Black Hole Masses and Broad Line Region Geometry of Quasars

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Introduction

It is now believed that (supermassive) black holes (BHs) reside in the centres of practically all bulge galaxies. A number of relations scale the BH mass with host galaxy properties, in particular bulge luminosity and velocity dispersion. Concerning Active Galactic Nuclei (AGNs), the BH mass can be estimated given the size and velocity of the Broad Line Region (BLR) under the virial assumption. Reverberation mapping provides the most precise estimate of the radial size of BLR, however, the single-epoch method is less time-consuming and, therefore, applicable to larger samples. The BLR cloud velocity is usually inferred from the line width, assuming a deprojection factor *f*, responsible for the BLR geometry and kinematics. Thus, the BH mass expression can be disentangled into a putative part, the *f*-factor, and a measurable part, the so called virial product (VP).

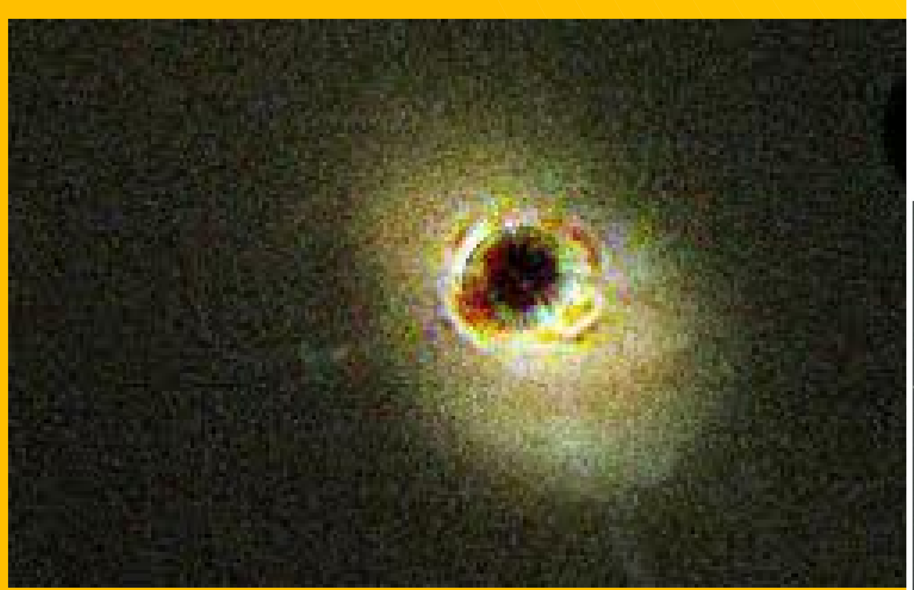
The aim of our study is to estimate and analyze the *f*-factors based on comparing the virial products and the BH masses determined on the base of host galaxy relations for high-luminosity AGNs. We present the detailed results for the blazar 3C 273.

