Comments on Swampland Conjectures and CYs

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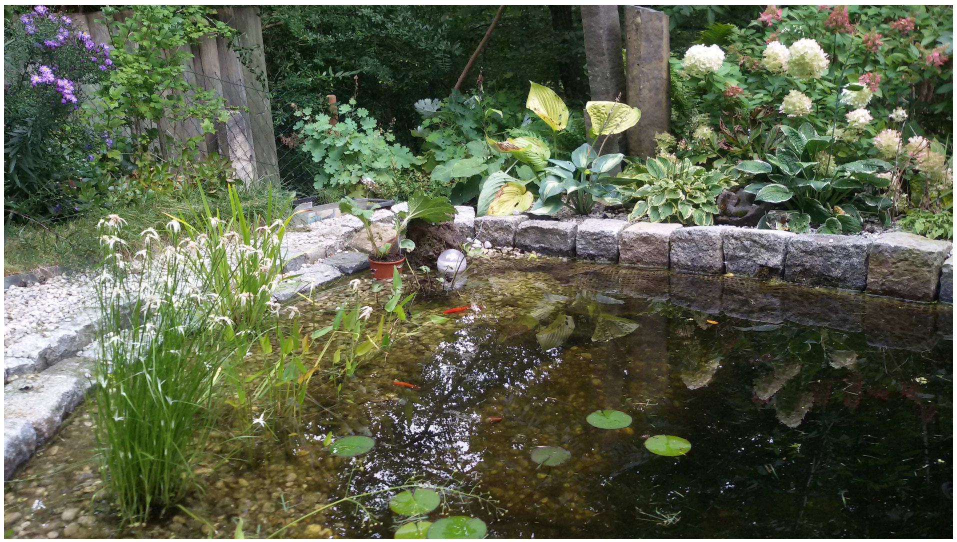

Introduction

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String theory is a well developed mathematical framework but some issues related to compactifications and the resulting effective field theories are hard to extract.

Open questions of recent concern:

- Can string theory realize large (single) field inflation in a controllable way?
- Are stable non-susy AdS-vacua in the swampland of string theory? (Ooguri, Vafa, 2017)
- Are dS-minima in the swampland of string theory? Thus, are there 10^{500} dS vacua or none? (Obied,Ooguri,Spodyneiko,Vafa, 2018)

These issues are related to supersymmetry breaking and control over the effective field theory.

Introduction

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Two attitudes towards these questions:

- Landscape approach: The space of string solutions is essentially dense in the parameter space (discretuum) so that any property is realized for at least some string models, though finding them might be difficult.

- Swampland approach: Taking concrete string model building failures really seriously and trying to extract/formulate the underlying conceptual quantum gravity constraint. Finding the issues that discriminates the landscape from the swampland.

Introduction

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Prototype examples:

- Weak gravity conjecture $\rightarrow$ constraints for instanton generated axion inflation
- Swampland distance conjecture $\rightarrow$ constraints for axion monodromy inflation
- OOSV conjecture, $|\nabla V| \geq cV$ for $V > 0$, $\rightarrow$ no dS minima

In this talk, comments on

- The refined swampland distance conjecture
- de Sitter uplifts employing warped throats

Swampland Distance Conjecture

Swampland Distance Conjecture

Swampland Distance Conjecture: (Ooguri,Vafa)

For any point p_0 in the continuous scalar moduli space of a consistent quantum gravity theory, there exist other points p at arbitrarily large distance. As the distance $d(p_0, p)$ diverges, an infinite tower of states exponentially light in the distance appears, i.e. the mass scale of the tower varies as

$$m \sim m_0 \, e^{-\lambda d(p_0,p)} \, .$$

Note, the swampland distance conjecture describes a property of models in the landscape!

