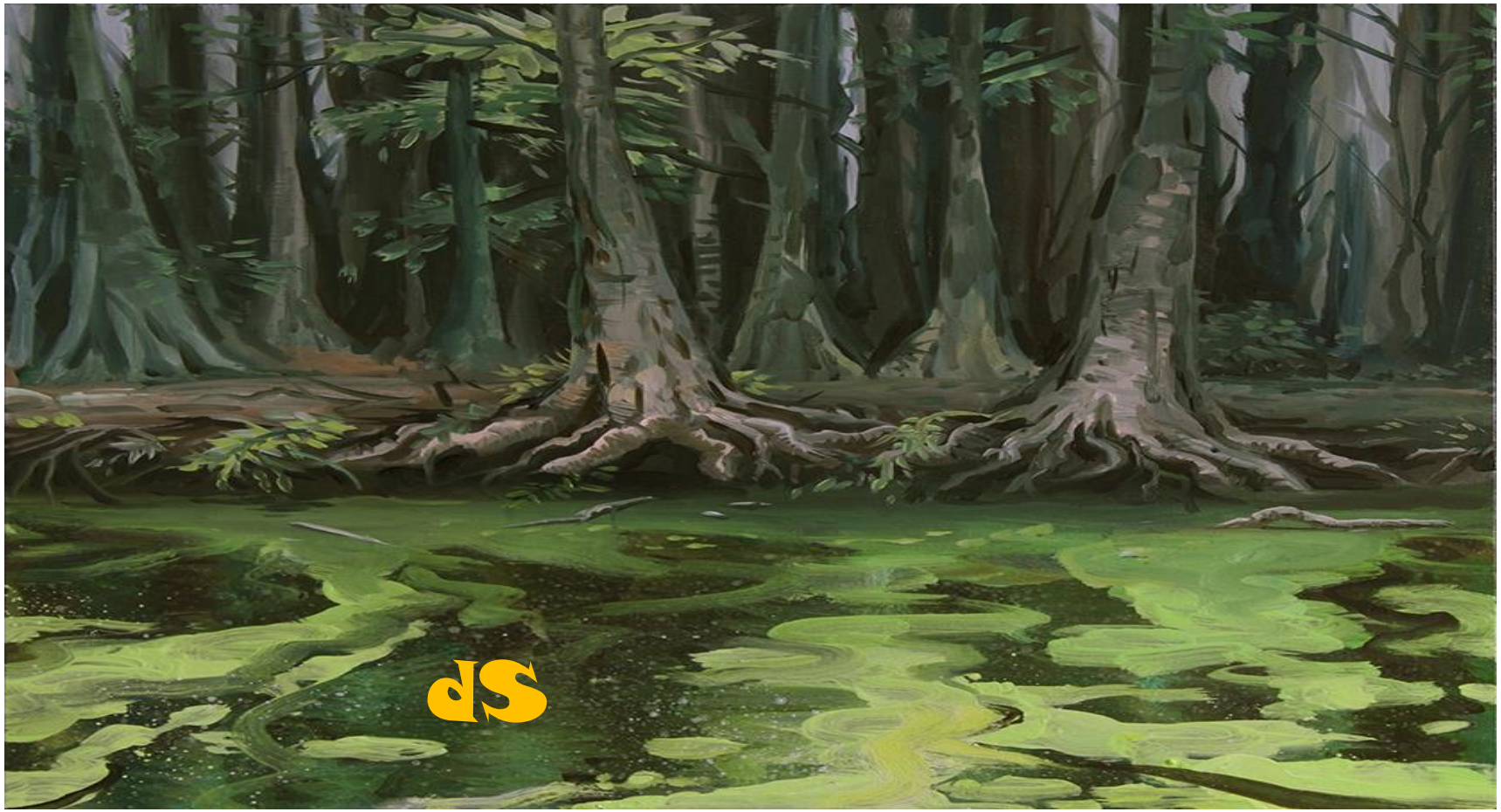
The tension between dS uplifts, 10d supergravity and 3D CFTs



Thomas Van Riet -- KULeuven

Vistas over the Swampland, Madrid, 2018.

