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ORIGINAL ARTICLE

Massive scalar field quasinormal frequencies in black hole with a deficit solid angle

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Abstract Massive scalar field quasinormal modes of black hole with a deficit solid angle are studied by using the third-order WKB approximation. From the numerical results obtained, we find that scalar field with higher mass u will oscillate more quickly but decay more slowly, while with larger deficit solid angle ε will oscillate and decay more slowly. Moreover, the imaginary parts of quasinormal frequencies are almost linearly related to the real parts with u and ε.

Keywords Quasinormal frequencies · WKB approximation · Deficit solid angle

1 Introduction

The concept of quasinormal modes (QNMs) was firstly pointed out by Vishveshwara (1970) in calculations of the scattering of gravitational waves by a black hole. QNMs are characterized by a spectrum of discrete, complex frequencies, whose real parts determine the oscillation frequency and whose imaginary parts determine the rate at which each mode is damped as a result of the emission of radiation. In astrophysics, it is widely believed that the QNMs reflect the characteristic sounds of a black hole and can give a direct way for an astrophysicist to identify the existence of a black hole because QNMs frequencies are independent of the initial perturbation and just dependent on the black hole's mass, electric charge and angular momentum. So, a lot of effort has been devolved into the study of QNMs in different background spacetimes (Nollert 1993; Konoplya 2002; Cho 2003; Cardoso et al. 2004; Berti et al. 2009; Giammatteo and Jing 2005; Chen and Jing 2010; Wang et al. 2010; Wang and Gao 2012; Fernando and Correa 2012; Kim et al. 2012).

In this paper, we will discuss QNMs of black hole with a deficit angle for massive scalar field perturbations. We know that phase transitions of quantum fields in the early universe may produce point-like defects known as monopoles. A black hole with a deficit solid angle occur in the field theories containing the solution of global monopoles, which undergo spontaneous symmetry breaking. The plan of this paper is as follows. In Sect. 2, we consider the massive scalar field equation in this black hole and its reduction into a Schrödinger-like equation with a particular effective potential. In Sect. 3, we evaluate the quasinormal frequencies using the third-order WKB approximation for massive scalar field and the numerical results are obtained. Summary is presented in last section.

2 Metric and massive scalar field perturbation

At first we briefly review the metric of the black hole with a deficit solid angle (Li et al. 2000, 2001). The work under a particular model in unit $c=1$ was study, where the global $O(3)$ symmetry is broken down to $U(1)$. The Lagrangian density is

$$L = g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi^* + \frac{1}{2}g^{\mu\nu}\partial_\mu\sigma^a\partial_\nu\sigma^a - \eta^2\sigma^a\sigma^a\phi\phi^* - \eta^2(\phi\phi^*)^2 - \frac{\lambda^2}{8}(\sigma^a\sigma^a - \sigma_0^2)^2 \quad (1)$$

where σ^a is a triplet of scalar fields, isovector index $a = 1, 2, 3$. ϕ is a complex scalar field with the $U(1)$ symmetry

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