BI model

An Extension of Starobinsky model induced by SUGRA

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Man Ping Kwan, Ellgan

Department of Pure and Applied Physics,
Graduate School of Advanced Science and Engineering,
Waseda University

ellgan101@akane.waseda.jp

Abstract

We analyze BI model in a complete form and compare the predictions with that of Starobinsky model. Under the parameter constraints in Planck 2018, we find that the dynamics of the whole inflation process described by BI and Starobinsky models are nearly the same, even though there are some differences in the regions out of inflation. We also find the scales of parameters in BI model and initial inflaton values required to implement inflation. The changes of (n_s, r) fingerprints of BI model and that of evolutions of inflaton field due to the variations of relevant parameters are also investigated.

Introduction

Slow-roll parameters	Range(s)	Spectral indices	Range(s)
ϵ_V	< 0.004	$n_s - 1$	$[-0.0423, -0.0327]$
η_V	$[-0.021, -0.008]$	$\alpha_s := \frac{dn_s}{d\ln k}$	$[-0.008, 0.012]$
ξ_V	$[-0.0045, 0.0096]$	$\beta_s := \frac{d^2 n_s}{d\ln k^2}$	$[-0.003, 0.023]$
H_{hc}	$< 2.7 \times 10^{-5} M_{\text{pl}}$	V_{hc}	$< \left(1.7 \times 10^{16}\ \text{GeV}\right)^4$

Table 1: Slow roll potential parameters and spectral indices in Planck 2018

Cosmological inflation is a powerful solution to the flatness and horizon problems at the beginning of the standard Big Bang scenario. The constraints of observation data of Planck 2018 are listed in Table 1. So far, Starobinsky model, motivated by modified gravity, has provided the most promising prediction, leading to many discussions about properties of Starobinsky-like models during and after inflation[3].

Motivations

BI model is motivated by the following.

1. Starobinsky model provides the best prediction of inflation dynamics.
2. SUGRA has been the best model to unify gravity with particle physics beyond the standard model of elementary particles and the standard model of cosmology.

In this research, we are going to study the scales of parameters and the initial inflaton value ϕ_{hc} of BI model in a complete form[1] and compared these with those of Starobinsky model.

Starobinsky model and BI model

Starobinsky model is given by

$$V_{\text{Starobinsky}}(\phi) = \frac{M_{\text{pl}}^2}{32g^2}\left(1 - e^{-\sqrt{\frac{2}{3}}\frac{\phi}{M_{\text{pl}}}}\right)^2, \tag{1}$$

while BI model, motivated by [1] and [2], is given by

$$V_{\text{BI}}(\phi) = \frac{M_{\text{pl}}^2}{12\beta} e^{-2\sqrt{\frac{2}{3}}\frac{\phi}{M_{\text{pl}}}} \left\{4g^2 - \sqrt{16g^4 - 3\beta\left(e^{\sqrt{\frac{2}{3}}\frac{\phi}{M_{\text{pl}}}} - 1\right)^2}\right\}. \tag{2}$$

where $g = \frac{1}{eM_{\text{pl}}}$ and $\beta = \frac{1}{e^2 M_{\text{BI}}^4} = \frac{g^2}{\alpha^4 M_{\text{pl}}^2}$.

