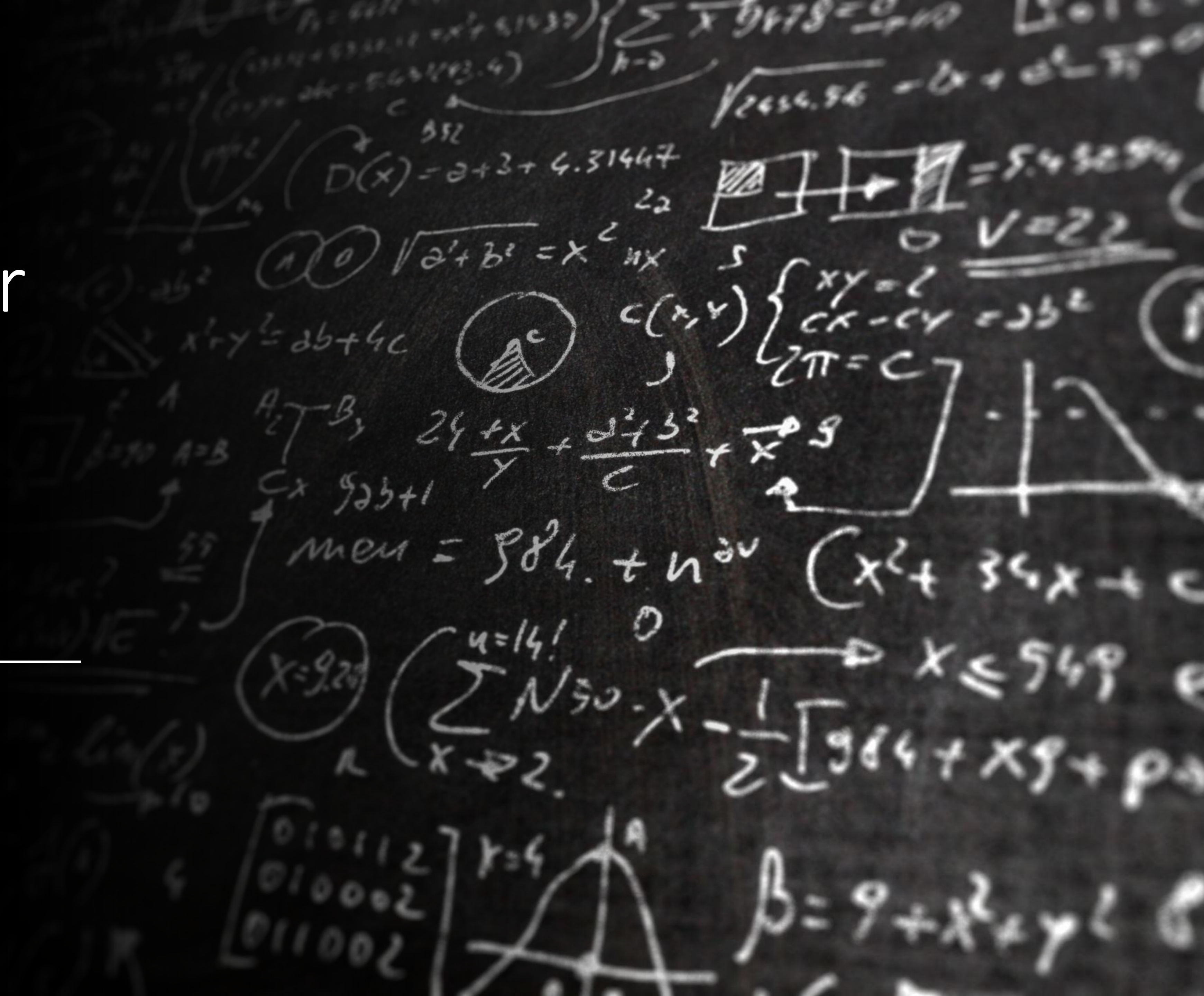
On cosmological inflation in Palatini F(R,φ) gravity

Mahmoud Alhallak

Contents:

- Why F(R,phi) gravity?
- Analytical treatment.
- Cosmological inflation in F(R,phi)
- Case study: consine and exponential potentials

Motivation for F(R,phi) theories of gravity



Historical Motivation:

Scientific Curiosity

Eddington, A. S., 1923, The Mathematical Theory of Relativity (Cambridge University Press, Cambridge).

