Loop Blow-Up Inflation

A new inflationary model from string theory

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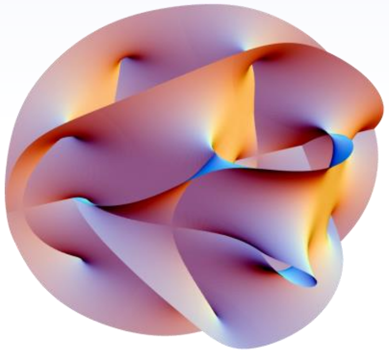
Based on:
S. Bansal, LB, M. Cicoli, A. Hebecker, R. Kuespert: 2403.04831

Kähler moduli and Inflation

D = 10 TYPE IIB
STRING THEORY



D=4 $\mathcal{N}$=1
SUGRA EFT

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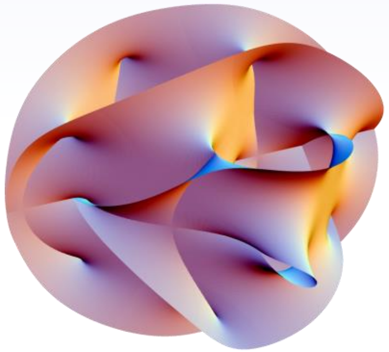

Moduli

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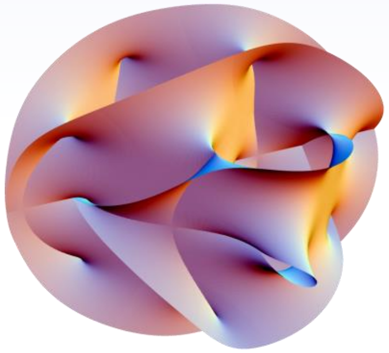


Moduli

Complex Structure Moduli:
Fixed semiclassically by fluxes

Kähler Moduli
Fixed by quantum corrections

D=4 $\mathcal{N}$=1
SUGRA EFT

Kähler moduli and Inflation

$$V \sim \left(B \frac{\sqrt{\tau}\, e^{-2a\tau}}{\mathcal{V}} - C \frac{\tau\, e^{-a\tau}}{\mathcal{V}^2} + \frac{\xi}{\mathcal{V}^3} \right)$$

$\tau \gg 1$

$$V \simeq V_0 \left(1 - C \frac{\tau\, e^{-a\tau}}{\mathcal{V}^2} \right)$$

Canonical normalization

$$V(\varphi) \simeq V_0 \left[1 - C\, \varphi^{4/3} e^{-\mu\, \varphi^{4/3}} \right]$$

