F-term axion monodromy inflation with complex structure moduli

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Talk based on A. Hebecker, P. Mangat, FR, L. Witkowski [Nucl. Phys.B 894, arXiv:1411.2032].

Motivation and introduction

$\rightarrow$ With $r \leq 0.08$, still room for Large Field displacements: $\Delta\phi \gtrsim \left(\frac{r}{0.01}\right)^{1/2} M_{Pl}$.

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→ Focus of this talk: challenges for string-theoretic supegravity models of axion monodromy inflation with complex structure moduli.

F-term axion monodromy inflation

- Consider a shift symmetric Kähler potential

$$\mathcal{K} \equiv \mathcal{K}(z^n, \bar{z}^n, u + \bar{u})$$

- The inflaton candidate is $y = Im(u)$. $z^n, u = x + iy$ are complex structure moduli of a CY 3-fold. More generally, one can consider complex structure of CY 4-folds. Then brane position moduli are also included.

- Such a shift symmetry arises at special points of moduli space. In our case, we require u to be in the Large Complex Structure (LCS) regime. [Arends, Hebecker, Heimpel, Kraus, Lüst, Mayrhofer, Schick, Weigand /McAllister, Silverstein, Westphal, Wrase/ Blumenhagen, Herrschmann, Plauschinn/Hayashi, Matsuda, Watari/Garcia-Extebarria, Grimm, Valenzuela.]

- The shift symmetry is weakly broken by the superpotential. In the simplest case, by a flux choice we can consider:

$$W = w\left(\{z^i\}\right) + au, \quad \text{with } a \ll w \sim O(1) \Rightarrow a \equiv a\left(\{z^i\}\right)$$

see also [Blumenhagen, Herrschmann, Plauschinn '14] for the alternative choice $w \gg 1$.

Features of the F-term potential

- The inflaton candidate acquires an F-term potential:

$$V_F = e^{\mathcal{K}} \left[\mathcal{K}^{I\bar{J}} D_I W \overline{D_J W} \right] + \overbrace{V_{\text{Kähler moduli}} - 3|W|^2}^{\simeq 0 \text{ due to no-scale structure}}$$

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- The result is a quadratic potential for y, with *moduli-dependent* cross-couplings:

$$V_F(x, y, z, \bar{z}) = A(z, \bar{z}, x) + B(z, \bar{z}, x)y + C(z, \bar{z}, x)y^2, \tag{1}$$

with $A = B = 0$ at the global minimum $(z_0, \bar{z}_0, x_0, y_0)$.

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- Tuning: Flat direction requires $C(z_0, \bar{z}_0, x_0) \ll 1$. Which quantities do we need to tune?

Additional tunings

Around the minimum the scalar potential is exactly quadratic in $\Delta y \equiv y - y_{min}$:

$$V = e^{\mathcal{K}}\left[\mathcal{K}^{u\bar{u}}|\mathcal{K}_u a|^2 + \mathcal{K}^{i\bar{j}}(a_i + \mathcal{K}_i a)\overline{(a_j + \mathcal{K}_j a)}\right](\Delta y)^2$$
$$+\left[(\mathcal{K}^{u\bar{j}}(\mathcal{K}_u a)(\overline{a_j + \mathcal{K}_j a}) + h.c.)\right](\Delta y)^2 + \underbrace{\ldots}_{\text{backreaction of } x, z^i}$$

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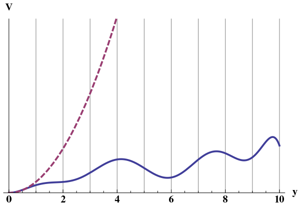
- The result of this tuning is a very flat *naive* inflationary potential:

$$V_{naive} = \mu^2 \Delta y^2 \tag{2}$$

where $\mu^2 \sim e^{\mathcal{K}} \epsilon^4 \ll 1$.

The problem of backreaction

As Δy moves along the inflationary trajectory, the other moduli $\{z^i, x\}$ can be displaced from their values at the minimum.



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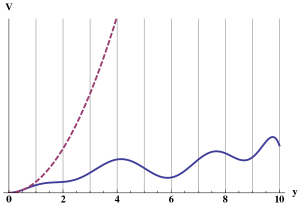

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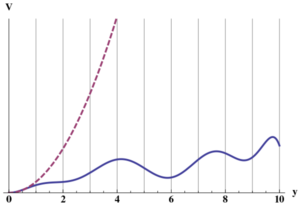

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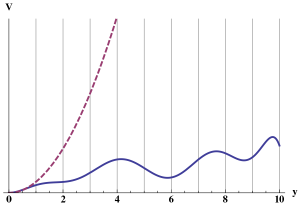

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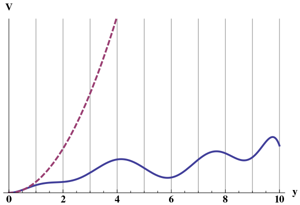

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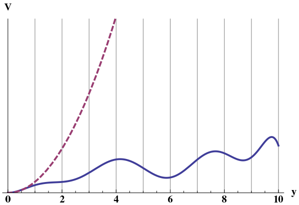

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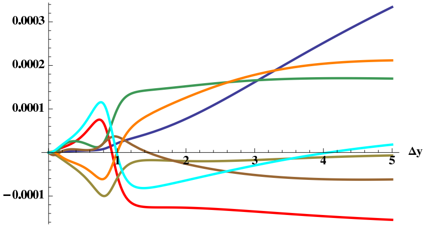
$\rightarrow$ Δ_{min} describes how the moduli shift as Δy moves away from the minimum.

