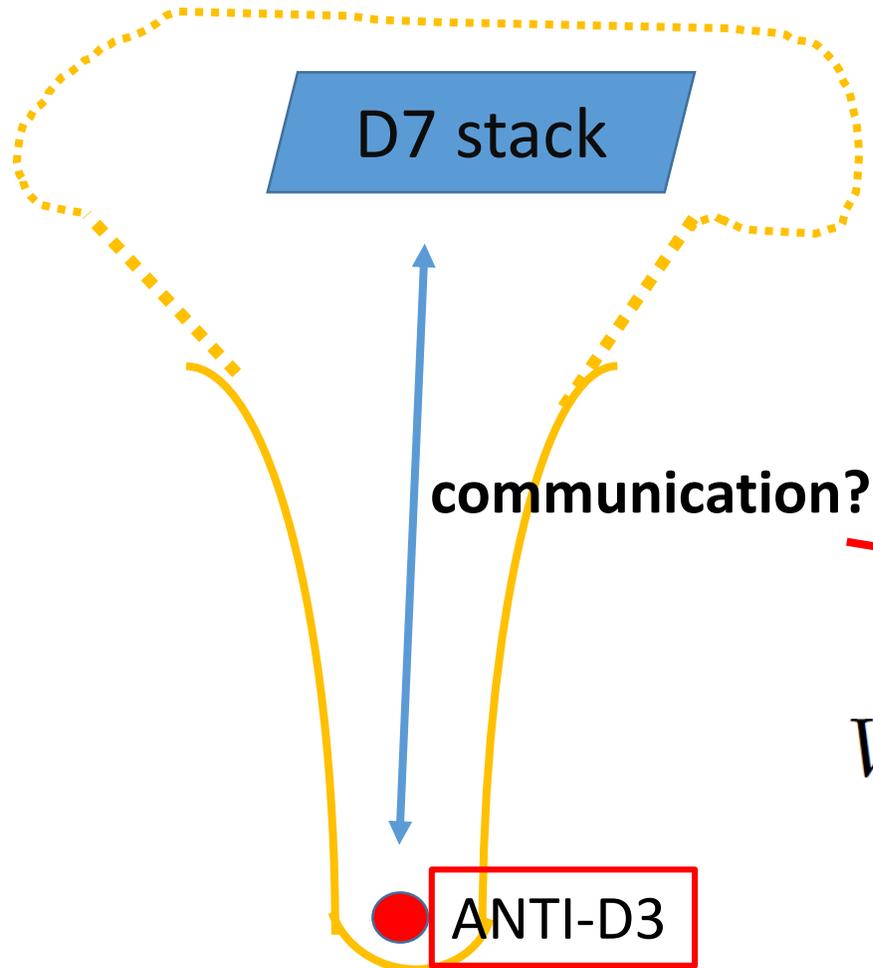
Two issues:

1. Throat cannot “be long enough” & lack of tuning freedom [Bena, Dudas, Grana, Lust, 2018, Carta, Moritz, Westphal 2019, Blumenhagen, Klawer, Schlechter 2019,....]
2. “Blue-shift” of gaugino-condensate towards tip of throat. No decoupling. Corrections to KKLT potential [Moritz, Retolaza, Westphal 2017 & follow-ups].

