BLR velocities in optically and X-ray selected AGN samples

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Abstract

We have analyzed optical spectra of 473 X-ray and 235 optically selected AGNs, to study their emission line properties. We present results of an analysis of the Hβ linewidths. We find that the linewidth distribution of quasars is shifted towards higher velocities ($\langle v \rangle = 4300$ km s$^{-1}$) compared to the distribution of Sy 1s ($\langle v \rangle = 3000$ km s$^{-1}$). There are no Narrow Line Quasars, i.e. there are no AGNs with quasar luminosities and FWHM(Hβ) < 2000 km s$^{-1}$. NLSy1s comprise 20–30% of the AGN population at faint absolute magnitudes ($M_B > -22$), irrespective of the selection method. In the RASS sample we find $\Gamma [0.1-2.4 \text{ keV}] < 3.3$. The $\Gamma$ vs. FWHM(Hβ) distribution for Sy 1 galaxies is consistent with previous work. For QSOs the spectral index also flattens with increasing FWHM(Hβ), but they have larger linewidths than Seyfert 1s.

Key words: galaxies: active; galaxies: Seyfert; quasars: emission lines; X-rays: galaxies

1 Introduction

Seyfert 1 galaxies with small widths ($< 2000$ km s$^{-1}$) of the permitted emission lines coming from the broad line region (BLR) have been given a separate name Narrow Line Seyfert 1 galaxies (NLSy1), although they probably do not form a class physically separated from classical Sy 1s. Close attention was drawn to them resulting from the discovery that steep soft X-ray spectra of AGNs are almost always associated with NLSy1s (1). It was also claimed that X-ray selected samples contain considerably more NLSy1s than optically selected ones (2). Since Sy 1 galaxies are not the most luminous examples of AGNs, we searched for similar effects among quasars, their high luminosity counterparts. We analyzed the Hamburg database of optical AGN spectra to determine the fraction of NLSy1s in optically and X-ray selected samples, to search for Narrow Line QSOs, and to study the relation between soft X-ray spectral index and linewidth, as a function of luminosity.
2 The sample

The Hamburg database of optical AGN spectra consists of several data sets obtained from follow-up spectroscopy of AGN candidates, identified from the objective prism plates of the Hamburg Quasar Survey (HQS; (3)). The first set (hereafter: RASS) contains spectra of X-ray selected AGNs discovered by the ROSAT All-Sky Survey (RASS). 253 spectra were taken from (2) and 189 spectra are yet unpublished. ROSAT X-ray selected AGNs have typical redshifts $z=0.2$ and optical brightnesses $B=18–19$ mag.

![Fig. 1. The absolute magnitude distribution of the full sample (HQS + RASS). The HQS sample is hatched.](image)

The second set (hereafter: HQS) contains the spectra of AGNs optically selected from the HQS plates, and consists of 123 spectra from the lists of (4) and (6), and 112 spectra from the Hamburg/CfA Bright Quasar Survey (3). The HQS AGNs generally have $B<18$ mag. In both sets we restricted the redshifts to $z<0.7$. The database is inhomogeneous, as the spectra differ in resolution and signal-to-noise ratio. We singled out spectra with sufficient signal-to-noise ratio to obtain reliable measures of linewidths using Gaussian fits. Because of the differing optical limits of both sets, the HQS sample is biased towards quasars (defined as AGNs with $M_B< -23$), and the RASS sample is biased towards Seyfert galaxies (Figure 1).

3 H$_\beta$ linewidths and the search for “Narrow Line Quasars”

The H$_\beta$ linewidth distribution is markedly different for the Seyfert galaxies and the quasars (Figure 2a). The latter group has a median linewidth of $<v>=4300$ km s$^{-1}$ compared to 3000 km s$^{-1}$ for the Seyferts. This difference does not depend on the selection method. Both distributions have a long tail extending up to 10000 km s$^{-1}$.
Fig. 2. Left: H$\beta$ linewidth distribution of the full sample (HQS + RASS). The distribution of the QSOs is hatched. Right: Fraction $\chi$ of Narrow Line AGNs per luminosity bin as function of absolute optical magnitude. Symbols are offset by 0.1 around the bin center for clarity.

The handful of quasars with FWHM(H$\beta$) $<$ 2000 km s$^{-1}$ only marginally surpass the luminosity cut-off, which was set arbitrarily. In Figure 2b we plot the fraction $\chi$ of Narrow Line AGNs as function of absolute magnitude. In both samples none are found at luminosities $M_B$ $< -23.5$, indicating that broad-line regions with very small velocities exist only among low luminosity AGNs: There are no Narrow Line QSOs. The non-existent NLQSOs should not be confused with Type 2 QSOs, which are the high-luminosity counterparts of Seyfert 2s, and have not been found either. The fraction of NLSy1s rises to 20–30% for $M_B$ $>$ $-22$, irrespective of the selection method.

4 H$\beta$ linewidths and X-ray spectral index

X-ray spectral photon indices $\Gamma$ were calculated from the hardness ratios as described by (2). Figure 3 plots $\Gamma$ vs. FWHM(H$\beta$). Seyfert galaxies occupy the same area as in (1), except that the sample contains no ultrasoft X-ray AGNs ($\Gamma$ $>$ 3.3). Both Seyfert galaxies and quasars show a modest anti-correlation between $\Gamma$ and H$\beta$ linewidth. This is consistent with the model of Wandel & Boller (10, 11), who attribute this relation to an increased ionizing flux associated with the steeper X-ray spectral slopes. For a given black hole mass this shifts the BLR radius outwards leading to smaller velocities.

The H$\beta$ linewidths are thought to reflect the velocity dispersion in the BLR. We found that this dispersion increases with AGN luminosity, as does the BLR radius (2). This suggests that the central black hole masses must increase as well, if the cloud motions are virialized. Narrow Line AGNs are common among low luminosity AGNs (Seyferts), and their X-ray properties in general do not differ from other AGNs. The larger number of NLSy1s detected in X-ray surveys is due to the higher selection efficiency of Seyfert 1s in general, compared to optical surveys. There appear to be no physical differences between X-ray
and optically selected Narrow Line AGNs.

We have not found objects with extreme $\Gamma$'s (> 3.3), which were so obvious in the sample of (1). It seems that these ultrasoft AGNs are very rare, and that they are only picked-up in surveys with high efficiency in the soft X-ray band. They may not be restricted to low luminosities, as at least one example in known eg. RX J0947.0+4721 with a QSO luminosity (8). RX J0947.0+4721 was discovered in a pointed ROSAT observation, and the RASS might not have been sensitive enough to detect more of them. The rarity of ultrasoft AGNs may be a consequence of the transient nature of the ultrasoft state, which may be short compared to the timescales that the nuclei are active.

Fig. 3. ROSAT X-ray spectral slope $\Gamma$ [0.1-2.4 keV] vs. H$_\beta$ linewidth for RASS AGNs.

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