$\rightarrow$ Minimised potential takes into account the effect of backreaction.

Results for model with 4 moduli, $\mathcal{K}_{I\bar{J}} \sim O(1)$, $\epsilon \sim 10^{-2}$.

Plots of δx (blue), δv^1, δw^1, δv^2, δw^2, δv^3, δw^3 vs. Δy.



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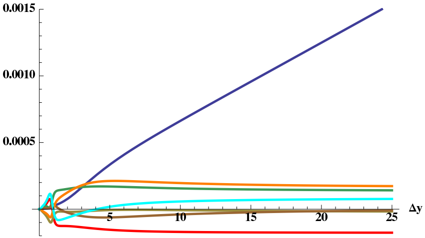

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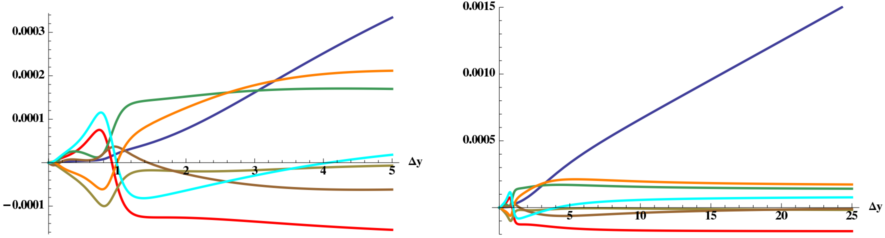

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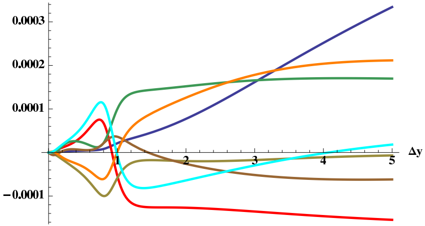

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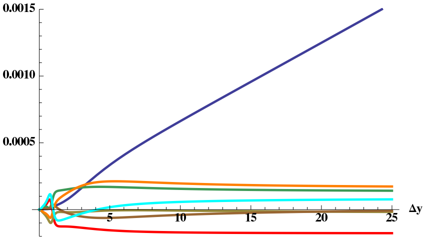

(f)

1. $\Delta y \lesssim O(1)$: the displacements are generic functions of Δy. Backreaction is not always under control.

2. Interesting regime for large field inflation: $O(1) \lesssim \Delta y \ll 1/\epsilon$: $\delta v^i, \delta w^i \sim \epsilon^2$, $\delta x \sim \epsilon^2 \Delta y$. Backreaction is under control!

The effective potential in the regime $O(1) \lesssim \Delta y \ll 1/\epsilon$

The backreacted potential is given by:

$$V_{eff} \simeq \underbrace{-O(1)e^{\mathcal{K}}\epsilon^4\Delta y^2}_{\equiv V_{backreaction}} + \overbrace{\mu^2\Delta y^2}^{\equiv V_{naive}} \equiv \mu_{eff}^2\Delta y^2, \quad \text{with } \mu \sim e^{\mathcal{K}}\epsilon^4$$

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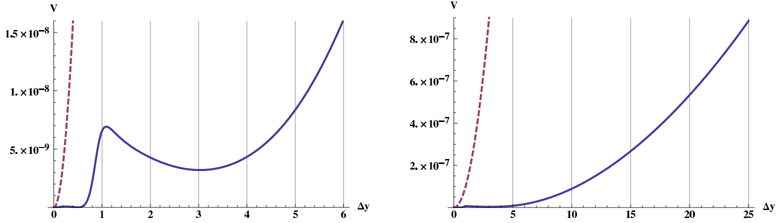
→ Plots of the effective inflaton potential (blue, solid) and the 'naive' inflaton potential (red, dashed) vs. Δy.



(i) (j)

→ The potential is quadratic and in principle suitable for inflation. Backreaction leads to flattening: $\mu_{eff} < \mu$!

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$\rightarrow$ **Many thanks!**

Superpotential and Kähler potential

$$\Pi = \begin{pmatrix} 1 \\ z^I \\ \frac{1}{2}\kappa_{IJK} z^J z^K + non - pert. \\ -\frac{1}{3!}\kappa_{IJK} z^I z^J z^K + non - pert. \end{pmatrix}. \tag{3}$$

$$W = (N_F - SN_H)^\alpha \Pi_\alpha(z, u) \tag{4}$$

$$\mathcal{K} = -\ln(S - \bar{S}) - \ln\left[\Pi_\alpha(z, u)\bar{\Pi}^\alpha(\bar{z}, \bar{u})\right] \tag{5}$$

In the LCS for u:

$$W = w(S, z) + a(S, z)u + \frac{1}{2}b(S, z)u^2 + \frac{1}{3!}c(S)u^3 \tag{6}$$

with $c(S) \sim (m + nS)$.

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→ The resulting potential is a quadratic form in Δ

$$V_F = \frac{1}{2}\Delta^T \mathcal{D}(\Delta y)\Delta + [\mathbf{b}(\Delta y, \eta_I)]^T \Delta + \mu^2(\Delta y)^2,$$

where $\mathcal{D} \equiv \mathcal{D}_{ij}$ and $\mathbf{b}$ contain second and first derivatives of the potential respectively and $\mu \sim \epsilon^4$ is the naive inflaton mass.

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2. Minimize V_F with respect to Δ for fixed Δy:

$$\mathcal{D}\Delta_{min} = -\mathbf{b}.$$

⇒ The result $\Delta_{min} \equiv \Delta_{min}(\Delta y)$ describes how the moduli are displaced as Δy moves away from the minimum.