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Spitzer 24 μm imaging of Faint Radio Sources in the FLSv: a new radio-loud, Mid-IR/optically obscured population?

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Abstract. Data from the Spitzer Space Telescope (the First Look Survey - FLS) have recently been made public. We have compared the 24 μm images with very deep WSRT 1.4 GHz observations (Morganti et al. 2004), centred on the FLS verification strip (FLSv). Approximately 75% of the radio sources have corresponding 24 μm identifications. Such a close correspondence is expected, especially at the fainter radio flux density levels, where star forming galaxies are thought to dominate both the radio and mid-IR source counts. Spitzer detects many sources that have no counter-part in the radio. However, a significant fraction of radio sources detected by the WSRT (~ 25%) have no mid-IR identification in the FLSv (implying a 24 μm flux density $\leq$ 100 μJy). The fraction of radio sources without a counterpart in the mid-IR appears to increase with increasing radio flux density, perhaps indicating that some fraction of the AGN population may be detected more readily at radio than Mid-IR wavelenghts. We present initial results on the nature of the radio sources without Spitzer identification, using data from various multi-waveband instruments, including the publicly available R-band data from the Kitt Peak 4-m telescope.

1. Introduction

Deep radio surveys (S $\leq$ 1 mJy) have clearly indicated the emergence of a new population of radio sources at mJy and sub-mJy levels. At flux densities in excess of 1 mJy, the source counts are dominated by AGN, in which the energy mechanism is believed to be accretion of matter onto a supermassive black hole. Several class of object have been invoked to explain the steep rise in the integral radio source counts at faint sub-mJy levels: star forming galaxies, similar to M 82 and Arp 220 (Rowan-Robinson et al. 1993); low-luminosity AGN like M 84, and strongly evolving spirals (Condon 1989).

The fact that the locally derived far-IR/radio correlation (e.g. Helou & Bicay 1993) also applies to the vast majority of the faint (and cosmologically distant) radio source population (Garrett 2002), strongly supports the idea that star forming galaxies begin to dominate the microJy radio source population.

The recently launched *Spitzer Space Telescope*, is an order of magnitude more sensitive than previous infrared-telescopes, providing an important opportunity to constrain the nature of the sub-mJy radio source population. The First Look Survey (FLS) was the first survey undertaken by Spitzer. In particular, a small but deeper subset of the survey is focused on an area of 0.26 square degrees (the verification strip or FLSv), reaching completely unexplored (3σ) sensitivity level of ~ 0.08 μJy at 24 μm (Marleau et al. 2004).

In this paper we compare the deep (1σ rms noise-level ~ 8.5 μJy) WSRT radio image of the FLSv field (Morganti et al. 2004) with the recent Spitzer 24 μm public images of the same field (Fig. 1).

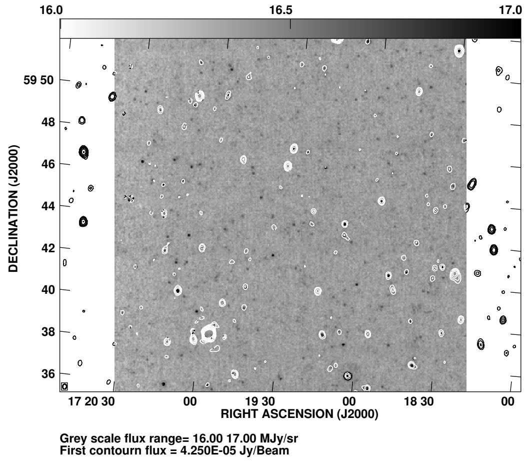

Fig. 1. An example of Spitzer MIPS-24 image with the WSRT radio contours superimposed. The first contour is 5σ = 42.5 μJy/beam, contour levels increase by a factor 2.

