Astrophys Space Sci (2012) 338:211–216
DOI 10.1007/s10509-011-0921-5

ORIGINAL ARTICLE

Noether gauge symmetry for $f(R)$ gravity in Palatini formalism

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Received: 7 October 2011 / Accepted: 5 November 2011 / Published online: 23 December 2011
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Abstract In this study, we consider a flat Friedmann-Robertson-Walker (FRW) universe in the context of Palatini $f(R)$ theory of gravity. Using the dynamical equivalence between $f(R)$ gravity and scalar-tensor theories, we construct a point Lagrangian in the flat FRW spacetime. Applying *Noether gauge symmetry approach* for this $f(R)$ Lagrangian we find out the form of $f(R)$ and the exact solution for cosmic scale factor. It is shown that the resulting form of $f(R)$ yield a power-law expansion for the scale factor of the universe.

Keywords $f(R)$ gravity · Palatini formalism · Noether gauge symmetry

1 Introduction

It is well-known that the Einstein-Hilbert action produces general relativity (GR) which leads mostly to observational success. Furthermore the modified gravity theories issued by more general gravitational actions could explain the observational facts. Observations of the supernovae Type Ia (Riess et al. 1998; Perlmutter et al. 1999) and the cosmic microwave background radiation (Netterfield et al. 2002) indicate that current expansion of the universe is accelerating, on the contrary to Friedmann-Robertson-Walker (FRW) solution of GR. To explain such an accelerated expansion, in the framework of GR, many authors introduced mysterious cosmic fluid, the so-called *dark energy* which can be described by the cosmological constant (Copeland et al. 2006; Durrer and Maartens 2008).

On the other hand, to get a solution of this problem, some modifications in GR theory have been proposed. The $f(R)$ gravity theory is a particular class of modified gravity theories (Sotiriou and Faraoni 2010; Nojiri and Odintsov 2007; De Felice and Tsujikawa 2010). The simplest form of this theory can be constructed by replacing the Ricci scalar R with an arbitrary function $f(R)$ in the Einstein-Hilbert Lagrangian (EHL). In recent literature some different forms of $f(R)$ gravity have been proposed, and discussed in different contexts. For example, it has been shown that early-time inflation and current cosmic acceleration may take place by adding negative and positive powers of curvature into the EHL (Nojiri and Odintsov 2003). Carroll et al. (2004) have also proposed that a small correction to the EHL by adding an inverse term of R would lead to cosmic speed-up which originates from purely gravitational effects. Similar modifications of GR have also been proposed to drive inflation (Starobinsky 1980). On the other hand, it is worth noting that the main deficiency of such theories is that they are seriously constrained by solar system tests (Olmo 2005a; Chiba et al. 2007). A number of viable $f(R)$ models that can satisfy both cosmological and local gravity constraints have been proposed in Amendola et al. (2007), Starobinsky (2007), Cognola et al. (2008).

There are two kinds of Noether symmetry approach for cosmological studies in the literature: The first one is the so-called Noether symmetry approach in which the Lie derivative of a given Lagrangian vanishes (Capozziello and de Ritis 1993; de Ritis et al. 1990; Demianski et al. 1992; Sanyal and Modak 2001; Camci and Kucukakca 2007; de Souza and Kremer 2008) and the second one is the so-called Noether gauge symmetry (NGS) approach (Jamil et

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