

Hawking non-thermal and thermal radiations of Schwarzschild anti-de Sitter black hole by Hamilton-Jacobi method

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Abstract The massive particles tunneling method has been used to investigate the Hawking non-thermal and purely thermal radiations of Schwarzschild Anti-de Sitter (SAdS) black hole. Considering the spacetime background to be dynamical, incorporate the self-gravitation effect of the emitted particles the imaginary part of the action has been derived from Hamilton-Jacobi equation. Using the conservation laws of energy and angular momentum we have showed that the non-thermal and purely thermal tunneling rates are related to the change of Bekenstein-Hawking entropy and the derived emission spectrum deviates from the pure thermal spectrum. The result obtained for SAdS black hole is also in accordance with Parikh and Wilczek's opinion and gives a correction to the Hawking radiation of SAdS black hole.

Keywords Massive particle tunneling · SAdS black hole

1 Introduction

According to the information loss paradox (Hawking 1974, 1975), the information carried out by a physical system falling toward black hole singularity has no way to recover after a black hole has completely disappeared because the state of the radiation is determined only by the geometry of

the black hole outside the horizon, and the black hole has no hair that records any detailed information about the collapsing body. With the emission of thermal radiation (Hawking 1974, 1975), a black hole has radiated away most of its mass and becomes smaller and smaller until evaporate away completely. In this basis, many research works on the thermal radiation of black holes have been made (Damour and Ruffini 1976; Gibbons and Hawking 1977; Sannan 1988; Jing 2001). This procedure provides a leading correction to the tunneling probability (emission rate) arising from the reduction of the black hole mass because of the energy carried by the emitted massive quanta.

Taking quantum process into account, the situation has changed. It seems that an initially pure quantum state (original matter), by collapsing to a black hole and then evaporating completely, has evolved to a mixed states (the thermal spectrum at infinity) that violates the fundamental postulate of quantum mechanics due to prescribe a unitary time evolution of basis states. When the black hole has evaporated down to the Planck size, quantum fluctuations dominate and the semi-classical calculations would no longer be valid, as spacetime is subject to violent quantum fluctuations on this scale. Therefore, it is still mysterious how the information be recovered. Recent development of string/M theory and the AdS/CFT correspondence argued that the information could be recovered if the outgoing radiation were not exactly thermal but had subtle corrections (Damour and Ruffini 1976). Other possibilities include the information being contained in a Planckian remnant left over at the end of Hawking radiation or a modification of the laws of quantum mechanics to allow for non-unitary time evolution.

Wilczek and his collaborators have developed two universal methods to correctly recover Hawking radiation of black holes. One is the gravitational anomaly method (Robinson and Wilczek 2005) in which the Hawking radiation can be

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