Probing the Central Engine of the Narrow-Line Seyfert 1 Galaxies

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Abstract

The central engine of the Narrow Line Seyfert 1 galaxies is being probed. We use the ASCA and RXTE data to model the X-ray primary continuum as well as the reflected component and iron Kα line. Since these are strongly coupled, we obtain independent measurements of the disc ionization level and the orientation dependent reflection amplitude. Using the available Optical/UV data we also estimate the black hole masses and the $L/L_{Edd}$ ratios, which are probably related to Boroson & Green eigenvector 1.

1 Introduction

Studies of optical emission lines in quasars have revealed strong correlations between emission line properties, that are possibly related to the central accreting black hole system. Boroson & Green (1992) used the Bright Quasar Sample (BQS) and identified a set of optical emission line properties that vary together (optical FeII and [OIII] λ5007 strengths, Hβ width and blue asymmetry), called the Boroson & Green eigenvector 1 (EV1). Eigenvector 1 was found by Boller & Brandt (1998) to correlate with X-ray properties ($\alpha_x$, $L_{2keV}$). As the X-rays originate in the vicinity of the central black hole (at distances $<100R_g$), hence eigenvector 1 is possibly linked to and driven by the central engine. To find the parameters of the central engine that drive eigenvector 1, we examined first objects with extreme EV1 properties. A class of Narrow-Line Seyfert 1 galaxies (NLS1s) is found to lie at the low EV1 end of the Bright Quasar Sample studied by Boroson & Green. These objects exhibit particularly narrow Hβ line, of FWHM<2000 km/s, strong Fe II emission and [O III]/Hβ <3. Narrow Line Seyfert 1 galaxies, when compared to typical AGN, show hotter and more pronounced big blue bumps and steeper soft-X-ray slopes. This can be explained due to higher ratios of their luminosity to the Eddington luminosity (e.g. Pounds et al. 1995), however there have also been
objects

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\begin{array}{cccccc}
\text{Object name} & \log L_\nu(2500\text{Å}) & \log L_{2-10\text{keV}} & L/L_{\text{Edd}} & M_{\text{BH}} \\
\hline
\text{PKS 0558-504} & 45.31 & 44.66 & 0.33 & 3.345 \\
\text{IRAS 13349+243} & 45.11 & 44.17 & 0.20 & 1.84 \\
\text{PG 1211+143} & 45.01 & 44.59 & 0.27 & 1.79 \\
\text{ARK 564} & 43.97 & 43.71 & 0.10 & 0.18 \\
\end{array}
\]

attempts to explain the extreme properties and variability of the NLS1 class by their high inclination angles to the line of sight (e.g. Brandt & Gallagher, 2000). This points towards either \( L/L_{\text{Edd}} \) or orientation as the primary driver of eigenvector 1.

For large accretion rates the matter of the accretion disk is more ionized, leading to an increase of the \( K_\alpha \) line centroid energy above the neutral case value of 6.4 keV (see Matt, Fabian & Ross 1993, Życki & Czerny 1994). This fluorescent line is linked to the Compton reflection feature, as they are both resulting from the irradiation of the disk surface by the hard X-rays. Therefore, in the spectral analysis we used the model of the reflection hump plus the iron line ( Życki, Done & Smith, 1997).

## 2 Results of the spectral analysis

Both literature and archives (NED, HEASARC) were searched to obtain a complete UV to hard-X-ray continuum for each source. The bolometric luminosity \( L_{\text{bol}} \) was estimated using the extrapolation of \( V \) magnitude to the 2500Å bandpass, with the assumption of the continuum slope of 0.5, and taking into account the X-ray luminosity \( L_{2-10\text{keV}} \) derived from the spectral fits. Then we calculated the accretion rate assuming the accretion efficiency of 1/16 and the central black hole mass was estimated from the standard relation \( \dot{M} \sim \nu^{-1/3}(M\dot{M})^{2/3} \). To calculate distances we assumed \( H=50 \text{ km s}^{-1} \text{ Mpc}^{-1} \) and \( q=0 \).

