Studies on Black Hole Growth During Cosmosic Time and its Relationship to the Evolution of the Galaxy are being carried out.

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Abstract

In this paper, the findings of a search for AGN indications in the centre spectra of 542 local galaxies collected from the Calar Alto Legacy Integral Field Area (CALIFA) survey. These galaxies have z-coordinates between 0.005 and 0.03. The redshift range of CALIFA is covered by an aperture that measures 300 by 3000 pixels, which corresponds to the central 100 by 500 pc. We began by categorising all 526 CALIFA emission-line galaxies into four different kinds using diagnostic diagrams for emission-line ratios: starforming, LINER-like, Seyfert 2 and intermediates. In addition, we were able to discover evidence of the broad H component in 89 of the sample's spectra. Of these spectra, more over sixty percent were found to be present in the core spectra of LINER-like galaxies. These BELs have luminosities in the range of 1038 to 1041 erg s-1, however their FWHMs are in the same ballpark as those of luminous high-z AGN, falling somewhere between 1000 and 6000 kilometres per second. Based on this finding, we may extrapolate that type 1 AGN do, in fact, occur pretty commonly in our area of the universe. Moreover, by applying the emission-line ratio diagnostic diagrams, we were able to distinguish an additional 29 Seyfert 2 galaxies. Active Galactic Nuclei (AGN) are assumed to be the principal powering source for active galaxies. These are areas in the cores of active galaxies that comprise core Super Massive Black Holes (SMBHs), which have masses between and gravitationally pull the surrounding material via accretion.

Keywords: Black Hole, AGN, SMBHS

Introduction

Black holes may range in mass from millions to billions of times that of the sun, and they can be found at the centre of the great majority of enormous galaxies, including the one in which we find ourselves. Due to the growth of these black holes, tremendous amounts of energy are released. This energy is subsequently utilised to power quasars and other active galactic nuclei of a smaller intensity. Even if only a negligible portion of this energy were taken in by the galaxy that is now housing it, it may be enough to prevent new stars from forming by heating up the gas in the vicinity and compelling it to escape. Huge elliptical galaxies frequently have very little

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cold gas and extremely few newborn stars as compared to spiral galaxies. As a result, the extent to which this process has led to the reduction of star formation in large galaxies is a prominent issue in the study of galaxy evolution.

The elliptical form, sometimes known as the "football shape," and the spiral shape are the two most prevalent shapes for galaxies (also known as "disk-shaped"). Because the gas in spiral galaxies tends to be far colder than the gas in elliptical galaxies, it is more suited for the generation of stars than the gas in elliptical galaxies. Because of this, elliptical galaxies do not have the young, blue stars that are normally seen in spiral galaxies; rather, the stars in elliptical galaxies are typically somewhat red. In addition, spirals have core bulges that are structurally comparable to ellipticals when seen in microscopic form. Because of these parallels, we use the term "bulges" to refer to both the bulges that occur within spirals and the bulges that occur within ellipticals interchangeably. Each bulge has a core black hole, the mass of which is precisely proportional to the stellar mass of the bulge itself (MBH = 0.001Mbulge). Each bulge also contains a centre supermassive neutron star. Both black holes and bulges began to form about the same time throughout the span of the Universe's history, which was around 13.7 billion years ago. According to the findings of these investigations, it would appear that the formation of black holes and the expansion of bulges are deeply intertwined with one another. A vast quantity of energy is released whenever a black hole is permitted to receive stuff that is allowed to fall into it. This energy is on the order of 10 percent of the energy that is contained in the mass when it is at rest, which can be determined by applying the formula E = mc 2 to the situation. This energy is released in two primary forms: first, as photons, and second, as radio-luminous jets of charged particles. Photons account for the majority of the energy that is released. Because even a minuscule portion (less than one percent) of the energy generated within each bulge is capable of heating and obliterating its whole gas content, the absence of star formation in bulges may be explained by this phenomenon. This is because even a minuscule portion of the energy generated within each bulge is capable of destroying its entire gas content. The theorist's goal is to understand these facts by fitting them into a cosmological framework, which is the purpose of the theory. A unexplained element referred to as "dark matter" is thought to compose the great bulk of the cosmos, as stated by the hypothesis that is currently the most widely accepted. The rest is made up of basic particles like as protons, electrons, and neutrons, which are found in both gas and stars. They do not have any other interactions with dark matter save gravity, which is the major force that determines the tremendous scale expansion of the universe. After the Big Bang, there were very few things that the different portions of the cosmos shared in common with one another. They were able to gravitationally pull the things that were surrounding them, and as a result, they eventually grew into lumps that we call halos. The fight between gravitational heating and radiative cooling will determine the fate of the gas that is trapped within of these haloes. In low-mass halos, the process of cooling is the one that predominates. The gradual addition of gas into galaxies is what causes this expansion over the course of time. This gas is carried by cold flows into the centre of the galaxy, where it finally condenses into disks19 (but see refs) and forms stars. However, after the halo mass reaches a certain quantity, around 1012

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solar masses18, heating becomes the main driver, and gas no longer accretes onto galaxies after that point. When two or more haloes combine, the resulting haloes are massive. These large haloes might include tens or even hundreds of galaxies, and as a result, they are referred to as groups or clusters. Galaxy mergers inside haloes are the final possibility for galaxy development once they have finished accreting gas. These mergers transform discs into bulges and are the final step in the evolution of galaxies. This is due to the fact that galaxy mergers take place within haloes rather than outside of them. However, the connection between active galactic nuclei (AGN) and mergers is still up for debate based on observational evidence. When two galaxies that are still accreting gas collide, the gas falls to the centre of the galaxy, which causes starbursts and is frequently observed to feed the rapid growth of black holes.