Numerical calculations

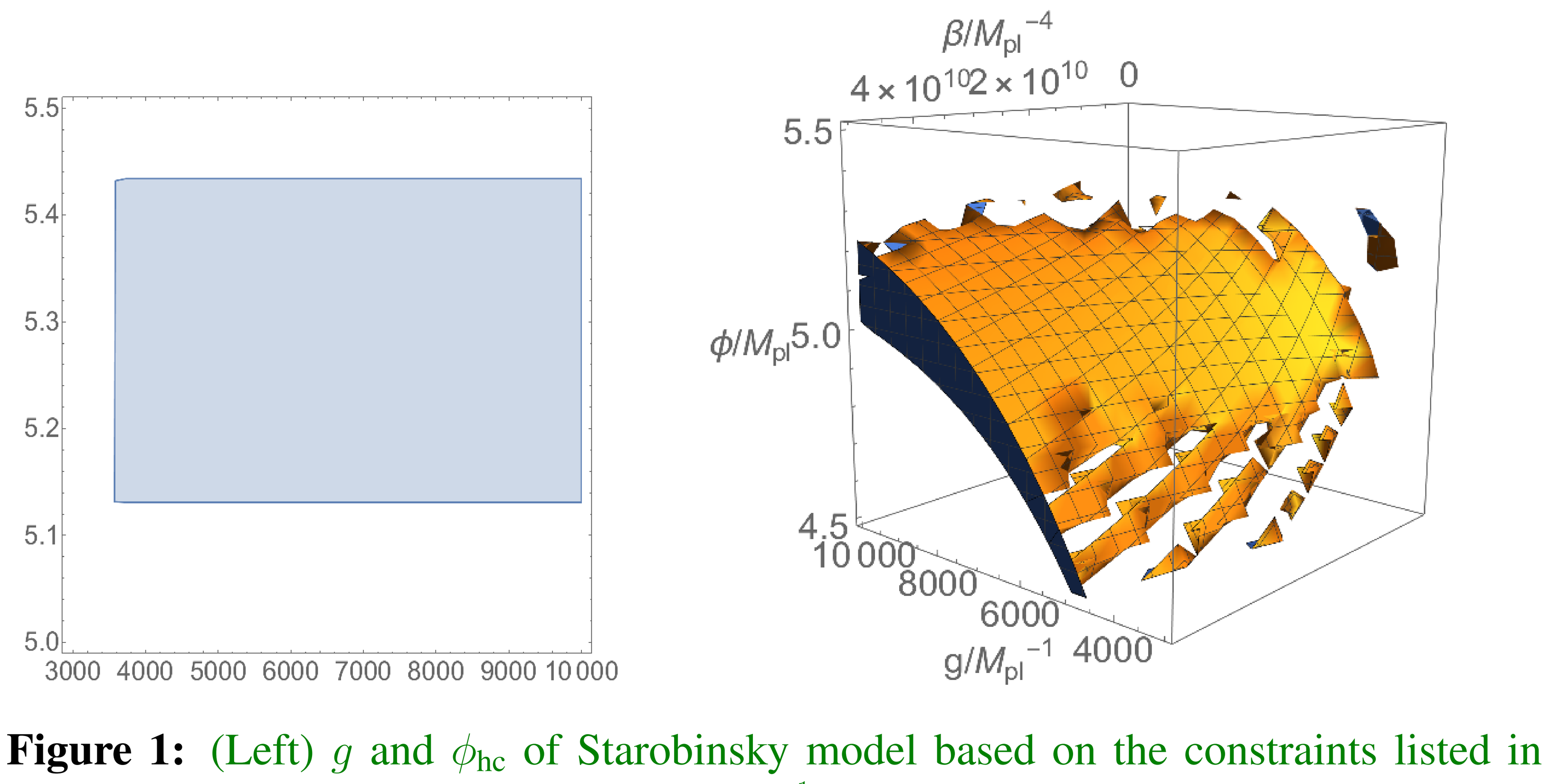

Figure 1: (Left) g and ϕ_{hc} of Starobinsky model based on the constraints listed in Table 1. x and y axes correspond to g/M_{pl}^{-1} and $\phi_{\text{hc}}/M_{\text{pl}}$ respectively. (Right) g, β and ϕ_{hc} of BI model. The x, y and z axes correspond to g/M_{pl}^{-1}, β/M_{pl}^{-4} and $\phi_{\text{hc}}/M_{\text{pl}}$ respectively. (Please pay attention to the magnitude direction of each axis.)

[1] In this paper, it is assumed that the beginning of inflation is the first horizon crossing.

