Loop Blow-up Inflation

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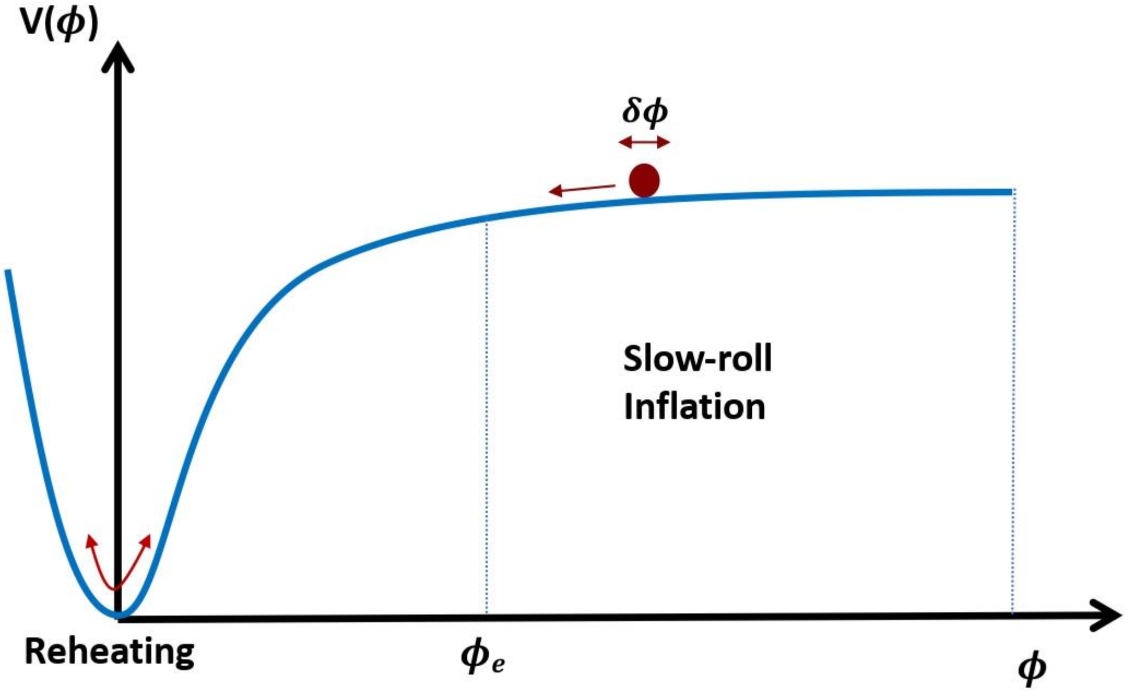
Based on:

S. Bansal, L. Brunelli, MC, A. Hebecker, R. Kuespert, 2403.04831

Standard slow-roll



$$V(\phi) = V_0[1 - g(\phi)] \simeq V_0$$ since $g(\phi) \ll 1$ for $\phi \gg 1$

Inflating with the Kaehler moduli

- Slow-roll picture with inflaton ϕ reproduced with type IIB Kaehler moduli
- Volume mode $\mathcal{V}$ couples to all sources of energy due to $e^K = \mathcal{V}^{-2}$

  → cannot have a ϕ-independent plateau if $\phi \equiv \mathcal{V}$

  → ϕ should be a direction $\perp \mathcal{V}$: $\phi \equiv \tau_\phi$

- Since each term in V depends on $\mathcal{V}$, $V(\phi) \simeq V_0$ only if leading dynamics fixes $\mathcal{V}$ but not τ_ϕ

  → $\phi \equiv \tau_\phi$ is a leading order flat direction with an approximate shift symmetry

  [Burgess,MC,Quevedo,Williams][Burgess,MC,deAlwis,Quevedo]

- Type IIB Kaehler sector: tree-level no-scale cancellation
  + 1-loop extended no-scale [MC,Conlon,Quevedo]

- Leading no-scale breaking effects lift only $\mathcal{V}$:

i) $V_{\alpha'^3}(\mathcal{V})$ from $O(\alpha'^3)$ effects [Becker,Becker,Haack,Louis]
ii) $V_{up}(\mathcal{V})$ from uplifting (anti-D3, T-branes, $F^{cs} \neq 0$, FI-terms,….)
iii) $V_{np}(\mathcal{V})$ from non-pert. effects on n_{dP} dP divisors (after integrating out the dP moduli)

→ LVS dS min with $(h^{1,1} - 1 - n_{dP})$ flat directions which can all be ϕ

→ ϕ lifted by subdominant quantum effects

Leading dynamics

- Total potential with 1 leading order flat direction τ_ϕ:

$$V_{tot}(\mathcal{V},\tau_\phi) = V_{lead}(\mathcal{V}) - V_{sub}(\mathcal{V},\tau_\phi) \qquad\qquad V_{sub}(\mathcal{V},\tau_\phi) \ll V_{lead}(\mathcal{V})$$

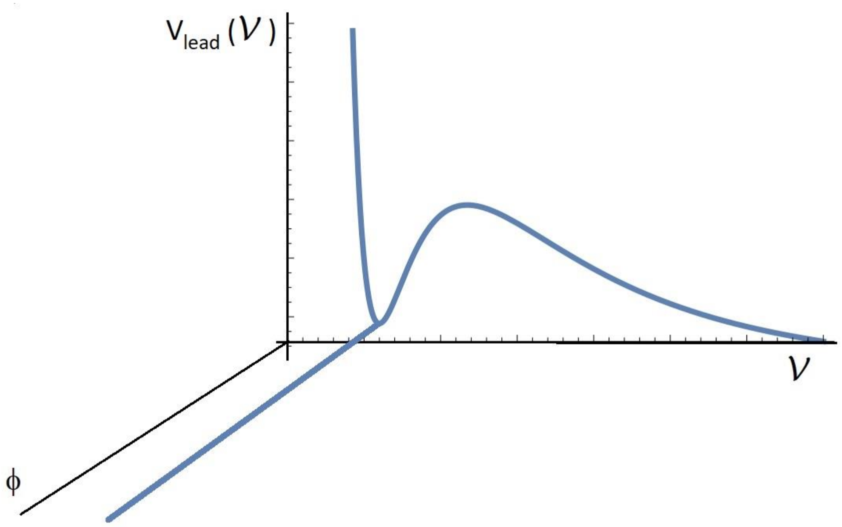
- Stabilisation:

$$\frac{\partial V_{lead}}{\partial \mathcal{V}}(\langle\mathcal{V}\rangle) = 0 \qquad \text{and} \qquad \frac{\partial V_{sub}}{\partial \tau_\phi}(\langle\mathcal{V}\rangle,\langle\tau_\phi\rangle) = 0$$

with:

$$V_{lead}(\langle\mathcal{V}\rangle) = V_{sub}(\langle\mathcal{V}\rangle,\langle\tau_\phi\rangle)$$

$$\longrightarrow \quad V_{tot}(\langle\mathcal{V}\rangle,\langle\tau_\phi\rangle) = 0$$



Subleading dynamics

- Setting $\mathcal{V} = \langle\mathcal{V}\rangle$, $V_{\rm tot}(\langle\mathcal{V}\rangle, \tau_\phi)$ becomes:

$$V(\phi) = V_0[1 - g(\phi)]$$

with:

