Instituto de Física Teórica UAM-CSIC

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Large field inflation in type IIA string theory

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StringPheno
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Based on 1505.0787,1511.08820 with A. Landete, F. Marchesano & D. Regalado

Outline

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- Current observational evidence $r < 0.12$ Planck+BICEP '15

UV sensitivity

Large field inflation is hard to control in EFT

$$\mathcal{L}_{\text{eff}} = \mathcal{L}[\phi] + \sum_{n=1}^{\infty} c_n \frac{\phi^{4+2n}}{\Lambda^{2n}} + \ldots\ldots\ldots$$

generically $c_n \sim \mathcal{O}(1)$ and $\Lambda \lesssim M_p$

Such a corrections to the effective potential might spoil inflation (e.g. η-problem)

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$$V(\phi) = \Lambda^4 \left(1 + \cos\left(\frac{\phi}{f}\right)\right)$$

$f > M_p$ hard of realizing in String Theory Banks et al. 03

Axion Monodromy Inflation

String theory contains a lot of axions arising from integrating gauge fields over suitable non-trivial cycles $c_j(x) = \int_{\Pi_p^j} C_p$ (typically sub-Planckian)

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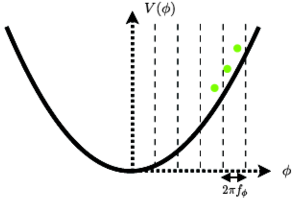
  The effective field range is much larger than the fundamental period Silverstein & Westphal '08



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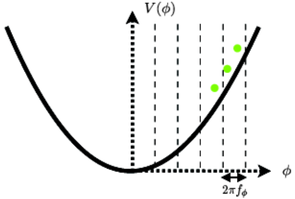
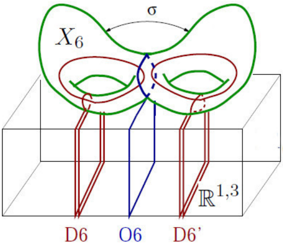
- F-term axion monodromy
  Fluxes generate a potential for the axions Marchesano et al. '14



The setup

Type IIA compactifications on CY orientifolds X_6 Grimm & Louis '05



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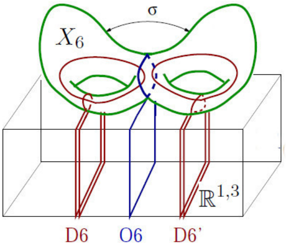

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- Supersymmetric D6-branes
- 06-planes
- Background fluxes

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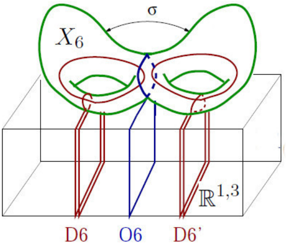

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Supersymmetry conditions

- $J_c|_{\Pi_3} - \frac{l_s^2}{2\pi} F = 0$
- $\Omega|_{\Pi_3} = 0$

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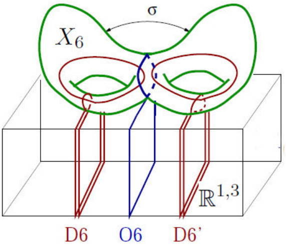

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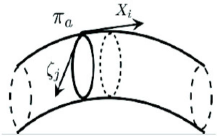
Tadpole cancellation condition

$$\sum_{a=1}^{K} N_a \, [\Pi_3^a] = 4 \left[\Pi^{06}\right]$$

D6-brane scenario

D6-brane wrapping a SLag 3-cycle Π_3

$$b_1(\Pi_3) = 1 \Rightarrow \pi_2 \in H_2(\Pi_3, \mathbb{Z})$$



Whether π_2 is non-trivial in $H_2(X_6, \mathbb{Z}) \Rightarrow \frac{1}{l_s^2}\int_{\pi_2} \omega = 1$

The D6-brane generates a superpotential Marchesano et al. 14

$$W = a\,T\,\Phi \qquad \text{with} \quad \Phi_{\mathrm{D6}} = \frac{l_s}{\pi}\left(A - \iota_{\varphi_X} J_c|_{\Pi_3}\right) = \Phi\zeta$$

$$T = \frac{1}{l_s^2}\int_{\pi_2} J_c = \sum_a n_a T^a$$

$T = T^1 - T^2 \Longrightarrow T = 0$ does not require any 2-cycle shrinking to vanishing size

The Kähler potential Kerstan & Weigand '11

$$K_K = -\text{Log}\left[\frac{i}{6}\mathcal{K}_{abc}\left(T^a - \bar{T}^a\right)\left(T^b - \bar{T}^b\right)\left(T^c - \bar{T}^c\right)\right]$$

$$K_Q = -2\text{Log}\underbrace{\left[\frac{\mathcal{F}_{KL}}{16i}\left(N^K - \bar{N}^K + \frac{iQ^K}{4}\Phi\bar{\Phi}\right)\left(N^L - \bar{N}^L + \frac{iQ^L}{4}\Phi\bar{\Phi}\right)\right]}_{\text{modified in the presence of open string moduli}}$$

Alternatively, we can consider a Kähler potential in which Φ enjoys a shift symmetry

Moduli stabilisation and inflation

String compactifications contain a lot of scalar fields.

