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Accretion Parameters and AGN Diversity

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Abstract. We calculate black hole mass (M) and source luminosity to mass ratio (L/M) under the virial assumption for a sample of ≈300 low redshift quasars. Comparison of $H\beta_{BC}$ line profile fits with M and L/M estimates indicate that a Lorentz function better fits higher L/M sources while a double Gaussian between described profiles in sources with lower L/M. The second (redshifted) Gaussian component often appears as a red asymmetry which becomes stronger in larger M and lower L/M sources. Radio-loud and radio-quiet samples systematic differences in M and L/M, in terms of M being larger and L/M being lower in radio-loud sources. This effect seems to be ultimately due to the preferential occurrence of narrower Hβ line profiles (Population A sources) in radio-quiet sources.

Key words. quasars: emission lines – galaxies: active

1. Sample

We consider moderate quality spectra (S/N∼20-50) for a sample of 287 AGN. We cover the rest frame spectral region between 4200–5300 Å. Our Eigenvector 1 (E1) sample of 215 sources Marziani et al. (2003) is supplemented here with spectra for 63 soft X-ray selected AGN Grupe et al. (1999) and 9 unpublished VLT-ISAAC spectra for higher redshift sources.

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Black hole masses are estimated from results of reverberation mapping studies Kaspi et al. (2000): $M = 4.817 \times FWHM^2(\lambda L_{5100})^{0.7}$, where M is the black hole mass in solar units, FWHM is the full width at half maximum of Hβ broad component, L_{5100} is the specific flux at 5100 Å (in units of erg $s^{-1}cm^{-2}$ Å^{-1}). The derived masses are thought to be reliable within a factor of ≈ 2-3 Woo & Urry (2002), Vestergaard (2002).

Our sample (Fig.1) covers an absolute B magnitude range $-20 < M_B < -28$ and includes estimated black hole masses in the range $10^7 M_\odot < M < 10^{10} M_\odot$. The Eddington limit defines an approximate upper boundary to the luminosity distribu-

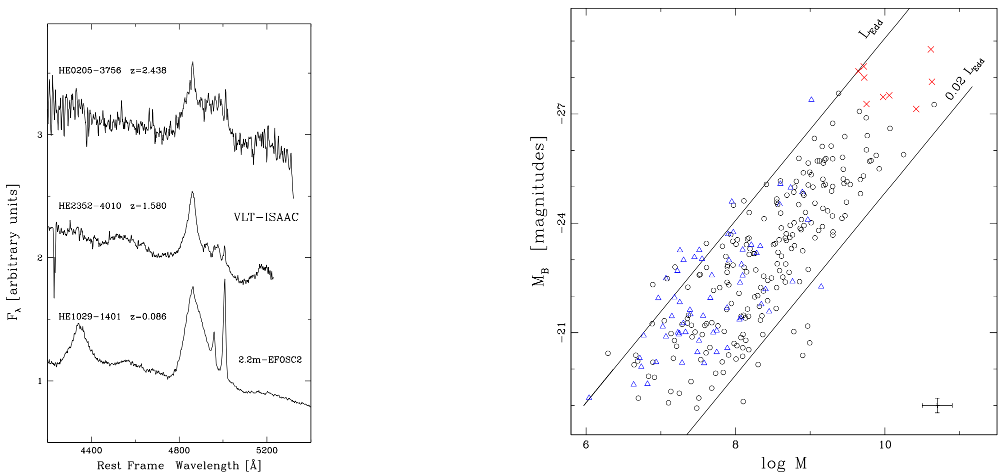

Fig. 1. Left panel: Examples of our (deredshifted) spectra. **Right panel:** Absolute B magnitude (M_B) versus estimated black hole mass M (in solar units) for sources in our sample. M_B values are corrected for galactic extinction. Circles represent the E1 sample Marziani et al. (2003), triangles Grupe et al. (1999), and crosses – the first sources from our unpublished VLT-ISAAC high z sample. Typical uncertainties are indicated in the lower right corner.

tion, and there are almost no sources with $L/L_{Edd} < 0.01$. Fig.1 and 2 (left panels) suggests that there might be fewer high mass sources near the Eddington limit. If we exclude selection effects, this might be an indication that galaxies with the largest black hole masses are unable to supply enough fuel for the AGN to radiate at high L/M, and that only sources radiating at $0.01<L/L_{Edd}<1.00$ produce a stable broad line region.

