

The Impact of Super Massive Black Hole (SMBH) on Galaxy and Star

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Abstract. Black hole, one of the most inscrutable objects in the universe have been confirmed that nearly every galaxy contain a super massive black hole (SMBH) at its centre. SMBH's mass is astounding high which contains millions of solar masses, such huge black hole will generate huge gravitational effect on the region nearby. However, studies indeed found the correlation between black hole and its host galaxy. This paper investigates the impact of black holes on galaxies' structure and stars based on different black hole mass relation simulations. The exact effects on black holes on galaxies remain unclear, but different simulations certainly found the correlations of black hole's mass with galaxy's variables and stars. According to the analysis, correlations of MBH, σ_e , stellar mass, star formation rate and kinetic energy shows the energy emitted by the ANG/black hole affect the inner structure of the galaxy and the properties of stars which disturbing the gas reservoir in the galaxy. The impact on stars can be reflected by the impact on galaxies. Study galaxies is a good way to find more properties and details about the growth and the formation of SMBHs at the centre of the galaxies. The general structure of the galaxy also provides an indication of the structure of the universe and stars' organizations.

Keywords: super massive black hole; galaxies; evolutions; star formation.

1. Introduction

Contemporarily, more advance telescopes and investigations have found more interesting discoveries in black holes and galaxies/clusters. Follow with the first image of black hole M38 and the image galaxy cluster from JWST [1]. More detailed properties of black holes have been revealed and more attention have been put on one of the most mysterious objects in the space, black hole. The studies on black hole helps us to understand the structure and the formation of the galaxies. Furthermore, galaxy is the fundamental bricks of universe, which dominate the most of the observable universe. Striding the galaxies show us more information of the structure of the universe, the organizations of the stars and the formation of the stars. Previous study which focusses on different galaxy simulations which focused on galactic nuclei, stellar mass, and centre black hole mass [2], which provided a better resolution and properties of the galaxies. However, the best model for galaxy survey is called hydrodynamic simulations which involve the dark matter and baryonic components thus produce more details and higher resolution about the fuelling and feedback effect based on 3D model [3]. Even though, the hydrodynamic simulations haven't accomplished fully yet, several other investigations indeed succeed in the general properties of galaxies. Different simulations results have been proposed including the stellar mass, stellar formation rate, galactic feedback, wind, halo and etc, which produce more practical size and masses of galaxies [4-6].

On the other hand, it is generally agreed that there is a super massive black hole lays at the centre of the galaxies which is millions massive than our sun [7]. In resent year, human took the first image of the black hole M87 which is in the middle of galaxy [8]. Previous observations already find out some correlations between black holes and its hosted galaxies [9]. It is noticed that galaxies will undergo different stages which interfere the galaxies' star formation rate and its density. Star-forming galaxies will experience a rapid transformation from star-forming in to quiescent galaxies [10], where the gas in the galaxies is depleted and stop forming stars. What exactly cause the rapid transformation remain unknown, however, later researches predict the general timescale of the quenching events [11].

The paper is composed in following parts. Section 1 displays the impact of black holes on galaxies and the relations were used for the analysis. Section 2 shows the impact of black hole on stars, including the star formation rate, stellar mass, and ANG feedback which also determines the density of the galaxies. Section 3 shows the remaining problems and future expectations. And the conclusion is shown in Section 4.

2. Impact on galaxy

The black holes at the centre of the galaxies contains huge amount of mass. Such super mass black hole (SMBH) has a wild gravitational impact on the surrounding, which indeed causing a vital impact on the evolution and the inner structure of the galaxy which it hosted. So far, several research have done to find out the co-evolution between the SMBH hosted galaxies and the SMBH. Several study aspects have done in order to figure out the impacts of the accretion of the black hole, BH wind, energy released by the black hole and its accretion disk, etc. It should be noticed that the BHs mainly correlate with galactic bulge, which is the centre region of the galaxy. Finding the co-evolution factors/variables is not an easy thing to do. However, the method which derive the relation is by adding black hole mass in to the fundamental plane (FP) [12]. The fundamental plane shows the relation of different variables to their host galaxies, by adding the black hole mass in to the fundamental plane and observing the changes between different relation between MBH and other variables. In addition, the variable that mainly affects the correlation between black holes and the galaxies is the relation between black hole’s mass MBH and the effective velocity dispersion σ_e . The relation of σ_e -MBH indeed correlate more to the central super massive black hole than other variables in the FP (e.g., luminosity or effective radius of the galaxies) and confirming the relation between black holes and the bulges of host galaxies [12].

