dS extrema and the swampland

Timm Wrase

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

INSTITUTE FOR THEORETICAL PHYSICS

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FWF
Der Wissenschaftsfonds.

dS extrema and the swampland

- Recent papers call for a paradigm change

Brennan, Carta, Vafa 1711.00864
Danielsson, Van Riet 1804.01120
Obied, Ooguri, Spodyneiko, Vafa 1806.08362
Agrawal, Obied, Steinhardt, Vafa 1806.09718

$$|\nabla V| \geq c\, V \quad \text{for} \quad c \sim O(1)$$

Inflation $\Rightarrow$ string gas cosmology, bouncing cosmology, …

dS vacua $\Rightarrow$ quintessence

dS extrema and the swampland

- What are these claims based on?

  Obied, Ooguri, Spodyneiko, Vafa 1806.08362

- Given the controversy in our community about construction that use non-perturbative effects and anti-D3-branes, the authors of 1806.08362 discard all constructions that involve quantum effects (KKLT, LVS, …)

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- What are these claims based on?

  Obied, Ooguri, Spodyneiko, Vafa 1806.08362

- Given the controversy in our community about construction that use non-perturbative effects and anti-D3-branes, the authors of 1806.08362 discard all constructions that involve quantum effects (KKLT, LVS, …)

- Then they study the following classical setups:
  - M-theory ($AdS_4 \times S^7$ gives $c \sim 1.4$)
  - O(16)xO(16) non-SUSY string theory ($c \sim 3.5$)
  - NEC and SEC ($c_{NEC} \sim 1.2$ and $c_{SEC} \sim 1.6$)
  - Type II supergravity → this talk

Type IIA on CY_3

- Using fluxes F_0, F_2, F_4 and H_3 together with O6-planes, one can stabilize all moduli classically in AdS_4

  DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160

- However, it is impossible to have dS vacua

  Hertzberg, Kachru, Taylor, Tegmark 0711.2512

$$\rho = (vol_6)^{\frac{1}{3}}, \qquad \tau = e^{-\phi}\sqrt{vol_6}$$

$$V(\rho,\tau) = \frac{A_H}{\rho^3\tau^2} + \sum_p \frac{A_p}{\rho^{p-3}\tau^4} - \frac{A_{O6}}{\tau^3}, \qquad A_* > 0,$$

$$-\rho\frac{\partial V}{\partial \rho} - 3\tau\frac{\partial V}{\partial \tau} \geq 9\,V$$

Type IIA on group/coset spaces

- Considering compactifications on spaces with *curvature* changes things

summarized in Wrase, Zagermann 1003.0029

Curvature	No-go, if	No no-go in IIA with	No no-go in IIB with
$V_{R_6} \sim -R_6 \leq 0$	$q+p-6 \geq 0,\ \forall p,q,$ $\epsilon \geq \frac{(3+q)^2}{3+q^2} \geq \frac{12}{7}$	O4-planes and H, F_0-flux	O3-planes and H, F_1-flux
$V_{R_6} \sim -R_6 > 0$	$q+p-8 \geq 0,\ \forall p,q,$ (except $q=3, p=5$) $\epsilon \geq \frac{(q-3)^2}{q^2-8q+19} \geq \frac{1}{3}$	O4-planes and F_0-flux O4-planes and F_2-flux O6-planes and F_0-flux	O3-planes and F_1-flux O3-planes and F_3-flux O3-planes and F_5-flux O5-planes and F_1-flux

Table 1 The table summarizes the conditions that are needed in order to find a no-go theorem in the (ρ, τ)-plane and the resulting lower bound on the slow-roll parameter ϵ. The third and fourth column spell out the minimal ingredients necessary to evade such a no-go theorem.

- Oq-planes and F_p fluxes (for lowest q and p)

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Also extending an argument of
[Hertzberg,Kachru,Taylor,Tegmark] and [Wrase,Zagermann]:

q	No-Go (positive or zero $\langle\mathcal{R}\rangle$)	$c_\star^2$	No-Go (negative $\langle\mathcal{R}\rangle$)	$c_\star^2$
3	Yes w/o F_1 RR flux	6	Indeterminate	-
4	Yes w/o F_0 RR flux	98/19	Indeterminate	-
5	Yes	32/7	Yes w/o F_1 RR flux	2
6	Yes	54/13	Yes w/o F_0 RR flux	18/7
7	Yes	50/12	Yes	8/3
8	Yes	242/67	Yes	50/19
9	Yes	24/7	Yes	18/7

Constrains on $|\nabla V|/V$ in Type IIA/B compactifications to 4 dimensions with arbitrary RR and NS-NS flux (unless otherwise noted) and Oq-planes and Dq-branes with fixed q. The constant $c_\star$ in each entry is a lower bound on $|\nabla V|/V$.

So the upshot is that the conjecture is not unreasonable with c of order 1 in Planck units.