Black holes in galaxy evolution

In addition to the problem that galaxy clusters have with the flow of cool gas, giant elliptical galaxies also have the additional problem of far more stringent limitations on the amount of gas that can get cooled and form stars. Stellar populations, chemical abundances, and structural aspects of large elliptical galaxies (specifically, the absence of intense central light cusps) all imply that since these galaxies were born, very little gas has dropped to the centre and generated stars. This is because the absence of intense central light cusps is one of the structural aspects of large elliptical galaxies. The problem of cooling flow is more severe within galaxies than it is within clusters due to the fact that the dying stages of life of massive stars return approximately 30–40 percent of the total stellar mass to the interstellar medium over the course of the existence of the universe. This is true even if one ignores the hot gas in the halo, which is why the problem is more severe within galaxies than it is within clusters. This indicates that the issue with the cooling flow is far more severe inside of galaxies than it is inside of clusters. If even a small percentage of the gas from enormous stars that are dying were to accrete, it would result in black holes that are considerably more massive than the estimates that are determined from observations. This would be the case even if only a small portion of the gas were to accrete. When attempting to apply the same explanation to galaxies as was done in the past with clusters, the fact that jets are frequently collimated on galactic proportions provides a hurdle. As a consequence of this, they punch through the gas that is all around them and discharge the great majority of their energy beyond the galaxy in which they were produced. This point is referred to as the entropy shelf 2 kpc, and it is approximately 2,000 light-years away. Even if the surrounding NGC seems to indicate that the heating has only been considerable at the Perseus cluster's radii r, it does not appear that the jets are impeding the creation of stars in the centre galaxy, which is a member of the 25 percent of cD galaxies that are blue. Because it is considerably harder to confine the jets in galaxies that are not at the centres of clusters, the situation is far more terrible than it already was. This is due to the fact that the atmospheres of these galaxies do not have the same level of pressure as the atmospheres of cluster centres. When operating in cosmic space, jets expend all of their potentially useful energy since there is nothing for them to constrain their activity against (for example, Cygnus A). On the other side, there are

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counter-examples where the jets have produced upheaval in the hot gas on galactic scales; for example, in Centaurus A, M84, and NGC 3801. These galaxies are all examples of this phenomenon. In addition, a jet can depart the galaxy in which it was hosted while still continuing to transmit some of its energy to the interstellar medium after it has done so. This can happen long after the jet has left the galaxy. The presence of knots in the jet of the galaxy M87 is one probable example of evidence that the galaxy has been in touch with the interstellar medium. In spite of this problem, it is intriguing to note that the fraction of elliptical galaxies that host a radio source scales with MBH in the same way that the estimated gas cooling rate does. Additionally, it is intriguing to note that the time-averaged jet power matches the gas X-ray luminosity over two orders of magnitude in galaxy mass. Both of these observations are interesting for their own reasons. The existence of a correlation between the two variables is indicated by these two findings, which go in the same direction. In the event that jets are unable to couple to the gas that is surrounding them and maintain their temperature, cooling will ultimately cause an optical AGN to be triggered. This optical AGN has the capacity to heat the gas through radiative processes.

Method

Super massive black holes as central powering source of AGN

SMBH mass estimation methods

Direct dynamical SMBH measurements”

It is a well-established fact that supermassive black holes (SMBH) in the cores of galaxies are unable to be directly viewed and can only be inferred from the impact they have on the material in the space around them. This is one of the reasons why they are referred to as "invisible eyes" in the scientific community. Before SMBH can be located, it is important to arrive at a precise resolution of the sphere of effect that it possesses. This must be done in order to locate it. The radius at which the core SMBH may still have an impact on the dynamics of the stars that are surrounding it is known as the sphere of influence. You may determine this radius by using the following formula:

$$R_{inf} = \frac{G_{M_{BH}}}{\sigma_*} = 10.8\,\mathrm{pc}\,(\frac{M_{BH}}{10^8\,M_\odot})(\frac{\sigma_*}{200\,\mathrm{km\,s^{-1}}})$$

Where can we find the stellar velocity dispersion of the stars that are situated in the galaxy's central bulge As long as it stays inside this radius, the accreting material will travel in a Keplerian orbit around the SMBH core. After a certain distance, the gravity of the core SMBH, which is known to as Rin, will no longer have an effect on the gas and stars that are located in the surrounding area. f As a consequence of this, the effect that SMBH has on the material that is close by can no longer be distinguished if the spatial resolution is decreased until it is lower than the sphere of influence. This specifies the utmost spatial resolution that the telescopes are

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capable of reaching in order to directly estimate the masses of black holes that are located at the centres of galaxies.

By a wide margin, the mass of the black hole designated as SgrA has been measured with the greatest accuracy. One possible location for this specific black hole is in the centre of our very own galaxy, the Milky Way. In order to compute the proper movements and radial velocities of the individual stars that circle around the SgrA, high-resolution data in the near-infrared have been employed. It has been determined from these computations that the mass of the primary source is around 4.1. By examining the gravitational impact that black holes have on the gas and stars that are located in their immediate surrounds, it is also feasible to arrive at an accurate estimate of the masses of these cosmic oddities. Since the Milky Way is the galaxy that is nearest to us, the Supermassive Black Hole (SMBH) that resides at its centre provides us with information that is pertinent to our understanding of black holes that reside in the centres of other galaxies.

H2O megamaser dynamics

Utilizing the H2O megamaser dynamics, the one of the black hole in the centre of Seyfert 2 galaxy NGC 4258 is one of the most perfect measurements of the MBH to date". Water masers, also known as Microwave Amplification by Simulated Emission of Radiation, are capable of creating coherent electromagnetic waves. This ability is supported by the theory of stimulated emission, which states that masers work by stimulating the emission of microwaves. In the AGN torus, it is possible to generate these masers "They are produced as a consequence of the X-ray radiation from the inner accretion disc heating the gas" that surrounds the core SMBH of the black hole and causing it to expand and heat up. Following this stage, the deformed circlumnuclear molecular gas disc may be generated, which would result in the emission of H2O at a frequency of 22 gigahertz. Within a few milliarcseconds of the SMBH located in the disc's centre, an examination of a molecular disc of this sort is possible. The problem of using this approach is that masers are exceedingly rare, and they can only be found in Seyfert 2 galaxies and LINERs that have accretion discs that are oriented edge-on toward the observer. This is due to the fact that The Mahamaser Cosmology Project is the most in-depth maser studies that has ever been finished up to this date. There are 180 galaxies in it that are able to be identified as having megamasers. The most important discovery that was made while researching megamasers was the finding that the masses of SMBHs obtained from their dynamics appear to be smaller when compared to the masses predicted using other approaches for the same objects. This was the most notable observation that was made during this research. In addition to this, masers may usually be seen in barred galaxies that have low masses in the region of S0-Sbc (Greene et al., 2016). This method has been employed throughout the course of the past several years to get some estimates for the masses of a few extra black holes. It is not yet obvious if the disparity in mass was brought about by the selection of the samples or whether there is an underlying problem that was introduced by one of the other methods. Neither of these possibilities is clear at this time.

