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Creation and Annihilation of Ordinary Particles and Tachyon Particles from Black Hole

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ABSTRACT

Ordinary massive particles move with a velocity less than the velocity of light in vacuum but tachyon particles move with a velocity greater than the velocity of light. Considering the variation of combined mass of an ordinary particle and a tachyon particle with velocity and wave nature of black holes, we show that both ordinary particles and tachyon particles can be created and annihilated from black holes.

Keywords: *Universe; Black hole; Tachyon particle; Special theory of relativity*

1. INTRODUCTION

The tachyon particle moves with a velocity greater than the velocity of light. In the language of special theory of relativity (STR), a tachyon would be a particle with spacelike four-momentum and imaginary proper time. Since they are travelling faster than light their existence would create problems in modern physics. In quantum field theory (QFT) it has different interpretation [1]. In QFT, a tachyon is a quantum of field – usually a scalar field – whose squared mass is negative, and is used to describe spontaneous symmetry breaking. In QFT, every particle is associated with a field ϕ. The squared mass of the particle is the second derivative of the effective potential $V(\phi)$, at a point where the first order derivative is zero. The negative squared mass implies that the potential $V(\phi)$ has a maximum at that point and the system is unstable. Thus, the tachyon particle has an imaginary mass. This imaginary mass would induce tacyon condensation [2]. Another peculiar property of the tachyon particle is that, the speed of a tachyon increases as its energy decreases whereas the speed of ordinary particles decreases as their energy decreases. Tachyons are appeared theoretically in a variety of theories, such as bosonic string theory but there is no experimental evidence for the existence of tachyon particles yet.

Black holes are one of the most fascinating predictions of Einstein's general theory of relativity [3], which predicts that if matter is sufficiently compressed, its gravity becomes so strong that it carves out a region of space from which nothing can escape. Classically a black hole absorbs everything that comes too close and does not emit anything. However, when quantum effects are considered black holes create and emit particles [4, 5]. Although there is no conclusive evidence, there are a lot of indirect evidences for their existence and their study occupies a central role in modern high energy astrophysics [6]. Their existence is a test of our understanding of strong gravitational fields, beyond the point of small corrections to Newtonian physics, a test of our understanding of astrophysics, particularly stellar evolution [7,8]. Since black hole radiation involves a mixture of gravity and quantum physics this connection leads us into the territory of quantum gravity. Research on the physics of black holes over the last few decades has helped us for understanding some very fundamental and unanswered questions of physics [9,10]. One of them is "Can the tachyon particle be created from black hole?". In this paper, we investigate this issue on theoretical grounds. We show that both ordinary particles and tachyon particles can be created and annihilated from black holes.

2. VARIATION OF COMBINED MASS OF ORDINARY PARTICLE AND TACHYON PARTICLE WITH VELOCITY

When a particle having mass m_{01} is moving with velocity $v < c$, the variation of its mass with respect to velocity can be written as [11,12]:

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$$m_1 = \frac{m_{01}}{\sqrt{1-\frac{v^2}{c^2}}}, \qquad (1)$$

where m_{01} is the rest mass and m_1 is the mass of the particle moving with velocity $v < c$. Similarly, when a tachyon particle having an imaginary mass im_{02} is moving with velocity $v > c$, the variation of its mass with respect to velocity can be written as

$$m_2 = \frac{m_{02}}{\sqrt{\frac{v^2}{c^2}-1}}, \qquad (2)$$

where im_{02} is the rest mass and m_2 is the moving mass of tachyon particle moving with velocity $v > c$.

The total combined mass of the particle and the tachyon particle can be written as:

$$M = m_1 + m_2 = \frac{m_{01}}{\sqrt{1-\frac{v^2}{c^2}}} + \frac{m_{02}}{\sqrt{\frac{v^2}{c^2}-1}} \qquad (3)$$

The variation of combined mass of the particle and the tachyon particle given in equation (3) can be considered in two different cases as follows:

CASE I: When $v < c$, their combined mass

$$M_P = \frac{m_{01}}{\sqrt{1-\frac{v^2}{c^2}}} + \frac{m_{02}}{i\sqrt{1-\frac{v^2}{c^2}}},$$

$$= \frac{M_0}{\sqrt{1-\frac{v^2}{c^2}}} \exp(-i\varphi), \qquad (4)$$

Where, $\varphi = \tan^{-1}\frac{m_{02}}{m_{01}}$, and $M_0 = \sqrt{{m_{01}}^2 + {m_{02}}^2}$.

CASE II: When $v > c$, their combined mass

$$M_T = \frac{m_{01}}{i\sqrt{\frac{v^2}{c^2}-1}} + \frac{m_{02}}{\sqrt{\frac{v^2}{c^2}-1}},$$

$$= \frac{-iM_0}{\sqrt{\frac{v^2}{c^2}-1}} \exp(i\varphi), \qquad (5)$$

Here m_{01} and m_{02} are real masses but M_P and M_T are complex masses.

