On the fine-tuning of Higgs inflation in metric and Palatini formulations

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Abstract

- Sensitivity of Higgs(-like) inflation to **higher dimensional operator** in nonminimal coupling and in potential, both in metric and Palatini formulations.
- Inflationary predictions relatively **stable** in **metric**, but extremely **sensitive** in **Palatini**.
- This extreme sensitivity from **absence of attractor** in Palatini. **Challenge** of viable inflationary models in Palatini.

Difference between metric and Palatini

metric formulation

$$S = S(g)$$

Independent variables: $g_{\mu\nu}$

Palatini formulation

$$S = S(g, \Gamma)$$

Independent variables: $g_{\mu\nu}, \Gamma^{\mu}_{\alpha\nu}$

Same dynamics in GR but different dynamics for general action.
Different dynamics in Higgs inflation. [Bauer, Demir, 08; 11; …]

Why focus on Palatini

Metric (g) and **connection** (Γ) are originally independent.

$$\begin{cases} g_{\mu\nu}: & \text{Distances \& angle in tangent space} \\ \Gamma^{\mu}{}_{\lambda\nu}: & \text{Geometric object which connects nearby tangent spaces} \end{cases}$$

When choosing both torsion-free and metricity,
the connection can be expressed in terms of metric.

$$\Gamma^{\mu}{}_{\lambda\nu} - \Gamma^{\mu}{}_{\nu\lambda} = 0, \nabla_{\mu} g_{\nu\lambda} = 0 \Leftrightarrow \Gamma^{\mu}{}_{\lambda\nu} = \Gamma^{\mu}{}_{\lambda\nu}(g)$$

Palatini is more natural ?

Action for Higgs inflation

@Jordan frame

$$S = \int dx^4 \sqrt{-g_J} \left[\frac{\Omega^2(\phi)}{2} g_J^{\mu\nu} R_{J\mu\nu}(\Gamma) + \cdots \right]$$

Conformal transformation

$$g_{J\mu\nu} \to g_{\mu\nu} = \Omega^2(\phi) g_{J\mu\nu}$$

@Einstein frame

$$S \supset \int dx^4 \sqrt{-g} \left[\frac{1}{2} g^{\mu\nu} R_{\mu\nu}(\Gamma) - \frac{V(\phi)}{\Omega^4(\phi)} + \cdots \right]$$

Nonminimal coupling

$$\Omega^2(\phi) \equiv 1 + \xi_2 \phi^2 + \xi_4 \phi^4$$

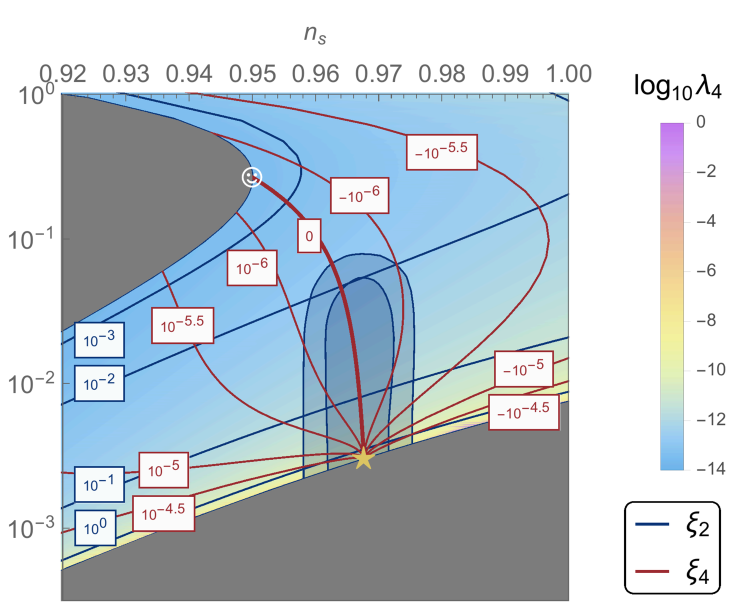
Higgs(-like) potential

$$V(\phi) \equiv \lambda_4 \phi^4 + \lambda_6 \phi^6$$

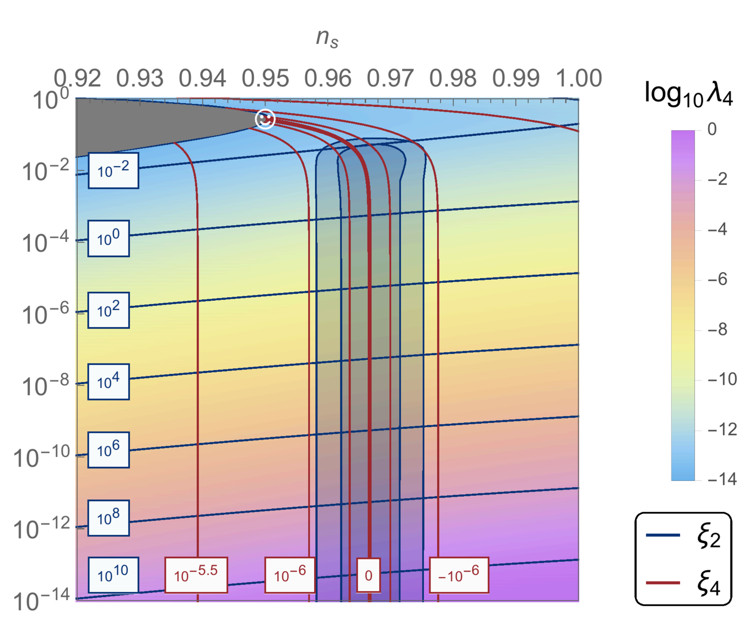
* ξ_4 and λ_6 are higher order couplings

