A COMPARISON OF HARD X-RAY PHOTON INDICES AND IRON Kα EMISSION LINES IN X-RAY LUMINOUS NARROW- AND BROAD-LINE SEYFERT 1 GALAXIES

Xin-Lin Zhou1 and Shuang-Nan Zhang2,3

1 Key Laboratory of Optical Astronomy, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China; zhouxl@nao.cas.cn
2 Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China; zhangsn@ihep.ac.cn
3 Physics Department, University of Alabama in Huntsville, Huntsville, AL 35899, USA

ABSTRACT

We use publicly available XMM-Newton data to systematically compare the hard X-ray photon indices, $\Gamma_{2-10}$ keV, and the iron Kα emission lines of narrow- and broad-line Seyfert 1 (NLS1 and BLS1) galaxies. We compile a flux-limited ($f_{2-10}$ keV $\gtrsim 1 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$) sample including 114 radio-quiet objects, with the 2–10 keV luminosity ranging from $10^{41}$ to $10^{49}$ erg s$^{-1}$. Our main results are: (1) NLS1s and BLS1s show similar luminosity distributions; (2) the weighted means of $\Gamma_{2-10}$ keV of NLS1s, BLS1s, and the total sample are 2.04 ± 0.04, 1.74 ± 0.02, and 1.84 ± 0.02, respectively; a significant anti-correlation between $\Gamma_{2-10}$ keV and FWHMHβ suggests that $\Gamma_{2-10}$ keV $> 2.0$ may be taken to indicate the X-ray luminous NLS1 type; (3) the 6.4 keV narrow iron Kα lines from NLS1s are generally weaker than that from BLS1s; this would indicate a smaller covering factor of the dusty torus in NLS1s if the line emission originates from the inner boundary region of the dusty torus in an active galactic nucleus; and (4) all the broadened iron Kα lines with intrinsic width $\sigma > 0.5$ keV correspond to FWHMHβ $\leq 4000$ km s$^{-1}$.

Key words: accretion, accretion disks – line: profiles – surveys – X-rays: galaxies

Online-only material: color figures, machine-readable table

1. INTRODUCTION

It was found that a power-law component dominates the observed X-ray spectra of Seyfert 1 galaxies above 2 keV (Mushotzky et al. 1980). Other complex spectral features can be modeled by reprocessing of the hard power-law continuum in the circumnuclear cold matter (Pounds et al. 1990), with the mean photon index $\Gamma_{2-10}$ keV $\sim 1.9-2.0$ (Nandra & Pounds 1994), where $f(E) \sim E^{-\Gamma}$. Therefore, the hard photon index, $\Gamma_{2-10}$ keV, characterizes the basic X-ray spectral shape of Seyfert galaxies, giving important clues to the emission mechanism and source properties.

Narrow-line Seyfert 1 (NLS1) galaxies (Osterbrock & Pogge 1985) are a subset of Seyfert 1 galaxies conventionally defined from their optical parameters (see Komossa 2008, and references therein). Many previous studies have suggested that NLS1 galaxies may have softer X-ray spectra than those of broad-line Seyfert 1 (BLS1) galaxies (Laor et al. 1994; Boller et al. 1996; Wang et al. 1996). There is an anti-correlation between $\Gamma_{2-10}$ keV and FWHM of the optical Hβ lines found in Seyfert 1 galaxies (Brandt et al. 1997). Therefore, NLS1 galaxies have generally been believed to show softer X-ray spectra, similar to the high/soft-state spectra from Galactic X-ray binaries (Pounds et al. 1995; Zhou et al. 2007). However, recent studies suggested that the anti-correlation shows large scatter (Piconcelli et al. 2005) and some NLS1 galaxies selected from the Sloan Digital Sky Survey (SDSS) do not display softer X-ray spectra (Zhou et al. 2006).

