Bounding parameters in the web of swampland conjectures

Niccolò Cribiori

TECHNISCHE UNIVERSITÄT WIEN

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Based on 2004.00030, with D. Andriot and D. Erkinger

Introduction

Effective theories and quantum gravity

Can **all** consistent effective theories be coupled to gravity in UV?

- Yes - Gravity is not really constraining low energy physics.
- No - Gravity is constraining low energy physics non-trivially.

Effective theories and quantum gravity

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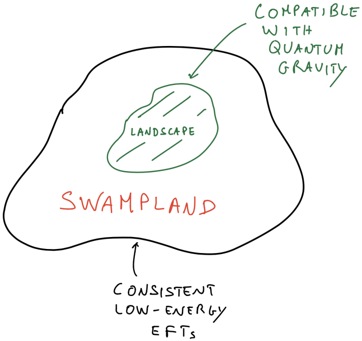
String theory points towards no.

Not everything goes: an example

- It is believed that string theory admits **no global symmetries.**
- Proved in specific setups using AdS/CFT correspondence. [Harlow, Ooguri '18]
- Hard to prove in AdS (QG), but accessible from the dual CFT.
- Can we go beyond? Other properties of quantum gravity?

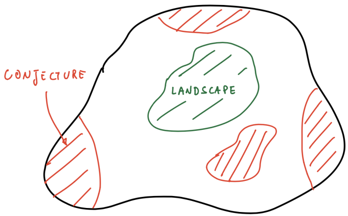
The swampland program

- NOT everything goes in quantum gravity/string theory.
- **Swampland program**: distinguish effective theories which can be completed into quantum gravity in the UV from those which cannot. [review: Palti '18]



The present approach

- String theory is not completely understood.
- Try to guess general properties from (few) known examples.
- Formulate conjectures (heavily tested).



A constructive viewpoint

- The formulation of conjectures means there is something to understand better.
- Conjectures suggest to look into promising directions. Helpful, since string theory is vast.
- Possibly relate them one another: **web of conjectures**.
- Make them sharp: **bound parameters**.

The web of swampland conjectures

A (work in progress) list

1 no global symmetries
2 gravity is the weakest force
3 non-susy AdS is unstable
4 no scale separation in AdS

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.

n-2 no de Sitter conjecture
n-1 Transplanckian censorship conjecture
n distance conjecture

no de Sitter conjecture

[Obied, Ooguri, Spodyneiko, Vafa '18]

Conjecture:
Any scalar potential consistent with quantum gravity satisfies

$$|\nabla V| \geq \frac{c}{M_P} V, \qquad \textit{with} \quad c \sim \mathcal{O}(1) \quad \textit{and positive}$$

- No neat de Sitter vacuum from string theory (nevertheless, recall KKLT and LVS)
- No-go theorems against dS, under assumptions.
- We can **calculate** c in string compactifications.

Transplackian censorship conjecture

[Bedroya, Vafa '19]

Conjecture:
Sub-Planckian quantum fluctuations should remain quantum and never become larger than the Hubble horizon

$$\frac{a_f}{a_i} < \frac{M_P}{H_f}$$

- Motivated by a physical principle.
  (see [Dvali, Kehagias, Riotto '20] for criticism)
- When applied to a FLRW model with $V(\phi)$, gives ($M_P = 1$)

$$\left\langle \frac{|\nabla V|}{V} \right\rangle_{\Delta\phi\to\infty} \geq \frac{2}{\sqrt{(d-1)(d-2)}} \overset{d=4}{=} \sqrt{\frac{2}{3}}$$

This reminds the parameter c of the de Sitter conjecture!

Distance conjecture

[Ooguri, Vafa '06]

Conjecture:
As the geodesic distance between two points in field space $d(P, Q) \to \infty$*, an infinte tower of states with mass*

$$M \sim M_0 e^{-\lambda d(P,Q)}, \qquad \lambda > 0$$

enters the effective theory.

- The EFT breaks down in the asymptotic regions of field space.
- An infinite number of external light states enter the EFT.
- In specific setups ($\mathcal{N} = 1, 2$ SUSY), λ can be calculated. [Grimm, Palti, Valenzuela '17; Blumenhagen, Klaewer, Schlechter, Wolf '18; Erkinger, Knapp '19; Rojo, Plauschinn '20]

Calculating, relating and bounding parameters

[Andriot, NC, Erkinger '20]

Testing the no de Sitter conjecture

framework: 10d SUGRA = low energy EFT of string theory

- A scalar potential $V(\phi)$ arises when compactifying $10d \to 4d$.

- We calculated $V(\rho, \tau, \sigma)$ from type II SUGRA with fluxes+sources and obtain no-go inequalities under assumptions

$$aV + \sum_{i=\rho,\tau,\sigma} b_i \partial_i V \leq 0, \qquad a > 0$$

- Then, the parameter c is

$$c^2 = \frac{a^2}{b_\rho^2 + b_\tau^2 + b_\sigma^2}$$

The parameter c and the TCC bound

- We calculated 10 different values of c. All of them satisfy the bound

$$c \geq \sqrt{\frac{2}{3}}.$$

- **It matches the TCC bound in $d = 4$!**

- This supports the relationship between the de Sitter conjecture and the TCC.

- TCC bounds the parameter c in the de Sitter conjecture.

The distance conjecture parameter λ

The distance conjecture parameter λ

$$M \sim M_0 e^{-\lambda d(P,Q)}, \qquad d(P,Q) \to \infty$$

can also be calculated in well defined setups.

framework: $\mathcal{N} = 2$ supersymmetric theories on Calabi-Yau:

- BPS Brane states $M = Z$
- KK states $M \sim \frac{1}{L_{compact}}$

We considered 19(known)+3(new) values of λ.
All of them satisfy the bound

$$\lambda \geq \frac{1}{2}\sqrt{\frac{2}{3}}$$

(Confirmed from BH studies in [Gendler, Valenzuela '20])

Relating the bounds

- The parameters c and λ are calculated in well defined but completely different setups.

- A priory, no relation between them: λ and c might have been **generic** order 1 numbers.

- We found that in all examples analysed they obey a simple relation

$$\lambda \geq \lambda_0, \qquad c \geq c_0, \qquad 2\lambda_0 = c_0 = \sqrt{\frac{2}{3}}$$

- **Proposal**: correspondence between conjectures

$$m \leftrightarrow |V|^{\frac{1}{2}} \qquad \text{in asymptotic regions}$$

Conclusion

- Understand properties of quantum gravity/string theory.
- Conjectures are the starting point of quantitative analysis. Finding relations is a step forward to a simpler picture.
- We found evidence that some parameters are related and bounded.
- Physical principle underlying (the web of) conjectures?

Thank you!