The new primary X-ray spectral component of IC4329A confirmed with *Suzaku* and *NuSTAR*

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Abstract

The bright and highly variable Seyfert I active galactic nucleus, IC4329A, was observed simultaneously with *Suzaku* and *NuSTAR* for about 3 days. Within the observation, the 2–10 keV flux changed by a factor of 1.5 around the mean of $\sim 1.0 \times 10^{-10}$ erg cm^{-2} s^{-1}. Using the model-independent spectral decomposition method developed by Noda et al. (2011), the time-averaged *Suzaku* and *NuSTAR* spectra (3–70 keV) were consistently decomposed into a fast and a slowly varying components. While the former can be modeled as a power-law (PL) with a photon index $\Gamma = 2.1$, the latter was interpreted as the sum of a harder primary PL ($\Gamma = 1.4$) and the reflection. By combining the *Suzaku* and *NuSTAR* data, the presence of this new primary PL, first revealed in the *Suzaku* data (Miyake et al. 2016), has been reinforced.

Key words: galaxies: active — galaxies: individual (IC4329A) — galaxies: Seyfert — X-rays: galaxies

1. Introduction

X-ray spectra of Seyfert I active galactic nuclei (AGNs) were considered to consist of a power-law (PL) like primary component, and its reflection component accompanied by an Fe Kα line (Fabian & Miniutti 2005). However, it is in reality difficult to observationally extract the primary PLs, because different components are mixed in an observed spectrum (Cerruti et al. 2011). Noda et al. (2011, 2013a) developed a model-independent spectral decomposition method, the "Count-Count Correlation with Positive Offset" (C3PO) method. Using it, we discovered that X-ray spectra of many AGNs harbor the two distinct primary PLs (Noda et al. 2013b, 2014).

2. Observation and Data Reduction

IC4329A is a bright and highly variable Seyfert I AGN (Perola et al. 1999). This source was observed in 2012 August 13 simultaneously with *Suzaku* and *NuSTAR*. We had already analyzed this *Suzaku* data set, and confirmed the $\Gamma = 1.4$ PL in the 2–45 keV spectra (Miyake et al. 2016). In the present work, we try to strengthen the result by incorporating the *NuSTAR* data. We analyzed publicly available XIS 0, XIS 3, and HXD-PIN data of *Suzaku*, and FPMA and B data of *NuSTAR*. XIS 0 and 3 data were co-added and are referred to as XIS FI. On-source events of the XIS and FPM were extracted from a circular region of 3′ radius, and background events from an annular region of the radii 4′.8–7′.8. From the HXD-PIN data, we subtracted Non X-ray Background estimated by Fukazawa et al. (2009) and Cosmic X-ray Background (Boldt 1987).

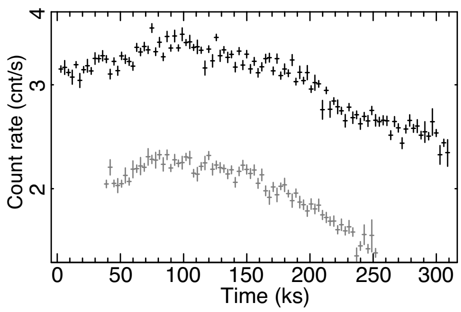

Fig. 1. Background subtracted and dead-time corrected light curves of IC4329A in 2–10 keV with FPMA (black) and XIS FI (gray). Time 0 is 2012 August 13 UT 02:13:09.

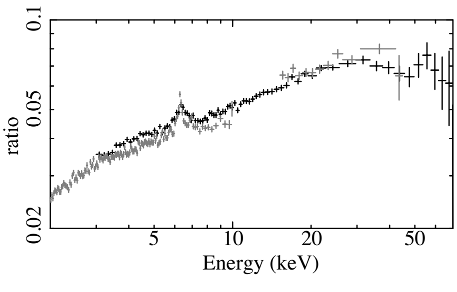

Fig. 2. Background-subtracted time-averaged spectra of IC4329A obtained with FPMA (black), and XIS FI and the HXD (gray).

3. Data Analysis

3.1. Light curves and spectra

Figure 1 shows background subtracted and dead-time corrected light curves in 2–10 keV obtained with *NuSTAR* and *Suzaku*, with net exposures of 162 and 102 ks, respectively. The source varied by a factor of ~ 1.5 in the observation, around a mean 2–10 keV flux of $\sim 1.0 \times 10^{-10}$ erg cm^{-2} s^{-1}. In the present work, we utilize the *NuSTAR* data only over the period which is simultaneous with *Suzaku*; the net exposure is reduced to 68 ks. Figure 2 shows background-subtracted time-averaged spectra in the form of their ratios to a PL model with photon index $\Gamma = 2$. In addition to an approximately PL-like continuum with a cutoff at ≥ 40 keV, they exhibit Fe Kα line and edge at 6.4 and 7.2 keV in the rest frame, respectively.