$$T = \tau + i\,\vartheta$$

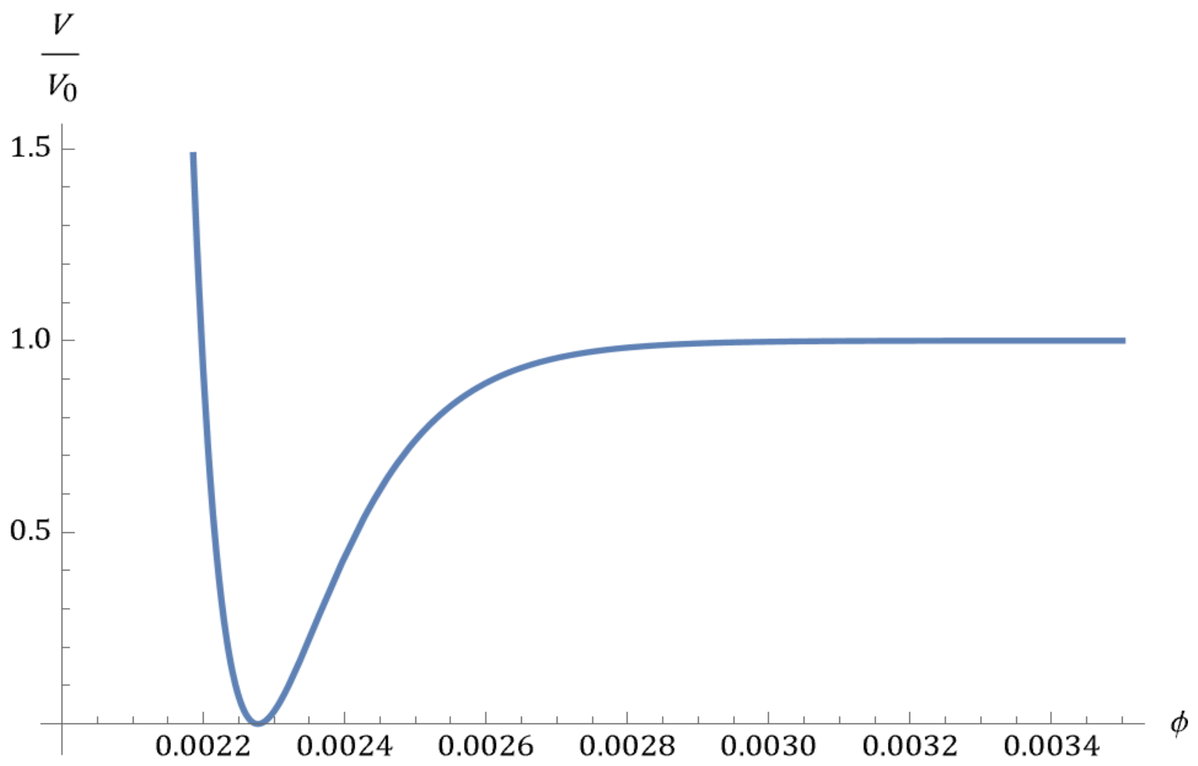
Large Volume Stabilisiation

Kähler Moduli

Fixed by quantum corrections

Kähler moduli and Inflation

$$V \sim \left(B \frac{\sqrt{\tau}\, e^{-2a\tau}}{\mathcal{V}} - C \frac{\tau\, e^{-a\tau}}{\mathcal{V}^2} + \frac{\xi}{\mathcal{V}^3} \right) \xrightarrow[\tau \gg 1]{} V \simeq V_0 \left(1 - C \frac{\tau\, e^{-a\tau}}{\mathcal{V}^2} \right) \xrightarrow[\text{Canonical normalization}]{} V(\varphi) \simeq V_0 \left[1 - C\, \varphi^{4/3} e^{-\mu\, \varphi^{4/3}} \right]$$



Blow-Up Inflation
[Conlon, Quenevo: 2005]

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Exponential plateau ‘spoiled’ by string-loop corrections [Cicoli, Mazumdar: 2010]

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For a blow-up modulus τ [Cicoli, Conlon, Quevedo: 2008]

$$\delta V \sim \frac{1}{\mathcal{V}^3\sqrt{\tau}} \quad \Rightarrow \quad V \simeq \tilde{V}\left(\frac{\beta}{\mathcal{V}^3} - C\,\frac{\tau\, e^{-a\tau}}{\mathcal{V}^2} - \frac{c_{loop}}{\mathcal{V}^3\sqrt{\tau}}\right)$$

For $c_{loop} > 10^{-6}$ loops immediately dominate:

$$V \simeq V_0\left(1 - \frac{c_{loop}}{\sqrt{\tau}}\right) = V_0\left(1 - \frac{b\, c_{loop}}{\mathcal{V}^{1/3}\varphi^{2/3}}\right)$$

