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Comparative Study of the Entropy Change of Spinning Black Holes Due to Mass Change in XRBs and AGN

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Abstract

The present paper gives the comparative study of the entropy change of spinning black holes due to mass change in XRBs & AGN and concludes that the ratio of the entropy change in XRBs and AGN decreases with the increase in mass of different test spinning black holes.

Keywords: Entropy change, Spinning black holes and Angular momentum

1. Introduction

The black hole is a marvellous gift of nature. When a large weight star dies after emitting all its electrons and the nuclear particles are compressed by unbelievably high gravitational pressure to occupy the smallest possible space, the star is supposed to die leaving a matter of extremely high density. The mass and density of a black hole becomes so high that its gravity becomes too abnormal that nothing even, the light ray passing near it, is trapped by it and hence, it is known as black hole [1,2]. Mahto et al. proposed a model for the change in energy and entropy and calculated their values for different test black holes in XRBs and AGN [3]. Mahto et al. gave a model for the change in entropy of Non-spinning black holes w.r.t. the radius of the event horizon in XRBs [4]. Mahto et al. applied also the same model for AGN black holes and calculated the entropy change of different test black holes in AGN [5]. Mahto, D. and Kumari, A. proposed a model for change in entropy of spinning black holes due to corresponding change in mass in XRBs and calculated their values for different test black holes[6]. They applied the same model for AGN black holes to calculate their values [7].

The present paper reviews the theoretical model for the entropy change of spinning black holes due to the mass change as proposed by Mahto, D. and Kumari, A. This also gives the comparative study of the entropy change of spinning black holes due to mass change in XRBs and AGN.

2. Theoretical Model Used

The change in entropy due to change in mass of the spinning black holes for unit angular momentum and spin parameter is given by [6].

$$\left|\frac{\delta S}{\delta M}\right| = 24\pi M^2 \tag{1}$$

Where $$\kappa = \frac{1}{6M} \tag{2}$$

The term (κ) is known as surface gravity of the spinning black holes, while its value for non-spinning black holes is given by the following equation [7]

$$\kappa = \frac{1}{4M} \tag{3}$$

3. Data in the support for mass of the sun & spinning black holes in XRBs and AGN:

Mass of sun ($M_\odot$) = 1.99 x 10^{30} kg. [8].

Mass of the black holes in XRBs- M ~ 5 20 $M_\odot$ [8].

Mass of the SBH in AGN- 10^6 – $10^{9.5}$ $M_\odot$ [8], 3x10^7 $M_\odot$ [9]. 2x10^6 – 3x10^9 $M_\odot$ [10].

Using the above data in the equation (1), entropy change of spinning black holes for XRBs and AGN of different test spinning black holes of spin parameter a*=1 and unit angular velocity is estimated for their comparative study of both categories of black holes.

Table 1: Mass ratio and Entropy change ratio of XRBs & AGN Spinning Black holes

S. No.	**Mass of BHs in XRBs**	$\left\|\frac{\delta S}{\delta M}\right\|$ **(J/K/$M_\odot^2$)**	**Mass of BHs in AGN**	$\left\|\frac{\delta S}{\delta M}\right\|$ **(J/K/$M_\odot^2$)**	M_{XRBs}/M_{AGN}	$\frac{\partial S_{XRBs}}{\partial S_{AGN}}$
1	5$M_\odot$	7.536x10^3	.1x$10^7M_\odot$	0.7536x10^{14}	50x10^7	10x10^{-11}
2	6$M_\odot$	10.851x10^3	.3 x$10^7M_\odot$	2.260x10^{14}	·20x10^7	4.8x10^{-11}
3	7$M_\odot$	14.770 x10^3	.5 x$10^7M_\odot$	3.968 x10^{14}	14x10^7	3.7x10^{-11}
4	8$M_\odot$	19.292 x10^3	.7 x$10^7M_\odot$	5.275 x10^{14}	11.4x10^7	3.6x10^{-11}
5	9$M_\odot$	24.416 x10^3	1 x$10^7M_\odot$	7.5360x10^{14}	9x10^7	3.2x10^{-11}
6	10$M_\odot$	30.144 x10^3	3 x$10^7M_\odot$	22.603x10^{14}	3.3x10^7	1.33x10^{-11}
7	11$M_\odot$	34.740 x10^3	5 x$10^7M_\odot$	39.680 x10^{14}	2.2x10^7	0.87 x10^{-11}
8	12$M_\odot$	43.407 x10^3	7 x$10^7M_\odot$	52.752 x10^{14}	1.7x10^7	0.82 x10^{-11}

9	$13M_{\odot}$	50.943×10^{3}	$10 \times 10^{7} M_{\odot}$	75.360×10^{14}	1.3×10^{7}	0.67×10^{-11}
10	$14M_{\odot}$	59.082×10^{3}	$30 \times 10^{7} M_{\odot}$	226.030×10^{14}	0.4×10^{7}	0.26×10^{-11}
11	$15M_{\odot}$	67.824×10^{3}	$50 \times 10^{7} M_{\odot}$	396.800×10^{14}	0.3×10^{7}	0.17×10^{-11}
12	$16M_{\odot}$	77.168×10^{3}	$70 \times 10^{7} M_{\odot}$	527.520×10^{14}	0.2×10^{7}	0.14×10^{-11}
13	$17M_{\odot}$	87.116×10^{3}	$100 \times 10^{7} M_{\odot}$	753.600×10^{14}	0.1×10^{7}	0.11×10^{-11}
14	$18M_{\odot}$	97.666×10^{3}	$300 \times 10^{7} M_{\odot}$	2260.30×10^{14}	$.06 \times 10^{7}$	0.04×10^{-11}
15	$19M_{\odot}$	108.81×10^{3}	$500 \times 10^{7} M_{\odot}$	3968.00×10^{14}	$.03 \times 10^{7}$	0.02×10^{-11}
16	$20M_{\odot}$	120.57×10^{3}	$700 \times 10^{7} M_{\odot}$	5275.20×10^{14}	$.02 \times 10^{7}$	0.01×10^{-11}

