Higgs – Modular Inflation

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1. Introduction

○ Higgs Inflation (HI)

- simple and successful inflation model

○ Modular Inflation (MI)

- favored by string compactifications

○ Our approach

- Higgs charged under modular symmetry
  (motivated by string compactifications)
- introducing modular symmetry into HI

2. Model Setup

○ Modular symmetry : SL(2,$\mathbb{Z}$)

$$\tau \to \gamma\tau = \frac{p\tau + q}{r\tau + s} \qquad \gamma = \begin{pmatrix} p & q \\ t & s \end{pmatrix} \in SL(2,\mathbb{Z})$$

$$H \to (r\tau + s)^{-k_H}\rho(\gamma)H$$

k_H : modular weight

$\rho(\gamma)$: representation

○ Lagrangian

$$\frac{L_J}{\sqrt{-g_J}} = \left[\frac{1}{2} + \xi\frac{|H|^2}{(2\mathrm{Im}\tau)^{k_H}}\right]R_J - \frac{|D_\mu H|^2}{(2\mathrm{Im}\tau)^{k_H}} - \frac{|\partial_\mu\tau|^2}{(2a\mathrm{Im}\tau)^2} - \lambda\frac{|H|^4}{(2\mathrm{Im}\tau)^{2k_H}} - V_J(\tau,\bar{\tau})$$

$$D_\mu = \partial_\mu + \frac{i\pi k_H}{6}E_2(\tau)\partial_\mu\tau \qquad V_J(\tau,\bar{\tau}) \simeq V_0\left(1 - \frac{c}{\mathrm{Im}\tau}\right)^2$$

E_2 : Eisenstein series

[Ref] arXiv : 2407.12081

3. Inflationary analysis

○ Effective single-field Lagrangian

Extremum condition

$$\partial_h V_E = 0 \quad \Longrightarrow \quad h^2 \simeq 4\xi(2\tau_2)^{k_H}\lambda^{-1}V_J$$

$$\frac{L_{\mathrm{eff}}}{\sqrt{-g}} = -\frac{1}{2}\frac{\lambda + 4a^2k_H^2\xi V_J\left(1 - \frac{\pi\tau_2}{3}\right)^2}{4a^2(\lambda + 4\xi^2 V_J)\tau_2^2}(\partial_\mu\tau_2)^2 - V_{\mathrm{eff}}$$

$$\tau_2 \coloneqq \mathrm{Im}\tau \qquad V_{\mathrm{eff}} \coloneqq \frac{\lambda V_J(\tau_2)}{\lambda + 4\xi^2 V_J(\tau_2)}$$

○ Classification of regimes : Cases Ⅰ , Ⅱ

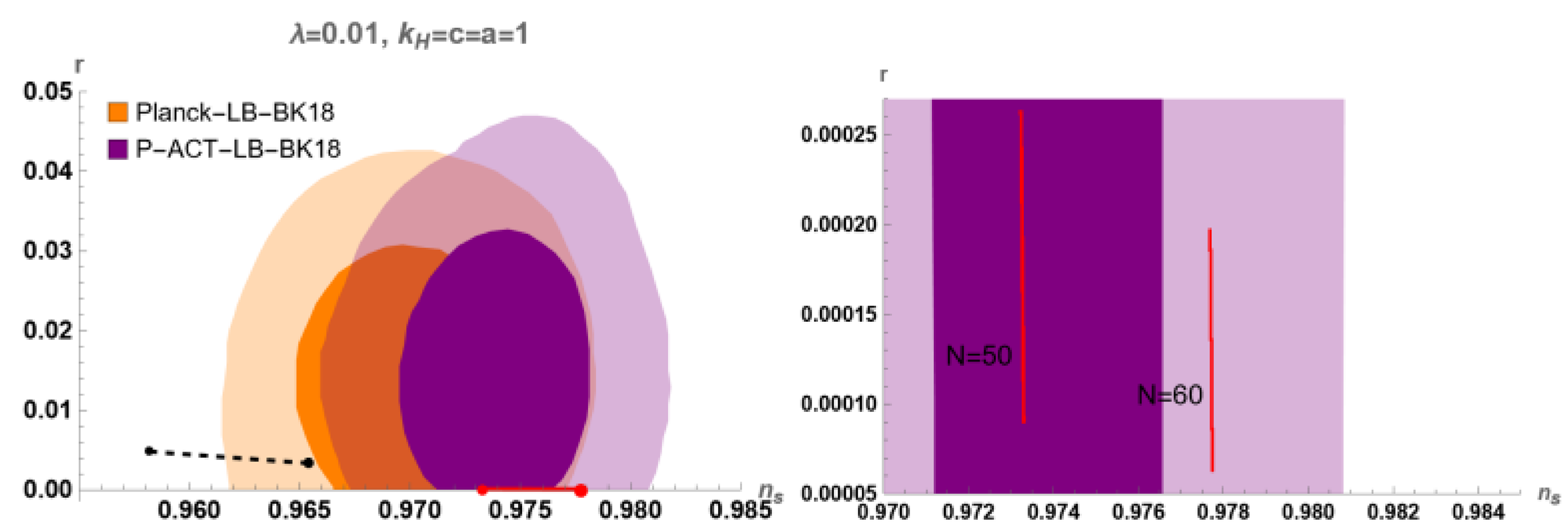
Case Ⅰ : $\lambda \gg k_H^2\xi V_J\tau_2^2$, $\tau_2 > 1$ (MI like)

