D7-brane inflation with stabilizer fields

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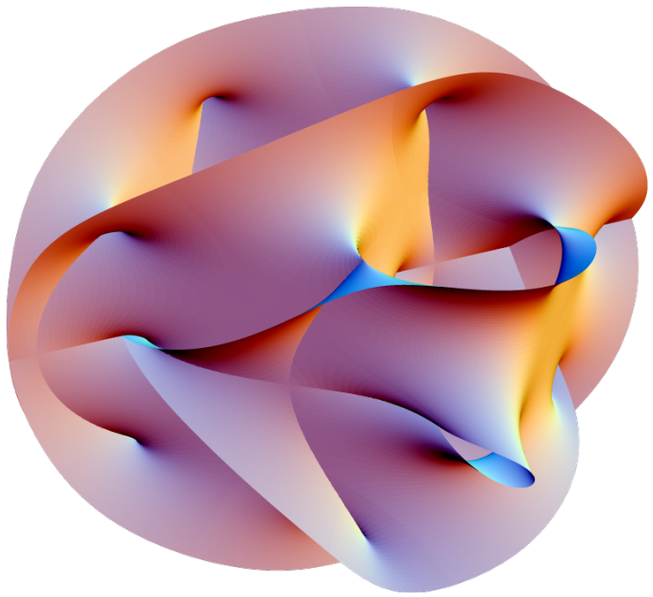
Ioannina, June 23, 2016

Based on 1606.xxxx with A. Landete, F. Marchesano

See also: Talks by Escobar, Landete, Marchesano, Zoccarato

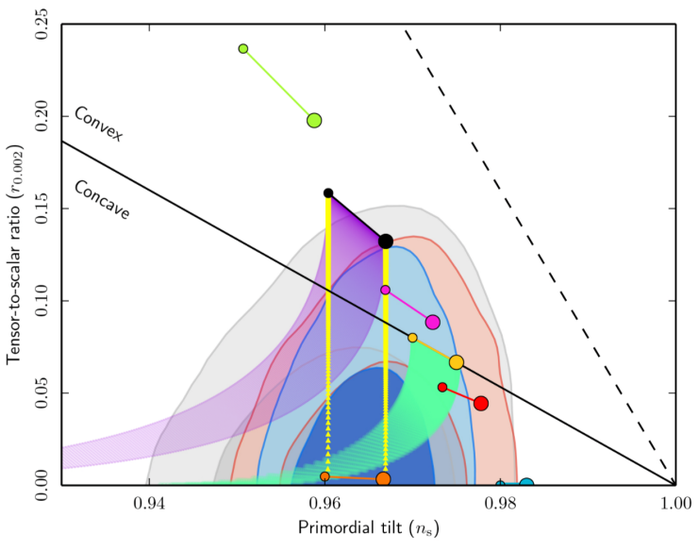
Motivation



By Lunch - own work by lunchhttp://en.wikipedia.org/wiki/Image:Calabi-Yau.png

Moduli, axions,
non-perturbative
objects, ...

Large-field inflation
in string theory



pressure on
tensor modes,
spectral tilt, ...

?

Outline

1. Large-field inflation with a stabilizer field

2. From D6- to D7-brane inflation

3. A working toy model

4. Discussion

1. Large-field inflation with a stabilizer field

Inflation with a stabilizer field

Consider a model in $\mathcal{N}=1$ supergravity with two chiral multiplets,

$$K = (\Phi+\bar{\Phi})^2 + |S|^2 + \xi|S|^4\,, \qquad W = aS\Phi$$

Inflation with a stabilizer field

Consider a model in $\mathcal{N} = 1$ supergravity with two chiral multiplets,

$$K = (\Phi + \bar{\Phi})^2 + |S|^2 + \xi |S|^4 \,, \qquad W = aS\Phi$$

Inflaton field, shift-symmetric

Stabilizer field, with extra mass term

constant parameter

Inflation with a stabilizer field

Consider a model in $\mathcal{N}=1$ supergravity with two chiral multiplets,

$$K = (\Phi+\bar{\Phi})^2 + |S|^2 + \xi|S|^4\,, \qquad W = aS\Phi$$

Supergravity scalar potential is suitable for inflation along $\mathrm{Im}\,\Phi$,

$$V = e^K\left(K^{ij}F_i\bar{F}_j - 3|W|^2\right) = \tfrac{1}{2}a^2\varphi^2$$

[Kawasaki et al. '00; Kallosh et al. '11]

