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ORIGINAL ARTICLE

Static wormhole solutions in $f(R)$ gravity

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Abstract In this work, we study static spherically symmetric wormhole solutions in $f(R)$ gravity. We explore wormhole solutions for anisotropic and isotropic fluids as well as barotropic equation of state with radial pressure. The behavior of weak and null energy conditions is investigated in each case. It is found that these energy conditions are violated for both the anisotropic and isotropic case but are satisfied for barotropic fluids in particular regions. This confirms the existence of wormholes obeying the energy conditions in these regions.

Keywords Modified gravity · Wormholes

1 Introduction

Several independent observational data of high precision provide an evidence for the accelerated expansion of the universe (Perlmutter et al. 1999; Riess et al. 2001; Bennett et al. 2003). This suggests that apart from baryonic and dark matter, a new component with large negative pressure must be present to account for such an expansion. This component, termed as dark energy, dominates the total energy density of the universe. The simplest candidate for dark energy is the cosmological constant (Λ), but it faces problems like the cosmic coincidence and the fine tuning.

Modifying gravity is another approach to explain the cosmic acceleration providing a gravitational alternative to dark energy. This gives rise to alternate theories of gravity like $f(T)$ gravity (Ferraro and Fiorini 2007; Bengochea and Ferraro 2009; Linder 2010), Gauss-Bonnet gravity (Carroll et al. 2005; Cognola et al. 2006), etc. The $f(R)$ theory of gravity is the outcome of these attempts which helps to explore cosmic expansion. It is the simplest modification to general relativity as the Einstein-Hilbert action for this gravity contains an arbitrary function of the Ricci scalar $f(R)$. Such a modification was first proposed by Buchdahl (1970) and was further developed by some other people (Duruisseau et al. 1983; Kerner 1982).

In the context of cosmic expansion, models of the form $f(R) \propto R^2$ were first studied to explain the inflationary scenario (Allemandi et al. 2004; Corda and Mosquera Cuesta 2011; Corda et al. 2012) but failed to account for the late-time cosmic acceleration. The Starobinsky (1980) inflationary model is the most popular example of such models. On the other hand, models containing inverse powers of R were also analyzed (Capozziello et al. 2006, Nojiri and Odintsov 2003, 2006) which help to explain the current accelerated expansion of the universe but faced some problems (Chiba 2003; Dominguez and Barraco 2004). The $f(R)$ gravity provides a natural unification of the early-time inflation and late-time cosmic acceleration. It was shown that the $f(R)$ models containing both positive and negative powers of R can account for such a unification (Nojiri and Odintsov 2007, 2011). These models also pass the solar system tests. The terms containing positive powers of R become dominant at the early epoch and account for the inflation while those with negative powers play the role of DE and support the current expansion.

A wormhole is a hypothetical path, tunnel or bridge connecting two different parts of the spacetime through which observers may traverse freely. Morris and Thorne (1988) showed that there could exist wormhole like solutions of the

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