Astrophysical Results of the Mauritius Radio Telescope.

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Abstract. One of the first scientific justifications of building the Mauritius Radio Telescope (hereafter referred to as MRT) was to complement the Cambridge 6C survey, which is a radio map of most of the northern sky at 150 MHz [1]; the MRT would then be the equivalent of the 6C survey for the southern sky and together we would obtain a whole sky radio map at 150 MHz. When the MRT was built, there were no radio surveys of the southern sky at frequencies less than 408 MHz; the frequency of 150 MHz was also chosen to complement the other radio surveys of the southern sky, which have been done at higher frequencies. Furthermore low radio frequencies like 150 MHz are bound to see new sources that would have been missed at higher frequencies due to the form of their spectra. Interesting features of resolved objects can also be studied in more details. In this paper, a brief description of the MRT will be made as well as the observations and imaging with the MRT data, and some astrophysical results obtained since its commissioning in 1992 (20 years of existence this year 2012).

1. Introduction
Early radio surveys were made at decametre wavelengths, and as higher-frequency receivers became available, observations of higher resolution at centimetre wavelengths became possible. A few major problems encountered by radio astronomers wishing to perform high-resolution, high-sensitivity observations at low frequencies, are the very large aperture dimensions required, phase perturbations caused by the ionosphere [2], and interference from terrestrial transmitters becoming severe.

Surveys are like bread and butter for astronomers as they form the starting point of identification of any class of celestial objects with well-defined criteria. For any survey it is desirable to have nearly uniform sensitivity across the sky. This gives a more reliable overall view of the sky and a more homogeneous sample. Using their statistical properties one can study/infer cosmological evolution. The unbiased and homogeneous samples from surveys are essential for testing models of source evolution. In addition, they provide a list of sources with well defined criteria and define interesting regions of the sky which can be chosen for further studies depending upon the scientific objectives in mind. Most classification schemes for Galactic and Extragalactic objects have emerged from surveys and have henceforth evolved by imaging a given sample of objects from the survey at multi-wavelengths, most often with higher resolution and sensitivity, and also by obtaining polarimetric and spectral line information.
In this paper, we highlight some of the results from the Mauritius Radio Telescope (MRT) as a surveying instrument. In Section 2, we give a brief overview of the MRT. In Section 3, we touch on the imaging problem followed by some of the results obtained using the MRT from galactic to extra-galactic radio astronomy. We also show some of the pulsar work and finally conclude in Section 4.

2. The Mauritius Radio telescope (MRT)

The Mauritius Radio Telescope is a Fourier synthesis array, which has been constructed and operated collaboratively by the University of Mauritius, the Raman Research Institute (India) and the Indian Institute of Astrophysics (India). MRT is situated at Bras d’Eau (Latitude 20.14° South, Longitude 57.73° East) in the North-East (NE) of Mauritius. The array consists of helical antennas which have the best response in the frequency range of between 80 MHz and 200 MHz and could stand cyclonic wind gust above 200 kmh$^{-1}$. MRT is a T-shaped non-co-planar array with a 2048 m long East-West (EW) arm having 1024 helical antennae and a 880 m long North-South (NS) arm having 15 mobile trolleys with 4 helical antennae each. The helical antennae are mounted with a tilt of 20° towards the south so that they point towards a Declination ($\delta$) of -40.14° at the meridian of transit. This tilt allows a better coverage of the southern sky including the southern-most part of the Galactic plane, a region largely unexplored at meter wavelengths.

The antennae in the EW are divided into 32 groups and there are 16 groups in the NS. The signal from each group is then filtered, down-converted into an intermediate frequency (IF), amplified and sent to the telescope building where it is digitized. The digitized signals are processed in a 1024-channel correlator. Custom written software running on GNU/Linux OS computers is used to transform these correlated signals into raw images called dirty maps.