Based on

- *Supersymmetric dS/CFT.* With **T. Hertog, G. T.-Mazzucchelli, G. Venken** [1709.06024]
- *Racing through the swampland: de Sitter uplift vs Weak Gravity.* With **J. Moritz**, [1805.00944]
- *The tension between dS uplifts, 10d supergravity and 3D CFTs.* With **M. Buican, F. Gautason, V. Van Hemelrijck**, to appear.
- *What if string theory has no dS vacua?* With **U. Danielsson** [1804.01120]

The dS Swampland *conjecture*

What if string theory has no dS vacua? With U. Danielsson [1804.01120]

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If the "no-de Sitter conspiracy" is correct, does it work via [Obied, Ooguri, Spodyneiko, Vafa, 2018]

$$|\nabla V| \geq c \cdot V \quad ?$$

Evidence against inequality?

1. All dS vacua in string theory ever proposed ☺

2. Higgs potential in standard model! [Denef, Hebecker, Wrase, 2018]

3. SUSY KKLT & racetrack models have unstable dS critical point away from AdS vacuum [Conlon 2018].

4. ``Classical" dS solutions [Flauger, Paban, Robbins, Wrase 2008, Caviezel, Koerber, Kors, Lust, Wrase, Zagermann 2008 & many follow ups]

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→Examples 2, 3, 4 are **all tachyonic**. Maybe the Swampland inequality needs to be extended to include second derivatives (epsilon and eta) ? [Andriot 2018].

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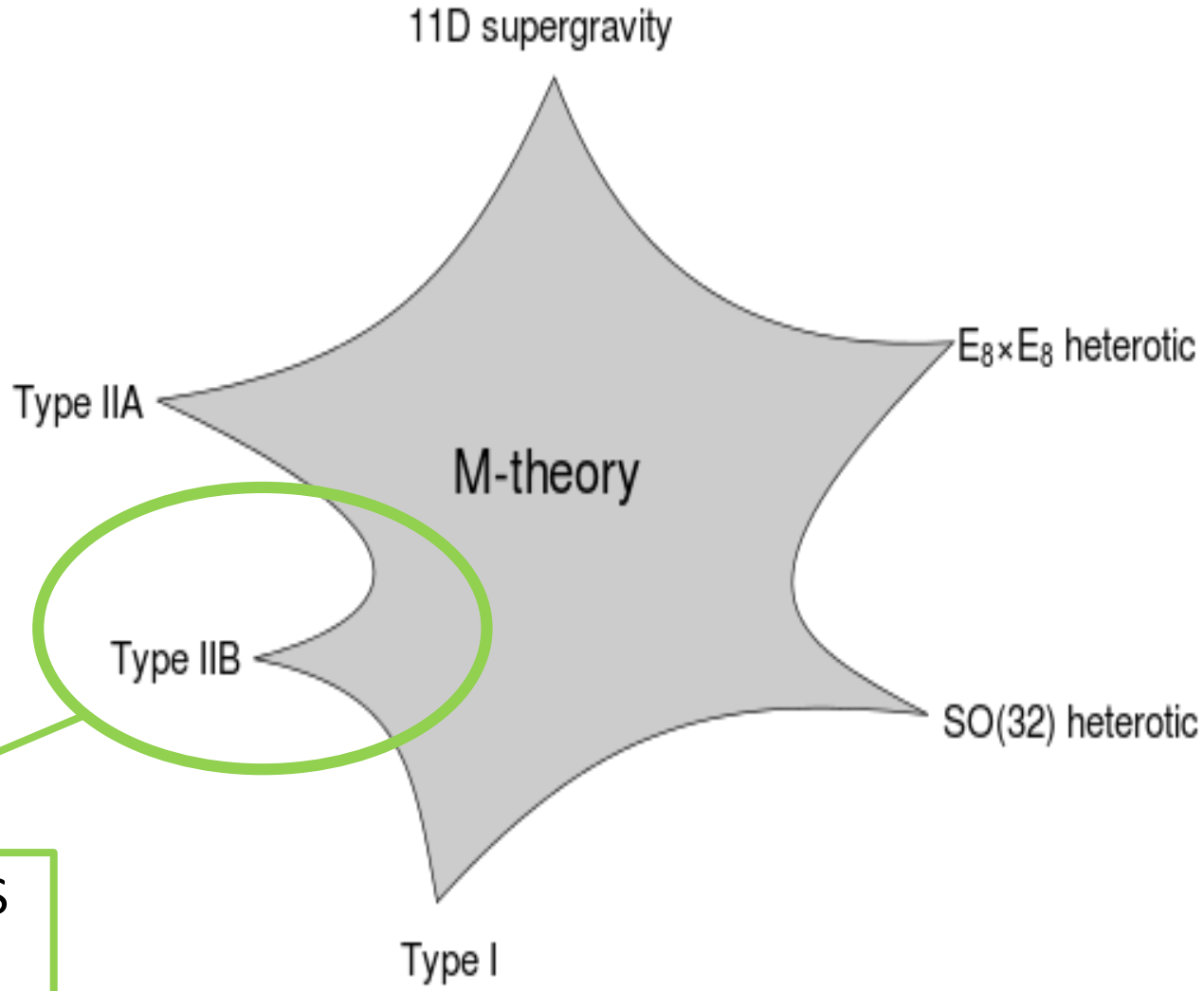
→ Not unreasonable that there is perturbative brane-flux decay. Needs to be checked…..

