REHEATING IN α-ATTRACTORS*

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α-attractors is a very promising class of inflationary models, utilizing a non-canonical form of the kinetic term to solve the problem of flatness of the potential. This mechanism has significant implications for the dynamics of the (p)reheating. In the current manuscript, we extend past studies of the simple α-attractor T-model (in linear approximation) to the recently proposed α-attractor hypernatural T-model.

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1. Introduction

Preheating is the period after the end of the inflationary evolution of the Universe, when oscillations of the inflaton scalar field induce an exponential growth of its fluctuations. Fluctuations of other fields coupled to the inflaton, called spectators, can also be produced. This growth can very efficiently transfer the energy of the homogeneous scalar field to spatial fluctuations. Thus, preheating serves as the first stage of reheating.

Preheating can be studied using the Floquet theory (like in [1, 2]). When oscillations of the inflaton are faster than the expansion of the Universe, we can approximate the fields' evolution as a damped oscillator. The analysis yields the so-called *Floquet exponents*, whose real parts describe the rate of the exponential growth of the fluctuations.

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In this manuscript, the Floquet exponents calculated in [1] for the simple T-model [3–5] are compared with newly computed ones for the hypernatural inflation T-model proposed in [6].

2. α-attractor type models

α-attractor models of inflation can be naturally implemented in the supergravity with hyperbolic geometry as presented in the vast literature [4, 5, 7–13].

It is usually assumed that, in so-called half-plane variables, T and $\bar{T}$, the Kähler potential, with parameter $\alpha > 0$, takes the form

$$K_H = -\frac{3\alpha}{2}\log\left(\frac{\left(T+\bar{T}\right)^2}{4T\bar{T}}\right) + S\bar{S}\,. \tag{1}$$

One of the simplest and most studied models of this class is known as the T-model and is given by the superpotential in the following form:

$$W_H = \sqrt{\alpha}\mu S\left(\frac{T-1}{T+1}\right)^n, \tag{2}$$

where $n > 0$ and μ is a constant parameter.

As was shown in [11], the superfield S can be stabilised during and after inflation. Therefore, its contribution to the evolution of the Universe can be neglected, and the scalar sector of the model can be described by two real fields, parametrising the complex scalar component of the T superfield.

The parametrisation, in terms of ϕ and χ fields, used in [1, 14] was constructed in such a way to obtain canonical kinetic terms for the considered linear fluctuations along the inflationary trajectory ($\chi = \text{const.}$) in order to simplify the performed Floquet analysis. The potential of the model in these variables (with $M^4 = \alpha\mu^2$ and $\beta = \sqrt{2/3\alpha}$) reads

$$V(\phi,\chi) = M^4\left(\frac{\cosh(\beta\phi)\cosh(\beta\chi)-1}{\cosh(\beta\phi)\cosh(\beta\chi)+1}\right)^n\left(\cosh(\beta\chi)\right)^{2/\beta^2}. \tag{3}$$

The Floquet charts of the described simple T-model are presented in Fig. 1, for representative choice of parameters $\alpha = 10^{-3}$ and $n = 4$ for which the strong instability of the spectator's linear perturbations $\delta\chi$ are predicted (right panel of Fig. 1). Plotted real parts of the Floquet exponents μ_k are functions of the maximal value of the homogeneous inflaton background during oscillation, denoted as ϕ (vertical axis of plots) and the wavevector k of the induced mode of fluctuations (horizontal axis). As was already noticed in [1], fluctuations of the spectator are characterised by higher values of real parts of Floquet exponents, *i.e.* are more unstable than the inflaton's perturbations.

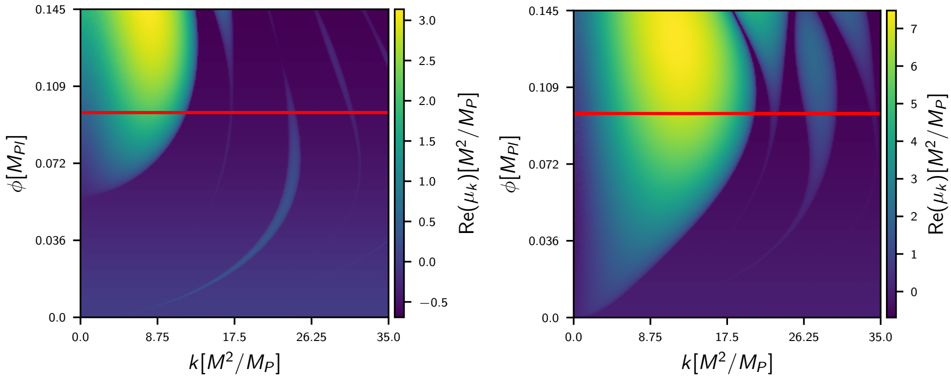

Fig. 1. Floquet charts for the inflaton ϕ (left panel) and the spectator χ (right panel) in the T-model, for $\alpha = 10^{-3}$ and $n = 4$, for evolution along the radial direction. The red lines indicate the end of inflation.

