The Mileura Widefield Array

as an EOR Machine

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For the MWA Collaboration
What is the MWA?

A wide-field imaging array

- Optimized for wide FOV, high survey speed
- Maximum frequency $\sim 1.6$ GHz
  - Dishes with phased array feeds $> 500$ MHz
  - Dipole-based antenna systems $< 300$ MHz
- Demonstrator-class instruments up to 2010
  - Expansion based on demonstrator results
- Located in RFI-quiet site in Western Australia
Where is it?

$\rho_{\text{humans}} \sim 10^{-2} \text{ km}^{-2}$

$\rho_{\text{kangaroos}} \gg \rho_{\text{humans}}$
The Low Frequency Demonstrator

• ~$10M effort by international collaboration
  – MIT
  – Australian University Consortium
  – CfA
  – CSIRO/ATNF
  – Government of WA

• Capability to detect/characterize 21cm signal
  – 8000 dual-polarization dipoles
  – >400 deg² instantaneous FOV
  – 80-300 MHz frequency range
Demonstrator Vital Statistics

- **500 antenna tiles, 80-300 MHz**
  - Each a 4x4 crossed dipole array
  - Electronic analog steering of tile beam
  - Total collecting area ~8000 m² at 150 MHz

- **Full cross-correlation architecture**
  - Simpler, easier, cheaper, *better for wide FOV*

- **Tiles scattered across 1.5 km region**
  - Angular resolution: a few arcminutes
  - Superb *instantaneous* PSF characteristics

- **32 MHz processed bandwidth**
  - For sensitivity. Custom, FPGA-based processing.

- **Campaign-based observing model**
  - Affordable, focused operations
Physical Layout

**Antenna tile (~4m diam.)**

**Cluster (50-100m diam.)**

**Array (~1.5km diam.)**

- Tile beamformer
- Coax out
- Fiber out

Central Processing
Tile Design

- 16 dipoles
- ~4m x 4m size
- Dual-polarization
- 80-300 MHz
- Analog beamformer
- 30° min elevation

Target cost $2000 each
Focusing on cold sky

Compromise between $T_{\text{sys}}$ and FOV
The issue is *Foregrounds*

- **RFI**
  - Low-level, broadband will be worst
  - Intermodulation products
  - Excision punches holes in contiguous datasets

- **Continuum**
  - Galactic (Thermal
  - Extragalactic and nonthermal)

- **Spectral line**
  - RRLs

- **Polarized galactic emission**
  - Strong, *frequency-dependent* structure on EOR scales
  - Modulated on *short timescales* by ionosphere
  - Requires high precision polarimetric calibration
Calibration and Control of Systematic Errors

MWA-LFD designed from the ground up for this:

- Full band sampling – no mixers, minimal filtering
- High spectral D.R. via polyphase filterbanks
- Pseudo-random 500-tile configuration
  - Superb instantaneous point spread function
  - Excellent native spatial dynamic range
- Full cross-correlation, 125,000 baselines
  - No “boundaries” within FOV
  - Heavily overconstrained calibration system
  - Complete flexibility in coherent postcorrelation data combination
- Correlator FOV: horizon-to-horizon
Prototyping Expeditions
Tile 1 + Mission Control
Pemus >> Pantennas
Mileuran sky at 108 MHz
Solar interferometry at 96 MHz

(Yes, that is smack in the middle of the FM band …)
The RFI Environment

"OrbComm" LEO Satellite constellation
137.2-137.8 MHz

EOR range

10 dB level

80-200 MHz spectral occupancy

At 1 dB above galaxy: $1.0 \times 10^{-3}$

At 0.7 dB above galaxy: $1.3 \times 10^{-3}$

At 0.3 dB above galaxy: $1.6 \times 10^{-3}$

RFI log(N)/log(S) promising
RFI Environment
Noise-limited performance

\[ t^{-1/2} \]
EOR Analysis

• **Need long integrations**
  – Hundreds of hours
  – Control over what data gets included
  – Information to support various foreground subtraction approaches

• **Database of 10-minute integrations**
  – Remove bright sources using calibration data
  – Store each 10-minute integration with metadata
  – Database interface to create customized long integrations

• **Detailed analysis of exported data**
  – Long integrations are manageable size (~10s of Gbytes)
  – Support multiple groups in parallel
Sensitivity for EOR

- Principal figures of merit
  - Collecting area: \( \sim 8000 \text{ m}^2 \) @ 150 MHz
  - System temperature: \( \sim T_{\text{sky}} \)
  - Field of view: \( \sim 300 \) to \( \sim 1500 \text{ deg}^2 \)
  - Processed bandwidth: 32 MHz

MWA, 360 hrs, 8 MHz, full array model. EOR model: density only, no velocity effect.
Plans and Timescale

• Continue “early deployment” prototyping
  – Steady expansion as resources permit

• Remainder of funding ~Q4, 2005
  – Pending NSF proposal, submitted September 2004

• Critical Design Review ~Q2, 2006

• Initial data ~Q4, 2007

EOR science results ~Q4, 2008

http://web.haystack.mit.edu/arrays/MWA
The End
Mileuran sky at 200 MHz
Interferometry on an AGN