A Multifrequency Interferometry Telescope for Radio Astronomy: MITRA

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Outline

- Overall description
- Station outline
- Recent developments
- Preliminary tests
- People
- Future & funding
MITRA: Overall description

- A sensitive high resol multi-frequency dual polarity
- Frequency range 200 to 800 MHz
- Multiple independent stations of low-cost dipoles
- Baselines: ~metres, 250-500-1000-3000-5000 km-
- Instrument & station: modular & subsets
- Technical specifications function of number of stations

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MITRA: Station outline

- Each station can observe on its own.

- Sufficient sensitivity and resolution built in.

- The front-end & the back-end should be integrated with the data acquisition locally.

- The data pipeline should also cater for intra-station as well as inter-station correlation.

- Local hub managing system which will be synchronised, centrally, with other stations.
- Sky noise ~300 K at 150 MHz; up to 1000 K in the Galaxy (Golap 1998, Issur 2003)

- No cooling of field electronics: science & cost factor

- ~250 mJy point source sensitivity per station for 1024 antennas. (Golap 1998, Pandey 2006, Daiboo 2012). 32 EW 16 NS: BL 1 MHz BW, 16 s integration, area ~4000 m²

- Aim to improve: $\Delta S \sim (\Delta \nu \cdot n \cdot \Delta t)^{-1/2}$. 

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- The w term

- Convolution & Gridding

- Primary beam

- Phasing & Bandwidth decorrelation

- Ionospheric effects
<table>
<thead>
<tr>
<th>ν (MHz)</th>
<th>λ (10m)</th>
<th>Resolution (arcseconds)</th>
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</thead>
<tbody>
<tr>
<td>50</td>
<td>6.0</td>
<td>123758.9 12375.9 1237.6 5.0 2.5 1.24 0.495 0.248</td>
</tr>
<tr>
<td>100</td>
<td>3.0</td>
<td>61879.4 6187.9 618.8 2.5 1.2 0.62 0.248 0.124</td>
</tr>
<tr>
<td>200</td>
<td>1.5</td>
<td>30939.7 3094.0 309.4 1.2 0.6 0.31 0.124 0.062</td>
</tr>
<tr>
<td>300</td>
<td>1.0</td>
<td>20626.5 2062.6 206.3 0.8 0.4 0.21 0.083 0.041</td>
</tr>
<tr>
<td>400</td>
<td>0.8</td>
<td>15469.9 1547.0 154.7 0.6 0.3 0.15 0.062 0.031</td>
</tr>
<tr>
<td>500</td>
<td>0.6</td>
<td>12375.9 1237.6 123.8 0.5 0.2 0.12 0.050 0.025</td>
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<tr>
<td>600</td>
<td>0.5</td>
<td>10313.2 1031.3 103.1 0.4 0.2 0.10 0.041 0.021</td>
</tr>
<tr>
<td>700</td>
<td>0.4</td>
<td>8839.9 884.0 88.4 0.4 0.2 0.09 0.035 0.018</td>
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<tr>
<td>800</td>
<td>0.4</td>
<td>7734.9 773.5 77.3 0.3 0.2 0.08 0.031 0.018</td>
</tr>
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</table>

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Connectivity

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http://manypossibilities.net/africa-undersea-cables
Extremely wide field imaging with heterogeneous non coplanar arrays

- Short spacing
- w/n term, sampling & visibility
- Primary beams: size and dep, on position
- Bandwidth decorrelation
- Imaging & CLEANing etc
- Future problem for the SKA

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MITRA: Science I

- Solar: flares, coronal mass ejections (de Pontieu et al 2011, Zaarashvili et al 2013)
- The Milky Way, Galactic centre star forming regions (Yusef-Zadeh et al 2013)
- Galaxies and clusters of galaxies (van Weeren et al 2011)
- Pulsars & Supernova remnants (Stappers et al 2011, Han et al 2013)
MITRA: Science II

- Low brightness wide sources (Dodson 1997)
- Spectral and recombination line observations (De Pree et al 1997)
- Spectral indices of sources (Miley et al 2008)
- Ionospheric and Space Weather (Judd et al 1987)

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**MITRA: Technology I**


- Data acquisition system design (N. Pirthee 2013)

- Radio Frequency (RF) Electronics (UOM & DUT projects with collaboration)

- Networking (Conhyea 2007, Armoogum 2013)

