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Status of Spinning Black Holes in AGN

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Abstract

The present article gives the M.-L relation, M.-σ relation and M.-C relation to specify the status of AGN on the basis some experimental evidence and observed data from different research papers & literatures regarding the characteristics of black holes in AGN and provides also the same facts on the basis of M.-L relation and M.-η relation as per the model $L_E = 1.13\times10^{38}(M/M_{\oplus})erg/\sec.$ and $\eta = L_E/\dot{M}c^2$ respectively. This concludes that the mass is only function of the radiative efficiency so that heavier the mass, larger the radiative efficiency and it is analogous to the M-L relation as per the model taken into consideration in the present work.

Keywords: Luminosity, Radiative efficiency and AGN

1. Introduction

The word AGN derived from Active Galactic Nuclei is a compact region at the centre of a galaxy having much higher luminosity than that of normal luminosity over at least of electromagnetic spectrum and the radiation coming from it is believed to be a result of accretion of matter by super massive black holes at the centre of its host galaxy. This can be used for the discovery of distant objects in the universe, their evolution as a function of cosmic time etc.[1]. The first extraordinary luminous, extra galactic example was found in the Seyfert2 galaxy NGC4945 [2]. The super massive black holes form or grow in a galactic nucleus and it produce a cusp in the stellar density [3]. In 1995, Kormendy and Richstone also demonstrated some effectively regarding the same fact which shows that the production of light cusps is not necessary condition for the formation of super massive black holes [4]. In 2001, Milosavljevic and Merrit have shown that the central density cusps can be destroyed during galaxy mergers or a consequence of the hardening of the SBH binary which forms at the centre of the merger product [5]. In 2005, some experimental evidence and observed data have been given to discuss about the origin, evolution, composition and present status of AGN regarding the M.-L relation, M.- σ relation and M.-C relation[1]. In 2013, Mahto et al. [6] calculated the radiative efficiency of super massive black holes in AGN using the model $L/\dot{M}c^2$ and compared their results with the works done previously to conclude that the mass of super massive black holes could not be greater than 5x 10^9 times the solar mass [7].

In the present work, we have presented the M.-L relation, M- σ relation and M.-C relation to discuss the status of AGN on the basis some experimental evidence and observed data from different research papers & literatures including the M.-L relation and M.-η relation as per the model taken into consideration.

Black holes in AGN

The Hubble Space Telescope would be able to resolve the sphere of influence only of a SBH more massive than a few $10^8 M_\Theta$ at a distance of 7.2Mpc and the low bulge velocity dispersion of the galaxy [1]. This telescope has high resolution factor and is used to detect Maser clouds (NGC4258) emitting the radiations at 22GHz with instantly pushing ability to detect a SBH to correspondingly smaller masses. The most recent and most promising results have been obtained regarding the current status of super massive lack holes in AGN [8]. The discovery of the massive black holes in NGC4258 marked the beginning of an unexpected and powerful new way to measure central masses in AGN [9].

Now we shall discuss some of the scaling relations to specify the different characteristics of the super massive black holes in AGN like M-L relation, M- σ relation, M.-C relation.

The M -L Relation

In 1995, Kormendy and Richstone by using the eight SBH detection available at the time, noticed that there is a definite correlation between the super massive black hole mass (M) and the blue luminosity of the surrounding hot stellar component in the entire galaxy. They also pointed out that the existence of the correlation indicates that the super massive black holes (SBH) and bulge formation are tightly connected or even, based on the claimed absence of a SBH in the bulge- less spiral M33, that the presence of a bulge might be essential for SBH formation [4]. Further SBH detections have confirmed the existence of a correlation. Now a day, the scatter in the M - L relation has become the subject of debate. Marconi and Hunt find that the scatter in the K band, the M- L relation is very small near about 0.31 dex comparable to the scatter in the M- σ relation, no matter whether spiral galaxies are included or not [10]. This is not altogether surprising. Both the M-σ and M - L relation betray the existence of a correlation between the mass of the super massive black holes and the mass of the host bulge.