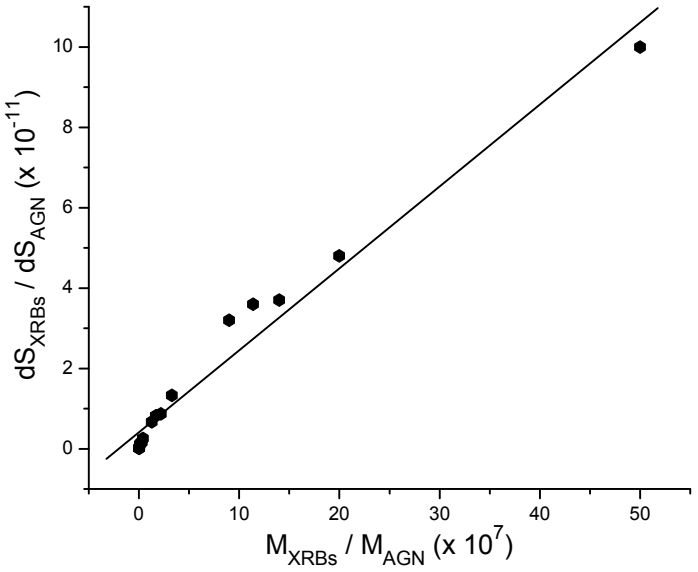

Fig. 1: The graph plotted between the mass ratio and entropy change of spinning black holes of XRBs & AGN.

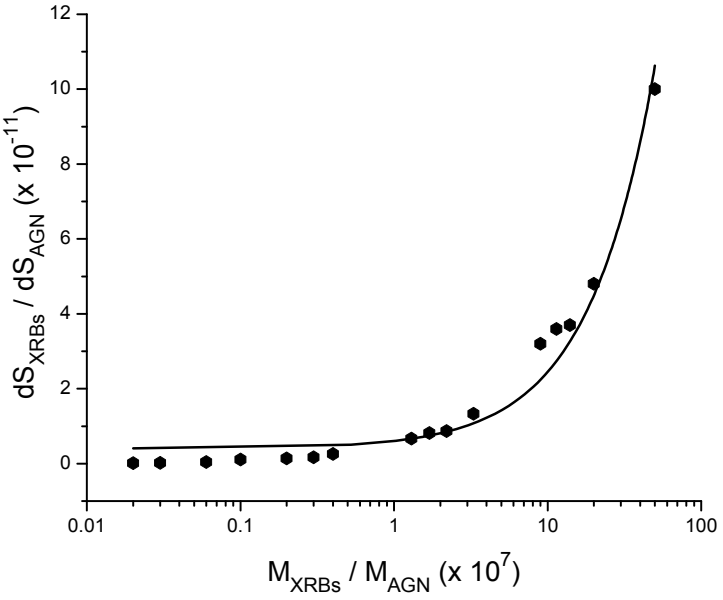

Fig. 2: The graph plotted between the mass ratio and entropy change of spinning black holes of XRBs & AGN using logarithmic scale.

4. Results and Discussion

In the present work, we have used the model for the change in entropy of uncharged spinning black hole with respect to the change in mass (dS/dM) in terms of mass only by the equation $\left|\frac{\delta S}{\delta M}\right| = 24\pi M^2$ to compare their entropy change of the spinning black holes in XRBs and AGN for unit spin parameter and angular velocity.

When the table 1 is observed, we see that the magnitude of change in entropy with change in mass increases with the increase the mass of black holes in XRBs as well as AGN for unit spin parameter and angular velocity. It is also observed that the ratio of the entropy change in XRBs and AGN decreases with the increase in mass of different test spinning black holes. The observation also shows that the ratio of mass in XRBs & AGN black holes also decreases with the increase in mass of different test spinning black holes. From the table, it is also clear that the change in entropy with respect to mass increases with increase in masses of different test black holes in XRBs as well as AGN.
We have plotted the graph between:

1. Mass ratio of spinning black holes and entropy change ratio in XRBs & AGN using the normal scale as shown in the Fig. 1.
2. Mass ratio of spinning black holes and entropy change ratio in XRBs & AGN using the logarithmic scale as shown in the Fig. 2.

The figure 1 shows that there is approximately linear variation in entropy change ratio with mass ratio of both categories of black holes with some deviation at the some points, while the figure 2 shows that these variations remain constant up to some fixed points and after this point, the entropy change ratio increases abruptly with mass ratio. This difference in variation is only due to the powers.

5. Conclusion

We have concluded the following facts during the research work as follows;
1. The mass ratio as well as entropy change of XRBs & AGN black holes also decreases with the increase in mass of different test spinning black holes.
2. The magnitude of the change in entropy with change in mass of uncharged spinning black holes in XRBs and AGN are essentially the functions of their masses.
3. The change in entropy with respect to mass increases with increase in mass of different test black holes decrease in XRBs as well as AGN.
4. The ratio of the entropy change in XRBs and AGN decreases with the increase in mass of different test spinning black holes.
5. The ratio of entropy change of XRBs & AGN black holes has negligible change in comparison to the mass ratio.

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