2. The samples

We have extracted a catalogue of sources observed by Spitzer's Multiband Imaging Photometer at 24 μm (MIPS-24), from the Post-Basic Calibrated Data (PBCD), using the Starfinder code (Diolaiti et al. 2000). It should be noted that since the WSRT observations cover a bigger area than the FLSv field, only 389 sources of the 1048 sources detected in the WSRT catalogue are located within the FLSv region. We identify two distinct samples from the FLSv radio catalogue:

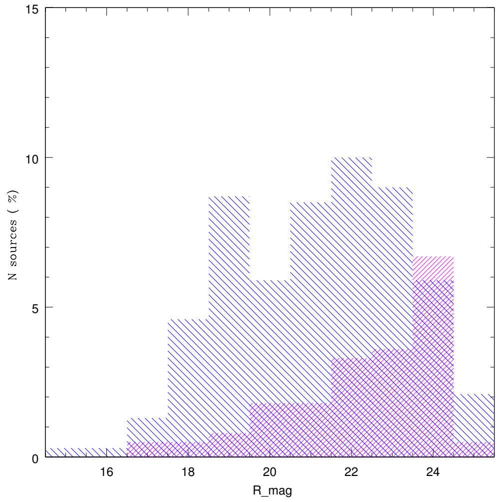

Fig. 2. The R-band magnitude distribution of the radio sources in the FLSv field. The radio sources with MIPS-24 counterparts are indicated in blue, while the radio sources without MIPS-24 identification are in magenta.

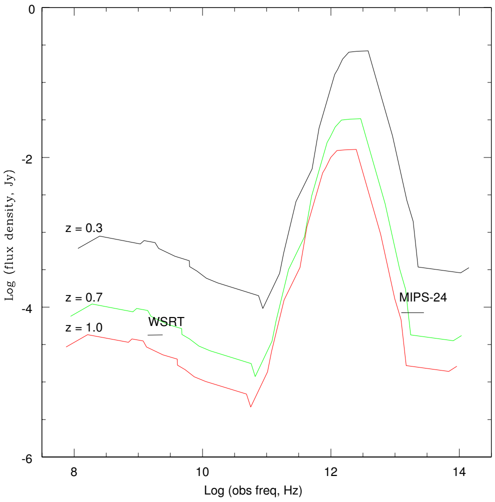

Fig. 3. The SED of Arp 220 (at radio, sub-mm and FIR frequencies) projected to various redshifts (z=0.3, 0.7, 1.0). The 5σ and 3σ detection threshold for both WSRT at 1.4 GHz and Spitzer at 24 μm respectively (solid lines), are presented.

- Sample I: 292 radio sources with clear MIPS-24 identifications, comprising ~ 75% of the complete FLSv radio sample;
- Sample II: 97 radio sources *without* MIPS-24 identifications, comprising ~ 25% of the complete FLSv radio sample.

Both samples were cross-correlated with the optical R-band FLS catalogue from the Kitt Peak 4-m telescope (Fadda et al. 2004). Although the optical catalogue is estimated to be 50% complete at R=24.5 (Vega), in both samples we find ~ 20% of radio sources without optical identification.

3. Results

Although Spitzer is able to pinpoint the sub-mm SCUBA population (Frayer et al. 2004), there is a significant fraction of radio sources (~ 25%) which have no MIPS-24 counterparts (Sample II). The two radio samples have a different radio flux density distribution: Sample I is dominated by the faintest radio sources, with flux densities typically ≤ 300 μJy. Sample II appears to comprise the brighter radio sources typically ≥ 1 mJy.

Figure 2 shows that the R-band magnitude distributions of the two radio source samples are also quite different. In particular, while 53% of the radio sources with MIPS-24 identification (Sample I) have optical counterparts brighter than R=22.5, this figure is only 35% for Sample II. These results suggest that the two samples are dominated by two different source populations. This is in agreement with the hypothesis that the mJy population is dominated by the faint tail of the AGN population, while star forming galaxies dominate at sub-mJy and microJy radio flux density levels (Prandoni et al. 2001; Richard 2000). Our results suggest that the radio sources without MIPS-24 identification (Sample II) are likely to be dominated by distant low-luminosity AGN. A study of the SED of various class of objects projected to various redshifts also supports this hypothesis. For example, an Ultra-luminous IR Galaxy like Arp 220 is detectable to z ~ 0.7 with both the WSRT and Spitzer (see Fig. 3). However, a low-luminosity AGN can be detected up to z ~ 0.7 by WSRT but only to z ~ 0.15 by Spitzer. Another possible explanation is related to the mass and temperature of the dust in the host galaxy. A star forming galaxy with the same dust mass of Arp 220, but with a lower temperature (e.g. ≤ 30 K), is only detectable to z ~ 0.1 by MIPS-24. VLBI, sub-mm and X-ray observations will be crucial in order to further constrain the nature of this class of radio source not detected by Spitzer at 24 micron.

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