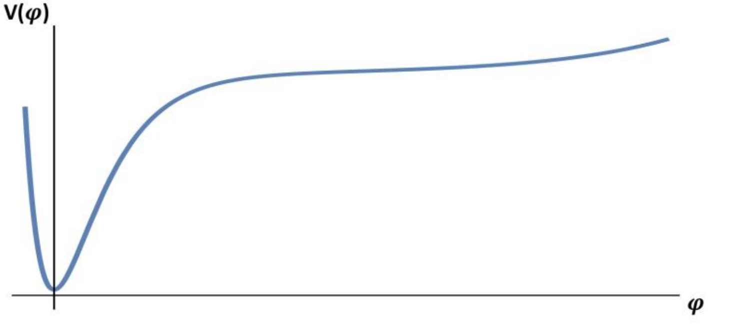
$$V_0 \equiv V_{\rm sub}(\langle\mathcal{V}\rangle, \langle\tau_\phi\rangle) \qquad \text{and} \qquad g(\phi) \equiv \frac{V_{\rm sub}\left(\langle\mathcal{V}\rangle, \tau_\phi(\phi)\right)}{V_{\rm sub}(\langle\mathcal{V}\rangle, \langle\tau_\phi\rangle)}$$

where $\tau_\phi(\phi)$ is determined by canonical normalisation

- Since τ_ϕ is a leading order flat direction

$$V_{\rm sub}(\langle\mathcal{V}\rangle, \tau_\phi) \ll V_{\rm sub}(\langle\mathcal{V}\rangle, \langle\tau_\phi\rangle) \qquad \text{for} \quad \tau_\phi > \langle\tau_\phi\rangle$$

$\longrightarrow$ $g(\phi) \ll 1 \quad \text{and} \quad V(\phi) \simeq V_0 \quad \text{for} \quad \phi \gg 1$



String inflation potentials

Function $g(\phi)$ depends on 2 features:

1. Origin of effects which generate $V_{\rm sub}(\langle\mathcal{V}\rangle, \tau_\phi)$:

- Perturbative effects:

$$V_{\rm sub}(\langle\mathcal{V}\rangle, \tau_\phi) \propto \frac{1}{\tau_\phi^p} \longrightarrow 0 \quad \text{for} \quad \tau_\phi \to \infty \quad \text{if} \quad p > 0$$

- Non-perturbative effects:

$$V_{\rm sub}(\langle\mathcal{V}\rangle, \tau_\phi) \propto {\rm e}^{-{\rm k}\tau_\phi} \longrightarrow 0 \quad \text{for} \quad \tau_\phi \to \infty \quad \text{if} \quad {\rm k} > 0$$

2. Topology of τ_ϕ which determines $\tau_\phi(\phi)$ (canonical normalisation):

- Bulk (fibre) modulus:

$$\tau_\phi = e^{\lambda\phi} \qquad \text{with} \qquad \lambda \sim \mathcal{O}(1)$$

- Local (blow-up) modulus:

$$\tau_\phi = \mu\,\mathcal{V}^{2/3}\,\phi^{4/3} \qquad \text{with} \qquad \mu \sim \mathcal{O}(1)$$

String inflation potentials

$$V(\phi) = V_0[1 - g(\phi)]$$

- Non-perturbative Blow-up Inflation: [Conlon,Quevedo][Bond,Kofman,Prokushkin,Vaudrevange]

$$g(\phi) \propto e^{-k\mu \mathcal{V}^{2/3} \phi^{4/3}} \ll 1 \qquad \text{for} \qquad \phi > 0$$

- Non-perturbative Fibre Inflation: [MC,Pedro,Tasinato][Luest,Zhang]

$$g(\phi) \propto e^{-k\, e^{\lambda\phi}} \ll 1 \qquad \text{for} \qquad \phi > 0$$

- Loop Fibre Inflation: [MC,Burgess,Quevedo][Broy,Ciupke,Pedro,Westphal][MC,Ciupke,deAlwis,Muia]

$$g(\phi) \propto e^{-p\lambda\phi} \ll 1 \qquad \text{for} \qquad \phi > 0$$

- Loop Blow-up Inflation: [Bansal,Brunelli,MC,Hebecker,Kuespert]

$$g(\phi) \propto \frac{1}{\mathcal{V}^{2p/3}\, \phi^{4p/3}} \ll 1 \qquad \text{for} \qquad \phi \lesssim 1$$

$$p = 1/2 \longrightarrow \boxed{V = V_0\left(1 - \frac{c}{\mathcal{V}^{1/3}\phi^{2/3}}\right)}$$

The model

- Type IIB compactification on CY with volume:

$$\mathcal{V} = \tau_b^{3/2} - \tau_s^{3/2} - \tau_\phi^{3/2} \simeq \tau_b^{3/2} \qquad\qquad T_i = \tau_i + i\vartheta_i$$

- Kaehler potential (tree-level + α'^3) and superpotential (tree-level + non-pert.):

$$K = -2\ln\left(\mathcal{V} - \frac{\xi}{2g_s^{3/2}}\right) \qquad\qquad W = W_0 + A_s\, e^{-a_s T_s} + A_\phi\, e^{-a_\phi T_\phi}$$

- Scalar potential:

$$V = V_{\text{lead}}(\mathcal{V}, \tau_s) + V_{\text{sub}}(\mathcal{V}, \tau_\phi)$$

$$V_{\text{lead}}(\mathcal{V}, \tau_s) = C_0\left[\frac{C_{up}}{\mathcal{V}^2} + C_s\,\frac{\sqrt{\tau_s}\, e^{-2a_s\tau_s}}{\mathcal{V}} - D_s\,\frac{\tau_s\, e^{-a_s\tau_s}}{\mathcal{V}^2} + \frac{3\xi}{4g_s^{3/2}\mathcal{V}^3}\right]$$

$$V_{\text{sub}}(\mathcal{V}, \tau_\phi) = C_0\left[C_\phi\,\frac{\sqrt{\tau_\phi}\, e^{-2a_\phi\tau_\phi}}{\mathcal{V}} - D_\phi\,\frac{\tau_\phi\, e^{-a_\phi\tau_\phi}}{\mathcal{V}^2}\right] \qquad\qquad a_s^{3/2} \ll a_\phi^{3/2}$$

- Minkowski mininum at:

$$\tau_s \sim (\xi/2)^{2/3} g_s^{-1} \qquad\qquad \mathcal{V} \sim e^{a_s\tau_s} \sim e^{a_\phi\tau_\phi}$$

Loop corrections

- 1-loop K computed only in toroidal orientifolds: [Berg,Haack,Koers]

$$\mathcal{V} = \sqrt{\tau_1 \tau_2 \tau_3} \qquad \qquad \delta K_{(g_s)} = \delta K_{(g_s)}^{KK} + \delta K_{(g_s)}^{W}$$

i) tree-level exchange of KK closed strings between parallel D7/O7s:

$$\delta K_{(g_s)}^{KK} = g_s \left(\frac{C_1^{KK}(U,\bar{U})}{\tau_1} + \frac{C_2^{KK}(U,\bar{U})}{\tau_2} + \frac{C_3^{KK}(U,\bar{U})}{\tau_3} \right)$$

ii) tree-level exchange of winding closed strings at D7 intersection:

$$\delta K_{(g_s)}^{W} = \frac{C_1^{W}(U,\bar{U})}{\tau_2 \tau_3} + \frac{C_2^{W}(U,\bar{U})}{\tau_1 \tau_3} + \frac{C_3^{W}(U,\bar{U})}{\tau_1 \tau_2}$$

- Closed string 1-loops (Klein bottle) cancel with some open string 1-loops (Moebius strip)

→ remain with just open string 1-loop correction to K
not necessarily true for CYs (with different brane setups)

- Conjecture for 1-loop K for CYs: [Berg,Haack,Pajer]

$$\delta K_{(g_s)}^{KK} = g_s \sum_i \frac{C_i^{KK}(U,\bar{U})\, t_i}{\mathcal{V}} = \frac{g_s}{\mathcal{V}} \sum_i C_i^{KK}(U,\bar{U})\, M_{KK,i}^{-2}$$

