Small Field Polynomial Inflation

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based on 2104.03977 with Manuel Drees

Sep.8 CoCo 2o21

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Outline

1. Why polynomial model?
2. Predictions?

Why Small Field Polynomial Model?

- Monomial: $V(\phi) \sim \phi^{n}$, tensor-to-scalar ratio

$$r \propto \left(\frac{V'}{V}\right)^2 \sim \frac{4n}{N_{\mathrm{CMB}}}$$

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  - $V(\phi)$: most general renormalizable inflaton potential

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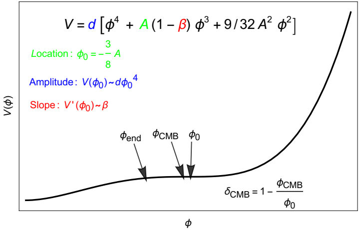
  3. d: $\longleftrightarrow$ Amplitude (power spectrum)

Slow-Roll Predictions



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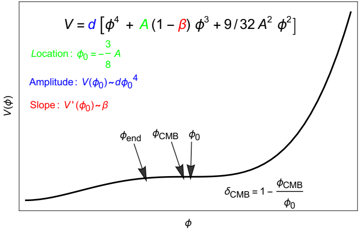

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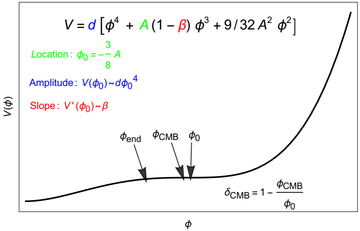

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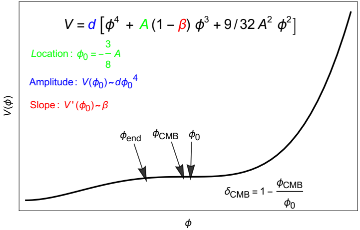

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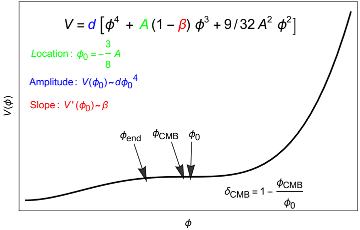

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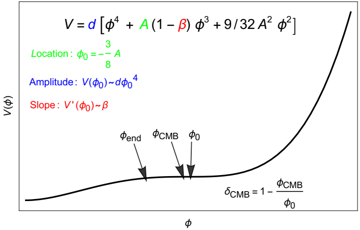

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  - $r \propto \left(2\beta + \delta^2\right)^2/\phi_0^2$
  - $\alpha \simeq -\frac{576(2\beta+\delta^2)}{\phi_0^4}$
  - $\mathcal{P}_\zeta \simeq \frac{d\phi_0^6}{5184\pi^2(\delta^2+2\beta)^2}$
- $n_s = 0.9649$, $N_{\mathrm{CMB}} = 65$, $\mathcal{P}_\zeta = 2.1 \cdot 10^{-9}$ $\Rightarrow$ fix:

$$\delta_{\mathrm{CMB}} = 7.31 \times 10^{-4}\phi_0^2$$
$$\beta = 9.73 \times 10^{-7}\phi_0^4$$
$$d = 6.61 \times 10^{-16}\phi_0^2$$

- Predictions for r and α?

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- r not detectable ☹

$$\frac{r}{7.09\times 10^{-9}\,\phi_0^6} = 1 - 3.9\cdot 10^{-2}(65 - N_{\mathrm{CMB}})$$

$$+\, 15.0\,(0.9649 - n_s) + 175\,(0.9649 - n_s)^2$$

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$$\alpha = -1.43 \cdot 10^{-3} - 5.56 \cdot 10^{-5}\,(65 - N_{\mathrm{CMB}})$$

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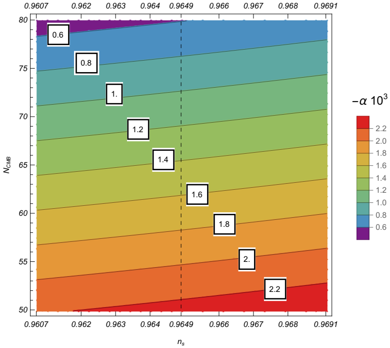

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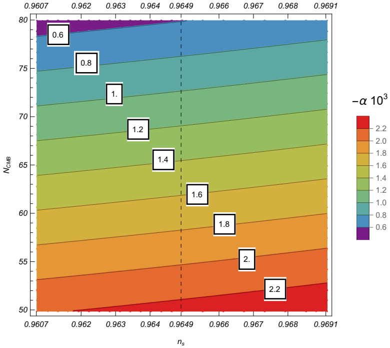

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- Question: What's the lower bound for ϕ_0?

