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Accuracy of EGB exponential inflationary scenario

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Abstract: Early we constructed model with exponential form potential and of Gauss-Bonnet interaction. This model can be considered such as appropriate inflationary scenario. In this model attractor inflationary parameters correspond to ones from cosmological attractor model in leading order approximation in inverse e-folding number. We study how many orders of inverse e-folding numbers are included to spectral index in exponential inflationary scenario in the Einstein-Gauss-Bonnet gravity.

1. Introduction

Early we constructed the inflationary scenarios of exponential type [1] in Einstein-Gauss-Bonnet gravity

$$S=\int d^4x\sqrt{-g}\left[\frac{R}{2}-\frac{\partial^\nu\phi\partial_\nu\phi}{2}-V(\phi)-\frac{\xi(\phi)}{2}\mathcal{G}\right],\quad \text{where}\quad \mathcal{G}=R_{\mu\nu\rho\sigma}R^{\mu\nu\rho\sigma}-4R_{\mu\nu}R^{\mu\nu}+R^2;. \tag{1}$$

We reformulated equations of motion in spatially flat FLRW space-time in slow-roll regime

$$H^2\simeq\frac{V}{3},\quad (\phi')^2\simeq\frac{V'}{V}+\frac{4}{3}\xi'V=\frac{(H^2)'}{H^2}+4H^2\xi'. \tag{2}$$

and inflationary parameters

$$n_s=1-2\epsilon_1+\frac{r'}{r},\quad r=8(\phi')^2,\quad \epsilon_1=\frac{1}{2}\frac{(H^2)'}{H^2}. \tag{3}$$

in terms of e-folding numbers. Accordingly to inflationary parameters of cosmological-attractor models [2] without the Gauss-Bonnet term spectral index includes only logarithmic derivative of tensor-to-scalar ratio

$$r\approx\frac{12C_\alpha}{(N+N_0)^2},\quad \frac{r'}{r}=-\frac{2}{N+N_0},\quad \text{and}\quad n_s\approx 1+\frac{r'}{r}\approx 1-\frac{2}{N+N_0}. \tag{4}$$

in the leading order of $1/N$ approximation.

2. Exponential model

In [1] the exponential inflationary scenario with the Gauss-Bonnet which allows to reproduce cosmological attractor prediction in leading order approximation was obtained.

The model obtained within the framework of slow-roll approximation has the following form:

$$\xi = \xi_0 \exp\left(\frac{3C_\beta}{2(N+N_0)}\right), \quad H^2 = H_0^2 \exp\left(-\frac{3C_\beta}{2(N+N_0)}\right), V = 3H^2, \tag{5}$$
(6)

where C_β is a constant

$$C_\beta = \frac{C_\alpha}{1-4\xi_0 H_0^2}, \quad H_0^2 \neq \frac{1}{4\xi_0}. \tag{7}$$

Accordingly to (3), (4) the derivative of field is related with e-folding number:

$$(\phi')^2 = \frac{3C_\alpha}{2(N+N_0)^2}, \quad \phi' = \frac{\omega_\phi \sqrt{\frac{3C_\alpha}{2}}}{N+N_0}, \quad \omega_\phi = \pm 1 \tag{8}$$

from here

$$\phi = \omega_\phi \sqrt{\frac{3C_\alpha}{2}} \ln\left(\frac{N+N_0}{N_\phi}\right), \quad N+N_0 = N_\phi \exp\left(\omega_\phi \sqrt{\frac{2}{3C_\alpha}}\phi\right). \tag{9}$$

Using (2), (5) and (9) we constructed family of the models with the Gauss-Bonnet interaction and potential with variable parameter C_α:

$$V = 3H_0^2 \exp\left(-\frac{3}{2}\frac{C_\beta}{N_\phi}\exp\left(-\omega_\phi\sqrt{\frac{2}{3C_\alpha}}\phi\right)\right), \xi = \xi_0 \exp\left(\frac{3}{2}\frac{C_\beta}{N_\phi}\exp\left(-\omega_\phi\sqrt{\frac{2}{3C_\alpha}}\phi\right)\right) \tag{10}$$

leading to appropriate inflationary scenarios.