→ Extended no-scale cancellation in V [MC,Conlon,Quevedo]

$$\delta K_{(g_s)}^{W} = \sum_i \frac{C_i^{W}(U,\bar{U})}{\mathcal{V}\, t_i} = \frac{1}{\mathcal{V}} \sum_i C_i^{W}(U,\bar{U})\, M_{W,i}^{-2}$$

Loop corrections from 4D

- 1-loop K yields corrections to kinetic terms and V

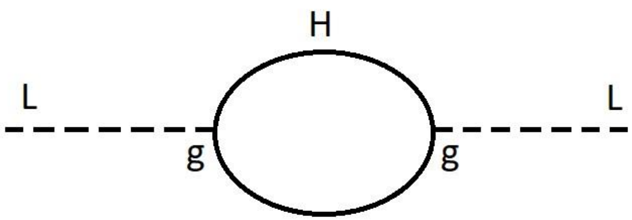
→ field theory interpretation [von Gersdorff,Hebecker][MC,Conlon,Quevedo][Gao,Hebecker,Schreyer,Venken]

- Heavy mode H coupled to a light mode L

$$\mathcal{L} \supset M^2 H^2 + g\, L\, H^2$$

- 2-point function 1-loop renormalisation:

$$\mathcal{L}_{kin} = \left[1 + c_{\rm loop}\left(\frac{g}{M}\right)^2\right]\partial_\mu L \partial^\mu L \qquad c_{\rm loop} \simeq \frac{1}{16\pi^2}$$



- Compute coupling g:

$$M^2(\tau)\, H^2 \simeq M^2\, H^2 + \left.\frac{\partial M^2}{\partial \tau}\right|_{\langle\tau\rangle} \hat{\tau}\, H^2 \simeq M^2\, H^2 + M^2\,\frac{\hat{\tau}}{\langle\tau\rangle}\, H^2 \qquad M^2 \equiv M^2(\langle\tau\rangle)$$

$$\frac{\hat{\tau}}{\langle\tau\rangle} \simeq \frac{L}{M_p} \qquad \Rightarrow \qquad g \simeq \frac{M^2}{M_p}$$

- 1-loop correction to K:

$$\mathcal{L}_{kin} = \left[1 + c_{\rm loop}\left(\frac{M}{M_p}\right)^2\right]\partial_\mu L \partial^\mu L \simeq \left[1 + c_{\rm loop}\left(\frac{M}{M_p}\right)^2\right]\frac{\partial_\mu \hat{\tau}\partial^\mu \hat{\tau}}{\langle\tau\rangle^2} = (K_{\tau\tau} + \delta K_{\tau\tau})\, \partial_\mu \hat{\tau}\partial^\mu \hat{\tau}$$

→ $$K_{\tau\tau} \simeq \frac{1}{\tau^2} \qquad \delta K_{\tau\tau} \simeq \frac{c_{\rm loop}}{\tau^2}\left(\frac{M}{M_p}\right)^2 \qquad \Rightarrow \qquad K = -3\ln\tau \qquad \boxed{\delta K \simeq c_{\rm loop}\left(\frac{M}{M_p}\right)^2}$$

Loop corrections from 4D

$$\delta K \simeq c_{\text{loop}} \left(\frac{M}{M_p} \right)^2$$

- If H = massive string state:

$$M \equiv M_s \simeq \frac{M_p}{\sqrt{\mathcal{V}}} \quad \Rightarrow \quad \delta K \simeq \frac{c_{\text{loop}}}{\mathcal{V}}$$

matches scaling of $\delta K_{\alpha'^3}$ [Becker,Becker,Haack,Louis]

no dependence on τ_ϕ → irrelevant for inflation

- If H = winding mode:

$$M \equiv M_W \simeq M_s \tau^{1/4} \simeq \frac{M_p}{\sqrt{\mathcal{V}}} \tau^{1/4} \quad \Rightarrow \quad \delta K \simeq c_{\text{loop}} \frac{\sqrt{\tau}}{\mathcal{V}}$$

matches scaling of $\delta K_{(g_s)}^{KK}$ [Berg,Haack,Pajer]

→ $\delta K_{(g_s)}^{KK}$ = tree-level KK closed strings = 1-loop winding open strings

extended no-scale suppresses contribution to V → irrelevant for inflation

- If H = Kaluza-Klein mode:

$$M \equiv M_{KK} \simeq \frac{M_s}{\tau^{1/4}} \simeq \frac{M_p}{\sqrt{\mathcal{V}}\, \tau^{1/4}} \quad \Rightarrow \quad \delta K \simeq \frac{c_{\text{loop}}}{\mathcal{V}\sqrt{\tau}}$$

matches scaling of $\delta K_{(g_s)}^{W}$ [Berg,Haack,Pajer]

→ $\delta K_{(g_s)}^{W}$ = tree-level winding closed strings = 1-loop KK open strings

if $\tau = \tau_\phi \quad \delta K \simeq \dfrac{c_{\text{loop}}}{\mathcal{V}\sqrt{\tau_\phi}} \quad \Rightarrow \quad \boxed{\delta V \simeq \dfrac{c_{\text{loop}}}{\mathcal{V}^3\sqrt{\tau_\phi}}}$ leading correction to V → crucial for inflation

Loop corrections from 4D

- 1-loop K from KK modes in loop should match 1-loop Coleman-Weinberg potential:

$$V^{CW}_{1\text{-loop}} \simeq \frac{1}{16\pi^2}\,\Lambda^2\,\mathrm{Str}\,M^2$$

[MC,Conlon,Quevedo]

- Supertrace in supergravity:

$$\mathrm{Str}\,M^2 \simeq m^2_{3/2} \simeq \frac{M_p^2}{\mathcal{V}^2}$$

- Cut-off Λ given by KK mass of open strings on D7s

i) D7s on τ_b: $\Lambda \simeq \frac{M_p}{\mathcal{V}^{2/3}}$

$$\delta V_{(g_s)} \simeq \frac{c_{\rm loop}}{\mathcal{V}^{10/3}}$$

no dependence on τ_ϕ → irrelevant for inflation

ii) D7s on τ_ϕ: $\Lambda \simeq \frac{M_p}{\tau_\phi^{1/4}\sqrt{\mathcal{V}}}$

$$\delta V_{(g_s)} \simeq \frac{c_{\rm loop}}{\mathcal{V}^3\sqrt{\tau_\phi}}$$

same τ_ϕ dependence as from 1-loop 2-pt function

- If there is no D7 on τ_ϕ, can still have KK modes of τ_ϕ (closed strings) in loop
- τ_ϕ and its KK modes are localised around blow-up mode → again $\Lambda \simeq \frac{M_p}{\tau_\phi^{1/4}\sqrt{\mathcal{V}}}$

