A Southern Sky Survey at 151.5 MHz using the Mauritius Radio Telescope

A Thesis submitted to the
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by

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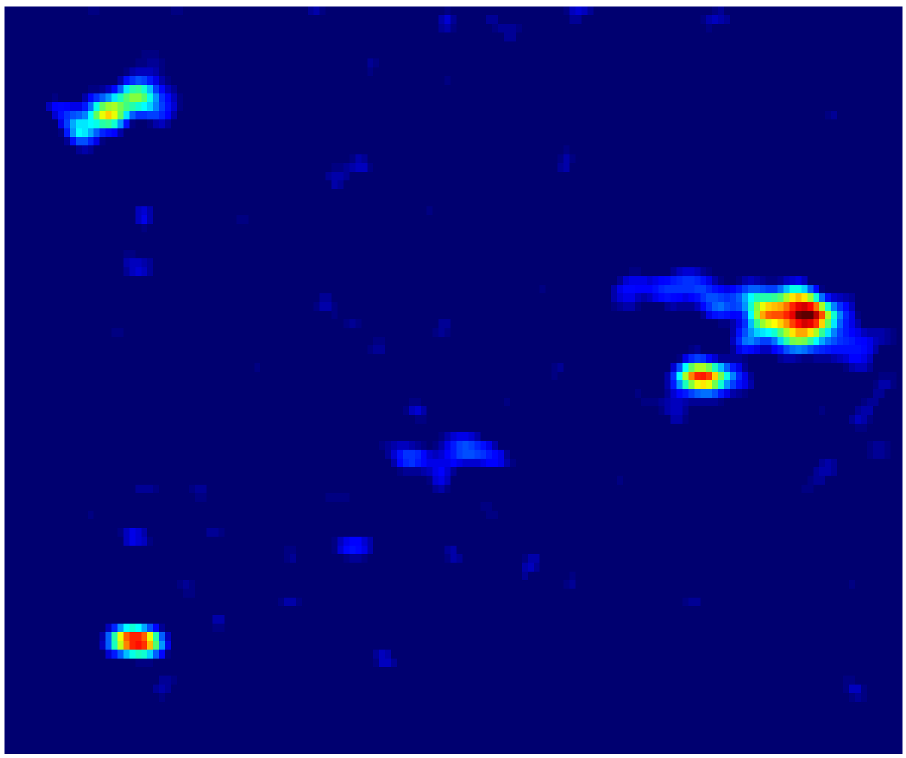

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Certificate

This is to certify that the thesis entitled "A Southern Sky Survey at 151.5 MHz using the Mauritius Radio Telescope" submitted by Vishambhar Nath Pandey for the award of the degree of Doctor of Philosophy of Jawaharlal Nehru University, New Delhi is his original work. This has not been published or submitted to any other University for any other Degree or Diploma.

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Declaration

I hereby declare that the work reported in this thesis is entirely original. This thesis is composed independently by me at the Raman Research Institute under the supervision of Prof. N. Udaya Shankar. I further declare that the subject matter presented in this thesis has not previously formed the basis for the award of any degree, diploma, membership, associateship, fellowship or any other similar title of any University or Institution.

(Prof. N. Udaya Shankar) (Vishambhar Nath Pandey)

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ॐ सह नाववतु। सह नौ भुनक्तु। सह वीर्यं करवावहै।
तेजस्वि नावधीतमस्तु। मा विद्विषावहै।

ॐ शान्तिः शान्तिः शान्तिः॥

"Om Sahana Vavatu; Sahanao Bhunaktu; Sahaveeryam Karvaa vahai;
Tejaswee Naava Dheeta Mastu; Ma Vidvishaa vahai;

Om Shanti! Shanti! Shanti!."

- Katha/Shvetashwatara Upanishad

Let us come together; Let us nourish together; Let our strengths come together;
Let us work to move from darkness to light; But we may not despise each other;

That way lies the progress of peace.

To the loving, caring and conscious people...