Fluorescent iron Kα lines are the most prominent reprocessed features in the X-ray spectra of Seyfert galaxies. XMM-Newton observations revealed that a narrow iron Kα line (NIKAL) at 6.4 keV is almost ubiquitous, with a substantial fraction of objects showing broadened iron Kα line (BIKAL) emission (Reeves et al. 2006; Nandra et al. 2007, hereafter N07). NIKAL was suggested to provide information of the geometry of the molecular torus, indicating changing active galactic nucleus (AGN) populations (Zhou & Wang 2005; Bianchi et al. 2007). BIKAL probes the strong gravity and spin of a black hole (e.g., Fabian et al. 2009; see the reviews by Reynolds & Nowak 2003 and Miller 2007). Note that the line profile seems to be very different in different sources. Studying the line profile as a function of source type is useful for future iron line surveys, since it is still unclear whether NLS1s are different from BLS1s in terms of iron Kα emission.

Here we make a systematic comparison of $\Gamma_{2-10}$ keV and the iron Kα emission lines of NLS1s and BLS1s based on XMM-Newton observations of X-ray luminous Seyfert 1 galaxies. Throughout this Letter, we use the cosmological parameters of $h_0 = 70$ km s$^{-1}$ Mpc$^{-1}$, $\Omega_m = 0.27$, and $\Omega_{\Lambda} = 0.73$ (Komatsu et al. 2009).

2. SAMPLE AND DATA REDUCTION

We compile a flux-limited ($f_{2-10}$ keV $\gtrsim 1 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$) and radio-quiet Seyfert 1 sample from the XMM-Newton archive, as listed in Table 1; 86 out of these 114 AGNs are included in the CAIXA catalogue (Bianchi et al. 2009a). The redshift range of the present sample is $z < 0.37$, with only seven objects having $z > 0.2$. The sample includes most of well-studied Seyfert 1 galaxies.

The data have been reduced as homogeneously as possible. Only the EPIC PN (Strüder et al. 2001) data are used in our analysis. The SAS v7.0 software,4 with the corresponding calibration files, are used for the data reduction. The X-ray events corresponding to patterns 0–4 for the PN data are selected; hot or bad pixels are also removed. We extract the source spectra from a circle within 40′′ of the detected source position, with the background being taken from the circular source-free regions; the CCD chip gaps are all avoided. The presence of background flaring in the observation has been checked and removed using a Good Time Interval file. We also

4 http://xmm.esac.esa.int/
check the pile-ups in the data with the SAS task \textit{epatplot}. The response files are generated with the SAS tools \textit{rmfgen} and \textit{arfgen}.

The spectral fittings are performed via a basic model expressed as \texttt{phabs} * \texttt{zphabs} * \texttt{zedge(powerlaw + Nzgauss)} in \textsc{xspec} (Arnaud 1996) over the 2–10 keV band; however, the 2–7 keV band is used for 1H0707-495 since there is a sharp drop around 7 keV found in this object (Boller et al. 2002). Errors are quoted at the 90\% confidence level. For 108 out of 114 objects in Table 1, there exist published spectral fitting results (see the machine-readable table in the online journal). We add an additional Gaussian in our fits, if there was evidence for such a component in the published fits; we only add a single Gaussian to obtain line measurements in the remaining six AGNs. We note that we have not tested independently the significance of including this additional component. All the fittings include the absorption due to the line-of-sight Galactic column density (Dickey & Lockman 1990). The neutral reflection model (Magdziarz & Zdziarski 1995) is also tried for each spectrum. However, these fits generally do not improve significantly in the 2–10 keV band compared with the power-law fits. Thus, we use the results returned from the basic model.

### 3. RESULTS

Panel (a) in Figure 1 shows the distribution of 2–10 keV luminosity for the whole sample (thin solid line), compared with that of NLS1s (thick solid line) and BLS1s (dotted line). The luminosity of the NLS1s and BLS1s spans the same range from $10^{41}$ to $10^{45}$ erg s$^{-1}$; this is natural since this sample is flux-limited.