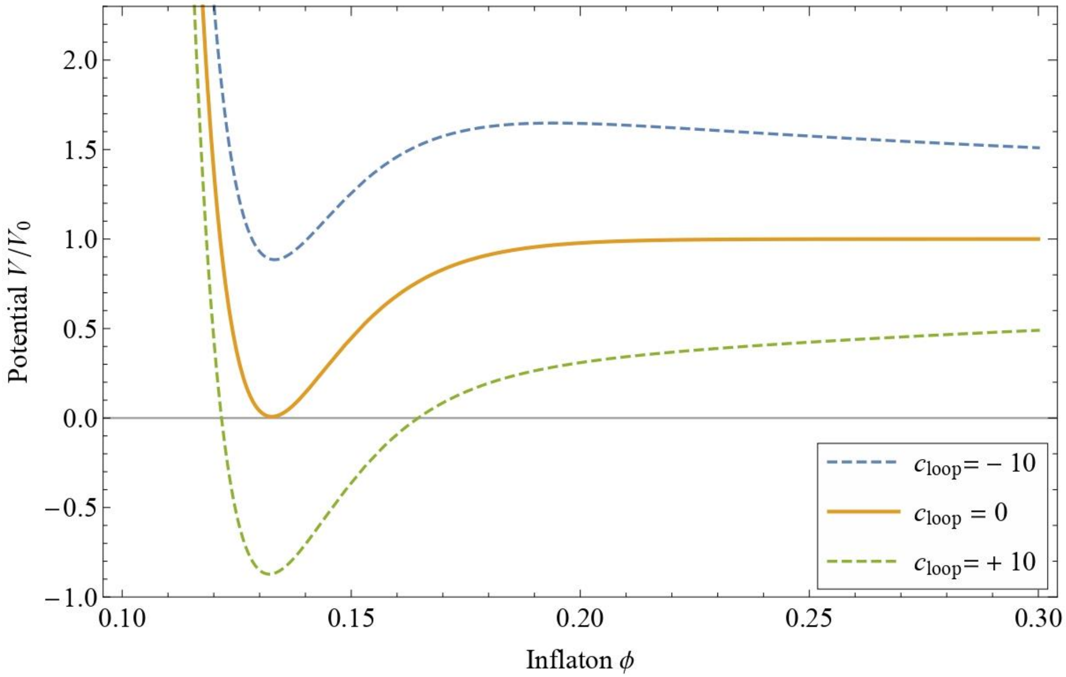
→ τ_ϕ-dependent loop corrections to V are unavoidable

Inflaton potential

- Total potential including loops:

$$V(\tau_\phi) = C_0\left[\frac{\beta}{\mathcal{V}^3} + C_\phi\,\frac{\sqrt{\tau_\phi}\,e^{-2a_\phi\tau_\phi}}{\mathcal{V}} - D_\phi\,\frac{\tau_\phi\,e^{-a_\phi\tau_\phi}}{\mathcal{V}^2} - \frac{c_{\rm loop}}{\mathcal{V}^3\sqrt{\tau_\phi}}\right] \qquad \phi = \sqrt{\frac{4}{3\mathcal{V}}}\,\tau_\phi^{3/4}$$

Fixed parameters: $\mathcal{V} = 1000$, $C_\phi = D_\phi = a_\phi = \beta = 1$



- Non-perturbative blow-up inflation requires $c_{\rm loop} \ll 10^{-6}$
- For $c_{\rm loop} \gtrsim 10^{-6}$ potential in inflationary region is:

$$V \simeq C_0\left(\frac{\beta}{\mathcal{V}^3} - \frac{c_{\rm loop}}{\mathcal{V}^3\sqrt{\tau_\phi}}\right) = V_0\left(1 - \frac{b\,c_{\rm loop}}{\mathcal{V}^{1/3}\phi^{4/3}}\right) \qquad V_0 \equiv C_0\,\frac{\beta}{\mathcal{V}^3} \qquad b \equiv \frac{1}{\beta}\left(\frac{4}{3}\right)^{1/3}$$

Inflationary dynamics

- Slow-roll parameters:

$$\epsilon = \frac{1}{2}\left(\frac{V_\phi}{V}\right)^2 \simeq \frac{2}{9}\frac{\left(b\, c_{\text{loop}}\right)^2}{\mathcal{V}^{2/3}\phi^{10/3}}$$

$$\eta = \frac{V_{\phi\phi}}{V} \simeq -\frac{10}{9}\frac{b\, c_{\text{loop}}}{\mathcal{V}^{1/3}\phi^{8/3}}$$

- Cosmological observables:

$$N_{\text{e}} = \int_{\phi_{\text{end}}}^{\phi_*} \frac{\text{V}}{\text{V}_\phi}\, \text{d}\phi \simeq \frac{9}{16}\frac{\mathcal{V}^{1/3}\phi_*^{8/3}}{b\, c_{\text{loop}}}$$

$$\hat{A}_s = \frac{9V_0}{4}\frac{\mathcal{V}^{2/3}\phi_*^{10/3}}{\left(b\, c_{\text{loop}}\right)^2} \simeq 2.5 \times 10^{-7}$$

$$\phi_* = 0.06\, N_e^{7/22}$$

$$\mathcal{V} = 1743\, N_e^{5/11}$$

$$n_s = 1 + 2\,\eta - 6\,\epsilon \simeq 1 - \frac{20}{9}\frac{b\, c_{\text{loop}}}{\mathcal{V}^{1/3}\phi_*^{8/3}}$$

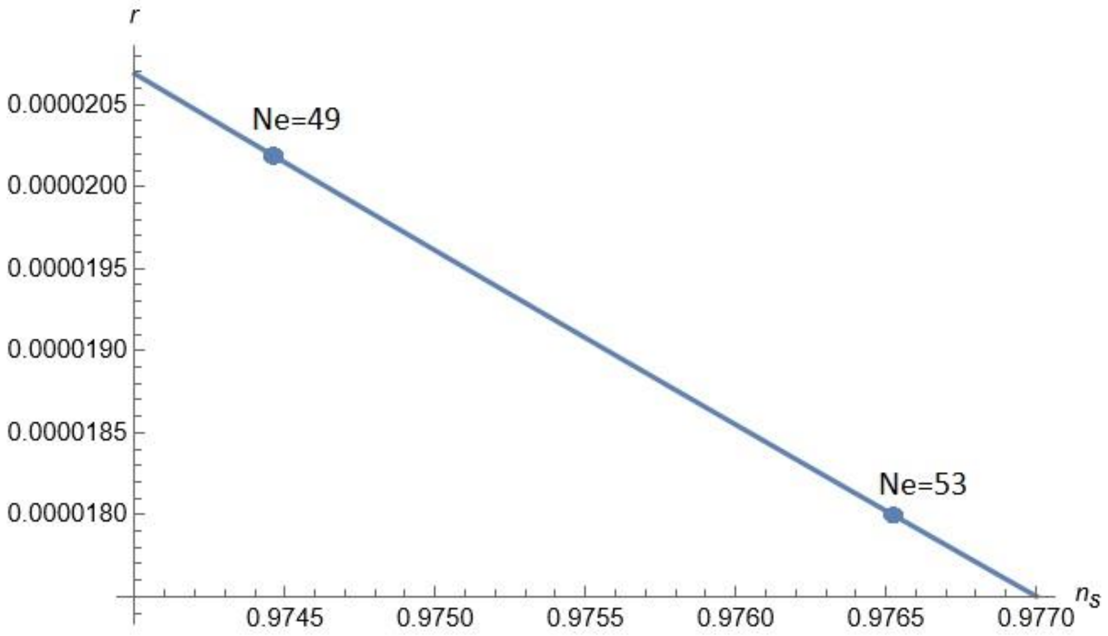
$$r = 16\,\epsilon \simeq \frac{32}{9}\frac{\left(b\, c_{\text{loop}}\right)^2}{\mathcal{V}^{2/3}\phi_*^{10/3}}$$

$$n_s \simeq 1 - \frac{1.25}{N_e} \qquad r \simeq \frac{0.004}{N_e^{15/11}}$$

$$\rightarrow \quad \boxed{r \simeq 0.003(1 - n_s)^{15/11}}$$

Cosmological predictions

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



for $49 \lesssim N_e \lesssim 53$ n_s in agreement with CMB data $r \simeq 2 \times 10^{-5}$

determined by post-inflationary evolution

Control over EFT

- Values of microscopic parameters:

for $49 \lesssim N_e \lesssim 53$ $\mathcal{V} = 1743\, N_e^{5/11} \sim \mathcal{O}(10^4)$ $\phi_* = 0.06\, N_e^{7/22} \sim \mathcal{O}(0.2)$

- Canonical normalisation: $\phi \simeq \tau_\phi^{3/4}/\sqrt{\mathcal{V}}$

$\phi \sim \mathcal{O}(0.2)$ implies $\tau_\phi \lesssim \tau_b$ ⟶ can have inflation within Kaehler cone?