Thesis Abstract:

This dissertation describes the results of the work carried out for the southern sky survey at 151.5 MHz using the Mauritius Radio Telescope (MRT). The primary objective of this survey is to image the southern sky at metre wavelengths and derive a catalogue of radio sources.

The consolidated results of the present work are presented in the form of deconvolved images covering more than one steradian of the sky ($18^{h} \leq \alpha \leq 24^{h}30^{m}$, $-75^{\circ} \leq \delta \leq -10^{\circ}$)[1] with an angular resolution of $4' \times 4'.6 \sec(\delta+20^{\circ}.14)$ and having an rms noise of $\approx$260 mJy beam^{-1}. A catalogue of nearly 2,800 sources and its initial analysis is presented. As a representative of interesting sources in the images, we briefly discuss a few steep spectrum sources, giant radio sources, double sources, cluster radio relics/fossil galaxies and report the structure of a few resolved supernova remnants. A comparative study including cross identification with the Molonglo Reference Catalogue at 408 MHz and Culgoora catalogue at 160 MHz is described. MRT with its availability of short spatial frequencies and nearly complete *uv* coverage is sensitive to extended features in the sky. In this context, dirty images of a large part of the southern Galactic plane including the Galactic center ($\approx$0.5 steradian, $15^{h}06^{m} \leq \alpha \leq 18^{h}$, $-75^{\circ} \leq \delta \leq -10^{\circ}$) are presented.

The imaging has been accomplished using the software system developed in-house. Additions to provide many new functionalities and various improvements (eXtended-MARMOSAT) to the existing software system MARMOSAT (**MA**u**R**itius **M**inimum **O**perating **S**ystem for **A**rray **T**elescopes) were carried out to make it complete and robust. This required optimizing, modifying/tailoring the conventional techniques for data processing, making the right choice of methods to analyse, browse and display large amounts of data obtained at different stages of imaging. A hierarchical software system based on a mix of top-down and bottom-up approaches consisting of separate application programs with specific functionalities (top-most layer) and using general purpose generic libraries (lowest layer) was developed to accomplish this purpose. It is written in *C, Perl, Matlab* and *F77* and comprises of more than 60,000 lines of code.

Many aspects of imaging with the MRT are special and challenging due to its non-coplanarity and the large size of database of visibilities. In this context we have presented a novel framework developed and implemented for automatic evaluation of data quality which was essential to classify the $\approx$20,000 hours of astronomical observations for the survey. With suitable modifications, an astronomical tool based on such a framework can potentially be employed on data sets from other interferometric arrays and to monitor the performance of an observatory. A hierarchical Radio Frequency Interference (RFI) mitigation system developed and implemented for offline processing of the recorded visibilities using a conjunction of techniques both linear and nonlinear at various stages of data processing is discussed. The system creates an RFI database which is valuable in combating it. The interesting aspects of statistics of interference are also described. Such an approach exploiting the natural strengths of both linear and nonlinear signal processing techniques and judiciously applying them at various stages of data processing is an important step towards achieving the ultimate goal of automatic data flagging. We have later presented an algorithm which uses the concept of minimum number of look-up Point Spread Functions (PSFs) of appropriate size for deconvolution of wide field images made using a non-coplanar array. This scheme does not require PSF interpolation in the image plane during every iteration in the CLEAN loop. The procedure developed for flux calibration which involves scaling different images to a common level, estimation of the primary beam shape of the helix and recovery of the amplitude information of the signal lost in a 2-bit 3-level correlator with an AGC (Automatic Gain Control unit) is discussed. An algorithm developed for construction of the source catalogue from the wide field deconvolved images is also described.

[1] α and δ refer to Right Ascension and declination in J2000 epoch.

Acknowledgements:

"I keep my ideals, because in spite of everything,
I still believe that people are really good at heart."
Anne Frank

A journey is easier when we travel together. Independence needs to be fairly balanced with interdependence. This thesis is a result of more than six and a half years of work whereby I have been accompanied and supported by many people. It is a pleasure to thank them who have directly or indirectly contributed to the realization of this thesis.

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[2]http://www.perlmonks.org

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