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A 2.5-5 μm spectroscopic study of hard X-ray selected AGNs with AKARI

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Abstract. We explore the relationships between the 3.3 μm polycyclic aromatic hydrocarbon (PAH) feature and active galactic nucleus (AGN) properties of a sample of 54 hard X-ray selected bright AGNs, including both Seyfert 1 and Seyfert 2 type objects, using the InfraRed Camera (IRC) on board the infrared astronomical satellite *AKARI*. The sample is selected from the 9-month *Swift*/BAT survey in the 14-195 keV band and all of them have measured X-ray spectra at $E \lesssim 10$ keV. These X-ray spectra provide measurements of the neutral hydrogen column density ($N_{\rm H}$) towards the AGNs. We use the 3.3 μm PAH luminosity ($L_{3.3\mu{\rm m}}$) as a proxy for star formation activity and hard X-ray luminosity ($L_{14-195{\rm keV}}$) as an indicator of the AGN activity. We searched for possible difference of star-formation activity between type 1 (un-absorbed) and type 2 (absorbed) AGNs. Our regression analysis of $\log L_{14-195{\rm keV}}$ versus $\log L_{3.3\mu{\rm m}}$ shows a positive correlation and the slope seems steeper for type 1/unobscured AGNs than that of type 2/obscured AGNs. The same trend has been found for the $\log(L_{14-195{\rm keV}}/M_{\rm BH})$ versus $\log(L_{3.3\mu{\rm m}}/M_{\rm BH})$ correlation. Our analysis show that the circum-nuclear star-formation is more enhanced in type 2/absorbed AGNs than type 1/un-absorbed AGNs for low X-ray luminosity/low Eddington ratio AGNs.

Keywords. galaxies: active — X-rays: galaxies

1. Description of the research

Infrared spectroscopy is a powerful tool for the diagnostic buried AGNs, because the effect of dust extinction is relatively small (Imanishi *et al.* 2010). It allows to study sources in which both an AGN and a starburst (SB) are present. Very hard X-ray surveys such as available with *Swift* Burst Alert Telescope (BAT), provide efficient way of constructing a fair sample of AGNs including heavily obscured ones. The infrared 2.5-5 μm spectra available with the Infrared Camera (IRC) grism mode on board *AKARI* provide us with rich pieces of information with emission/absorption lines such as the 3.3 μm polycyclic and the broad 3.1 μm H_2O ice, 3.4 μm bare carbonaceous dust, 4.26 μm CO_2 and 4.67 μm CO absorptions. In this work, we use the 3.3 μm PAH feature as a proxy for star formation and explore the relation between AGN activity, type and circum-nuclear star-formation.

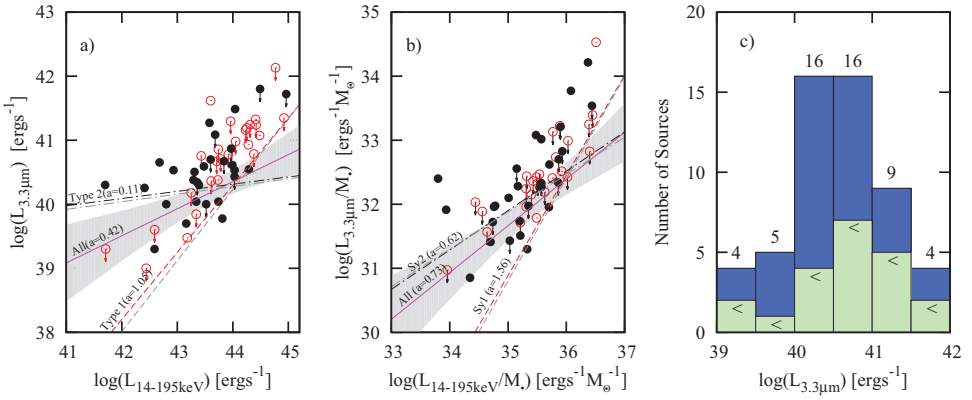

Figure 1. (*a*) $\log(L_{14-195\mathrm{keV}})$ versus $\log(L_{3.3\mu\mathrm{m}})$ and (*b*) $\log(L_{14-195\mathrm{keV}}/M_{\mathrm{BH}})$ versus $\log(L_{3.3\mu\mathrm{m}}/M_{\mathrm{BH}})$ relations. Open red circles are used for Optical type 1 objects and filled black circles for Optical type 2 objects. Arrows are for upper-limits. The best-fit lines from linear regressions with upper limits are also shown. (*c*) Distribution of $\log(L_{3.3\mu\mathrm{m}})$.

2. Results and Conclusions

We use a linear regression analysis using the E-M method available within ASURV package (Isobe *et al.* 1986) among observed quantities. We have studied the dependencies between the liminosity of the PAH at $\lambda_{rest} = 3.3$ μm ($L_{3.3\mu\mathrm{m}}$) emission line to the X-ray luminosity in the 14-195 keV band ($L_{14-195\mathrm{keV}}$) for the entire sample:

$$\log(L_{3.3\mu\mathrm{m}}) = (0.4 \pm 0.1)\{\log(L_{14-195keV}) - 43.6\} + (40.2 \pm 0.1) \quad (2.1)$$

$$\log(L_{3.3\mu\mathrm{m}}/M_{\mathrm{BH}}) = (0.7 \pm 0.2)\{\log(L_{14-195keV}/M_{\mathrm{BH}}) - 35.4\} + (31.9 \pm 0.1) \quad (2.2)$$

We have made separate regressions for samples divided in optical classification (type 1 vs. type 2 AGNs) as well as X-ray absorption divided samples ($\log N_{\mathrm{H}}[\mathrm{cm}^{-2}] < 22$ [unabsorbed] or > 22[absorbed]). Our analysis show that significant correlations have been found between 3.3 μm PAH luminosity in the circumnuclear and the 14-195 keV luminosity for type 1/unabsorbed AGNs, while the correlation is weaker for the type 2/absorbed AGNs.

We divided the sample into high and low $L_{14-195\mathrm{keV}}$ (or $L_{14-195\mathrm{keV}}/M_{\mathrm{BH}}$) and compared the mean $\log L_{3.3\mu\mathrm{m}}$ (or $L_{3.3\mu\mathrm{m}}/M_{\mathrm{BH}}$) values of the type 1/unabsorbed and type 2 absorbed AGNs. Our analysis show that the circum-nuclear star-formation is more enhanced in type 2/absorbed AGNs than type 1/un-absorbed AGNs for low X-ray luminosity/low Eddington ratio AGNs, while there is no significant dependence of star-formation activities on the AGN type in the high X-ray luminosities/Eddington ratios. We note that the underlying assumption of applying the EM-algprithm is that the objects are normally distributed around the regression line.

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