3. ENERGY STATES OF BLACK HOLE FOR CREATION AND ANNIHILATION OF ORDINARY AND TACHYON PARTICLES

It has been shown that black holes are quantized in different discrete energy states [13,14]. The variation of combined mass of particle and tachyon particle with variation in velocity can be correlated with different energy states of black hole for the creation and annihilation of ordinary and tachyon particle. In this case, the creation and annihilation of ordinary particle from black hole can be given by the energy state of black hole as:

$$E_P = M_P c^2 = \frac{M_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} \exp(-i\varphi). \qquad (6)$$

The creation and annihilation of tachyon particle from black hole can be given by the energy state of black hole as:

$$E_T = M_T c^2 = \frac{-iM_0 c^2}{\sqrt{\frac{v^2}{c^2}-1}} \exp(i\varphi). \qquad (7)$$

If a black hole is with excited energy E_P then it leads to the creation and annihilation of particles which will move with velocity $v < c$. If a black hole is with excited energy E_T then it leads to the creation and annihilation of tachyon particles which will move with velocity $v > c$.

Hence, there is the possibility of existence of black holes with the energy states E_P and E_T in the universe which would have lead to the creation and annihilation of ordinary particles and tachyon particles.

4. CREATION AND ANNIHILATION OF ORDINARY PARTICLES AND TACHYON PARTICLES FROM BLACK HOLE

It has been shown that a black hole with mass *M* behaves like a wave with the Compton wavelength $\lambda\!\!\!^{-} = \hbar / Mc$ [13,14]. Classically a black hole absorbs everything that comes too close and does not emit anything. However, quantum mechanically a black hole does create and emit particles [4,5] as if it were a hot body with temperature $T \approx (8\pi M)^{-1}$, where *M* is the mass of the black hole. A black hole, which is an excited state of gravitation field, decay quantum mechanically and because of quantum fluctuation of the space-time metric, energy tunnels out of the potential well of the black hole. Just outside the event horizon of the black hole there will be virtual pairs of particles, one with negative energy and one with positive energy. The negative energy particle tunnels the event horizon to the region inside the black hole where the Killing vector which represents time translation is spacelike. The positive energy particle escapes to the infinity.

The authors [15] have studied the higher order quantum corrections to particle creation/annihilation by black hole. They find that the temperature of the quantum corrected black hole is lower than that of a classical black hole and the stable critical mass remnants are natural final states of the Hawking evaporation process. Recently, the authors [16] have showed that the quantum evaporation of a black hole is related to the today's acceleration of the universe.

Let us consider some special cases of energy states given in equations (6) and (7):

CASE I: $\varphi = 0$

$$E_P = \frac{M_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}},\ E_T = \frac{-iM_0 c^2}{\sqrt{\frac{v^2}{c^2}-1}} \qquad (8)$$

In this case ordinary particles will be created but tachyon particles will be annihilated i.e. if the black hole has excited gravitational field energy E_P given in equation (8) ordinary particles will be created.

CASE II: $\varphi = \frac{\pi}{4}$

$$E_P = \frac{M_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} \exp(-i\frac{\pi}{4})$$

$$= \frac{M_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} [\frac{1}{\sqrt{2}} - \frac{i}{\sqrt{2}}] \qquad (9)$$

$$E_T = \frac{-iM_0 c^2}{\sqrt{\frac{v^2}{c^2}-1}} \exp(i\frac{\pi}{4})$$

$$= \frac{M_0 c^2}{\sqrt{\frac{v^2}{c^2}-1}} [\frac{1}{\sqrt{2}} - \frac{i}{\sqrt{2}}] \qquad (10)$$

In this case the same amount of ordinary particles will be created and annihilated; similarly the same amount of tachyon particles will be created and annihilated.

CASE III: $\varphi = \frac{\pi}{2}$

$$E_P = \frac{M_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} \exp(-i\frac{\pi}{2}) = \frac{-iM_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} \qquad (11)$$

$$E_T = \frac{-iM_0 c^2}{\sqrt{\frac{v^2}{c^2}-1}} \exp(i\frac{\pi}{2}) = \frac{M_0 c^2}{\sqrt{\frac{v^2}{c^2}-1}} \qquad (12)$$

In this case, ordinary particles will be annihilated but tachyon particles will be created i.e. if the black hole has excited gravitational field energy E_T given in equation (12) tachyon particles will be created.

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Thus, both ordinary particles and tachyon particles can be created and annihilated from the black hole depending upon different phases of energy states.

5. CONCLUSION

The tachyon particle that moves faster than light poses a number of intriguing problems and possibilities to the field of physics. Tachyon particles are appeared theoretically in a variety of theories, such as bosonic string theory but there is no experimental evidence for the existence of tachyon particles yet. It is well-known that black holes will play a central role in our understanding of fundamental physics. From this paper, we have come to the conclusion that black hole shows wave nature possessing different phases for different energy states which leads to the creation and annihilation of particles and tachyon particles in the universe. Our results are not conclusive but they are tantalizing. They might be due to some peculiar properties of black hole that we can not quite yet estimate precisely. We hope that next years will bring us a lot of new results in tachyon physics as well as in black hole physics.

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