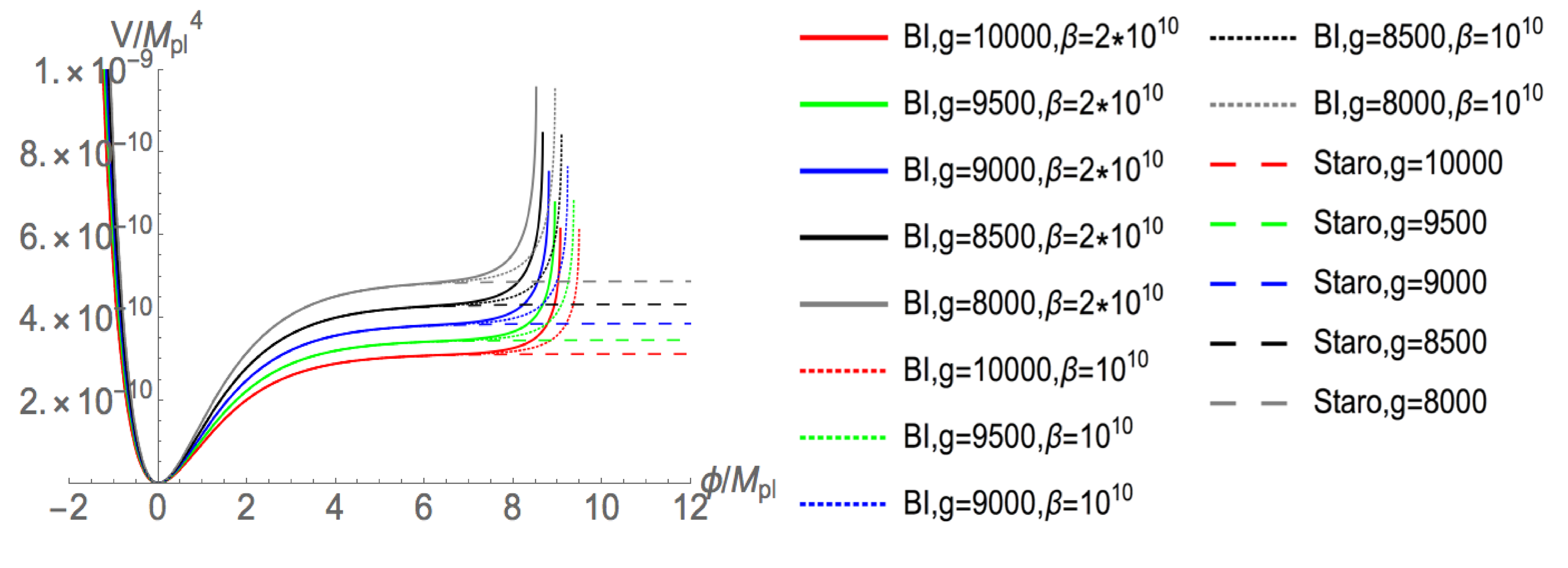

Figure 2: This graph shows potentials Eq.(1) and Eq.(2) against inflaton field values. The solid, tiny dashed and large dashed lines describe BI potential at $\beta = 2\times10^{10} M_{\text{pl}}^{-4}$, the counterpart at $\beta = 10^{10} M_{\text{pl}}^{-4}$ and Starobinsky potential respectively. The legends are on the right side.

