ICRAR

International Centre for Radio Astronomy Research

MWA
MURCHISON WIDEFIELD ARRAY

Workshop summary

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Curtin University

THE GOVERNMENT OF WESTERN AUSTRALIA

THE UNIVERSITY OF WESTERN AUSTRALIA

High-level (Melanie and Steven)

Successes

- Defined by publication numbers and completion of large-scale observing programs (EoR, GLEAM)
- Array stability, uptime, utilisation

Moving forward

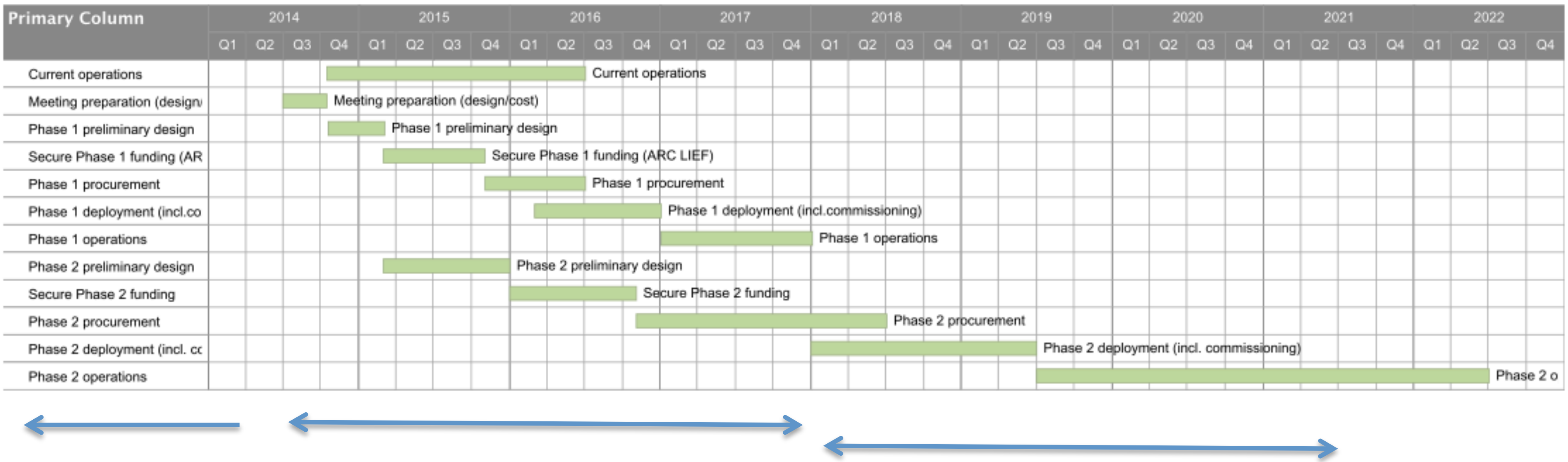
- Partners to stay in collaboration or buy in. Details to be finalised by December meeting
- Participant interest may depend on what is being proposed. Configuration matters.

Funds:

- To be gathered from partners and LIEF
- Phase 1: approx $3M

Off by 1 error?

