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Extra-Planar Radio Emission from Edge-on Disk Galaxies

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1. Introduction

The Giant Metrewave Radio Telescope (Ananthakrishnan & Rao, 2002) has been used to observe a number of nearby-galaxies ($\leq$100 Mpc) as part of a long term key programme of the GMRT observatory. Star formation in the disks of these galaxies can cause an outflow of matter. The resulting radio haloes in these objects are more easily observed at low radio frequencies, due to the steep spectral indices arising from their synchrotron emission (we define spectral index α by $s\alpha\ \nu^{-\alpha}$). The presence and properties of such radio haloes are found to be associated with the degree of star formation in the galaxy disks (Dahlem et al, 1995), although such correlations have been questioned in more recent studies (Irwin et al., 1999). A detailed study of a complete sample of nearby galaxies using the GMRT is being attempted to provide a better insight into this problem. Although their nuclei may be bright, the halo emission from these galaxies is weak beyond a few arc minutes and the spectra are steep calling for high sensitivity at low radio frequencies.

We describe here preliminary results on two edge-on galaxies that have been observed at different frequencies using GMRT.

2. UGC 4961 (NGC 2820)

UGC4961 was observed on 16 July 2002 at 1280 MHz and on 19 August 2002 at 330 MHz. A bandwidth of 9.4 MHz was used. Data analysis was done using standard procedures in the Astronomical Image Processing System developed by NRAO. 3–D imaging was used for 330 MHz data to account for wide field effects. Both the 1280 and 330 MHz images were self-calibrated. The final images convolved to a resolution of 20″ x 14″ have an rms noise of 1 mJy/beam and 80 μJy/beam at 330 and 1280 MHz respectively. The spectral index between the 1280 and 330

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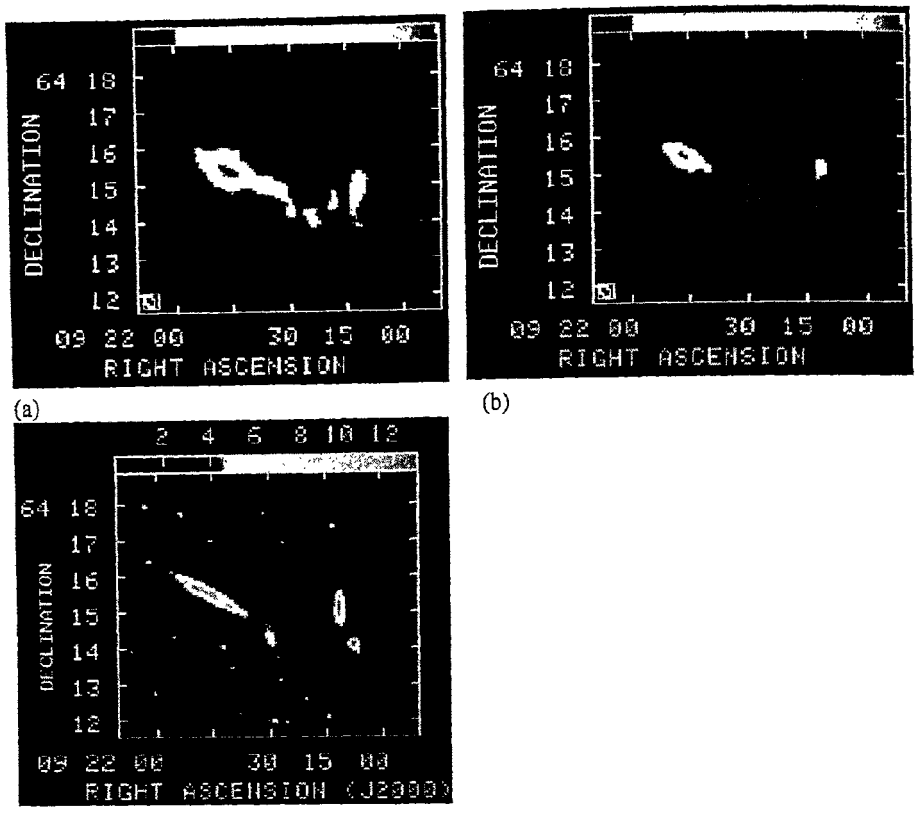

Figure 1. Radio image of UGC 4961 at (a) 330, (b) 1280 MHz and (c) optical image. All the images have been precessed to J2000 coordinates.

MHz ranges from 0.6 at the galaxy center to 1.5 for the halo emission seen at high-latitude. The optical image (Fig. 1 c) shows three galaxies clearly — NGC2820, Mk108 and NGC2814, which can also be discerned in the radio images. Comparing the extent in optical with our radio image at 330 MHz highlights the halo and a bridge connecting the galaxies. The halo extends to ~ 1′ above and below the optical disk. At a distance of 15.6 Mpc, this gives a z-extent of ~4.5 kpc. The bridge has been previously detected at 1465 MHz by van der Hulst & Hummel (1985). We do not detect this bridge at 1280 MHz, possibly due to a combination of sensitivity and u-v coverage effects.

