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Higher spins tunneling from a time dependent and spherically symmetric black hole

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Abstract The discussions of Hawking radiation via tunneling method have been performed extensively in the case of scalar particles. Moreover, there are also several works in discussing the tunneling method for Hawking radiation by using higher spins, e.g. neutrino, photon, and gravitino, in the background of static black holes. Interestingly, it is found that the Hawking temperature for static black holes using the higher spins particles has no difference compared to the one computed using scalars. In this paper, we study the Hawking radiation for a spherically symmetric and time dependent black holes using the tunneling of Dirac particles, photon, and gravitino. We find that the obtained Hawking temperature is similar to the one derived in the tunneling method by using scalars.

1 Introduction

General relativity predicts the existence of the black holes, i.e. objects from which nothing can escape. Hawking found that incorporating quantum mechanics changes this understanding as regards black holes [1,2]. He showed that black holes are not completely black. They radiate a thermal spectrum due to the quantum effects. Furthermore, Hawking found a connection between the surface gravity of a black hole and its corresponding temperature.

There are several ways in understanding the mechanism of the black holes to radiate. One of the latest approaches was given by Parikh and Wilczek [3,4], where the radiation of the black holes is described as a quantum tunneling effect of particles through the event horizon. This method is found to be simpler and more intuitive. In the Parikh–Wilczek (PW) method, which sometimes is called the radial null geodesic method, one first computes the amplitude of tunneling across the horizon as an exponentiation of the imaginary part of the corresponding particle's action in the outgoing mode. Then the principle of detailed balance is used to connect the tunneling amplitude with the Boltzmann factor, hence the temperature can be obtained.

In fact, the radial null geodesic method is not the only way to describe the Hawking radiation by using the tunneling mechanism. There is an alternative, known as the Hamilton–Jacobi method [5–8], where one solves the semi-classical equation of motion for the tunneled particles by using the Hamilton–Jacobi ansatz for the corresponding particle's wave function. The treatments of the Hamilton–Jacobi method in discussing the Hawking temperature and black hole thermodynamics for various cases and black holes have been performed in [9–43]. However, most of them are confined to the tunneling of scalar fields where one starts with a Klein–Gordon equation in curved spacetime and solves it by using the Hamilton–Jacobi ansatz.

For static spacetimes, the tunneling mechanism for Hawking radiation has been extended to the case of spin $\frac{1}{2}$ fermion [44,45], as well as photon and gravitino [46]. These works motivated us to study the Hawking mechanism for time dependent black hole's radiation as the tunneling processes of massless higher spins particles. The work presented in this paper can also be considered as an extension of our previous work [47] where we studied the scalar tunneling which gives rise to the Hawking temperature of Vaidya black holes. Since we keep the spherically symmetric and time dependent spacetime metric in this paper quite general, i.e. we stick to a spacetime whose line element can be written as Eq. (5), the results presented in this paper should be relevant to this class of spacetime.[1]

The organization of this paper is as follows. In the next section, we review the null geodesic method for a general time dependent metric background. In Sect. 3, we discuss the tunneling of massless Dirac particles across the time dependent black hole's horizon. By using the solutions of massless Dirac fields and then the detailed balance principle, we can

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[1] For example to those discussed in [48–52].

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