Panel (b) in Figure 1 shows the distribution of $\Gamma_{2-10}$ keV for the whole sample, compared with that of NLS1s and that of BLS1s. The vertical dashed lines denote the weighted means of that of NLS1s, BLS1s, and the total sample at 2.04 ± 0.04, 1.74 ± 0.02, and 1.84 ± 0.02, respectively; (c) distribution of the EW of the 6.4 keV narrow iron Kα lines for the whole sample, compared with that of NLS1s and BLS1s. The vertical dashed lines denote the weighted means of that of NLS1s, BLS1s, and the total sample at 40 ± 5, 125 ± 7, and 105 ± 7 eV, respectively.

(A color version of this figure is available in the online journal.)

#### Table 1

| Source     | Type  | $f_{2-10}$ keV | $\Gamma_{2-10}$ keV | EW(NIKAL) | $L_{2-10}$ keV | FWHM(Hβ) | log($L/L_{Edd}$) |
|------------|-------|---------------|--------------------|-----------|---------------|----------|-----------------|
| Mrk 335    | NLS1  | 13            | 2.28 ± 0.03        | $\leq 54$ | 43.27         | 1629     | 0.05            |
| ESO 113-G10| NELG  | 2.7           | 1.91 ± 0.04        | 54(36–85) | 42.58         | ...      | ...             |
| ESO 244-G17| BLS1  | 3.1           | 1.89 ± 0.05        | 142(128–156) | 42.57         | 3317     | ...             |

Notes. Column 1: source name; Column 2: source type. NELG: narrow-emission-line galaxy; NLS1: narrow-line Seyfert 1 galaxy; BLS1: broad-line Seyfert 1 galaxy. NELGs are intermediate Seyfert galaxies whose broad-line regions are slightly obscured. We take NELGs with $\Gamma_{2-10}$ keV > 2.0 as NLS1s in our analysis; Column 3: absorption-corrected 2–10 keV flux, in unit of $10^{-12}$ erg s$^{-1}$ cm$^{-2}$; Column 4: 2–10 keV photon index; Column 5: EW of the 6.4 keV narrow iron Kα line, in unit of eV. The intrinsic width is fixed at 10 eV for the EW measurements; Column 6: log of the 2–10 keV luminosity; calculated from the 2–10 keV flux; Column 7: FWHM of the broad Hβ line, in unit of km s$^{-1}$; Column 8: Eddington ratio, calculated from the data available in Bianchi et al. (2009a).

* Objects with the FWHM(Hβ) calculated from the FWHM(Hα) using the relation $\text{FWHM(Hβ)} = 1070 \times (\text{FWHM(Hα)/1000})^{0.03}$ km s$^{-1}$ given in Greene & Ho (2005). These objects have the FWHM(Hα) measurements but lacking the FWHM(Hβ) measurements. FWHM(Hα) of these objects are taken from Pietsch et al. (1998), Rodríguez-Ardila et al. (2000), and Piconcelli et al. (2006), respectively.

(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)

5 http://astrostatistics.psu.edu/statcodes/asurv
Panel (c) in Figure 1 shows the distribution of equivalent width (EW) of 6.4 keV NIKAL for the whole sample, compared with that of NLS1s and that of BLS1s. The vertical dashed lines denote the weighted means of that of NLS1s, BLS1s, and the total sample, which are 40 ± 5, 125 ± 7, and 105 ± 7 eV, respectively. Thirty-four out of these 114 AGNs have only upper limit data, with 20 out of 37 NLS1s and 14 out of 77 BLS1s, respectively; the values of EW are taken as half of the upper limits. It can be seen that NIKALs from NLS1s are systematically weaker than that from BLS1s. The generalized Wilcoxon test shows the statistical value of 4.0, giving a probability of <0.01% that NLS1s and BLS1s were drawn from the same parent population.