The MRT uses the technique of aperture synthesis to simulate a 1 km by 1 km filled array. Observations are made with the trolleys in the NS arm at their nearest position from the array centre. The trolleys are then moved further south and the observations repeated 62 times. This process continues until the end of the south arm is reached. The data for each day is added so as to make a 2-D map of the sky. Also, the non-co-planarity of the EW arm combined with the wide primary beam (full width at half maximum (FWHM) $\sim 60^\circ$) have led to new imaging techniques used in CLEANing the raw data. To summarize, wide field imaging with non-coplanar baselines [3] where the data has been collected for more than 5 years, has made the processing of the data into radio images more complex, which have led to many innovative ideas in the imaging process [4, 5, 6, 7].

Although the MRT was primarily designed to conduct the 151.5 MHz survey, it has also been used for pulsar observations. During pulsar observations, only the EW arm is used. The group outputs are added together, with a tracking capability of about 2 degrees for a source transiting at meridian. This corresponds to 8 minutes for an equatorial source. The data is recorded at a fast rate over a bandwidth of 1 MHz. The data processing is done to produce a de-dispersed output in the desired format, including the pulsar profile unique to each pulsar [8].

3. MRT images and astrophysical analysis

3.1. Continuum Survey

The MRT does not produce instantaneous 2-D images of the radio sky seen by the EW and NS groups of helices. It obtains information over a time period from which an image can be constructed later. The imaging is restricted to making 1-D scans along the meridian and the 2-D image is time stacks of these 1-D scans. The 24-h ‘dirty’ images of the southern sky visible from the MRT site have already been made and the process of deconvolving the images is currently being finalized. It is the first time that galactic and extragalactic sources of the southern sky have been imaged at 150 MHz, with a synthesized beam width of $4^\prime \times 4.6^\prime \sec(\delta + 20.14^\circ)$. 
With a very modest resolution, the continuum radio images obtained using the MRT contain a considerable amount of astrophysical information. Fig.1 shows the galactic centre as seen by the MRT. We first extracted a sample of sources with flux densities > 10 Jy at 150 MHz from our images and we have called it the MRT10 sample. Using the spectral index between 150 MHz and 408 MHz [10], we have made another sample of sources with flux densities > 10.9 Jy at 178 MHz (similar to the 3CRR survey [11]) and we have called it the SMRT10 sample. We compared the SMRT10 sample with the 3CRR and found that they have many similarities as expected [12].

![Figure 1](image)

**Figure 1.** Our galactic plane in the MRT radio images. The contour levels are at: [-0.5, -4, -3, -2, -1, 1, 2, 3, 4, 5, 7, 10, 14, 20, 29, 40, 54, 72, 90, 100, 136, 180, 216, 288] Jy beam$^{-1}$

3.2. **Pulsar observations at the MRT**

The MRT has been used to observe some Southern Sky pulsars at 150 MHz. A tracking system allowing observation of a source for $8 \times sec \, \delta$ minutes of time and a fast data acquisition system (FDAS) was added to the MRT. With this new system, pulsars with an average flux density of about 100 mJy could be observed. Sources were tracked between the half power points of the EW group beam.

From observation of the pulsar J0437-4715, we observed a very broad profile with a width at outer half-power points of about 125$^\circ$ in longitude, Fig.2. Three components are observed with a possible suggestion of a fourth component.

4. **Conclusions**

Until 2010, the MRT was the only radio telescope operating at 150 MHz in the southern hemisphere and the 150 MHz radio images of the southern sky made at the MRT have provided and will provide a wealth of astrophysical data for the community of astronomers. Two radiotelescopes which will also bring new data at low frequencies are the Precision Array to Probe the Epoch of Reionization (PAPER) [13], operating from 120 to 190 MHz and the Murchinson Wide Field Array (MWA) [14], operating from 80 to 300 MHz. Both PAPER and MWA will probe the epoch of re-ionization. Many innovative techniques have gone in the design of the
Figure 2. Figure shows the Millisecond pulsar J0437-4715 observed at the MRT, with an average flux density (measured on 27 July 1996) of 620 mJy with a peak of more than 2 Jy, assuming an effective sky background temperature of about 220K.

hardware, software and the mechanical system of the MRT array. Some astrophysical results have been presented in this paper.

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