2. Hβ profile

We investigated the influence of M and L/M on profile shape using our E1 binned average quasar spectra. We generated median spectra in binned ranges of derived M and L/M. The adopted binning is shown in Fig.2 with a few examples of the median spectra (normalized to the local continuum) (right panel). The median Hβ_{BC} profile computed for each bin suggests that: (1) Lorentz functions provide good fits to median profiles in bins for log(L/M)>3.9. (2) If log(L/M)<3.4, profiles are better fit with double Gaussian models, and are strongly red-ward asymmetric. The amplitude of the redward asymmetry appears to be strongly influenced by M. This is easily seen by comparing the solid (lower mass) and overlayed dashed (higher mass) profiles in Fig.2. The measured line centroids at 1/4 fractional intensity are also significantly redshifted for the bins corresponding to larger M. We conclude that the Lorentzian-double Gaussian profile transition may be governed by a critical L/M value and should occur between 3.4<log(L/M)<3.9. A more precise value could be derived by taking into account the source orientation. In some sources the Gaussian component that is redshifted and very broad may even dominate the Hβ_{BC} emission. This has implications both for reverberation mapping measures and the black hole mass derivations if this component can be associated to a distinct Very Broad Line Region (VBLR). A strong VBLR component will lessen a mea-

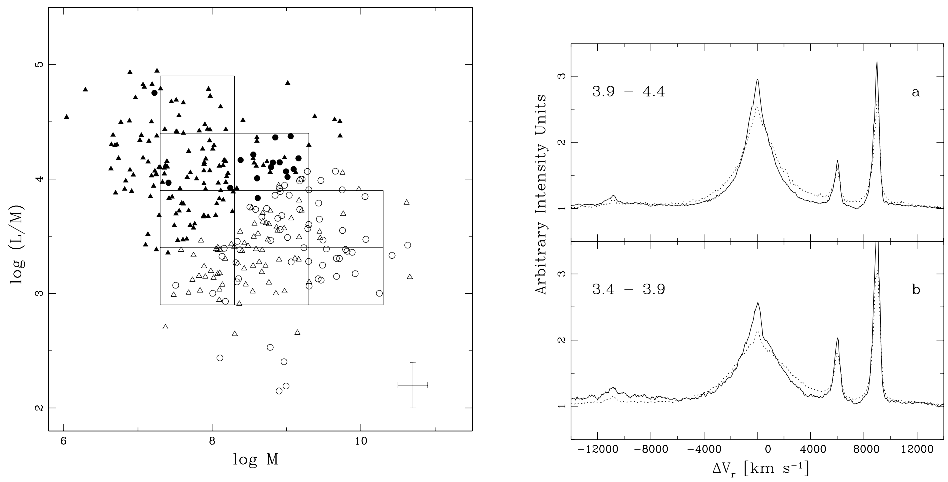

Fig. 2. Left panel: L/M ratio versus M for our sample of AGN (axes in solar units). Triangles and circles indicate radio-quiet (RQ) and radio-loud (RL) sources respectively. Filled symbols distinguish Population A (FWHM<4000 km s^{-1}) from Population B (FWHM>4000 km s^{-1}, open symbols). The grid shows the binning for computation of the median spectra. **Right panels:** Average Hβ spectra after FeII subtraction: **(a)** 3.9<log(L/M)< 4.4; **(b)** 3.4 <log(L/M)< 3.9; Solid profiles correspond to 7.3<log M<8.3, and dashed profiles to 8.3<log M<9.3.

sured reverberation amplitude and increase a derived black hole mass.

