Loop corrections in curved spacetime – could they really generate the Starobinsky inflation?

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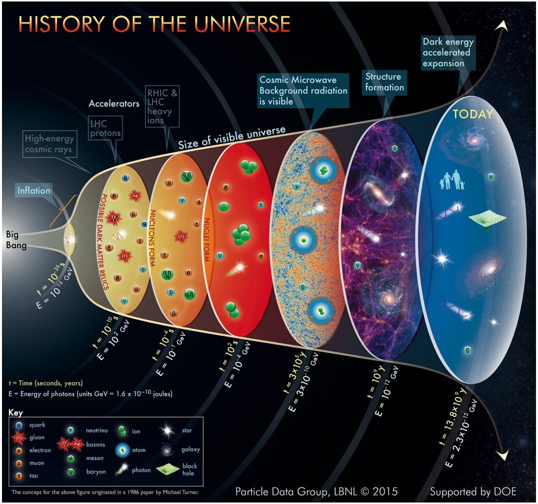
Outline

1. Inflation: what for?
   - Standard cosmological model and the need for inflation
   - Planck data
2. Starobinsky inflation and loop corrections
   - The matter model
   - Results

Concept of inflation



Problems of
the Hot Big Bang Theory:

- horizon problem,
- flatness problem,
- entropy problem,
- primordial perturbation problem.

Planck 2015 data

Planck Collaboration, A&A 594 (2016) A20
'Planck 2015 results XX. Constraints on inflation'

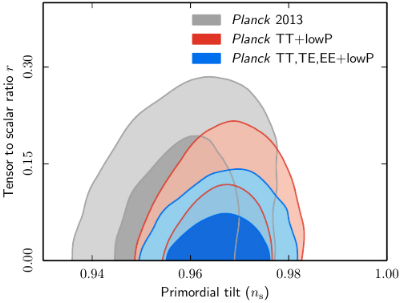


Fig. 6. Marginalized joint confidence contours for (n_s , r), at the 68 % and 95 % CL, in the presence of running of the spectral indices, and for the same data combinations as in the previous figure.

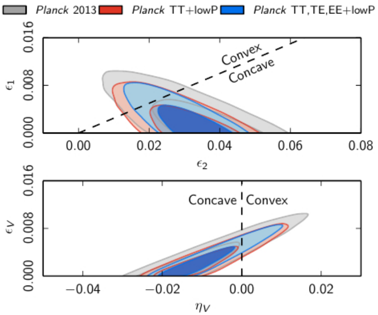


Fig. 10. Marginalized joint 68 % and 95 % CL regions for (ϵ_1 , ϵ_2) (top panel) and (ϵ_V , η_V) (bottom panel) for *Planck* TT+lowP (red contours), *Planck* TT,TE,EE+lowP (blue contours), and compared with the *Planck* 2013 results (grey contours).

Action for the model and relevant parameters

- Gravity: Einstein-Hilbert + $\sum_i \alpha_i \mathcal{R}_i^2$
- Matter: Standard Model + real scalar field X (interactions: Higgs portal + non-minimal coupling to gravity $\xi_i \phi_i^2 R$)

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Relevant and irrelevant data

- New parameters: α_i, ξ_i.
- Details of the gauge and the fermionic sector – unimportant.
- Details of the scalar sector – relevant, to some extent.

$$\left.\begin{aligned} -R \quad &\gg m_X^2 > |m_H^2|, \\ \xi_i \quad &> 100, \end{aligned}\right\} \Rightarrow X = 0, h = 0$$

- Relevant couplings α_3, ξ_H, ξ_X, what about α_1 and α_2?

