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INFLATIONARY MODELS, REHEATING AND SCALAR FIELD CONDENSATE BARYOGENESIS

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Abstract. We discuss the baryon asymmetry value generated for 70 sets of parameters of the Scalar Field Condensate Baryogenesis (SFC) model in different inflationary scenarios and for different reheating scenarios. In previous paper we have found sets of SFC model's parameters, for which the observed value of the baryon asymmetry of the Universe can be successfully generated in the following inflationary scenarios: modified Starobinsky inflation, chaotic inflation in SUGRA and chaotic inflation in case of delayed thermalization. Here we expand our analysis to study baryon asymmetry generation in quintessential inflation. We have found several sets of parameters of SFC baryogenesis model for which successful baryogenesis is possible in case of quintessential inflation. On the contrary new inflation, Shafi-Vilenkin chaotic inflation and MSSM inflation lead to baryon asymmetry generation by several orders of magnitude higher than the observed one.

1. INTRODUCTION

In this work we present an update of our results concerning the generation of baryon asymmetry in Scalar Field Condensate (SFC) baryogenesis model (first studied in Dolgov and Kirilova (1990, 1991) in different inflationary scenarios and for different possibilities of the reheating after inflation. Preliminary results on these issues were presented in Kirilova and Panayotova (2019).

SFC baryogenesis model is among the preferred baryogenesis models today because it allows the generation of the baryon asymmetry of the Universe to proceed at lower energies, thus it is compatible with inflationary paradigm and also evades the problem of overabundance of gravitino and of magnetic monopoles. According to SFC baryogenesis model the baryon excess B is contained in baryon charge carrying scalar field φ, which transfers it to quarks during its decay. The baryon excess is generated at earlier epochs due to B-violating terms in the potential of φ.

An important feature of this model is that after inflation φ oscillates around its equilibrium point and its amplitude decreases due to the Universe expansion and the particle creation caused by the coupling of the scalar field to fermions $g\varphi f_1 f_2$, where $g^2/4\pi = \alpha_{GUT}$ (Dolgov and Kirilova 1990; Kirilova and Panayotova 2007). Hence, the baryon charge B, contained in φ condensate, is reduced due to particle production at the high energy stage, where BV is considerable. If the rate of particle creation Γ is a decreasing function of time, the damping is slow and B survives until the decay of φ, when B is transferred to fermions. The generated baryon asymmetry strongly depends on α.In this work we have accounted for the particle creation process numerically.

The produced baryon asymmetry depends on the baryon excess B, the reheating temperature of the Universe T_R and the value of the Hubble parameter at the inflationary stage H_I. Hence, there is a big variety of possible H_I and T_R values following from different inflationary and reheating scenarios.

Today there exist numerous inflationary models. Besides the reheating process at the end of the inflationary stage may have proceeded through perturbative and nonperturbative mechanisms (Traschen, Brandenberger 1990; Dolgov, Kirilova 1990; Kofman, Linde, Starobinski 1994) and also through different decay channels and different decay rates of the inflaton and different thermalization (instant or delayed). The efficient or delayed thermalization were discussed in (Mazumdar, Zaldivar 2014).

2. INFLATIONARY SCENARIOS, REHEATING AND BARYOGENESIS

We have analyzed the baryon asymmetry generation in SFC baryogenesis model for more than 70 sets of parameters of the SFC model, presented in detail in (Kirilova, Panayotova 2015; Kirilova, Panayotova 2014). The studied ranges of the models parameters were: $H_I = 10^7$ - 10^{16} GeV, m = 100 - 1000 GeV, $\alpha = 10^{-3}$ – 5.10^{-2}, $\lambda_i = 10^{-3} – 5.10^{-2}$.

Now there exist numerous models of inflation (Martin, Ringeval, Vennin, 2014). In our previous work we have discussed the following inflationary scenarios: new inflation, chaotic inflation, Shafi-Vilenkin chaotic inflation, chaotic inflation in SUGRA, Starobinsky inflation and MSSM inflation. It was found that there exist possibility for generation of the baryon asymmetry with similar to the observed value $\boldsymbol{\beta}_{obs} = 6.10^{-10}$, where $\boldsymbol{\beta}$~BT_R/H_I, for the following models: the simplest Shafi-Vilenkin model (Shafi, Vilenkin 1984) in chaotic inflation for $T_R = 10^{12}$ - 10^{13} GeV again in case of delayed thermalization; modified Starobinsky inflation (Starobinsky 1980) for $T_R = 10^9$ GeV, $H_I = 10^{11}$ GeV, for the efficient thermalization and chaotic inflation in SUGRA (Nanopoulos, Olive, Srednicki 1983) $T_R > 10^9$ GeV. All other considered models were shown to produce baryon asymmetry many orders of magnitude bigger than the observed one.

Here we consider quintessential inflationary models (Peebles, Vilenkin 1999), which are among the preferred inflationary models today, because they allow simultaneous explanation of the inflationary expansion at the very early universe and the accelerated expansion of the Universe at late epochs using a single scalar field potential:

$$V = \lambda(\phi^4 + M^4), \quad \phi < 0$$

$$V = \lambda M^8/(\phi^4 + M^4), \ \phi \geq 0$$

At $\phi \gg M$ this is a chaotic inflation potential, at . $\phi \ll M$ it is a quintessence form, $\lambda \sim 10.^{-14}$. Some model modifications were provided recently to obtain agreement with the Plank18 observational data

We have considered different types of reheating after inflation, in particular models with instantaneous and with delayed thermalization were analyzed. We have found that in quintessential inflation for $T_R = 2.10^5$ GeV, $H_I = 10^{12}$ GeV there exist several realizations of the SFC baryogenesis model with successful production of the observed baryon asymmetry value, namely for m = 350 GeV and $\alpha = 10^{-3}$ and the following range of models self-coupling parameters: $\lambda_1 = 10^{-3} - 5.10^{-2}$, $\lambda_2 = \lambda_3 = 10^{-4} - 5.10^{-3}$.

Thus, the numerical analysis of SCF baryogenesis model in quintessential inflationary model predicts successful generation of the observed baryon asymmetry of the Universe for several sets of SCF model parameters.

Planck missions releases have put constraints on the inflationary models.

It is interesting that most of the inflationary models in which successful SCB baryogenesis is possible are also among the observationally preferred ones by the latest Planck data.

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