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CHANDRA OBSERVATIONS OF THE AKARI NEP DEEP FIELD

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ABSTRACT

The AKARI NEP Deep Field Survey is an international multiwavelength survey over 0.4 deg^2 of the sky. This is the deepest survey made by the InfraRed Camera (IRC) of the infrared astronomical satellite AKARI with 9 filters continuously covering the 2-25 μm range, including three filters in the Spitzer gap between the IRAC and MIPS coverages. This enabled us to make sensitive MIR detection of AGN candidates at z∼ 1, based on hot dust emission in the AGN torus. It is also efficient in detecting highly obscured Compton-thick AGN population. In this article, we report the first results of X-ray observations on this field. The field was covered by 15 overlapping Chandra ACIS-I observations with a total exposure of ∼300 ks, detecting ≈ 450 X-ray sources. We utilize rest-frame stacking analysis of the MIR AGN candidates that are not detected individually. Our preliminary analysis shows a marginal detection of the rest-frame stacked Fe Kα line from our strong Compton-thick candidates.

Key words: surveys – galaxies: active – galaxies: seyfert – infrared: galaxies – X-rays: galaxies

1. INTRODUCTION

The census of the AGN population as a function of redshift is crucial in tracing accretion and its history. Current imaging surveys in X-rays are most efficient in making a census of unobscured (type I) and obscured (type II) AGNs in the Compton-thin range ($N_{\rm H} \lesssim 10^{24}{\rm cm}^{-2}$). *NuSTAR* is the first imaging X-ray observatory that can probe the $E \gtrsim 10$ keV universe and therefore gives a census to cosmological evolution of modestly Compton-thick (CTK) AGNs ($N_{\rm H} \lesssim 10^{25}{\rm cm}^{-2}$) with limited sensitivities. Hot dust heated by the intense AGN radiation up to almost sublimation temperatures, which are thought to reside in the clumpy circum-nuclear torus, gives a characteristic mid-infrared bump. This makes MIR emission an excellent probe of the obscured AGN

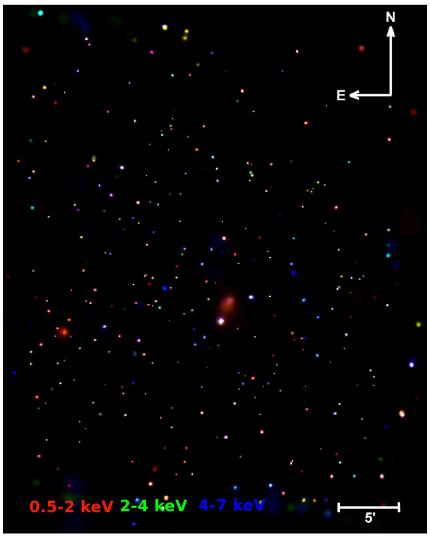

Figure 1. *Left:* An adaptively-smoothed Chandra image color-coded by photon energies (see labels) are shown. The color version of this figure is available on-line.

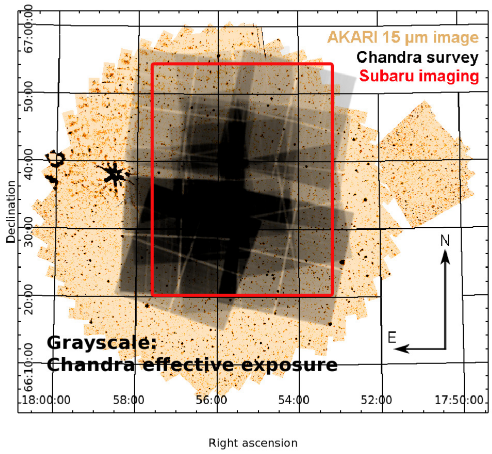

Figure 2. *Right:* Chandra exposure map (gray scale) is overlaid on the AKARI IRC 15 micron map (yellow). Celestial coordinates are shown for reference. The red rectangle is the FOV of the deep Subaru Suprime-cam observations. The color version of this figure is available on-line.

activity to even larger absorbing column densities than those reachable by *NuSTAR*. The hot AGN dust emission fills the "valley" between the stellar emission and the warm dust associated with star formation, producing a power-law like continuum over the rest frame 3-8 μm band.