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Gas kinematics

There are some galaxies that have discs of ionised gas in their nuclear regions (Tran et al., 2001) and these discs have the potential to be utilised in the process of estimating the masses of the SMBHs that are situated in the middle of the galaxy. It is not essential to have a high angular resolution because the velocity of the ionised gas may be “detected in the optical nebular emission lines (Balmer Hydrogen lines and forbidden lines of [OIII] and [NII])”. One of the advantages of gas dynamics is that it allows for the gas to settle into the rotating disk-like shape more quickly than stars do. This is an advantage that gas dynamics offers over other fields, such as chemistry (Peterson, 2014). This strategy has been implemented in the building of a great number of elliptical In order to calculate the mass of the SMBH utilising gas kinematics, spectroscopic mapping of the central region of the galaxies is performed. Following this step, the two-dimensional velocity field is reconstructed based on the recorded intensities of the emission lines, and it is then fitted to the data. Using the star density, the contribution of the ionised gas disc, and the gravitational potential of the central source, an estimate of the simulated rotational velocity may be made. In order to do this, we make the assumption that there is a slender disc of ionised gas rotating in the direction of our line of sight. Next, an estimate of the mass of the core SMBH is produced from the fit using the data. In spite of the fact that modelling ionised gas is very straightforward, doing so needs us to be aware of the angle at which the disc is inclined. If we do not have this knowledge, the mass estimate will be highly inaccurate, which might have significant repercussions. Furthermore, the presence of magnetic fields, radiation pressure, and dust, in addition to processes such as turbulence and shocks, can change the flow of gas away from Keplerian orbits which shows that estimates of the mass of black holes are incorrect.

Stellar kinematics

Because ionised gas discs are only discovered in a limited proportion of galaxies, it is only possible to compute the masses of the black holes in galaxies that contain such discs in order to determine the diameters of the black holes in those galaxies. On the other hand, dynamical modelling of star kinematics is applicable to every galactic system since it does not need the presence of any extra components. This makes it possible for it to be relevant in any context. If one considers just the force of gravity to be responsible for the motion of the star components that make up a galaxy, then one may conceive of galaxies as being collisionless systems. This is the case in the simplest feasible situation. The gravitational potential of all of the stars in the galaxy in addition to the supermassive black hole at the centre of the galaxy and the dark matter, is what ultimately determines the speed at which the stars move across the galaxy. The motions of the stars may then be applied to the problem of estimating the mass of the black hole using an approximation. This method is most commonly utilised for determining the mass of SMBHs in early-type galaxies. This is due to the fact that the complexity of the model is caused by the presence of phenomena such as dust, spiral structures, or triaxial gravitational potential. The line-of-sight velocity distribution may be used to specify how stars should be represented in the distribution function, which may then be used to infer the stellar kinematics of the system. This may be done by using the distribution to determine how stars should be represented in the function. The stellar gravitational potential is assumed to be connected to the velocity field once dynamical equilibrium has been achieved. It is possible to express the stellar gravitational potential as a function of the star mass density, which may be calculated based on the brightness of the galaxy that has been observed. This makes it possible to compute the gravitational potential of the star system. After the distribution function has been computed using the data, the gravitational potential of the entire system may be simply estimated using this information. This can be done after the distribution function has been computed. After establishing a connection between the total and the stellar gravitational potential, the Poisson equation may be applied to arrive at an estimate of the mass density of the whole system. This may be accomplished by establishing a connection between the entire thing and the gravitational potential of the star. The star mass density, the mass density of black holes, and the mass density of dark matter are the three components that go into making up the overall mass density. However, because dynamical models almost never include dark matter, it follows that the mass of a stellar massive black hole may be easily inferred from the stellar mass density. This is because the stellar mass density is proportional to the stellar mass. Because not all of the components of the distribution function are capable of being estimated only based on the observations, it is required to make some additional assumptions in order to proceed with the estimation process. Sargent et al. and Young et al. completed the first black hole mass calculation using the star kinematics dynamical models for the case of the M 87 galaxy, assuming spherical symmetry and isotropy of the non-rotating system. This was done for the case of the galaxy.

In the instance of the M 87 galaxy, this was carried out. This model's distribution function may be represented in its entirety by a single integral of motion, the value of which corresponds to the total energy contained inside the system. Because of this, it is the simplest model that may possibly be created. An anisotropic velocity distribution is required in the Jeans model, which is somewhat more difficult than other models. The distribution function is dependant on two integrals of motion: the total energy and the component of the angular momentum that is vertical. Both of these integrals are reliant on the distribution function. The approach developed by Schwarzschild (1979) is the one that is utilised by researchers the majority of the time. Within the context of this approach, the distribution function is dependent, to some extent, on the third integral of motion. If this method is chosen, then the orbital library will be constructed based on a gravitational potential that has previously been established for the galaxy. This will be the case if this strategy is used. In order to appropriately show the kinematics of the system and determine the best match that can precisely represent the true distribution of the starlight, it is required to calculate a large number of different orbits. This may be done by using a computer programme. The Schwarzschild model has the advantage of being able to compute more complex potentials, such as axisymmetric and triaxial potentials. This is one of the model's many benefits. This is one of the most significant benefits offered by the approach. Unfortunately, the method is prone to a number of inaccuracies, and as a consequence, it can only be used for regular early-type galaxies. This limits its applicability significantly. It is essential to have knowledge of the

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inclinations of galaxies, despite the fact that this is a fact that is only sometimes known with a high degree of precision. In addition to this, the existence of dust and LLAGN may also present additional hurdles for the model to contend with.