Whack a mole: Instabilities in dS model building

Issues with dS uplifts

Let us take vanilla models: KKLT, LVS,…



90% of all papers on dS
"corrections to GKP"

Problem 0: Bunch Davies is unphysical

IR backreaction effects of particle production in dS space; dS space decays no matter what.
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SUSY-breaking GKP fluxes have higher derivative forces who cannot be ignored and lead to runaway instead. See [Kachru, Trivedi 2018] for critical remarks.

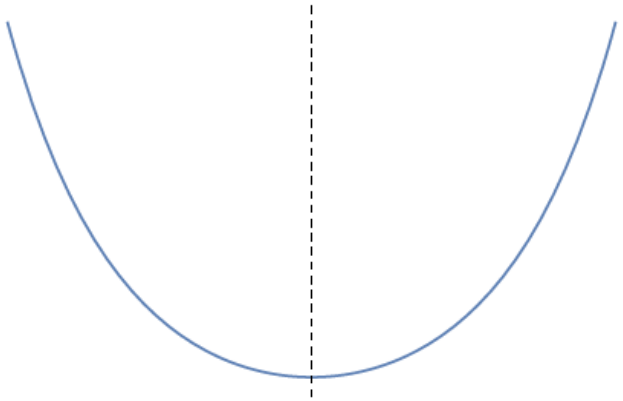

Figure 1: A good starting point.

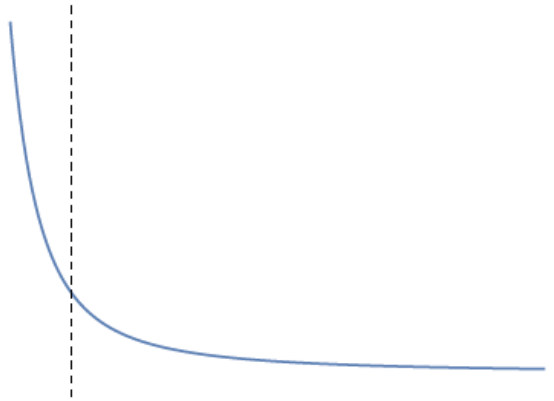

Figure 2: A not so good starting point.

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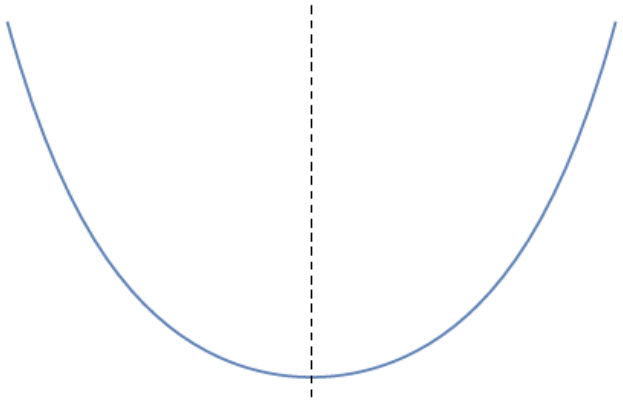

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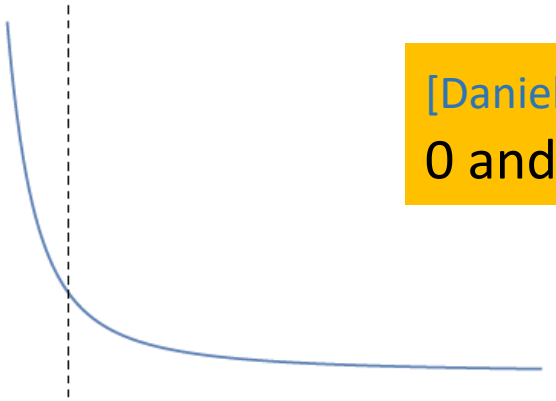

Figure 2: A not so good starting point.

