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Einstein's Field Equations as a Fold Bifurcation

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Abstract

It is shown that Einstein's field equations for *all* perfect-fluid $k = 0$ FLRW cosmologies have the same form as the topological normal form of a fold bifurcation. In particular, we assume that the cosmological constant is a bifurcation parameter, and as such, fold bifurcation behaviour is shown to occur in a neighbourhood of Minkowski spacetime in the phase space. We show that as this cosmological constant parameter is varied, an expanding and contracting de Sitter universe *emerge* via this bifurcation.

1 Introduction

The Einstein field equations of General Relativity are a highly nonlinear system of partial differential equations. In particular, for a four-dimensional spacetime, they consist of a coupled set of ten, nonlinear, hyperbolic partial differential equations. By examining Einstein's equations (in combination with Killing's equations) in the context of different types of matter configurations, one is able to form very detailed studies of the dynamics of cosmological models, which are largely governed by classical general relativity. It is then expected that many of the strong nonlinearities are present in these cosmological models as well [1].

In fact, in considering spatially homogeneous cosmological models, the Einstein field equations themselves become a coupled system of nonlinear *ordinary* differential equations [2], and are thus ripe for study using various techniques from dynamical systems theory [3].

One such area of interest is in the possible applicability of bifurcation theory to these cosmological models. Bifurcations naturally arise in such models, as the majority of these cosmological models are dependent on at least one free parameter. As such, it is interesting to see how the local stability of fixed points of the Einstein field equations changes with

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