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ORIGINAL ARTICLE

Three classical tests of Hořava-Lifshitz gravity theory

Shi-Wei Zhou · Wen-Biao Liu

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Abstract Recently, a renormalizable gravity theory has been proposed by Hořava, and it might be an ultraviolet completion of general relativity or its infrared modification. Particular limit of the theory allows for the Minkowski vacuum. A spherical asymptotically flat black hole solution that represents the analogy of Schwarzschild solution of general relativity has been obtained. It will be very interesting to find the difference between traditional general relativity and Hořava-Lifshitz gravity theory. The three classical tests of general relativity including gravitational red-shift, perihelion precession of the planet Mercury, and light deflection in gravitational field in the spherical asymptotically flat black hole solution of infrared modified Hořava-Lifshitz gravity are investigated. The first order corrections from the standard general relativity is obtained. The result can be used to limit the parameters in Hořava-Lifshitz gravity and to show the viability of the theory.

Keywords Schwarzschild space-time · Gravitational red-shift · Perihelion precession · Light deflection · Hořava-Lifshitz gravity

1 Introduction

Recently, Hořava proposed a non-relativistic renormalizable theory of gravitation (Hořava 2009), which is inspired by the anisotropic scaling between time and space in condensed matter systems, where the degree of anisotropy between space and time is characterized by the "dynamic critical exponent" z. It is well-known that relativistic systems automatically satisfy $z = 1$ as a consequence of Lorentz invariance. In Hořava-Lifshitz theory, systems' scaling at a short distance exhibits a strong anisotropy between space and time with $z > 1$. This will change the short-distance behavior of the theory. The anisotropy at short distance can be lost for long distance while the Lorentz symmetry would appear as an emergent symmetry. After Hořava-Lifshitz gravity was proposed, much attention has been attracted. In Lü et al. (2009), a static spherical black hole solution in Hořava-Lifshitz gravity theory was given. In Cai et al. (2009a, 2009b), Cai and Ohta (2010), Castillo and Larranga (2011), Myung and Kim (2009), Ghodsi and Hatefi (2010), Zhou and Liu (2011), the topological black hole solutions were obtained and the associated thermodynamic properties were discussed. Moreover, a great deal of efforts have been made on the application on cosmology, dark energy, and dark matter under Hořava-Lifshitz theory (Park 2010; Setare 2009; Kiritsis and Kofinas 2009; Piao 2009; Mukohyama et al. 2009).

The black hole solution of original Hořava-Lifshitz gravity doesn't recover the usual Schwarzschild-anti-de Sitter black hole with the detailed-balance condition. A relevant operator proportional to the $3D$ geometry Ricci scalar of the original Hořava-Lifshitz theory action was introduced (Kehagias and Sfetsos 2009) and it deviated from detailed-balance. This does not modify the ultraviolet properties of the theory. However, it modifies the infrared Hořava-Lifshitz gravity theory. So a Schwarzschild-anti-de Sitter solution can be realized in infrared modified Hořava-Lifshitz gravity theory and the Minkowski vacuum is also allowed. On the limit of vanishing Λ_ω, a spherical black hole solution has been obtained by Kehagias and Sfetsos (2009), which is the analogy of Schwarzschild black hole in general relativity and is exactly asymptotically flat. The low-

S.-W. Zhou · W.-B. Liu (✉)
Department of Physics, Institute of Theoretical Physics, Beijing Normal University, Beijing 100875, China
e-mail: wbliu@bnu.edu.cn