- Check in an explicit CY example from [MC,Krippendorf,Mayrhofer,Quevedo,Valandro]:

$$\mathcal{V} = \frac{1}{9}\sqrt{\frac{2}{3}}\left(\tau_b^{3/2} - \sqrt{3}\,\tau_s^{3/2} - \sqrt{3}\,\tau_\phi^{3/2}\right) \qquad \tau_b = \frac{27}{2}\,t_b^2 \qquad \tau_s = \frac{9}{2}\,t_s^2 \qquad \tau_\phi = \frac{9}{2}\,t_\phi^2$$

- Kaehler cone conditions:

$$t_b + t_s > 0 \qquad t_b + t_\phi > 0 \qquad t_s < 0 \qquad t_\phi < 0$$

- From canonical normalisation:

$$\tau_\phi = \left(\frac{\sqrt{3}}{4}\right)^{2/3} \mathcal{V}^{2/3}\phi^{4/3} \simeq \left(\frac{1}{18\sqrt{2}}\right)^{2/3} \tau_b\, \phi^{4/3}$$

- At horizon exit:

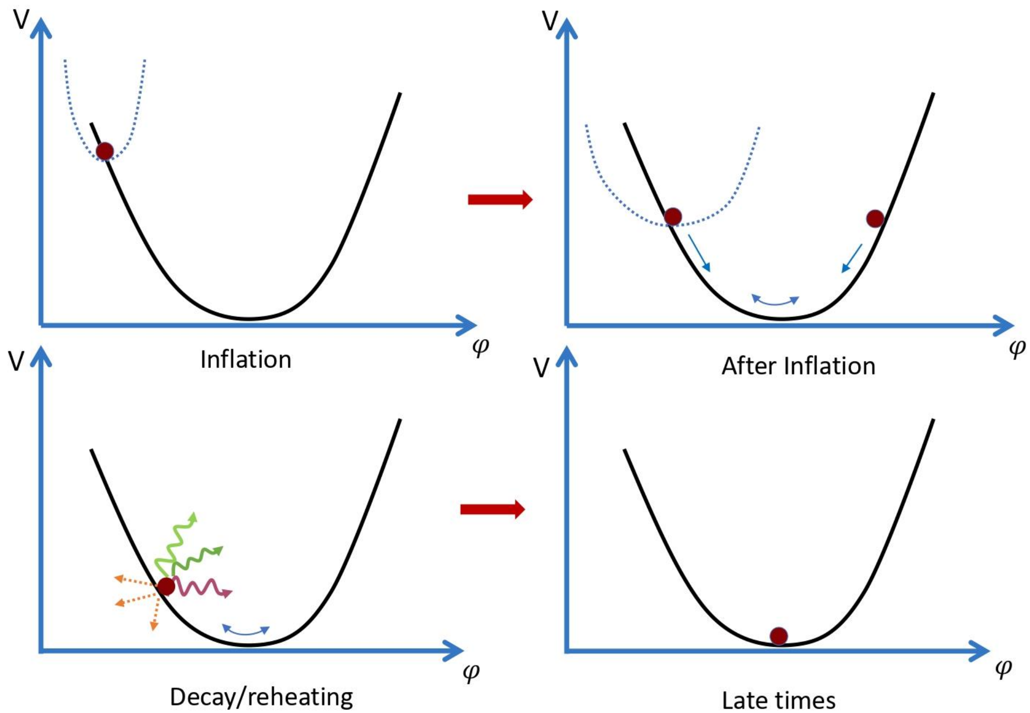
$$\frac{|t_\phi|}{t_b} = \left(\frac{1}{2\sqrt{6}}\right)^{1/3} \phi^{2/3} \simeq 0.6\,\phi^{2/3} \simeq 0.2 \quad \text{for} \quad \phi \simeq 0.2$$

well inside Kaehler cone!

N_e from post-inflation

$$N_e \simeq 57 + \frac{1}{4}\ln r - \frac{1}{4}N_\phi - \frac{1}{4}N_\chi + \frac{1}{4}\ln\left(\frac{\rho_*}{\rho(t_{\rm end})}\right)$$

τ_ϕ domin. $\quad$ $\mathcal{V}$ domin.



$\varphi \equiv \tau_\phi$ or $\mathcal{V}$

φ

$\Gamma_{\varphi\to SM}$ $\quad$ $\Gamma_{\varphi\to \vartheta_b\vartheta_b}$

SM dof $\quad$ τ_b axions → $\Delta N_{\rm eff} \neq 0$

$\Delta N_{\rm eff} \lesssim 0.2 - 0.5$ at 95% CL

SM realisation

- SM D7s cannot wrap τ_s due to tension between non-pert effects and chirality [Blumenhagen,Moster,Plauschinn]
- SM D7s cannot wrap τ_ϕ since τ_ϕ-dependent FI-term would make τ_ϕ too heavy

  → need to introduce 2 additional intersecting blow-ups τ_{SM} and τ_{int}

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

- D-term stabilisation:

$$\xi_{FI} = 0 \quad \Leftrightarrow \quad \tau_{SM} = \lambda^2(\tau_{int} - \tau_{SM})$$

i) if $\lambda = 0$, $\tau_{SM} \to 0$ → SM on D3-branes at a CY singularity

ii) if $\lambda \neq 0$, $\xi_{FI} = 0$ fixes τ_{int} in terms of τ_{SM} and τ_{SM} remains as a flat direction fixed by loops

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

[MC,Mayrhofer,Valandro]

→ $$\tau_s = \left(1 + \sqrt{\frac{g_{loop}}{d_{loop}}}\right)^2 \tau_{SM} \sim \tau_{SM} \sim \mathcal{O}(10) \simeq g_{SM}^{-2}$$

→ SM on D7-branes wrapped around τ_{SM}

Volume decay rates

- Masses of canonically normalised moduli: τ_ϕ becomes ϕ and $\mathcal{V}$ becomes χ

$$m_\phi \simeq \frac{W_0 \ln \mathcal{V}}{\mathcal{V}} M_p \qquad \text{and} \qquad m_\chi \simeq \frac{W_0}{\mathcal{V}^{3/2}\sqrt{\ln \mathcal{V}}} M_p$$

- Volume χ:

i) decay into closed string axions ϑ_b

$$\Gamma_{\chi\to\vartheta_b\vartheta_b} = \frac{1}{48\pi}\frac{m_\chi^3}{M_p^2}$$

ii) decay into MSSM Higgses H_u and H_d

$$\Gamma_{\chi\to H_u H_d} = \frac{Z^2}{24\pi}\frac{m_\chi^3}{M_p^2} = 2Z^2\,\Gamma_{\chi\to\vartheta_b\vartheta_b}$$

iii) decay into SM Higgses h

$$\Gamma_{\chi\to hh} = \frac{c_{\text{loop}}^2}{32\pi}\left(\frac{m_0}{m_\chi}\right)^4 \frac{m_\chi^3}{M_p^2}$$

$$\longrightarrow \quad \frac{\Gamma_{\chi\to hh}}{\Gamma_{\chi\to\vartheta_b\vartheta_b}} \simeq c_{\text{loop}}^2\left(\frac{m_0}{m_\chi}\right)^4$$

SM on D7s: $\quad m_0 \simeq \frac{M_p}{\mathcal{V}} \gg m_\chi \qquad \frac{\Gamma_{\chi\to hh}}{\Gamma_{\chi\to\vartheta_b\vartheta_b}} \simeq \left(c_{\text{loop}}\mathcal{V}\right)^2 \gg 1$

$\longrightarrow$ χ decays into SM Higgses h

SM on D3s: $\quad m_0 \lesssim m_\chi \qquad \frac{\Gamma_{\chi\to hh}}{\Gamma_{\chi\to\vartheta_b\vartheta_b}} \lesssim c_{\text{loop}}^2 \ll 1$