Results

Black Hole mass estimation

We relied on the BEL detection technique that was explained in Section 3.2.2 in order to identify type 1 AGN from the other galaxies that were included in the sample. This was done so that we could compare type 1 AGN to the other galaxies. There are 483 CALIFA galaxies that have emission lines that can be identified, and 89 of those galaxies have a large H line present in the spectra of the centre of their galaxy. All of these objects are exceedingly weak, with H fluxes that vary from 13.48 1017 erg s1 cm2 2 to 82.26 1017 erg s1 cm2 2, with the mean value being 82.26 1017 erg s1 cm2 2. The average energy contained within each of these things is calculated to be 82.26 1017 erg s. On the other hand, the FWHMs of these objects are comparable to the FWHMs of "typical" luminous type 1 AGN at high redshifts, occupying the range of values between 1000 km s1 and 6000 km s1, with an average of 3000 km s1. This is because both types of AGN emit light with a width-half-maximum (FWHM) of about the same magnitude. These objects have FWHMs that, when shifted to high redshifts, are comparable to the FWHMs of bright type 1 AGN. We were able to measure broad H luminosities LH that varied from 0.23 to 303.25 1039 erg s-1, with an average value of 7.21 1039 erg s-1. Our sample contains only one moderately bright type 1 AGN, and its designation is Mrk 79 (UGC 03973). Its luminosity is measured at 3.03 1041 erg s1. With the exception of Mrk 79 (UGC 03973), which is the only comparatively light type 1 AGN in our sample, the vast majority of the objects in our sample have extremely low LH, reaching below 1039 erg s1. Mrk 79 (UGC 03973) is the only relatively luminous type 1 AGN in our sample. Histograms are contained therein, and they depict the vast range of luminosities in H.

MBH − σ∗ correlation

It is essential to have a solid connection between the masses of black holes and the star velocity dispersions in the bulges of galaxies in order to have an accurate understanding of the coevolution of supermassive black holes and the galaxies that host them over the course of the entire history of the cosmos. Even in circumstances in which it is not possible to detect MBH directly, such as at higher redshifts or in LLAGN, proving this relationship is still extremely significant. This is something that may happen in either of these scenarios. If this is the case, then connecting bulge star velocity dispersions with can lead to an estimate of the masses of black holes that has a high degree of precision. If this is the case, then this estimate can be obtained. The MBH correlation was initially discovered for quiescent galaxies whose MBH was measured directly from star or gas kinematics. This was the case since these galaxies were considered to be more stable. The study focused primarily on this particular group of galaxies to

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gather its data. It is very difficult to quantify in these objects because the starlight from the host galaxy is usually tainted by the intense radiation that is released by dazzling AGN. Because of the exceptionally low amounts of AGN emission, this is not the case with LLAGN. Because of this, we are able to estimate the properties of the host galaxy without the contamination of AGN. This is a key step in the process of establishing objective linkages between AGN and the galaxies that they occupy. Consequently, The assumption of a constant MBH link between "quiescent galaxies and AGN served as a starting point in the construction of the connection for active galaxies". This assumption was made in order to establish the connection for active galaxies. On the other hand, it was found that different samples of active galaxies all had much steeper slopes, as well as lower normalizations of MBH. This was one of the main findings. The disparity in correlations between active and quiescent galaxies may be the result of biases imposed in sample choices, or it may suggest a real physical difference between active galactic nuclei (AGN) and quiescent galaxies, as well as co-evolution with their hosts. Both of these possibilities are possible explanations for the phenomenon. shown that dynamically based MBH correlations exhibit a bias towards more massive galaxies with larger. showed that this bias exists. This is due to the fact that the resolution of the telescope is restricted, which makes it impossible to differentiate between smaller circles of effect caused by black holes. Because of this, the MBH correlations that are predicted to come from dynamically based black hole masses will have a stronger normalisation, and as a consequence, they will be steeper than those that result from AGN. They established through Monte Carlo simulations that if we include the same bias in AGN samples, relationships between active and quiescent galaxies would be constant. They did this by including the bias in AGN samples. This is due to the fact that the bias would be consistent across both samples. In order to achieve the goals of this study, we made use of the MBH correlation that had previously been established for a group of 25 reverberation-mapped AGN. The Keck, Palomar, and Lick Observatories provided the information that was used to compile this sample. Because their sample of AGN also comprised of adjacent spirals, just like ours does, we chose to use this specific connection as a technique of calculating the mass of black holes. This decision was made because our sample of AGN also consists of adjacent spirals. As a method for determining the approximate mass of black holes, they provide the following equation:

$$\log(\frac{M^{\sigma}_{BH}}{M_{\odot}}) = (7.31 \pm 0.15) + (3.46 \pm 0.61) \log(\frac{\sigma_{*}}{200 \text{ km s}^{-1}})$$

e0 was calculated to have an inherent scatter of 0.41 0.05. The slope that they found is lower than what is seen in galaxies that are in a state of quiescence, but it is compatible with the MBH correlations that have been established in the past for AGN.

We used the method described in Section to determine the bulge stellar velocity dispersions of 404 different objects. Out of these 404 objects, 55 have been found to have a detectable broad H component, and as a result, they are classified as type 1 asymmetric galactic nuclei (AGN). The star velocity dispersions of CALIFA type 1 AGN lay somewhere in the range of 118 to 397 kilometres per second, with a value of 212 kilometres per second serving as the mean. After then, in order to carry out the computations required to ascertain the masses of these black holes, M BH, we resorted to Equation 3.4. We were able to determine that the masses of black holes range from 3.3 to 2.1 x 107 M on average, with the numbers ranging anywhere from 3.3 to 3.3. This finding suggests that the masses of black holes sit on the lower end of the MBH correlation, which is consistent with what is anticipated for LLAGN at low z.