Figure 2 shows $\Gamma_{2-10 \text{ keV}}$ against FWHM H$\beta$ for AGNs with available broad H$\beta$ measurements. The anti-correlation is significant, with the Spearman’s coefficient of $-0.59$; the Spearman’s probability associated with this coefficient is <0.01%. A linear regression by applying the parametric expectation-maximization algorithm gives

$$
\Gamma_{2-10 \text{ keV}} = (2.20 \pm 0.05) - (1.0 \pm 0.01) \left( \frac{\text{FWHM} H\beta}{10^4 \text{ km s}^{-1}} \right) .
$$

(1)

This suggests $\Gamma_{2-10 \text{ keV}} > 2.0$ for FWHM H$\beta < 2000 \text{ km s}^{-1}$ in this sample. We therefore choose to label the AGN with $\Gamma_{2-10 \text{ keV}} > 2.0$ as X-ray luminous NLS1 type. This criterion is useful for understanding the intermediate Seyfert galaxies (Sy 1.8 and 1.9) whose broad-line regions are lightly obscured, and for AGNs lacking the follow-up optical spectroscopies found in extragalactic surveys.

A flattening is also likely around FWHM H$\beta \sim 4000 \text{ km s}^{-1}$ in Figure 2. We give a separate fit for AGNs with FWHM H$\beta < 4000 \text{ km s}^{-1}$ (so-called Population A sources, Sulentic et al. 2008):

$$
\Gamma_{2-10 \text{ keV}} = (2.45 \pm 0.07) - (2.0 \pm 0.02) \left( \frac{\text{FWHM} H\beta}{10^4 \text{ km s}^{-1}} \right) .
$$

(2)

Panel (c) in Figure 1 shows the distribution of equivalent width (EW) of 6.4 keV NIKAL for the whole sample, compared with that of NLS1s and that of BLS1s. The vertical dashed lines denote the weighted means of that of NLS1s, BLS1s, and the total sample, which are 40 ± 5, 125 ± 7, and 105 ± 7 eV, respectively. Thirty-four out of these 114 AGNs have only upper limit data, with 20 out of 37 NLS1s and 14 out of 77 BLS1s, respectively; the values of EW are taken as half of the upper limits. It can be seen that NIKALs from NLS1s are systematically weaker than that from BLS1s. The generalized Wilcoxon test shows the statistical value of 4.0, giving a probability of <0.01% that NLS1s and BLS1s were drawn from the same parent population.

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This suggests $\Gamma_{2-10 \text{ keV}} > 2.0$ for FWHM H$\beta < 2000 \text{ km s}^{-1}$ in this sample. We therefore choose to label the AGN with $\Gamma_{2-10 \text{ keV}} > 2.0$ as X-ray luminous NLS1 type. This criterion is useful for understanding the intermediate Seyfert galaxies (Sy 1.8 and 1.9) whose broad-line regions are lightly obscured, and for AGNs lacking the follow-up optical spectroscopies found in extragalactic surveys.

A flattening is also likely around FWHM H$\beta \sim 4000 \text{ km s}^{-1}$ in Figure 2. We give a separate fit for AGNs with FWHM H$\beta < 4000 \text{ km s}^{-1}$ (so-called Population A sources, Sulentic et al. 2008):

$$
\Gamma_{2-10 \text{ keV}} = (2.45 \pm 0.07) - (2.0 \pm 0.02) \left( \frac{\text{FWHM} H\beta}{10^4 \text{ km s}^{-1}} \right) .
$$

(2)

Figure 3. Distribution of the EW of the BIKALs for NLS1s (thick solid line), compared with that of BLS1s (dotted line) in Nandra et al. (2007). NLS1s plausibly show a more homogeneous distribution. (A color version of this figure is available in the online journal.)

Figure 4. Intrinsic width of BIKALs as a function of FWHM H$\beta$ in Nandra et al. (2007). All the large width values (intrinsic width $\sigma > 0.5 \text{ keV}$) correspond to FWHM H$\beta \leq 4000 \text{ km s}^{-1}$.

4. BROADENED IRON K$\alpha$ LINES

N07 performed an XMM-Newton survey of BIKAL based on 37 observations of 26 luminous Seyfert galaxies. Since data with high signal-to-noise ratios in the hard X-ray band are required to characterize the line profiles in detail, they only selected the objects with at least 30,000 net counts in their EPIC PN spectra in the 2–10 keV band. They derived the BIKAL parameters from a homogeneous spectral analysis after taking into account the NIKAL emission and the absorption due to a zone of ionized gas along the line of sight.