In the present work, we have used the model represented by equation (1) to establish also M-L relation. Our M-L relation shows that the uniform variation between the mass of different black holes and Luminosity indicating that all the SBHs have the same nature regarding the origin, composition, evolution etc. and their luminosity is the function of mass only. This shows that heavier the mass, larger the luminosity. From the graph as shown in the figure 1, it is obvious that the luminosity of the spinning black holes increases gradually with mass in the lower mass range, but rapidly in the heavier mass range.

As per our works regarding the M-L relation, the following facts can be taken into consideration:

1. There is a uniform variation between the mass and Luminosity of the spinning black holes in AGN.
2. The mass of the spinning black holes is only main function of the Luminosity to discuss their different characteristics.
3. The Luminosity of the spinning black holes increases gradually with mass in the lower mass range, but rapidly in the heavier mass range.
4. Heavier the mass of the spinning black holes, larger the Luminosity.

The M-σ Relation

The M- σ relation is tighter and more fundamental than that of the M- L relation and other relations. In 2000, Ferrarese and Merritt have discussed the first M- σ relation regarding the super massive black holes in AGN and showed that the scatter in the M-σ relation is significantly dependent on sample selection. The scatter in the M- σ relation decreases significantly when the restricted sample is used [11]. On the basis of findings as per above relations, they concluded that the reliability of the SBH mass depends critically on the spatial resolution of the data.

The study of M- σ relation of SBHs gives the fundamental relevance as follows [1]:

1. This relation permits one to infer SBH masses with 30% accuracy from a single measurement of the large scale bulge velocity dispersion.
2. This relation plays vital role in deriving the character of nuclear activity in the different classes of AGNs.
3. This relation has become the litmus test for the verification and justification of models of SBH formation and evolution.

M- C relation

Graham et al. find that the scatter in the M- C relation decreases significantly when only SBH masses derived from data which resolve the sphere of influence are used. The M- C relation is however, dependent a parametric characterization of the light profile using a Sersic law, which might not prove to be a good fit for some galaxies. They pointed that CD and merging / interacting galaxies might be particularly problematic and exclude NGC6251, M87 and NGC4374 from their analysis [1]. The M- C and M- L relations have the practical advantages of needing only imaging data than the spectroscopic data.

2. Model used

The formula of Eddington Luminosity for a black hole of given mass may be calculated as follows [1]:

$$L_E = 1.3 \times 10^{38} \left(\frac{M}{M_{\otimes}} \right) erg/\sec. \tag{1}$$

The formula of Radiative efficiency for a black hole of mass is given by following equation as [6].

$$\eta = L_E / \dot{M} c^2 \tag{2}$$

where L_E is the total luminosity emitted from the accretion flow and $\dot{M}$ is the corresponding mass accretion rate of the system [12].

The M- η relation:

In the present work, we have used the model represented by equation (2) to establish M- η relation for discussing the current status of SBHs in AGN. Our relation shows the uniform variation between the different test spinning black holes and radiative efficiency. The straight line nature of the graph drawn with the help of equation(2) indicates that all the SBHs having the masses ranging from 10^6 to $10^{9.5}$ of the solar mass have the same type of origin and evolution and mass is only function of the radiative efficiency so that heavier the mass, larger the radiative efficiency. From the graph as shown in the figure 2, it is obvious that the radiative efficiency of the spinning black holes increases gradually with mass in the lower mass range, but rapidly in the heavier mass range.

This relation gives the following characteristics:

1 There is a uniform variation between the mass and radiative efficiency of the spinning black holes in AGN.

2 The mass of the spinning black holes is only main function of the radiative efficiency to discuss their different characteristics.

3 The radiative efficiency of the spinning black holes increases gradually with mass in the lower mass range, but rapidly in the heavier mass range.