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H.Weyl, A New Extension of Relativity Theory, Annalen Phys. 59(1919), 101-133 doi:10.1002/andp.19193641002

Contemporary Motivation

Example: Explaining the Current accelerated expansion

$$S = S_{g,\varphi} + S_{\varphi}$$

$$S = \int d^4x\, \sqrt{-g}\, [F(R,\varphi)] + \int d^4x\, \sqrt{-g}\, \left[\frac{1}{2}\, g^{\mu\nu}\, \partial_\mu\varphi\, \partial_\mu\varphi - V(\varphi)\right]$$

The Model

By introducing an auxiliary scalar field , one can re-express the last theory as Brans-Dicke theory

$$S = \int d^4x\, \sqrt{-g}[(\chi + f(\varphi))R \;- - \frac{1}{2}\, g^{\mu\nu}\, \partial_\mu\varphi\, \partial_\mu\varphi - V(\varphi) - V_{eff}(\chi)]$$

The Model

$$S = \int d^4x \sqrt{-g}\left[(\chi + f(\varphi))R - \frac{1}{2}\, g^{\mu\nu}\, \partial_\mu\varphi\, \partial_\mu\varphi - V(\varphi) - V_{eff}(\chi)\right]$$

By Applying a conformal transformation as:

$$\tilde{g}_{\mu\upsilon} = \Omega^2 g_{\mu\upsilon}$$

$$\Omega^2 = (\chi + f(\varphi))$$

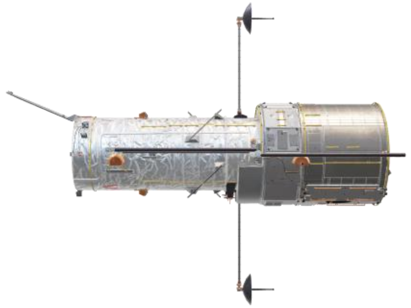
$$S_\phi = \int d^4x \sqrt{-g}\left\{\sum_{j=1}^{j=2} G_j(\phi) X^j + \frac{V}{M_j(\phi) V^{j-1}}\right\}$$

$$G_j(\phi) = \frac{(2\alpha)^{j-1}(1+f(\phi))^{2-j}}{(1+f(\phi))^2 + (8\alpha V)},$$

$$M_j = (1+f(\phi))^{2j-4} + (8\alpha)^{j-1}$$

$$X = \frac{1}{2} g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi$$

Limits of the model



Limit 1

$2\alpha X \ll (1 + f)$

slow-roll canonical inflation

$$S_{limI} = \int d^4x \sqrt{-g}\frac{1}{2}\left\{R - g^{\mu\nu}\partial_\mu\varphi\partial_\nu\varphi - 2V_{eff}(\varphi(\phi))\right\}$$

Limit 2

- $\alpha \gg 1$

slow-roll K-inflation

$$S_{limII} = \int d^4x \sqrt{-g}\frac{1}{2}\left\{R + \frac{1}{2}(g^{\mu\nu}\partial_\mu\chi\partial_\nu\chi)^2 - 2V_{eff}(\chi(\phi))\right\}$$

Limit 3

- $\alpha \ll 1$

Constant-roll K-inflation

$$S_{limIII} = \int d^4x \sqrt{-g}\frac{1}{2}\left\{R + \alpha(g^{\mu\nu}\partial_\mu\varphi\partial_\nu\varphi)^2 - g^{\mu\nu}\partial_\mu\varphi\partial_\nu\varphi - 2V_{eff}(\chi(\phi))\right\}$$