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How to lower the inflaton mass?

- Different sources for moduli stabilization and inflaton potential,

$$W = \underbrace{W_{\rm flux}\left(T^i, N\right) + W_{\rm D2}\left(\Phi, N\right) + W_{\rm WS}\left(\Phi, T^i\right)}_{W_{\rm mod}} + W_{\rm inf}\left(T, \Phi\right)$$

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- Warping effects

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- Warping effects
- Turning on large flux quanta (Upper bounds)

Moduli stabilisation

Assumptions

- $W_{\rm mod}$ does not depend on T
- Moduli are stabilized with a very small or vanishing value of $W^0_{\rm mod}$
- $\Phi = {\rm Im}\, T = 0$

Imposing the F-term conditions

$$
\begin{aligned}
D_{N^K} W_{\rm mod} &= 0 \qquad \Longrightarrow \qquad D_{N^K} W = K_{N^K} W \\
D_{T^i} W_{\rm mod} &= 0 \qquad \Longrightarrow \qquad D_{N^{T^i}} W = K_{T^i} W
\end{aligned}
$$

At the locus $\Delta V = V - V_0$

$$
\Delta V = \kappa_4^{-2} e^K \left[K^{\Phi\bar{\Phi}} |\partial_\Phi W_{\rm inf}|^2 + \left(K^{T\bar{T}} + 4\,({\rm Te}\, T)^2 \right) |\partial_T W_{\rm inf}|^2 \right] + \mathcal{O}\left(W^0_{\rm mod} \right)
$$

Inflating with the B-field

$$b = \mathrm{Re}\, T = \frac{1}{l_s^2} \int_{\pi_2} B$$

Chaotic inflation potential (small field approximation) Kawasaki et al.'00, Kallosh & Linde '10

$$V = e^K K^{\Phi\bar{\Phi}} |T|^2 \qquad \Longrightarrow \qquad m_{\rm inf}^2 = \kappa_4^{-2} \frac{e^K K^{\Phi\bar{\Phi}}}{K^{T\bar{T}}}$$

Lowering the inflaton mass through warping effects

- $K_{\Phi\bar{\Phi}} \gg K_{\alpha\beta} \quad \alpha, \beta = N^K, T^i$ (D6-brane located at a strong warping region)

DBI analysis

Performing the dimensional reduction of D6-brane action on $X_4 \times \Pi_3$

$$S_{4\mathrm{d}} = -\int_{X_4} d^4x \left[V_0 + \frac{1}{2}(\partial_\mu \varphi \, \partial_\mu \xi) \, \mathbf{M} \begin{pmatrix} \partial^\mu \varphi \\ \partial^\mu \xi \end{pmatrix} \right]$$

The D6-brane scalar potential

$$V_{D6} = \frac{g_s^{3/4}}{2\pi \kappa_4^4 \hat{V}_{X_6}^2} \int_{\Pi_3} d\hat{\mathrm{vol}}_{\Pi_3} \sqrt{1 + \frac{1}{2g_s}\mathcal{F}_{ab}\mathcal{F}^{ab}} - l_s^3 \mathrm{Re}\,\Omega$$

It will vanish in the supersymmetry case.

Whether Π_3 is not Lag

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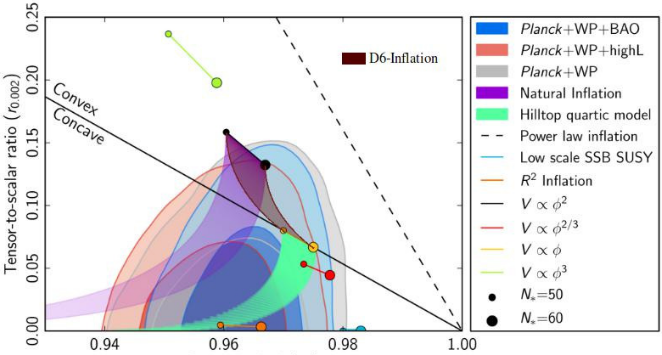
- It encodes α' corrections to the effective supergravity potential.

B-field potential for large field values

$$V(\phi_b) = c\, M_p^4 \left(\sqrt{1 + a \left(\frac{\phi_b}{M_p} \right)} - 1 \right)$$

Choosing

$$\hat{V}^{\rm st}_{X_6} \sim 10^3, \;\; \hat{V}^{\rm st}_{\Pi_3} \sim 10, \;\; g_s^2 \sim 0.1 \Longrightarrow a \sim 10^{-1}\text{–}10^{-3}, \quad \sqrt{a\,c} \sim 10^{-5}\text{–}10^{-6}$$



Conclusions

- This model provides a simple way to embed SUGRA chaotic inflation models in string theory.
- Depending on the choice of the compactification parameters, this model interpolates between quadratic and linear potentials.
- The inflationary parameters obtained from the α'-corrected potential nicely fit with the current bounds from Planck collaboration.
- This framework can be extended to other setups like Type IIB/F-theory with D7-branes.

Thank you