Case Ⅱ : $\lambda \ll k_H^2\xi V_J\tau_2^2$ (HI like)

○ Inflationary Observables

Case Ⅰ : Almost identical to pure HI / MI

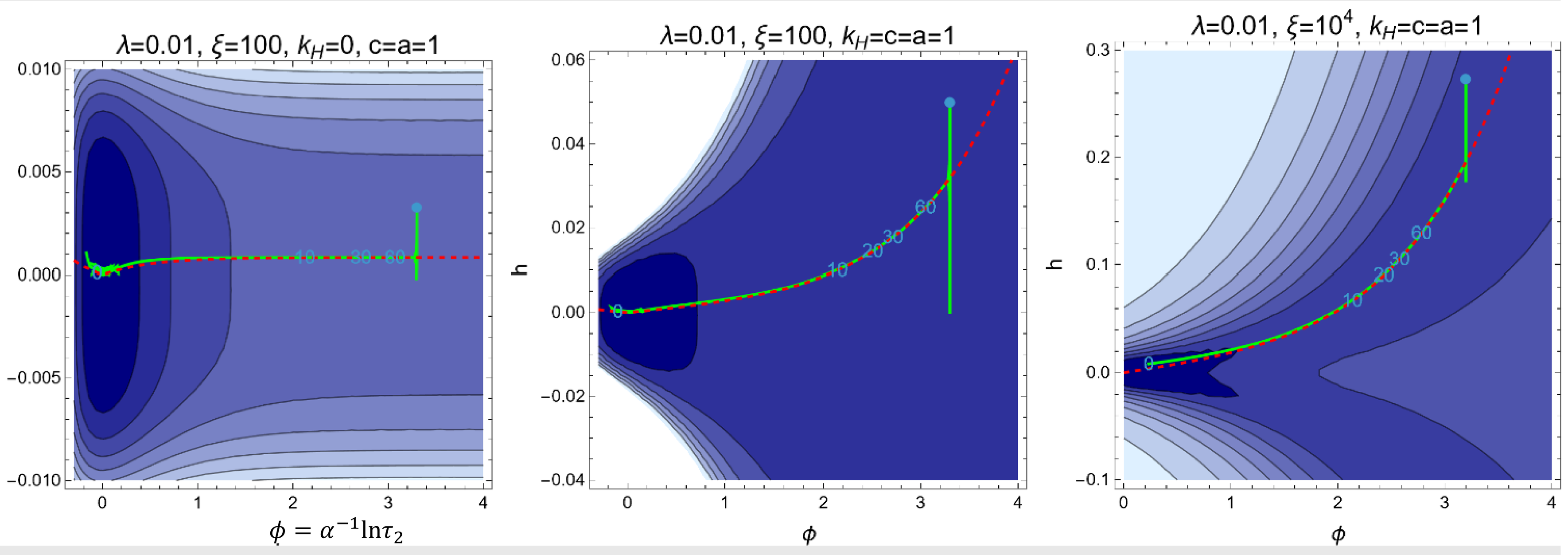
Case Ⅱ : Predictive behavior favored by ACT



○ Attractor

Red : Extremum (analytic) $\quad \partial_h V_E = 0$

Green : Numerical solutions



Case Ⅰ $\qquad$ Case Ⅱ

○ Unitarity

Cut-off scale : $\Lambda \sim |R|^{-1/2}$ [Ref] arXiv : 2308.15420

During inflation	Reheating epoch
$\frac{H}{\Lambda_{\mathrm{inf}}} \sim \begin{cases} 5\times10^{-3} & (\text{Ⅰ}) \\ 0.1 & (\text{Ⅱ}) \end{cases}$	$\frac{V_{\mathrm{end}}^{1/4}}{\Lambda_{\mathrm{reh}}} \sim \begin{cases} 0.8 & (\text{Ⅰ}) \\ 94 & (\text{Ⅱ}) \end{cases}$

○ Reheating $\qquad$ Assume : $a = c = 1$

$$T_{\mathrm{reh}} \sim \begin{cases} (\Gamma_\varphi M_{\mathrm{p}})^{1/2} \sim 10^{10}\mathrm{GeV} & (\text{Ⅰ}) \quad \xi = 10^2 \\ (\Gamma_h M_{\mathrm{p}})^{1/2} \sim 10^{12}\mathrm{GeV} & (\text{Ⅱ}) \quad \xi = 10^4 \end{cases}$$

4. Summary

- Higgs-Modular Inflation : HI + modular symmetry
- Consistent with ACT (attractor behavior)
- Unitarity issue may remain in Case Ⅱ after inflation
- Higher reheating temperature via new channels