Case study

Case study

Case 1

$V = V_0[1 + \cos\left(\frac{\varphi}{f}\right)]$

F(φ)=-$\xi\varphi^2 R$

Case 2

$V = V_0[1 + \cos\left(\frac{\varphi}{f}\right)]$

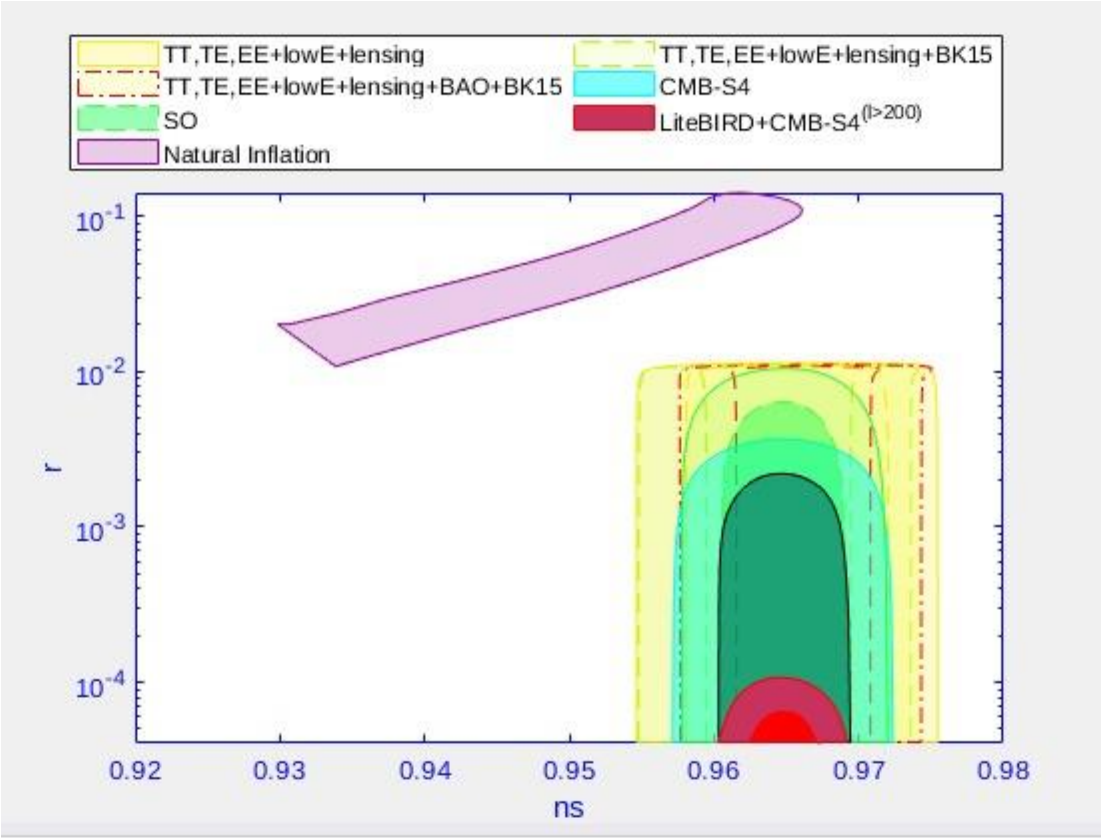
F(φ)=$\lambda(1 + \cos\left(\frac{\varphi}{f}\right))$