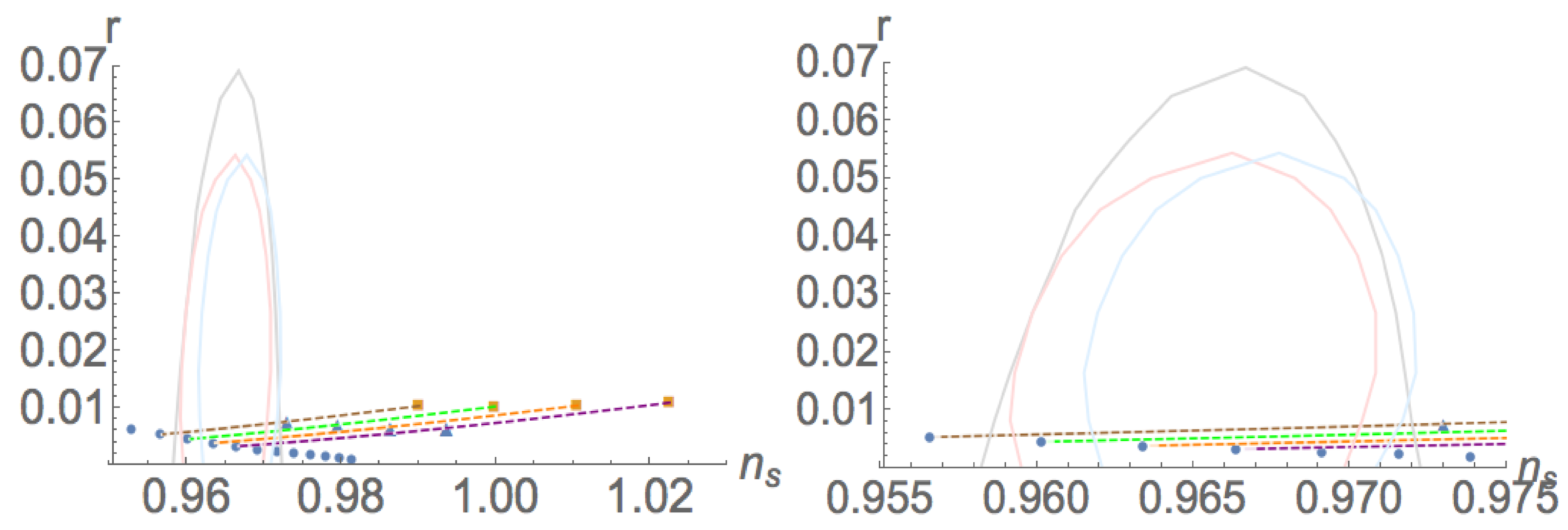

Figure 3: (Left) The tensor-to-scalar ratio r is plotted against the scalar spectral index n_s. The blue dots represent the fingerprints of Starobinsky model, from the initial inflaton values $\phi_{\text{initial}} = 5\ M_{\text{pl}}$ on the left to $\phi_{\text{initial}} = 6.1\ M_{\text{pl}}$ on the right with a spacing of $0.1\ M_{\text{pl}}$. Square points represent the fingerprints of BI model at $g = 5000\ M_{\text{pl}}^{-1}$ and $\beta = 2\times10^{10}\ M_{\text{pl}}^{-4}$ while triangle points represent the counterparts at $g = 5000\ M_{\text{pl}}^{-1}$ and $\beta = 10^{10}\ M_{\text{pl}}^{-4}$. The brown, green, orange and purple dashed lines represent the initial inflaton values $\phi_{\text{initial}} = 5.1\ M_{\text{pl}},\ 5.2\ M_{\text{pl}},\ 5.3\ M_{\text{pl}},\ 5.4\ M_{\text{pl}}$ respectively. As g increases, the fingerprints evolve from the square/triangle points to that around the Planck 2018 data regions. (Right) A close shot in the data regions.

