MRC

MAURITIUS RESEARCH COUNCIL

STUDY OF EXTENDED GALAXIES AT 151.6 MHZ USING THE MAURITIUS RADIO TELESCOPE

Final Report

MAURITIUS RESEARCH COUNCIL

Address:

Level 6, Ebène Heights,
34, Cybercity,
Ebène 72201,
Mauritius.

Telephone: (230) 465 1235
Fax: (230) 465 1239
Email: mrc@intnet.mu
Website: www.mrc.org.mu

This report is based on work supported by the Mauritius Research Council under award number MRC/RUN-9811. Any opinions, findings, recommendations and conclusions expressed herein are the author's and do not necessarily reflect those of the Council.

STUDY OF EXTENDED RADIO GALAXIES AT 151.6 MHZ USING THE MAURITIUS RADIO TELESCOPE

RADHAKHRISHNA SOMANAH
Faculty of Science, University of Mauritius, Reduit, Mauritius
E-mail: dinesh@uom.ac.mu

N. UDAYA SHANKAR
Raman Research Institute, Sadashivanagar, Bangalore 560080, India

Abstract. The MRT survey will be by far one of the most extensive survey at low frequencies. This survey will provide a moderately deep radio catalog reaching a source density of about 2×10^4 sr^{-1} over the southern sky with an angular resolution of $4' \times 4'$ and a limiting flux density of 70 mJy (1σ) at 151 MHz. The availability of zero spacing and short baselines in the MRT array will make it sensitive to the background temperature and to large scale features in the sky. In addition to this feature, the low frequency operation makes a study of continuum emission from large radio sources by MRT to have several interesting and important implications in the study of radio galaxies. This paper discusses the parameter space of radio galaxies which can be explored using the MRT. Images of a few extended radio galaxies are also presented.

1. Introduction

It is estimated that there are over 100 billions of galaxies in the universe. Only a small percentage of them are radio galaxies. The optical counterparts of most strong radio galaxies have been identified and are found to be ellipticals. The optical counterpart identification is important to estimate the redshifts and hence to calculate the intrinsic properties of the radio galaxies, like radio luminosity, energy density, pressure and magnetic field.

Since the identification of strong radio sources with the galaxies M87 and NGC5128 as early as 1949 by Bolton and Stanley, much progress has been made in the understanding of different classes of radio galaxies. But still a study of continuum emission from large radio sources at low frequencies has several interesting and important implications to the study of radio galaxies. These include the studies of large-scale diffuse structures such as lobes, plumes and bridges which are due to the 'old' electrons and hence more prominent at low frequencies. The MRT survey can make interesting contributions in the areas like studies of the aging of the radiating electrons and re-acceleration processes by combining the low-frequency images with similar data at higher frequencies, identification of giant radio sources which are in the last stages of evolution, constraining models of evolution of radio sources, identifying dead or relic radio sources and possibly probing the external environment on different scales and redshifts.

Astrophysics and Space Science **282:** 57–67, 2002.

3. Minimum Energy Density of Radio Galaxies in the MRT Survey

The energetics of radio sources are important not only because of their relation to the source-production mechanism but because they also play an important role in all considerations of how radio sources are held together or confined. Total intensity distributions provide information about the minimum energies involved. A good discussion of source energetics is given by Moffet (1975). The minimum energy condition corresponds almost to equipartition of the energy between the relativistic particles and the magnetic field. The minimum energy density, U_{me} is given by Miley (1980)

$$U_{me} = .0928 B_{me}^2 ergscm^{-3}$$

The magnetic field in the radio source can be written as follows.

$$B_{me} = 5.69 \times 10^{-5}$$

$$\left[\frac{(1+K)(1+z)^{3-\alpha}}{\eta} \times \frac{1}{S\theta_x\theta_y Sin^{\frac{3}{2}}\phi} \times \frac{S_0}{\nu_0^{\alpha}} \times \frac{\nu_2^{\alpha+\frac{1}{2}} - \nu_1^{\alpha+\frac{1}{2}}}{\alpha+\frac{1}{2}}\right]^{2/7} gauss$$

- K = Ratio of energy in the heavy particles to that in electrons.
- η = Filling factor for emitting regions.
- ϕ = angle between uniform magnetic field and line of sight.
- $S_0 \rightarrow$ Jy per beam.
- S = size in Kpc
- ν_1, $\nu_2 \rightarrow$ lower and upper cut off frequencies in GHz.

