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ORIGINAL ARTICLE

Inhomogeneities as a possible factor responsible for the acceleration of the Universe: a (2 + 1)-gravity study

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Abstract Here we present an inhomogeneous cosmological model, in $2+1$ gravity, which satisfy all the energy conditions, although it generates non deaccelerated universes. We work in a self-similar $2+1$ gravity scenario, in order to simplify the equations system and to allow us to find analytical and simple solutions. Our propose is basically to improve our understanding on the role of inhomogeneities on the acceleration of the Universe.

Keywords Accelerated universe · Inhomogeneities · $(2+1)$-gravity · Energy conditions

1 Introduction

Over the past decade, one of the most remarkable problems is to explain the acceleration of the Universe as inferred by supernovae Ia (Riess et al. 1998, 2004; Perlmutter et al. 1999; Astier et al. 2006) and confirmed later by cross checks from the cosmic microwave background radiation (Bennett et al. 2003; Spergel et al. 2003) and large scale structure (Tegmark et al. 2004; Abazajian et al. 2003, 2004, 2005; Hawkins et al. 2003; Verde et al. 2002). In the standard cosmological model, to account for such an expansion, one needs to introduce a component to the matter fields of the Universe with a large negative pressure, which is dubbed as *dark energy*. In this context, astronomical observations indicate that our Universe is flat and currently consists of approximately 70% dark energy, 25% dark matter and 5% baryon matter and radiation. The nature of dark energy is unknown and many radically different models have been proposed, such as, quintessence (Caldwell et al. 1998; Liddle and Scherrer 1999; Steinhardt et al. 1999), Chaplygin gas (Kamenshchik et al. 2001), phantom (Caldwell 2002), and dark energy in brane worlds (Cai and Wang 2005; Sahni 2005; Yang and Wang 2005), among many others. (See the review articles Carroll 2001; Padmanabhan 2003; Peebles and Ratra 2002; Sahni and Starobinsky 2000; Sahni 2004, and references therein.)

Nowadays, there is an interesting debate in the literature, concerning if the standard model of cosmology is able to describe a averaged model (Buchert 2007). If this is confirmed, we have to conjecture that backreaction effects are negligible. In addition, the concomitance between the onset of the apparent acceleration and the beginning of structure formation in the Universe suggest that the SN Ia observations could be consequence of an effect of large scale inhomogeneities (Célérier 2000, 2005, 2007; Carroll 2001; Dabrowski and Hendry 1998; Pascual-Sanchez 1999; Tomita 2000). Besides, at very large scales, even the Universe seeming to be homogeneous and isotropic, as supported by the observed isotropy of the cosmic microwave background, on smaller scales ($\leq$100 Mps) the actual Universe is neither homogeneous nor isotropic. Then the large-scale smooth structure, considered by standard cosmological model, from lumpiest inhomogeneous dynamics on smaller scales needs to be justified (Ellis 1984; Zalaletdinov 2008). Reinforcing these directions, recently Moffat (2007) showed that, the Szafron inhomogeneous cosmological solution can lead to an accelerating inflationary period without a large initial vacuum energy and with $\Lambda = 0$ in the early Universe near the Planck time, combined with an accelerating Universe at late times, in the non-linear regime with galaxy

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