2. From D6- to D7-brane inflation

D6-brane inflation—recap

A D6-brane in type IIA string theory background wrapping a suitable cycle may have the following $\mathcal{N}=1$ effective theory:

[Marchesano et al. '14; Escobar et al. '16]

$$K_{\mathsf{K}} = -\log\left[\tfrac{1}{6}(T_{\mathrm{v}}+\bar{T}_{\mathrm{v}})^3 - \tfrac{1}{2}(T_{\mathrm{v}}+\bar{T}_{\mathrm{v}})(S+\bar{S})^2\right] ,$$

$$K_{\mathsf{cs}} = -2\log\left\{\tfrac{1}{16}\left[U+\bar{U}-\tfrac{1}{8}(\Phi+\bar{\Phi})^2\right]^2\right\} ,$$

$$W = aS\Phi + W_{\mathsf{mod}}(U, T_{\mathrm{v}})$$

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Kahler moduli

$$K_{\mathsf{cs}} = -2\log\left\{\tfrac{1}{16}\left[U+\bar{U}-\tfrac{1}{8}(\Phi+\bar{\Phi})^2\right]^2\right\} ,$$

complex structure modulus

Inflaton field, open-string modulus

$$W = aS\Phi + W_{\mathsf{mod}}(U, T_{\mathrm{v}})$$

D6-brane inflation—problems

But: After integrating out U and $T_{\rm v}$, effective theory is tachyonic along direction S

$$V_{\rm eff} \simeq a^2\varphi^2 + (1-3\varphi^2)a^2|S|^2\,.$$

↳ Due to shift symmetry of stabilizer field in K

$K = K(\Phi+\bar{\Phi}, S+\bar{S})$ is unsuited for large-field inflation with a stabilizer field

From D6-branes to D7-branes

Shift symmetry in Type IIA Kahler sector expected to be broken away from large volume,

$$\mathcal{G} = \frac{1}{6}\kappa_{abc}T^aT^bT^c + \frac{1}{2}S_{ab}T^aT^b + P_aT^a + Q + \mathcal{G}_{\text{exp}}$$

From D6-branes to D7-branes

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Use type IIB dual description with D7 brane:

Kahler moduli $\longleftrightarrow$ Complex structure moduli

Kahler potential at small complex structure should have the right form, so that one of the moduli can be the stabilizer field

Kahler potential in Type IIB

Now, with $S \in \{U_a\}$ we have in general

$$K_{\text{cs}}(S,\bar{S}) = -\log\left[\gamma_0 + \gamma_1(S+\bar{S}) + \gamma_2|S|^2 + \gamma_3(S^2+\bar{S}^2) + \dots\right]$$

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↳ Some terms break the shift symmetry, others act destabilizing!

Important ingredient for stable trajectory:
Open-string Kahler potential also depends on complex structure moduli

[Carta et al. '16]

Kahler potential in Type IIB

D7-brane Wilson line moduli redefine holomorphic Kahler variables

$$T_\alpha + \bar{T}_\alpha \to T_\alpha + \bar{T}_\alpha - \frac{1}{8}\sum_A \frac{\mathcal{C}_\alpha^A}{\mathrm{Re}\, f^A(U_a)}(\Phi^A + \bar{\Phi}^A)^2$$

