Study on the Four-dimensional black Hole Vector Particle Tunneling Radiation

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Abstract: Based on the study of tunneling radiation of scalar particles and fermions, the tunneling radiation of vector particles is discussed. The motion of vector particles follows the Proca equation. Using the WKB approximation, the tunneling rate of vector particles in a two-dimensional black hole is studied, and the black hole Hawking temperature is obtained by the tunneling rate. The results show that the black hole temperature can also be obtained by the tunneling radiation of vector particles.

1. Introduction

In the original literature, Hawking believes that black hole radiation is a quantum tunneling effect caused by vacuum fluctuations near the black hole horizon. The tunneling image can be described as: due to the vacuum quantum fluctuation, when a virtual particle pair is generated in the horizon (near the horizon), the negative energy particles are absorbed by the black hole, so that the black hole mass is reduced, and the positive energy particles pass through the tunnel effect. Wear out, and then realize as physical particles to escape to infinity, manifested as Hawking radiation. Conversely, if the virtual particle pair is generated outside the horizon (near the horizon), since the negative energy orbit exists only inside the black hole horizon, the negative energy virtual particle will enter the black hole through the quantum tunnel, and the positive energy particle will escape to infinity, which is expressed as Hawking radiation. In the above two descriptions of Hawking radiation, there is a clear tunneling process. However, most of the proofs about Hawking radiation are not initiated by the quantum tunneling method, because the true meaning of the tunneling process is not found. The barrier on the top. In addition, in many proofs of Hawking radiation, the space-time background is fixed, and the reaction of radiation particles to space and time is not considered. In the above two cases, the obtained Hawking radiation spectrum is a pure thermal spectrum, which leads to the loss of information in the black hole radiation process, and thus destroys the principle of positive in quantum theory. Therefore, Hawking's black hole radiation theory has encountered a lot of troubles since its birth. It contradicts the law of conservation of information that many physicists insist on, and even threatens the foundation of quantum mechanics.

In classical theory, a black hole is a one-way film, and anything that includes light cannot escape. In 1974, British physicist Hawking theoretically proved that black holes are not completely black and can radiate particles like black bodies. Due to the vacuum fluctuation phenomenon, virtual particle pairs are generated at the black hole horizon. The total energy of these virtual particle pairs is zero, and consists of one positive energy particle and one negative energy particle. Since negative energy particles can only exist in black holes, negative energy particles in virtual particle pairs can only fall into black holes. Therefore, Hawking innovatively uses the tunneling effect to explain the radiation process of black holes. He believes that if the virtual particle pair is generated in the horizon, the negative energy particle will move in the black hole in the time direction until it reaches the singularity, and the positive energy particle will pass through the tunneling effect to the outside of the horizon and run to infinity. If the virtual particle pair is generated outside the horizon, the negative energy particle will enter the black hole through tunneling, reaching the singularity along the time direction, and the positive energy particle will run to infinity. In this way, the observer at infinity finds that the black hole radiates the particles, so that their energy and quality are continuously reduced, and then shrinks and eventually evaporates completely. In the literature,

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Hawking used the tunneling effect to analyze the radiation process of the Schwarzschild black hole, and obtained the emission spectrum as a pure thermal spectrum. The black hole radiation has a black body temperature, in which the surface gravity is a Boltzmann constant. However, this result led to the problem of black hole information loss and the quantum theory being broken. Because its background time and space is static and does not consider the reaction of radiated particles to space and time, the black hole Hawking radiation spectrum obtained is pure thermal spectrum.

2. Quantum tunneling radiation method

As the black hole radiates particles, the background time and space of the black hole should be considered as a dynamic variable. F. Wilczek and P. Kraus corrected this Hawking pure thermal spectrum in consideration of this dynamic effect. They considered the black hole Hawking radiation as a quantum tunneling effect, considering the self-gravitational interaction of the particles. Firstly, the shell and the black hole are combined to form a physical system with the freedom of radiation particles and gravitational field dynamics. The constraint equation is used to eliminate the non-physical freedom of the gravitational field in the system, and then the semi-classical WKB approximation is used to obtain the effective effect of the radiating particles. The expression of the quantity finally obtains the black hole Hawking radiation spectrum by using the Poggorov coefficient and finds that it deviates from the pure heat spectrum. However, all previous studies on black hole Hawking radiation, whether it is Hawking's tunneling model or F. Wilczek et al.'s quantum tunneling model, did not mention the barriers required during tunneling. In 2000, F. Wilczek and M. K. Parikh et al. innovatively believed that under the condition of conservation of energy, the black hole shrinks due to the decrease in mass and energy of the radiating particles, and the radius of the horizon is smaller than the initial radius. The interval formed by this radius contraction determines the barrier required for tunneling radiation. The magnitude of the difference in the horizon radius caused by the contraction is regarded as the distance between the two turning points of the barrier. The amount of contraction depends on the energy of the exiting particles. Then they use this model to discuss the Hawking radiation of massless particles in static spherically symmetric black holes, and give the imaginary part of the amount of tunneling particles passing through the classical forbidden zone, and obtain the true black hole Hawking radiation spectrum and Bekenstein before and after particle radiation. Hawking entropy change is related.

