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ORIGINAL ARTICLE

Steady Flow cosmological model

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Abstract The possibility that the cosmological constant is decaying as the observable universe grows is explored, and we define a cosmological parameter, depending of the vacuum energy and the universe radius, which should be presently ca. 122 orders of magnitude smaller than at the Planck epoch. From it, a new version of the Friedmann equation for a flat universe is obtained, which allows the estimation of the Hubble parameter at any epoch and the reconstruction of the expansion history. The main result is a quasi-linear expansion dynamics in concurrence with a number of previous works. This behavior is compatible with the main features of observational cosmology and avoids the horizon, flatness, cosmological constant, coincidence and age problems without the need of neither inflation nor initial fine-tuning.

Keywords Cosmological constant · Hubble flow · Primordial nucleosynthesis · Cosmology: theory · Early universe

1 Introduction

During decades the expansion of the universe was assumed to be decelerated by gravitation and the Einstein–de Sitter model without cosmological constant (Λ) was favored as the Standard cosmology (see e.g. curve $\Omega_{\mathrm{M}} = 0.3$ in Fig. 1). However, measurements of type Ia supernovae (SNe Ia) demonstrated that their luminosity distance is larger than expected in such a model (Perlmutter et al. 1998a, 1998b; Riess et al. 1998, 2001; Tonry et al. 2003; Wang et al. 2003). In order to fit these observations within a new Standard model, a positive Λ was reintroduced in the Friedmann equations and a repulsive dark energy, derived from the concept of cosmological constant, has been postulated to drive an slightly accelerated expansion of the universe in our epoch.

The resulting Concordance model, gives a quite elaborate picture for the dynamics of the universe: an inflationary period, right after the initial creation event, with an exponential acceleration, followed by a long lasting deceleration era (including 2 different expansion regimes depending on radiation or matter dominance) and, since redshift $z \sim 1$, a new era of tiny acceleration driven by dark energy (see upper curve of Fig. 1). In this description the role of Λ is still unclear since it appears and disappears as required. Even so, a possible relationship between a minuscule Λ today and a large cosmological term driving inflation, along with the important number of works on the subject (Sahni and Starobinsky 2000), advise considering seriously the case for a $\Lambda > 0$.

The current value of Λ obtained from cosmological data is of the order of $10^{-9}\ \mathrm{J\,m^{-3}}$. At a theoretical level, dark energy was formerly identified with the vacuum energy, which is expected to arise out of zero-point quantum vacuum fluctuations of several fundamental fields. In Quantum Field theory (QFT), these fluctuations would have Planck energy density, i.e. about $10^{113}\ \mathrm{J\,m^{-3}}$. So, the discrepancy between theory and observations is of 122 orders of magnitude. Such a huge gap constitutes the cosmological constant problem (Weinberg 1989). The nature and composition of dark energy remains one of the major challenges of modern cosmology.

As a related issue, the cosmic coincidence problem wonders why the density of matter, which decreases as the universe expands, and Λ, which should be constant by defini-

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