3.2. C3PO method

We applied the C3PO method to *NuSTAR* data for the first time. The 2–3 keV band of XIS FI was selected as the reference band, because it exhibited the highest variability. Figure 3 shows examples of Count-Count Plots (CCPs). Since all CCPs in finer bands from 3 to 70 keV showed good linearity like figure 3, we applied the C3PO method to the present data. As shown in figure 4, we successfully decomposed the time-averaged spectra of IC4329A into fast (FS) and slowly variable spectra (SS). The result of the decomposition was consistent between the *NuSTAR* and *Suzaku* data. The FS has a PL shape with $\Gamma \sim 2$, while the SS has the Fe K line.

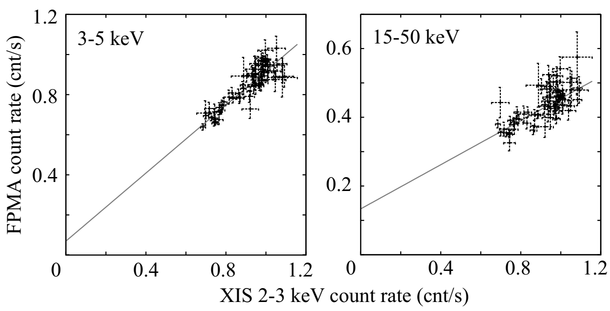

Fig. 3. CCPs between the reference XIS 2–3 keV and a broad FPMA band. The best-fitting straight line is shown in gray.

The C3PO method performs a simultaneous fitting using two model components denoted as `model_F` and `model_S`. The FS is fitted with `model_F`, the SS with `model_S`, and the time-averaged spectrum with `model_F`+`model_S`. As discussed in Miyake et al. (2016), the SS of the *Suzaku* data requires not only the reflection but also another PL. Therefore, we adopted a PL as `model_F`, and again the sum of reflection and another PL as `model_S`. As a result of the simultaneous fitting with parameters common to the *NuSTAR* and *Suzaku* data, the fit was successful with $\chi^2/\mathrm{d.o.f.} = 427/368$.

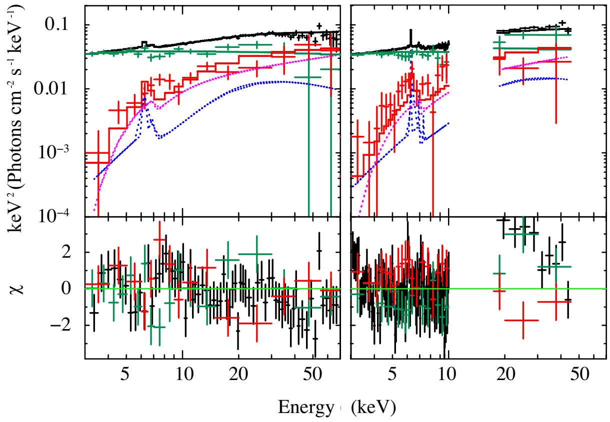

Fig. 4. The time-averaged spectra (black) shown with the FSs (green) and SSs (red), fitted with the sum of the fast variable PL (green), the slowly variable PL (magenta), and the reflection (blue).

The PL of `model_F` has $\Gamma = 2.0$, while `model_S` consists of another $\Gamma = 1.5$ PL, strongly-absorbed with a column density $N_{\mathrm{H}} = 3.7 \times 10^{23}$ cm^{-2}, and reflection with the abundance fixed at 1 solar and the solid angle of 1.0π.

4. Discussion and Conclusion

The spectra of IC4329A was successfully decomposed with the C3PO method, and they were well reproduced by considering two primary PL radiation as other AGNs.

So far, the *NuSTAR* spectrum of IC4329A has been considered to include a relativistically smeared Fe line (e.g. Brenneman et al. 2014). When the relativistic reflection was adopted instead of the slowly variable PL, the fit became unaccepted with $\chi^2/\mathrm{d.o.f.} = 648/367$. Thus, the advantage of our modeling over the relativistic Fe line interpretation has been very much strengthened by incorporating the *NuSTAR* data, because these modelings gave fit $\chi^2/\mathrm{d.o.f.}$ of 200/168 and 205/169, respectively, when using only the *Suzaku* data. Therefore, our "two primary PLs" interpretation has been reinforced by combining both the *NuSTAR* and *Suzaku* data.

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