Swampland Distance Conjecture

Swampland Distance Conjecture

Comments:

- Beyond $d(p_0, p) \sim \lambda^{-1}$ the exponential drop-off becomes essential
- Infinitely many light states $\rightarrow$ quantum gravity theory valid at the point p_0 only has a finite range $d_{\rm c}$ of validity
- At this level, the axions have a shift symmetry and are compact

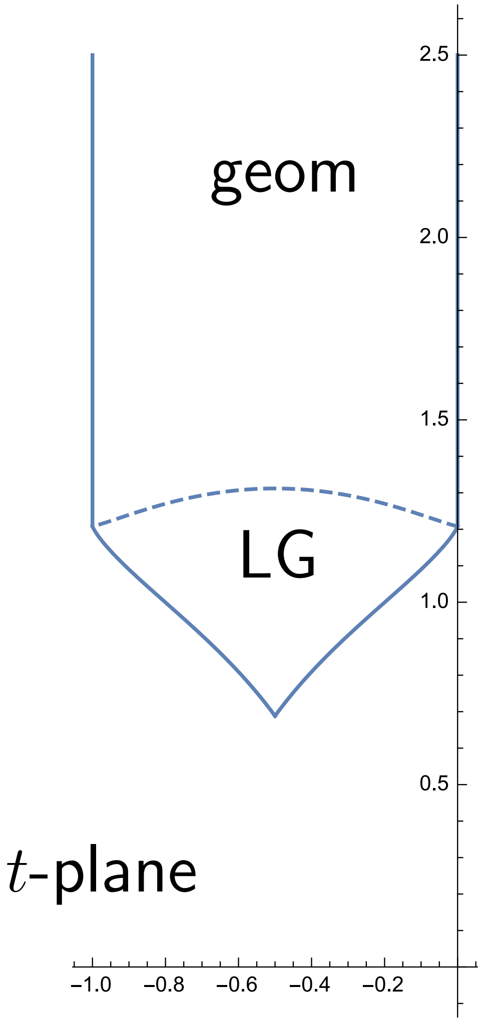
The Refined Swampland Distance Conjecture (RSDC) adds to the OV one: $\Theta_c \sim O(1) M_{\rm pl}$ (Kläwer,Palti).

Here: Quantitative test of the RSDC in the moduli space of Calabi-Yau compactifications (Bhg,Kläwer,Schlechter,Wolf) related recent work: (Grimm,Palti,Valenzuela)

RSDC for CY moduli space

RSDC for CY moduli space

Consider example of moduli space of the quintic: $\mathbb{P}_4[5]$:

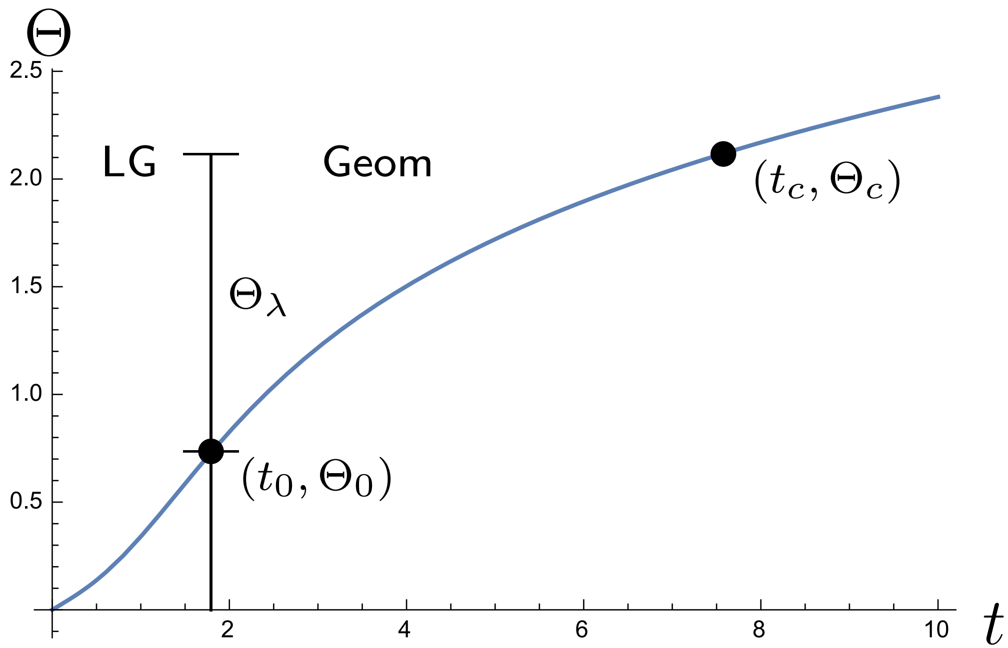


- Kähler moduli space
- geometric regime: $\Theta \sim \lambda^{-1} \log t$
- Landau-Ginzburg: Finite radius Θ_0

