MITRA 2.0

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Abstract. We give the rationale of building a new innovative radio telescope in Mauritius. The instrument will tackle important astrophysical areas, such as the detection and imaging of the Deuterium line and of recombination lines, as well as bridging a gap in the technological area. The telescope will be composed of low cost dipole antennas, arranged in planar stations with a bandwidth of $\sim 200$MHz. The Front-End Electronics will have GaS-HEMT technology Low Noise Amplifiers to constrain the value of the system temperature to a minimum. The signals will be digitized and Fast Fourier Transformed. The post-processing used will be dependent on the science observed. It could be a case of either accumulation or FX correlation.

1. Introduction
The Square Kilometre Array (SKA) radiotelescope will be hosted by South Africa and Australia. South Africa will host the telescope in collaboration with a number of partner countries, mostly in Southern Africa. Mauritius is one of the partner countries. The Multifrequency Interferometry Telescope for Radio Astronomy (MITRA) is a deliberate attempt by some members of the Mauritian radioastronomy community to actively support the SKA consortium by making tangible contributions in science and technological areas. One of its main aims is to study the solar corona, the ionosphere, etc. The MITRA project is designing and developing novel technologies. These are then being shared with a broader global audience. All of this activity will also help in building human capacity around radioastronomy.

A number of SKA related radiotelescopes are being built and commissioned around the world. These are SKA precursors and pathfinders. MeerKAT, ASKAP and LoFAR are a few of them. Others, even without an SKA designation of pathfinder, like the Deuterium Array, are still working on SKA related science and technology. The Southern Hemisphere has been devoid of low and midfrequency radiotelescope for a long time. Presently, the active low frequency instruments are the Murchison Widefield Array (MWA) and Precision Array for Probing the Epoch of Reionization (PAPER). The addition of these telescopes is essential to complement the work done by Northern Hemisphere ones.

The MITRA project will focus on designing and building a sensitive high resolution multifrequency dual polarity instrument. Multiple stations of low-cost dipoles, such as log-periodic antennas, will be used. The operating bandwidth will be in the range of $\sim 200$--$\sim 450$ MHz. The instrument and each station will be modular in nature. A station will be able to function in its own right. Subsets of the whole instrument could also be used. We are targeting spectral lines such as Deuterium, red-shifted lines of hydrogen, carbon recombination lines and all-sky surveys. These science targets are crucial to the progress of astrophysics. Telescopes such as the Deuterium Array in MIT, Haytstack, USA, and LoFAR, in the Netherlands, are active in
some of these areas. Such a telescope in Mauritius will be able to complement, and add a new perspective, to any work done in the North. Here we present details of our proposed instrument and our intended plan.

2. Radioastronomy between \( \sim 200 \) and \( \sim 450 \) MHz

2.1. Deuterium Line at 327 MHz in the Southern Hemisphere

Deuterium is one of the primordial elements formed after the Big Bang. Shklovskii (1952) discussed its astrophysical importance. Subsequently, the line proved to be a determining factor in finding the baryon density of the Early Universe (Wagoner, 1973). Several attempts have been made since then to observe the Deuterium line at 327.4 MHz. Anantharamaiah & Radhakrishnan (1979) and Heiles et al. (1993) placed an upper limit of almost \( 5.8 \times 10^{-5} \) for D/H ratio, in absorption, in the Galactic center, and Cassiopeia A. Chengalur et al. (1997) obtained a marginal detection of the emission from the anticenter to place the D/H ratio between \( 2.9 \times 10^{-5} \) and \( 4.9 \times 10^{-5} \). Rogers et al. (2005) observed the anticenter for two years and came up with a definitive value of \( (2.3 \pm 0.4) \times 10^{-5} \).

2.2. Carbon Radio Recombination Lines

Radio Recombination Lines (RRL) are an important probe to study the cold, diffuse, atomic clouds of the Interstellar Medium (ISM). RRLs are particularly interesting because dust and contaminants have little impact on them. They are being used to constrain the temperature and density of the cold ISM. Carbon Radio Recombination Lines (CRRRLs) have proved to be excellent tracers of the physical conditions in cold, diffuse clouds. Despite its usefulness, only a few surveys have been done on CRRRLs at low-frequency (Anantharamaiah and Kantharia 1999, Kantharia & Anantharamaiah 2001; Roshi et al. 2002). More recently Asgekar et al. (2013) used the LOw Frequency ARray (LOFAR) to observe the CRRRLs towards Cassiopeia A at very low frequencies. The MITRA telescope with its wide bandwidth will be able to look at CRRRL lines with the principal quantum \( 249 < n < 288 \) which corresponds to a frequency range of \( \sim 275 < \nu < \sim 425 \) MHz.

