MAXI and AKARI investigation of nearby active galactic nuclei

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Abstract

X-ray and infrared properties of nearby active galactic nuclei were studied with MAXI and the Japanese infrared observatory AKARI, respectively. Among the 100 active galactic nuclei (except for blazars) tabulated in the second MAXI catalog, 69 ones were found to have an infrared counterpart in the AKARI point source catalog. The X-ray luminosity of these objects was corrected for absorption by referring to the X-ray hardness ratio measured with MAXI. The absorption-corrected X-ray luminosity of Compton-thin objects was found to be linearly correlated to their observed IR luminosity. This kind of correlation is widely interpreted by the so-called clumpy torus model. In contrast, NGC 1365, only one Compton-thick object in the MAXI catalog, was found to deviate from the correlation, toward a lower X-ray luminosity by nearly an order of magnitude. It was verified that Compton-thick objects are effectively picked up by using the relation between the X-ray spectral hardness and X-ray-to-infrared color.

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

1. Introduction

Based on the unified picture (e.g., Antonucci 1993), it is widely believed that the central engine of the active galactic nuclei is a supermassive black hole accompanied by a mass-accreting disk, and they are surrounded by a parsec-scale dust torus. However, our knowledge on their detailed spatial configuration and physical condition still remains far from satisfactory. Especially, the astrophysical importance of the Compton-thick objects, defined as heavily obscured objects with a hydrogen column density of $N_H > 1.5 \times 10^{24}$ cm^{-2}, has been widely recognized (e.g., the origin of the X-ray background; Ueda et al. 2014). Since these obscured sources are elusive in the optical band due to significant dust extinction, a useful identification technique is urgently requested.

It is widely thought that X-ray emission from active galactic nuclei originates in the vicinity of the central engine. These nuclear photons are absorbed in the dust torus, and are re-emitted into the infrared (IR) band. Therefore, a combination of X-ray and IR observations provides us with a useful probe for the central region of the active galactic nuclei. In addition, the X-ray and IR color information is proposed to effectively pick up the heavily obscured sources (Terashima et al. 2015).

The present study utilizes the second release of the all-sky X-ray source catalog (hereafter the 2MAXI catalog; Hiroi et al. 2013) and the AKARI all-sky survey point source catalog (Ishihara et al. 2010; Yamamura et al. 2012) to systematically diagnose nearby active galactic nuclei (Isobe et al. 2016). The sensitivity of the 2MAXI catalog is highest among the available all-sky X-ray surveys. The IR spectrum is thought to be dominated by the torus emission in the 10–20 μm range, where the AKARI catalog has a high sensitivity. These make the combination of the 2MAXI and AKARI catalogs the ideal tool for investigation of active galactic nuclei.

2. Results

The 2MAXI catalog lists 95 Seyfert galaxies and 5 quasars, located at the redshift of $z = 0.002$–0.15.

