J. Astrophys. Astr. (2011) **32,** 269–272

Estimation of Black Hole Masses from Steep Spectrum Radio Quasars

Ye Chen[1,*], Zhi-Fu Chen[1], Yi-Ping Qin[1,2] & You-Bing Li[3]
[1]*Center for Astrophysics, Guangzhou University, Guangzhou 510006, People's Republic of China.*
[2]*Physics Department, Guangxi University, Nanning 530004, People's Republic of China.*
[3]*Guangzhou City Construction College, Guangzhou, People's Republic of China.*
[*]*e-mail: ppchen824@yahoo.com.cn*

Abstract. In this work, we employ a sample of 185 steep-spectrum radio quasars (SSRQs) to estimate their black hole masses from broad emission lines. Our black hole masses are compared with the virial black hole masses estimated by Shen (2010). We find that there is a large deviation between the two kinds of values if the black hole masses are estimated from broad emission line of CIV. However, both values are in agreement if the black hole masses are estimated from broad emission line of MgII or Hβ.

Key words. Black hole physics—methods: statistical—galaxies: jet.

1. Introduction

The optical continuum luminosity and broad emission line width are often adopted to estimate the black hole mass (virial black hole mass). However, when the orientation of jets is close to the line of sight, jet emission would contribute significantly to the optical continuum. Therefore, the black hole mass estimated by this method is probably overestimated (Wu *et al.* 2004).

According to radio luminosities, quasars are sorted into radio-quiet quasars and radio-loud quasars. With the radio spectral index α ($f \propto \nu^{-\alpha}$), the radio-loud quasars can also be sorted into steep spectrum radio quasars (SSRQs, $\alpha > 0.5$) and flat spectrum radio quasars (FSRQs, $\alpha < 0.5$). In this work, we estimate the black hole mass of SSRQs from broad emission lines using the following empirical relations:

$$M_{\rm BH}({\rm H}\beta) = 4.68 \times 10^6 \times \left(\frac{L({\rm H}\beta)}{10^{42}\ {\rm erg\ s^{-1}}}\right)^{0.63} \times \left(\frac{{\rm FWHM}({\rm H}\beta)}{1000\ {\rm km\ s^{-1}}}\right)^2 M_\odot$$

(Vestergaard & Peterson 2006), (1)

$$M_{\rm BH}({\rm MgII}) = 2.9 \times 10^6 \times \left(\frac{L({\rm MgII})}{10^{42}\ {\rm erg\ s^{-1}}}\right)^{0.573} \times \left(\frac{{\rm FWHM}({\rm MgII})}{1000\ {\rm km\ s^{-1}}}\right)^2 M_\odot$$

(Kong *et al.* 2006), (2)

$$M_{\rm BH}({\rm CIV}) \;=\; 4.6\times10^{5}\times\left(\frac{L({\rm CIV})}{10^{42}\ {\rm erg\ s^{-1}}}\right)^{0.60}\times\left(\frac{{\rm FWHM(CIV)}}{1000\ {\rm km\ s^{-1}}}\right)^{2} M_{\odot}$$

$$\text{(Kong } et\ al. \text{ 2006)}, \qquad (3)$$

where $L(\mathrm{H}\beta)$, L(MgII) and L(CIV) are the luminosities of broad emission lines, and FWHM($\mathrm{H}\beta$), FWHM(MgII) and FWHM(CIV) are the FWHM of broad emission lines. Each emission line is modelled by two Gaussians with one for broad emission line and the other for narrow line. Our results will be compared with the virial black hole masses.

2. Sample

Our sample is based on the catalogue of quasar properties from SDSS DR7 (Shen *et al.* 2010) and the radio catalogue of the FIRST 20 cm survey (White *et al.* 1997) and the GB6 6 cm survey (Gregory *et al.* 1996). We build a RASS-SDSS-FIRST-GB6 cross-identified SSRQs sample of 185 quasars with radio spectral index $\alpha > 0.5 (f \propto \nu^{-\alpha})$ by cross-identifying the sample of Shen *et al.* (2010) and the FIRST and GB6 radio-detected sources. The virial black hole masses are adopted from Shen *et al.* (2010), and the radio luminosities at 5 GHz are derived from the radio luminosities at 20 cm and 6 cm and their spectral indices. The method of estimating the virial black hole masses of Shen *et al.* (2010) assumed that the broad line region is virialized, the continuum luminosity is considered as a proxy of the broad line region radius, and the broad line width is considered as a proxy of the virial velocity. And their virial mass estimation can be expressed as:

$$\log\left(\frac{M_{\rm BH}}{M_{\odot}}\right) = a + b\log\left(\frac{\lambda L_{\lambda}}{10^{44}{\rm erg\ s^{-1}}}\right) + 2\log\left(\frac{\rm FWHM}{\rm km\ s^{-1}}\right), \qquad (4)$$

where a and b are empirically calibrated against local AGNs (see Shen *et al.* 2010 for details).

3. Result

Figure 1 shows that the black hole masses estimated by broad emission lines are directly compared with virial black hole mases available from Shen (2010). In this figure it indicates significantly that the virial black hole masses are indeed overestimated when compared to the black hole masses estimated from CIV broad emission lines, as what has already been predicted by Wu *et al.* (2004), while they are consistent with those estimated from MgII or $\mathrm{H}\beta$ broad emission lines, which do not meet the expectation.