$\longrightarrow$ χ decays into ϑ_b axions, H_u and H_d

Inflaton decay rates

- Inflaton wrapped by hidden D7s:

decay into hidden gauge bosons γ_h

$$\Gamma_{\phi\to\gamma_h\gamma_h} \simeq \frac{\mathcal{V}}{64\pi}\frac{m_\phi^3}{M_p^2}$$

- Inflaton not wrapped by any D7:

i) decay into volume moduli χ and ϑ_b axions

$$\Gamma_{\phi\to\chi\chi} \simeq \Gamma_{\phi\to\vartheta_b\vartheta_b} \simeq \frac{(\ln\mathcal{V})^{3/2}}{64\pi\,\mathcal{V}}\frac{m_\phi^3}{M_p^2}$$

SM on D7s: χ then decays istantaneously into h h

SM on D3s: χ then decays later on into H_u and H_d, and ϑ_b ϑ_b

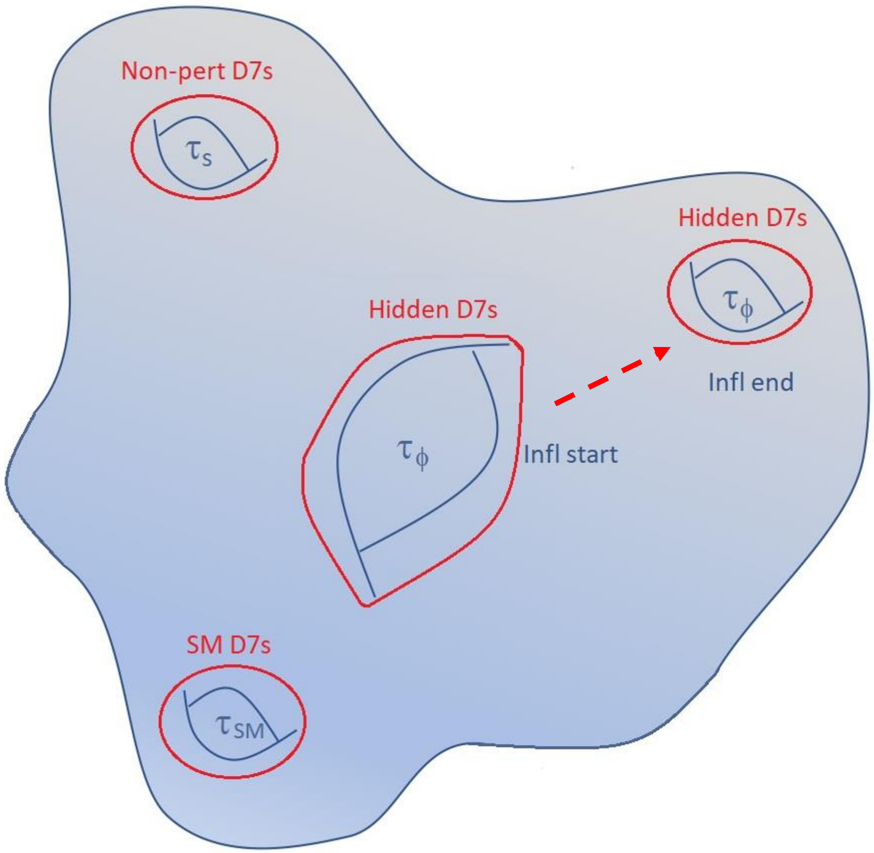
ii) for SM on D7s, extra decays into SM gauge bosons γ, τ_{SM} moduli and ϑ_{SM} (QCD) axions

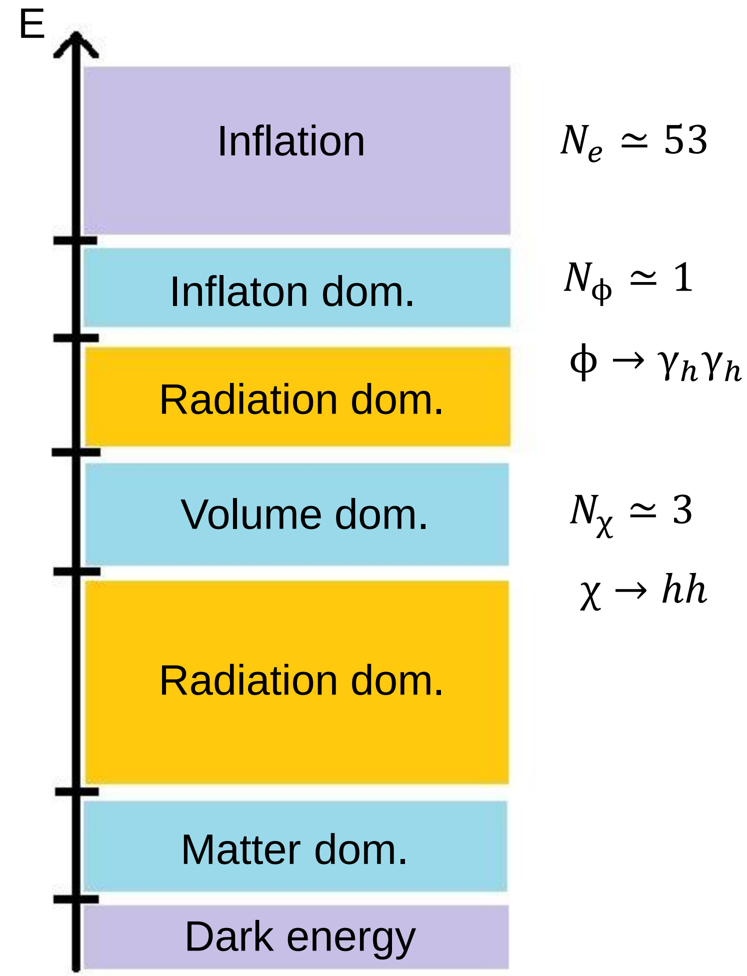
$$\Gamma_{\phi\to\tau_{SM}\tau_{SM}} \simeq \Gamma_{\phi\to\vartheta_{SM}\vartheta_{SM}} \simeq \Gamma_{\phi\to\chi\chi} \qquad \Gamma_{\phi\to\gamma\gamma} \simeq N_g\,\Gamma_{\phi\to\chi\chi} \simeq 12\,\Gamma_{\phi\to\chi\chi}$$

τ_{SM} then decays istantaneosuly into γ γ, and ϑ_{SM} ϑ_{SM} with [MC,Hebecker,Jaeckel,Wittner]

$$\frac{\Gamma_{\tau_{SM}\to\gamma\gamma}}{\Gamma_{\tau_{SM}\to\vartheta_{SM}\vartheta_{SM}}} = 8\,N_g \geq 96 \gg 1$$

