Moduli Stabilisation near the Conifold

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String Moduli Stabilisation at the Conifold arXiv:1605.06299

Ralph Blumenhagen, DH, Florian Wolf

Motivation

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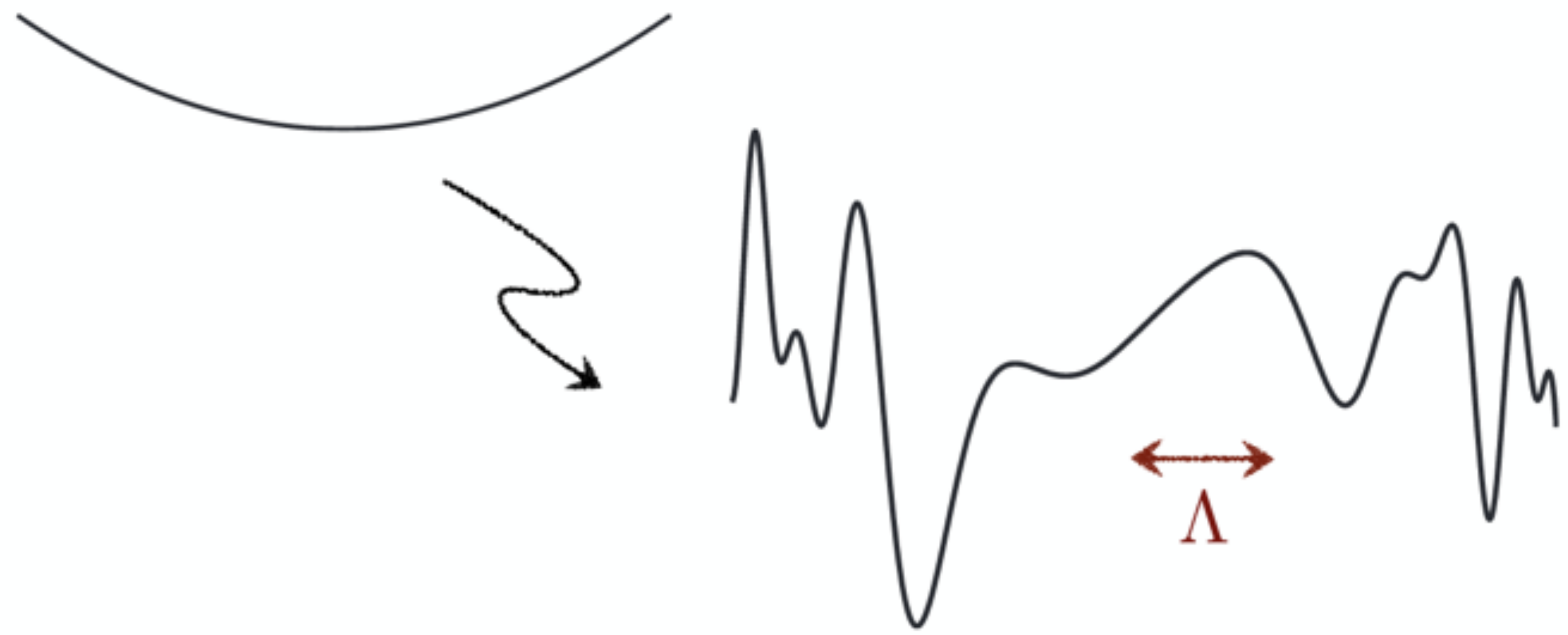
Large field inflation in string theory

Motivation

axionic shift symmetry of an inflaton protects from corrections

$$\mathcal{L}(\phi) = \frac{1}{2}(\partial\phi)^2 - \frac{1}{2}m^2\phi^2 + \sum_{i=1}^{\infty} c_i \phi^{2i} \Lambda^{4-2i}$$



