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Exact cosmological solutions with nonminimal derivative coupling

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Abstract

We consider a gravitational theory of a scalar field φ with nonminimal derivative coupling to curvature. The coupling terms have the form κ1Rφ,μφ,μ and κ2Rμνφ,μφ,ν, where κ1 and κ2 are coupling parameters with dimensions of length squared. In general, field equations of the theory contain third derivatives of gμν and φ. However, in the case -2κ1=κ2≡κ, the derivative coupling term reads κGμνφ,μφ,ν and the order of corresponding field equations is reduced up to second one. Assuming -2κ1=κ2, we study the spatially-flat Friedman-Robertson-Walker model with a scale factor a(t) and find new exact cosmological solutions. It is shown that properties of the model at early stages crucially depend on the sign of κ. For negative κ, the model has an initial cosmological singularity, i.e., a(t)~(t-ti)2/3 in the limit t→ti; and for positive κ, the Universe at early stages has the quasi-de Sitter behavior, i.e., a(t)~eHt in the limit t→-∞, where H=(3κ)-1. The corresponding scalar field φ is exponentially growing at t→-∞, i.e., φ(t)~e-t/κ. At late stages, the Universe evolution does not depend on κ at all; namely, for any κ one has a(t)~t1/3 at t→∞. Summarizing, we conclude that a cosmological model with nonminimal derivative coupling of the form κGμνφ,μφ,ν is able to explain in a unique manner both a quasi-de Sitter phase and an exit from it without any fine-tuned potential.

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