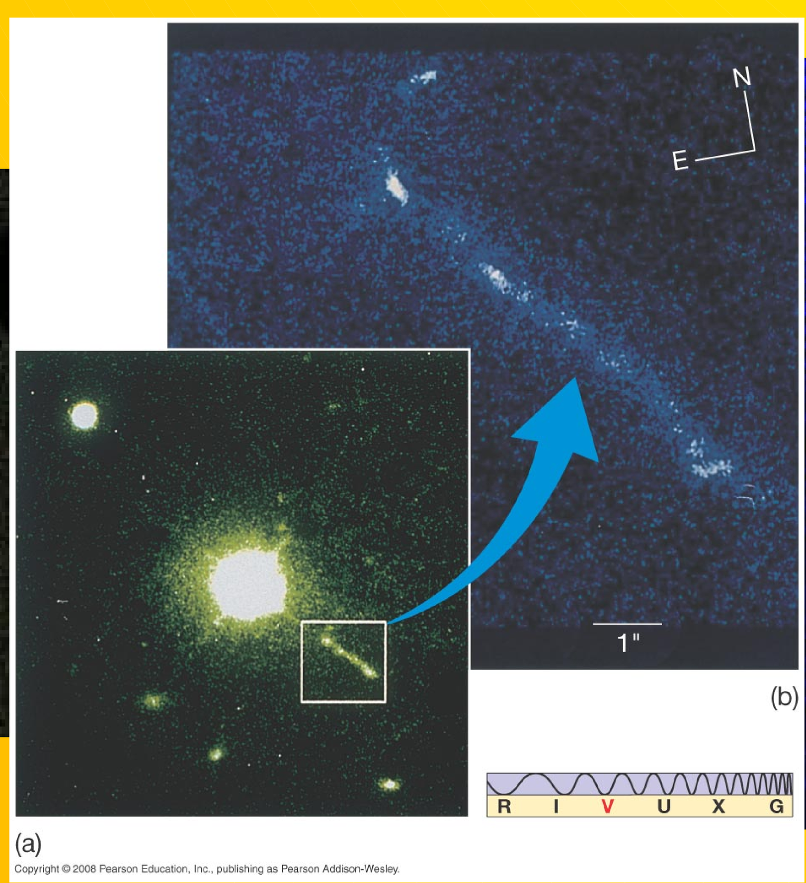
Results and Discussion

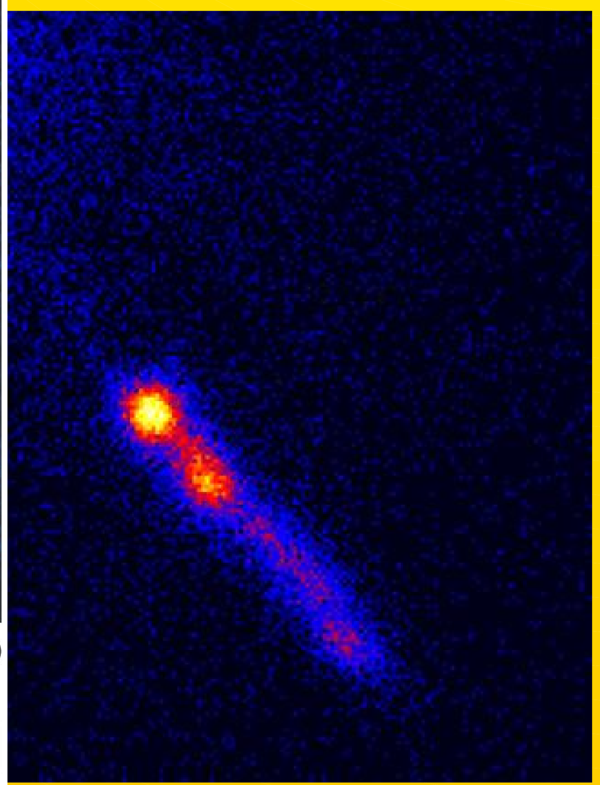
3C 273 is among the closest (z = 0.158, D_L = 749 Mpc) and brightest (M = −26.7 mag) quasars. In articularly, it is a flat spectrum radio quasar. 3C 273 has approximately 23″ (60 kpc) long jet outlined in the radio, optical, and X-ray domain (Figs. 1, 2). The host galaxy is an E4 elliptical about 30″ in diameter (Fig. 3).