The radio emission is usually used to indicate the jet emission (Gu & Chen 2010). Here, we investigate the relationship between radio luminosities at 5 GHz and the departures of black hole masses estimated by the two methods and to investigate between radio loudness and the departures of black hole masses, if the departures are

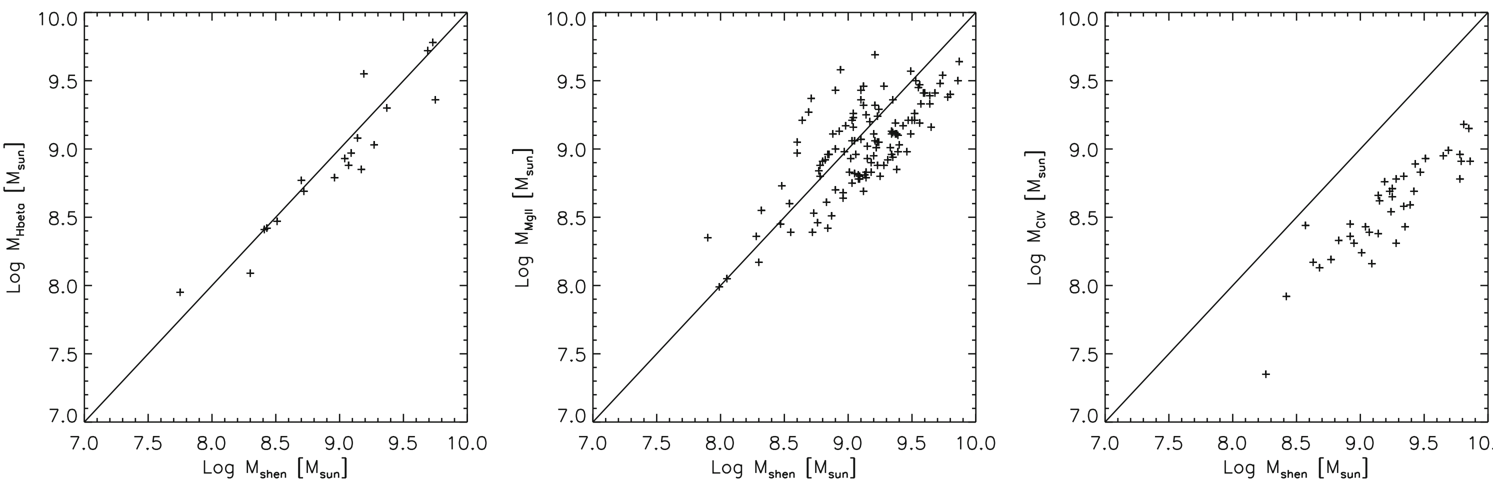

Figure 1. Comparison of black hole masses estimated by two different methods. X-axis represents the virial black hole mass and Y-axis stands for the black hole mass estimated by broad emission line in each panel. The left panel: Black hole masses are estimated from Hβ broad emission line. The middle panel: Black hole masses are estimated from MgII broad emission line. The right panel: Black hole masses are estimated from CIV broad emission line.

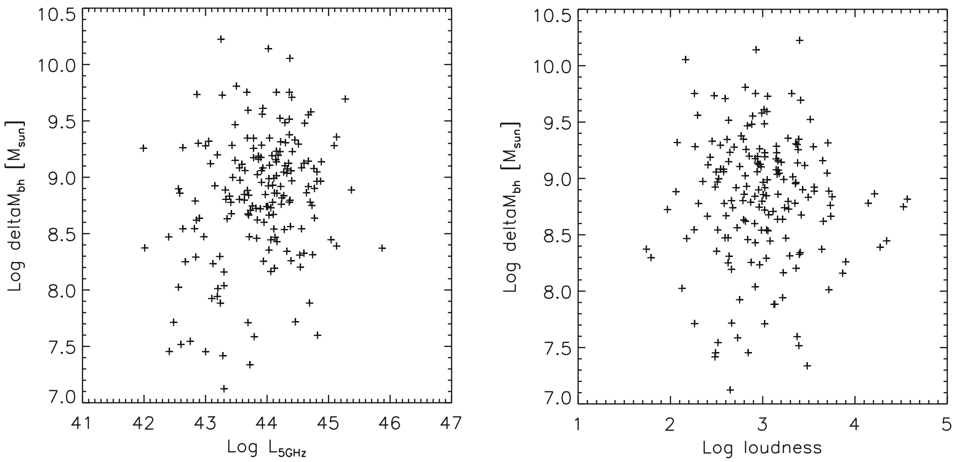

Figure 2. Left panel: Radio luminosities at 5 GHz versus the departures of black hole masses. Right panel: Radio loudness versus the departures of black hole masses.

caused by the radio emission. The results are plotted in Fig. 2. No strong correlations are observed.

References

Gu, M. F., Chen, Z. Y. 2010, *ScChG*, **53**, 202.
Gregory, P. C., Scott, W. K., Douglas, K., Condon, J. J. 1996, *Astrophys. J. Suppl.*, **103**, 427.
Kong, M. Z., Wu, X. B., Wang, R., Han, J. L. 2006, *Chinese J. Astron. Astrophys.*, **6**, 396.
Shen, Y., Hall, P. B., Richards, G. T. 2010, arXiv: 1006.5178.
Vestergaard, M., Peterson, B. M. 2006, *Astrophys. J.*, **641**, 689.
White, R. L., Becker, R. H., Helfand, D. J., Gregg, M. D. 1997, *Astrophys. J.*, **475**, 479.
Wu, X. B., Wang, R., Kong, M. Z., Liu, F. K., Han, J. L. 2004, *Astron. Astrophys.*, **424**, 793.