Case 3

$V = V_0 \exp(-l \quad)$

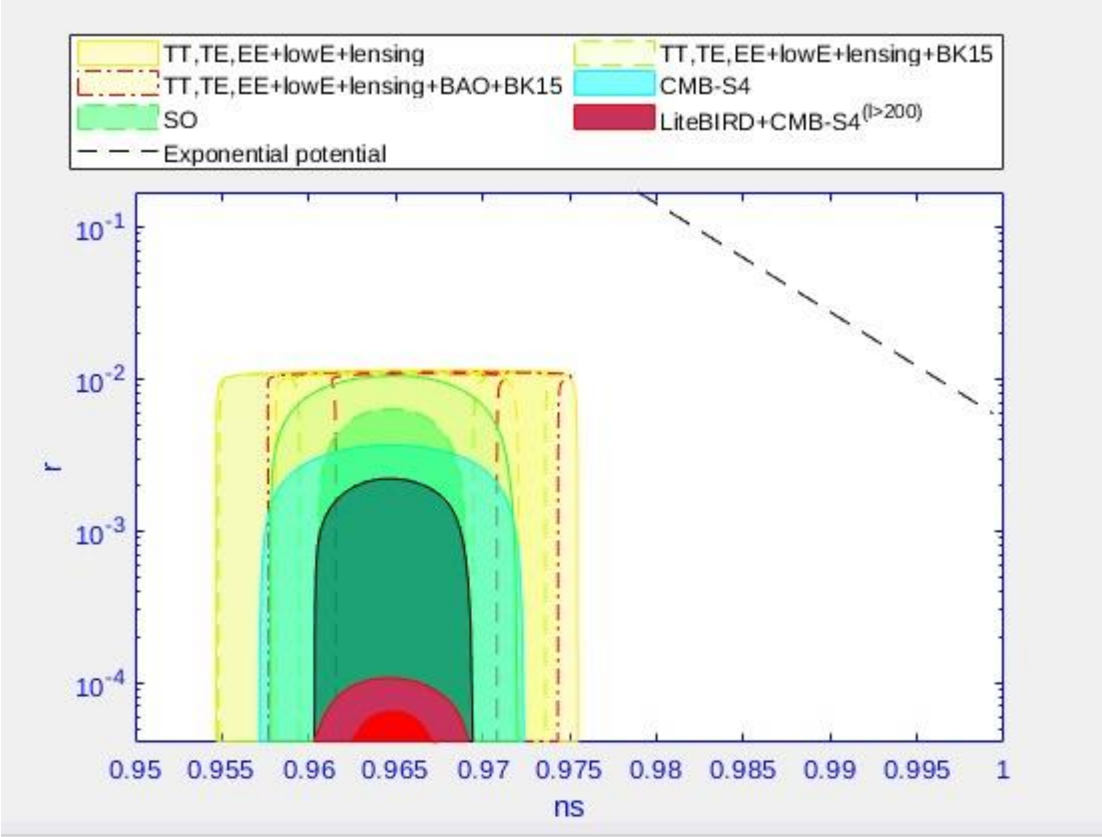
F(φ)=$-\xi\exp(-2l\varphi)$

Natural Inflation In Standard GR gravity



- The model failed to accommodate the observational results.

Inflation with Exponential potential In Standard GR gravity



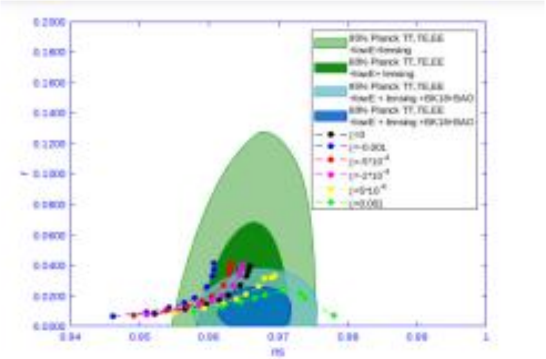
- The model failed to accommodate the observational results.

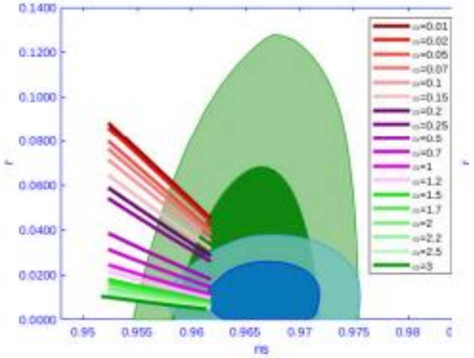
Results

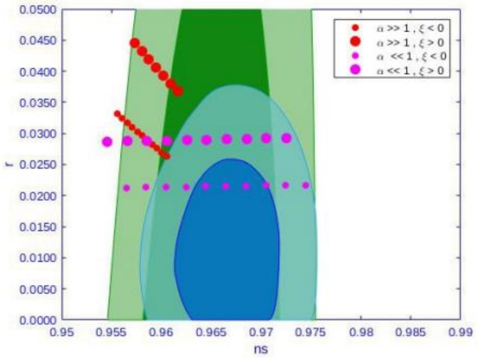
- By studying the effects upon modifying the model, we found that the αR^2 -gravity influences the scalar-tensor ratio r values. In contrast, NMC to gravity significantly impacts the spectral index values (n_s).
- As current observational constraints on parameter α and ξ/λ are pretty loose, having contributions from both terms allows the models to accommodate the observational constraints.

