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High-redshift radio galaxies from DEEP2 fields

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Abstract. It is now well established that the high redshift radio galaxies exhibit steep radio spectra, and hence ultra-steep spectrum radio sources provide good candidates for high-redshift radio galaxies. Nearly all of the high redshift radio galaxies have been found using this relation. We have started a programme with GMRT to exploit this correlation at flux density levels of about 10 to 100 times deeper than the known high-redshift radio galaxies. Here, we have obtained deep, high resolution radio observations at 150 MHz with GMRT for several 'deep' fields which are well studied at higher radio frequencies and in optical, with an aim to detect candidate high redshift radio galaxies. In this work we present ultra-steep spectrum (USS) samples from two of the DEEP2 deep fields using the 150 MHz Giant Meter-wave Radio Telescope (GMRT) observations. From correlating these radio sources w.r.t to the high-frequency catalogues such as FIRST and NVSS at 1.4 GHz, and optical catalogues such as SDSS and DEEP2, we derive a list of steep spectrum (spectral index, alpha > 1) radio sources which remain undetected in SDSS and DEEP2 optical images. These are good candidates for high redshift radio galaxies and will be followed up with large optical telescopes.

Keywords : galaxies: active - galaxies: high-redshift - radio continuum: galaxies

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1. Introduction

It has been nearly 15 years since the discovery of highest redshift powerful radio galaxy at a redshift of 5.19 (van Breugel et al. 1999). Till date, close to 50 radio galaxies are known beyond redshift of 3 (see Miley & de Breuck, 2008 and references therein), most of them were discovered using the empirical correlation that the high-redshift radio galaxies tend to exhibit steep radio spectra. We plot the extrapolated flux densities at 150 MHz of all known HzRGs (z > 3; Figure 1) in order to understand whether the known HzRGs represent typical FRII radio sources at high-redshifts, or the highest luminosity sources in that category. The figure suggests that nearly all of the known HzRGs are two to three orders of magnitude more luminous than the FRI/FRII break luminosity. This could be due to the selection effects like use of shallow sky surveys. The median flux density of all known HzRGs at z > 3 at 150 MHz is ~ 1.3 Jy, which is more than two magnitude brighter than the FRI/FRII break luminosity. This indicates that the known HzRGs represent the tip of the ice-berg in luminosity. A large number of HzRGs are yet to be discovered which are 10 to 100 times less luminous than the known HzRGs. The 150 MHz band of GMRT (Giant Metrewave Radio Telescope, India, http://www.ncra.tifr.res.in) with its large field of view (3 degrees), high angular resolution (~ 20$''$) and better sensitivity (~ 1 mJy from a full synthesis observation) is well suited to fill this large gap, by searching for steep spectrum sources using deep radio observations (C.H. Ishwara-Chandra et al. 2010; Bisoi et al. 2011). We have started a programme to observe several carefully chosen deep fields at 150 MHz with GMRT with an aim to detect steep spectrum radio sources to flux density levels much fainter than that of known high-redshift radio sources. In

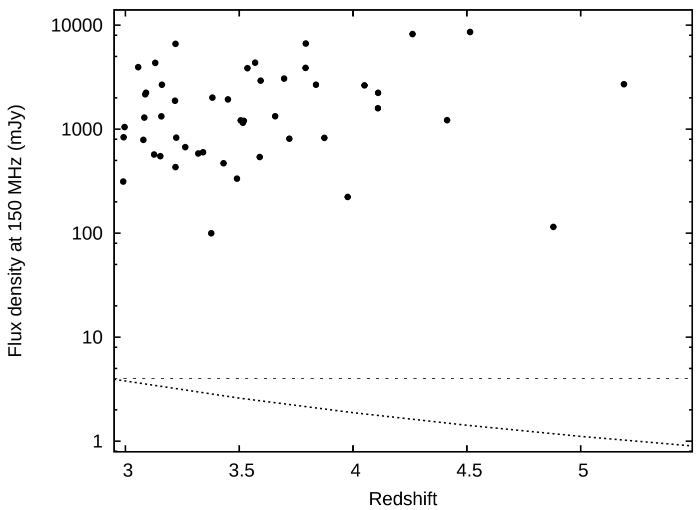

Figure 1. 150 MHz flux density of known HzRGs. The dashed horizontal line is the 5 sigma detection limit at 150 MHz from one full synthesis observations. The dotted line is the FRI/FRII break luminosity.