The bridge connecting the galaxies is an unusual feature and we discuss it briefly. The usual minimum energy arguments give a total energy of ~ 10^{53} ergs and B of ~ 6 – 8μG. (a) If this synchrotron-emitting region is confined by an external thermal medium, then the pressure needed corresponds to an nT product ~ 10^4K/cm^3 which is about twice observed in the ISM of our galaxy.

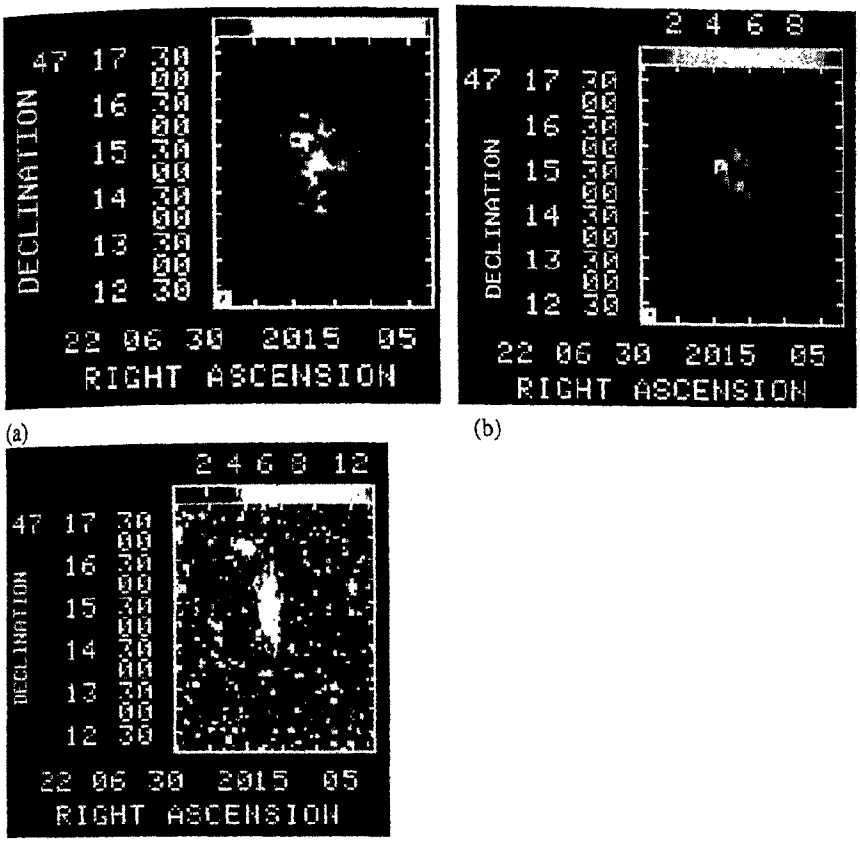

Figure 2. Radio image of UGC 11909 at (a) 330, (b) 610 MHz and (c) optical image. All the images have been precessed to J2000 coordinates.

One should then seek other evidence for such a medium. Two other possibilities are (b) that the bridge is not confined but is expanding and (c) that there is a well ordered magnetic field along the bridge whose tension is sufficient to confine the plasma. In case (b) the characteristic timescale for expansion should not be too short (i.e., not $\ll 10^8$ years) for a viable model. Case (c) can be tested observationally by polarisation measurements. In all three cases, the origin of the bridge remains an intriguing problem.

3. UGC 11909

UGC11909 was observed on 19 August 2002 at 330 MHz and in the dual mode at 610 and 235 MHz on 6 September 2002. The final images of the galaxy (Fig. 2 a & b) had an rms of 0.4

mJy/beam at 330 MHz with a bandwidth of 9.4 MHz and an rms noise of 0.2 mJy/beam at 610 MHz with a bandwidth of 4.2 MHz. At both the frequencies the synthesised beamwidth was $\sim 10''$.

The radio source to the northeast of the galaxy is believed to be a background source. UGC11909 is a disk galaxy with its major axis aligned in the north-south direction (Fig. 2 c). In the 330 MHz map, the galaxy shows extensions at 3 sigma levels beyond the optical disk. These extensions are less pronounced in the 610 MHz map. Rough estimates of the spectral index show it to vary from 0.5 at the galaxy center to > 1 in the western extension. A more detailed study is required.

4. Conclusion

The GMRT has been used for sensitive observations of weak and diffuse radio features in disk galaxies. The preliminary results show that rms levels at 0.4 mJy at 300 MHz to 0.08 mJy at 1000–1400 MHz can be reached currently, based on a few hours of observations. The images are dynamic-range limited. Data at more frequencies of GMRT will allow detailed modelling and a larger sample will bring out meaningful correlations with other properties of these disk galaxies.

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