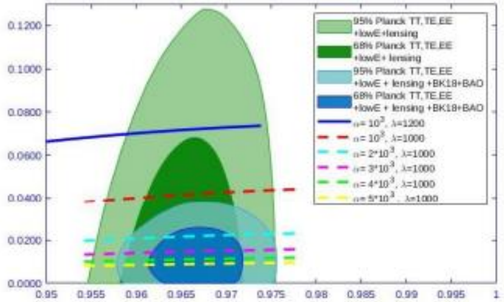
Results: Cosine Potential

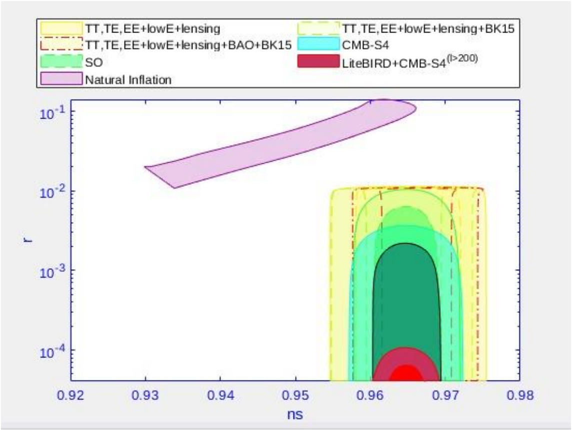
M.AlHallak, N.Chamoun and M.S.Eldaher, Natural Inflation with non minimal coupling to gravity in R ^2 gravity under the Palatini formalism, JCAP ,2022), 001
doi:10.1088/1475-7516/2022/10/001