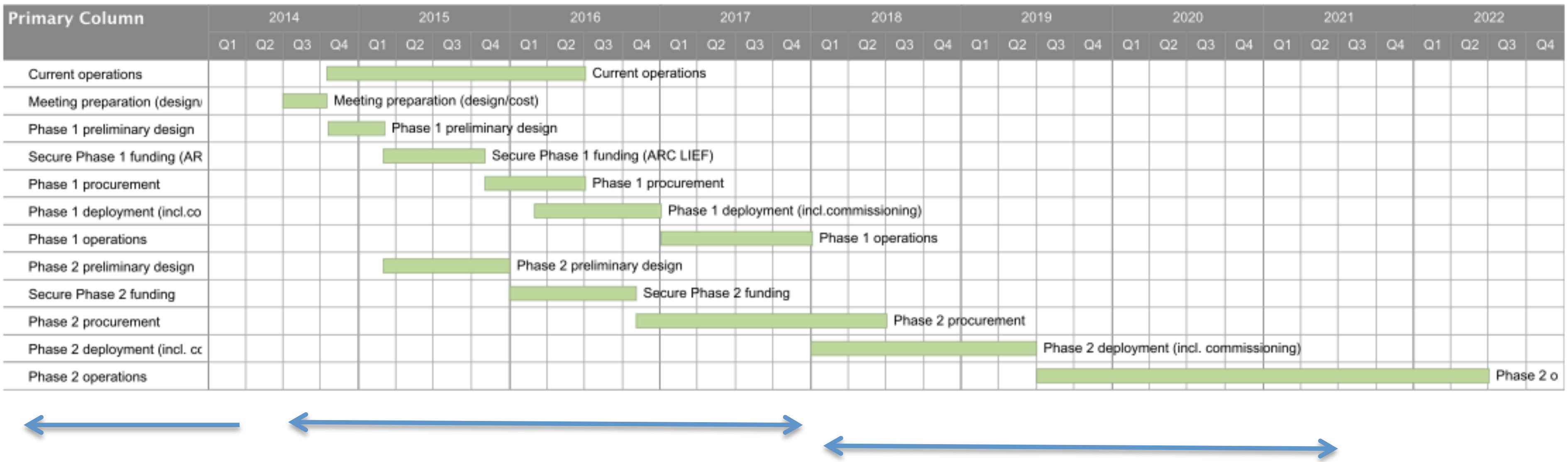
Cost/schedule



"Phase 0" "Phase 1" "Phase 2"

Off by 1 error?

Cost/schedule



~~"Phase 0"~~ ~~"Phase 1"~~ ~~"Phase 2"~~

"Phase 1" "Phase 2" "Phase 3"

Fortran array indexing scheme suggested.

Current MWA capabilities

Tingay et al. 2013, PASA, 30, 7
(MWA system description paper)

- 128 tiles; MORE!
- 3 km maximum baseline; MORE!
- Configuration balanced between short baselines for EoR and longer baselines for surveys/solar; Good
- 80 – 300 MHz frequency range; MORE!
- 30 MHz processed bandwidth. MORE!

Science priorities and issues

Will systematics beat us?

- Foregrounds:
  - point sources ✔
  - extended sources ✔
  - smooth galactic emission ✔ and polarisation ~
- Instrumental:
  - RFI ✔
  - coarse band edges ~
  - cable reflections ~
- Algorithms:

Limiting factors unknown at this time

EoR

- On paper, we have enough data to detect EoR
- Still many unknowns
- There are “features coming through the signal path that we'd rather see the back of.”
- Known known systematics:
  - Coarse band edges, cable reflections
- Known unknowns: polarised foregrounds

Science priorities and issues

EoR

- Desired:
  - More tiles
  - redundant design "particularly compelling”
  - 50 MHz -> x-ray heating signature

Utility of even longer baselines not quantified.

Excellent proof of concept for **hybrid** array design -> HERA

New software pipeline?

Science priorities and issues

EoR

- 1D power spectrum simplest and most likely option for first MWA power spectrum

1D Power Spectra - SNRs - FG bias removed

$$\Delta P = \left(\sum_k \left(\mathcal{H}^\dagger C^{-1} \mathcal{H}\right)^2\right)^{-1/2} \simeq \frac{1}{\sqrt{M_k}}(N(k) + C_{\mathrm{FG}}(k) + P_{21})$$

	α/σ_α	$\Delta_p^2/\sigma_{\Delta p2}$
Current	8.3	6.8
256TCore	26.9	15.6
256TArms	21.3	13.2
Smooth BP	8.7	7.1
Hexagonal	55.6	25.2
Hexagonal (perturbed)	51.9	22.5