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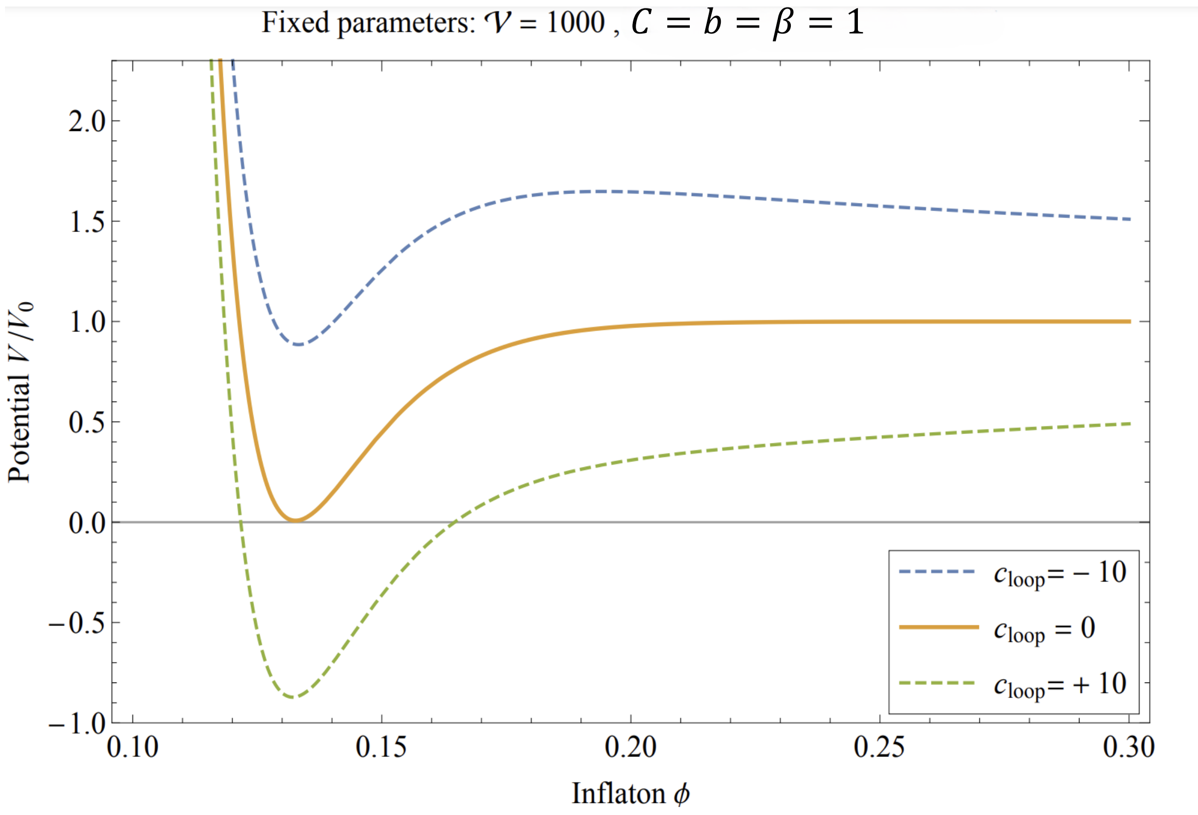

Cosmological Parameters

Spectral Index n_S and Tensor-to-Scalar Ratio r

$$\begin{cases} n_S \simeq 1 - \dfrac{20}{9} \dfrac{b c_{loop}}{\mathcal{V}^{1/3} \, \varphi_*^{\,8/3}} \\ \\ r \simeq \dfrac{32}{9} \dfrac{\left(b c_{loop}\right)^2}{\mathcal{V}^{2/3} \varphi_*^{\,10/3}} \end{cases}$$

Imposing CMB bounds with $c_{loop} \simeq 1/(16\,\pi^2)$

$$\begin{cases} \varphi_* = 0.06\, N_e^{7/22} \\ \\ \mathcal{V} = 1743\, N_e^{5/11} \end{cases}$$

