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Black hole mass estimating from optical band observation of AGN

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In this article considered, black hole mass estimation methods from using spectral and photometric observations of active galactic nuclei in the optical range. In addition, here has been proposed a new method for estimating the mass of a black hole using only photometric observations in the optical range.
Keywords: black holes, active galactic nuclei, observation of AGN

I. ANALYZING OF BLACK HOLE MASS ESTIMATION METHODS.

It is necessary to analyze a large amount of observational data to estimate the mass of the black hole in their central part from spectral and photometric observations of active galactic nuclei (AGN) in different bands. Using data from spectral observations, we can estimate black hole masses using various methods, but the method of estimation from photometric observations in the optical range alone has not been considered yet [1, 2]. In the following sections, we first consider how to estimate black hole mass from spectral and photometric observations, and then how to estimate black hole mass from only photometric observations (B,V,R) in optical band. Here we use observational data from several well-studied AGN [1–5]. In order to analyze the methods of black hole mass estimation, we collected data from different sources on different types of active galaxies. In addition, we have obtained additional information about our facilities from https://simbad.u-strasbg.fr/simbad/sim-fid an online database of additional facilities. After analyzing and studying all these, we estimated various parameters of some poorly studied objects through our proposed method [2, 4–7].

In the follow we first looked at the methods of estimating the mass of the black hole in their central part based on the observational data of active nuclei galaxies, and then we analyzed the results obtained by which method are closer to the observational data. Considering the methods, we performed some typical calculations and compared them with observational data of well-studied quasars, Seyfert I and Seyfert II type AGN. Our main goal is to show that by analyzing these methods it is possible to estimate the mass of the black hole in their central part only through the quantities obtained from photometric observation in the optical band.

1.1 Masses from the Virialized Motion. Assuming that broad-line clouds are virialized, for which there has been increasing evidence (Krolik et al. 1991; Wandel, Peterson, and Makkan 1999; cf. Krolik 2001), the black hole mass can be estimated as

$$M_{bh} = R_{BLR} \cdot \frac{v^2}{G} \quad ; \quad G = 6.67 \cdot 10^{-11} N \cdot m^2/kg^2 \tag{1}$$

The virial assumption may not be correct, however ; radiation pressure or magnetic fields may contribute significantly to the dynamics and outflows or winds could cause the observed line widths to exceed those induced by the black hole potential alone. In these cases the black hole mass calculated from equation (1) would be over estimated [1-2].

1.2 Black hole mass from stellar velocity dispersion. We can use the Stellar Velocity Dispersion to estimate the black hole mass at the center of nearby galaxies because in nearby galaxies there is apparently a close connection between the central black hole and the bulge kinematics [3, 5, 8]. For example, black hole mass (determined from spatially resolved kinematics) correlates

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well with stellar velocity dispersion, as $M_{bh} \propto \sigma^{3.75}$ (Gebhardt et al. 2000a) or $M_{bh} \propto \sigma^{4.8}$ (Ferrarese & Merritt 2000). In generally relation between M_{bh} and σ described as follow:

$$M_{bh} = 10^c \cdot (\frac{\sigma}{200km/s})^d \tag{2}$$

Here c and d constant coefficients, their values for low luminosity AGN: $c = 8.13 \pm 0.06$ and $d = 4.02 \pm 0.32$ [4, 9].

1.3 Mass estimation from luminosity of AGN. In general case black hole mass estimation from luminosity of AGN as follow:

$$ln(\frac{M_{bh}}{M_0}) = a + b \cdot ln(\frac{L(510nm)}{10^{44}erg/s}) + c \cdot ln(\frac{FWHM}{km/s}) \tag{3}$$

Here a, b, c are constant coefficients. FWHM is line width. The values of coefficients a, b, c take different values for different objects, for example, for $z \sim 3.5$ quasars $a = 1.07 \pm 2.62$, $b = 0.48 \pm 0.88$ and $c \approx 2$ [2, 4]. There are many empirical relations similar to the above, and almost all of them depend on spectral observations. Our goal is to try to estimate through photometric observations the mass of the black hole in the central part of AGN. In the appendix 1 given some well-studied AGNs and their observational data. We use these data, as well as observational data from other AGNs using the Symbad search engine, to explore how to estimate black hole mass below.

II. THE OPTIMIZATION METHOD FOR ESTIMATION OF BLACK HOLE MASS.

Figure 1 shows the relationship between the luminosity of some well-studied AGNs and the logarithmic values of the black hole masses in their central part. As can be seen from the figure, there is a linear regression between the luminosity of some AGNs and the black hole mass, and for some there is almost no such relationship (inside the rectangle in the figure on the right those given). In the Figure 2 given black hole mass and velocity dispersion relations for some well studied AGNs.