The hypernatural T-model was introduced in [6], in the parametrisation leading to the potential in the form

$$V(\varphi, \vartheta) = M^4 \left[\left(1 - c^{-2} \tanh^2 \frac{\varphi}{\sqrt{6\alpha}} \right) + 8A \cos^2 \frac{n\vartheta}{2} \tanh^{n+2} \frac{\varphi}{\sqrt{6\alpha}} \right] , \quad (4)$$

which emphasises the connection with well-known natural inflation.

The parametrisation of [6] is not convenient for studying preheating in a situation when the inflation proceeds along the radial direction φ (with $\vartheta = \text{const.}$), since linear fluctuations of the spectator $\delta\vartheta$ are not canonically normalised along the inflationary path.

In the previously introduced parametrisation, the hypernatural generalisation of the T-model has the potential given by

$$\begin{aligned} V(\phi, \chi) \;=\; & M^4 \left[\left(1 - c^{-2} \left(\frac{\cosh(\beta\phi)\cosh(\beta\chi) - 1}{\cosh(\beta\phi)\cosh(\beta\chi) + 1} \right)^2 \right) \right. & (5) \\ & -4A \left(\frac{\cosh(\beta\phi)\cosh(\beta\chi) - 1}{\cosh(\beta\phi)\cosh(\beta\chi) + 1} \right) \\ & \times \left[\left(\frac{\sinh(\beta\phi)\cosh(\beta\chi) + i\sinh(\beta\chi)}{\cosh(\beta\phi)\cosh(\beta\chi) + 1} \right)^n \right. \\ & + \left(\frac{\sinh(\beta\phi)\cosh(\beta\chi) - i\sinh(\beta\chi)}{\cosh(\beta\phi)\cosh(\beta\chi) + 1} \right)^n \\ & \left. \left. - \left(\frac{\cosh(\beta\phi)\cosh(\beta\chi) - 1}{\cosh(\beta\phi)\cosh(\beta\chi) + 1} \right)^{n/2} \right] \right] , & (6) \end{aligned}$$

with 4 parameters α, c, A, and n.

The Floquet charts for the hypernatural T-model are presented in Fig. 2 for an exemplary set of parameters.

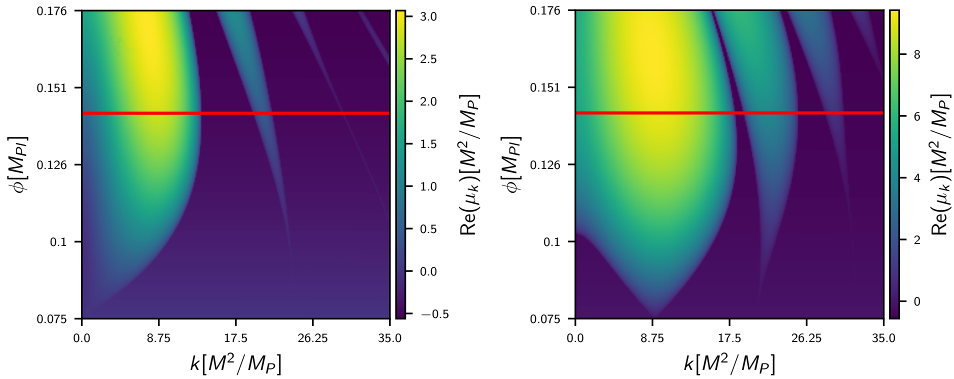

Fig. 2. Floquet charts for the inflaton ϕ (left panel) and the spectator χ (right panel) in the hypernatural T-model, for $\alpha = 10^{-3}$, $c = 0.75$, $A = 1$ and $n = 4$, for evolution along the radial direction. The red lines indicate the end of inflation.

3. Conclusions

The computed Floquet exponents in the T-model and the hypernatural T-model show that efficient preheating is possible in these models due to the significant growth of fluctuations in the spectator direction χ. A comparison of Figs. 1 and 2 shows that the Floquet exponents for both models are of the same order, with slightly larger values for the spectator χ in the case of the hypernatural inflation.

Qualitative differences in the shapes of the first instability band for both the inflaton ϕ and the spectator χ can be noticed. The first instability band of the inflaton in the hypernatural model stretches to small amplitudes of oscillations of the homogeneous background, while in the simple T-model, the first instability band is present only for large enough oscillations. The Floquet charts for spectator fields display another intriguing feature. In hypernatural generalisation, long-wavelength modes (small k) are stable for background oscillations with small amplitude (bottom left corner of the chart). In contrast, in the simple T-model, the first instability band extends up to vanishing amplitude for IR modes.

Hypernatural generalization of α-attractors has more parameters than the simple models, such as the T-model and the E-model, extensively studied in the past, thus the broad study of the parametric dependence of the instability pattern for these models needs to be performed. However, this is beyond the scope of the current manuscript and is postponed for future research.

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