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MITRA: Technology II

- Data Management (Brunner et al 2001, Morgan et al 2013, Grange et al 2012)
- VLBI and e-VLBI (e.g EVN)

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MITRA Preliminary work: Antenna design Version 1

Prayag, Lallbarry & Beeharry @ Bras d'Eau, Mauritius

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MITRA Preliminary work: 1st antenna 100-850 MHz

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MITRA Preliminary work: Type 3 Solar flare antenna V1 20.4.2011

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MITRA Preliminary work:
new antenna design 200-800 MHz

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MITRA Preliminary work:
New Antenna design 200-800MHz

Model fit needed

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MITRA Preliminary work: Antenna design Version 2

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MITRA Preliminary work: Front end 15.02.2014

K Bhoyrub & A Chataroo
Bras d'Eau, Mauritius

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K Bhoyrub & A Chataroo
Bras d'Eau, Mauritius
MITRA Preliminary work: Antenna design Version 3 March 2014

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Shibchurn, Lallbaree, Beeharry @ Bras d’Eau, Mauritius 2012-13

Sug. H. Reader Feb 2014 Stellenbosch meeting
MITRA Preliminary work: Solar flare with antenna V2 16.2.2014

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MITRA Preliminary work:
16 channel receiver pre-processor

Two 16 channel receivers built in parallel
UoM&UdM

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MITRA Preliminary work: 
Antenna V2 18.02.2014

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K Bhoyrub & A Chataroo, Bras d’Eau, Mauritius
MITRA Preliminary work: back end: Durban

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MITRA Preliminary work: Interference Mauritius

C. Monstein 2013

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Dominique Ingaia @DUT
MITRA Preliminary work
16 antenna array Durban

S. MacPherson, G. van Vuuren, D Ingala DUT 2013

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MITRA Preliminary work
16 antenna array Mauritius

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MITRA Preliminary work
16-\rightarrow 64\ antenna\ array\ March\ 2014

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MITRA Preliminary work: USRP control using GNU Radio Companion

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MITRA Preliminary work: FFT

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15 min obs files 21.02.2014

1 D dirty smoothed scan (8 antennas) 150 MHz RF 2-channel correlator ADC card

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MITRA Preliminary work
antenna V1 31.03.2014 (Betchoo)
Pictor A 150 MHz & Hydra A 408 MHz
MITRA Preliminary work: Recent relevant software

Software correlation on CPU (Jheengut)

ADC card acquisition software CPU (Ginourie)

ADC card acquisition software GPU (Platel)

CALLISTO flare detector (Benfifi)

USRP1 programming (Mondon)
MITRA Preliminary work: Recent & future

Design & construction of a 16 channel receiver (Bhoyrub & Chataroo 2011-12)

Front end
Construction of 2 groups, with 8 antennas per group (Shibchurn 2012-13) May be extended to 8 x 8.
Set up of optical fibre network (Armoogum 2012-13)

Back end
Integration of receiver & USRP programming using GNU Radio companion (N.Pirthee 2012-13, Prayag)

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MITRA Preliminary work: Correlator

FX FPGA Correlator

Preliminary work on low cost FPGA on the USRP board

GPU array

ROACH board

Uniboard

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<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Cost (MUR)</th>
<th>Cost (ZAR)</th>
<th>Notes</th>
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<td>4,445</td>
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<td>3,081,152</td>
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<td>10,105</td>
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## Cost: Scenarios

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<tr>
<th>Version</th>
<th>Station 512 antennas</th>
<th>Station 1024 antennas</th>
<th>Relative Sensitivity</th>
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<tbody>
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<td>Version 1 (MUR)</td>
<td>18,953,984</td>
<td>37,907,968</td>
<td>1</td>
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<td>Version 1 (ZAR)</td>
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<td>9,975,480</td>
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<tr>
<td>Version 2 (MUR)</td>
<td>12,820,224</td>
<td>24,640,448</td>
<td>0.7</td>
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<tr>
<td>Version 2 (ZAR)</td>
<td>3,473,596</td>
<td>6,747,152</td>
<td>0.7</td>
</tr>
<tr>
<td>Relative sensitivity</td>
<td>0.7</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

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People in Mauritius

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People in Durban
South Africa

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Future: 8x8 array

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Future: Plans

- Collaborations: DUT, SUN, CPO, Astron, SKA

- Training ground for African students, academics, engineers, technicians,

- Bursary programme

- Running our MSc
Thanks!