4 Heavier the mass of the spinning black holes, larger the radiative efficiency.

Thus we can say that for the detailed information regarding the status of spinning black holes, the M- η relation has vital role for their discussion in addition to the M- σ relation, M- C relation and M_*- L relation.

Data Used:

$\dot{M}$ =One solar mass/one year [12].
Mass of sun (M_{Θ}) = 1.99 x 10^{30} kg.[6].
Mass of the SBH in AGN-10^{6} – $10^{9.5}$ M_{Θ} [6], 3x10^{7} M_{Θ} [6]. 2x10^{6} – 3x10^{9} M_{Θ} [13].

On the basis of the data mentioned above regarding the mass of black holes in AGN in terms of solar masses, we have calculated the Luminosity & radiative efficiency of different black holes in AGN.

3. Result and Discussion

In the present work, we have calculated Luminosity (L_E) and radiative efficiency (η) for different test spinning black holes existing in AGN. Our calculation shows that the Luminosity and radiative efficiency η lies between 1.3×10^{44} and 3.9×10^{47} erg/s & 0.00022 and 1.388 respectively corresponding to the mass ranging from $10^{6}M_{\Theta}$ *to* $5\times10^{9}M_{\Theta}$ of the spinning black holes in AGN, which is clearly shown in the table 1. We have plotted the graph between:

1. The mass of different test spinning black holes and their corresponding luminosity.
2. The mass of different test spinning black holes and their corresponding radiative efficiency.

Both the graph has the same nature as clear from the figure 1 and 2. From the data observed from the table 1and graph plotted in figure 1 and 2, it is clear that the Luminosity as well as Radiative efficiency of the spinning black hole increase with increasing the mass of different test spinning black holes. The result shows that Luminosity as well as Radiative efficiency of the spinning black holes increase uniformly with increase of the mass of different test spinning black holes. This means that there is uniform variation between the mass and Luminosity as well as Radiative efficiency of the spinning black holes.

The M-L relation (Kormendy and Richstone, 1995) indicates that the super massive black holes and bulge formation are tightly connected or even that the presence of a bulge might be necessary condition for the formation of super massive black holes.

In the present work, we have used the model represented by equation (1) to establish also M-L relation. Our M-L relation shows that the uniform variation between the mass of different black holes and Luminosity indicating that all the SBHs have the same nature regarding the origin, composition, evolution etc. and their luminosity is only the function of mass. This shows that heavier the mass, larger the luminosity.

The other relations like M- σ relation and M-C relation have been also proposed with the help of data available from lunched telescope to discuss the position, position, evolution and cosmic relevance of the spinning black holes (Ferrarese & Ford, 2005).

In the present work, we have used the model represented by equation (2) to establish M- η relation for discussing the current status of SBHs in AGN. Our relation shows the uniform variation between the different test spinning black holes and radiative efficiency. The straight line nature of the graph drawn with the help of equation(2) indicates that all the SBHs having the masses ranging from 10^{6} to $10^{9.5}$ of the solar mass have the same type of origin and evolution and mass is only function of the radiative efficiency so that heavier the mass, larger the radiative efficiency.

From above discussion, the results may be summarized as: The M- C and M- L relations have the practical advantages of needing only imaging data than the spectroscopic data. The M-σ relation gives the character of nuclear activity in the different classes of AGNs and has become the litmus test for the verification and justification of models of SBH formation and evolution. The M- η relation shows the uniform variation between the different test spinning black holes and radiative efficiency. The mass is only function of the radiative efficiency so that heavier the mass, larger the radiative efficiency and it is analogous to the M-L relation done by our research work.

