Reheating in Inflationary Cosmology: Theory and Applications

Rouzbeh Allahverdi [1], Robert Brandenberger [2], Francis-Yan Cyr-Racine [3], Anupam Mazumdar [4, 5]
[1] *Physics Department, University of New Mexico, Albuquerque, NM, 87131, USA*
[2] *Physics Department, McGill University, H3A 2T8, Canada.*
[3] *Department of Physics and Astronomy, Univ. of British Columbia, Vancouver, BC, V6T 1Z1, Canada.*
[4] *Physics Department, Lancaster University, Lancaster LA1 4YB, United Kingdom.*
[5] *Niels Bohr Institute, Blegdamsvej-17, Copenhagen, DK-2100, Denmark.*

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

I. INTRODUCTION

The inflationary model [1] has become the current paradigm of early universe cosmology. The first key aspect of the model is a phase of accelerated expansion of space which can explain the overall homogeneity, spatial flatness and large size of the current universe. Microscopic-scale quantum vacuum fluctuations during the phase of acceleration are red-shifted to currently observable scales, and lead to a spectrum of cosmological fluctuations which becomes scale-invariant in the limit in which the expansion rate becomes constant in time [2].

Reheating at the end of the period of accelerated expansion is an important part of inflationary cosmology. Without reheating, inflation would leave behind a universe empty of matter. Reheating occurs through coupling of the inflaton field ϕ, the scalar field generating the accelerated expansion of space, to Standard Model (SM) matter. Such couplings must be present at least via gravitational interactions. However, in many models of inflation there are couplings through the matter sector of the theory directly.

Reheating was initially [3] analyzed using first order perturbation theory and discussed in terms of the decay of an inflaton particle into SM matter particles. As first realized in [4] (see also [5]), such a perturbative analysis may be rather misleading since it does not take into account the coherent nature of the inflaton field. A new view of reheating was then proposed [4] which is based on the quantum mechanical production of matter particles in a classical background inflaton field [1]. As this analysis showed, it is likely that reheating will involve a parametric resonance instability. This proposal was studied more carefully in [8, 9] and then analyzed in detail in [10]. The term "preheating" was coined [8] to describe the initial energy transfer from the inflaton field to matter particles.

[1] See also [6, 7] for other approaches to the out-of-equilibrium dynamics of the inflaton field.