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THE AGN POPULATION IN THE AKARI NEP DEEP FIELD

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ABSTRACT

The AKARI North Ecliptic Pole Deep Field is a natural location to accomplish deep extragalactic surveys. It is supported by comprehensive ancillary data extending from radio to X-ray wavelengths, which have been used to classify radio sources as radio-loud and radio-quiet objects and to create a catalogue of Active Galactic Nuclei (AGN). This has been achieved by using a radio-optical classification and colour-colour diagrams rather than the more usual way based on spectroscopy Furthermore, we explore whether this technique can be extended by using a far-Infrared (FIR) colour-colour diagram which has been used to identify 268 high redshift candidates.

Key words: NEP— multi-wavelength survey — galaxies — AGN — high redshift

1. NORTH ECLIPTIC POLE (NEP) DEEP FIELD

The NEP Deep Field is in a favourable location for space telescopes, it was observed by AKARI several times per day, allowing the study of very faint sources. It covers a 0.54 deg^2 circular area centered at RA = $17h\ 55m\ 24s$ Dec = $66^\circ\ 37'\ 32''$ (Matsuhara et al., 2006), and has been observed at many different wavelengths including far-infrared (FIR) (Pearson, et al., in prep); infrared (IR) and optical (Murata et al., 2013); and X-ray (Krumpe, et al., 2015) wavelengths. We have used these data to identify both Active Galactic Nuclei (AGNs) and high redshift candidates.

2. RADIO-OPTICAL SELECTION

The AKARI point source catalogue (Murata et al., 2013) has been cross-correlated with a GMRT 610 MHz radio catalogue (∼2000 sources) (White, et al., in prep.), to search for positional matches, using a $4''$ search radius. This provides a total of 399 reliable associations which are analyzed in this study.

High radio/optical ratios can indicate radio-loud AGN candidates, whereas low radio/optical ratios may either be radio-quiet AGN, or star forming galaxies. This radio-optical selection technique has been used to classify the sample into radio-quiet (RQ) and radio-loud (RL) sources. Quantitatively, this classification can be made by using the radio-loudness parameter (Ivezic, et al., 2002) extrapolating the equation:

$$R_i = \log\left(\frac{0.779 \times \text{Flux (610 MHz)}}{\text{Flux (7840 Å)}}\right) \quad (1)$$

where $R_i > 2$ indicates RL, and $R_i < 1$ denotes RQ sources (see Figure 1).

We identify 32 RL and 65 RQ sources. This classification has been verified with IR colour-colour diagrams (see Figure 2).

3. AKARI COLOUR-COLOUR DIAGRAMS

In order to check the reliability of the radio-loudness classification given by Equation 1, the AKARI near and mid-infrared fluxes of the detected GMRT radio sources have been plotted in

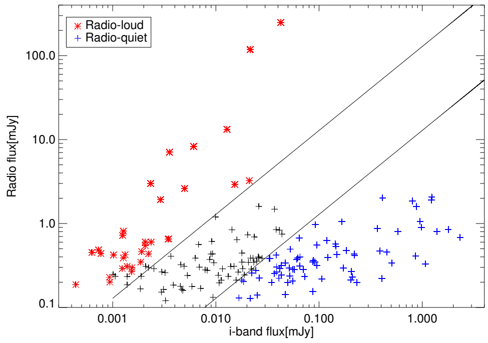

Figure 1. GMRT radio flux at 610MHz plotted against the optical i-band flux band from the CFHT data. RL sources are marked in red, and RQ sources in blue.

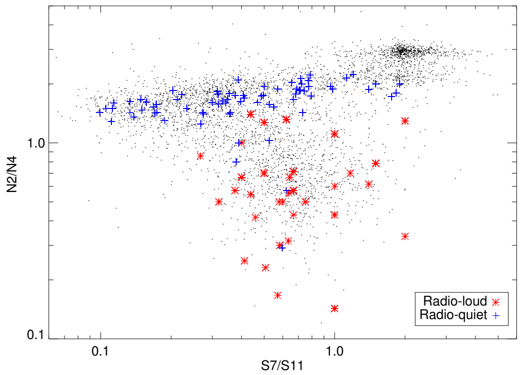

Figure 2. Colour-colour plot of AKARI $N2/N4$ ratios against $S7/S11$ ratios. Selected sources in Figure 1 have been overplotted: red and blue dots indicate radio-loud (AGN) and radio-quiet sources (AGN and star forming galaxies) respectively.

colour-colour space: N2(2.4μm)/N4(4.4μm) against S7(7.3μm)/S11(10.9μm). In previous studies, this diagram has been used together with spectroscopic data to classify AGNs (e.g. Kim, et al., 2012; Shim, et al., 2013). Figure 2 allows us to distinguish between RQ (upper part of the diagram) and RL (lower part of the diagram), showing a clear segregation between the populations of the two types of sources by the radio-optical selection.