Apart from the basic assumption that the radiation is synchrotron emission , there are several uncertainties inherent in these formulas. Using the values generally quoted in the literature and the parameters of MRT, one gets for

K =1, $\eta = 1$, $\phi = 90^o$,
$S_0 = 0.2 Jy$, (The minimum detectable flux of the MRT)
$\theta_x, \theta_y \rightarrow$ Half Power Beam Width of the MRT array,
$\Rightarrow \theta_x \approx \theta_y = 240''$
ν_1 = .01 GHz, ν_2 = 100 GHz ,
α = -0.7

$$U_{me} \approx 4.08 \times 10^{-13} (S)^{-4/7} (1+z)^{2.3}$$

Considering the local neighborhood, z≈0 and S=200 Kpc which is the typical size of FRIIs,

$$U_{me}(MRT) \approx 2 \times 10^{-14} ergscm^{-3} = 2 \times 10^{-15} Jm^{-3}$$

TABLE I

The table shows the variation of l with z for Ω_0=1 and$\theta = 4'$

z	.001	.01	.1	.5	1.0	1.5	2.0	3	4	5
D Mpc	6	60	600	2200	3500	4400	5070	6000	6633	7100
l Kpc	1.75	17.5	175	1700	2000	2050	2000	1700	1500	1400

Thus if we fix θ, it can be easily seen from the expression for l that for a given value of Ω_0, there will be a value of z for which l will be maximum. For $\Omega_0 = 1$, the maximum l is around z = 1.5.

For $\theta = 4'$, Table I shows the variation of l with z.

Most FRII sources have linear dimensions in the range 100 Kpc $< l <$ 250 Kpc. Thus for Z $\leq$ .1, many FRII sources may be resolved in the MRT survey. Detailed analysis of these sources by comparing them with high frequency images may provide interesting results.

For z $>$ .1, most FRII sources will be seen as point sources and MRT survey will be able to get only the flux densities of these sources and get an estimate of the spectral index by comparing them with images at other frequencies.

4.1. Limiting Redshift of the Survey for a Given Luminosity

It is also interesting to investigate the red-shift up to which we will be able to see FRIs and FRIIs.

The observed flux density is related to the actual luminosity of a source by the equation:

$$S_\nu(\nu_{obs}) = \frac{L_\nu(\nu_{obs})}{4\pi D^2(1+z)^{1+\alpha}}$$

For $\Omega_o \approx 1$, Scott et al. (1994)

$$D = \frac{2c}{H_0}\left(1-(1+z)^{-1/2}\right)$$

FRIs have been found in the luminosity range (L_ν) : $10^{23} \rightarrow 10^{25} W/Hz$ and FRIIs in the the range: $10^{25} \rightarrow 10^{28} W/Hz$. Equating the observed flux density to the minimum detectable flux density of the MRT array, one gets for:

$$S_\nu(\nu_{obs}) = \text{sensitivity limit of MRT} = 200 \text{ mJy}$$

$$(1+z)^\alpha S_\nu 4\pi \times \frac{4c^2}{H_{0^2}\{1-(1+z)^{-1/2}}^{2} = L_\nu$$

5.2. High Redshift Radio Galaxies

Similar to giant radio sources many high redshift radio galaxies were discovered in low frequency radio surveys due to their steep spectral index. Thus the MRT database will be a powerful tool to look for High Redshift Radio Galaxies also. One may ask the question why should it be interesting to find these distant radio galaxies when quasars are much easier to detect? Because radio galaxies appear extended in the optical/near-infrared band. This provides an opportunity to separate the stellar component from the AGN where as in QSO the AGN outshine every thing else. This also allows one to study the kinematics and the ionization structure of the, often very extended-emission line gas. Thus radio galaxies are crown witness to early galaxy formation and evolution (Meisenheimer, 1996).

5.3. Diffuse Cluster Radio Sources

Diffuse radio sources in clusters remain a poorly understood phenomenon. They are very extended sources (0.4–0.6 Mpc), of low surface brightness and steep spectrum, which cannot be identified with any active radio galaxy. They are a rare phenomenon, as they have been found so far in a few clusters of galaxies. Two important classes of diffuse cluster radio sources are cluster-wide halos and relics. Cluster-wide halos include sources located at the cluster centres, while relics are those diffuse extended sources located at the cluster peripheries. The surface brightness sensitivity of MRT and its low frequency operation which enables it to probe radiatively aged regions of clusters may lead to possible detections of new diffuse cluster radio sources (Feretti and Giovannini, 1996).

6. Present Status of the Study at MRT

We have chosen 25 EGRS with angular sizes $> 8'$, south of declination $-30°$ for imaging with the MRT. This list was made using the Molonglo Radio Catalogue (MRC) (Large et al., 1981) and is given in Table III.

Most of the above sources have been imaged at 408, 843 and 5000 MHz with the Molonglo, MOST and Parkes telescopes due to the overlapping sky regions (Mills, 1981; Jones and McAdam, 1992). A study of these sources at a lower frequency by MRT will enable detailed investigations of these sources.