2.3. Red-shifted of the 21cm Hydrogen Line

Neutral Hydrogen emits a radiation at 21 cm, when its ground state goes through a hyperfine splitting. The line occurs when there is a spin-flip transition from the highest state (spins of proton and electron are parallel) to the lowest state (antiparallel spins). With hydrogen being ubiquitous in the universe, it is a wonderful tracer for galaxy surveys. The red-shifted hydrogen line will allow us to map the sky at redshifts of \( 2.5 < z < 4 \) which corresponds to an Universe being \( \sim 1.5 \) \( < \) age \( < 2.5 \times 10^9 \) years. The early Universe is yet to be fully understood. Surveys of this type are important to study the evolution of the Universe from the epoch of reionization till now.

3. Design Requirements

3.1. Antenna and Front-End Electronics

3.1.1. Antenna A multifrequency and multiscience telescope meant that we had to look at broadband antennas that could offer a relatively linear performance over the band of interest. Log-Periodic Antennas (LPDAs) are the ideal candidates. These antennas respond to a wide range of frequencies, without a significant degradation in the antenna parameters such gain, beam pattern, and SWR. They are relatively easy to construct and are low cost.
Table 1: SUMMARY OF ANTENNA CHARACTERISTICS

| Characteristics               | Value       |
|-------------------------------|-------------|
| Bandwidth                    | ∼200MHz-∼450MHz |
| Gain                         | ∼9dBi       |
| Polarization                 | Dual Linear |
| Collecting Area at 327MHz    | 0.6m²       |

3.1.2. Front-End Electronics

The Front-End Electronics (FEE) will consist of a matching circuit, a filter and a Low-Noise Amplifier (LNA). The first amplification stage is the most crucial part in constraining the value of the system temperature to a minimum. Each science case will have a dedicated FEE. Since the spectral lines are our primary scientific targets, the bandwidth of the filter will be science-limited so that the power noise level of the LNA is at a minimum. Most of the components will be off-the-shelf.

Table 2: SUMMARY OF FEE CHARACTERISTICS

| Low Noise Amplifier | Filter |
|---------------------|--------|
| Parameters          |        |
| Value               |        |
| Power Consumption   | <100mW |
| Bandwidth           | ∼10MHz |
| Gain                | >20dB  |
| Tolerance           | <0.5   |

3.2. Array and Station SubArray

The telescope will be composed of 2D sub-stations arranged in a T-shaped array. It will be a 200 m East-West arm with a 400 m South arm. The array will be modular, ie, each station will work independently. Each substation will either be a 4×4 or 5×5 planar array. This arrangement is ideal for our work because it allows for high level of flexibility. The sub-stations can be moved along the array and can either increase or decrease in size depending on the needs. The antennas will be placed on square frames which could also be tilted to scan further on the northern or southern declination. Beamforming can be easily adapted. More than one beam can be obtained from a sub-station.

3.3. Signal Transfer

RFoF photonics technology will be used to carry Radio Frequency (RF) over fibre cables. Outdoor Non Metallic Armoured Singlemode 24 Core fibre cables have already been laid out at the telescope site with a 24 port singlemode Fibre Optic Patch Panel. The RF signal will be modulated by a laser diode and demodulated by a PIN detector. Appropriate amplification stages will be added in case of signal attenuation. The modulators and demodulators will be made using off-the-shelf components. We are expecting to achieve very good results, at a very low-cost.

3.4. Receiver

Each channel will be amplified, filtered, and down converted using a double downconversion superheterodyne receiver. The first and the second one Intermediate Frequency (IF) will be 30 MHz and 10.7 MHz respectively. The IF will then be converted to a digital signal by sampling using a high speed digital acquisition board. The signal will be digitally filtered to a 250 KHz bandwidth in the process. Graphical Processing Units (GPUs) will be used for most of the
Digital Signal Processing (DSP). The digital outputs will be passed to the GPUs for Fast Fourier Transform and correlation. 1024 FFT channels at a frequency resolution of 244 Hz will be obtained.

![Block diagram of receiver](image-url)

**Figure 1.** Block diagram of receiver

4. Conclusion
In this paper we have clearly outlined the scientific importance of our work, in the Square Kilometre Array project context. Section 2 goes through the main scientific targets and Section 3 targets the instrumental and technological requirement of the telescope.

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