Because we are unable to obtain measurements of brightness at all wavelengths for LLAGN, it is impossible for us to calculate the bolometric luminosity of an active galactic nucleus (Lbol). As a consequence of this, we came to the conclusion that the wide H luminosity LH would serve as an adequate stand-in for the value of Lbol. The correction factor is 9.26, and the link is described in the following way, as stated by Richards et al. (2006a):

$$L_{bol}^{\sigma} = 130 \, {}^{\times 2.4}_{\div 2.4} \times L_{H\alpha}$$

.Room Stern et al. (2012), we obtained L_{bol}^{σ} in range (3.5 × 1040 − 3.9 × 1043) erg s−1 with the average value of 1.2 × 1042 erg s−1 . From estimated L_{bol} and $L_{Edd} = 1.25 \times 10^{38} \left(\frac{M_{BH}^{\sigma}}{M_{\odot}}\right) \text{erg s}^{-1}$. Using Equation 3.3, we were able to derive Eddington ratios (computed for Thompson scattering opacity and pure hydrogen composition, Shankar, Weinberg, and Miralda-Escudé (2013)). With the exception of Mrk 79, which has a value of 4.3 x 10-2, we found that can occupy extremely low values throughout a wide range. These values range from 4.1 x 10-5 to 2.4 x 10-3. Table A.3 in the appendix has the documentation for all of the measurements. We come to the conclusion that the LLAGN in the CALIFA sample reside at the low-mass end of the AGN population, which also has an exceedingly low accretion rate. In order to avoid any confusion, we referred to black hole masses, bolometric luminosities, and Eddington ratios estimated from the MBH − σ∗ correlation established by Woo et al. (2013) as M_{BH}^{σ}, L_{bol}^{σ}, and λ^{σ}, and the ones estimated using the virial method as M_{BH}^{vir}, L_{bol}^{vir}, and λ^{vir}. „

Virial Black Hole masses

By applying the virial theorem, which is summed up by the equation, we are able to calculate the masses of black holes. Because of the premise that gravitational accretion onto the central SMBH is the primary force driving the motion of gas in the BLR, this is now theoretically feasible. When attempting to determine the velocity of the gas in the BLR, it is common practise to utilise the complete width at half maximum of the broad H emission line. It is possible to calculate the quantity of BLR by measuring the temporal delays that occur between the changes in the fluxes of BELs and continuum. This is possible due to the fact that fluctuations in the flow of BELs follow fluctuations in the flux of continuum. The actual delays can be measured, but doing so requires time and is only possible for the lightest things that are immediately close; as a result, it is more convenient to make use of some other secondary mass indication. The radius–

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luminosity connection, which is represented by Equation 3.2, is used to characterise the empirical correlation between BLR size and AGN continuum brightness at 5100 angstroms. Bentz et al. (2013) utilised RM measurements of 41 neighbouring AGN in order to uncover a relationship between radius and luminosity at the low-luminosity end of the spectrum. This link was observed at the following end of the spectrum:

$$\log(\frac{R_{BLR}}{\text{lt-day}}) = 1.527^{+0.031}_{-0.031} + 0.533^{+0.035}_{-0.033} \log(\frac{L_{5100}}{10^{44}\ \text{erg s}^{-1}})$$

Where L5100 is AGN continuum luminosity at 5100Å

The problem with LLAGN is that its continuum and wide H lines are very faint, making it difficult or perhaps impossible to detect them. This is a significant difficulty. Greene and Ho (2005) demonstrated that the wide H luminosity LH and its full width at half maximum (FWHM) may be substituted for the L5100 and FWHM of the H line, respectively. Because of these connections, we are able to estimate the masses of black holes using only the width and brightness of the wide H line as our data. According to Greene and Ho's (2005) research, we have:

$$L_{H\alpha} = (5.25 \pm 0.02) \times 10^{42}\ (\frac{L_{5100}}{10^{44}\ \text{erg s}^{-1}})^{(1.133\pm0.005)}\ \text{ergs s}^{-1}$$

And

$$FWHM_{H\beta} = (1.07 \pm 0.07) \times 10^{3}\ (\frac{FWHM_{H\alpha}}{10^{3}\ \text{km s}^{-1}})^{(1.03\pm0.03)}\ \text{km s}^{-1}$$

Which gives us the estimates of L5100 and FWHMHβ.

Greene and Ho (2005) used the total H luminosity in their equation, which is something that ought to be acknowledged. The explanation for this is that the researchers discovered consistent associations whether they employed both wide and total LH, and the narrow H luminosities from their sample only account for 7 percent of the total H luminosities. This is the reason why this is the case. The researchers also observed that the narrow H luminosities from their sample only account for 7% of the overall H luminosities. We only used the wide component of LH in Equation 3.7 because the broad luminosities are substantially smaller in our circumstance, accounting for less than fifty percent of the total. This is because the broad luminosities account for less than fifty percent of the total. This statement's argument has additional weight due to the fact that only BLR can track the AGN continuum.

In the process of computing MBH, an extra parameter called the virial factor f is taken into consideration. When determining the value of the f factor, the geometry, kinematics, and inclination of the BLR are all taken into account. The fact that these other properties of the black hole are unknown makes it possible that the f factor is the source of the substantial uncertainty that exists in the evaluation of the black hole's mass. It's probable that the virial factor changes significantly based on the particulars of each one-of-a-kind object, but we won't know for certain unless we have access to an extra exact method of calculating MBH in the meanwhile. Calculating the mean value of f is made a great deal less complicated and time-consuming when RM data are scaled to the MBH correlation of inactive galaxy populations. As a direct consequence of this, doing so is now a lot less difficult and more straightforward. As was said in the previous section of this conversation, using this method necessitates the incorrect presumption that active galactic nuclei adhere to the same MBH correlation as do quiescent galaxies. This assertion is not entirely accurate. In order to arrive at an estimate of the masses of black holes, we made use of the most recent value of the virial factor log(f). This value was determined by Grier et al. (2017) through the utilisation of RM measurements of 9 distinct AGN. The figure in question was 0.18.