[Danielsson 2018]: problem 0 and 1 not unrelated

Problem 2: 6D backreaction of antibranes

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

Review soon.

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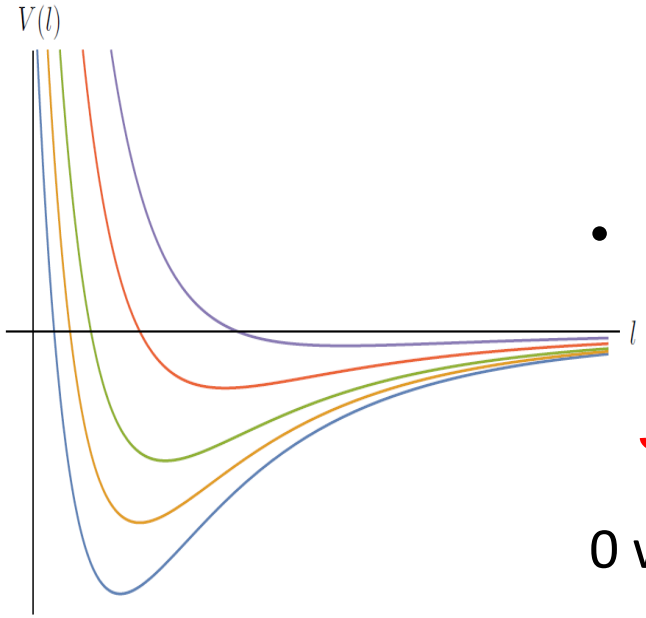
- So it could have been a red herring. However, brane repelling tachyons [Bena, Grana, Kuperstein, Massai 1402.2294, 1410.7776 & Bena, Kuperstein 1504.00656 & Bena, Blaback, Turton 1602.05959]. See also [Danielsson, 1502.01234 & Nakai, Ookouchi, Tanahashi, 1808.10235]

Problem 3: 4D backreaction of antibranes [Moritz, Retolaza, Westphal 1707.08678]

When KKLT uplifting is studied from a 10D point of view, we find AdS at best!



$$S_{D7} \supset \int_{\mathcal{M}_{10}} \delta_D^{(0)} e^{\phi/2} e^{-4A} \frac{\bar{\lambda}\bar{\lambda}}{16\pi^2} G_3 \wedge \star_{10}\Omega + c.c.\,,$$

[Baumann, Dymarsky, Kachru, Klebanov, McAllister, 2010]

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$$\nabla^2\Phi^- = R_4 + e^{-6A}\left|\mathrm{d}\Phi^-\right|^2 + \frac{e^{2A}}{\mathrm{Im}(\tau)}\left|G_3^-\right|^2 + \Delta_{\text{gaugino}}$$

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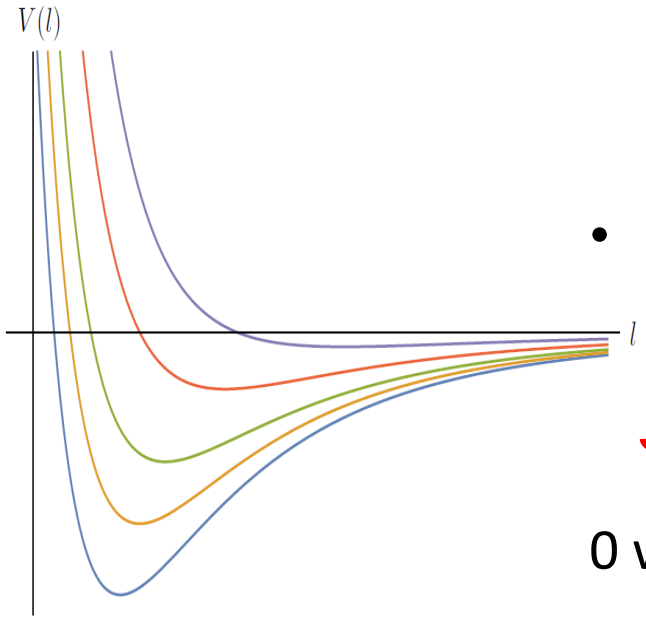

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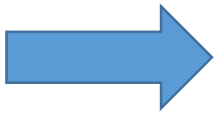
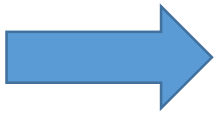
- After uplift: extra term on RHS $e^{4A}(T^{\mu}_{\mu} - T^{m}_{m})$  Same sign as other terms !

