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ORIGINAL ARTICLE

Hawking radiation of Kerr-de Sitter black holes using Hamilton-Jacobi method

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Abstract Hawking radiation of Kerr-de Sitter black hole is investigated using Hamilton-Jacobi method. When the well-behaved Painleve coordinate system and Eddington coordinate are used, we get the correct result of Bekenstein-Hawking entropy before and after radiation but a direct computation will lead to a wrong result via Hamilton-Jacobi method. Our results show that the tunneling probability is related to the change of Bekenstein-Hawking entropy and the derived emission spectrum deviates from the pure thermal but it is consistent with underlying unitary theory.

Keywords Kerr-de Sitter solution · Hawking radiation · Hamilton-Jacobi method

The black hole thermal radiation techniques in quantum field theory was initially discovered by Hawking and the derived radiation spectrum is purely thermal in nature (Hawking 1974, 1975). Hawking radiation is a quantum tunneling process triggered by vacuum fluctuations near the horizon. A virtual particle pair creates spontaneously at a point just inside of the black hole horizon. The positive energy particle tunnels out of the horizon and materializes as a real particle, while the negative energy particle remains behind the horizon and is absorbed by the black hole, causing back reaction of the particles. From the black hole thermodynamics, the surface gravity may be taken as temperature and the area of event horizon is taken as entropy (Bekenstein 1973, 1974; Bardeen et al. 1973). During the study of Hawking thermal radiation, there are two important points to be highlighted. The first point is the information lost, which indicates that a pure quantum state will be changed into a mixed one and its does not satisfy an underlying unitary theory. The second point is the technical problem. Kraus and Wilczek (1994, 1995), Parikh and Wilczek (2000) investigated the Hawking radiation as a quantum tunneling process where a particle moves in a dynamical geometry. They find out the tunneling potential barrier which is created by the outgoing particle and causes of mechanism corresponding to tunneling potential hill has been resolved. Considering energy conservation and unfixed background space-time, the radial null geodesic of the emitted particle and imaginary part of the particle action were obtained. Utilizing the WKB approximation and Hamilton equations, the relationship between tunneling probability and classical action of the particle are derived in the spherically symmetric space-time. Following their work, Zhang and Zhao (2005a, 2005b, 2005c), Yang (2005), Yang et al. (2005), Yang and Chen (2007) have extended the method to charged particle and a great deal of success was made. Recently, Yang and Chen (2007, 2008) investigated the tunneling effect of the rotating non-stationary black holes.

Angheben et al. (2005) put forward another method to deal with the tunneling for extremal and rotating black hole using Hamilton-Jacobi equation and WKB approximation without considering back reaction effect of the emitted particle. In addition, for rotating space-time, the dragging coordinates transformation was not used in the process. They have shown that the Naive coordinate leads to an imaginary contribution of action which is one half of the correct

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