Comparison between virial black hole masses and the ones estimated from MBH − σ∗

We estimated the mass of black holes using two separate approaches, and the findings for each of these approaches were very different from one another. In the following phase, we carried out an investigation to determine which of these two approaches yields more accurate results when determining the mass of black holes. We were particularly interested in determining which of these two approaches the most effective option was. On Figure 1, we compared the distributions of black hole masses (left) and Eddington ratios (right), both of which were derived utilising the virial technique as well as the MBH correlation of Woo et al. (2013). These distributions were compared using the left side of the figure. On the left are representations of the distributions of black hole masses, while on the right are representations of Eddington ratios (which will be referred to in the following as W13). On average, MBH is nine times larger than MvirBH, and the difference between the two can reach a factor of more than thirty for exceptionally enormous systems.

On the other hand, Eddington ratios that are determined via the use of the virial technique vir are, on average, a factor of 12 larger than those computed through the use of MBH. This is due to the fact that the virial technique vir uses a different method to determine Eddington ratios (). (right side of Figure 1) This finding is in line with what is stated in the Bondi accretion, which indicates that the ratio of MBH to BONDI need to be employed. The virial Eddington ratios are still in a state that is considered to be one of active or at the very least moderate accretion. During this time, can have values as low as log (), which is equal to 4.5. On the other hand, the vast majority of objects have values that are greater than the log() function's default value of 3.75.

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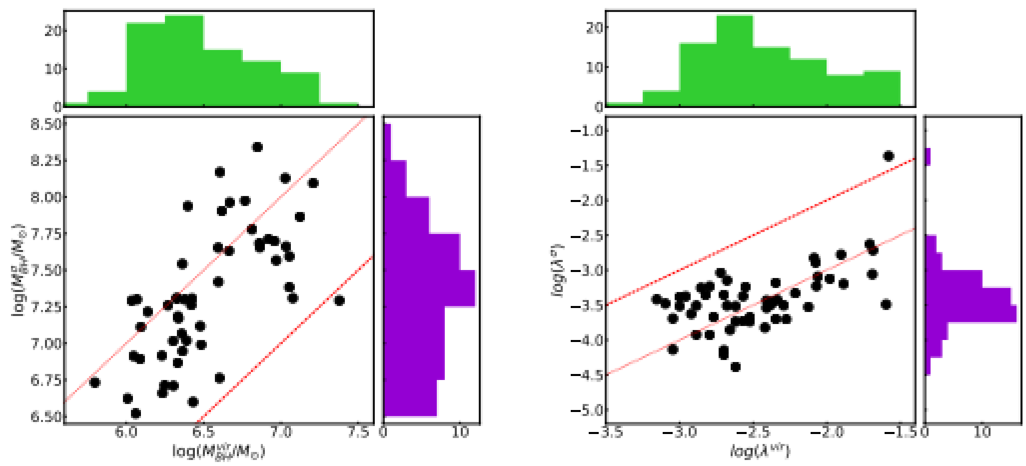

FIGURE 1: Left: A comparison is made between the masses of virial black holes and those calculated from the MBH correlation that was published by Woo et al. (2013), as well as their relative distributions. The green histogram depicts Mvir BH, whereas the purple histogram illustrates MBH. The line with dashes represents a correlation of 1 to 1 between Mvir BH and MBH, whereas the line with dots represents a correlation of 1 to 10. The difference in size between M BH and Mvir BH is typically a factor of nine, but can reach a factor of thirty for more gigantic systems. A comparison of the various Eddington ratios, vir and, can be seen on the right. In this particular instance, the dotted line depicts a correlation of 10 to 1 between vir and vir. The average size of a vir is around 12 times that of an average.

"On Figure 2 we wanted to show where virial black hole masses M_{BH}^{vir} fall on some previously established $M_{BH} - \sigma_*$ correlations. We included both $M_{BH} - \sigma_*$ correlation lines taken from W13 and Shankar et al(2016) .s research (in further read S16)". It is not hard to notice that the gap is greater for things that have a bigger value for. Only a few of the items with the lowest are positioned near to the W13 line, which they are still below; nonetheless, all of them are exceedingly low.

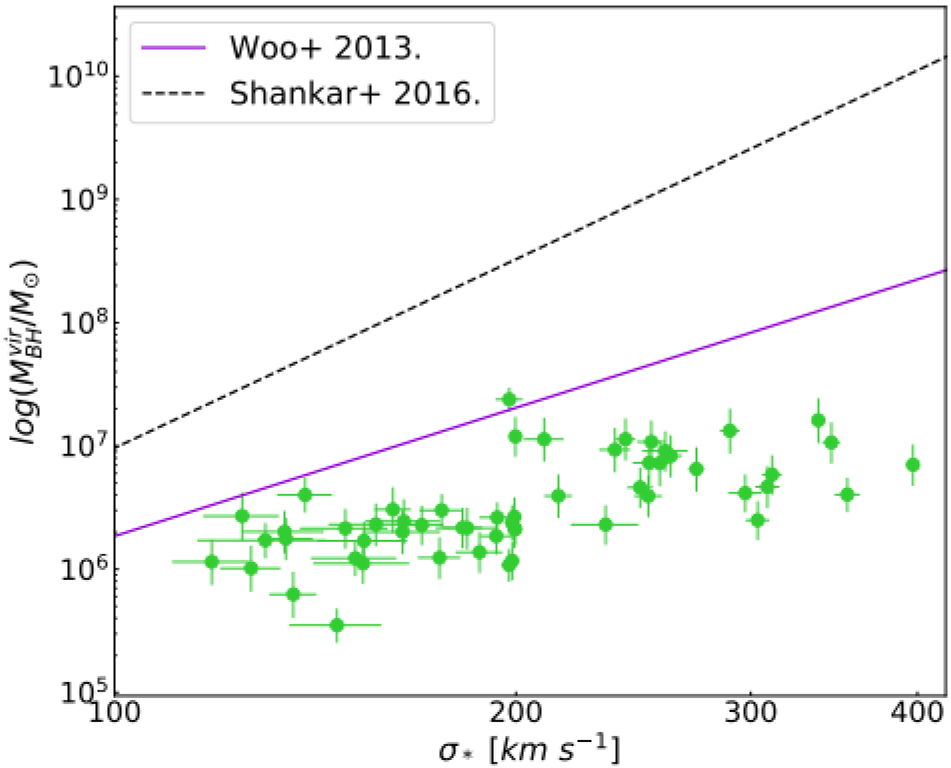

FIGURE 3.2: Estimates of the mass of the virial black hole, shown by the green dots, displayed on the MBH plane. The correlation from Woo et al. (2013) that we utilised to estimate MBH is shown by the purple line, while the correlation between MBH and is represented by the dashed black line. The correlation between MBH and comes from Shankar et al (2016). If we believe that MBH is a credible black hole mass estimator for LLAGN, then the fact that the majority of Mvir BH sit below the two correlation lines suggests that we have underestimated Mvir BH.