RSDC for CY moduli space

RSDC for CY moduli space

Starting at the LG locus, one expects the relation $\Theta(t)$ to be of the form:



Total field range before exponentially light states appear

$$\Theta_c = \Theta_0 + \Theta_\lambda$$

RSDC for CY moduli space

RSDC for CY moduli space

Therefore:

- If $\Theta_0 \gg 1$, the RSDC will be falsified or
- $\Theta_0 < 1$ is a necessary condition for the RSDC

Objectives of (Bhg,Kläwer,Schlechter,Wolf):

- Compute the periods and Kähler potential in non-geometric phases (LG and hybrid) of CY manifolds with $h_{11} \in \{1, 2, 101\}$
- Compute the Θ_0 and Θ_λ for various geodesic and trajectories in these highly curved moduli spaces

Methods for computing K

Methods for computing K

We used two methods to obtain the Kähler potential on the Kähler moduli space:

- In the gauged linear sigma model approach K is related to the 2D sphere partition function as

$$e^{-K} = Z_{S^2}$$

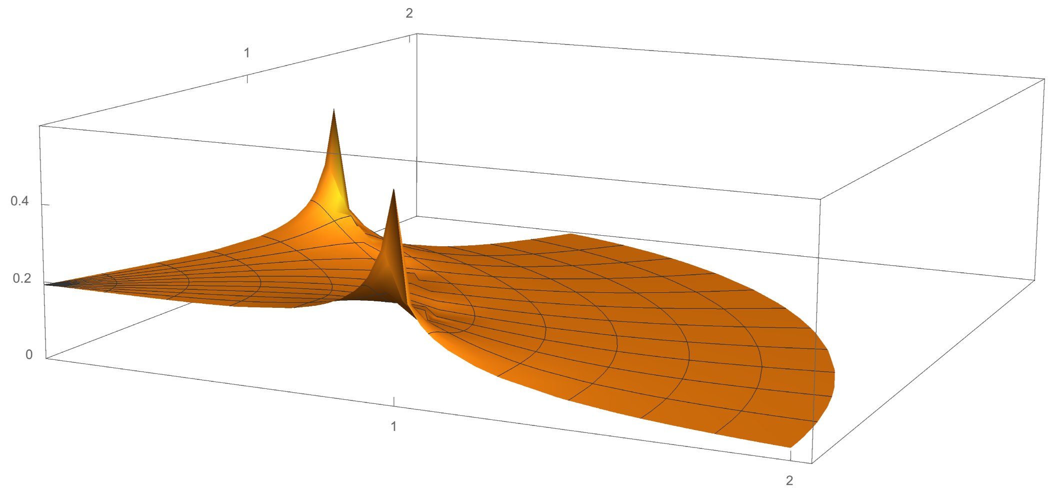
- Traditional approach via mirror symmetry:

