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ORIGINAL ARTICLE

Higher-order Gauss-Bonnet cosmology by Lagrange multipliers

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Abstract We study cosmological models derived from higher-order Gauss-Bonnet gravity $F(R,G)$ by using the Lagrange multiplier approach without assuming the presence of additional fields with the exception of standard perfect fluid matter. The presence of Lagrange multipliers reduces the number of allowed solutions. We need to introduce compatibility conditions of the FRW equations, which impose strict restrictions on the metric or require the introduction of additional exotic matter. Several classes of $F(R,G)$ models are generated and discussed.

Keywords Dark energy · Gauss-Bonnet gravity · Lagrange multiplier

Mauro Francaviglia is deceased.

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1 Introduction

Astrophysical data indicate that the observed universe is in an accelerated phase (Riess et al. 1998; Perlmutter et al. 1998; Hicken et al. 2009; Dunkley et al. 2009; Percival et al. 2010). This acceleration could be induced by the so-called dark energy (see Bamba et al. 2012 for a recent review and references therein) the nature and properties of which are not yet understood at fundamental level.

There are several models for dark energy, but, in general, such a constituent can be figured out, in a coarse grain approach, as being constituted by some ideal fluid whose equation of state (EoS) exhibits non-standard properties, in particular, a non standard adiabatic index. On the other hand, dark energy can be considered as a global phenomenon associated with modifications of gravity (Nojiri and Odintsov 2007; Capozziello and Francaviglia 2008; Cai et al. 2010; Nojiri and Odintsov 2011b; Capozziello and De Laurentis 2011), which are given by extensions of General Relativity (implying modifications of the Hilbert-Einstein action by introducing scalar fields, curvature invariants like the Ricci scalar R or the Ricci and Riemann tensors $R_{\mu\nu}$ and $R^{\alpha}_{\beta\mu\nu}$ or the Gauss-Bonnet topological invariant (Nojiri and Odintsov 2005; Cognola et al. 2006; Nojiri et al. 2006; Koivisto and Mota 2007a, 2007b; Leith and Neupane 2007; Nojiri et al. 2007; Bamba et al. 2007; Granda and Loaiza 2012a; Setare and Saridakis 2008; Sadeghi et al. 2009a, 2009b; Nozari et al. 2009; Granda and Loaiza 2012b; Granda et al. 2013). Such extended actions describe effective theories coming from fundamental interactions (Capozziello and Faraoni 2010) and, from a cosmological point of view, they should consistently describe the early-time inflation and late-time acceleration, without the introduction of any other material dark component. In this picture, the dark side of the universe could be traced as the lack of a final theory