Far from S16 intrinsic line. The only object that is located slightly above the relation of W13 is Mrk 79. Mrk 79 even has a higher black hole mass and L_{bol} estimated from virial method than from $M_{BH} - \sigma_{*}$ of W13. Kaspi et al. (2000) obtained RM measurements for this object and reported $M_{BH} = 7.2 \times 10^7\ M_{\odot}$ and $\log(L_{bol}) =$ 44.6. Using the W13 relation we obtained somewhat lower black hole mass and bolometric luminosity $(M_{BH}^{\sigma} = 2 \times 10^7\ M_{\odot}, \log(L_{bol}) = 43.6)$, while virial estimation gave $M_{BH}^{vir} = 2.4 \times 10^7\ M_{\odot}$ and $\log(L_{bol}) = 43.9$. If we use the S16 line, we get a mass of 5.9 x 107 M for the black hole, which is closer to the RM figure than any other number. Despite this, the S16 line is developed for elliptical systems, which make up just a small percentage of our LLAGN sample. Because the RM measures have a little bias towards LLAGN we do not have a clear image of the precise situation when it comes to this regime. It is vital to emphasise this, as it is also necessary to mention.

From obtained results, we can conclude that Mvir BH are underestimated, according to predictions from MBH − σ∗ correlations. This implies that we trust that MBH − σ∗ correlation still holds in such low-luminosity regime. This will be discussed further. We wanted to investigate whether the black hole mass ratio Mσ BH/Mvir BH somehow scales with λ σ or λ vir. Due to similarity of results for λ σ and λ vir, we will only discuss λ σ, in order to avoid unnecessary repeating. On Figure 3 we plotted $M^{\sigma}_{BH}/M^{vir}_{BH}$ over λ σ (black dots) and noticed that the area covering low λ^{σ} $(\log(\lambda^{\sigma}) < -3.6)$ and high mass ratio $(M^{\sigma}_{BH}/M^{vir}_{BH} > 14)$ remains blank (no black dots). In order to establish whether this is due to selection effects or perhaps lack of objects in this area has actual physical meaning, we designed a test that will show us where the hypothetical objects with low detection probability would be located on this diagram. We divided the $M^{\sigma}_{BH}/M^{vir}_{BH} - \lambda^{\sigma}$ plane into 4 different areas, and analized FWHMs and broad Hα luminosities of objects falling into these 4 quadrants. We found that objects with extremely low λ^{σ} $(\log(\lambda^{\sigma}) < -3.6)$ and smaller discrepancy between black hole masses estimated from virial method and MBH − σ∗ correlation $(M^{\sigma}_{BH}/M^{vir}_{BH} < 14)$, have the lowest broad Hα luminosities $(2.7 \times 10^{38}\ \mathrm{erg\ s^{-1}} < L_{H\alpha} < 1.0 \times 10^{39}\ \mathrm{erg\ s^{-1}})$.

Relationship between black hole masses and total galaxy stellar masses”

In order to investigate the connection between AGN and their host galaxies beyond the bulge region, we investigated how well our black hole mass estimates fit on the previously established correlations between MBH and total galaxy's stellar mass M. These correlations have been established between MBH and total galaxy's stellar mass M. Because of this, we were able to explore the link between AGN and the galaxies in which they are hosted outside the bulge area. These relationships may provide more insight into the ways in which AGN and their hosts have coevolved throughout the course of time”.

The CALIFA team (Walcher et al., 2014) was able to calculate the total star masses by utilising the ugriz growth curve magnitudes that were obtained from the Sloan Digital Sky Survey (SDSS). The M estimate method took use of the models produced by Bruzual and Charlot (2003) and merged them with an Initial Mass Function (IMF) developed by Chabrier. Bruzual and Charlot (2003) were responsible for the development of these models (2003). This strategy takes into account both the potential of bursts and the varied degrees of dust extinction that may occur. “We found that type 1 AGN from CALIFA are hosted by the most massive galaxies in the sample” $(10^{10.2} - 10^{11.9})\ M_{\odot}$, $M_{*} \approx 10^{11}\ M_{\odot}$ on average. On the we present the link between Hubble types of type 1 AGN hosts from CALIFA, and their total stellar masses. As we can see from the figure, these objects cover wide range of morphological classes, but majority of them are distributed between S0 and Sbc Hubble types. This was our motive to use W13 $M_{BH} - \sigma_{*}$ correlation for black hole mass estimations, since their sample consists mainly of spirals.