Table 1: Luminosity & Radiative efficiency of spinning black holes in AGN

Sl. No.	**Mass of BHs (M) in terms of solar mass**	**R_{bh}=1475x10^{10} (M/ $M_\odot$) (m)**	**log(R_{bh}) (m)**	**Luminosity (L_{acc}) in erg/s**	**Velocity of light (c) in m/s**	**Radiative efficiency (η)**
1	1x10^6	0.1475	9.1687	1.3×10^{44}	3×10^{8}	0.00022
2	2x10^6	0.2950	9.4698	2.6×10^{44}	3×10^{8}	0.00044
3	3x10^6	0.4425	9.6459	3.9×10^{44}	3×10^{8}	0.00066
4	4x10^6	0.5900	9.7708	5.2×10^{44}	3×10^{8}	0.00088
5	5x10^6	0.7375	9.8677	6.5×10^{44}	3×10^{8}	0.00110
6	6x10^6	0.8850	9.9469	7.8×10^{44}	3×10^{8}	0.00132
7	7x10^6	1032	10.0136	9.1×10^{44}	3×10^{8}	0.00154
8	8x10^6	1180	10.0718	10.4×10^{44}	3×10^{8}	0.00176
9	9x10^6	1327	10.1228	11.7×10^{44}	3×10^{8}	0.00198
10	1x10^7	1475	10.1687	1.3×10^{45}	3×10^{8}	0.00227
11	2x10^7	2950	10.4698	2.6×10^{45}	3×10^{8}	0.00454
12	3x10^7	4425	10.6459	3.9×10^{45}	3×10^{8}	0.00681
13	4x10^7	5900	10.7708	5.2×10^{45}	3×10^{8}	0.00908
14	5x10^7	7375	10.8677	6.5×10^{45}	3×10^{8}	0.01135
15	6x10^7	8850	10.9469	7.8×10^{45}	3×10^{8}	0.01362
16	7x10^7	10.32	11.0136	9.1×10^{45}	3×10^{8}	0.01589
17	8x10^7	11.80	11.0718	10.4×10^{45}	3×10^{8}	0.01816
18	9x10^7	13.27	11.1228	11.7×10^{45}	3×10^{8}	0.02043
19	1x10^8	14.75	11.1687	1.3×10^{46}	3×10^{8}	0.02277
20	2x10^8	29.50	11.4698	2.6×10^{46}	3×10^{8}	0.04554
21	3x10^8	44.25	11.6459	3.9×10^{46}	3×10^{8}	0.06831
22	4x10^8	59.00	11.7708	5.2×10^{46}	3×10^{8}	0.09108
23	5x10^8	73.75	11.8677	6.5×10^{46}	3×10^{8}	0.11385
24	6x10^8	88.50	11.9469	7.8×10^{46}	3×10^{8}	0.13662

25	$7x10^8$	103.2	12.0136	9.1×10^{46}	3×10^8	0.15939
26	$8x10^8$	118.0	12.0718	10.4×10^{46}	3×10^8	0.18216
27	$9x10^8$	132.7	12.1228	11.7×10^{46}	3×10^8	0.20493
28	$1x10^9$	147.5	12.1687	1.3×10^{47}	3×10^8	0.22776
29	$2x10^9$	295.0	12.4698	2.6×10^{47}	3×10^8	0.45552
30	$3x10^9$	442.5	12.6459	3.9×10^{47}	3×10^8	0.68328