Motivation

axionic shift symmetry of an inflaton protects from corrections

string theory has many axionic moduli

★**Ramond-Ramond p-forms**

gauge symmetry → shift symmetry

★**complex structure moduli**

at special points in moduli space

Motivation

axionic shift symmetry of an inflaton protects from corrections

string theory has many axionic moduli

★**axion monodromy inflation**

potential polynomial, generated by fluxes

★**natural, aligned, .. inflation**

potential periodic, generated by e.g. instantons

Moduli stabilisation

WANTED

single field inflation

inflaton axionic modulus

moduli stabilisation leaves only one axion light

not easy at all

[Hebecker, Mangat, Rompineve, Witkowski]
[Blumenhagen, DH, Plauschinn]
[Escobar, Landete, Marchesano, Regalado], [Landete, Marchesano, Wieck]
[Palti]
…

How to stabilise moduli for aligned inflation?

Aligned inflation

[Kim, Nilles, Peloso]

- two axions with sub-Planckian axion decay constant

- two axionic linear combinations, one heavy, the other

aligned inflation potential

$$V(\zeta) = \Lambda^4 \left[1 - \cos\left(\frac{\zeta}{f_{eff}}\right)\right]$$

with super-Planckian effective

axion decay constant

So what leads to a *cos*-potential?

The conifold

conifold condition e.g. quintic $|Z| \sim u = 5(\psi - 1) = 0$

vicinity of the conifold $|Z| \ll 1$

[Giddings, Kachru, Polchinski]

backreaction of fluxes leads to a warped CY

$$ds^2 = e^{2A(y)}\eta_{\mu\nu}\, dx^\mu\, dx^\nu + e^{-2A(y)} g_{\mu\nu}\, dy^\mu\, dy^\nu$$

strongly warped regime not so well controllable

The vicinity of the conifold

★ **negligible warping ..**

low energy sugra

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

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

three-cycle volume stays large $V(A) = \mathcal{V}^{\frac{1}{2}}\,|\int_A \Omega_3| = (\mathcal{V}\,|Z|^2)^{\frac{1}{2}}$

we get this e.g. by requiring $M_{string} \gg M_Z$

The vicinity of the conifold

★**exponential mass hierarchies**

single field inflation

origin: log-term in the periods

$$X^1 \sim Z \, \log Z + ...$$

example quintic: consider axio-dilaton + c.s.

$$W = f \, X^1 + i \, h \, S \, F_1 - i \, h' \, S \, X^0$$

$$D_Z W = 0 \qquad D_S W = 0$$

The vicinity of the conifold

★**exponential mass hierarchies**

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origin: log-term in the periods

$$X^1 \sim Z \, \log Z + \ldots$$

example quintic:

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

$$M_Z \sim \frac{1}{\mathcal{V}|Z|} \qquad M_{mod} \sim \frac{1}{\mathcal{V}}$$

What about the volume moduli?

The conic LARGE volume scenario

we only considered the GVW part

Reminder

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

$$Z \sim e^{-s t h} \qquad\qquad \Rightarrow \mathcal{V} \gg e^{2\, s t h}$$

LARGE volume scenario natural candidate
to stabilise the volume in the controllable regime
near the conifold

The conic LARGE volume scenario

$$K = -2\log\left(\tau_b^{\frac{3}{2}} - \tau_s^{\frac{3}{2}} + \frac{\zeta}{2} Re(S)^{\frac{3}{2}}\right)$$

assume superpotential $W = W_0 + A_s\, Z^N\, e^{-a_s T_s}$

standard LVS with $\boxed{A_s \to A_s\, Z^N}$

simple example quintic $Z \sim \exp\,(-\frac{2\pi h}{f} S)$

$$\mathcal{V}|Z|^2 \sim \exp\left[\frac{a_s}{g_s}\left(\frac{h(N-2)}{f} + (4\zeta)^{\frac{2}{3}}\right)\right]$$

large if N > 1, else fluxes can fix it

Shift symmetries of complex structure moduli

Shift symmetry of complex structure moduli

[Garcia-Extebarria, Grimm, Valenzuela]

Kalb-Ramond field and RR fields: shift symmetry from **gauge** symmetry

complex structure moduli shift symmetric at special points

large complex structure

$$K_{c.s.} = -\log f\left(\Re U_i\right)$$

imaginary parts of c.s. moduli axionic

$$\Im U_i \to \Im U_i + a$$

Shift symmetry of complex structure moduli

[Garcia-Extebarria, Grimm, Valenzuela]

