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ORIGINAL ARTICLE

Accelerating universe with time variation of G and Λ

F. Darabi

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Abstract We study a gravitational model in which *scale transformations* play the key role in obtaining dynamical G and Λ. We take a non-scale invariant gravitational action with a cosmological constant and a gravitational coupling constant. Then, by a scale transformation, through a dilaton field, we obtain a new action containing cosmological and gravitational coupling terms which are dynamically dependent on the dilaton field with Higgs type potential. The vacuum expectation value of this dilaton field, through spontaneous symmetry breaking on the basis of *anthropic principle*, determines the time variations of G and Λ. The relevance of these time variations to the current acceleration of the universe, coincidence problem, Mach's cosmological coincidence and those problems of standard cosmology addressed by inflationary models, are discussed. The current acceleration of the universe is shown to be a result of phase transition from radiation toward matter dominated eras. No real coincidence problem between matter and vacuum energy densities exists in this model and this apparent coincidence together with Mach's cosmological coincidence are shown to be simple consequences of a new kind of scale factor dependence of the energy momentum density as $\rho \sim a^{-4}$. This model also provides the possibility for a super fast expansion of the scale factor at very early universe by introducing exotic type matter like cosmic strings.

Keywords Time variation of G and Λ · Acceleration of the universe

F. Darabi (✉)
Department of Physics, Azarbaijan University of Tarbiat Moallem, Tabriz 53714-161, Iran
e-mail: f.darabi@azaruniv.edu

F. Darabi
Research Institute for Astronomy and Astrophysics of Maragha (RIAAM), Maragha 55134-441, Iran

1 Introduction

The question of varying gravitational "constant" has been among the most controversial issues in fundamental physics. It raised by Dirac who introduced the large number hypothesis (Dirac 1937, Paper I; Dirac 1938, Paper II; Dirac 1979, Paper III), and has recently become a subject of intensive experimental and theoretical studies (Uzan 2003). Modern theories, like the string/M-theory or brane models do not necessarily require such a variation but they provide a natural and self consistent framework for such variations by assuming the existence of additional dimensions. Time variation of couplings in these multidimensional theories has also recently been studied and their consistency with the available observational data for distant Type Ia supernovae has been analyzed in Loré-Aguilar et al. (2003). It was shown that in these models a small variation of gravitational coupling arises that makes distant supernovae to appear brighter, in contradiction with recent observations of high z supernovae. However, due to the fact that the magnitude of the effect is not large enough, one could not safely discard these multidimensional models. For example, a positive rate of variation $\frac{\dot{G}(t)}{G(t)}$ has been predicted within a $N = 1$ ten-dimensional supergravity and with non-dynamical dilaton (Wu and Wang 1986).

There are also other models in which the time variation of couplings is generated by the dynamics of a cosmological scalar (dilaton) field. For example, Damour et al. have constructed a generalized Jordan-Brans-Dicke model in which the dilaton field couples with different strengths to visible