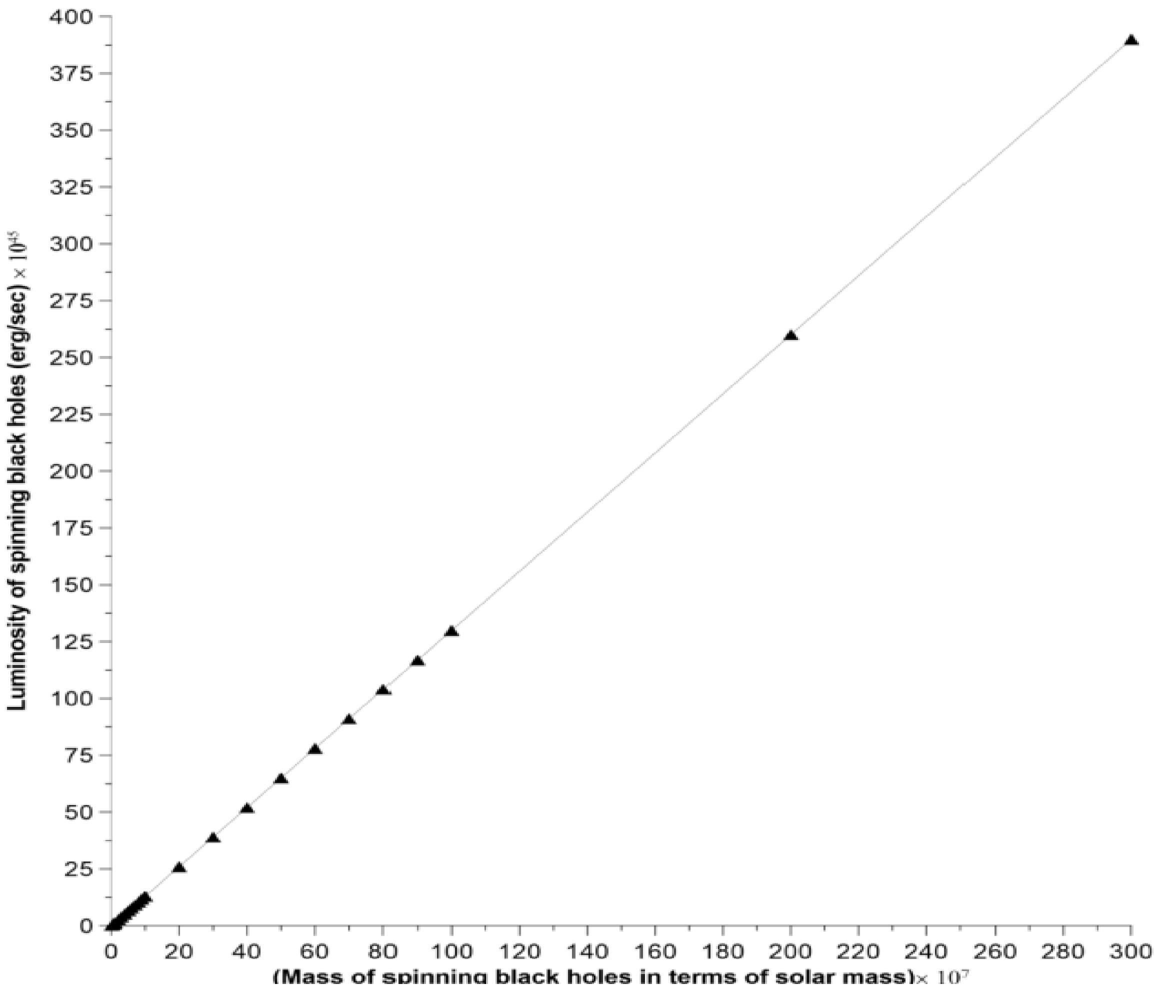

Fig. 1: The graph plotted between the mass of spinning black holes and their corresponding luminosity indicating the M-L relation.

