## Reheating in Inflationary Cosmology: Theory and Applications

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Reheating is an important part of inflationary cosmology. It describes the production of Standard Matter particles after the phase of accelerated expansion. We give a review of the reheating process, focusing on an in-depth discussion of the preheating stage which is characterized by exponential particle production due to a parametric resonance or tachyonic instability. We give a brief overview of the thermalization process after preheating and end with a survey of some applications to supersymmetric theories and to other issues in cosmology such as baryogenesis, dark matter and metric preheating.

## Contents

## INTRODUCTION

I.	Introduction	1	The inflationary model [1] has become the current
тт	Inflation Models and Initial Conditions for	210	paradigm of early universe cosmology. The first key
11.	Reheating	2	aspect of the model is a phase of accelerated expan-
	Itelleating	4	sion of space which can explain the overall homogene-
TTT	Inflaton Decay	3	ity, spatial flatness and large size of the current universe.  Microscopic-scale quantum vacuum fluctuations during
111.	A. Perturbative Decay	3	the phase of acceleration are red-shifted to currently ob-
	B. Preheating	4	servable scales, and lead to a spectrum of cosmological
	C. Preheating in an Expanding Background	5	fluctuations which becomes scale-invariant in the limit in
	D. Termination of Preheating	6	which the expansion rate becomes constant in time [2].
	~	7	Reheating at the end of the period of accelerated ex-
	E. Tachyonic Preheating	1	pansion is an important part of inflationary cosmology.
T3/	Thermalization	7	Without reheating, inflation would leave behind a uni-
1 V .	A. Perturbative Considerations	7	verse empty of matter. Reheating occurs through cou-
	B. Non-Perturbative Considerations	8	pling of the inflaton field $\phi$ , the scalar field generating
	B. Non-1 et du bative Considerations	O	the accelerated expansion of space, to Standard Model
$\mathbf{V}$	Reheating in Supersymmetric Models	9	(SM) matter. Such couplings must be present at least
٠.	A. Inflaton Couplings to Matter Fields	9	via gravitational interactions. However, in many models
	B. Supersymmetric Flat Directions	10	of inflation there are couplings through the matter sector
	C. Perturbative Decay	10	of the theory directly.
	D. Non-perturbative Decay	10	Reheating was initially [3] analyzed using first order
	E. Thermalization	11	perturbation theory and discussed in terms of the decay
	E. Thermanzation	11	of an inflaton particle into SM matter particles. As first
VI.	Consequences of Reheating/Preheating	12	realized in [4] (see also [5]), such a perturbative analy-
	A. Non-thermal Particle Creation	12	sis may be rather misleading since it does not take into account the coherent nature of the inflaton field. A new
	1. Baryogenesis and Leptogenesis:	12	view of reheating was then proposed [4] which is based on
	2. Dark matter:	12	the quantum mechanical production of matter particles
	3. Moduli and Gravitino Production	12	in a classical background inflaton field <sup>1</sup> . As this analysis
	B. Metric Preheating	13	showed, it is likely that reheating will involve a paramet-
	1. Entropy fluctuations	13	ric resonance instability. This proposal was studied more
	2. Gravity waves:	14	carefully in [8, 9] and then analyzed in detail in [10]. The
	2. Gravity waves.	17	term "preheating" was coined [8] to describe the initial

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energy transfer from the inflaton field to matter particles.

VII. Discussion and Conclusions

Acknowledgments

<sup>&</sup>lt;sup>1</sup> See also [6, 7] for other approaches to the out-of-equilibrium dynamics of the inflaton field.

References