Table. 1 from reveal the results of the correlation between MBH and different galaxy parameters.

The first column shows the independent variables, including luminosity L, effective dispersion velocity σ_e and the effective radius R_e of the galaxy. The second column shows the subgroup of galaxy. The fifth column shows the intrinsic scatter of the galaxy for σ_e -MBH relation.

Variable(s)	subgroup	α	β	γ	ϵ	(x)	(y)
σ_e	All	5.07 ± 0.27	-	8.30 ± 0.05	0.42 ± 0.04	2.291	-
	ClBul	4.48 ± 0.30	-	8.60 ± 0.05	0.38 ± 0.04	2.333	-
	Pseudo	3.50 ± 0.70	-	7.14 ± 0.07	0.27 ± 0.08	2.135	-
L	All	1.12 ± 0.08	-	8.48 ± 0.06	0.53 ± 0.05	10.913	-
	ClBul	1.00 ± 0.09	-	8.71 ± 0.06	0.47 ± 0.05	11.074	-
	Pseudo	0.49 ± 0.47	-	7.10 ± 0.12	0.43 ± 0.14	10.109	-
R_e	All	1.07 ± 0.10	-	8.43 ± 0.07	0.63 ± 0.06	0.306	-
	ClBul	0.91 ± 0.12	-	8.70 ± 0.07	0.60 ± 0.06	0.500	-
	Pseudo	0.15 ± 0.23	-	7.10 ± 0.12	0.39 ± 0.12	-0.502	-

$\sigma_e - Re$	<i>All</i>	3.95 ± 0.34	0.39 ± 0.09	8.43 ± 0.05	0.38 ± 0.04	2.301	0.310
	<i>ClBul</i>	0.69 ± 0.34	0.32 ± 0.09	8.68 ± 0.05	0.38 ± 0.04	2.341	0.500
	<i>Pseudo</i>	2.80 ± 0.83	-0.14 ± 0.19	7.05 ± 0.08	0.27 ± 0.11	2.120	-0.529
$\sigma_e - L$	<i>All</i>	3.48 ± 0.43	0.43 ± 0.11	8.48 ± 0.05	0.37 ± 0.04	2.303	10.923
	<i>ClBul</i>	3.20 ± 0.43	0.37 ± 0.11	8.69 ± 0.05	0.34 ± 0.04	-2.341	11.074
	<i>Pseudo</i>	2.9 ± 1.3	-0.08 ± 0.46	7.10 ± 0.10	0.30 ± 0.13	-2.096	10.113

Table. 1 shows the strong relevance of σ_e -MBH relation collected the data. The first three row shows the different data of three independent variables. The fourth and fifth shows the data of the correlations of effective dispersion velocity with other two independent variables. However, the data of intrinsic scatter do not vary much through the fifth column, which shows the correlation between σ_e do not change much even combining the σ_e with other galaxy parameters. In addition, the bonding between σ_e -MBH in this conclusion is considered to be much stronger than previous thought [12]. Even though the results indeed appear the relation between σ_e -MBH and its host galaxies. Only when the mass of hosted black hole reaches a certain value, the change in AGN will shift from momentum-driven in to energy-driven which influence the structure of galaxy bulge. In this case, the outflow of the black hole's wind will exceed the bonding energy of the bulges [12]. Those ejected particles (BH wind) will eventually affect the structure and the co-evolution of the galaxy.

Other scholar also argued that the MBH is strongly tide up with the mass of the galaxy spheroid. Galaxies are regulated by the outflow and the inflow, it could be the energy from other body, cosmic ray or other events which inject matters in to the galaxy or forming other things in the galaxy. BH at the centre of the galaxy plays and important role on the outflow energy and galaxy's gas reservoir which indeed changes the regulation of the inner galaxy in different aspects [13]. However, both the mass and effective velocity dispersion changes the way of the future galaxy evolution. BHs loss mass through Hawking radiation since it was formed. In this case, the co-evolution of black hole and its host galaxy is considered to be the consequence of the balance between accreting black hole and galactic bulges [14].

