FIR-radio correlation of extragalactic objects in the AKARI All Sky Survey

Agata Pępiak[1], Agnieszka Pollo[1·2], Aleksandra Solarz[2] and Paweł Piątek[2]

1. National Center for Nuclear Research, ul. A. Sołtana 7, 05-400 Otwock, Poland
2. Astronomical Observatory of the Jagiellonian University, Orla 171, 30-001 Cracow, Poland

We present preliminary measurements of the radio-FIR correlation for local extragalactic objects found in the newest release of the AKARI Far-Infrared All Sky Survey, cross-correlated with the NVSS and SDSS surveys. We found a tight correlation between radio and far-infrared emission for all the selected sample of local extragalactic objects, both star forming galaxies and galaxies containing an AGN. Among objects deviating from this trend, a larger number have an upscatter in radio than in the infrared, and a percentage of AGNs among radio-upscattered sources is higher than both in the infrared-upscattered population and in the population following the main correlation trend.

1 Introduction

A tight correlation between far-infrared (FIR) and radio fluxes of galaxies has been first found based on the Infrared Astronomical Satellite (IRAS) data Helou et al. (1985); Condon (1992) and later confirmed for a large range of galaxy types, masses, luminosities and redshifts. Usually it is attributed to star forming processes in galaxies, which result both in heating dust by young stars and in synchrotron radiation induced by supernovae. However, this correlation is found not only for star forming galaxies but also for galaxies hosting Active Galactic Nuclei (AGN; however, with larger scatter). In particular, Morić et al. (2010) cross-correlated a large sample of NRAO VLA Sky Survey (NVSS), IRAS and Sloan Digital Sky Survey (SDSS) data and found that on average FIR-radio correlation for galaxies and AGNs is statistically indistinguishable.

All the previous all sky studies of the FIR-radio correlation were based on the IRAS data. In our work, we aim at testing and improving these results making use of the newer and more accurate FIR all sky survey based on the observations of the AKARI satellite. The previous attempt (Pepiak et al., 2014) was based on the first official data release of the AKARI All-Sky Survey (Yamamura et al., 2010). Here we improve those results making use of the new improved release of these data (Doi et al., 2015; Takita et al., 2015).

2 Data

AKARI was a Japanese astronomical satellite which performed a survey of all sky in the infrared, with a wavelength coverage of 2 to 160 μm, with a more than twice better resolution than the survey made by its predecessor IRAS, and depth down to 0.2 Jy at 90 at μm at the 3σ detection level.

In this work we make use of the newest release of the AKARI all sky survey (Doi et al., 2015; Takita et al., 2015) in the FIR (four bands centered at 60 μm,

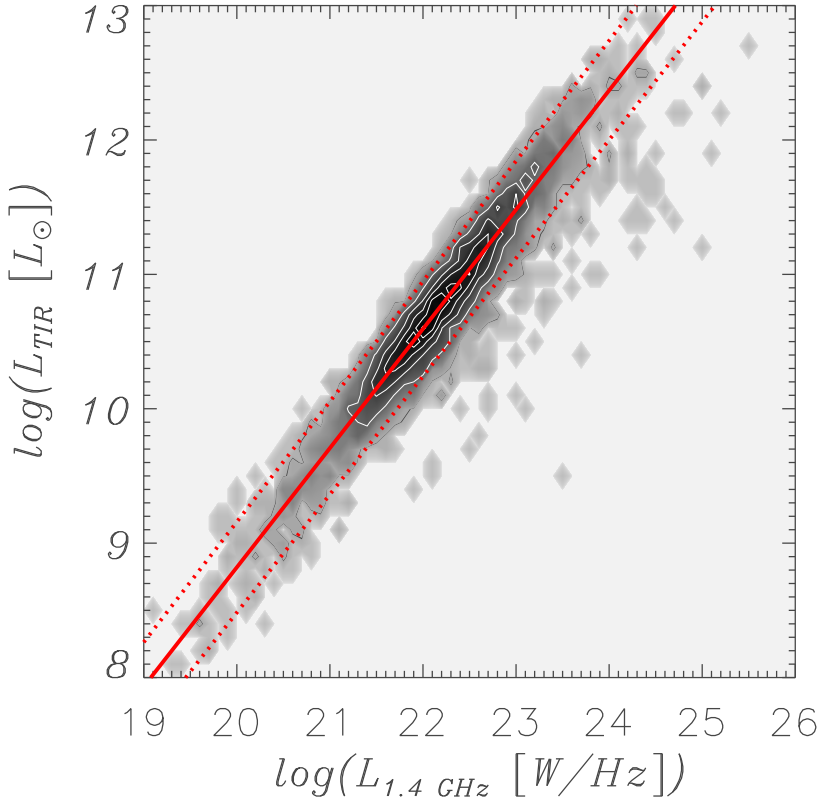

Fig. 1: Total infrared luminosity ($L_{\rm TIR}$) of AKARI All-Sky extragalactic sources plotted against their radio luminosity ($L_{1.4\rm GHz}$). The solid line represents the best least-square fit to the data, and the dashed lines represent the 95% confidence interval of the linear regression. Grey lines mark density contours in the logarithmic scale.