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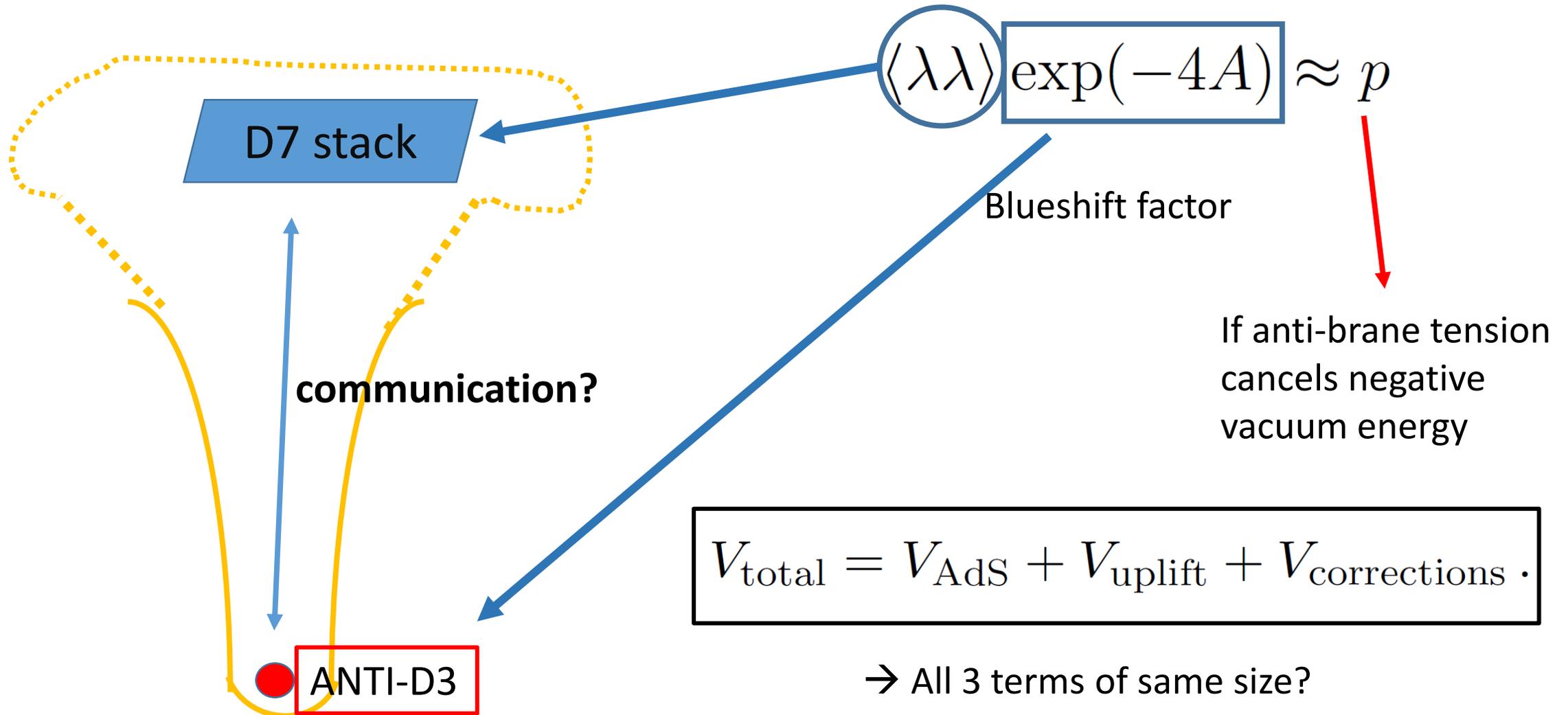


$$V_{\text{total}} = V_{\text{AdS}} + V_{\text{uplift}} + V_{\text{corrections}}$$

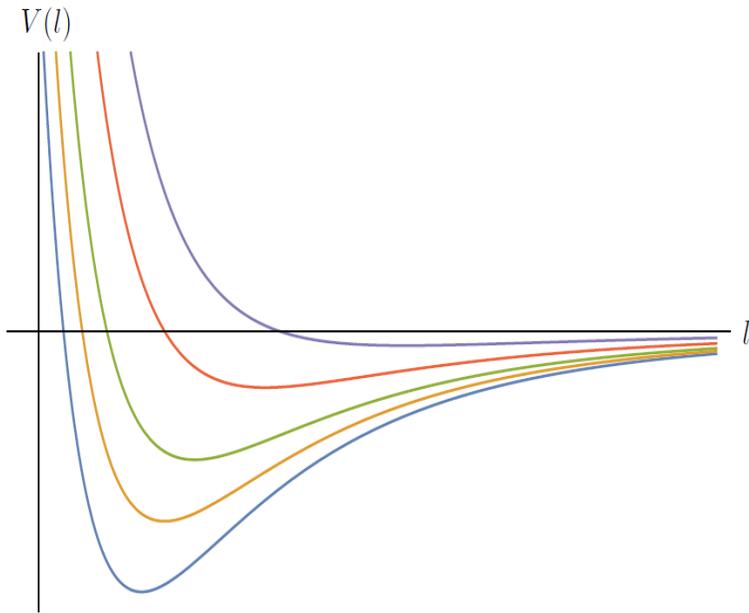
Sufficiently warped down?

Back of the envelope argument [Moritz, Retolaza, Westphal, 2017]:

→ UV correction (gaugino condensation) is order 1 effect in IR.