$$K = -\log(-i\overline{\Pi}\Sigma\Pi)$$

with $\Pi = \int \Omega_3$ being the periods of the mirror CY

Kähler metric

Kähler metric



LCS regime: $K = -3\log\Big(-i(t-\bar{t}) + C + O(e^{-2\pi t})\ldots\Big)$

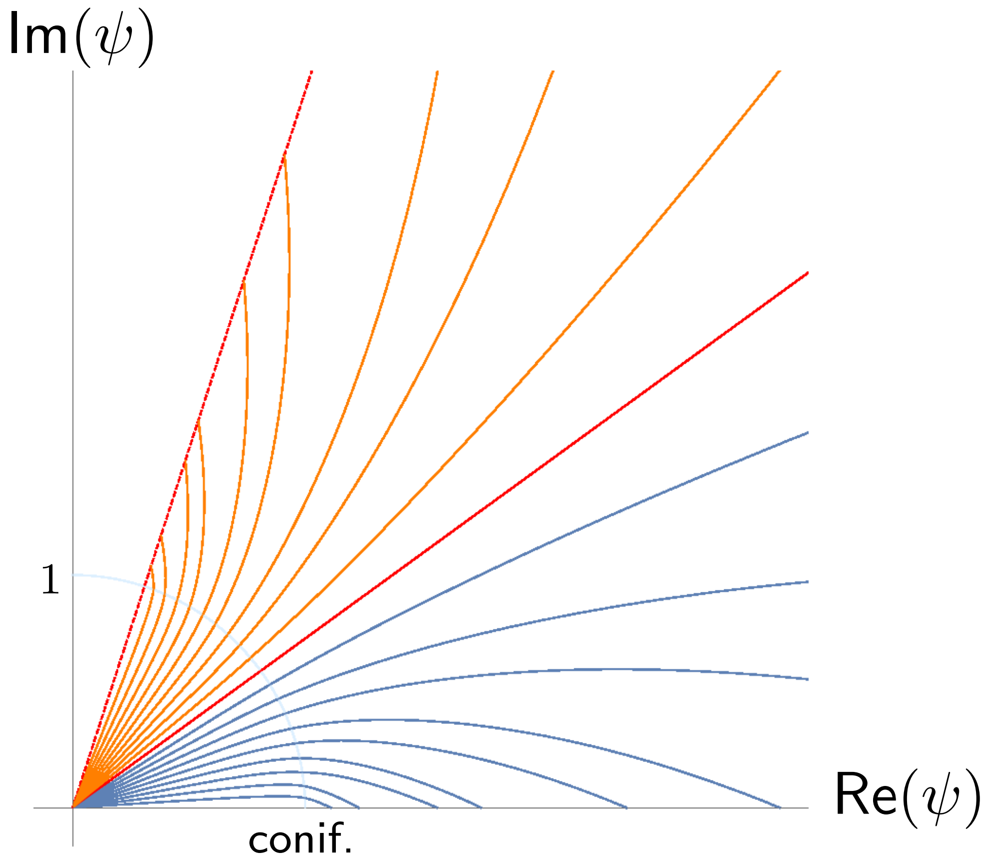
LG regime:

$$K = -\log\Big(\alpha\,|\psi|^2 + \beta\,|\psi|^4 + \gamma\,|\psi|^6 + \delta\,|\psi|^7\cos(5\theta) + \ldots\Big)$$

Geodesics

Geodesics

Geodesics for the initial data $(r, \dot{r}, \alpha, \dot{\alpha}) = (0, 1, n \cdot \pi/50, 0)$, for $n = 1, \ldots, 10$ and $\psi = r \exp(i\alpha)$:



Results for geodesic of quintic

Results for geodesic of quintic

The angular distribution of Θ_λ, Θ_0 and Θ_c

$\alpha_{\text{init}} \cdot 60/\pi$	λ^{-1}	Θ_0	Θ_c
3	0.9605	0.4262	1.3866
4	0.9865	0.4261	1.4125
5	0.9780	0.4260	1.4040
6	0.9567	0.4259	1.3827
7	0.9611	0.4259	1.3869
8	0.9275	0.4258	1.3533
9	0.9253	0.4257	1.3510
10	0.8969	0.4257	1.3226
11	0.8845	0.4257	1.3102
12	0.8657	0.4256	1.2914

More results

More results

Analyzed many more CYs:

- In all other examples with $h_{11} \in \{1,2\}$ we found $\Theta_0 = O(1)$ and $\lambda^{-1} = O(1)$,
- Mirror quintic with $h_{11} = 101$. Employing the recent results for the 101 periods (Aleshkin, Belavin, arXiv: 1710.11609), we found for the size of LG phase in various directions:

direction	$\Delta\Theta$
Φ_0	0.4656
Φ_1	0.0082
Φ_2	0.0670
Φ_3	0.0585
Φ_4	0.0089

More results

More results

Compelling relation

$$\frac{\Theta_0}{\text{phase}} \cdot \#(\text{phases}) < M_{\text{pl}} \,.$$

Comments

- All our findings are consistent with the RSDC in the original saxionic OV setting
- The generalization to an axionic RSDC for axion monodromy potentials is more involved, but gives the potential to provide an upper bound $r < 10^{-3}$ for controllable string derived effective field theories for inflation.