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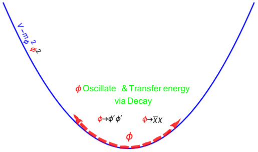

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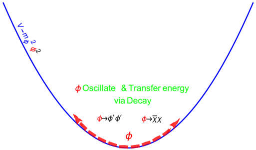

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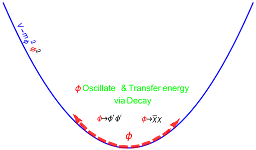

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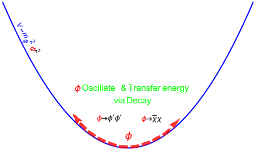

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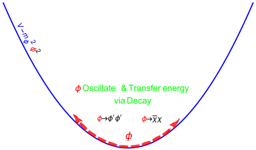

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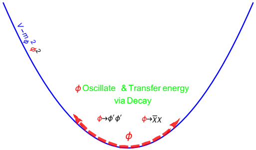

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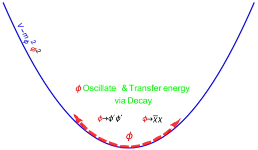

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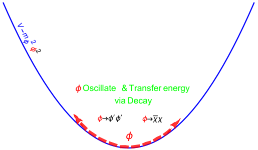

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  2. Though $m_{\phi'}^2 \sim g\phi$ ⇒ tachyonic resonance, still ok here, due to (sizeable) self-coupling $\lambda\phi'^4$ (⇒ back-reaction $m_{\phi'}^2 \sim \lambda\langle\phi'^2\rangle$); Pauli blocking for χ ⇒ Preheating not efficient here

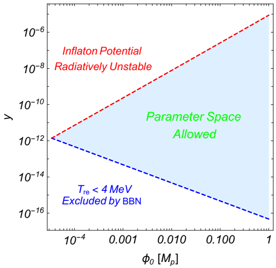
- Question: What are the upper bounds for the couplings? ⇒ Radiative stability

Radiative Stability $\Rightarrow$ Upper Bound

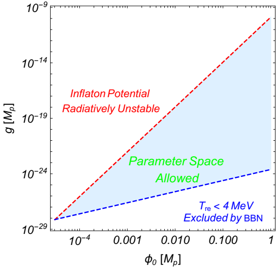
- Require:
  $\Delta V_{1-\mathrm{loop}}(\phi_0) \ll V(\phi_0)\,;\Delta V'(\phi_0) \ll V'(\phi_0)\,;\Delta V''(\phi_0) \ll V''(\phi_0)$, with

$$\Delta V_{1-\mathrm{loop}} = \frac{1}{64\pi^2}\sum_{\psi=\phi',\chi}(-1)^{2s_\psi}g_\psi\widetilde{m}_\psi(\phi)^4\left(\ln\left(\frac{\widetilde{m}_\psi(\phi)^2}{Q_0^2}\right)-\frac{3}{2}\right)$$

- Upper bounds for y (coupling $y\phi\bar{\chi}\chi$):
  $\left|\frac{y^4-3y^4\ln(y^2)}{4\pi^2}\right| < 16d\beta$



- Upper bounds for g (coupling $g\phi|\phi'|^2$):
  $\frac{g^2}{8\pi^2}\left|\ln\left(\frac{g}{\phi_0}\right)-1\right| < 8d\beta\phi_0^2$



- Radiative Stability + Reheating $\Rightarrow$ Lower bound $\phi_0 > 3\cdot 10^{-5} M_p$

Summary

- A simple polynomial model fits data very well:

$$V \equiv d\left[\phi^4 + A\,(1-\beta)\,\phi^3 + \frac{9}{32}A^2\phi^2\right]$$

with $A = -8/3\phi_0$; $\beta = 9.73 \times 10^{-7}\phi_0^4/M_p^4$; $d = 6.61 \times 10^{-16}\phi_0^2/M_p^2$.

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  1. $r \simeq 7.1\cdot10^{-9}\phi_0^6/M_p^6$ ☹
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    1. $m_\phi \simeq 5.1 \times 10^{-8}\phi_0^2/M_p$ ⇒ as light as $\mathcal{O}(100)$ GeV (EW scale);
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Thank you for your attention!