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INFRARED – X-RAY CONNECTION IN NEARBY ACTIVE GALACTIC NUCLEI; AKARI AND MAXI RESULTS

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ABSTRACT

Combining the AKARI Point Source Catalog and the 37-month Monitor of All-sky X-ray Image (MAXI) catalog, the infrared and X-ray properties of nearby active galactic nuclei were investigated. The 37-month MAXI catalog tabulates 100 nearby Seyfert galaxies, 73 of which are categorized into Seyfert I galaxies. Among these Seyfert galaxies, 69 ones were found to have an AKARI infrared counterpart. For the Seyfert I galaxies in this sample, a well-known correlation was found between the infrared and X-ray luminosities. However, the observed X-ray luminosity of the Seyfert II galaxies tends to be lower for the infrared luminosity than the Seyfert I galaxies. This suggests that the X-ray absorption is significant in the Seyfert II galaxies. The Seyfert II galaxies seem to have a bimodal distribution of the IR color between 18 μm and 90 μm. Especially, a large fraction of the Seyfert II galaxies exhibits a redder IR color than the Seyfert I galaxies. A possible origin of the redder IR color is briefly discussed, in relation to the star formation activity in the host galaxy, and to the X-ray absorption.

Key words: galaxies: active — infrared: galaxies — X-ray: galaxies

1. INTRODUCTION

Based on the unified picture (e.g., Antonucci, 1993) of active galactic nuclei (AGNs), X-ray emission from AGNs is widely believed to originate in the vicinity of their central supermassive black hole and accretion disk. It is thought that the nuclear photons are absorbed in the pc-scale dust torus and clouds surrounding the supermassive black hole, and they are reprocessed into the infrared (IR) radiation. Therefore, a combination of X-ray and IR observations is expected to provide us with one of the most efficient probes for the AGNs. Actually, an IR to X-ray luminosity correlation was reported from a number of AGN samples (e.g., Gandhi et al., 2009; Matsuta et al., 2012). This correlation favors a clumpy torus model (e.g., Krolik & Begelman, 1998).

In the present paper, we investigated the X-ray and IR properties of nearby AGNs, by utilizing the two recent all-sky surveys. For the X-ray survey, we adopted the all-sky X-ray catalog (Hiroi et al., 2013), created in the 37 month observation with the Monitor of All sky X-ray Image (MAXI). The sensitivity of the 37-month MAXI catalog (7.5×10^{-13} ergs s^{-1} cm^{-2} in the 4 – 10 keV range) is the highest among the available all-sky X-ray surveys. For the IR survey, the AKARI Point Source Catalog (Ishihara et al., 2010; Yamamura et al., 2012), covering the wavelengths from 9 – 160 μm with the 6 photometric bands, is utilized. There are several advantages in the AKARI catalog for this study, including its wavelength coverage in the 10 – 20 μm range, where the torus emission is dominant. In addition, the data in the longer wavelengths (such as in 90 μm) is optimal to estimate the emission from the host galaxy.

2. RESULT

2.1. Source Identification

In the 37-month MAXI catalog, 500 X-ray sources are listed at high Galactic latitude of $|b| > 10°$. These include 100 nearby Seyfert galaxies (73 Seyfert I and 27 Seyfert II galaxies), located in the redshift range of $z = 0.002 - 0.15$. We searched the AKARI Point Source Catalog for IR counterparts of these Seyfert galaxies. Here, a search radius of 10" and 20" is adopted for the sources detected with the Infrared Camera and Far-infrared Surveyor, respectively, by considering the position accuracy in the AKARI catalog (Ishihara et al., 2010; Yamamura et al., 2012). As a result, we found an IR counterpart for 69 MAXI-selected Seyfert galaxies, at least in one AKARI photometric band.

2.2. IR to X-ray Luminosity Relation

Figure 1 shows the relation between the 18 μm IR luminosity, L_{18}, and the soft (3 - 4 keV) and hard (4 - 10 keV) band X-ray luminosities, L_S and L_H respectively, for the 69 Seyfert galaxies, detected with MAXI and AKARI. Here, the X-ray luminosity was uncorrected for the interstellar absorption, while dust extinction was not accounted for the IR luminosities. Since we deal with only the nearby sources at $z < 0.15$, the K-correction was not applied.

As is represented by the regression line in Figure 1 (the dashed line in each panel), the Seyfert I galaxies in this sample were found to exhibit the well-known correlation between the IR and X-ray luminosities (e.g., Gandhi et al., 2009; Matsuta et al., 2012). The partial correlation function between $\log(L_{18})$ and $\log(L_H)$, where the effect from the artificial correlation due to the redshift is removed, was evaluated as $\rho_z = 0.74$. In contrast, no significant correlation was derived for the Seyfert II galaxies, as is parameterized by the $\log(L_{18})$–$\log(L_H)$ and $\log(L_{18})$–$\log(L_S)$ partial correlation functions of $\rho_z = 0.04$ and -0.01, respectively. Especially, the observed X-ray luminosity of the Seyfert II galaxies tends to be lower for the IR luminosity than that of the Seyfert I galaxies. This tendency is more prominent in the $\log(L_{18})$–$\log(L_S)$ plot. We naturally attribute this to significant X-ray absorption in the Seyfert II galaxies, due to mechanisms such as the dust torus blocking our line of sight to their nucleus.

