Suzaku Discovery of a Hard Component that Varies Independently of the Power-Law in Several Seyfert Galaxies

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Abstract

We reanalyzed 30 archival *Suzaku* data sets of 18 AGNs, focusing on their hard band variability. In 6 objects including MCG–6-30-15, we discovered a new hard spectral component that varies independently of the power-law. In one observation of MCG–6-30-15 made on 2006 January 27, this component carried a considerable fraction of the hard X-ray bump which is usually attributed to disk reflecton. Taking this hard component into account, the solid angle of reflection reduced to $\sim 2\pi$ and the equivalent width of broad iron line to $\sim$ 140 eV. Although the nature of this new component is still open, it allows us to interpret the *Suzaku* data of this Seyfert without invoking the strong reflection nor the extremely broad iron line.

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

1. Introduction

The wide-band capability of *Suzaku* has allowed detailed studies of the iron emission line and the reprocessed hard X-ray hump in accreting black holes. In particular, Miniutti et al. (2007) reconfirmed the previous *ASCA* detection of the broad iron line from the Type I Seyfert galaxy MCG–6-30-15 (Tanaka et al. 1995), and interpreted the broadening as due to relativistic effects when line-emission materials are located close to the gravitational radius $R_{\rm g}$ around an extreme Kerr black hole. Furthermore, they argued that the implied large equivalent width ($\sim$ 320 eV) of the broad iron line is consistent with the strong reflection requiring $\Omega/2\pi \sim 4$. However, a very sophisticated model ("light bending model") must be invoked to explain the large value of $\Omega/2\pi$, and to reconcile the implied very close location of the reprocessing material with observed lack of variability in the iron line and hard-hump intensities.

Trying to find a more natural alternative to explain these properties of MCG –6-30-15 and similar objects, we here questioned the basic assumption, that the hard X-ray excess above an appropriately determined power-law is entirely due to a reflection component. For this purpose, we analyzed 30 archival *Suzaku* data sets of 18 AGNs, mainly Type I Seyfert galaxies, focusing on their spectral variability.

2. The extraction of the "second componen"

To study intensity-correlated spectral variations, we made Count-Count Plots (CCPs) of 18 objects. As exemplified in Fig. 1, the X-axis of each CCP gives XIS (3-10 keV) count rates of the source, while Y-axis gives its HXD-PIN (15-45 keV) count rates, both with typical binning of 10 ksec.

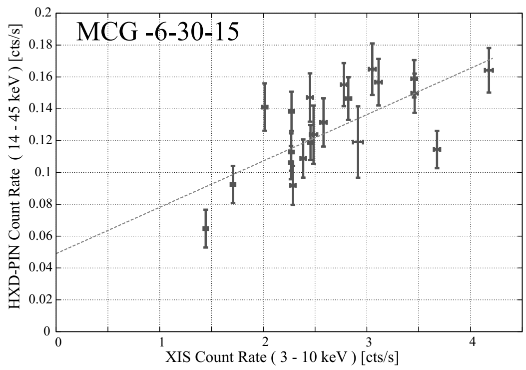

Fig. 1. The CCP of MCG–6-30-15 from the 2006 January 27 observation.

In CCPs of 12 objects, the data points exhibited one-dimensional distributions, in such a way that the soft and hard counts are in 1:1 correlation. Therefore, the source variation can be described by a single parameter, namely, the continuum intensity. On the other hand, CCPs of the other objects, including MCG–6-30-15, show two-dimensional data scatters, as shown in Fig. 1. In three cases, the source variation must involve at least two independent parameters.

In the CCP of MCG–6-30-15, we define "High" and "Low" phases, wherein the data points are above and below the straight line representing the general XIS vs. HXD correlation, respectively. Then, we subtracted the spectrum accumulated over the "Low" phase from that accumulated in the"High" phase. As shown in Fig. 2, this "High - Low" spectrum is very hard, and approximated by a single power-law with a photon index of $\Gamma \sim 1$. We call it "the second component", and regard it as representing the vertical data scatter in Fig. 1.
Physically, the "second component" may be interpreted as a thermal Comptonizaion component. As shown in Fig. 2b, it can actually be reproduced by a thermal Comptonization model, `compTT`, with an optical depth of $\tau \sim 10$ and an electron temperature of $T_{\rm e} \sim 10$ keV.