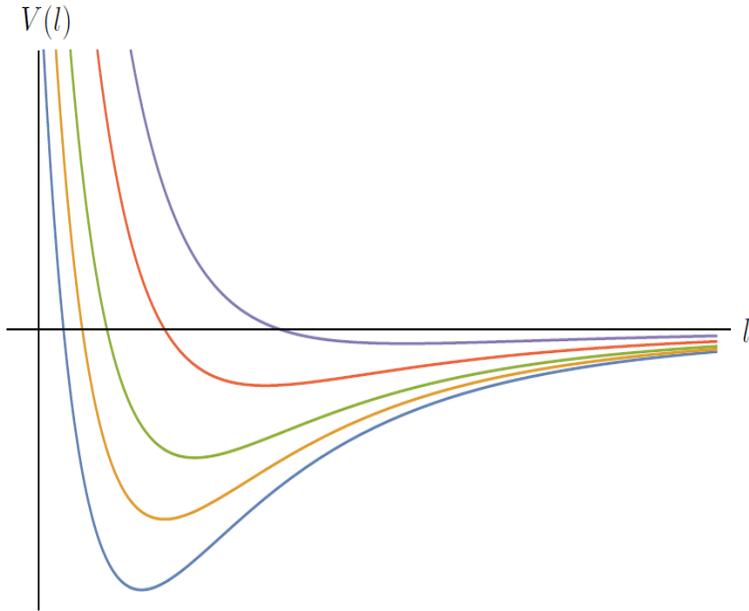


Flattening effects → you never get to de Sitter [Moritz, Retolaza, Westphal 2017]



- Not quite [Gautason, Van Hemelrijck, VR, 2018]
- **Singular expressions, you need quartic fermion term** [Hamada, Hebecker, Shiu, Soler 2018] → one should redo computation.

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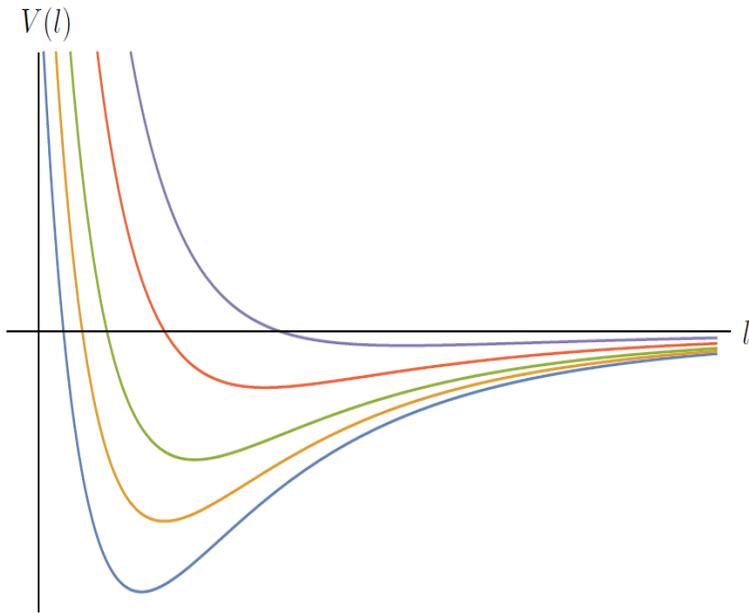


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2. “We get KKLT on the nose, no corrections” [Hamada, Hebecker, Shiu, Soler 2019] + talk McAllister.
3. “Don’t use the approach when SUSY is broken. Unclear whether there is an issue” [Carta, Moritz, Westphal 2019]

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Polarised Literature

Difference in approaches? → definition of semi-classical limit

$$G_{ab} = \langle T_{ab} \rangle$$

- [Gautason, Hemelrijck, VR, Venken 2019] : T-tensor obtained from varying 10D action wrt to metric keeping all other fields fixed. THEN we add fermion condensate vev in T.
- [Hamada, Hebecker, Shiu, Soler 2019] : Reverse order.

→ It matters since $\langle \lambda\lambda \rangle = -\frac{32\pi^2}{N} \mathcal{A} \exp\left(\frac{2\pi i}{N} \rho\right)$

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Who is correct? One should find corrections to KKLT that induces at least some flattening.

[Hamada, Hebecker, Shiu, Soler 2019] VS [Hamada, Hebecker, Shiu, Soler 2019]. Two extremes. Real answer in between?

Conclusion

Moduli stabilization & SUSY-breaking. Finite volume or not makes a world of difference! Infinite M_p seems ok. Polarisation “saves the day”. Similar technique (might) allow analytic handle on WGC – Cosmic Censorship connection

Finite M_p less obvious! → Consistent with spirit behind Swampland ideas. Non-trivial to decouple SUSY-breaking from moduli stabilization. Especially when trying to lift all the way to dS space.

- Link with observations? Some extra motivation to search for $p \neq -\rho$

Outlook

- Find general principles behind possible non-existence of dS space. Both from EFT and holography, string theory...: “vacuum **polarization** screening the cc” [Mottola, Polyakov, Dvali-Gomez-Sell, Woodard-Tsamis, Danielsson, Markannen,...]

Like the WGC there is an inequality which tells you when dS horizons decay:

$$m^2 > \frac{9}{4\ell^2}$$

(Wick-rotation BF bound in AdS.)

If a scalar satisfies this then dS decays through (gravitational) Schwinger effect. Competition between cosmic depletion and gravitational backreaction of particle creation

→ *Strong gravity conjecture* [Hertog, Janssen, Montero, Venken, VR, unpublished]