2.3. IR Color and X-ray Hardness

In the lower panel of Figure 2, the IR color between the luminosities at 18 μm and at 90 μm, L_{18}/L_{90},

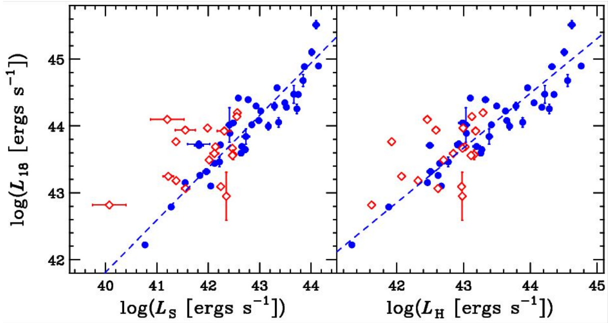

Figure 1. IR luminosity, L_{18}, plotted against the X-ray luminosities in the soft and hard bands, L_S and L_S respectively, for the Seyfert galaxies detected with MAXI and AKARI. The filled circles indicate the Seyfert I galaxies, while the open diamonds indicate the Seyfert II galaxies. The dashed line in each panel show the regression line ("OLS bisector" defined in Isobe et al., 1990) between the IR and X-ray luminosities for the Seyfert I galaxies.

is plotted against the X-ray hardness ratio, $HR = (L_H - L_S)/(L_H + L_S)$. As shown in the Figure 2 upper panel, the interstellar absorption hydrogen column density N_H is estimated from the X-ray hardness, assuming the photon index of the nuclear X-ray power-law spectrum as $\Gamma = 1.9$ (the typical value for Seyfert galaxies).

The Seyfert I galaxies occupy a relatively narrow region around $L_{18}/L_{90} = 0.5 - 1$ and $HR = 0 - 0.2$. The X-ray hardness is found to be insensitive to N_H for the Seyfert I galaxies. In contrast, the Seyfert II galaxies exhibit a higher X-ray hardness up to $HR \sim 0.9$, indicating a significant absorption of $N_H \lesssim 5 \times 10^{23}$ cm^{-2}. Interestingly, the IR color distribution of the Seyfert II galaxies seems to be bimodal, i.e., while some Seyfert II galaxies exhibit a L_{18}/L_{90} color similar to those of the Seyfert I galaxies, a larger fraction of the Seyfert II galaxies show a redder color, $L_{18}/L_{90} = 0.1 - 0.2$. Such a kind of the IR color distribution is not interpreted by the orientation of the dust torus to our line of sight. A lower L_{18}/L_{90} value indicates a higher contribution of the IR emission from the host galaxy. Therefore, we propose that a star formation rate is higher in the redder Seyfert II galaxies than in the bluer ones, including the Seyfert I galaxies. The high star formation activity in the red sources may increase the amount of dust, which also enhance the X-ray absorption.

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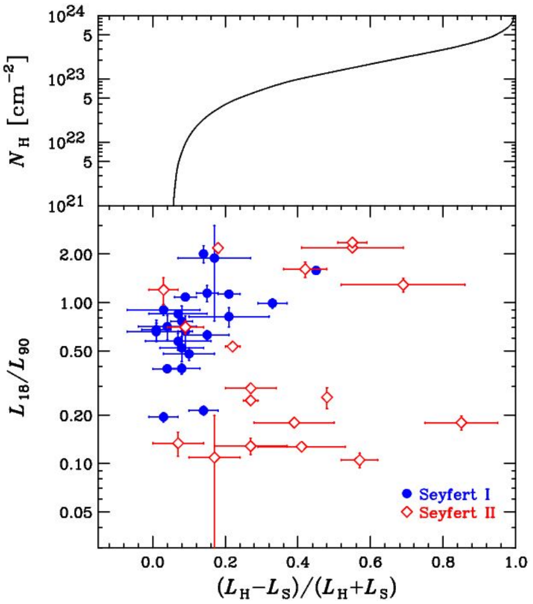

Figure 2. The lower panel plots the IR color L_{18}/L_{90} against the X-ray hardness $HR = (L_H - L_S)/(L_H + L_S)$. The Seyfert I and II galaxies are indicated with the filled circles and open diamonds, respectively. In the upper panel, the X-ray hardness is converted to the absorption column density N_H, assuming the intrinsic X-ray spectrum of power law with a photon index of $\Gamma = 1.9$.

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