Tachyons in Classical de Sitter Vacua

Daniel Junghans

Ludwig-Maximilians-Universität München

Based on: arXiv:1603.08939

Outline

Introduction

A Simple Model

General Lessons?

Conclusions

Introduction

dS Vacua in String Theory

Many known constructions of dS vacua in string theory
KKLT/LVS+anti-branes, Kähler uplift, non-geometric fluxes, …

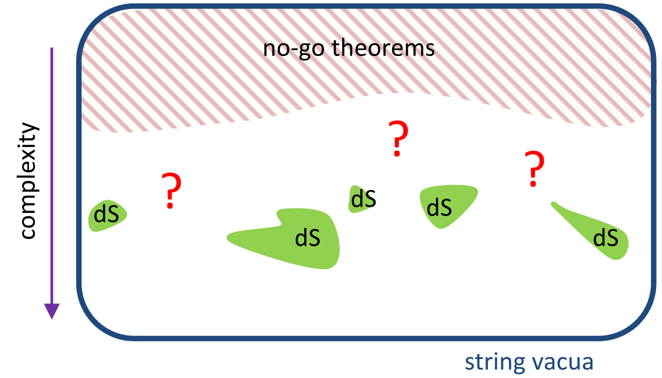
Kachru, Kallosh, Linde, Trivedi 03
Balasubramanian, Berglund, Conlon, Quevedo 05
Louis, Rummel, Valandro, Westphal 12
Burgess, Cicoli, Maharana, Quevedo 12
Blåbäck, Roest, Zavala 14
Rummel, Sumitomo 14
De Carlos, Guarino, Moreno 09
Blåbäck, Danielsson, Dibitetto 13
Hassler, Lust, Massai 14
Kallosh, Linde, Vercnocke, Wrase 14
Blumenhagen, Damian, Font, Herschmann, Sun 15
Retolaza, Uranga 15
(and many more…)

All rather involved, many different ingredients necessary
(e.g., flux background + instantons/α' corrections + uplift)

Only 4d description available

Interesting questions:

- What are the minimally required ingredients to get dS vacua in string theory?
- Are there simple, fully explicit 10d (toy) models?
- Are there mechanisms for dS we do not know yet?
- Are there universal structures that forbid/allow dS vacua in certain regions of the landscape?



Classical dS Hunting

Idea: construct simple, explicit (toy) models of dS vacua in string theory

- geometric flux compactifications of type IIA/B
- no α' or g_s corrections, instantons, non-geometry, etc.
- no-go theorems require O-planes and $R^{(6)} < 0$

Hertzberg, Kachru, Taylor, Tegmark 07
Silverstein 07

Maldacena, Nuñez 00
Hertzberg, Kachru, Taylor, Tegmark 07

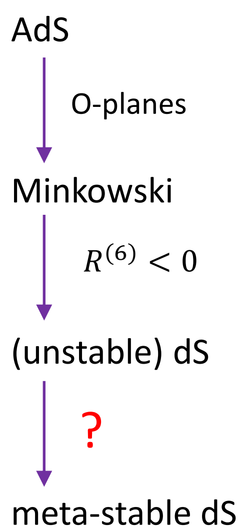
Extensive scans of many different models in the literature

Caviezel, Koerber, Kors, Lust, Wrase, Zagermann 08; Flauger, Paban, Robbins, Wrase 08; Danielsson, Haque, Shiu, Van Riet 09; Caviezel, Wrase, Zagermann 09; Danielsson, Koerber, Van Riet 10; Danielsson, Haque, Koerber, Shiu, Van Riet, Wrase 11

→ many dS critical points, but all unstable with $\eta = -O(1)$

(among other issues, see, e.g., Danielsson, Haque, Koerber, Shiu, Van Riet, Wrase 11)

Tachyons found numerically, typically combination of all moduli, not explained by any known no-go theorems



What is the reason for the tachyons?
Can we learn something general from this?

Stability Constraints

No-go theorems for stability:

- Constraints from universal moduli (volume, dilaton) — Shiu, Sumitomo 11
- Sgoldstino is the most dangerous modulus close to a SUSY Minkowski point

  Covi, Gomez-Reino, Gross, Louis, Palma, Scrucca 08

Statistical arguments: — Marsh, McAllister, Wrase 11; Chen, Shiu, Sumitomo, Tye 11

Probability of a dS critical point to be meta-stable: $P \sim e^{-cN^p}$ — N: # moduli c, p: constants

But: always 1 tachyon with $\eta = -O(1)$ and total tachyon number small

→ hidden structure?

Observations in a class of type IIA dS solutions: — Danielsson, Shiu, Van Riet, Wrase 13

- O-plane volume moduli are useful proxies
- Tachyon aligns with sgoldstino in SUSY Minkowski limit

  but is in general a complicated combination of all moduli

Origin of ubiquitous tachyons? Analytic understanding?