Slide taken from Vafa's talk at Strings

Type IIA on group/coset spaces

- Considering compactifications on spaces with *curvature* changes things

  summarized in Wrase, Zagermann 1003.0029

- Once curvature is included, dS vacua cannot be excluded and have been searched for

  Flauger, Robbins, Paban, TW 0812.3886
  Caviezel, Koerber, Körs, Lüst, TW, Zagermann 0812.3551
  Danielsson, Haque, Shiu, Van Riet 0907.2041
  Caviezel, TW, Zagermann 0912.3287
  Danielsson, Koerber, Van Riet 1003.3590

- No dS vacua have been found but dS critical points with $|\nabla V| = 0, V > 0$ have been constructed

Type IIA on group/coset spaces

- Existing dS critical points are not phenomenologically interesting but prove of concept against above no-go

Flauger, Robbins, Paban, TW 0812.3886
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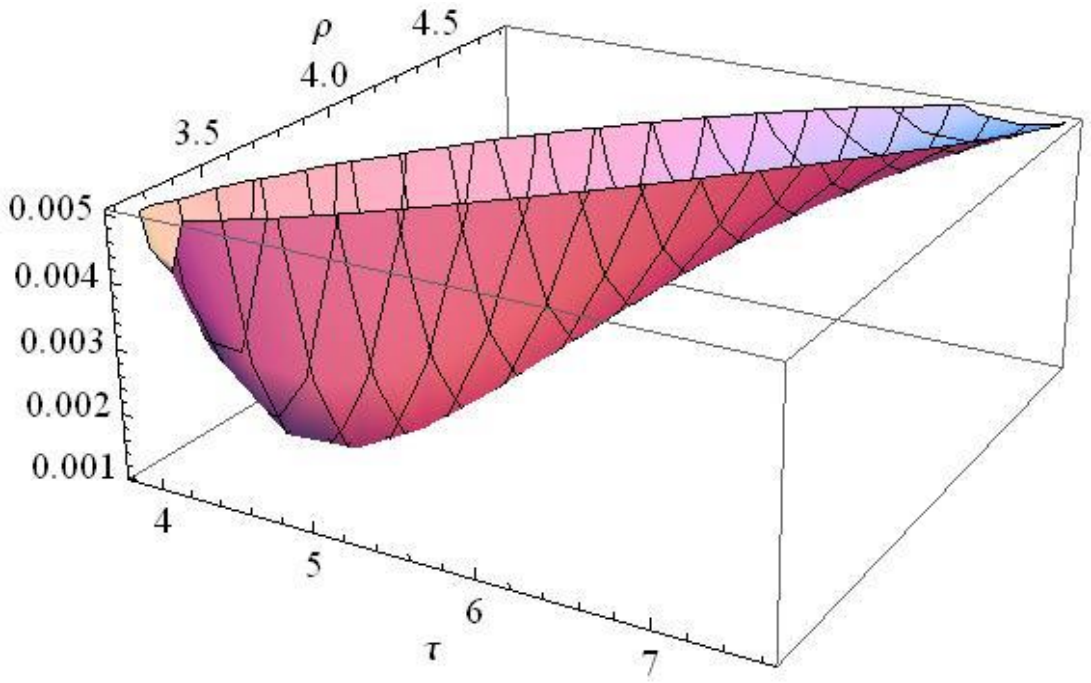

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Let us examine these more closely:

- IIA on $\frac{S^3 \times S^3}{Z_2 \times Z_2}$ with O6-planes and fluxes (including F_0)
  - O6-planes are smeared
  - Neglect potential blow-up modes from orbifolding
  - What are the moduli?
  - Mass parameter in type IIA
  - Flux quantization

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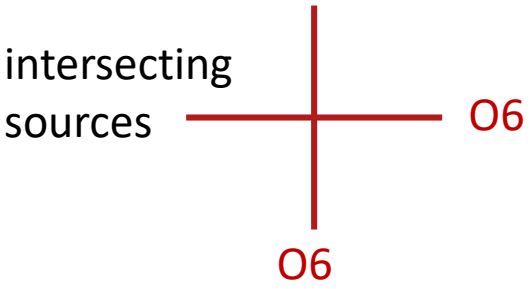

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See talk by David Andriot

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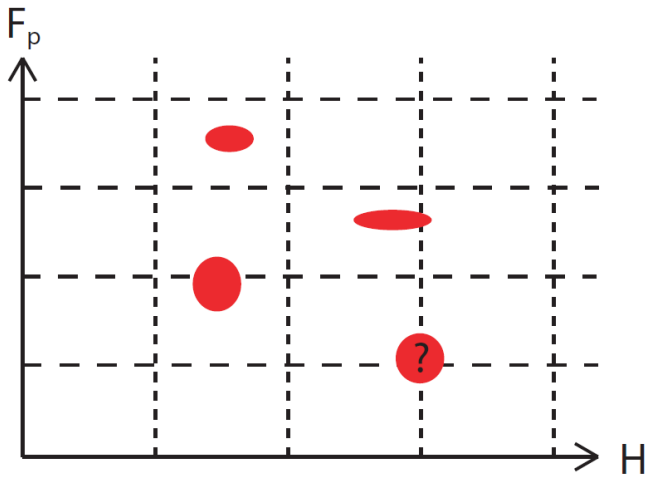
Type IIA on group/coset spaces

Are dS critical points compatible with flux quantization?



