Broadband spectral variation of Seyfert 1 Galaxy MCG-6-30-15

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Abstract

We have investigated spectral variation of the Seyfert 1 galaxy MCG-6-30-15 observed with Suzaku in January 2006 for three separate periods spreading over fourteen days. We found that the time-averaged continuum energy spectrum between 1 keV and 40 keV can be approximated with a spectral model composed of the direct power-law component, its reflection component, two warm absorbers with different ionization states, and neutral absorption. We found a clear correlation between the intensity in the 6 – 10 keV band and the spectral ratio of 0.5 – 3.0 keV/6.0– 10 keV. Such a spectral variation requires change of the apparent slope of the direct component, whereas the shape and intensity of the reflection component being invariable. The observed apparent spectral change is explained by variation of the ionization degree of one of the two warm absorbers due to intrinsic source luminosity variation. Current results suggest that the warm absorber has a critical role to explain the observed continuum spectral shape and variation of MCG-6-30-15, which is essential to constrain parameters of the putatively broadened iron line emission feature.

Key words: galaxies: active – galaxies: individual (MCG-6-30-15) – galaxies: Seyfert – X-rays

1. Introduction

ASCA discovered a broad and skewed emission line feature around 5–7 keV in the spectrum of MCG-6-30-15 for the first time (Tanaka et al. 1995). The iron line is emitted as a part of the reflection spectrum from the accretion disk, irradiated by a primary continuum of the central engine. Miniutti et al. (2007) claim that the strong reflection, the broad iron line and invariability of the iron line observed with Suzaku may be explained with the light-bending model, and suggest that the innermost disk radius extends down to about as low as two gravitational radii. Young et al. (2005) reported a weak and narrow emission line at 6.4 keV, which indicates that some reflection does take place in a distant material, e.g., the narrow-line region or the pc-scale torus. The broad band continuum in MCG-6-30-15 is complex, with strong modification from warm absorbers (e.g., Miller et al. 2008).

In this paper we attempt to comprehensively characterize the spectral variability of the source in a model independent manner as much as possible. We characterize spectral variations at different timescales, as well as at different source flux levels. We use Suzaku data taken in Jan 2006 (total exposure time is 339 ksec) for this purpose. Our goal is to find a reasonable spectral model of MCG-6-30-15 which is able to explain the observed spectral variation at various timescales with minimum numbers of parameters, and to study effects of warm absorbers.

2. Observation and Data Reduction

The Suzaku satellite (Mitsuda et al. 2007) has observed MCG-6-30-15 four times. In 2006 January, the source was observed three times, between 9–14 (143 ksec exposure), 23–26 (99 ksec), and 27–30 (97 ksec). In this paper, we use the data taken in 2006 January. For data reduction, see Miyakawa et al. (2009).

3. Data Analysis and Results

First, we study spectral variation of the source in a model-independent manner. As for making "intensity-sliced energy spectra", "bright spectra" and "faint spectra", see Miyakawa et al. (2009). From the eight intensity-sliced spectra, six bright spectra and six faint spectra thus created, we studied spectral variations in a model independent manner by calculating spectral hardness radios between different energy bands. Consequently, we discovered a significant correlation between the intensity in the 6.0 – 10 keV and the spectral ratio

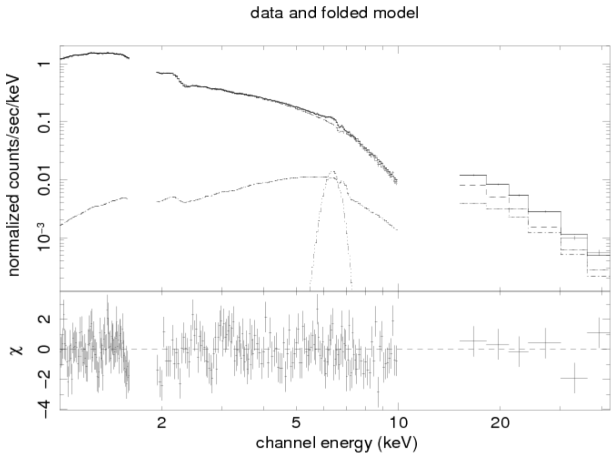

Fig. 1. Spectral fit result for the time-averaged XIS and PIN spectra (1–40 keV) with a *broad* iron emission line (intrinsic line width is allowed to be free and 1 σ=290 eV.)