- After uplift: extra term on RHS $e^{4A}(T^{\mu}_{\mu} - T^{m}_{m})$  Same sign as other terms !

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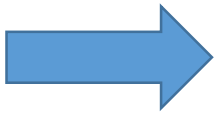
- After uplift: extra term on RHS $e^{4A}(T^{\mu}_{\mu} - T^{m}_{m})$  Same sign as other terms !

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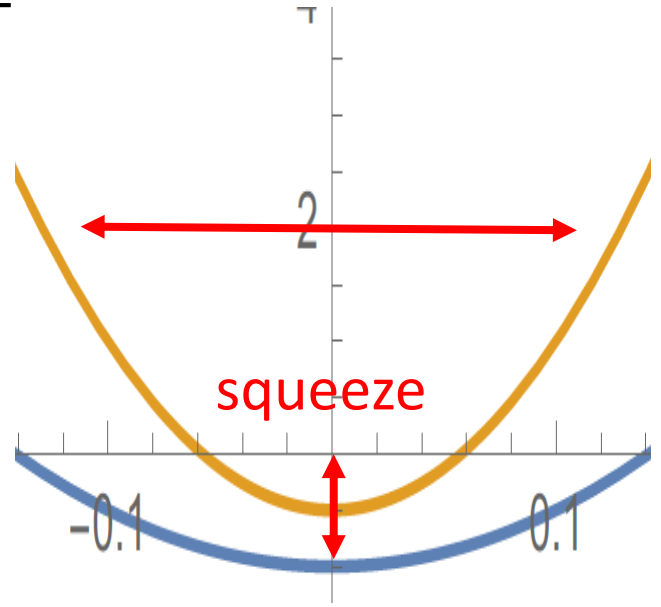
A way around problem 2 and 3 (controlled SUSY breaking) ?

If there exist SUSY AdS vacua for which *vacuum energy can be tuned to zero (from below) while keeping the masses of all modes fixed. Then any form of SUSY breaking leads to controlled dS vacua!*

$$m^2 R^2_{AdS} >> 1$$



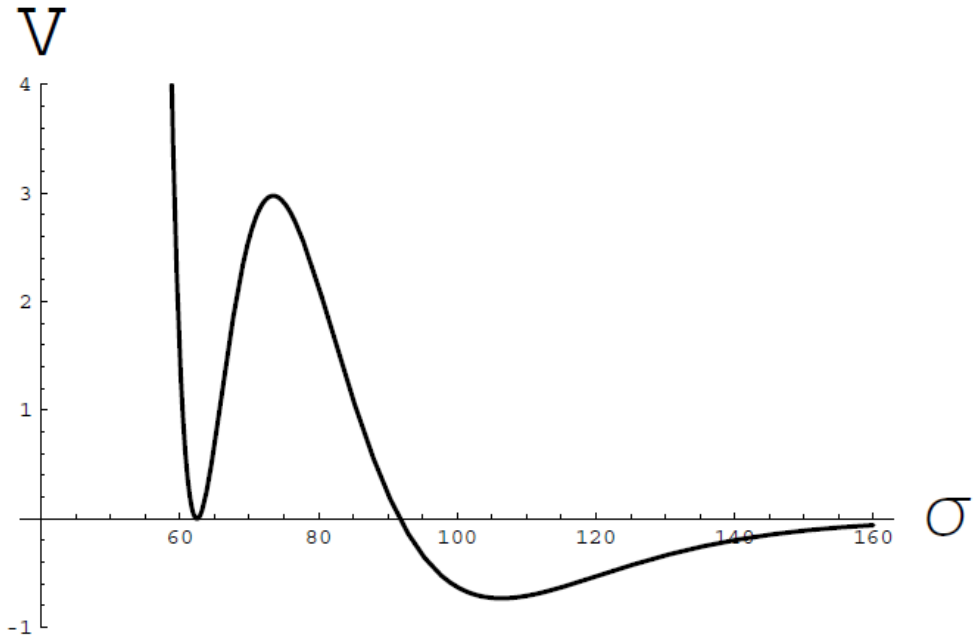
Claim: *such AdS vacua are in the Swampland.*