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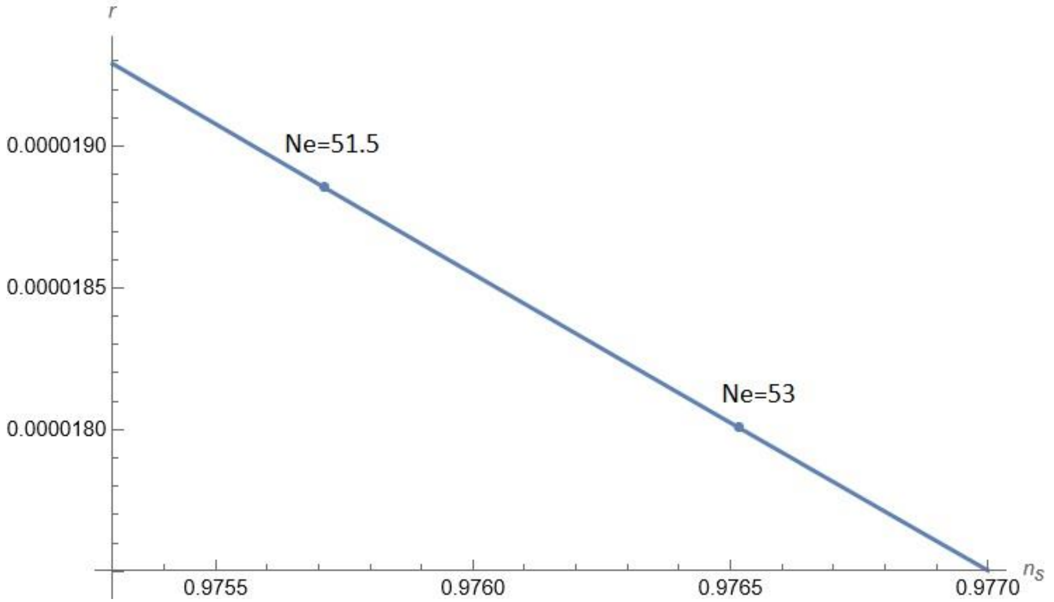
$r - n_s$ relation of the model

$$r = 0.003(1 - n_s)^{11/15}$$



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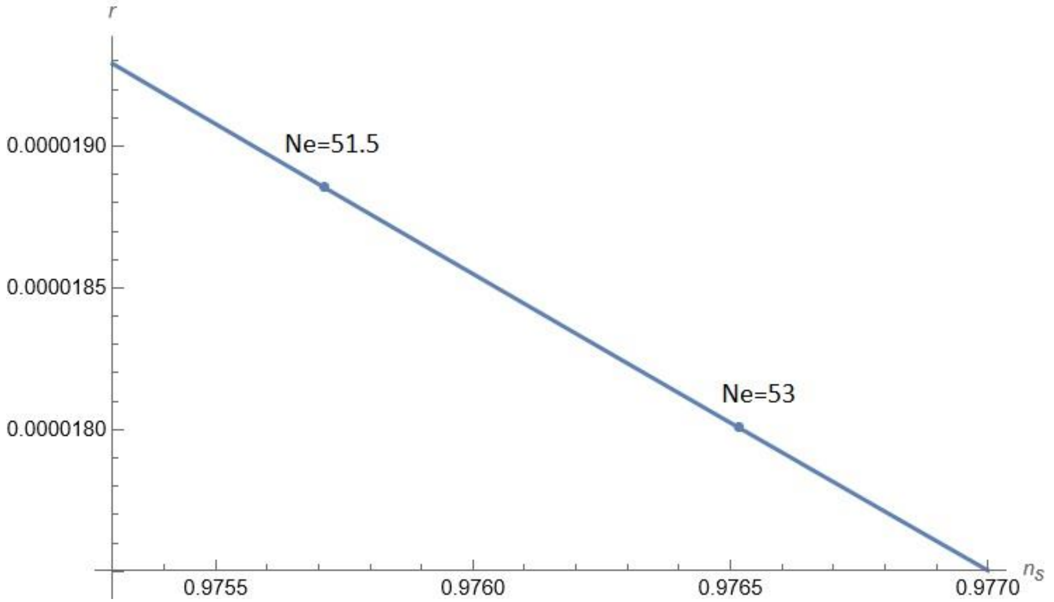

N_e from post-inflationary evolution and reheating:

$$N_e \simeq 57 + \frac{1}{4} \ln r - \frac{1}{4}\left(N_\varphi + N_\chi\right)$$

Depends on the microscopic details of SM realization (more on this in the poster session!)