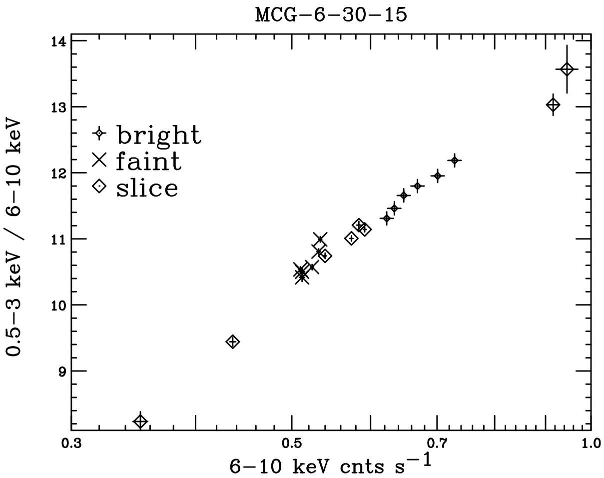

Fig. 2. Correlation between the flux in 6.0–10 keV and the hardness ratio of 0.5–3.0 keV/6.0–10 keV for the "intensity-sliced spectra" (black), "bright spectra" (red) and "faint spectra" (blue).

of 0.5 – 3.0 keV/6.0 – 10 keV. This correlation is shown in Figure 2.

Second, we study the time-average spectrum of MCG-6-30-15 to find a physically plausible spectral model. Then, we will use the same spectral model to see which parameters are variable to explain the observed spectral variation. The spectral model we adopt is the following; (1) power-law with an exponential cut-off, (2) disk reflection component from neutral matter ("pexrav"; Magdziarz & Zdziarski 1995), (3) iron emission line, (4) two warm absorbers with different ionization states, and (5) neutral photoelectric absorption ("phabs"; Balucinska-Church & McCammon 1992). (6) a narrow gaussian absorption line to account for the instrumental feature around the Au M-edge.

To model the warm absorber, we used XSTAR Version

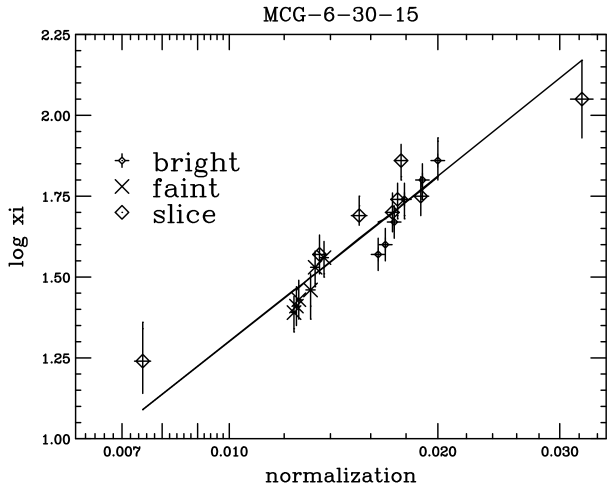

Fig. 3. Relation between the ionization degree and power-law normalization for the bright, faint and sliced spectra.

2.1kn8 (Kallman et al. 2004). We analyzed the total average spectrum (the intrinsic line width to be free), the fit significantly improved, where reduced chisq is 1.20 (χ^2/d.o.f = 267.4/222). Central energy of the line is 6.42±0.06 keV, and the width is 1 σ = 290 ± 60 eV (Figure 1). The equivalent width is 100±20 eV. In Fig.1, we show the fitting result for the total average spectrum with a broad line. Note that our model does not require an extremely broadened iron emission line, which may be expected from very vicinity of a fast rotating black hole.

We also fit the eight intensity-sliced spectra with the model varying the power-law normalization and the ionization parameter, where reduced chisq is 1.24 (χ^2/d.o.f = 267.4/222). Central energy of the line and line width are fixed at 6.35 keV, and 10 eV, respectively. In Fig. 3, we show relation between the power-law normalization and the ionization degree of the lower ionized warm absorber, which indicates a clear correlation as $\log \xi = (1.7 \pm 0.2) \times \log K + (4.7 \pm 0.3)$.

References

Balucinska-Church, M., & McCammon, D. 1992, ApJ, 400, 699
Kallman, T. R., et al. 2004, ApJS, 155, 675
Magdziarz, P., & Zdziarski, A. A. 1995, MNRAS, 273, 837
Miller, L., Turner, L. J. & Reeves, J. N. 2008, A&A, 483, 437
Miniutti, G., et al. 2007, PASJ, 59, 315
Mitsuda, K., et al. 2007, PASJ, 48, 211
Miyakawa, T., Ebisawa, K., Terashima, Y., Tsuchihashi, F., Inoue, H., and Życki, P. 2009, PASJ, resubmitted
Tanaka, Y., et al. 1995, Nature, 375, 659
Young, A. J., et al. 2005, ApJ, 631, 733