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Relativistic Surface Gravity for Half Spin Parameter of Black Holes in XRBs

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ABSTRACT The mass, angular momentum and charge are the functions of the surface gravity of spinning black holes. The present paper discusses the relativistic surface gravity of different test black holes half spin parameters existing in X-ray binaries and concludes that the relativistic surface gravity attains the maximum values for the lower masses and minimum value for higher masses. The spinning velocity is also responsible to increase or decrease the surface gravity of black holes depending on its values.

KEYWORDS Relativistic Surface gravity, Half Spin and XRBs

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1. INTRODUCTION

The surface gravity of non-spinning black hole is inversely proportional to its own mass (Narayan, 2005) and analogous to the temperature given as $\kappa = T/2\pi$ (Bardeen, Carter & Hawking 1973). The Kerr-Newman solution of surface gravity of black hole depends on its mass, angular momentum and charge (Newman & Janis 1965). The surface gravity of non-spinning black holes is greater than to that of the surface gravity of spinning black holes of maximum spin of the same mass (Mahto and Kumari, 2018). Mahto and Kumari, gave a model for the surface gravity of black holes in terms of mass and its spin parameter (Kumari & Mahto, 2019) and its relativistic treatment for quarter and three- quarter spin parameters in XRBs has been studied (Chandan, 2023).

A model for the relativistic gravitational force of black holes and light particles has been studied to conclude that the mass, spinning velocity and relativistic gravitational forces are correlated and dependable to each other (Mahto et al., 2023).

The present research paper discusses the relativistic study of surface gravity of some test black holes of half spin parameters in XRBs.

2. THEORETICAL DISCUSSION

The relativistic surface gravity of spinning black holes in terms of spin parameter (a*) is given by the following equation (Chandan, 2023).

$$\kappa_{rel} = \frac{1}{4M_0}\left(1-\frac{a^{*2}}{2}\right)\left(1-\frac{v^2}{2c^2}\right). \quad (1)$$

For a* = +1/2 and -1/2 represent half spin of co-rotation and counter rotation of the spinning black holes respectively. The sign (+) and (-) are taken into consideration for co-rotation and counter rotation of spinning black holes. For either rotation of the black holes, the net relativistic surface gravity of black holes remains the same for the particular test black holes due to the square of the spin parameter (a*). The surface gravity of some test black holes are calculated and listed in the following tables.

Table 1: The values of some specific terms: $\frac{7}{32M_0}(a^* = \pm\frac{1}{2})$.

S. No.	Mass of Black Holes in terms of solar mass (M_Θ)	$\frac{7}{32M_0}(a^* = \pm\frac{1}{2})$ **(x10^{-31})**
1.	5	0.21875
2.	10	0.10937
3.	15	0.07291
4.	20	0.05868

Table 2: Relativistic surface gravity of spinning black holes of spin parameter ($a^* = \pm\frac{1}{2}$) in XRBs

S. No	(%) Velocity	Velocity (10^8m/s)	$\kappa_{rel} = \frac{7}{32M_0}\left(1-\frac{v^2}{2c^2}\right)\times 10^{-34}$			
			M_0=5 M_Θ $\frac{7}{32M_0} = 0.21875\times10^{-31}$	M_0=10 M_Θ $\frac{7}{32M_0} = 0.109375\times10^{-31}$	M_0=15 M_Θ $\frac{7}{32M_0} = 0.072916\times10^{-31}$	M_0=20M_Θ $\frac{7}{32M_0} = 0.054687\times10^{-31}$
1.	50	1.50	191.406	95.703	63.801	47.851
2.	55	1.65	185.664	92.832	61.887	46.415
3.	60	1.80	179.375	89.687	59.791	44.843
4.	65	1.95	172.539	86.269	57.512	43.134
5.	70	2.10	165.156	82.578	55.051	41.288
6.	75	2.25	157.226	78.613	52.408	39.306
7.	80	2.40	148.750	74.375	49.582	37.187
8.	85	2.55	139.726	69.863	46.575	34.931
9.	90	2.70	130.156	65.078	43.385	32.538
10.	95	2.85	120.039	60.0195	40.012	30.009
11.	99	2.97	111.551	55.775	37.183	27.887

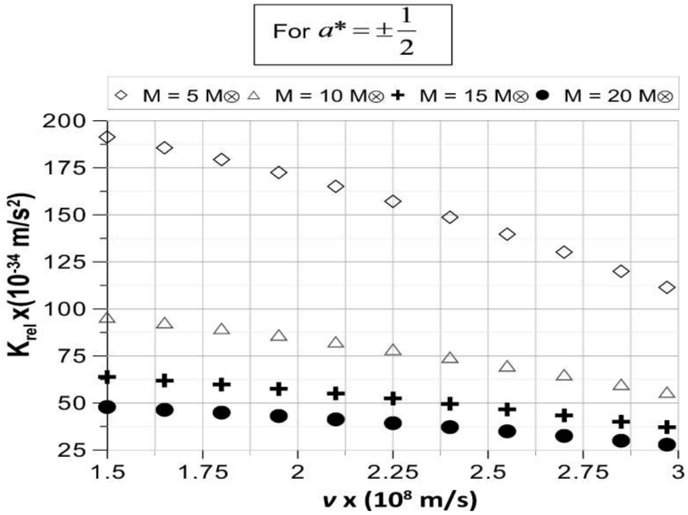

Figure 1: Relativistic surface gravity of black holes of spin parameter ($a^* = \pm 1/2$) in XRBs

3. RESULT AND DISCUSSION

The present work discusses the relativistic surface gravity of half spin black holes given by the equation (1). We have calculated the relativistic surface gravity for different spin parameters (a* = +1/2, -1/2) of different test black holes of 5, 10, 15, 20 of solar mass in XRBs. The relativistic surface gravity decreases with increase of spinning velocity of black holes for the heavier masses. The same change also occurs for other test black holes of lighter masses, but the difference in amount of change in the relativistic surface gravity are greater for the lower masses and smaller for heavier masses. The tables 2 and figure 1 show clearly that the increase of the velocity of black holes, the decreases in relativistic surface gravity is approximately linear. The observations from the table 2, we see that the relativistic surface gravity attains the maximum values for the lighter masses and vice-versa. Hence we conclude that the velocity of black holes is mainly responsible for either increasing or decreasing the surface gravity of black holes.

When we compare the variation of relativistic gravity with spinning velocity due to maximum spin and half spin parameters, then the observation shows that the nature of variation due to both spin parameters are the same and differing only for their magnitudes, although very small.

4. CONCLUSION

The relativistic surface gravity attains the maximum values for lighter mass of black holes and vice-versa. This also depends on the spinning velocity. The co-rotation and counter rotation makes no any change in the relativistic surface gravity.

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