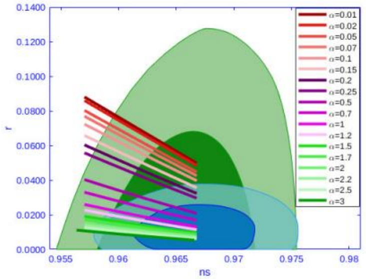
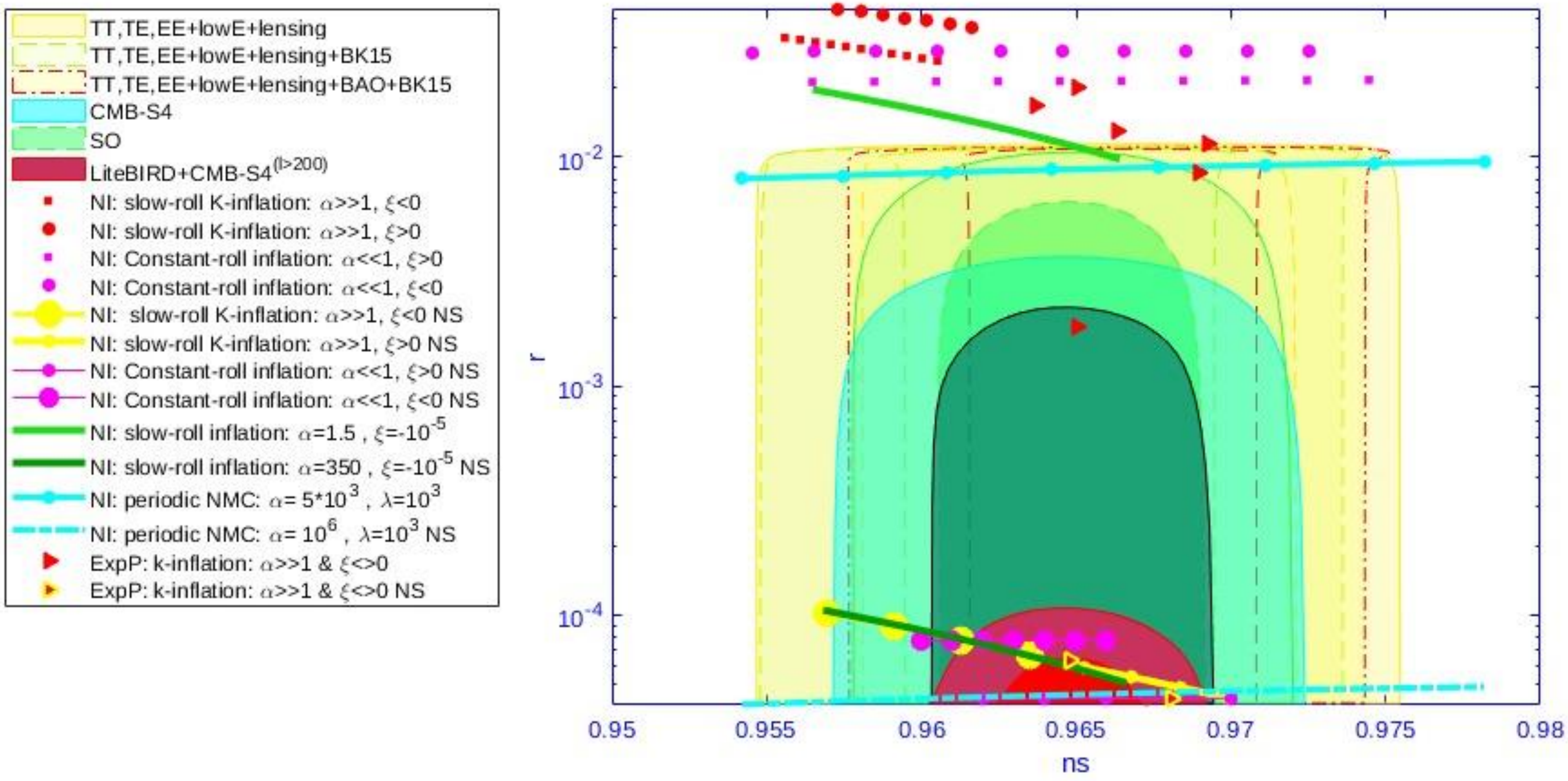


Figure 5: A plot of r and n_s for minimally coupled NI with extended αR^2 gravity. Each line corresponds to a fixed value for α and to scanned vlaues of N. Number of e-foldings N is scanned form 50 at left boundaries of the lines to 70 at right boundaries

Results:


TT,TE,EE+lowE+lensing
TT,TE,EE+lowE+lensing+BK15
TT,TE,EE+lowE+lensing+BAO+BK15
CMB-S4
SO
LiteBIRD+CMB-S4 (l>200)
NI: slow-roll K-inflation: α>>1, ξ<0
NI: slow-roll K-inflation: α>>1, ξ>0
NI: Constant-roll inflation: α<<1, ξ>0
NI: Constant-roll inflation: α<<1, ξ<0
NI: slow-roll K-inflation: α>>1, ξ<0 NS
NI: slow-roll K-inflation: α>>1, ξ>0 NS
NI: Constant-roll inflation: α<<1, ξ>0 NS
NI: Constant-roll inflation: α<<1, ξ<0 NS
NI: slow-roll inflation: α=1.5 , ξ=-10^-5
NI: slow-roll inflation: α=350 , ξ=-10^-5 NS
NI: periodic NMC: α= 5*10^3 , λ=10^3
NI: periodic NMC: α= 10^6 , λ=10^3 NS
ExpP: k-inflation: α>>1 & ξ<>0
ExpP: k-inflation: α>>1 & ξ<>0 NS
10^-2
10^-3
10^-4
r
0.95
0.955
0.96
0.965
0.97
0.975
0.98
ns

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Thanks for your listening