90 μm,140 μm and 160 μm) in order to investigate the FIR-radio correlation of extragalactic sources in the local Universe.

Out of 950, 365 sources contained in this dataset, we selected only those located in the sky areas scanned by AKARI at least three times, and having the highest flux quality flag FQUAL=3 at 90 μm. Additionally, following Pollo et al. (2010), we restrict our analysis to objects lying in regions of low Galactic emission $\leq$5 MJy sr^{-1} at 100 μm, based on the Schlegel et al. (1998) maps. Next, we cross-matched so-obtained sample with NVSS radio catalog (Condon et al., 1998) within a 15" matching radius, similarly to Pepiak et al. 2014, and with the Sloan Digital Sky Survey DR14 (Abolfathi et al., 2018) in order to confirm extragalactic nature of these objects and to obtain their redshift measurements. The sample is dominated by nearby objects with a maximum at $z \sim 0.03$; to exclude a few distant sources we further limited our sample to redshift $z < 0.25$. As a result, we obtained a sample of 6, 136

objects.

3 Results

In order to study the FIR-radio correlation of a sample defined in the previous section, we estimate the total FIR luminosity of our objects, $L_{\rm TIR}$, making use of a prescription given by Solarz et al. (2016) based on the FIR fluxes measured in AKARI bands. Corresponding radio luminosities were computed based on the NVSS radio fluxes $S_{1.4\rm GHz}$ as

$$L_{1.4\rm GHz} = \frac{4\pi D_L^2}{(1+z)^{1-\alpha}} S_{1.4\rm GHz}, \tag{1}$$

with $D_{\rm L}$ being a corresponding luminosity distance and radio spectral index α value assumed to be 0.75 following Condon (1992).

The resultant relation $L_{\rm TIR} - L_{1.4\rm GHz}$ is presented in Fig. 1. It demonstrates that extragalactic objects in general follow the radio-FIR correlation tightly, with regression parameters $a = 0.880 \pm 0.004$ and $b = -8.786 \pm 0.079$. Only 419 sources (i.e. 7% of the whole sample) deviate from this correlation at the level exceeding 2σ. A majority of these objects (304 sources) have an upscatter in the radio luminosity; the remaining 115 sources have an upscatter in the infrared.

Among sources with the upscatter in the radio luminosity, 117 ($\sim$ 38% of this group) are classified as AGN in the SDSS, more precisely as broadline QSO or as GALAXY with a subclass AGN BROADLINE. In contrast, among objects with the upscatter in IR we find only 20 ($\sim$17% of this group) classified as AGN. Among the population following the main FIR-radio correlation trend with accuracy better than 2σ, 10% are classified as AGN. It confirms earlier findings that AGN have indeed a larger scatter around the main FIR-radio correlation trend than star-forming galaxies, and more often they display an upscatter in the radio luminosity. However, a part of them displays also a scatter in the IR - a similar trend was, in fact, observed by Morić et al. (2010) for Seyfert galaxies.

4 Summary and conclusions

We conclude that local galaxies identified in the AKARI All-Sky Survey follow the FIR-radio correlation very tightly, with only 7% of the sample deviating from the trend more than 2σ. It applies both to normal star forming galaxies and to those which were found to host an AGN. Among the deviating sources, AGN are more abundant but not dominant, with a higher probability for an AGN to display an upscatter in the radio than in the infrared.

More in-depth analysis of the FIR-radio properties of this sample will be given by Solarz et al. (2019).

Acknowledgements. This work is based on observations with AKARI, a JAXA project with the participation of ESA. A.Pępiak was supported by the National Science Centre grant UMO-2014/13/N/ST9/00078.

References

Abolfathi, B., et al., *ApJS* **235**, 42 (2018)

Condon, J. J., *ARA&A* **30**, 575 (1992)

Condon, J. J., et al., *AJ* **115**, 1693 (1998)

Doi, Y., et al., *PASJ* **67**, 50 (2015)

Helou, G., Soifer, B. T., Rowan-Robinson, M., *ApJL* **298**, L7 (1985)

Morić, I., et al., *ApJ* **724**, 779 (2010)

Pepiak, A., et al., *Planetary and Space Science* **100**, 12 (2014), URL `http://www.sciencedirect.com/science/article/pii/S0032063314000749`, cosmic Dust VI

Pollo, A., Rybka, P., Takeuchi, T. T., *A&A* **514**, A3 (2010)

Schlegel, D. J., Finkbeiner, D. P., Davis, M., *ApJ* **500**, 525 (1998)

Solarz, A., Takeuchi, T. T., Pollo, A., *A&A* **592**, A155 (2016)

Solarz, A., et al., *PASJ* **71**, 2, 28 (2019)

Takita, S., et al., *PASJ* **67**, 51 (2015)

Yamamura, I., et al., *VizieR Online Data Catalog* **2298** (2010)