Figures 1, 2 and 3 show $4' \times 4'$ images of a few extended radio galaxies. These have not yet been deconvolved.

Figure 1 shows the inner lobes of Cen A (MRC1322-427) which is associated with the elliptical galaxy NGC 5128. The size of the inner lobes in our image is around $10'$. The diffuse external lobes of Cen A extend up to $10°$ and are not shown here. It is one of the most widely studied radio galaxy mainly because of its large size and flux density. It is the nearest galaxy having both a very active nucleus and extended radio lobes, thus making possible an exceptionally detailed investigation

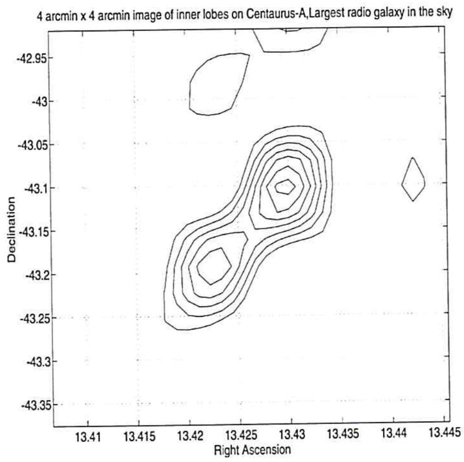

Figure 1. 151.6 MHz image of inner lobes on Centaurus-A, MRC1322-427.

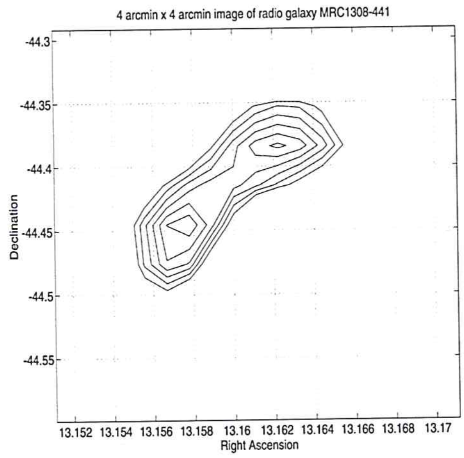

Figure 2. 151.6 MHZ image of MRC1308-441.

of its intrinsically faint and small emission feature. Cen A could be a double-double radio galaxy which is classified as edge-darkened complex FRI source with core component (Jones and McAdam, 1992).

Figure 2 shows MRC1308-441 which is a giant complex source which is an asymmetric double with diffuse lobes. It is classified as a FRI/FRII with core (Jones and McAdam, 1992).

Figure 3 shows MRC1333-337 which is a complex triple source. This is one of the largest known extragalactic source found in the MRT images ($33'$). One can easily see the three components of the source in the MRT image. It is classified as FRI/FRII without core (Jones and McAdam, 1992).

References

Fanaroff, B. and Riley, J.: 1974, *MNRAS* **167**, 31–35.

Feretti, L. and Giovannini, G.: 1996, R. Ekers, C. Fanti and L. Padrielli (eds.), in: *Extragalactic Radio Sources*, IAU Symposium **175**.

Golap, K., Issur, N., Somanah R., Dodson, R., Modgekar, M., Sachdev, S., Udaya Shankar, N. and Sastry, Ch. V.: 1995a, *Astrophys. Space Sci.* **228**, 373.

Golap, K., Issur, N., Somanah R., Dodson, R., Modgekar, M., Sachdev, S., Udaya Shankar, N. and Sastry, Ch. V.: 1995b, *J. Astrophys. Astron. Suppl.* **16**, 447.

Golap, K., Udaya Shankar, N., Sachdev, S., Dodson, R., and Sastry, Ch. V.: 1998, *J. Astrophys. Astron* **19**, 35.

Jones, P. and McAdam, W.: 1992, *Astrophys. J. Suppl. Ser.* **19**, 35.

Large, M.I., Mills, B.Y., Little, A.G., Crawford, D.F. and Sutton, J.M.: 1981, *MNRAS* **194**, 693.

Meisenheimer, K.: 1996, in: R. Ekers, C. Fanti and L. Padrielli (eds.), *Extragalactic Radio Sources*, IAU Symposium **175**.

Miley, G.: 1980, *Ann. Rev. Astron. Astrophys.* **18**, 165–218.

Mills, B.: 1981, *Proc. Astron. Soc. Australia* **4(2)**, 156–159.

Moffet, A.: 1975, in: *Strong Nonthermal Radio Emission from Galaxies*, The Univ. of Chicago Press, p. 211.

Scott, D., Silk, J., Kolb, E. and Turner, M.: 1994, in A.N. Cox (ed.), *Astrophysical Quantities*.

Somanah, R.: 1998, *University of Mauritius Journal of Science and Technology* **2**, 43.