Now we would like to compare order of inflationary parameters of obtained model (10) using field formulation of inflationary parameters.

3. Inflationary parameters

In this subsection, we get expressions for inflationary parameters in terms of fields and after that we reformulate results in terms of e-folding number. We use the tensor-to-scalar ratio and spectral index of scalar perturbations in the following form [1,3]:

$$r = 8Q^2, \quad n_s = 1 - Q\frac{V_\phi}{V} + 2Q_{,\phi}, \quad \text{where} \quad Q = V_{,\phi}/V + 4\xi_{,\phi}V/3. \tag{11}$$

For the exponential models we get

$$r = \frac{64\left(1-4H_0^2\xi_0\right)^2}{3C_\alpha}\left(\exp\left(-\omega_\phi\sqrt{\frac{2}{3C_\alpha}}\phi\right)\right)^2 \tag{12}$$

$$n_s = 1 - \frac{8}{3}\frac{\exp\left(-\omega_\phi\sqrt{\frac{2}{3C_\alpha}}\phi\right)\left(1+\exp\left(-\omega_\phi\sqrt{\frac{2}{3C_\alpha}}\phi\right)\right)\left(1-4H_0^2\xi_0\right)}{C_\alpha} \tag{13}$$

Now we apply relation between field and e-folding number (9) and obtain:

$$r = \frac{64\left(1-4H_0^2\xi_0\right)^2}{3C_\alpha}\left(\frac{N_\phi}{N+N_0}\right)^2 \tag{14}$$

$$n_s = 1 - \frac{8\left(1-4H_0^2\xi_0\right)}{3C_\alpha}\left(\frac{N_\phi}{N+N_0} + \left(\frac{N_\phi}{N+N_0}\right)^2\right) \tag{15}$$

To present this expressions in more regular form we apply (7)

$$r = \frac{64N_\phi^2(1-4H_0^2\xi_0)}{3C_\beta(N+N_0)^2} = \frac{64}{3}\frac{C_\alpha N_\phi^2}{(N+N_0)^2} \tag{16}$$

$$n_s = 1-\frac{8}{3C_\beta}\left(\frac{N_\phi}{N+N_0}+\left(\frac{N_\phi}{N+N_0}\right)^2\right) \tag{17}$$

substituting $N_\phi = \frac{3C_\beta}{4}$, $C_\beta = 1$ we get

$$r = \frac{64N_\phi^2(1-4H_0^2\xi_0)}{3C_\beta(N+N_0)^2} = \frac{12C_\alpha}{(N+N_0)^2} \tag{18}$$

$$n_s = 1-\left(\frac{2}{N+N_0}+\frac{9}{16(N+N_0)^2}\right) \tag{19}$$

Evidently that in the beginning of inflation then $N+N_0 \approx 60$ we can roughly suppose

$$r \approx \frac{12C_\alpha}{(N+N_0)^2}, \quad n_s \approx 1-\frac{2}{N+N_0} \tag{20}$$

The obtained approximations are coincide with inflationary parameters of attractors approximation [2] and in the case of $C_\alpha \approx 1$ with parameters of R^2 inflation [4]. The case $C_\alpha = 1$ leads to switch of Gauss-Bonnet interaction and to coinciding with exponential scenario early obtained in Einstein Gravity [5].

4. Conclusion

We considered the exponential inflationary scenario in Einstein-Gauss-Bonnet gravity and get that the direct calculations of spectral index for this model includes second order inverse e-folding number term. However such as in the beginning of inflation $N+N_0 \approx 60$ this term is negligible in relation to first order inverse e-folding number term. And roughly we can suppose that the cosmological attractor approximation for inflationary parameters are satisfied for considering model. Moreover the switch of Gauss-Bonnet interaction can leads R^2 gravity prediction for inflationary parameters in leading order approximation in inverse e-folding number.

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