[Carta et al. '16, cf. Talk by F. Marchesano this morning]

so that

$$K_{\mathrm{K}} = -\log\left[\mathcal{V}^2 - \frac{\mathcal{V}}{16}\sum_A \frac{\mathcal{C}^A}{\mathrm{Re}\, f^A}(\Phi^A + \bar{\Phi}^A)^2 + \dots\right]$$

Kahler potential in Type IIB

$$if^A(U_a) = \frac{d^b_A \mathcal{G}_b - p^a_A U_a}{c^a_A U_a}$$

In large complex structure limit, $f^A(U_a) \propto U_a$ so that shift symmetry is intact. But away from LCS limit we may expand

$$f(S) = a_0 + a_1 S + a_2 S^2 + \dots$$

↪ Shift symmetry breaking proportional to a_2

3. A working toy model

Low-energy effective supergravity

With what we have learned so far, we may consider the effective theory after integrating out all Kahler moduli and most CS moduli,

$$K = -\log\left[1 + (S + \bar{S})^2\right]$$

$$-\log\left[\mathcal{V} - \mathcal{V}^{1/3}(\Phi + \bar{\Phi})^2 + \frac{\mathcal{V}^{1/3} c^2}{2a_0 + a_2(S^2 + \bar{S}^2)}\right]$$

$$W = aS\Phi$$

with $c \sim \langle \mathrm{Re}\, \tilde{\Phi} \rangle$ from a second Wilson line modulus stabilized supersymmetrically at a high scale

Low-energy effective supergravity

Expand supergravity scalar potential in inverse powers of $\mathcal{V}$ and in $\epsilon = c^2/2a_0\mathcal{V}^{2/3}$,

$$V(\varphi, S) = \frac{1}{2}m^2\varphi^2 + \frac{1}{2}m^2|S|^2(1-3\varphi^2) + \frac{3a_2^2}{8a_0^2}\epsilon m^2\varphi^2|S|^2 + \dots$$

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Effective potential of D6-brane inflation, tachyonic

Stabilizing mass term from CS shift symmetry breaking in dual D7-brane setup

Low-energy effective supergravity

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With $\epsilon a_2^2/a_0^2 > 1$ achieve mass hierarchy $m_S \gg m_\varphi$ during inflation

Low-energy effective supergravity

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With $\epsilon a_2^2/a_0^2 > 1$ achieve mass hierarchy $m_S \gg m_\varphi$ during inflation

Constraint on derivatives of
prepotential and vevs of other U_a

60 e-folds of single-field inflation with $V = \frac{1}{2}m^2\varphi^2$

4. Discussion

The Picard-Fuchs basis and small CS

The proposed breaking of the CS shift symmetry is manifest in a different field basis for the U_a :

On certain CY manifolds with $h^{2,1} = 2$ one can obtain $\mathcal{G}$ and K_{cs} by direct integration of three-form Ω at small complex structure,

$$K_{\text{cs}}(S, \bar{S}) = -\log\left[\alpha_0 + \alpha_1 |S|^2 + \alpha_2 |S|^4 + \dots\right]$$

[Candelas et al. '93; Hosono et al. '93; Conlon, Quevedo '04]

Exactly what is needed, no terms proportional to $S + \bar{S}$ arise!

The Picard-Fuchs basis and small CS

However, this comes at the price of a more complicated superpotential,

$$W = \Phi(k_0 + k_1 S + k_2 S^2 + \dots) + \kappa_1 S + \kappa_2 S^2 + \dots$$

Supergravity analysis: Inflation ending in Minkowski or dS vacuum only possible for fine-tuned choice $k_0 = \kappa_1 = \kappa_2 = 0$, in which case the pure original setup is obtained

More ingredients necessary to understand this field basis?

Conclusions

- "D6-brane inflation" fails due to shift symmetry for stabilizer and backreaction of heavy moduli
- Consider dual type IIB theory with D7-branes, avoid shift symmetry by compactifying in different regime of moduli space
- 60 e-folds of single-field inflation possible, quadratic potential expected to be flattened by corrections from heavy fields