4. AGN CLASSIFICATION

We have used the X-ray catalogue (Krumpe, et al., 2015) to confirm the AGN classification. This has been carried out by cross-correlating our sample of RQ and RL sources with the X-ray catalogue and plotting in the IR colour-colour diagram, as illustrated in Figure 3. There are 11 RQ and 10 RL sources with X-ray emission which are AGN candidates.

An AGN catalogue of the NEP Deep Field was then

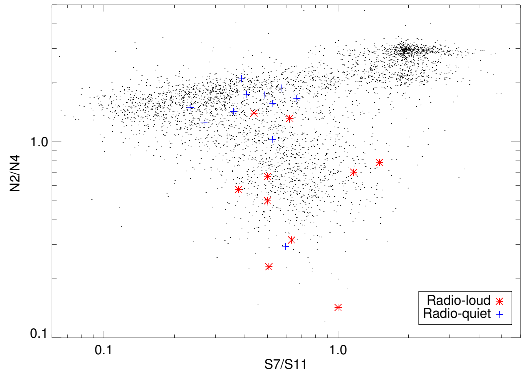

Figure 3. Colour-colour plot of AKARI bands $N2/N4$ against $S7/S11$ ratios, cross-correlating X-ray and radio, where the RQ and RL sources from the radio-optical selection are plotted.

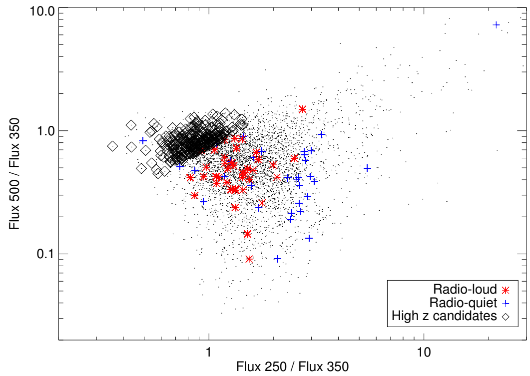

Figure 4. Colour-colour plot of 250μm/350μm ratio against 500μm/350μm ratio. Red and blue dots indicate radio-loud and radio-quiet objects respectively. Possible high redshift galaxies are shown as bold points, which cluster in the area of higher 500 μm/350 μm (> 0.4) and lower 250 μm/350 μm (< 1.5) ratios.

created. The objects included in the catalogue simultaneously satisfied the following criteria:

· Radio-optical selection based on radio-loud or radio-quiet sources (Figure 1).

· Suitable location in the infrared colour-colour diagram (Figure 2).

· Presence of X-ray emission (Figure 3).

Further studies will be made by spectral energy distribution (SED) fitting to confirm the classification.

5. FIR COLOUR-COLOUR DIAGRAM

We plot the sources additionally associated with *Herschel* sources on a far-infrared colour-colour plot in order to check if FIR colours can distinguish between RQ and RL sources. Furthermore, high redshift candidates have been found following the properties of the FIR peak: $F_{500\mu m}/F_{250\mu m} > 0.75$ and $F350\mu m > 35mJy$ conditions (Amblart, et al., 2010).

Although the colour-colour diagram in Fig 4 does not allow a clear separation of the radio-loud and radio-quiet populations, it does allow us to select the general region occupied by possible high redshift sources. Further studies using SED fitting will be able to confirm the 268 high redshift candidates detected in Fig 4.

6. CONCLUSIONS

By using a radio-optical classification we have detected 65 radio-quiet sources and 32 radio-loud sources in the NEP deep field. Combining this criterion with infrared colour-colour diagrams and X-ray detection, we associate 11 RQ and 10 RL of these sources respectively with potential AGNs.

Although the radio source populations are not distinguishable in the far-IR (*Herschel*) colour-colour space, the additional constraints provided by these longer wavelength colours can be used as an indicator of high redshift sources, classifying 268 high redshift candidates.

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