Here we re-analyze the results obtained in N07. Figure 3 plots the distribution of BIKAL EW of NLS1s, compared with that of BLS1s listed in N07. Most of the BLS1s show weak BIKAL emission. NLS1s plausibly show a more homogeneous distribution. However, the generalized Wilcoxon test shows the statistic value of 1.4, indicating a probability of 0.15 that NLS1s and BLS1s were taken from the same parent population. This makes it difficult to draw a firm conclusion. The intrinsic width ($\sigma$) of BIKAL denotes the velocity dispersion of the line emission region. We also study $\sigma$ listed in N07 as a function of FWHM H$\beta$ in Figure 4. All the large values ($\sigma > 0.5 \text{ keV}$) correspond to FWHM H$\beta \leq 4000 \text{ km s}^{-1}$. 
5. DISCUSSION

An NLS1 galaxy is conventionally defined from its optical line width (FWHM$\beta < 2000$ km s$^{-1}$), Zhu et al. (2009) had shown that for optically selected AGNs, NLS1s, and BLS1s have the same average accretion rate ($L/L_{Edd}$; see Figure 17(c) in Zhu et al. 2009); however, the black hole mass is significantly correlated with the broad emission line width (see Figure 17(a) in Zhu et al. 2009). They arrived at this conclusion by modeling the broad emissions lines of the SDSS sample with a physically realistic two-component model. For the flux-limited (i.e., X-ray luminous) AGN sample used here, the luminosity distribution of NLS1s is indistinguishable from that of BLS1s (see Figure 1(a)). Therefore, NLS1s must have on the average higher $L/L_{Edd}$ than BLS1s in this X-ray flux-limited sample, given that NLS1s contain less massive black holes. Consequently the X-ray luminous sample presented here is biased toward a higher $L/L_{Edd}$ for the narrower H$\beta$, unlike a significant fraction of the local optical AGN population (Heckman et al. 2005). Thus, the anti-correlation between $\Gamma_{2–10 \text{ keV}}$ and FWHM$\beta$ shown in Figure 2 must be due to the higher $L/L_{Edd}$ for the narrower FWHM$\beta$, in agreement with previous works on the correlation between $\Gamma_{2–10 \text{ keV}}$ and $L/L_{Edd}$ (e.g., Wang et al. 2004). This is further supported by the mean $L/L_{Edd}$ of $\sim 1.1$ for NLS1s and $0.16$ for BLS1s, respectively, as calculated from the data in Bianchi et al. (2009a; see Table 1). Vasudevan & Fabian (2007) found that the bolometric correction, $L_{\text{bol}}/L_{\text{2–10 keV}}$, depends on $L/L_{Edd}$, with a transitional region at $L/L_{Edd} \sim 0.1$; below which the bolometric correction is typically 15–25, and above which it is typically 40–70. Thus NLS1s, with the mean $L/L_{Edd} \sim 1$ in Table 1, have a higher bolometric correction, resulting in a smaller ratio of X-ray luminosity to bolometric luminosity than BLS1s. This also agrees with the conclusion of Bianchi et al. (2009b) that NLS1s are X-ray weaker, relative to BLS1s.

NIKAL are almost ubiquitous features in the present sample. The weighted mean width of NIKAL is $1350 \pm 1$ km s$^{-1}$ for a small Chandra sample (Yaqoob & Padmanabhan 2004), more than a factor of 2 lower than the weighted mean width of H$\beta$ of $3200 \pm 60$ km s$^{-1}$ (Nandra 2006). This provides compelling evidence that NIKAL is mainly emitted from the inner boundary region of the dusty torus in an AGN (Zhu et al. 2009). This agrees with previous suggestions that NIKAL unlikely originates from either the outer region of the accretion disk or the self-gravity-dominated disk (Zhou & Wang 2005) or the broad-line region (Wu et al. 2009). In particular, the X-ray variability can not account for the observed NIKAL EW variation (Jiang et al. 2006). That means, NIKAL may give measures of the covering factor of the dusty torus, indicating the changing AGN populations (Zhou & Wang 2005; Zhu et al. 2009). The relatively weaker NIKAL EW in NLS1 can be explained in terms of models that the radiation pressure blows the cold dusty gas away from the central engine (Fabian et al. 2008), or the outflow scenario which can be related with the high $L/L_{Edd}$ (Komossa et al. 2008). If this is true, some NLS1 galaxies may have geometrically thin tori, as indicated by their weaker NIKAL emission. Conversely, the tori in some AGNs can be very geometrically thick, as indicated by their very large NIKAL EW. NIKAL thus is very useful to identify this rare type of buried AGNs, which are difficult to detect so far (Ueda et al. 2007).