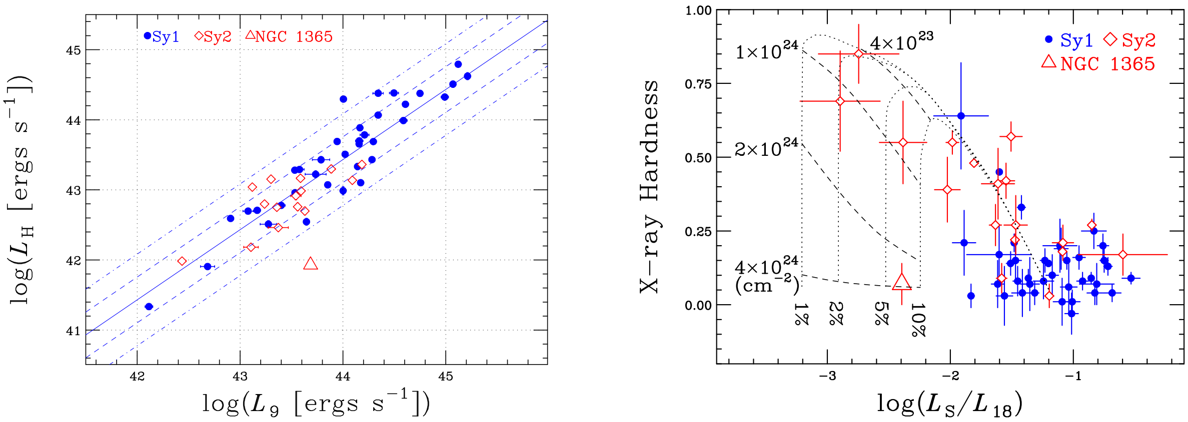

Fig. 1. (right) Relation between the absorption-corrected $4-10$ keV X-ray luminosity, L_H, and the 9 μm infrared luminosity, L_9. The filled blue circles and open red diamonds indicate the type-1 and type-2 Seyfert galaxies, respectively. The Compton-thick object, NGC 1365, is plotted with the open triangle. The average of the X-ray to IR luminosity ratio in the logarithmic space for the type-1 objects is shown with the solid line, while the 1σ and 2σ ranges are indicated by the dashed and dash-dotted lines, respectively. (left) X-ray hardness ratio, HR, plotted against the absorption-inclusive 3–4 keV X-ray to 18 μm IR luminosity ratio, L_S/L_{18}. The model track for some representative values of the scattered X-ray fraction are drawn with the dotted lines as a function of the column density, N_H, (the dashed line).

They are classified into 73 type-1 and 27 type-2 objects. Among them, 69 Seyfert galaxies, including 48 type-1 and 21 type-2 Seyfert galaxies, were identified as an AKARI source.

In the left panel of Figure 1, the 4–10 keV X-ray luminosity (L_H) is plotted against the 9 μm IR luminosity (L_9) for the Seyfert galaxies detected with both MAXI and AKARI. Here, the X-ray luminosity was corrected for absorption by utilizing the hydrogen column density which is inferred from the X-ray hardness ratio, HR, tabulated in the 2MAXI catalog (Ueda et al. 2011), while no correction was applied to the IR luminosity. Figure 1 strongly supports that the X-ray luminosity linearly correlates to the IR ones, regardless of the classification of the active galactic nuclei, at least for the Compton-thin objects.

A similar X-ray-to-IR correlation was commonly found in recent studies of nearby active galactic nuclei (Gandhi et al. 2009; Matsuta et al. 2012). A simple torus model with a smooth and homogeneous dust distribution fails to interpret this relation, because dust extinction to the IR luminosity is thought to become not negligible for type-2 objects with a high N_H value. Therefore, the so-called clumpy torus geometry (e.g., Krolik & Begelman 1988) is widely proposed.

In the 2MAXI catalog, one Compton-thick object, NGC 1365, is listed. It is important to note that this source significantly deviates from the L_H–L_9 correlation for the Compton-thin sources, as indicated by the red triangles in the left panel of Figure 1. This is because the absorption correction by the MAXI hardness ratio is only applicable to Compton-thin sources, of which the X-ray emission is dominated by the direct/absorved component from their nucleus. The method inevitably underestimate the intrinsic luminosity of Compton-thick objects, since their dominant spectral component is though to be reflected and/or scattered emission (Ueda et al. 2014).

This implies that the relation of the X-ray hardness to the X-ray-to-IR color is utilized as an effective tool to find Compton-thick active galactic nuclei (Terashima et al. 2015). In the right panel of Figure 1, the HR value derived with MAXI is plotted against the ratio of the 3–4 keV luminosity to the 18 μm IR one, L_S/L_{18}, for the 2MAXI-AKARI sources. With the direct and scattered/reflected components taken into account, the model spectrum is possible to qualitatively reproduce the properties of both the Compton-thin and -thick sources on this diagram, as shown with the dotted lines in the Figure 1 right panel. Especially, the figure confirms the ability of this kind of diagrams for discriminating Compton-thick objects from Compton-thin ones. This method will become a powerful tool to search for Compton-thick sources in future X-ray and IR surveys.

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