SM on D7s and inflaton wrapped by D7s

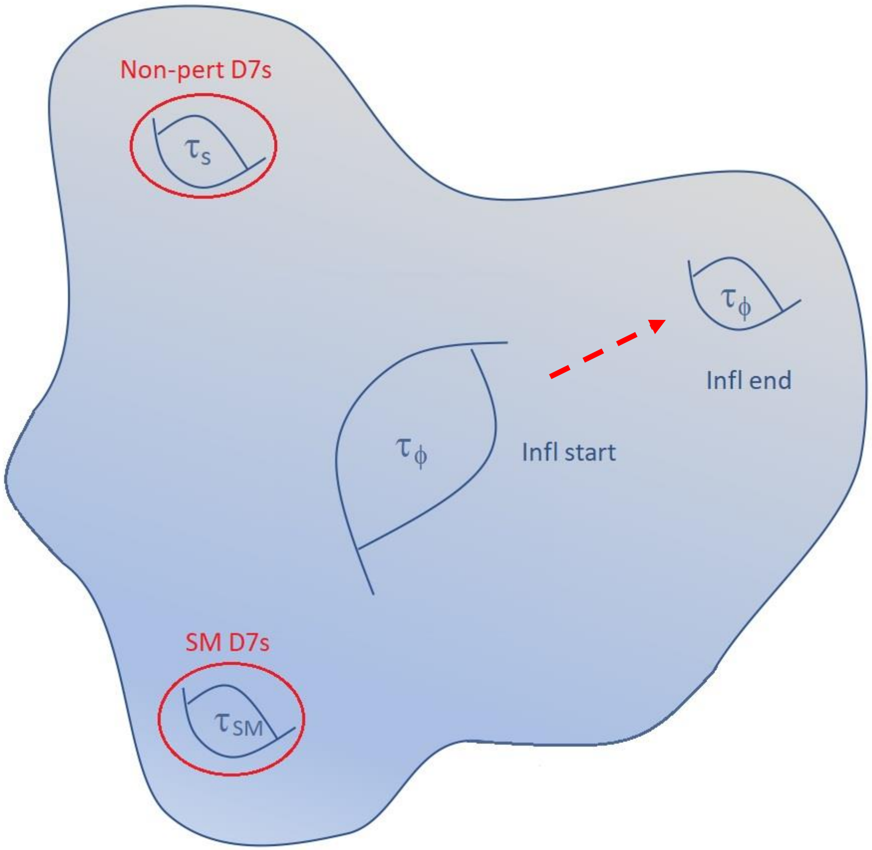


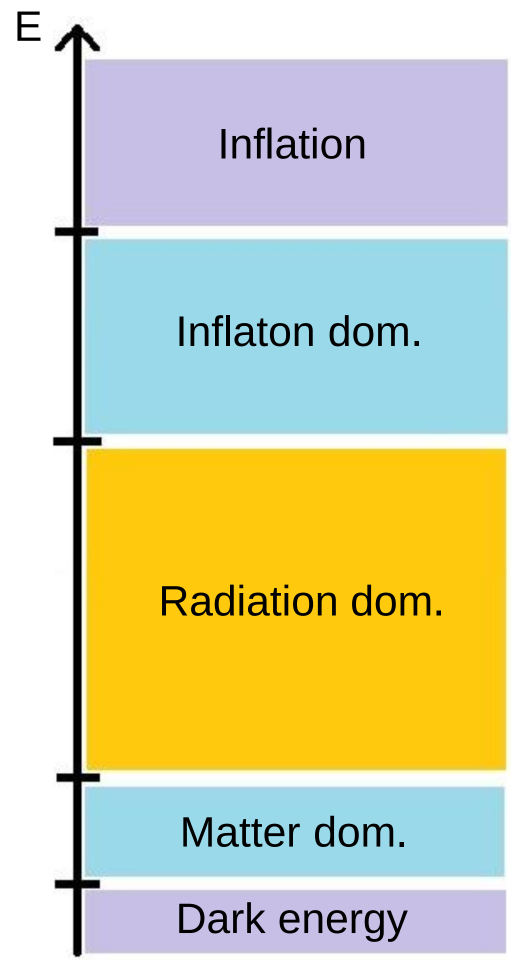


Predictions:

$n_s \simeq 0.9765$ $r \simeq 1.7 \times 10^{-5}$ $T_{\rm rh} \simeq 4 \times 10^{10}\ {\rm GeV}$ $\Delta N_{\rm eff} \simeq 0$

SM on D7s and unwrapped inflaton





$N_e \simeq 52$

$N_\phi \simeq 8$

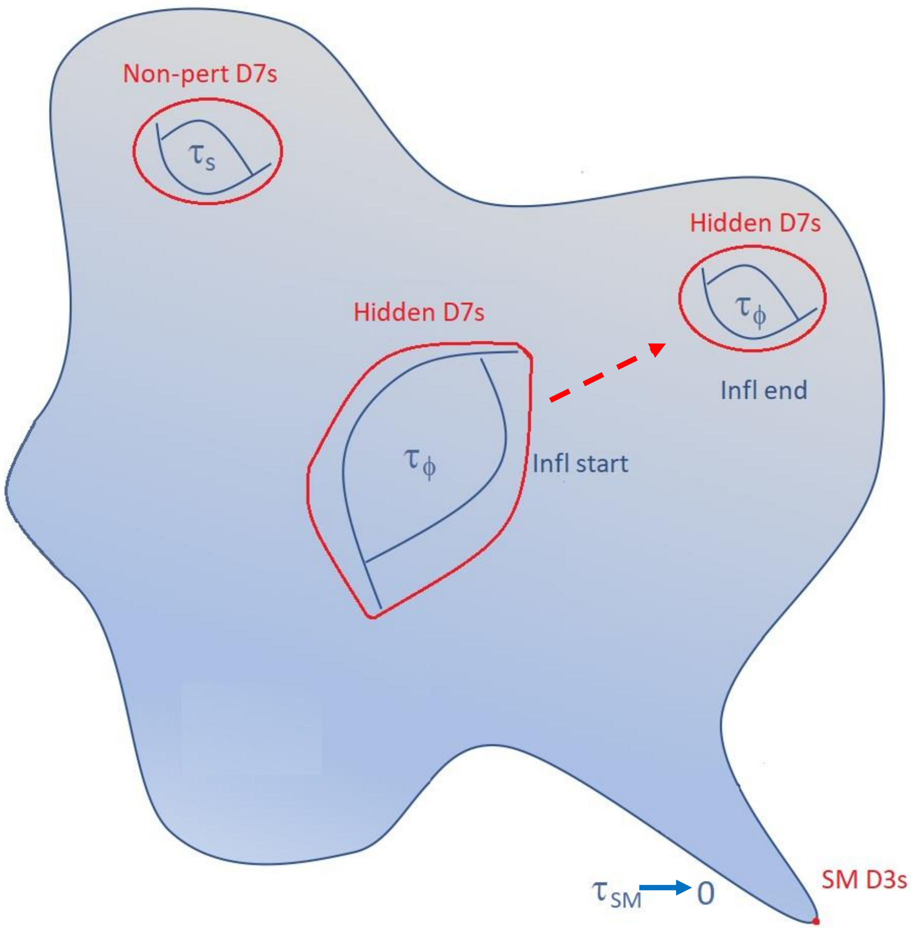
$\phi \to \gamma\gamma$

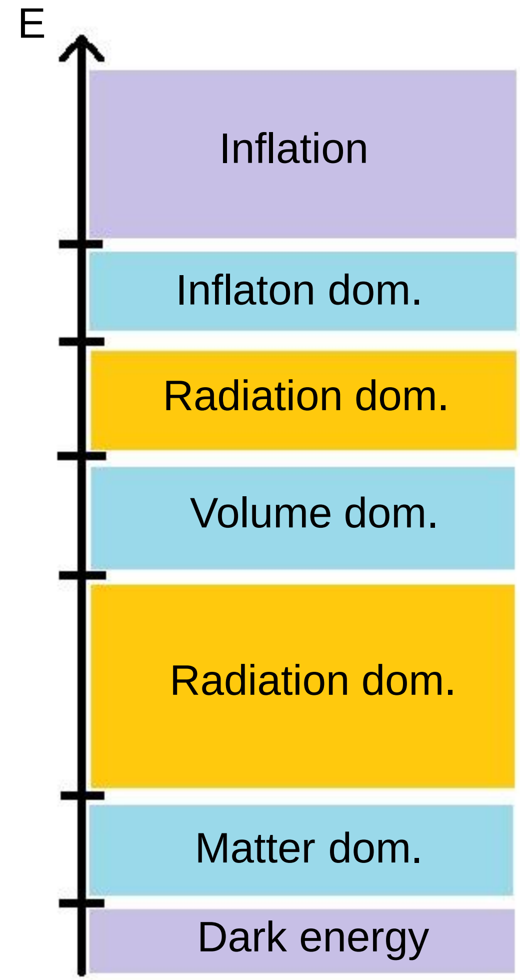
$N_\chi = 0$

Predictions:

