

## Nonsingular cosmological models: the massive scalar field case

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**Abstract.** The nonminimal coupling of a massive self-interacting scalar field with a gravitational field is studied. Spontaneous symmetry breaking occurs in the open universe even when the sign on the mass term is positive. In contrast to grand unified theories, symmetry breakdown is more important for the early universe and it is restored only in the limit of an infinite expansion. Symmetry breakdown is shown to occur in flat and closed universes when the mass term carries a wrong sign. The model has a naturally defined effective gravitational coupling coefficient which is rendered time-dependent due to the novel symmetry breakdown. It changes sign below a critical value of the cosmic scale factor indicating the onset of a repulsive field. The presence of the mass term severely alters the behaviour of ordinary matter and radiation in the early universe. The total energy density becomes negative in a certain domain. These features make possible a nonsingular cosmological model for an open universe. The model is also free from the horizon and the flatness problems.

**Keywords.** Symmetry breaking; cosmology; nonsingular cosmological models.

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### 1. Introduction

The most widely accepted model of the Universe today is the Friedmann-Robertson-Walker big bang model which is based on the general theory of relativity. It is rightly titled as the standard model, being the only one which is capable of explaining satisfactorily most of the cosmological data obtained in the past few decades. The cosmological redshift, the microwave background radiation, the relative abundance of elements are but only a few things which the model can account for (Weinberg 1972). However, it is well known that the big bang cosmology can at best be a working model which would guide us in our endeavour to understand the true nature of the Universe. The reason for this belief is that some of the drawbacks of the model like the initial singularity are conceptual in nature. These obstacles are not due to any spurious assumptions made in constructing the model; rather they are generic to general relativity on which the model is based (Hawking and Penrose 1970; Hawking and Ellis 1973). So one hopes that some day we would have a theory which would most likely give us a model of the Universe which would be rid of the problems encountered in the standard model. It is believed that a quantum theory of gravity would solve many problems confronted not just in cosmological models but elsewhere in general relativity. Using De Witt's formulation of quantum gravity Hawking has shown that for a Friedmann-Robertson-Walker universe minimally coupled to a