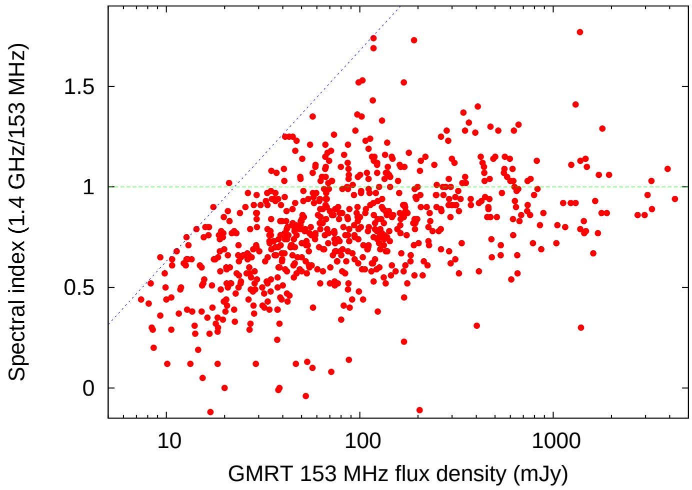

Figure 2. The spectral index distribution of sources from two of the DEEP2 fields. The dotted line is the spectral index limit w.r.t limiting flux density of the NVSS.

this paper we present deep 150 MHz radio observations of two of the DEEP2 fields with the GMRT with the primary aim of detecting steep spectrum radio sources which are candidate HzRGs.

2. Observation and Data Analysis

Three of the fields from DEEP2 survey (Newman et al. 2012), centered at 1652+3455, 2330+0000 and 0230+0000 were observed at 150 MHz with the Giant Metrewave Radio Telescope (GMRT) using a bandwidth of 16 MHz (Bisoi et al. 2011). The data from the first field was unusable due to heavy RFI. The data analysis of the remaining two fields were done both using the standard AIPS procedures and using the automated pipeline of Sandeep Sirothia (Sirothia et al. 2009). The images produced by the pipeline yielded relatively better rms and hence used in this work. The rms for the field 2330+0000 is 1.2 mJy/beam with a resolution of $\sim 20 \times 17$ arcsec and for the field 0230+0000 is 1.2 mJy/beam with a resolution of $\sim 21 \times 17$ arcsec.

3. Results and Discussion

The combined catalogue of both the DEEP2 fields have yielded $\sim$ 1100 sources down to flux density of 10 mJy. The median flux density of the sample is 55 mJy. We cross matched the 150 MHz sources with the NVSS (Condon et al. 1998) and VLA FIRST survey (Becker et al. 1995). About 65% of the sources have counterparts in NVSS. Spectral index was computed using the flux densities at 150 MHz and using the 1400 MHz flux density from NVSS. The median spectral index is 0.79. To have a sample of steep spectrum sources, we have adopted the spectral index cutoff of 1. We find about 150 radio sources with spectral index steeper than 1.

In order to cross match with SDSS, we have first cross matched the 150 MHz sources with that from VLA FIRST Survey. Wherever counterparts were found, the VLA FIRST position was used to search for counterparts in SDSS, due to better position accuracy. About 55% of the sources have counterparts in SDSS. Among sources with SDSS counterparts, 16.9% have spectral index steeper than 1. Among sources without SDSS counterparts, 26.0% have spectral index steeper than 1, the increased fraction of steep spectrum sources without optical counterparts is as expected in the redshift-spectral index correction. We propose K-band imaging for sources unidentified in SDSS, to obtain redshift estimate using the K-z relation. Spectroscopic determination of redshift for sources with redshift estimate > 3 is required thereafter.

One of the unresolved source from our sample at 150 MHz shows clear FRII morphology in FIRST. The counterpart for this source is not detected in SDSS. Using the FRI and FRII break luminosity and observed radio flux density, its redshift is estimated to be > 2.

Acknowledgments

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