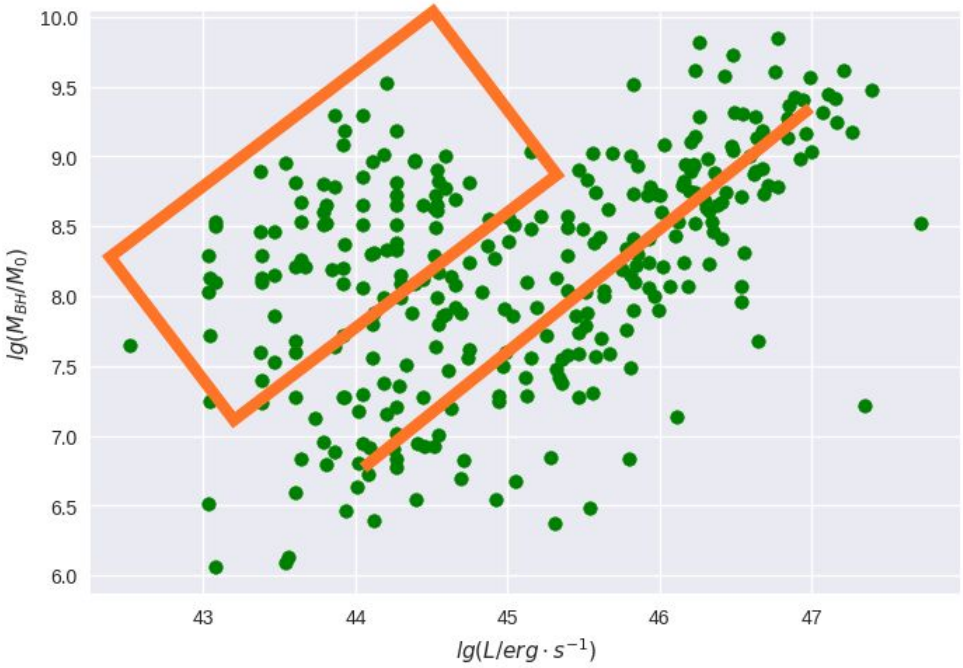


FIG. 1. Empirical relation between AGN luminosity and mass of the black hole

Here, for the AGNs given in the rectangle, there is almost no correlation between luminosity and black hole mass. There is a correlational connection between those given by a straight line. As can be seen from graph 1, there is an approximately linear empirical relationship between the luminosity of some AGNs and the black hole mass, and there is also an empirical relationship between the velocity dispersion and the black hole mass. In general, the linear regression relationship can be expressed as follows:

$$y = ax + b \quad ; \quad y = lg(\frac{M_{bh}}{M_0}) \quad , \quad x = \frac{L_g}{10^{44}erg/s} \tag{4}$$

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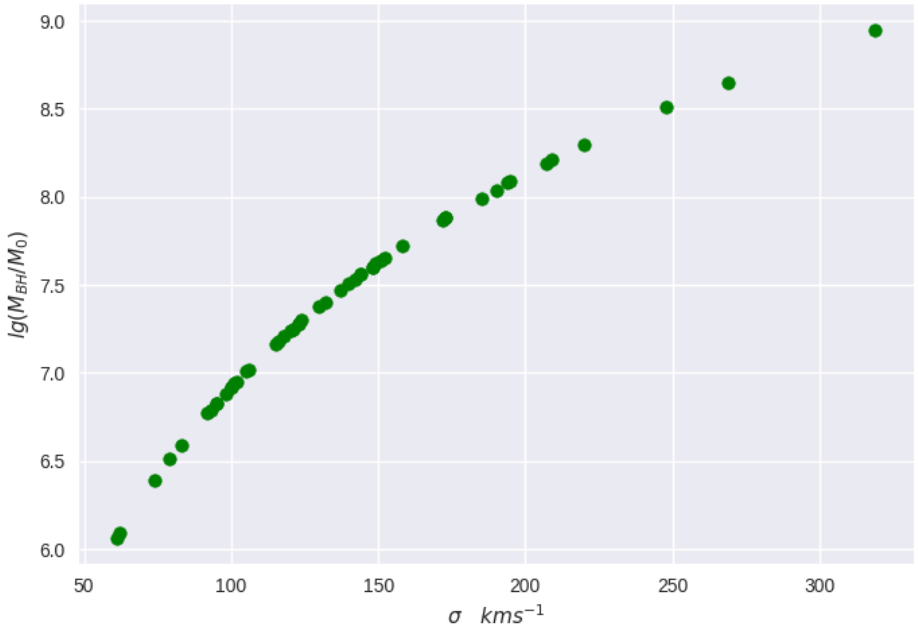


FIG. 2. Velocity dispersion and black hole mass relation.

Here L_g is generally estimated luminosity of AGN (it estimate from $B-V$ and L relation [ref].) and $M_0 \approx 2 \cdot 10^{30} kg$ mass of the Sun.

It should be noted that our results are based on the observational data of approximately 300 AGNs (all of the AGNs information taken from [1–11]), and in most cases give more accurate results for SY1 and SY2 type AGNs (i.e. give results close to the results obtained from spectral observations). For quasars and other objects with large redshifts, this relation cannot be applied.In the study of galaxies, the relationship between their bolometric luminosity and their magnitude has been well studied. Therefore, we did not look at it in detail.

III. RESULTS AND CONCLUSION.

So far, the mass of a supermassive black hole estimated by various methods is on the order of $10^8 M_0$ (M_0 is the mass of the Sun). In the theoretical calculations, including the calculation of the energy extraction through the Penrose mechanism, the maximum value of the mass of the supermassive black hole came out in the order of $10^{10} M_0$. We believe that the results obtained from spectral and photometric observations are closer to the real value. Therefore, when making typical calculations, the mass of a supermassive black hole should be considered to be in the order of from $10^8 M_0 - 10^{10} M_0$.

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