$n_s \simeq 0.9761$ $\quad r \simeq 1.7 \times 10^{-5}$ $\quad T_{\rm rh} \simeq 3 \times 10^{12}\,\text{GeV}$ $\quad \Delta N_{\rm eff} \simeq 0.14$

SM on D3s and inflaton wrapped by D7s





$N_e \simeq 51.5$

$N_\phi \simeq 1$

$\phi \to \gamma_h \gamma_h$

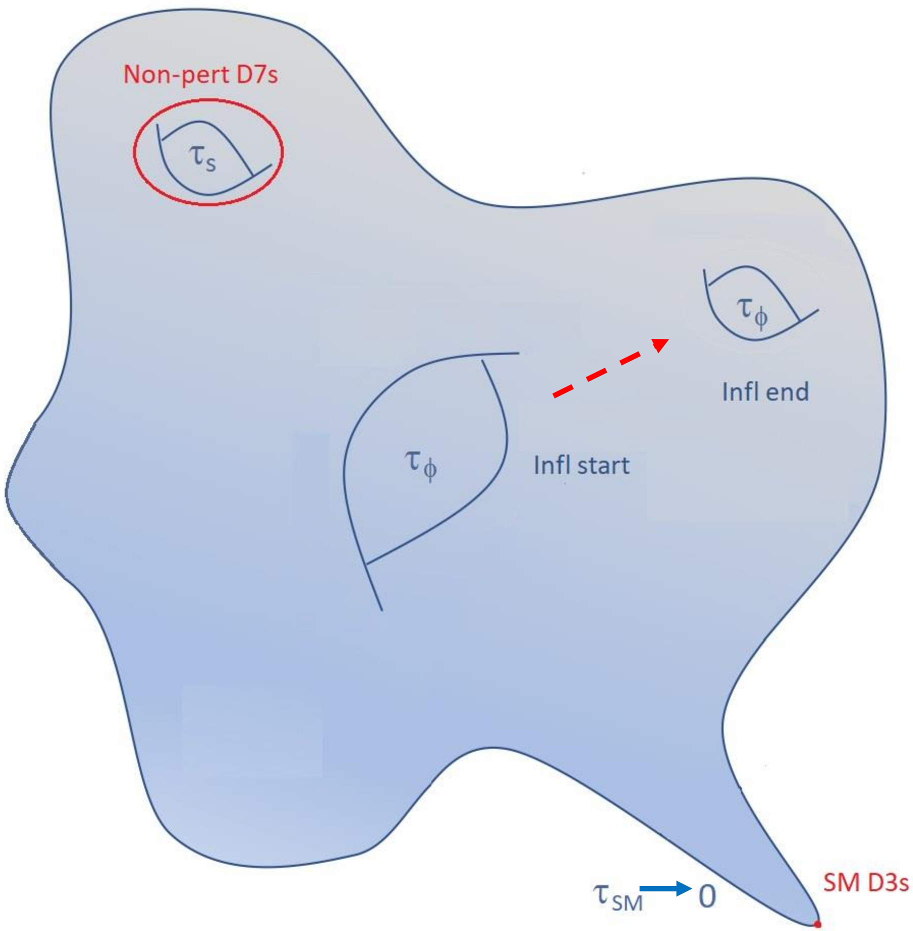
$N_\chi \simeq 10.5$

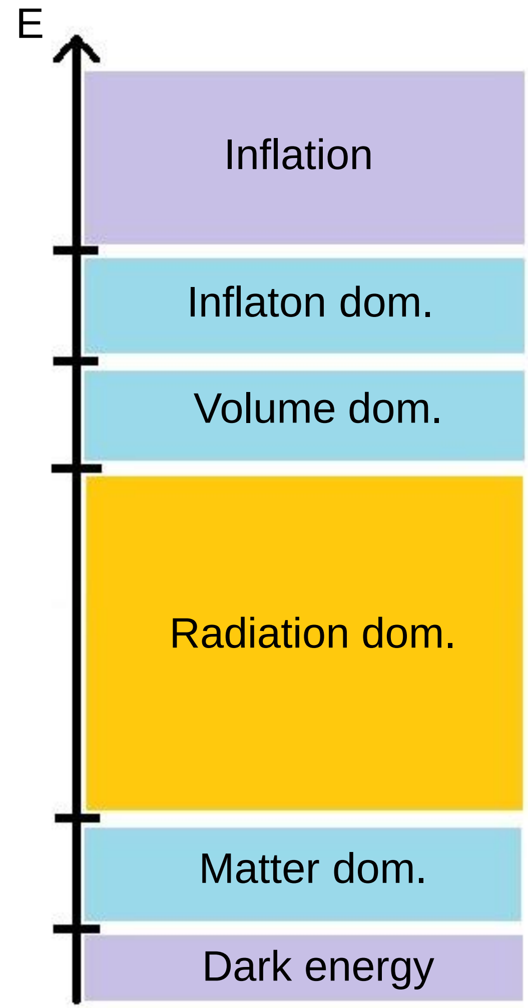
$\chi \to H_u H_d, \vartheta_b \vartheta_b$

Predictions:

$n_s \simeq 0.9757$ $\quad r \simeq 1.8 \times 10^{-5}$ $\quad T_{\rm rh} \simeq 1 \times 10^8\ {\rm GeV}$ $\quad \Delta N_{\rm eff} \simeq \frac{1.43}{Z^2} \simeq 0.36 \quad Z = 2$

SM on D3s and unwrapped inflaton





$N_e \simeq 49$

$N_\phi \simeq 11$

$\phi \to \chi\chi, \vartheta_b\vartheta_b$

$T_{\text{dec},\phi} < m_\chi$

$N_\chi \simeq 10.5$

$\chi \to H_u H_d, \vartheta_b\vartheta_b$

Predictions:

$n_s \simeq 0.9744$ $\quad r \simeq 1.9 \times 10^{-5}$ $\quad T_{\text{rh}} \simeq 2 \times 10^8\ \text{GeV}$ $\quad \Delta N_{\text{eff}} \simeq \frac{1.43}{Z^2} \simeq 0.36 \quad Z = 2$

Summary

- Type IIB Kaehler moduli $\perp \mathcal{V}$ are good inflatons ϕ due to approximate shift symmetries
- $V(\phi)$ determined by nature of breaking effects (pert/non-pert.) and topology (bulk/local cycle)

  → can have several scenarios
- New model: Loop Blow-up Inflation
- Inflation driven by a blow-up mode with $V(\phi)$ generated by 1-loop corrections to K
- 1-loop K: conjecture from toroidal computation

  + field theory matching with 1-loop 2-point function and Coleman-Weinberg potential
- Inflaton potential:

$$V(\phi) = V_0\left(1 - \frac{c}{\mathcal{V}^{1/3}\phi^{2/3}}\right)$$

- EFT under control with inflation inside Kaehler cone
- Microscopic parameters: $\mathcal{V} \sim \mathcal{O}(10^4)$ and $\phi_* \sim \mathcal{O}(0.2)$
- Predictions: $0.9744 \lesssim n_s \lesssim 0.9765$ and $r \simeq 2 \times 10^{-5}$
- Post-inflation with moduli domination and reheating from moduli decay
- Depending on SM realisation: $49 \lesssim N_{\rm e} \lesssim 53$ and $0 \lesssim \Delta N_{\rm eff} \lesssim 0.36$