One ought to notice that even though super massive black hole seems have huge gravitation effect on the galaxy regard to its huge mass. Researches have shown their impact does not affect beyond the bulge because the MBH does not relate to the disk parameter [15]. However, there is strong relation between both the density and size of the bulge and the mass of black hole, shown in [14]. Several other factors also reveal the correlations between the black hole and its hosted galaxy. Shown in fig. 1 [14]. There is a linear relation between the $\log MBH$ and $\log MBu\sigma^2$. $\log MBu\sigma^2$ refers to the kinetic energy of the galactic bulges. In addition, black hole also increases its mass through the accretion process which also change the size, velocity dispersion and other properties of the galaxy. In this case gas reservoir inside the galaxy may evolve in two different ways, which the gas could added in to the black hole accretion disk which increase MBH, or the gas will cause the formation of new stars. However, other researchers display the data which the accretion disk double the mass of the BH [14]. The results are presented in Fig. 1. The relation between the density of the centre galaxy and the mass of black hole [15], which the more massive black hole will increase the stellar mass in 1 kpc/ increase the centre galaxy's density as shown in Fig. 2. However, this correlation can be explained by the following section which is the impact of black hole on star formation.

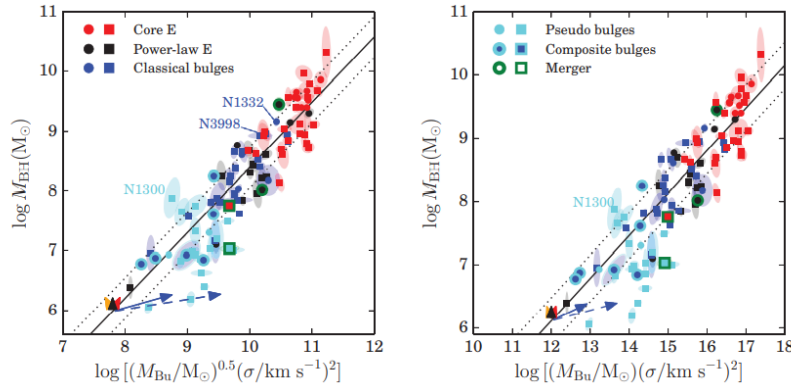


Fig. 1. The relation between bulge’s kinetic energy and the mass of the black hole.

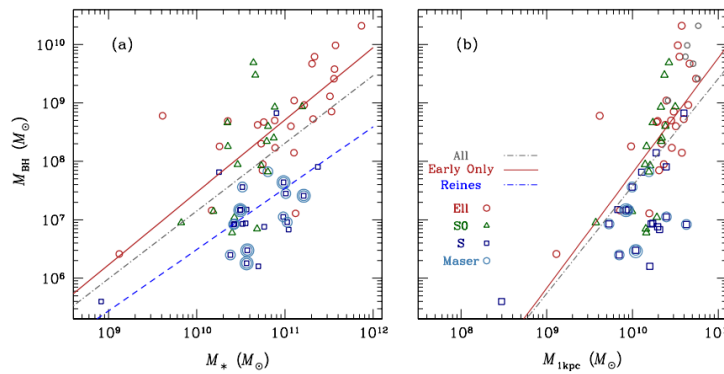


Fig. 2 (a): The relation of MBH and stellar mass (b): The relation of the MBH and the stellar mass within 1 kpc.

3. Impacts on stars

Black hole at the centre of the galaxy will emit huge amount of energy to the surroundings. Those energy will affect the star formation process. However, different black holes in different types of galaxies will form different ANG feedback, which is the result of black hole’s energy impact on star and galaxies’ gas reservoir. The way which determined the impact on star is mainly depends on the relation between star formation rate, stellar mass and the mass of black hole.

The formation rate of star is principally based on the gas reservoir inside the galaxy. Nevertheless, both the growth of black hole and stars are based on the gas cooling effect, shown in [16, 17]. There is strong correlation of AGN and star formation rate based on the gas reserve, which is the gas reservoir can increase both the mass of black hole or increasing the galaxy growth rate/star formation rate [16]. In this case, the outflow of ANG/radiative wind will affect the star in galaxy wide. Those radiation wind include X-ray, ultra-violet ray and etc, will place extra energy and angular momentum in to the available gas in the galaxy, consequently, those energy will induce heating, ionizing, material ejecting effect which increase heating the gas and preventing them to form stars or increase the black hole mass [15,16]. In addition, the growing black hole will increase the fraction of gas to enter the inner region of the galaxy which again decrease the available fuels/gases for star formation [16]. As shown in Fig. 3, the outflow indeed affects the star formation rate by exceeding the star formation rate. In this case, the gases/materials been removed from the galaxies before it could be cooling enough for star formation. Those results indeed reveal the positive relation between MBH and the formation rate of the star [16].