3. Radio Loudness

We did not detect an obvious influence of radio loudness on the Hβ_{BC} line profile, in the sense that we see RQ and RL sources with very similar Hβ_{BC} profiles when we select RQ and RL sources from the same M and L/M bins. Figure 2 and 3 also shows a mixture of RQ and RL sources at about logM$\sim$9 and logL/M$\sim$3.5. It is apparently possible for RQ and RL quasars to have the same M and L/M values although the former tend to have smaller masses and to radiate at correspondingly lower L/M. This is true for both the full original sample as well as for the distribution of a large number of resampled subsamples with matching redshift and apparent magnitude distribution (see Fig. 3). At the same time, the systematic differences between RQ and RL seem to be due a predominantly radio quiet population of narrower sources, FWHM(Hβ_{BC})<4000 km s^{-1}, conventionally indicated as Population A Sulentic et al. (2000), which seems to radiate at larger L/M. However, large M and low L/M are neither a sufficient nor a necessary condition to have a RL AGN, since small M ($\sim 10^7 M_\odot$) and large L/M ($\sim 10^4$ $(L/M)_\odot$) RL sources are present in our sample.

It is interesting to note that the black hole mass estimated for RL sources implies that the majority of them reside in elliptical galaxies. If we consider the relationship between black hole and "bulge" mass in the form provided by Laor (2000) we see that most RL sources are hosted in systems whose spheroidal component has mass larger than $10^{11} M_\odot$, the mass limit for bulges Benson (1996).

We can use most of our sources in creating better matched subsamples out of our working sample (bootstrap techniques): 1)

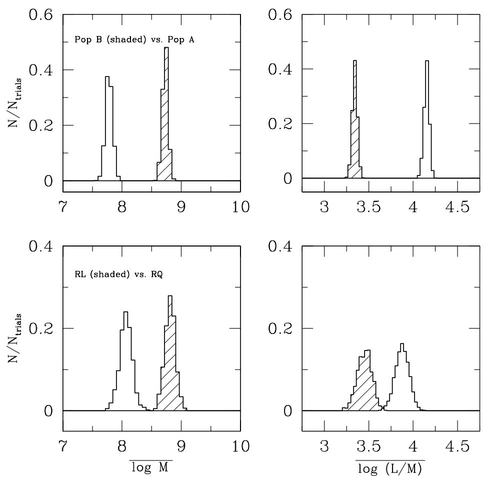

Fig. 3. Results of bootstrap simulations. Top panels: distributions of average M (left) and L/M (right) for 1000 pseudo samples of 132 Population A and a similar number (shaded) of population B objects, with matching apparent magnitude and redshift distribution. Bottom Panels: Same as above, for pseudo samples of 40 RL (shaded) and 40 RQ objects. They suggest that there are systematic differences in the sense that: 1) Pop.A have smaller M and higher L/M values than Pop.B and 2) RL sources have large M and lower L/M ratios than RQ AGN in our sample. The X axes are in solar units

we randomly selected two pseudo-samples with the same z and apparent magnitude distributions, indistinguishable within a 2σ limit, 2) we computed average M and L/M values for each subsample, 3) we repeated the selection $\sim$1000 times in order to compute the M and L/M distributions, 4) we computed the distribution of average M and L/M values for the pseudo samples (the *bootstrapped* samples). While we are not able to eliminate biases from our sample, we attempt to apply the same bias to both populations (see Fig.3).

4. Conclusions & Further Work

We identify several optical properties of quasars and luminous Seyfert 1 nuclei that are strongly dependent on two of the most important parameters in an accretion scenario: black hole mass and Eddington ratio. Acquisition of more data for high-z quasars may eventually provide an independent estimation of L and M from the E1 parameters. Towards this goal we also need estimates of the orientation angle for each source. We are investigating the influence of orientation on the CIVλ1549 profile which is expected to be strongly orientation-dependent.

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