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Comparative Study of the Radiation Power of Black Holes Due to Non-Relativistic & Relativistic Effect

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Abstract

In the present research paper, we have proposed a model for ratio of the radiation power & relativistic radiation power using the Stephen-Boltzmann-Schwarzschild-Hawking radiation formula $P = \frac{\hbar c^6}{15360\pi G^2 M^2}$ to apply the variation of mass with velocity and calculated their values for different test black holes. We also have concluded that the relativistic radiation power decreases with the increase of velocity of the spinning black holes and becomes half of the radiation power due to non-relativistic effect, while the ratio of radiation power & relativistic radiation power (P/P_{rel}) increases with the increase of spinning velocity of the black holes.

Keywords: Non-relativistic radiation power, relativistic radiation power and Spinning velocity

1. Introduction

Quantum mechanically, there is a possibility that one of a particle production pair in a black hole is able to tunnel the gravitational barrier and escapes the horizon of black holes. Thus it can radiate or evaporate particles in the form of hawking radiation [1]. Hawking introduced what is now called Hawking radiation as the effective black body radiation from a black hole in terms of the 4th power of the black hole temperature and the Stefan-Boltzmann constant [2,3]. Hawking radiation is the hypothetical black-body radiation emitted by black holes, at a temperature that depends on the mass, charge, and spin of the black hole [4]. Brajesh et al. converted the Stephen-Boltzmann-Schwarzschild-Hawking radiation formula $P = \frac{\hbar c^6}{15360\pi G^2 M^2}$ in terms of Chandrasekhar limit [M_{ch}] and also calculated their values for different test black holes existing in XRBs and AGN [5]. Mahto and Kumar gave a model for the relativistic radiation power of spinning black holes and concluded that the relativistic radiation power decreases with increase in the spinning velocity of black holes [6].

In the present research work, we have proposed a model for the ratio of radiation power & relativistic radiation power for the comparative study of radiation power due to non-relativistic and relativistic effect.

2. Theoretical discussion

Stephen-Boltzmann-Schwarzschild-Hawking radiation formula is given by the following equation [4].

$$P = \frac{\hbar c^6}{15360\pi G^2 M^2} \tag{1}$$

The above equation can be written as:

$$P = \frac{\hbar c^6}{15360\pi G^2}\left(M^{-2}\right) \tag{2}$$

or

$$P = \frac{\hbar c^6}{15360\pi G^2}\left(M\right)^{-2} \tag{3}$$

Some black holes have their spinning velocity in ranging from 50% to 99% of the velocity of light [7].

The relativistic radiation power of the spinning black holes is given by the following equation [6].

$$P_{rel} = \frac{\hbar c^6}{15360\pi G^2 M_0^2}\left[\left\{1-\left(\frac{v^2}{c^2}\right)\right\}\right] \tag{4}$$

The equation (1) is divided by the equation (4), we have

$$\frac{P}{P_{rel}} = \frac{\hbar c^6}{15360\pi G^2 M^2} \div \frac{\hbar c^6}{15360\pi G^2 M^2}(1-\frac{v^2}{c^2}) \tag{5}$$

$$\frac{P}{P_{rel}} = 1/\left(1-\frac{v^2}{c^2}\right) \tag{6}$$

$$\frac{P}{P_{rel}} = \left(1-\frac{v^2}{c^2}\right)^{-1} \tag{7}$$

Using binomial theorem to solve the above equation by neglecting the higher power of terms, we have

$$\frac{P}{P_{rel}} = \left(1+\frac{v^2}{c^2}\right) \tag{8}$$

The above equation gives a new model for the ratio of radiation power and relativistic radiation power.

For the spinning black holes having half velocity to that of the velocity of light, the above equation becomes.

$$\frac{P}{P_{rel}} = 1.25 \tag{9}$$

$$P = 1.25 P_{rel} \tag{10}$$

The equation (10) shows that the non-relativistic radiation power is 1.25 times to that relativistic radiation power for the spinning black holes having the velocity equal to the velocity of light.

For the spinning black holes having the velocity 3/4 to that of the velocity of light, the above equation becomes.

$$\frac{P}{P_{rel}} = 1.50 \tag{11}$$

$$P = 1.50 P_{rel} \tag{12}$$

The equation (12) shows that the non-relativistic radiation power is 1.50 times to that relativistic radiation power for the spinning black holes having the velocity equal to the velocity of light.