Comment on de Sitter vacua

Comment on de Sitter vacua

- Generic flux compactifications gives AdS or Minkowski minima
- Constructions of de Sitter vacua rely on the existence of an uplift mechanisms
- Like in KKLT this is often an anti $D3$-brane in a warped throat (needs a tiny warp factor to tune Λ positive)

Still emotionally discussed arguments why this procedure should or might not be controllable have been given

- Instability of stacks of $\overline{D3}$-branes, annihilation against flux
- It was questioned that the potential V is just a sum of GSUGRA terms and the uplift potential?

Warped CYs

Warped CYs

Here: Add another argument why the uplift utilizing warped throats might not be controlled (Bhg,Herschmann,Wolf, 2016).

Backreaction of a three-form flux leads to a warped CY metric (Giddings, Kachru,Polchinski)

$$ds^2 = e^{2A(y)}\eta_{\mu\nu}dx^\mu dx^\nu + e^{-2A(y)}\tilde{g}_{mn}dy^m dy^n$$

Warp factors:

- stack of D3-branes at $y = 0$

$$e^{-4A(y)} = 1 + \frac{4\pi g_s N}{|y|^4}$$

Warped CYs

Warped CYs

Warping close to a conifold singularity $Z = 0$ in the complex structure moduli space

- (H_3, F_3) form flux on an (A, B)-cycle:warped metric on the deformed conifold

$$e^{-4A} \sim 1 + \frac{1}{(\mathcal{V}|Z|^2)^{\frac{2}{3}}}\,.$$

Dilute flux limit

$$\mathcal{V}|Z|^2 \gg 1\,.$$

The physical size of the three-cycle A is

$$\mathrm{Vol}(A) = \mathcal{V}^{\frac{1}{2}} \left|\int_A \Omega_3\right| = (\mathcal{V}|Z|^2)^{\frac{1}{2}}$$

Periods close to conifold

Periods close to conifold

For evaluating superpotential $W = \int G_3 \wedge \Omega$ one needs the periods:

$$F_0 = 1\,,$$

$$F_1 = Z\,,$$

$$X^0 = a + bZ + \ldots\,,$$

$$X^1 = -\frac{1}{2\pi i} Z \log Z + B + \ldots\,,$$

Kähler potential

$$K_{\mathrm{cs}} = -\log\left[-i\Pi^\dagger \Sigma\, \Pi\right]$$

$$= -\log\left[\frac{1}{2\pi}|Z|^2 \log\left(|Z|^2\right) + A + C\,|Z|^2 \ldots\right]$$

Moduli stabilization

Moduli stabilization

Freeze Z via 3-form fluxes (GKP)

$$W = f\,X^1 + ihSF_1 - ih'SF_0$$
$$= f\left(-\frac{1}{2\pi i} Z \log Z + B + D\,Z + \ldots\right) + ihS\,Z - ih'S\,,$$

$F_Z = 0$ leads to

$$Z \sim \hat{C}\, e^{-\frac{2\pi h}{f} S}\,.$$

Integrating out Z:

$$W_{\text{eff}} = B\,f + \frac{f}{2\pi i}\hat{C}\, e^{-\frac{2\pi h}{f} S} - ih'S\,.$$

With $h' \neq 0$, the axio-dilaton gets stabilized at $S = B\frac{f}{h'}$.

Moduli masses

Moduli masses

Mass of axio-dilaton and cs. modulus Z::

$$m_S^2 \sim \frac{M_{\rm pl}^2}{\mathcal{V}^2} \sim \frac{M_{\rm s}^2}{\mathcal{V}}\,, \qquad m_Z^2 \sim \frac{M_{\rm pl}^2}{\mathcal{V}^2|Z|^2} \sim \frac{M_{\rm s}^2}{\mathcal{V}\,|Z|^2}$$

Comments:

- Controllable regime: $m_Z \ll M_s \Rightarrow \mathcal{V}\,|Z|^2 \gg 1$ dilute flux regime
- The highly warped region is not controlled by the employed SUGRA action.

Three form fluxes and $\overline{D3}$ branes in a warped throat are outside of control of the LEEA

Thank You!