Example: racetrack fine-tuning [Kallosh, Linde, 2004]

$$W = W_0 + A\exp(iaT) + B\exp(ibT)$$

$$a = \frac{2\pi}{N_1}\,, \quad b = \frac{2\pi}{N_2}$$

$$\boxed{N_1 = N_2 + 1 \sim N >> 1}$$



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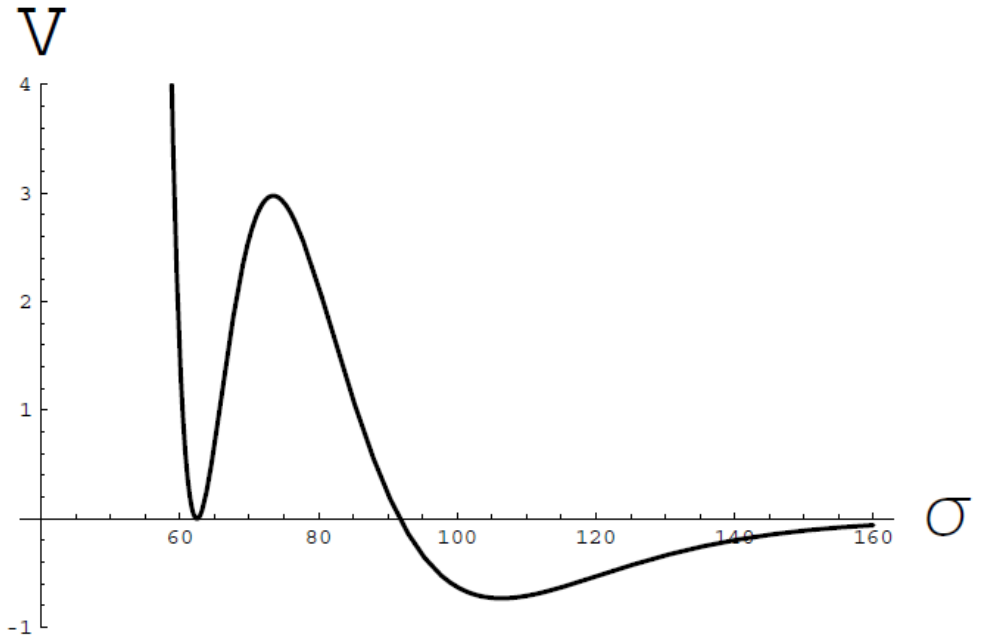

But exactly that limit makes the axionic partner of the volume modulus have parametrically large decay constant! [Moritz, VR, 1805.0944]

$$\boxed{f \sim N M_{pl}}$$

A violation of (the strong form) of the WGC for axions.

Beyond racetrack? → AdS/CFT & conformal bootstrap, general nogo.

Condition for AdS's suitable for parametrically controlled dS uplifts: $mR = \kappa \gg 1$

This implies that the dual 3D (N=1) CFT has not a single low-lying operator!

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

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} →crossing symmetry constraints of

$$\langle T_{\mu_1\nu_1}(x_1) T_{\mu_2\nu_2}(x_2) T_{\mu_3\nu_3}(x_3) T_{\mu_4\nu_4}(x_4) \rangle$$

lead to existence of operators for which: $\Delta^+ \leq 7\ , \quad \Delta^- \leq 11.78$

[Dymarsky, Kos, Kravchuk, Poland, Simmons-Duffin, 2017]

Parity preservation?

- No vevs of “axions”
- Restriction; but not unthinkable similar bounds exist in general case
- Racetrack SUSY AdS as proposed in [Kallosh&Linde 2004] has zero axion vev.

WGC-conjecture

Conformal Bootstrap

dS / CFT ?

Typical reasons dS/CFT is tough:

- Wickrotating AdS→dS typically inconsistent & No (simple) string theory background?
- Complex operator dimensions: $\Delta_{\pm} = \frac{3}{2} \pm \sqrt{\frac{9}{4} - m^2 R^2}$
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Why not supersymmetric (and hence stable?) dS?