For the spinning black holes having the velocity approximately equal to the velocity of light, the above equation becomes.

$$\frac{P}{P_{rel}} = 2 \tag{13}$$

$$P = 2 P_{rel} \tag{14}$$

The equation (14) shows that the non-relativistic radiation power is twice to that relativistic radiation power for the spinning black holes having the velocity equal to the velocity of light.

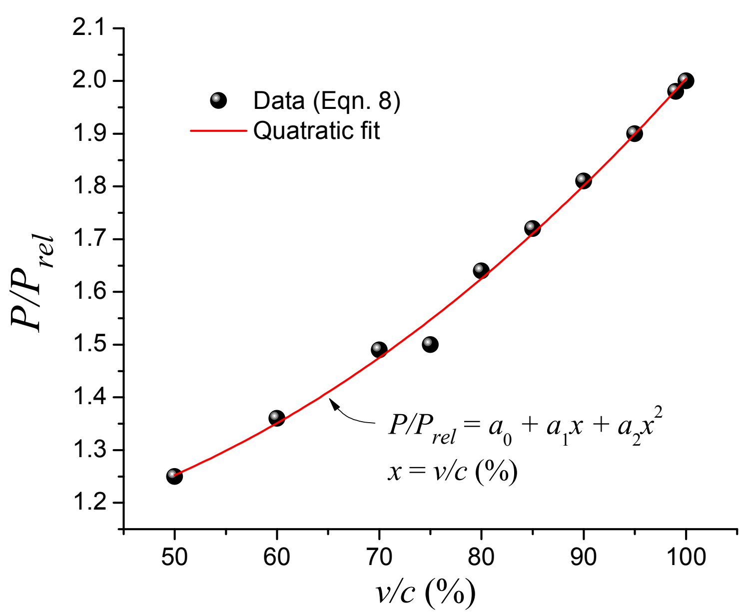
Similarly other values for P/P_{rel} for different velocities of test black holes are calculated and listed in the table 1. The above equation can be written as:

$$P_{rel} = P / 2 \tag{15}$$

The equation (15) shows that the relativistic radiation power becomes half to that non-relativistic radiation power of the spinning black holes having the velocity equal to the velocity of light.

Table 1: Comparative Study of the Radiation power of black holes due to Non-relativistic & Relativistic effect

S. No.	**Ratio of the velocity of spinning black holes and the velocity of light (v/c in %)**	**Ratio of the velocity of spinning black holes and the velocity of light(v/c)**	**Ratio of the radiation power of black holes due to Non-relativistic & Relativistic effect** (P/P_{rel})
1	50	0.50	1.25
2	60	0.60	1.36
3	70	0.70	1.49
4	75	0.75	1.50
5	80	0.80	1.64
6	85	0.85	1.72
7	90	0.90	1.81
8	95	0.95	1.90
9	99	0.99	1.98
10	100	1.00	2.00



Graph 1: The figure shows the graph plotted between the spinning velocity of black holes and their corresponding ratio of radiation power due to non-relativistic and relativistic effect.

3. Results and discussion

In the present work, the variation of mass with velocity is applied to the model of radiation power of black holes (Stephen-Boltzmann-Schwarzschild-Hawking radiation formula) to give a new model for the ratio of radiation power & relativistic radiation power. This new model is represented by the equation (8).

The present work calculates the ratio of the radiation power & relativistic radiation power of different test black holes for the comparative study of radiation power due to non-relativistic and relativistic effect. From the study of our theoretical discussion, it is clear that the relativistic radiation power decreases with the increase of velocity of the spinning black holes and becomes half of the radiation power due to non-relativistic effect, while the ratio of relativistic radiation power & non-relativistic power (P/P_{rel}) increases with the increase of spinning velocity of the black holes as per the quadratic equation represented by $P/P_{rel} = a_0 + a_1x + a_2x^2$, where $x=v/c$ (in %), $a_0 = 1.15166$, $a_1 = -0.00448$, $a_2 = 1.30014\text{x}10^{-4}$ and fitting with accuracy ($\chi^2 = 0.99389$).

From the graph, it is clear that there is some deviation to follow the path as specified by the quadratic equation discussed above regarding the variation of (P/P_{rel}) with velocity of light at 3/4th of the velocity of light which indicates that this type of black hole has some different character than that of rest black holes.

4. Conclusion

The relativistic radiation power decreases with the increase of velocity of the spinning black holes and becomes half of the radiation power due to non-relativistic effect, while the ratio of relativistic radiation power & non-relativistic power (P/P_{rel}) increases with the increase of spinning velocity of the black holes.

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