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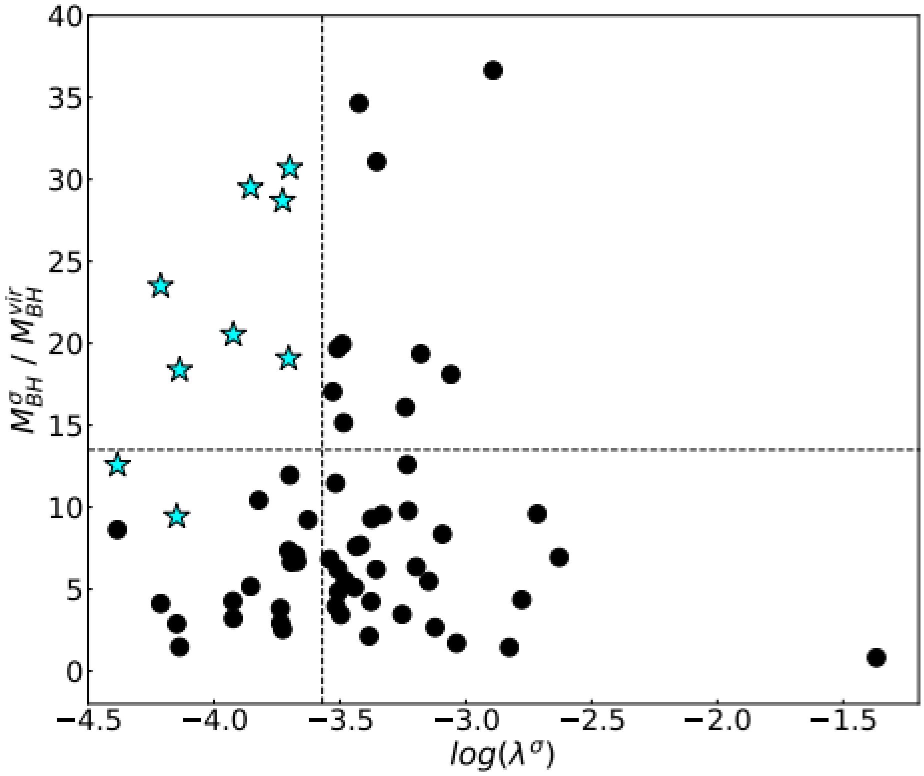

FIGURE 3: A graphical illustration of the influence that selecting type 1 LLAGN has on the MvirBH/MBH plane. Estimates of the BH mass and Eddington ratio for the CALIFA AGN are represented by the black dots. The objects that are located in the top right quadrant have the lowest wide H luminosities, whereas the objects that are located in the top bottom left quadrant have the lowest broad H FWHMs (below 50 percent detection probability). We estimated the hypothetical virial black hole masses (Mvir BH) of these objects and lowered the LH of the items in the bottom left region by fifty percent. The test items are denoted with cyan stars, and they fill in the blank area of the MBH/MvirBH diagram. This suggests that the absence of data points in this region is not owing to any special physical cause, but rather due to our inability to identify such faint things.

Discussion

According to what we have demonstrated in Section 3.3.3, the masses of black holes computed using the MBH correlation and those computed using the virial assumption do not accord with one another when compared side by side. In this part of the article, we are going to discuss the reliability of the methods that we used and try to provide some solutions to the issue of computing the masses of black holes in nearby LLAGN. Since it was created for both quiescent and active galaxies in a variety of redshift ranges, the MBH correlation is considered to be one of the most reliable black hole mass estimators. This is due to the fact that it was developed for both of these types of galaxies. On the other hand, the viral technique is commonly utilised as the methodology for calculating the mass of black holes in neighbouring AGN that is regarded to be the most accurate. This is because the virial approach was developed by a group of astronomers. Several researchers in the scientific community have relied on the virial assumption in order to calculate the masses of the black holes in the local LLAGN. However, previous research on this topic was conducted in an environment with a greater luminosity, with LH equivalent to or greater than 1040 erg s-1; we were only able to achieve a lower luminosity in our work. Our broad H luminosities are on the order of (1038–1039) erg s1, which is a regime that has not been completely examined up until this point for its full potential. Existing scaling connections between the luminosity of the continuum and the size of the BLR, as well as the luminosity of the continuum and broad line luminosities; do these relationships continue to hold true in this low-luminosity regime? Alternately, is it conceivable that the MBH correlation cannot be used to sources that are this faint because of its inherent sensitivity to brightness? Even if the most worst case scenario comes to reality, is it possible for us to be absolutely positive that the BELs that we detected do, in fact, indicate gas motion in the BLR? They could be an indication of another line-widening procedure, or they might be the cause of a mistake. The data that we have acquired can be interpreted in line with any one of the three possible scenarios that are listed below:

1. We did not in fact identify the BLR feature; rather, this is a mistake caused by the fitting procedure, or the BELs that we observed are formed by some other mechanism, and not by accretion onto the core SMBH.
2. The scaling relationships and the virial assumption are still correct even at extremely low luminosities; however, the MBH correlation no longer holds.
3. The MBH correlation is a valid method for estimating the mass of black holes in adjacent low-luminosity AGN; however, the virial scaling connections do not hold.

Conclusions

Local type 1 LLAGN are very difficult to find in the cosmos since their emission lines are weak and there is no typical power law AGN continuum present. This makes them one of the most difficult things to find. Despite this, they are extremely important for expanding our understanding of the population of black holes throughout the course of cosmic time as well as the coevolution of active galactic nuclei and the galaxies that they host. We relied on the CALIFA survey in order to determine the identities of these incredibly weak objects that are located in our local region of the cosmos. We made the startling discovery that the spectra of more than 16 percent of the galaxies contained in the CALIFA database contained BELs. In spite of the fact that these BELs have very low luminosities (LH values that are less than 1039 erg s1), their FWHM values are comparable to those of "typical" high-luminosity high-z type 1 AGN, which have an average velocity of 3000 km s1. We also measured the bulge velocity dispersions and total star masses M of the host galaxies of these objects, which helped us gain insight into the relationships between these parameters and the masses of black holes. This was accomplished by measuring the bulge velocity dispersions of the host galaxies. In order to estimate the masses of these type 1 LLAGN's black holes we first utilised the MBH correlation that was obtained in Woo et al. (2013), and then we used the virial assumption. Both of these methods are described in the following paragraphs. The differences between each of the outcomes that we obtained were not difficult to spot at all. Even though the Eddington ratios are, on average, twelve times larger, the black hole masses that can be determined from the MBH correlation are, on average, ten times lower than the black hole masses that can be computed using virial black holes. The difference narrows to less than a factor 10 in black hole mass for low-mass spiral galaxies, whereas it widens to more than 30 times that amount for large elliptical systems.

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