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HOW TO ACCURATELY ESTIMATE BH MASSES OF AGN WITH DOUBLE-PEAKED EMISSION LINES

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RESUMEN

Presentamos una nueva relación para determinar la masa virial del Agujero Negro central en Núcleos Activos de Galaxias con perfiles de doble pico en las líneas anchas de baja ionización. Se discute cuál es el parámetro adecuado para estimar la velocidad local de las regiones de emisión y la relación para estimar la distancia de éstas regiones a la fuente de ionización. Seleccionamos 17 objetos con perfiles de doble pico del SDSS y con líneas de absorción medibles para determinar las masas del hoyo negro mediante el método de dispersión de velocidades y comparar con nuestra determinación de masas viriales. Confirmamos un resultado previo (Zhang, Dultzin-Hacyan, & Wang 2007): que las relaciones para BLRs "normales" no son adecuadas para determinar las masas por el método virial en el caso de líneas anchas con doble pico.

ABSTRACT

A new relation is presented to estimate the virial BH masses of AGN with broad double-peaked low-ionization emission lines (hereafter, dbp emitters). A discussion is given on the adequate parameter to trace the local velocity of the Broad line Region (BLR), and the determination of the size of the BLR (its distance to the ionizing source) for dbp emitters. We select 17 dbp emitters from SDSS with measurable stellar absorption lines to determine BH masses from stellar dispersion velocities, and compare with our virial masses. We confirm a previous result that the relations to estimate virial BH masses for "normal" AGN are not appropriate for dbp emitters (Zhang, Dultzin-Hacyan, & Wang 2007).

Key Words: accretion, accretion disks — galaxies: active — quasars: emission lines

1. INTRODUCTION

Active Galactic Nuclei (AGN) with broad double-peaked low-ionization emission lines (hereafter, dbp emitters) are a special kind of AGN which provides direct evidence that these lines are originated from the accretion disk near the central black hole. These type of lines have been detected and studied for more than one decade (Chen & Halpern 1989; Halpern et al. 1996; Storchi-Bergmann et al. 1993, 1995, 1997, 2003). However, whether most of the dbp emitters have low accretion rate and/or most of the dbp emitters can be classified as LINERs, is an open question. In order to give an answer to the question, accurate determination of BH masses of dbp emitters are necessary. For low redshift and low luminosity AGN, accurate BH masses can be estimated from spectroscopic measurements of the stellar velocity dispersions from the absorption lines of the underlying host galaxy (Tremaine et al. 2002; Ferrarese & Merritt 2001; Gebhardt et al. 2000). For other broad line AGN without measurable stellar velocity dispersions, BH masses can be estimated from the line width of the broad (Balmer) emission lines under the assumption that the emitting clouds have motions dominated by gravity (these are often referred to as "virial masses"). The size of BLRs (the distance between central BH and the BLRs), $R_{\rm BLRs}$ is usually estimated using the empirical correlation with continuum luminosity found by Kaspi et al. (2000, 2005), and the expression the found by Peterson et al. (2004)

$$M_{\rm BH} = 2.15 \times 10^8 \left(\frac{\sigma_b}{3000 {\rm km\ s^{-1}}}\right)^2 \left(\frac{L_{5100\text{Å}}}{10^{44} {\rm erg\ s^{-1}}}\right)^{0.69} M_\odot \quad (1)$$

In the case of dbp emitters, only a small part of the them have apparent absorption lines which can be used to measure the stellar velocity dispersions. Thus to be able to estimate their virial BH masses is important. It is not trivial, however how to measure "line withs". It is also not obvious if the Kaspi relation holds for them.

With respect to the last point, we have shown in Zhang, Dultzin-Hacyan, & Wang (2007), that

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the value of $R_{\rm BLRs}$ estimated from the accretion disk model for dbp emitters should be systemically smaller than the value given by the Kaspi empirical relation between $R_{\rm BLRs}$ and the continuum luminosity. Furthermore, due to the special broad line shape of the profiles of the dbp emitters, the issue of how to measure the local velocity of the BLRs is not trivial.

In this short paper, we approach the question of how to estimate more accurately the virial BH masses of dbp emitters. In § 2, we determine which parameter is best to trace the local velocity of the BLRs, and how to estimate best their distance to the ionizing source (their size). Finally in § 3, we select 17 dbp emitters with detectable stellar absorption features from SDSS (Abazajian et al. 2004; Scott et al. 2004) in order to compare between BH masses determined from stellar velocity dispersions and our virial BH masses. In this paper, the cosmological parameters $H_0 = 70{\rm km\ s^{-1}Mpc^{-1}}$, $\Omega_\Lambda = 0.7$ and $\Omega_m = 0.3$ have been adopted.