The InfraRed Camera (IRC) on *AKARI* provided Near-IR to Mid-IR measurements with its continuous wavelength coverage over 2–25 μm in 9 filters, which filled the 9-20 μm gap between the wavelengths observable by the Spitzer IRAC+MIPS instruments. The combination gives a very powerful tool for mid-infrared selection of AGNs, especially in the $0.4 < z < 2$ range (Hanami et al., 2012). Because of the strict attitude and orbital constraints of *AKARI*, the *AKARI* NEP Deep and Wide surveys (Matsuhara et al., 2006) have a unique advantage in the MIR search for AGNs, since other premier fields have very little *AKARI* data. Motivated by these, we have observed the *AKARI* NEP Deep field in X-rays using *Chandra* ACIS-I.

2. OBSERVATIONS AND SOURCE DETECTION

A total of 250 ks of exposure was awarded from our own proposal. Including a re-observation of partially problematic data and archival data from another group, we have 302 ks of Chandra data after screening. An adaptively smoothed *Chandra* image, color coded by photon energies, is shown in Fig. 1. Fig. 2 shows our *Chandra* exposure map overlaid on the *AKARI* IRC 15 μm image, with a rectangle showing our Subaru Suprime Cam FOV.

We apply our sophisticated source detection and photometry technique for overlapped mosaics of *Chandra* fields, where the point spread function (PSF) degrades rapidly with off-axis angle. In this procedure, we use tools in the *XMM-SAS* analysis package (`http://xmm.esac.esa.int/sas/`) that have been modified for *Chandra* data, which involves joint PSF fits in the overlapped regions. Our method has been verified by extensive simulations.

We generated a source catalog, containing 457 unique sources that are detected at least in one of the standard bands of 0.5-7, 0.5-2, 2-4, 4-7 and 2-7 keV. The catalog provides basic properties for each source (e.g. flux, counts and count rates in each band). Sensitivity and upper limit maps are also provided. See Krumpe et al. (2014) for details.

3. SEARCH FOR COMPTON-THICK ACCRETION

The main scientific goal of our *Chandra* observations of the *AKARI* NEP Deep Field is to identify CTK AGNs among MIR selected AGNs and quantify their space density at $z \sim 1$. We use SED fits from Hanami et al. (2012) with star-formation/AGN decompositions, in which we derived the AGN infrared luminosity of each MIR source. This SED fit procedure is being revised by including *Herschel* PACS data (Ishigaki et al. in prep). In our preliminary analysis, we identify 28 strong CTK AGN candidates, which have been selected based on low X-ray luminosity to MIR luminosity (AGN component) ratios that indicate X-ray attenuation through absorbing columns with $N_{\rm H} > 10^{24}{\rm cm}^{-2}$. We test their CTK

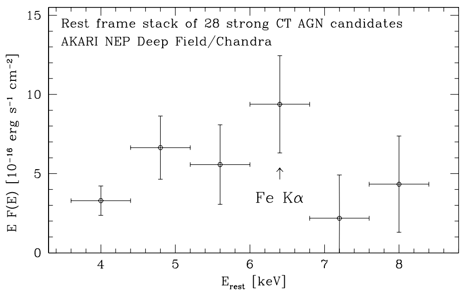

Figure 3. The mean $E\ \ F(E)$ spectrum in rest frame for the 28 strong CTK AGN candidates identified from our current data, obtained using the CSTACK utility (`http://lambic.astrosen.unam.mx/`). The significance of the Fe line is marginal (1.6σ) and its equivalent width of $EW = 1.0\pm0.6$ keV is consistent with those of typical known CTK AGNs.

AGN nature by a rest-frame stacking analysis to find integrated Fe Kα line that is characteristic of CTK AGNs. In our current data, we have marginal detection of the stacked Fe Kα line (Fig. 3), with an equivalent width of 1.0$\pm$ 0.6 keV, which is consistent of those of CTK AGNs. Additional *Chandra* Observations on this field would enable quantification of the CTK AGN population. For example, with a total of 750 ks of additional observations over the same fields, we expect a 4σ detection of the Fe Kα line from strong CTK AGN candidates, including newly identified ones.

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