BIKAL is believed to be associated with the accretion disk, probing the strong gravity of a black hole (Fabian et al. 1989; Laor 1991). Recently, Brenneman & Reynolds (2006) developed a disk-line model in which the black hole spin is a free parameter. This makes it possible to constrain the spacetime geometry close to distant black holes via X-ray spectroscopy. The results from N07 show that most of BLS1 galaxies show weak BIKAL emissions, with the EW less than 100 eV (Figure 3). This is in good agreement with the theoretical expectation of Ballantyne (2010). The mean EW and $\sigma$ of BIKAL in NLS1s are larger than that of BLS1s, indicating a smaller inner disk radius, in agreement with the expectation of the evaporation disk model, in which the inner radius of the disk is anti-correlated with $L/L_{Edd}$ (Liu et al. 1999).

6. CONCLUSIONS

We present an X-ray luminous ($\Gamma_{2–10 \text{ keV}} \geq 1 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$) Seyfert 1 sample including 114 radio-quiet objects, with the $2–10$ keV luminosity ranging from $10^{41}$ to $10^{45}$ erg s$^{-1}$. The NLS1s and BLS1s span the same luminosity range, indicating that NLS1s in this sample have higher accretion rate, $L/L_{Edd}$. The weighted mean of $\Gamma_{2–10 \text{ keV}}$ of NLS1s, BLS1s, and the total sample are $2.04 \pm 0.04$, $1.74 \pm 0.02$, and $1.84 \pm 0.02$, respectively. The anti-correlation between $\Gamma_{2–10 \text{ keV}}$ and FWHM$\beta$ is strong with a flattening at FWHM$\beta \sim 4000$ km s$^{-1}$. We propose that $\Gamma_{2–10 \text{ keV}} > 2.0$ may be taken to indicate the X-ray luminous NLS1 type, reflecting the higher $L/L_{Edd}$ in these objects.

The observed ratio between the average line width of NIKAL and that of H$\beta$ provides evidence that NIKAL mainly originates from the inner boundary region of the dusty torus in an AGN. The weighted means of the EW of NIKAL of NLS1s, BLS1s, and the total sample are $40 \pm 5$, $125 \pm 7$, and $105 \pm 7$ eV, respectively. Other than a few cases, NIKAL from NLS1s are generally weaker than that from BLS1s, indicating a smaller torus covering fraction in NLS1s. Some objects with an exceptionally larger EW, which may indicate a larger covering factor of the dusty torus, may represent a rare type of buried AGNs. Based on our re-analysis of the results in Nandra et al. (2007), the broadened iron K$\alpha$ lines from NLS1s plausibly show a more homogenous distribution than that from BLS1s. All AGNs with large intrinsic widths of iron K$\alpha$ lines ($\sigma > 0.5$ keV) have FWHM$\beta \leq 4000$ km s$^{-1}$. This may give important clues to target selections for future iron line surveys.

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REFERENCES

Arnaud, K. A. 1996, in ASP Conf. Ser. 101, Astronomical Data Analysis Software and Systems V, ed. G. H. Jacoby & J. Barnes (San Francisco, CA: ASP), 17
Ballantyne, D. R. 2010, ApJ, 708, L1
Bianchi, S., Guainazzi, M., Matt, G., & Fosseca, B. N. 2007, A&A, 467, L19
Bianchi, S., Guainazzi, M., Matt, G., Fonseca Bonilla, N., & Ponti, G. 2009a, A&A, 495, 421