Effect of ξ_4 in the nonminimal coupling (N=60)

metric formulation



Palatini formulation



Bule contours are 68% & 95% CL regions from [Planck 2018 results]

In $\xi_2 \gtrsim 10^8$

metric

$$\delta\xi_4 \sim 10^{-6} \leftrightarrow \delta n_s \sim 0$$

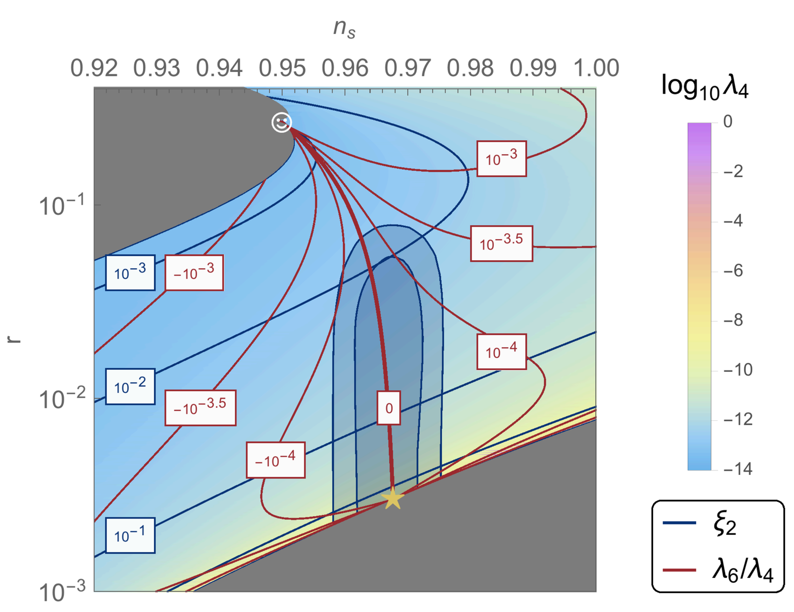
Palatini

$$\delta\xi_4 \sim 10^{-6} \leftrightarrow \delta n_s \sim 0.05$$

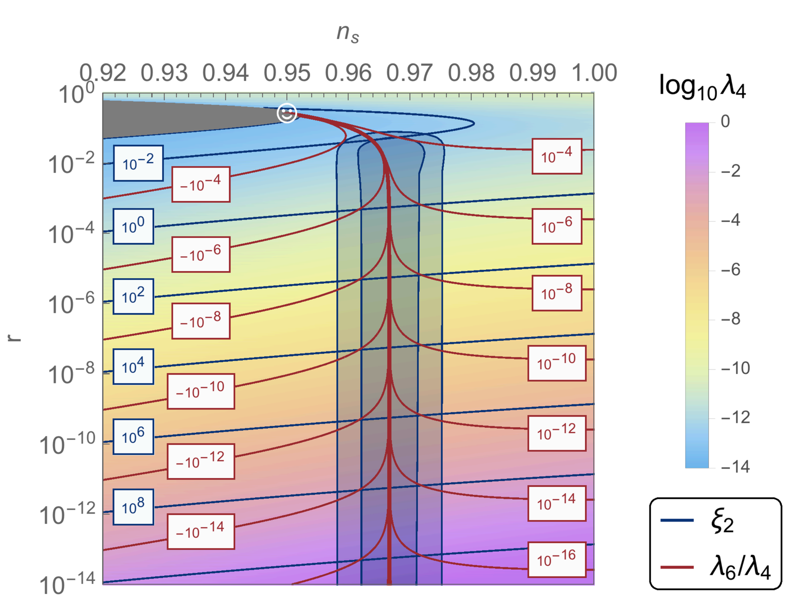
Prediction is more sensitive for ξ_4 in Palatini

Effect of λ_6/λ_4 in the potential (N=60)

metric formulation



Palatini formulation



Bule contours are 68% & 95% CL regions from [Planck 2018 results]

In $\xi_2 \gtrsim 10^{16}$

metric

$$\delta(\lambda_6/\lambda_4) \sim 10^{-4} \leftrightarrow \delta n_s \sim 0$$

Palatini

$$\delta(\lambda_6/\lambda_4) \sim 10^{-16} \leftrightarrow \delta n_s \sim 0.05$$

Prediction is more sensitive for λ_6 in Palatini

Summary

Prediction in Palatini case look like larger range, but is extremely more sensitive by higher dimensional operators:
$\xi_4 > 10^{-6}$ in nonminimal coupling and $\lambda_6 > 10^{-16}$ in potential spoils successful prediction.
Challenge of viable inflationary models in Palatini.