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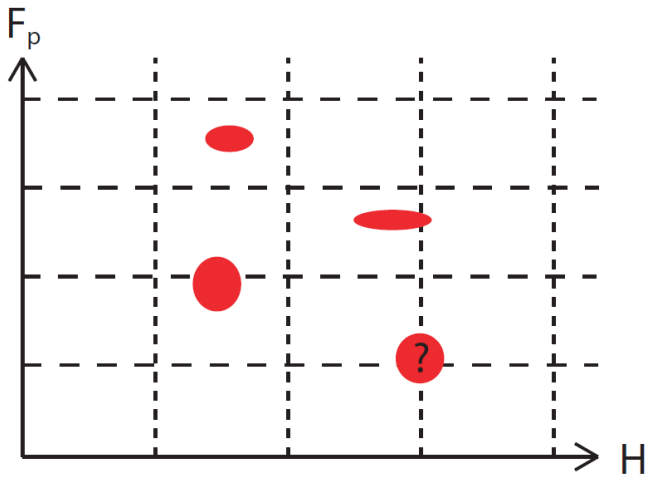

- Difficult due to H-flux
- For S^3xS^3/Z_2xZ_2 flux quantization only possible for small volume and large string coupling i.e. flux quantization kills this model! But there are many more examples…

  Danielsson, Haque, Koerber, Shiu, Van Riet, TW 1103.4858

- Only `T-dual' IIB example has similar problems

  Caviezel, TW, Zagermann 0912.3287

Conclusion

- Do we need a paradigm change in string cosmology?
- Why should we not allow for quantum effects?

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- Classical examples seem so far potentially compatible with the dS swampland conjecture
- Further examples might rule out the conjecture

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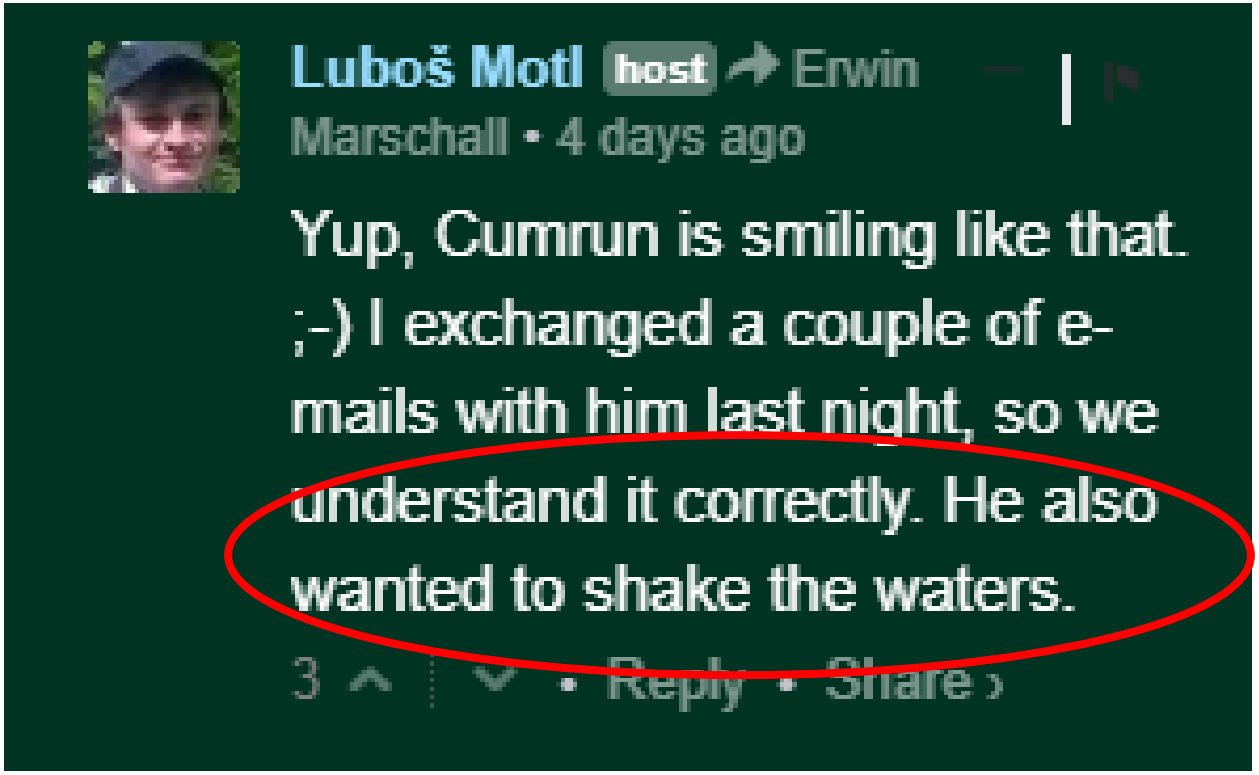
THANK YOU!


Luboš Motl host Erwin Marschall • 4 days ago
Yup, Cumrun is smiling like that. ;-) I exchanged a couple of e-mails with him last night, so we understand it correctly. He also wanted to shake the waters.
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