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 simple α-attractor T-model (in linear approximation) to the recently proposed α-attractor hypernatural T-model.

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 produced. This growth can very efficiently transfer the energy of the homogeneous scalar field to spacial fluctuations. Thus, preheating serves as the first stage of reheating in many models.

Preheating can be studied using 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*, which real parts describe the rate of the exponential growth of the fluctuations.

In this manuscript, Floquet exponents calculated in [1] for simple T-model [3, 4, 5] are compared with newly computed ones for the hypernatural inflation T-model proposed in [6].

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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 [7, 8, 5, 4, 9, 10, 11, 12, 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:

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

One of the simplest and mostly studied models of this class is known as 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 stabilized 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, parametrizing the complex scalar component of the T superfield.

The parametrization, in terms of ϕ and χ fields, used in [1, 14] was constructed in such a way to obtain canonical kinetic terms for considered linear fluctuations along the inflationary trajectory ($\chi = const$) 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

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

Floquet charts of 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 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 characterized by higher values of real parts of Floquet exponents, i.e. are more unstable than the inflaton's perturbations.

Hypernatural T-model was introduced in [6], in the parametrization leading to the potential in the form

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

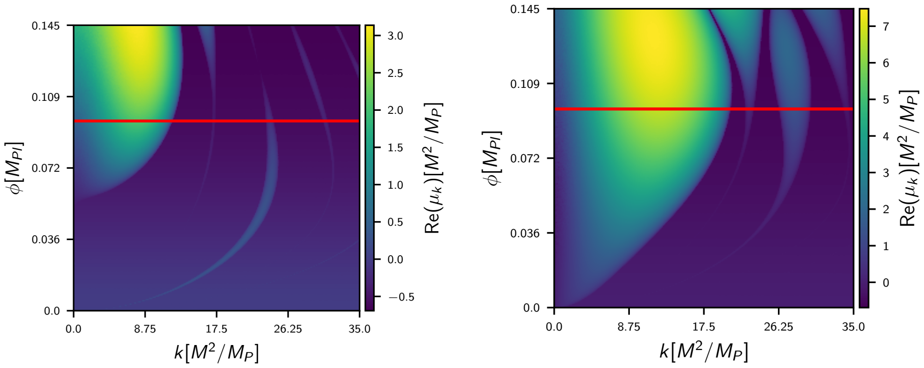

Fig. 1. Floquet charts for the inflaton ϕ (left panel) and the spectator χ (right panel) in the T-model, for $\alpha = 10^{-3}$ and $n = 4$, for evolution along the radial direction.

which emphasises the connection with well-known natural inflation.

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

In the previously introduced parametrization, the hypernatural generalization of the T-model has the potential given by

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

with 4 parameters α, c, A and n.

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

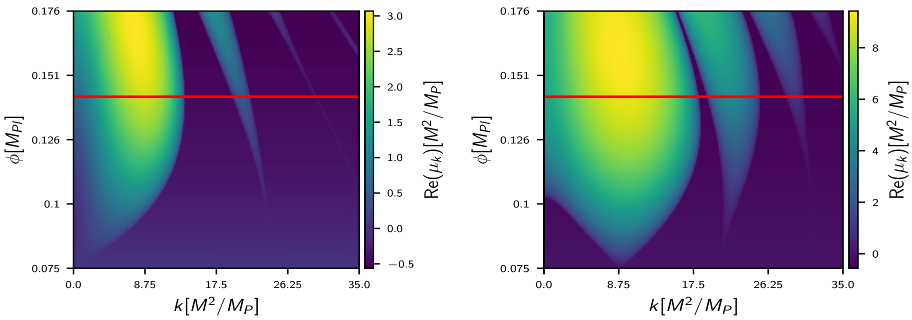

Fig. 2. Floquet charts for the inflaton ϕ (left panel) and the spectator χ (right panel) in the hypernatural T-model, for $\alpha = 10^{-3}$, $c = 0.75$, $A = 1$ and $n = 4$, for evolution along the radial direction.

3. Conclusions

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. Comparison of Figs. 1 and 2 shows that Floquet exponents for both models are of the same order, with slightly larger values for spectator χ in the case of the hypernatural inflation.

Qualitative differences in shapes of the first instability band for both inflaton ϕ and 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. Floquet charts for spectator fields display another intriguing feature. In hypernatural generalization, 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 have more parameters than simple models, like the T-model and the E-model, extensively studied in the past, thus the broad study of parametric dependence of the instability pattern for these models need to be performed, which is however beyond the scope of the current manuscript and is postponed for the future research.

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REFERENCES

[1] T. Krajewski, K. Turzyński, and M. Wieczorek, "On preheating in α-attractor models of inflation," *Eur. Phys. J. C*, vol. 79, no. 8, p. 654, 2019.

[2] K. Turzyński and M. Wieczorek, "Floquet analysis of self-resonance in single-field models of inflation," *Phys. Lett. B*, vol. 790, pp. 294–302, 2019.

[3] R. Kallosh and A. Linde, "Universality class in conformal inflation," *Journal of Cosmology and Astroparticle Physics*, vol. 2013, p. 002–002, July 2013.

[4] R. Kallosh, A. Linde, and D. Roest, "Superconformal Inflationary α-Attractors," *JHEP*, vol. 11, p. 198, 2013.

[5] R. Kallosh and A. Linde, "Multi-field Conformal Cosmological Attractors," *JCAP*, vol. 12, p. 006, 2013.

[6] A. Linde, D.-G. Wang, Y. Welling, Y. Yamada, and A. Achúcarro, "Hypernatural inflation," *JCAP*, vol. 07, p. 035, 2018.

[7] S. Ferrara, R. Kallosh, A. Linde, and M. Porrati, "Minimal Supergravity Models of Inflation," *Phys. Rev. D*, vol. 88, no. 8, p. 085038, 2013.

[8] R. Kallosh and A. Linde, "Non-minimal Inflationary Attractors," *JCAP*, vol. 10, p. 033, 2013.

[9] R. Kallosh and A. Linde, "Planck, LHC, and α-attractors," *Phys. Rev. D*, vol. 91, p. 083528, 2015.

[10] J. J. M. Carrasco, R. Kallosh, and A. Linde, "Cosmological Attractors and Initial Conditions for Inflation," *Phys. Rev. D*, vol. 92, no. 6, p. 063519, 2015.

[11] J. J. M. Carrasco, R. Kallosh, A. Linde, and D. Roest, "Hyperbolic geometry of cosmological attractors," *Phys. Rev. D*, vol. 92, no. 4, p. 041301, 2015.

[12] S. Ferrara and R. Kallosh, "Seven-disk manifold, α-attractors, and B modes," *Phys. Rev. D*, vol. 94, no. 12, p. 126015, 2016.

[13] A. Achúcarro, R. Kallosh, A. Linde, D.-G. Wang, and Y. Welling, "Universality of multi-field α-attractors," *JCAP*, vol. 04, p. 028, 2018.

[14] T. Krajewski and K. Turzyński, "(P)reheating and gravitational waves in α-attractor models," *JCAP*, vol. 10, p. 005, 2022.