2. LOCAL VELOCITY AND SIZE OF BLRS OF DBP EMITTERS

Due to the shape of line profiles of dbp emitters, the parameters of FWHM (full width at half maximum), and the second moment σ_b (definitions can be found in Peterson et al. 2004) should have different values at different times. For double-peaked emission lines, if the height of one peak is more than twice the other peak, the measurement of FWHM can be distorted (biased) and thus yield a smaller velocity than the real one. Moreover, if only one peak can be neatly distinguished, the value of mFWHM will be also difficult to determine. Thus in what follows, we prefer to use the second moment σ_b instead of the other two parameters to trace the local velocity of BLRs. This parameter is derived from the elliptical accretion disk model (Eracleous et al. 1995) with seven free parameters fitted to the observed profiles.

We also use this model to check the effects of variability on the second moment of the broad double-peaked profiles. Our results (Zhang, Dultzin, & Wang 2007) indicate that if the lines come from disks with small eccentricities, these effects can be ignored. The model is also used to derive the inclination angle of the disk. The local velocity of BLRs can be estimated from the observed profile by means of the simple relation $\sigma_{\rm loc} \sim \sigma_{\rm obs}/\sin(i)$.

From the definition of the ionization parameter,

$$\Gamma = \frac{Q}{4\pi r^2 c N_e} \tag{2}$$

we can see that the size of the BLRs must depend on both the continuum luminosity and the electron density. We (Zhang, Dultzin, & Wang, in preparation) consider the effects of electron density in the estimation of the BLR's size. As we see below in the determination of the virial BH masses of dbp emitters, the parameter of $\log(R_{\rm BLRs})$ is replaced by the function $a \times \log(R/R_G) + b \times \log(L_{5100\mathring{A}}) + c$, where R/R_G represents the flux weighted size of BLRs as we have defined it in (Zhang, Dultzin, & Wang, in prep.).

3. BH MASSES OF DBP EMITTERS

We selected 17 dbp emitters from SDSS DR4 with observable stellar contribution. We subtract the stellar continuum contribution through the PCA method (Hao et al. 2005; Li et al. 2005) and then measure stellar velocity dispersion from the absorption line MgIλ5175 Å (Rix & White 1992). Figure 1 of Zhang, Dultzin, & Wang (in prep.) shows an example of the subtraction of the stellar continuum contribution using the the PCA method. It also shows the best fitted results for the double-peaked emission lines from the elliptical accretion disk model.

In summary: The virial BH masses of dbp emitters can be calculated using the usual two parameters (albeit as defined above): the local velocity of the BLRs and their size. From the BH masses estimated from the stellar velocity dispersions and the virial BH masses of dbp emitters we find the relation:

$$\begin{aligned} &\sigma_{\rm loc} \sim \sigma_{\rm obs}/\sin(i) \\ &M_{\rm BH} = 1.37^{+5.64}_{-1.11} \times 10^5 \times \left(\frac{R}{R_G}\right)^{1.04\pm0.22} \\ &\quad \times \left(\frac{L_{5100\mathring{A}}}{10^{44}{\rm erg\ s^{-1}}}\right)^{0.41\pm0.08} \\ &\quad \times \left(\frac{\sigma_{\rm loc}}{3000{\rm km\ s^{-1}}}\right)^2 M_\odot \end{aligned} \tag{3}$$

The correlation between virial BH masses and BH masses estimated from the stellar velocity dispersions is shown in Figure 1.

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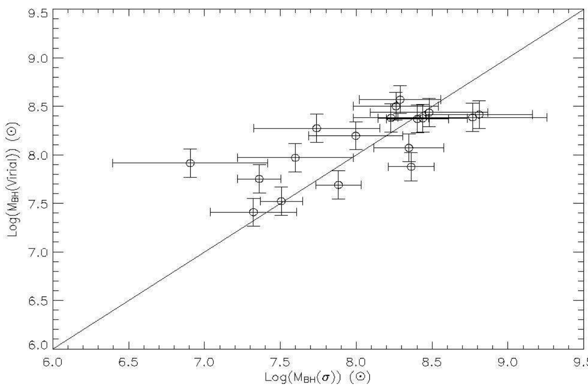

Fig. 1. The correlation between virial BH masses and BH masses estimated from the stellar velocity dispersions.

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