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ORIGINAL ARTICLE

Back reaction and quantum gravity corrections of Hawking radiation from Schwarzschild-de Sitter black hole

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Abstract Following the Parikh and Wilczek semiclassical tunneling method of massless particle, hawking radiation of Schwarzschild-de Sitter (SdS) black hole have been computed using null geodesic method. Purely thermal and quantum gravity corrections have been made and have shown that both the corrections give the same results and all the tunneling rates are related to change of Bekenstein-Hawking entropy of SdS black hole. The results obtained for SdS black hole are also in accordance with Parikh and Wilczek's opinion and gives a correction to the Hawking radiation of SdS black hole.

Keywords Massive particle Tunneling · SdS black hole

1 Introduction

Since the original derivation by Hawking (1974) and Hartle and Hawking (1975) of the radiation produced by black holes, several methods have been developed for deriving Hawking radiation. Among them, a semiclassical tunneling process was initiated by Kraus and Wilezek (1995) which reflects the real process of particle emission from black hole horizon and a lot of works for various spacetimes (Parikh and Wilezek 2000; Hemming and Keski-Vakkuri 2001; Medved 2002; Vagenas 2002, 2003; Zhang and Zhao 2005; Arzano et al. 2005; Medved and Vagenas 2005; Yang and Chin 2005; Liu et al. 2006; Liu 2006; Wu and Jiang 2006; Wu and Gao 2007; Kim 2007; Kim and Korean 2008; Ali 2007; Sarkar and Kothawala 2008; Nozari and Mehdipour 2008; Chen et al. 2008a,b; Jiang et al. 2009; Mehdipour 2010; Matsuno and Umetsu 2011; Usman et al. 2011) have been computed. In this tunneling process, the radiation is described by electron-positron pair creation starting just behind the horizon with the subsequent tunneling of one of the particles of the pair through the horizon to the opposite side and the sum of the particles energy must vanish so that energy conservation is preserved in total. When a particle escapes to infinity the black hole lose mass due to the negative energy of the particles which were excited through the vacuum by the horizon and shrinks slightly so that the radiated particle already appears outside the horizon. In other words, the particle with negative energy tunnels into the horizon and as absorbed, while the particle with positive energy left outside the horizon to infinite distance and forms the Hawking radiation.

For the infalling particles the action is classical, but for the reverse particle that tunneling through the horizon the action will be complex and therefore the probability of tunneling is based on the imaginary path of this action. Kraus and Wilezek (1995) first considered the calculation of the imaginary part of the action for the (classically forbidden) process of s-wave emission across the horizon, which in turn is related to the Boltzmann factor for emission at the Hawking temperature. Using the WKB approximation the tunneling probability for the classically forbidden trajectory of the s-wave coming from inside to outside the horizon is proportional to the exponential of minus twice the imaginary part of the action for this process. There are in general two approaches to obtain the imaginary part of the action: the Parikh-Wilczek radial null geodesic method initiated by Kraus and Wilezek (1995) and the Hamilton-Jacobi method developed by Angheben et al. (2005). In null geodesic method the imaginary part of the action only comes from the integration of the radial momentum p_r for the

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