Preparations for cosmic-ray studies with the Murchison Widefield Array

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Core idea: use an existing radio telescope

Pros:
- The array already exists, so you don’t have to build it.
- Other people are developing it.

Cons:
- The array wasn’t built to do what you want to do.
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- LOFAR; other talks
- MWA; this talk
- LWA; Munroe et al. (in prep.)
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Contents:
- the MWA in context
- where we’re up to
The MWA as a radio telescope

Precursor instrument for the Square Kilometre Array, at the same site.

Closest southern equivalent to LOFAR.

Targets EOR, radio galaxies, transients, heliosphere, ionosphere

- analogue tile beamforming
- coarse filterbank
- return selected channels
- correlate all active tiles

MWA
70–300 MHz
256 tiles

SKA
50–350 MHz
131,072 antennas
The MWA as a cosmic-ray instrument

Problem #1: analogue beamforming.
Solution #1: use non-commensal single-antenna feed-through mode.

Problem #2: radio triggering impractical.
Solution #2: particle-detector trigger.

figures: A. Nelles
Array layout & scale

figure: A. Zilles
Array layout versus shower footprint

Shown: vertical shower (smallest footprint)
Simulations from A. Zilles.
Note: optimal SNR at $\sim 100$–$200$ MHz (Balagopal et al., 2018)
Operation modes

1. Tests thus far.
   - two antennas
   - full baseband data
   - radio-triggered

2. Planned operation.
   - all core tiles
   - 24 × 1.28 MHz channels
   - particle-triggered

3. Future development.
   - all core tiles
   - full baseband data
   - particle-triggered

 invertible: see Tobias Winchen’s talk

polyphase filterbank
figure: Singh (2010)
Radio-triggered two-antenna tests

A few hours of radio-triggered data on two antennas.

Enough to sample the noise and RFI environment.
Particle-detector design constraints

SKA regulations on RFI:
- no switched-mode power supplies
- no RF signal cables
- no digital electronics

Also, for MWA:
- 300 m to nearest power
- 6000 m to signal backend
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Technologies

Silicon photomultiplier (SiPM) for optic pulse detection (low power, robust). RF-over-fibre signal (long range, no RFI). DC power from remote supply; feedback loop to control gain.

Histogram of output amplitude:

figure: B. Cropper & T. Howland
Our starting point

Scintillator module.
One of ~ 200 from KASCADE experiment.
Kindly provided by A. Haungs et al., Karlsruhe.
Our current prototype

benchtop prototype
(field prototype under construction; deployment later this year)

Working:
- power-regulation board
- photodetector board
- event reconstruction

In progress:
- amplifier feedback loop
- delay multiplexing
- improving sensitivity
Recent results

positional reconstruction of events

RFI isolation of power-regulation board

![Graph showing gain vs frequency for SKA-Low band for different power units.]

1 metre
Conclusions

The MWA is a potential radio cosmic-ray instrument with a dense antenna array and broad frequency coverage.

Much work is required to properly exploit it, but this has begun.

Pathfinder for the SKA: shares location & infrastructure.
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Thank you for your attention.