Subsequently, Zhang Jingyi, Zhao Wei and others extended the method to study the steady-state black hole with zero static mass of tunneling particles. Firstly, the geodesic equation of the tunneling particle is obtained by solving the group velocity and phase velocity of the tunneling particle Debroi wave. Then, the semi-classical WKB approximation is used to obtain the imaginary part of the action amount of the tunneling particle crossing the classical forbidden zone. The conclusion that the black hole Hawking radiation spectrum deviates from the pure thermal spectrum is obtained, which provides a possible explanation for the problem of black hole information loss. This method was subsequently widely accepted and extended to study the Hawking radiation that radiates mass or charged particles from tunnels of various types of black holes. In this way, the static mass and charged radiation particles are discussed, and the obtained Hawking radiation spectrum deviates from the pure thermal spectrum, and the same results as the literature are obtained.

However, Jiang Qingquan et al. recently believe that this method of Zhang Jingyi et al. has great flaws in the process of solving geodesic equations. First, this method uses different methods for deriving the geodesic equations of massless and mass tunneling particles. The line element (equivalent to the photon's 4-velocity is zero) is used to derive the geodesic equation of the massless tunneling particle, and the mass tunneling particles are derived by solving the relationship between the group velocity and the phase velocity of the Debroi wave. Obviously, the same derivation method should be used to uniformly process the geodesic equations of the two types of particles. Secondly, the method of deriving the geodesic equation of mass tunneling particles by deriving the relationship between group velocity and phase velocity is contrary to the action variation-first principle, because in general relativity, whether it is light-like or class-like the geodesic equations can be obtained from the Lagrangian action using the variational principle.

3. The main method of semi-classical quantization of black holes

How to establish a self-consistent quantum gravity theory is the most challenging problem in modern physics. So far, some possible quantum gravity theories have been proposed, such as: regular quantum gravity, perturbative quantum gravity, superstring and D-brane theory, loop quantum gravity, etc. But the quantization of gravity is still an open question. The quantum gain of the circle is a more likely way of passing the vector gravitation. So far, some important physical results have been achieved in the field of quantum quantum gravity. However, when using the quantum gain of the circle, the following problems also exist: one is that there will be an indeterminate free parameter, the so-called Immirzi parameter, so that the area quantum will not be unique. Second, the theory has no corresponding low energy approximation and high energy characterization. On the contrary, the theory does not fit well with Einstein's general theory of relativity at Planck's scale, which of course makes us unbelievable. The quantization scheme of black holes is an urgent problem to be solved in current gravity theory. Perhaps our current research on quantum gravity is in the Sommerfeld era, which was similar to the early development of quantum mechanics. Finding a semi-classical approach to the primary attempt to quantify the gravitational field will lead to some conclusions of physical significance. Beckenstein first made some attempts in these aspects. He believed that the position of black holes in gravity is the same as that of atoms in early quantum mechanics. Black holes should also be quantized and have corresponding energy spectra. Bekenstein found that for a non-extreme black hole, its horizon area is an adiabatic invariant. According to the Ehrenfest principle, any classical adiabatic invariant corresponds to a quantum quantity with spectral lines. Therefore, Bekenstein believes that non-extreme black holes also have separate eigen spectra. With the help of Christodoulou's point particle model.

With the development of physics, black hole physics has also developed rapidly in recent decades. Physicists have a deeper understanding of the nature of black holes, and some difficult problems of black hole physics have also been solved, but many problems remain unresolved. Gravitation and black hole quantization is one of the problems. This paper discusses some of these issues from a semi-classical perspective. Through the action variable method and the periodic method, we mainly study the spectral lines of black holes and their quantum correction. We studied the spectral line of the Schwarzschild Dexter black hole by the action variable method. In this chapter, we calculate from two different angles, one is to directly calculate the action variable after the black hole radiation particles, and the other is according to the effect. The basic properties of the quantity variable (also adiabatic invariant) are derived. The results we obtained were exactly the same as the original results of Beckenstein. Through the periodic method, we further studied the spectral line of the black hole. We studied the rotating BTZ black hole and the three-dimensional Gödel black hole. According to the high-order quantum correction of the action quantity, we first obtain the wave function modified by the radiation particle, and the modified motion period is further obtained from this wave function. By equating this cycle with the period of particle motion, we obtain the corrected area spectrum and entropy spectrum. The results show that the black hole line does not depend on the type of radiated particles. For the modified spectral line, we find that the entropy spectrum is universal, there is no correction, and the area spectrum has correction, and the correction value depends on the nature of the black hole itself.

4. Conclusion

The innovation of this method is to uniformly process the Hawking radiation of massless and mass tunneling particles, that is, to write the classical Lagrangian action amount, and uniformly obtain the geodesic equation through the variational principle, in this equation In the middle, the geodesic equation of massless particles is naturally obtained by taking the appropriate limit of the geodesic of the mass particles. This is the biggest difference from the previous work. It is the perfection of the Parikh Wilczek method and plays an important role in the development of this theory. It should be noted that this new processing method does not involve the correction of non-thermal spectra. At the same time, it is worth noting that although the Parikh-Wilczek quantum tunneling method can provide a specific physical image and calculation method for the black hole information, it is limited to the quasi-static reversible radiation process. Therefore, the black hole information is not solved in this way, it also needs a mature quantum gravity theory to solve.

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