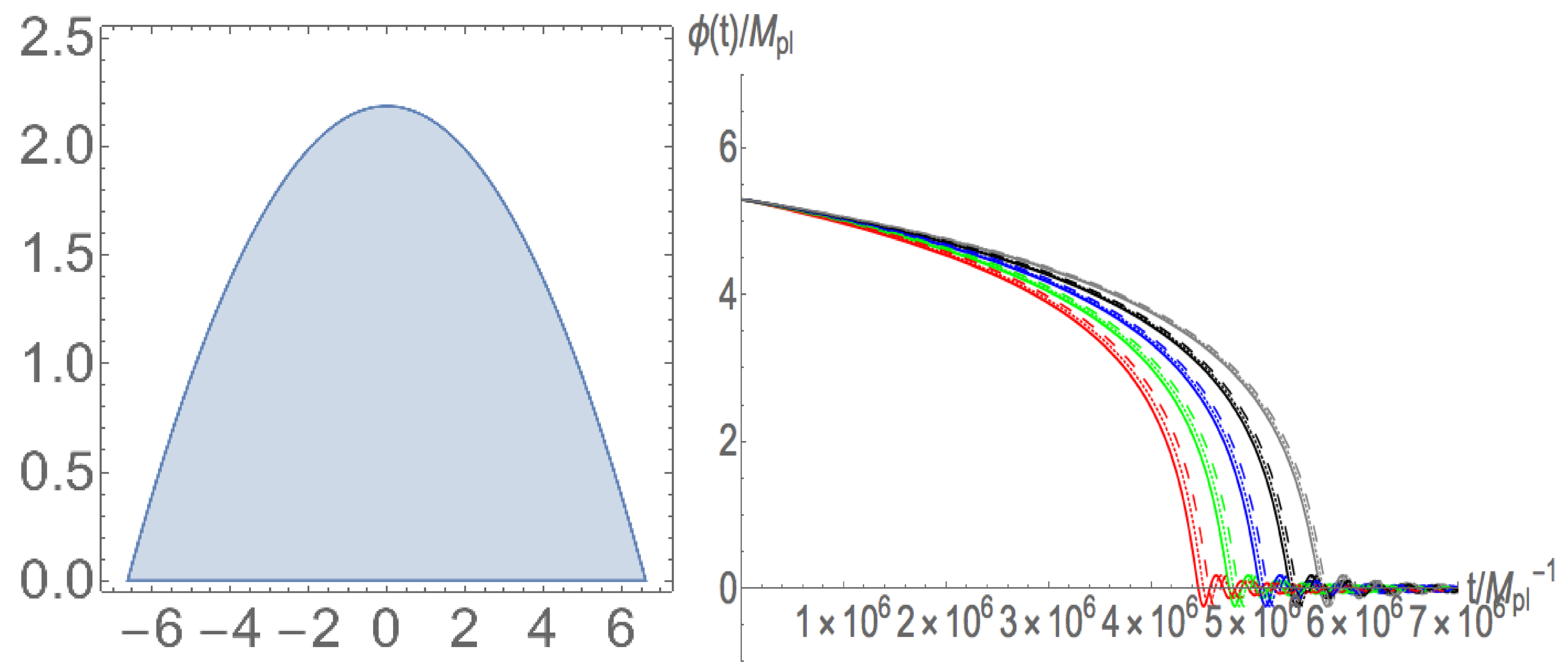

Figure 4: (Left) Initial potential scale (y-axis, $V(\phi)/10^{-9}M_{\text{pl}}^4$) is plotted against initial speed of inflaton field (x-axis, $\dot{\phi}(t=0)/10^{-5}M_{\text{pl}}^2$). (Right) Time evolution of inflaton field $\phi(t)/M_{\text{pl}}$ is plotted against cosmic time t/M_{pl}^{-1}. The legend is referred to Fig.(3).

Conclusions

- Inflation processes described by BI and Starobinsky models are nearly the same.
- $g \approx O\left(10^3\right) M_{\text{pl}}^{-1}$ and $\beta \approx O\left(10^{10}\right) M_{\text{pl}}^{-4} \Rightarrow e < 1.6667\times10^{-4}$ and $\alpha > 0.244949$.
- BI model can be one of the extensions of Starobinsky model for high energy scale during the initial stage of inflation.

References

[1] Hiroyuki Abe, Yutaka Sakamura, and Yusuke Yamada. Massive vector multiplet inflation with dirac-born-infeld type action. *Physical Review D*, 91(12):125042, 2015.

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[3] Sh Nojiri, SD Odintsov, and VK Oikonomou. Modified gravity theories on a nutshell: inflation, bounce and late-time evolution. *Physics Reports*, 692:1–104, 2017.