One-loop corrected Starobinsky-like model

Effective action for the inflationary sector

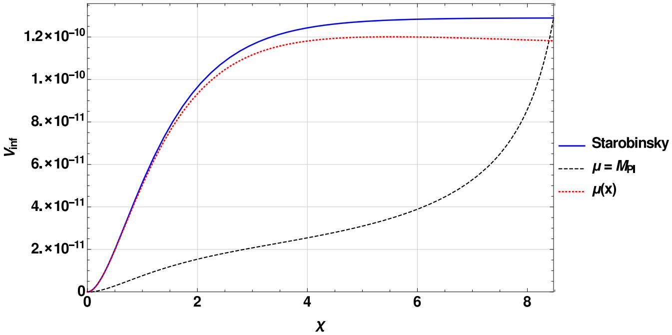
$$S_{inf} = \kappa^{-1} \int \sqrt{-g}\ d^4x \Bigg\{ -\frac{1}{2}\left[1 + \frac{\kappa m_X^2}{a}\bar{\xi}_X (3 - 2\ln\xi)\right] R +$$
$$+ \frac{\kappa}{a}\left[6\bar{\xi}_H^2 + \frac{1}{2}\bar{\xi}_X^2 (3 - 2\ln\xi)\right] R^2 - \frac{\kappa m_X^2}{a} m_X^2 \ln\left(\frac{-\bar{\xi}_H R}{\mu^2}\right) +$$
$$+ \frac{2\kappa m_X^2}{a}\bar{\xi}_X R \ln\left(\frac{-\bar{\xi}_H R}{\mu^2}\right) - \frac{\kappa}{a}(\bar{\xi}_X^2 + 4\bar{\xi}_H^2) R^2 \ln\left(\frac{-\bar{\xi}_H R}{\mu^2}\right) +$$
$$- \frac{\kappa}{a}\frac{1}{18}(\mathcal{K} - R_{\mu\nu}R^{\mu\nu}) \ln\left(\frac{-\bar{\xi}_H R}{\mu^2}\right) \Bigg\},$$

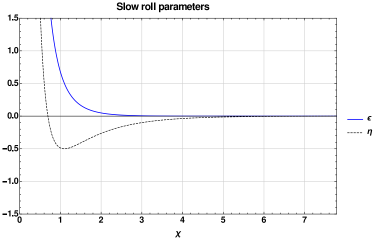
$$\mathcal{K} \equiv R_{\alpha\beta\mu\nu}R^{\alpha\beta\mu\nu}, \quad \bar{\xi}_H \equiv \xi_H - \frac{1}{6}, \quad \bar{\xi}_X \equiv \xi_H - \frac{1}{6}, \quad \xi \equiv \frac{\bar{\xi}_X}{\bar{\xi}_H}, \quad a = 64\pi^2, \quad \kappa = 8\pi G.$$

Inflationary sector after conformal transformation

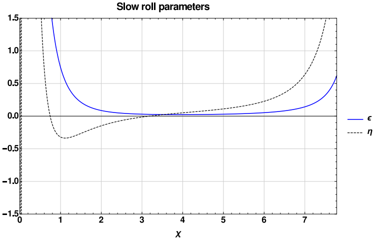
- General form of the action: $S_{inf} = \frac{1}{2\kappa}\int\sqrt{-g}d^4xF(R)$.
- Definitions of the new scalar field and its potential:

$$e^{\chi} = -\frac{dF(R)}{dR}, \qquad V_{inf} = \frac{1}{2\kappa}\frac{R\frac{dF(R)}{dR} - F(R)}{\left(-\frac{dF(R)}{dR}\right)^2}.$$

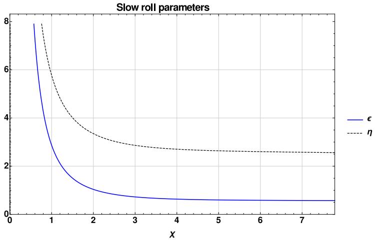




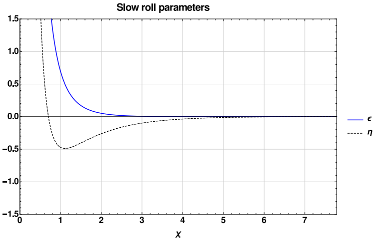
The pure Starobinsky case.



$\mu = \mathrm{M_{Pl}}$, no running of $\xi_{H,X}$.



$$\mu^2 = -\xi_H R(\chi).$$



$$\mu^2 = -\xi_H R(\chi), \quad c_{R^2 \log} \to \frac{c_{R^2 \log}}{100}.$$

Conclusions:

1. Loop-generated Starobinsky-like inflation
   - Nonminimal coupling of the scalar field to the gravity may generate R^2 term.
   - Couplings of the $\mathcal{K}$ and $R_{\mu\nu}R^{\mu\nu}$ terms are much smaller.
   - Nonminimal coupling generates also $R^2\log(R)$ terms.
   - There is no hierarchy amongst c_{R^2} and $c_{R^2 log}$ coefficients.
   - The obtained inflationary model is wrong.
2. Starobinsky-like inflation as a sign of new physics.
   - Starobinsky inflation fits observational data $\to$ phenomenological choice of the parameters α_i.
   - Loop effects will generate corrections to c_{R^2} and produce $c_{R^2 log}$ term.
   - Those corrections are controlled by ξ_i.
   - Demanding that one-loop corrections do not spoil tree-level predictions gives us perturbative bound on ξ_i, $\xi \leqslant 2.02 \cdot 10^5$.

Thank you for your attention.

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