Post-Inflation and Predictions

Post-inflation in 4 scenarios of SM realization: similar cosmological histories with generic features

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Post-inflation in 4 scenarios of SM realization: similar cosmological histories with generic features

- One or too periods of Early Matter Domination due to moduli oscillations

$$1 \leq N_\varphi \leq 11 \qquad 0 \leq N_\chi \leq 10.5$$

- Dark Radiation production in the form of volume-mode axions

$$0 \lesssim \Delta N_{eff} \lesssim 0.36$$

- Low tensor-to-scalar ratio

$$r \simeq 2 \times 10^{-5}$$

- Consistent prediction of the spectral index

$$n_s \simeq 0.976$$

Thank You for your Attention!

See you in the cloister for more details!

Backup

SM Realization and Scenarios

- SM D7-branes cannot wrap τ_s [Blumehagen, Moster, Plauschinn: 2007] nor τ_φ (FI terms would make it too heavy)
  ⇒ introduce τ_{SM} and τ_{int}

$$\mathcal{V} = \tau_b^{3/2} - \tau_s^{3/2} - \tau_\varphi^{3/2} - \tau_{SM}^{3/2} - \lambda(\tau_{int} - \tau_{SM})^{3/2}$$

- D-term stabilization ($\xi_{FI} = 0$):

$$\tau_{SM} = \lambda^2(\tau_{int} - \tau_{SM})$$

  - $\lambda = 0$ ⇒ $\tau_{SM} \to 0$: SM on D3-branes at singularity
  - $\lambda \neq 0$ ⇒ τ_{int} fixed in terms of τ_{SM}, still flat. Fixed by loop potential [Cicoli, Mayrhofer, Valandro: 2011]:

$$V_{loop}(\tau_{SM}) = \frac{W_0^2}{\mathcal{V}^3}\left(\frac{\gamma}{\sqrt{\tau_{SM}}} - \frac{\delta}{\sqrt{\tau_{SM}} - \sqrt{\tau_s}}\right)$$

⇒ SM on D7-branes

- 4 Scenarios:
  i. Scenario I: SM on D7, τ_φ wrapped by hidden-sector D7s
  ii. Scenario II: SM on D7, τ_φ *not* wrapped
  iii. Scenario IIIa: SM on D3, τ_φ wrapped by hidden-sector D7s
  iv. Scenario IIIb: SM on D3, τ_φ *not* wrapped

Comments on Spectral Index

- Scenario I:

$n_s \simeq 0.9765,\ \Delta N_{\text{eff}} \simeq 0$ ⟺ ($\sim 2\sigma$) $n_s = 0.9665 \pm 0.0038$ 68% CL [Planck: 2018]

- Scenario II:

$n_s \simeq 0.9761,\ \Delta N_{\text{eff}} \simeq 0.14$ ⟺ ($\sim 2\sigma$) $n_s = 0.9589 \pm 0.0084$ 68% CL, $N_{\text{eff}} = 2.89^{+0.36}_{-0.38}$ [Planck: 2018]

- Scenario III:

$n_s \simeq 0.9757,\ \Delta N_{\text{eff}} \simeq 0.36$ ⟺ ($\sim 1.2\sigma$) $n_s = 0.983 \pm 0.006$ 68% CL, $\Delta N_{\text{eff}} = 0.39$ [Planck: 2015]

- Possible improvements: include additional corrections
  - F^4 corrections [Cicoli, Licheri, Piantadosi, Quevedo, Shukla: 2023]
  - Subleading loop corrections