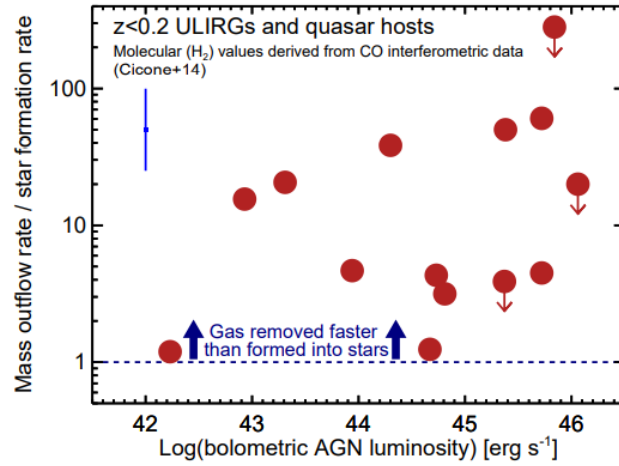


Fig. 3 Data of low redshift ultra-luminous infrared galaxies (ULIRGs) and quasar host galaxies, showing the ratio of H₂ masses and star formation rate for ANG luminosity.

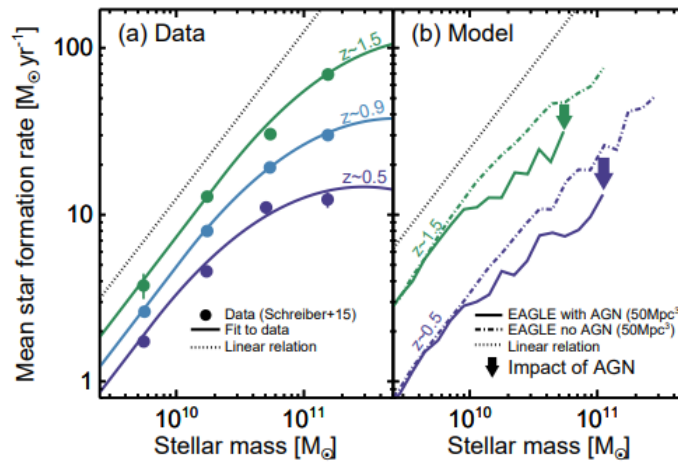


Fig. 4 Simulations from cosmological hydrodynamic EAGLE. (a) describes the data of currently observed star forming galaxies while (b) describe the change in mean star formation rate versus stellar mass with and without AGN effect.

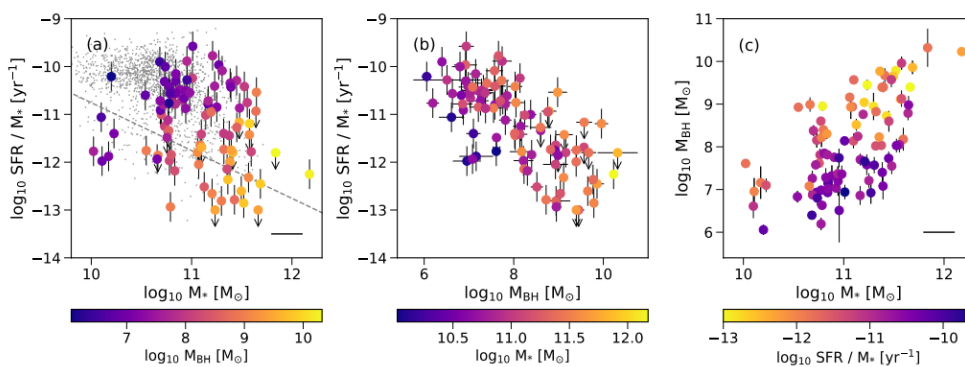


Fig. 5 The boxes show the relation between (a)sSFR–M*, (b)sSFR–MBH, and (c)MBH– M*.

Moreover, stellar mass which determined the density of the galaxies is also a good indicator of the interactions between black holes on galaxies. Notice that there are two types of galaxies, star-forming galaxies and quiescent galaxies. Galaxies with positive relations between stellar mass and star formation rate is called star-forming galaxies. Conversely the quiescent galaxies, which the display fraction of star-formation increases with stellar mass. in addition, as shown in the left in Fig. 4, the relation without ANG effect are much more flat than the dash-dot line which shows the relation with AGN effect, showing that the star formation rate per stellar mass unit is reduced by the effect from high mass ANG [16]. Furthermore, the mass of the galaxy also shows a correlation to the mass of

black hole, which is, more massive galaxies tend to have more massive black hole, conversely, less massive galaxies tend to have smaller. Fig. 5 and Fig. 6 exhibits the relation between three variables specific star formation rate (sSFR), MBH and M^* . It is obvious that the correlation between the mass of the black hole and star formation rate is strong [17, 18]. The tendency of MBH-sSFR relation shows the star formation rate decline with increase in the mass of black hole, this caused by the AGN effect which mentioned in above. Thus, more massive galaxy will have lower star formation rate compare to the less massive galaxy, which can also indicate that the black hole in more massive black hole has larger mass. Furthermore, those correlation display that high stellar mass/ low star formation rate galaxies tend to be quiescent.