The value of eigenvector 1 has been determined by Boroson & Green for only one quasar PG1211+143. For the other three objects we estimated this value by comparing the EV1 range of objects with similar values of FWHM H\( \beta \), FeII/H\( \beta \) and [O III] strength in the Boroson & Green PG sample. In Table 2 we show the minimum and maximum values of eigenvector 1 corresponding to the quasars with similar properties to our objects (up to 10% difference in FWHM H\( \beta \)), and the mean value <EV1>, weighted by the two other crucial properties: FeII/H\( \beta \) and [O III]. The values of H\( \beta \) width, FeII/H\( \beta \) and [O III]/H\( \beta \) were taken from Boller et al. 1996 and Leighly 1999.

The X-ray properties were examined by fitting simultaneously the
Emission line properties

| Object name | FWHM Hβ | Fe II/Hβ | [O III]/Hβ | EV1_{min} | EV1_{max} | < EV1 |
|-------------|---------|----------|------------|-----------|-----------|-------|
| PKS 0558-504 | 1500 | 1.56 | 0.04 | -5.92 | -2.93 | -4.77 |
| IRAS 13349+243 | 2100 | 6.5 | 0.13 | -5.39 | 2.07 | -4.67 |
| PG 1211+143 | 1900 | 0.52 | 0.14 | - | - | 0.464 |
| ARK 564 | 720 | 0.8 | 0.96 | -6.36 | -2.41 | -2.41 |

Results of simultaneous fitting to ASCA and RXTE data

| Object name | Γ | Ω/2π | ξ | cos i | R_{in} [R_g] | χ^2/d.o.f. |
|-------------|---|------|---|-------|-------------|-------------|
| PKS 0558-504 | 2.4 ± 0.02 | 1.5^{+0.5}_{-0.8} | 10^{+1.2}_{-1.0} | 0.3^{+0.2}_{-0.1} | 6.0^{+f}_{-f} | 1.0 (714) |
| IRAS 13349+243 | 2.21 ± 0.09 | 0.3^{+1.6}_{-0.25} | 160^{+1.500}_{-60} | 0.5^{f} | 6.0^{+f}_{-f} | 0.96 (127) |
| PG 1211+143 | 2.18 ± 0.03 | 0.85^{+0.05}_{-0.55} | 500^{+600}_{-450} | 0.9 ± 0.1 | 6.0^{+4.0}_{-4.0} | 1.04 (535) |
| ARK 564 | 2.68 ± 0.05 | 0.96 ± 0.36 | 529^{+1.400}_{-370} | 0.8^{f} | 6.0^{+7.0}_{-7.0} | 0.91 (1029) |

ASCA and RXTE data, using the XSPEC ver. 10.0. We used the power law continuum model, corrected for the galactic absorption. Then we added the reflection component, which in most cases gave a significant improvement in the fit. This spectral feature is parameterized by the ionization parameter ξ, reflection amplitude Ω/2π, inner disc radius R_{in} and the disc inclination cos i. The incident hard X-ray flux was assumed to have a radial distribution fixed at F_{irr} ∼ r^{-3}.

In Table 3 we show the results of spectral fitting to the X-ray data. The model ingredients for PKS 0558-504, IRAS 13349+243 and ARK 564 are: galactic absorption, power law and reflected component with iron line. The model ingredients for PG 1211+143 are: galactic absorption, comptonized black body, power law and reflected component with iron line.

3 Conclusions

Preliminary results showed that Narrow Line Seyfert 1 galaxies have high L/L_{Edd} ratios and relatively small black hole masses when compared to normal Seyfert 1 galaxies. The mass determination by means of the power density spectra (Czerny et al. 2001) indicates, that in case of Seyfert 1 galaxies logM_{BH} is ∼ 7.5, while luminosity is only about 2-5% of the Eddington luminosity. For NLS1 the corresponding values are logM_{BH} ∼ 6.5 – 8.2 and L ∼ 20 – 40%L_{Edd}. Since NLS1 have small eigenvector 1 values this finding points to L/L_{Edd} ratio (or accretion rate) as the primary driver of eigenvector 1 (see also Boroson 2001). This also points
to $L/L_{Edd}$ as the main physical parameter responsible for the extreme properties of the Narrow Line Seyfert 1 galaxies.

For larger $L/L_{Edd}$ the matter of the accretion disk is more ionized, having an impact on the reflected spectrum shape. In our sample for only PKS 0558-504 the neutral reflection was acceptable at 90% confidence level, while for the other three objects the fit required the disk surface to be mildly ionized. The disk seems to extend down to the marginal stable orbit ($R_{in} \sim 6.0 R_g$) in all objects. However, the results for the inclination angle do not seem to favor any particular orientation.

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