A Simple Model

A Type IIA Example

Massive type IIA on (orientifold of) the group space $\mathrm{SU}(2) \times \mathrm{SU}(2)$ with F_0, F_2, H_3 fluxes and 4 intersecting O6-planes

Caviezel, Koerber, Kors, Lust, Wrase, Zagermann 08
Danielsson, Koerber, Van Riet 10

One-parameter family of unstable dS solutions numerically known

Danielsson, Koerber, Van Riet 10

Analytic solution? Useful parametrization of ansatz:

$$g = a\,\mathrm{diag}(\epsilon, \epsilon^{-1}, \epsilon, \epsilon, \epsilon^{-1}, \epsilon^{-1}) \qquad F_2 = f_2 a (e^{16} - e^{24} + e^{35})$$

$$H_3 = \left(f_5 - \frac{f_6}{2\sqrt{3}}\right)\frac{a^{3/2}}{\sqrt{\epsilon}}(e^{456} + e^{236} + e^{125}) + \left(f_5 + \frac{\sqrt{3} f_6}{2}\right)\frac{\epsilon^{3/2}}{a^{3/2}} e^{134}$$

e^a: basis 1-forms
with $\mathrm{d}e^a = \frac{1}{2} f^a{}_{bc} e^{bc}$
and $e^{ab} = e^a \wedge e^b$, etc.

$R^{(6)} < 0$ requires $\epsilon \ll 1$ $\quad \rightarrow$ use ϵ as expansion parameter

Solve for other parameters $F_0, e^{\phi}, a, f_2, f_5, f_6$:

$$a = \frac{3\sqrt{21}}{16\epsilon^2} - \frac{63}{64\epsilon} + \cdots, \qquad f_2 = \frac{2}{21^{1/4}\sqrt{3\epsilon}} + \frac{21^{3/4}\sqrt{\epsilon}}{12\sqrt{7}} + \cdots,$$

$$f_5 = \frac{1}{4} - \frac{\sqrt{21}\epsilon}{7} + \cdots, \qquad f_6 = \frac{\sqrt{3}}{2} + \frac{2\epsilon}{\sqrt{7}} + \cdots$$

Tachyon vs Sgoldstino

Analyze mass matrix V_{ij} (3 complex moduli: 2 metric, 1 dilaton, 3 axions)

Tachyon lies in real part → 3d vector in moduli space

m_ϕ: sgoldstino mass
M: other moduli masses

$\epsilon \to 0$: SUSY Minkowski point with $m_\phi^2 \ll M^2$ → expect that tachyon=sgoldstino

But: Direction with $m^2 < 0$ close to, but not exactly aligned with the sgoldstino,
only aligns in Minkowski limit

Tachyon vector: $$\left(\frac{\sqrt{3}}{4} - \frac{169\sqrt{3}}{126}\epsilon^2 + \cdots, -\frac{7}{8\sqrt{3}} + \frac{101\sqrt{3}}{252}\epsilon^2 + \cdots, \frac{1}{8\sqrt{3}} - \frac{53\sqrt{3}}{36}\epsilon^2 + \cdots\right)$$

Sgoldstino vector: $$\left(\frac{\sqrt{3}}{4} - \frac{\sqrt{3}}{12}\epsilon^2 + \cdots, -\frac{7}{8\sqrt{3}} - \frac{\sqrt{3}}{8}\epsilon^2 + \cdots, \frac{1}{8\sqrt{3}} + \frac{5\sqrt{3}}{24}\epsilon^2 + \cdots\right)$$

Why? Generalize no-go theorem of Covi et al to finite distances from Minkowski point

$$V_{ij} = \begin{pmatrix} m_\phi^2 & \mu^2 \\ \mu^2 & M^2 \end{pmatrix}$$

eigenvalues: $m_\phi^2 - \frac{\mu^4}{M^2} + \cdots, \quad M^2 + \frac{\mu^4}{M^2} + \cdots$

eigenvectors: $\left(1, -\frac{\mu^2}{M^2}\right), \quad \left(\frac{\mu^2}{M^2}, 1\right)$

General Lessons?

General Lessons?

Analogous result in type IIB on (different orientifold of) the group space $SU(2) \times SU(2)$ with F_1, F_3, H flux and intersecting O5/O7-planes

Caviezel, Wrase, Zagermann 09

T-dual to non-geometric type IIA background

Same features as before:

- dS at a point in moduli space where sgoldstino is much lighter than the other moduli
- Tachyon almost aligned with sgoldstino, but rotated slightly into the other directions due to mass mixing terms

Work in progress:

Use insights from explicit models as a guidance to derive general, model-independent constraints for whole classes of compactifications

Necessary conditions for meta-stability on Kähler and superpotential?

Conclusions

Conclusions

Summary:

- Understanding the dS landscape of string theory is important
- All known classical dS solutions have at least one tachyon of unknown origin

  → universal structure?
- We analytically computed the tachyon in a type IIA model and showed that it is almost but not fully aligned with the sgoldstino
- This behavior is explained by a generalization of the no-go theorem by Covi et al to finite distances away from SUSY Minkowski points in moduli space
- Analogous results in a different model in type IIB and a more general analysis (in progress) may suggest a universal behavior for a large class of models

Future work:

- Derive model-independent constraints/necessary criteria for meta-stable dS vacua
- Understand relation to O-plane volume moduli
- Long-term goal: chart cosmological landscape of string theory

Conclusions

Summary:

- Understanding the dS landscape of string theory is important
- All known classical dS solutions have at least one tachyon of unknown origin

  → universal structure?
- We analytically computed the tachyon in a type IIA model and showed that it is almost but not fully aligned with the sgoldstino
- This behavior is explained by a generalization of the no-go theorem by Covi et al to finite distances away from SUSY Minkowski points in moduli space
- Analogous results in a different model in type IIB and a more general analysis (in progress) may suggest a universal behavior for a large class of models

Future work:

- Derive model-independent constraints/necessary criteria for meta-stable dS vacua
- Understand relation to O-plane volume moduli
- Long-term goal: chart cosmological landscape of string theory

Thank you!