Kalb-Ramond field and RR fields: shift symmetry from **gauge** symmetry

complex structure moduli shift symmetric at special points

conifold example **$\mathbb{P}_{11226}[12]$** $Z = |Z| e^{2\pi i \theta}$

$$K_{c.s.} = -\log\left(\frac{1}{2\pi}|Z|^2 \log|Z|^2 + C\,|Z|^2 + A + \Re Y + B\,\Re Y^2\right)$$

$$\theta \to \theta + const \qquad \Im Y \to \Im Y + const$$

in general higher orders break

$$\theta \to \theta + n$$

Realising inflation

Procedure for inflation

example $$W_{eff} = f_1 + f_2\,U + f_3\,S + \Delta W_{ax}$$

1. stabilise non-inflatonic moduli

   configurations with minimum number of fluxes (simple)

   leave inflatonic direction flat

2. turn on a small inflaton-dependent term

   e.g. polynomial for axion monodromy inflation

   here: **exponential** term from integrating out conic modulus

Aligned inflation example

$$W = f_1 + f_2\, U + f_3\, S + f_1 \big(\alpha\, Z + \beta\, Z\, \log Z + \gamma + ... \big)$$

Aligned inflation example

$$W = f_1 + f_2\, U + f_3\, S + f_1 \left(\alpha\, Z + \beta\, Z\, \log Z + \gamma + ...\right)$$

one axionic direction not stabilised

Aligned inflation example

$$W = f_1 + f_2\,U + f_3\,S + f_1\left(\alpha\,Z + \beta\,Z\,\log Z + \gamma + ...\right)$$

$$D_S\,W = 0 \qquad D_U\,W = 0$$

schematically.. some subtleties

integrate out *Z* $\quad M_Z \sim \dfrac{1}{\mathcal{V}|Z|}$

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$$W = f_1 + f_2\, U + f_3\, S + f_1 \left(\alpha\, e^{-(f_4\, S + f_5\, U)} + \ldots\right)$$

ΔW_{ax}

Aligned inflation example

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ΔW_{ax}

$$M_{mod} \sim \frac{1}{\mathcal{V}}$$

$$M_{ax} \sim \frac{|Z|}{\mathcal{V}}$$

exponentially light axionic inflaton

Periods.. example $\mathbb{P}_{11226}[12]$

remember $K_{c.s.} = -\log\left(\frac{1}{2\pi}|Z|^2 \log|Z|^2 + C\,|Z|^2 + A + \Re Y + B\,\Re Y^2\right)$

Periods

$$F_0 = 1\,, \qquad F_1 = Z$$

$$F_2 = c_1 + c_2\,Y + c_3\,Z + c_4\,Y^2 + c_5\,Y\,Z + c_6\,Z^2 + \ldots$$

$$X^0 = \tilde{c}_1 + \tilde{c}_2\,Y + \tilde{c}_3\,Z + \tilde{c}_4\,Y^2 + \tilde{c}_5\,Y\,Z + \tilde{c}_6\,Z^2 + \ldots$$

$$X^2 = r_1 + r_2\,Y + r_3\,Y^2 + i_1\,Y\,Z + r_4\,Z^2 + \ldots$$

$$X^1 = -\frac{1}{2\pi i} Z \log Z + \tilde{r}_1 + \tilde{r}_2\,Y + \tilde{i}_1\,Z + \ldots$$

we want: terms e.g. linear in *Z* & *Y* and a *Log* term

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some non-trivial cancellations can lead to simpler potentials

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even if we could control a part, we cannot control …

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Summary

★**region near the conifold**

exponential mass hierarchies with negligible warping

★**potential for aligned inflation**

generated purely by the form of the periods

★**exact form of the periods crucial**

Aligned inflation

more details

- potential
- mass hierarchies
- weak gravity conjecture
- challenges

Florian Wolf's talk

Summary

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THANK YOU!