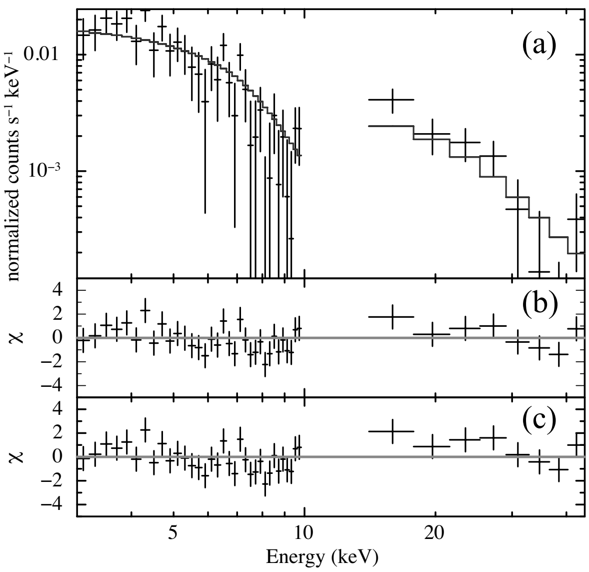

Fig. 2. The second component of MCG–6-30-15 fitted with `compTT` (a and b), or power-law (c)

3. Reanalysis of time-averaged spectra of MCG–6-30-15

First, we fitted the time-averaged XIS plus HXD spectra of MCG–6-30-15 with a standard model, `wabs *(gaussian*3 + laor + cutoffPL + pexrav)`, which is approximately the same as Miniutti et al.(Fig 3a). This model required a large solid angle as $\Omega/2\pi \sim 2.2$ and a large EW ~ 310 eV, in agreement with Miniutti et al. (2007).
Next, we fitted the same spectra by the same model, but adding a `compTT` component (Fig. 3b). Owing to the considerable contribution of `compTT` in the hard X-ray band, $\Omega/2\pi$ reduced to ~ 1. Simultaneously, the iron line EW reduced to ~ 140 eV, which is consistent with the reflection intensity. Thus, we have succeeded in reproducing the data without the strong reflection nor the extremely broad iron line.

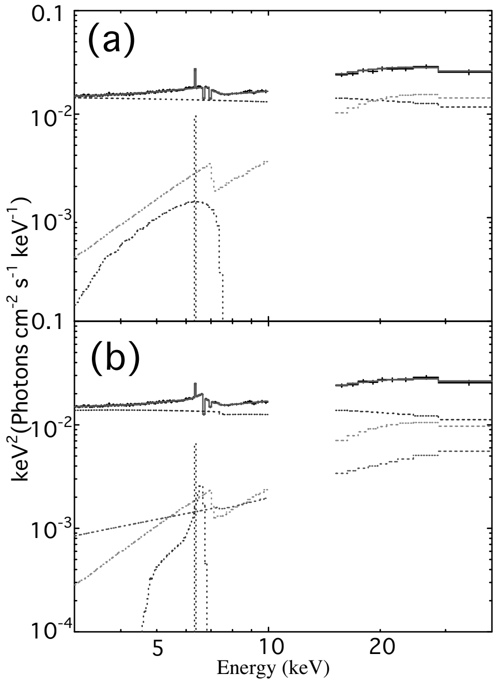

Fig. 3. The $\nu F\nu$ spectra of MCG–6-30-15, fitted with a power-law (purple), reflection (green), a broad Fe-K line, and a narrow Fe-K line. In panel (b), `compTT` (red) is added.

4. Conclusion

We discovered a hard spectrum component ("second component") that varies independently of the dominant power-law component. This new coomponent, which is significant in the HXD-PIN band, can be approximated by a power-law of $\Gamma \sim 1$, and tentatively interpreted as a thermal Compton signal. Taking this hard component into account, the time-averaged *Suzaku* spectra of MCG–6-30-15 can be reproduced without the strong reflection nor the extremely broad iron line.

References

Uehara, Y. 2009, Master Thesis, Univ. Tokyo
Miniutti, G. et al. 2007, PASJ, 59S, 315
Tanaka, Y. et al. 1995, Nature, 375, 659