

Cosmological global dynamical systems analysis

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Abstract

We consider a dynamical systems formulation for models with an exponential scalar field and matter with a linear equation of state in a spatially flat and isotropic spacetime. In contrast to earlier work, which only considered linear hyperbolic fixed point analysis, we do a center manifold analysis of the non-hyperbolic fixed points associated with bifurcations. More importantly though, we construct monotonic functions and a Dulac function. Together with the complete local fixed point analysis this leads to proofs that describe the entire global dynamics of these models, thereby complementing previous local results in the literature.

Keywords: cosmology, dynamical systems, global dynamics, scalar field, perfect fluid

1. Introduction

Dynamical systems and dynamical systems methods were introduced in cosmology in 1971 by Collins [1] who treated two-dimensional dynamical systems while Bogoyavlensky and Novikov (1973) [2] used dynamical systems techniques for higher dimensional dynamical systems in cosmology. This early work has subsequently been followed up and extended by many researchers, see e.g. [3–5]. The first dynamical systems analysis involving a minimally coupled scalar field was given by Belinskii and co-workers [6–9] who used dynamical systems to explore inflation, primarily focusing on the potentials $V(\varphi) = \frac{1}{2}m^2\varphi^2$ and $V(\varphi) = \frac{1}{2}\lambda(\varphi^2 - \varphi_0^2)^2$. In 1987 Halliwell [10] treated an exponential scalar field potential in Friedmann–Lemaître–Robertson–Walker (FLRW) cosmology, where the scalar field and an

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