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Higher Spin dS/Sp(N)-CFT can be consistently supersymmetrised by adding spinor fields! [Hertog, M.-Tartaglino, Venken, VR 2017]

SUSY Vasiliev AdS / free O(N) model ⟺ SUSY Vasiliev dS / free Sp(N) model

dS/CFT ? [Maldacena, 2003]

$$\Psi_{HH}[h_{ij}, A_s] = Z_{QFT}[\tilde{h}_{ij}, J_s] \exp(\mathrm{i}S_{st}[h_{ij}, A_s]/\hbar)$$

Spatial 3-metric

Matter fields

Sources related to boundary metric and matter fields

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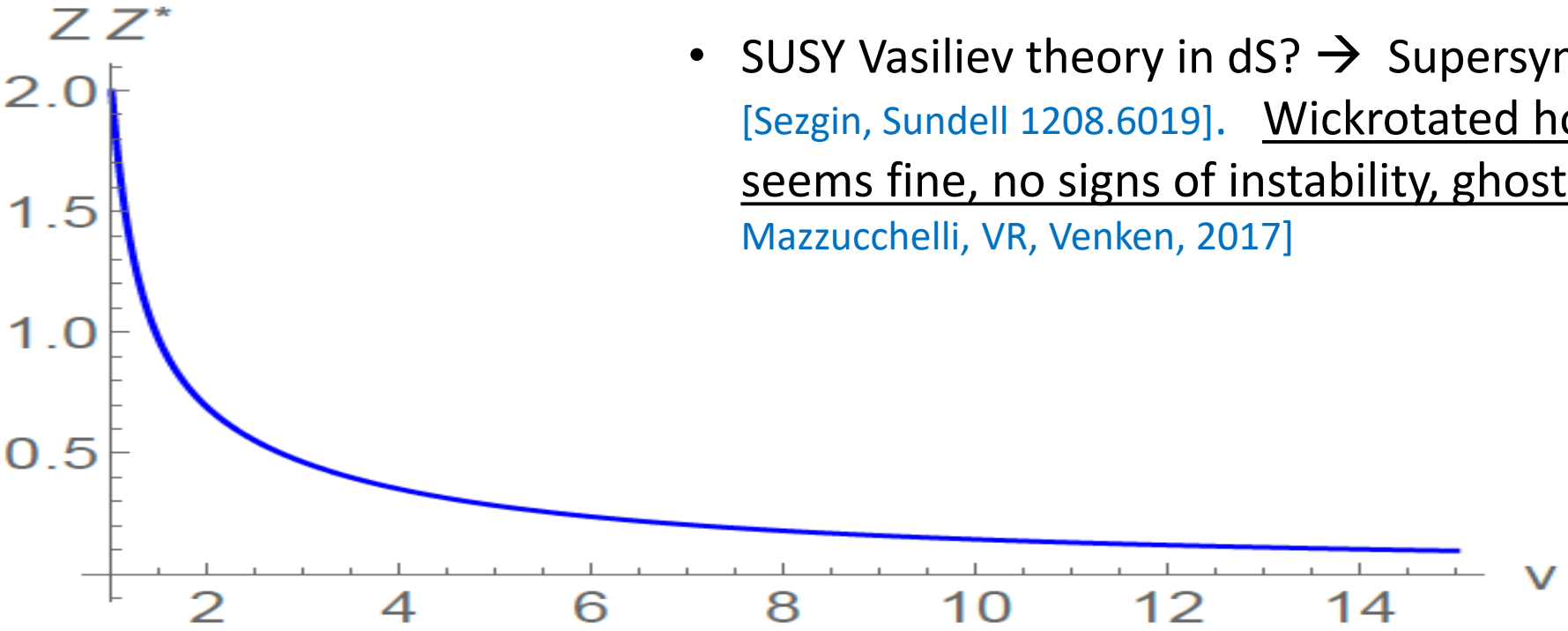
probability



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Deformation by bulk field

How? Hull ’98:

If the type II^* string theories are truncated down to their supergravity limits, the supergravity theories have ghosts. However, in the full string theories, it is possible that the string gauge symmetries can be used to eliminate the ghosts. Indeed, the type II^* theories are linked by T-duality to the type II theories which are ghost-free, at least perturbatively.

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→ The tensionless limit is exactly the trick to “integrate in “ all the string modes and be able to compute. We find no instabilities. Hull’s intuition was correct!? [Hull 1998, Dijkgraaf, Heidenreich, Jefferson, Vafa, 1603.05665]

Conclusions

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- It better rests on strong evidence. Ideas like KKLT are smart. But evidence not strong enough (yet?)

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But if I would have to bet now then:

My bet: