X-ray study of Compton-thick AGNs with *Suzaku*

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Abstract

We have obtained broad-band spectra of 11 Compton-thick Seyfert 2 galaxies with *Suzaku*. The spectra are well represented by a three component model, consisting of a soft component, an absorbed power-law component, and a reflection component, accompanied by both a strong iron Kα line and several weak lines. Fixing the photon indices of the power law and the reflection components at 1.9, we obtain the column density $N_{\rm H}$ and the intrinsic X-ray luminosity in the 2-10 keV band. We update the $N_{\rm H}$ distribution of the bright [OIII] sample by Risaliti et al. (1999), and find that observed luminosities of Compton thick AGNs are only 1-10% of the intrinsic luminosities in the 2-10 keV band. This is consistent with small ratios of $L_{\rm X}/L_{\rm [OIII]}$ of Compton thick AGNs.

Key words: galaxies: active — galaxies: Seyfert — X-rays: galaxies

1. Introduction

Risaliti et al. (1999; hereafter R99) presented a distribution of absorbing column densities ($N_{\rm H}$) among type 2 AGNs in a bright [OIII]λ5007 sample, and found that Compton-thick AGNs, which have $N_{\rm H} > 10^{24}$ cm $^{-2}$, are abundant in the local universe. Compton-thick AGNs are crucial for understanding some key problems in AGN research, for example synthesis modeling of the Cosmic X-ray Background (Ueda et al. 2003) and the growth of AGNs. Furthermore, Compton-thick AGNs are suitable for the study of reprocessed emission in AGNs, since the reprocessed emission dominates over their direct emission below 10 keV (e.g., Awaki et al. 2008). Studies of the reprocessed emission are conducive to revealing the environment of black hole, and hence help to understand problems of the fuel supply and evolution of supermassive black holes. However, their spectra are so complex that the detailed nature of Compton-thick AGNs has thus far been unclear.

The Japanese X-ray satellite *Suzaku* has a capability of obtaining a wide-band spectrum from 0.2 to 700 keV (Mitsuda et al. 2007). In addition, due to a long observation with an exposure time of longer than ~40 ks, we can obtain a high quality spectrum compared with short observations of about 10 ks with *XMM-Newton* and *Chandra* (e.g., Guainazzi et al. 2005a, 2005b). Therefore, our *Suzaku* observations are suitable for achieving the aims of revealing X-ray properties of Compton-thick AGNs (see Table 1).

2. Target Selection

We selected 11 Seyfert 2 galaxies in the [OIII]λ5007 bright sample by R99. Although their $N_{\rm H}$ were not measured, these galaxies were classified as Compton-thick AGNs in R99, since all galaxies have signatures of Compton-thick AGNs, such as a large equivalent width of iron Kα line and a small ratio of $L_{\rm X}/L_{\rm [OIII]}$, where $L_{\rm X}$ and $L_{\rm [OIII]}$ are X-ray and [OIII]λ5007 luminosities, respectively (e.g., Maiolino et al. 1998). Advantages of using the [OIII]λ5007 bright sample are (1) this sample is suitable for investigating the characteristics of Compton-thick AGNs due to less X-ray biased sample, and (2) their X-ray fluxes after absorption correction are expected to be large, since $L_{\rm X}$ is roughly related to $L_{\rm [OIII]}$ for Seyfert 1 galaxies (e.g., Heckman et al. 2005).

3. Analysis

After the nominal data reduction presented by the *Suzaku* first step manual, we produced XIS and HXD spectra of our target galaxies. For XIS spectra, we extracted X-ray events within a $2'$ radius centered on the target sources.

Since the half-power diameter of the *Suzaku* XRT and field of view of HXD-PIN are large, we searched for contamination sources around our target galaxies, using the *Chandra* and *XMM-Newton* serendipitous source catalogues for XIS data and the BAT 22-Month Source Catalog for HXD-PIN data. We found that there are no BAT sources within the PIN field of view.

We fitted the wide-band spectra with a base-line

Table 1. Count rate

Target Name	Exposure time		XIS FI count rate ($r<2'$)		HXD-PIN count rate	
	XIS (ks)	HXD (ks)	0.5 - 2 keV (c s^{-1})	2 -10 keV (c s^{-1})	15 - 40 keV (c s^{-1})	significance (σ)
Mrk 1073	39.5	34.8	0.0077±0.0004	0.0040±0.0004	0.012±0.003	3.6
NGC 1386	55.5	44.3	0.0123±0.0004	0.0066±0.0003	0.017±0.003	5.0
NGC 1667	39.2	33.3	0.0056±0.0003	0.0020±0.0002	-0.003±0.003	0
NGC 3393	55.2	45.1	0.0104±0.0004	0.0057±0.0003	0.019±0.003	5.3
IC 3639	53.4	46.6	0.0067±0.0003	0.0040±0.0003	0.004±0.003	1.1
NGC 4968	39.1	33.3	0.0031±0.0002	0.0044±0.0003	0.006±0.003	1.7
NGC 5135	52.5	46.6	0.0173±0.0004	0.0062±0.0003	0.021±0.003	6.4
NGC 5347	42.2	34.8	0.0011±0.0002	0.0032±0.0004	-0.005±0.003	0
NGC 5643	42.9	38.1	0.0162±0.0005	0.0177±0.0005	0.016±0.003	4.5
NGC 7130	44.5	34.4	0.0114±0.0004	0.0045±0.0003	0.010±0.003	2.9

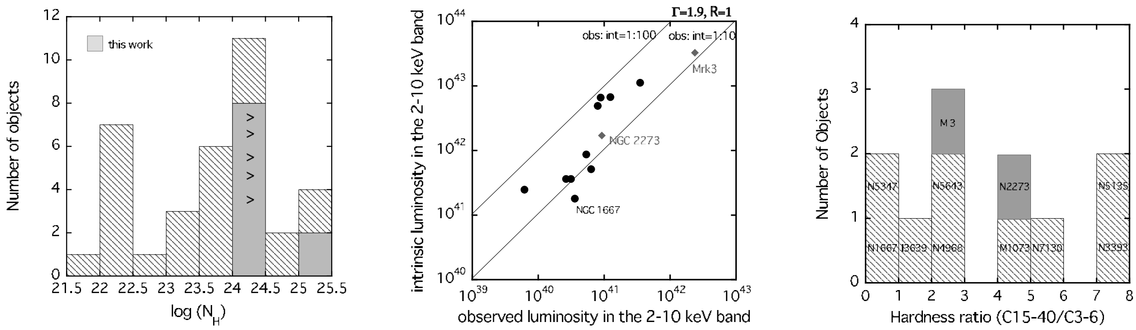

Fig. 1. X-ray properties of our sample. The left panel shows a $N_{\rm H}$ distribution. The ">" means a galaxy with a lower limit of the column density. The middle panel shows estimation of intrinsic luminosities in the 2– 10 keV band. The right panel shows a distribution of hardness ratios between 3–6 keV and 15–40 keV bands.

model, which consists of a soft component, an absorbed power law component ($N_{\rm H1}$, Γ_1, z), and an absorbed reflection component($N_{\rm H2}$, Γ_2, z, θ), accompanied by both strong iron Kα line and weak lines, where z is a redshift, and θ is the inclination angle. The soft component is represented by either power law emission or thin thermal emission (*apec*), and the reflection component is represented by the *pexrav* model with θ=60°. In the spectral analysis, we assumed Γ_1=Γ_2, and fixed Γ_1 at the canonical value of 1.9.

4. Results

$N_{\rm H1}$ of all our sample measured with *Suzaku* were larger than 10^{24} cm^{-2}. We updated the $N_{\rm H}$ distribution shown by R99, using our *Suzaku* results (see the left panel in figure 1). The ">" in the panel indicates a galaxy with a lower limit. The distribution may have a peak at $\log N_{\rm H}$ =24–24.5. The $N_{\rm H}$ distribution of a *Swift* survey sample has a peak at $\log N_{\rm H}$ =23.5–24 (Tueller et al. 2008). Thus the *Swift* survey may be affected by X-ray obscuration.

Intrinsic luminosities of Compton-thick objects were obtained after absorption correction, and are found to be 10–100 times larger than observed luminosities. This result well explains a small ratio of $L_{\rm X}/L_{\rm [OIII]}$, and suggests that the energy source of [OIII] line is strong emission from the nucleus similar to Seyfert 1 galaxy.

We found that the X-ray fluxes in the PIN band were different, while the X-ray fluxes in the 3–6 keV band were similar. This is clearly shown by hardness ratios between count rates in 15–40 keV and 3–6 keV, C15–40/C3–6. A high hardness ratio can be produced by a small reflection ratio (R) or a large $N_{\rm H2}$. Based on a simulation by Ikeda et al. (2009), the difference of hardness ratios may be caused by difference of viewing angles.

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