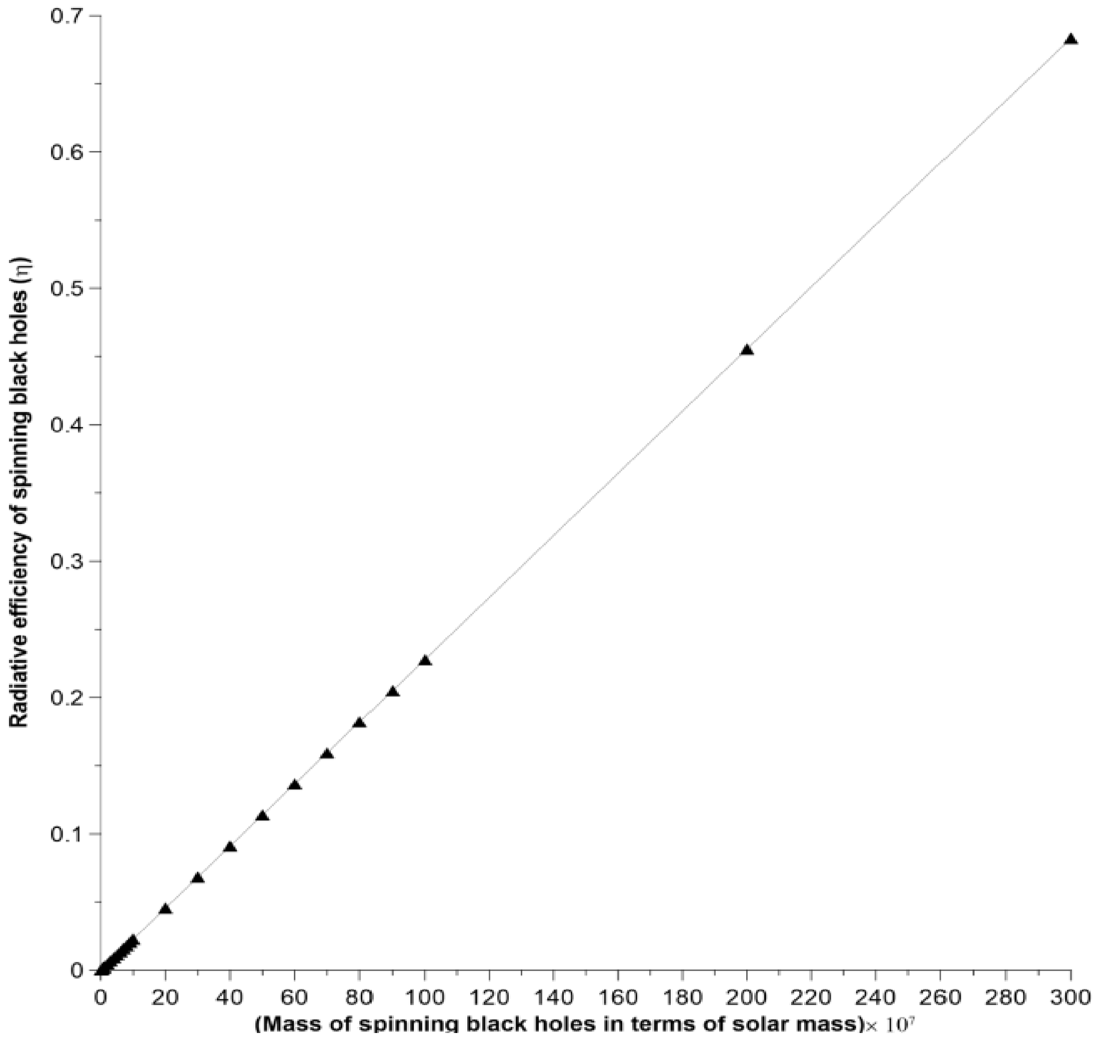

Fig. 2: The graph plotted between the mass of spinning black holes and their corresponding radiative efficiency indicating the M- η relation.

4. Conclusion

During the study regarding the M-L relation & M- η relation, the following conclusions may be taken into consideration:

1. There is a uniform variation between the mass and Luminosity as well as radiative efficiency of the spinning black holes in AGN.
2. The mass of the spinning black holes is only main function of the Luminosity and radiative efficiency to discuss their different characteristics.
3. The Luminosity and radiative efficiency of the spinning black holes increases gradually with mass in the lower mass range, but rapidly in the heavier mass range.
4. Heavier the mass of the spinning black holes, larger the Luminosity as well as radiative efficiency.

Thus we can say that for the detailed information regarding the status of spinning black holes, the M- η relation has vital role for their discussion in addition to the M_*- σ relation, M_*- C relation and M_*- L relation.

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