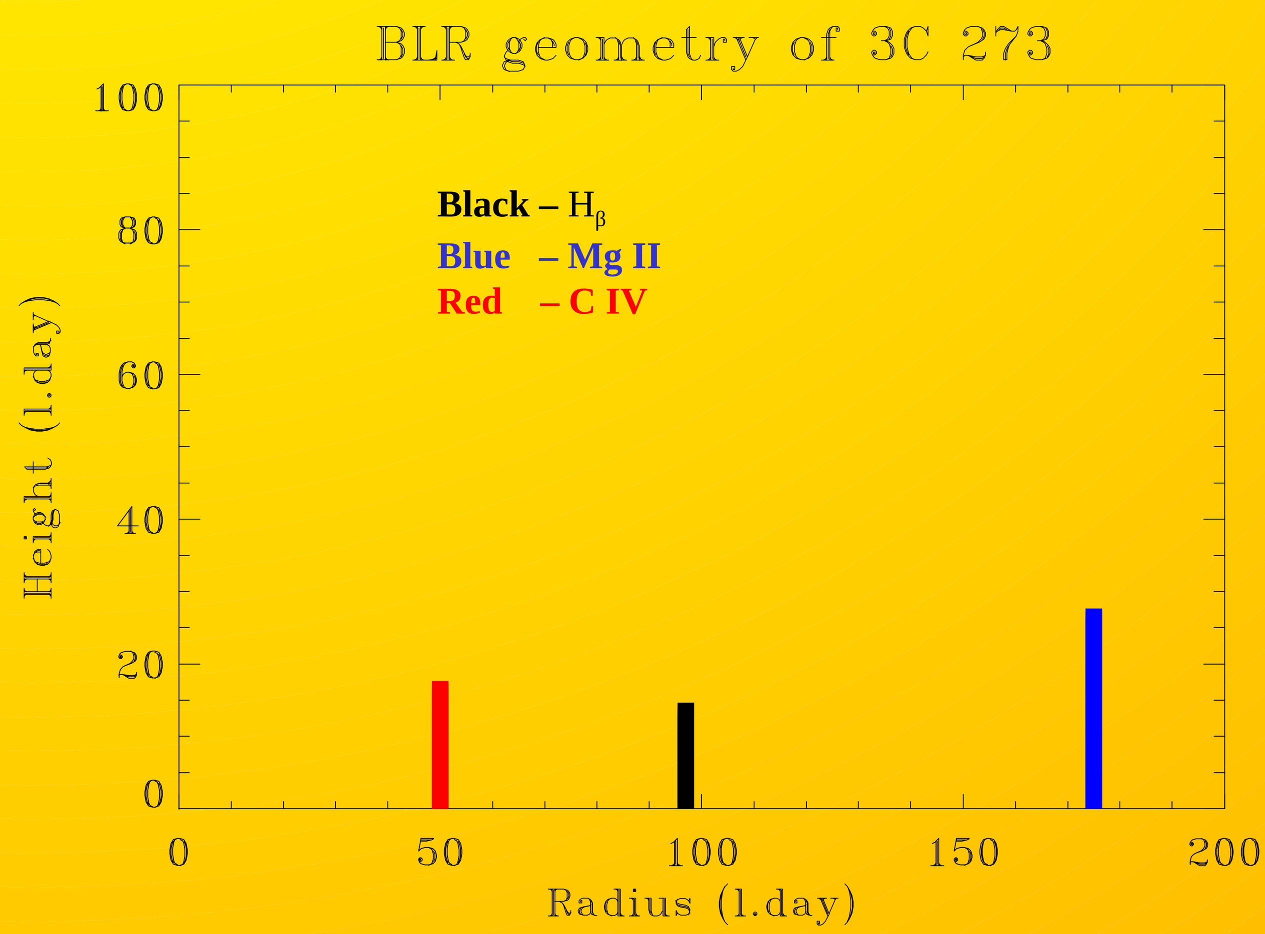
The angle between the jet and the observer was found $\theta = 3.31°$ (Hovatta et al. (2009). We used estimates of the the BLR size and cloud velocity in the C IV (Labita et al. 2006), H_β (Kawakatu et al. (2006), and Mg II (Decarli et al. (2008; 2011) lines (Table 1). The BLR sizes in the individual lines are in agreement with the predictions of the photoionization models. We estimated the *f*-factor, as well as the disk height and height-to-size ratio in the above three lines (Table 1). The height distribution across the radus can be traced in Fig. 4. The results imply an overall disk geometry of the BLR with indications for stratification.

The precise knowledge of the BLR geometry is significant for the accurate estimate of BH masses in AGNs.









From left to right. **Fig. 1**. The host galaxy of 3C 273 (HST). **Fig. 2**. The jet of 3C 273 in the optical (Pearson Prentice Hall). **Fig. 3**. The jet of 3C 273 in the X-ray (Chandra). **Fig. 4**. BLR height vs. radius of 3C 273 (see text).

Methods

The BH mass can be estimated through empirical relations with the host galaxy properties, e.g. absolute magnitude, M_R:

$$\lg(M_{BH}/M_{SUN}) = (-0.50 \pm 0.06)M_R - (3.00 \pm 1.13)$$ (Bettoni et al. 2003).

Under the virial assumption: $M_{BH} = R_{BLR} V^2 G^{-1}$, where $R_{BLR} \sim L^{\alpha}$ ($\alpha \approx 0.5$) is the BLR size, $V = f\,\mathrm{FWHM}$ - the BLR cloud velocity, L – luminosity, and f the f-factor, the BH mass could be expressed: $M_{BH} = f^2\,\mathrm{VP}$. We acquire the *f*-factors by comparing the VP and independent estimates of the BH mass based on the host galaxy properties.

The *f*-factor can be expressed as: $f = ½\,[(H/R_{BLR})^2] + \sin^2\theta]^{-1/2}$, where H is the disk height and θ the angle between the jet and the observer. The *f*-factor corresponding to the isotropic case is equal to $(¾)^{1/2}$.

Line	R_{BLR} [pc / l.day]	$(H/R)_{BLR}$	H_{BLR}[pc/l.day]	V_{BLR} [km/s]	f
C IV	**0.042 / 50.0**	**0.099**	**0.014 / 16.7**	**9 085**	**2.84**
$\mathbf{H_\beta}$	**0.081 / 96.5**	**0.143**	**0.012 / 14.3**	**12 707**	**3.62**
Mg II	**0.147 / 175.2**	**0.559**	**0.023 / 27.4**	**3 626**	**0.89**

Table. 1. Broad line region parameters of 3C 273 (see text).

References

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