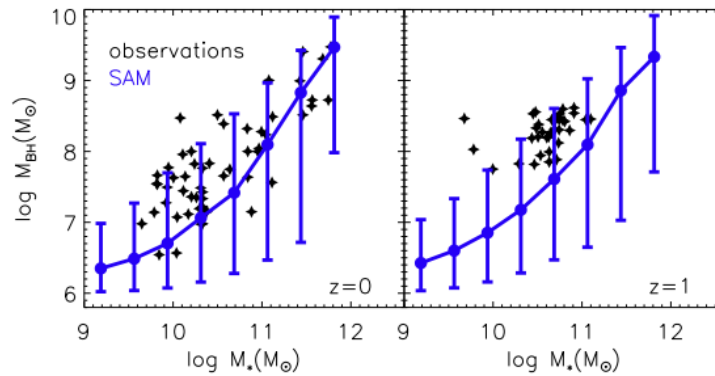


Fig. 6 The correlation of black hole’s mass as a function of stellar mass.

4. Limitations & Prospects

The process of star formation effect by black holes remains uncertain, currently, the most possible explanation is that the correlation is induced by black hole’s feedback/ANG feedback which act as a huge radiator at the centre of the galaxy. Because the limitation of the detectors and insufficient study on black hole and galaxies, it is hard to tell the physical properties of the black hole and its accretion disk or how does ANG feedback act as a counteraction to quench the star formation rate [14]. Notice that currently, the facilities used for galaxies detection produce in disagreement with other facilities because of different detection method, thus combing those variables in to relation may form measured scatter which can be solved in the future if detection is based on one specific detection method or detector e.g.[19]. On the other hand, most of the galaxy sample used for analysis is mainly massive galaxies and high mass black holes which low mass galaxies are hard to detect their properties or black holes sense it’s mass is to low [15,17]. This can be derived from the conclusion that more massive galaxies contain central black holes higher mass. Notice that there are several types of galaxy, different types of galaxy may appear different correlation when considering the black hole/ANG feedback. For example, the difference between classical bulge and pseudo-bulge, however, the limitations on samples make the distinctions more difficult [12]. In the future more advance equipment such as JWST or eRISOTA and ANG model are required for more accurate observations on the radiations and ANG feedback which counteract to star formation rate and for low mass galaxy observation [15,17]. In addition, hydrodynamic cosmological model can be used for the problems on ANG feedback and long-term impact on galaxy, see in [20]. It is uncertain about the time scale of ANG impact or the energy/momentum transformation process, ANG at the center of the galaxy may faint its luminosity or the outflow reduce to a certain level and become hard to observe [16]. Moreover, this model/simulation is useful because it allowed to trace the gas dynamic and it provide a statistically evolution prediction based on different galaxy samples [16,17]. It is possible that the large telescopes such as ALMA (Atacama Large Millimeter Array) will provide more information about the co-evolution and the impact of black holes on the galaxies and stars [21].

5. Conclusion

In conclusion, this paper mainly focus on the impact of centre super massive black hole (SMBH) on the galaxy it host and surrounding stars. The results indeed reveal the correlation of centre SMBHs and the regulation of galaxies and star formations. This paper can be concluded in three main aspect. The σ_e - MBH relation and M_{bulge}^2 - MBH display the way which super-massive black hole influence the outflow and the movement of gas in the galaxies which regulate the inner structure of the galaxies. The dependence of the size and density of the galaxy bulges on the mass of black hole and the way that centre super massive black holes regulate the gas reservoir and the outflow or inflow (ANG effect) of the galaxies which eventually affect the star formation rate. Moreover, the limitation on the galaxy samples and the observation scatter limits the information and analysis which can be obtained. More advance facilities, telescopes and models are required for more data about the exact correlation and the impact process. Study the relations of black holes will reveal the inner structure of the galaxies and the different ways which galaxies evolve. On the other hand, the ways which galaxies evolve will also affect the way which star form. To understand the organizations and the history of the universe, studying the relation between black hole and galaxy indeed plays an important role. Overall, these results offer a guideline for understanding the impacts of SMBH.

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