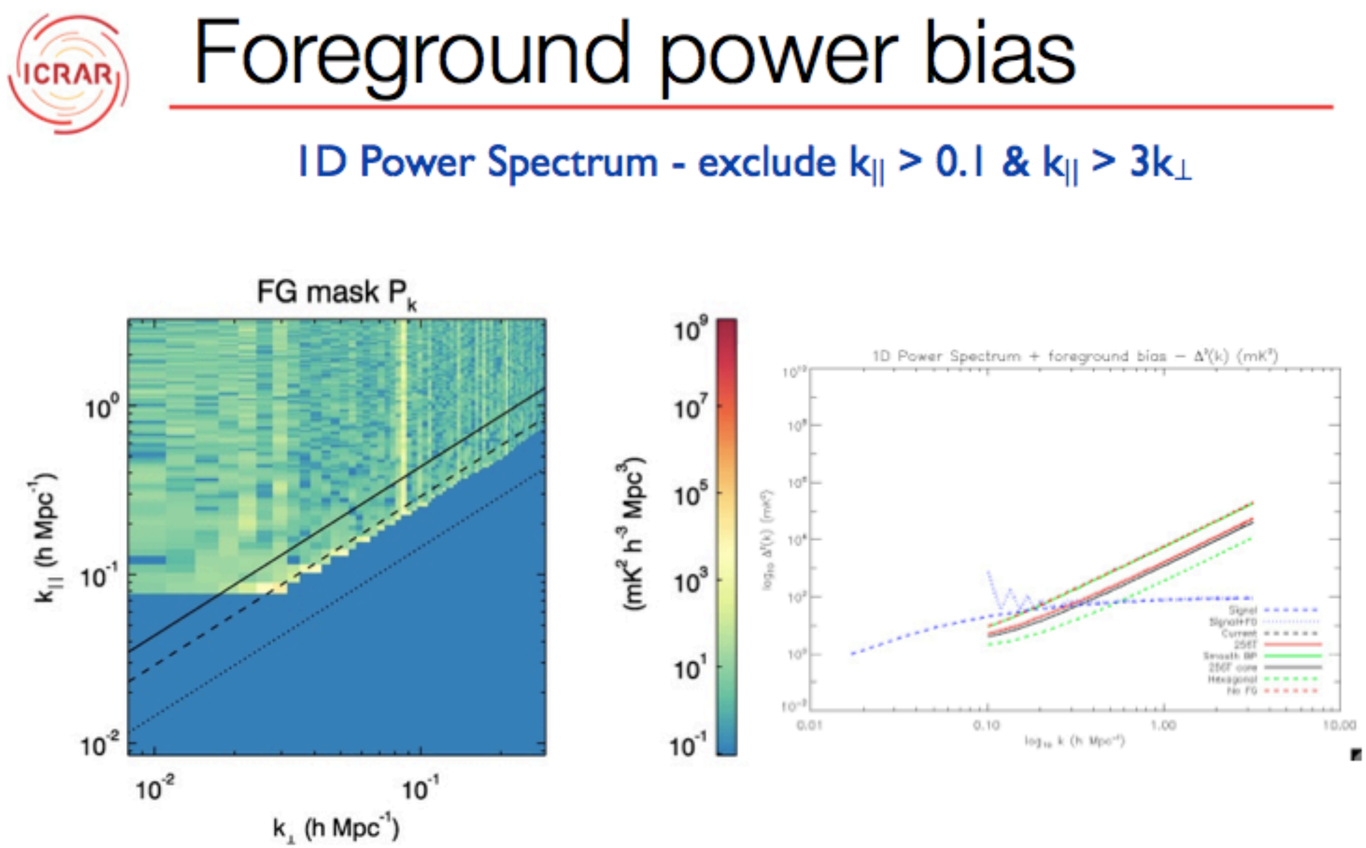
Smooth BP → Nominal sensitivity gain, but importance is in *calibration*

Hexagonal (perturbed) → Redundancy not crucial if sensitivity in right k-modes. Benefit in *calibration of systematics*

Science priorities and issues

EoR

- But it is still hard, even in the best case

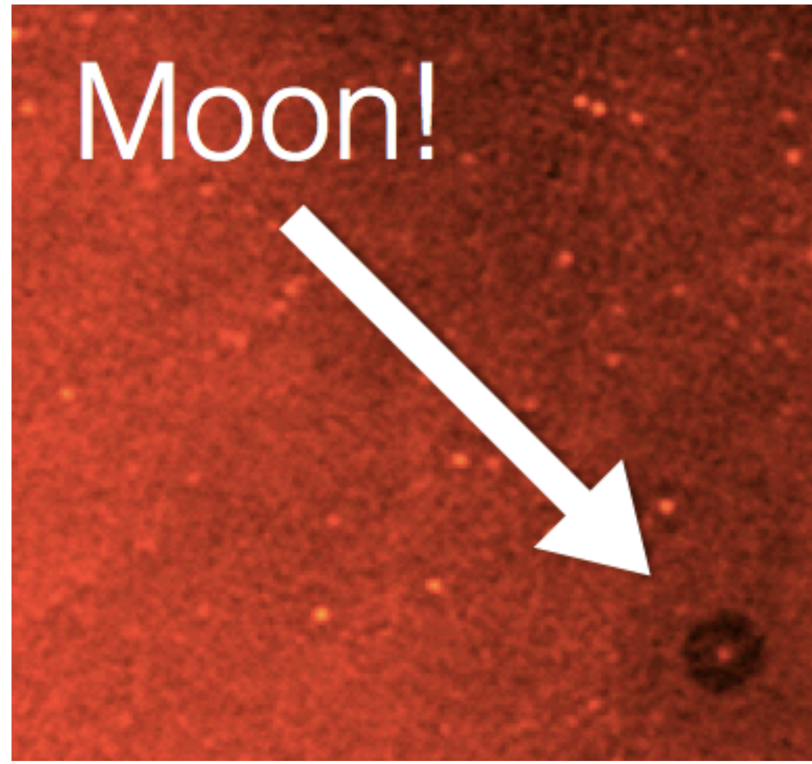


Science priorities and issues

EoR

- “Niche” EoR experiments are possible & desirable (moon global signal)

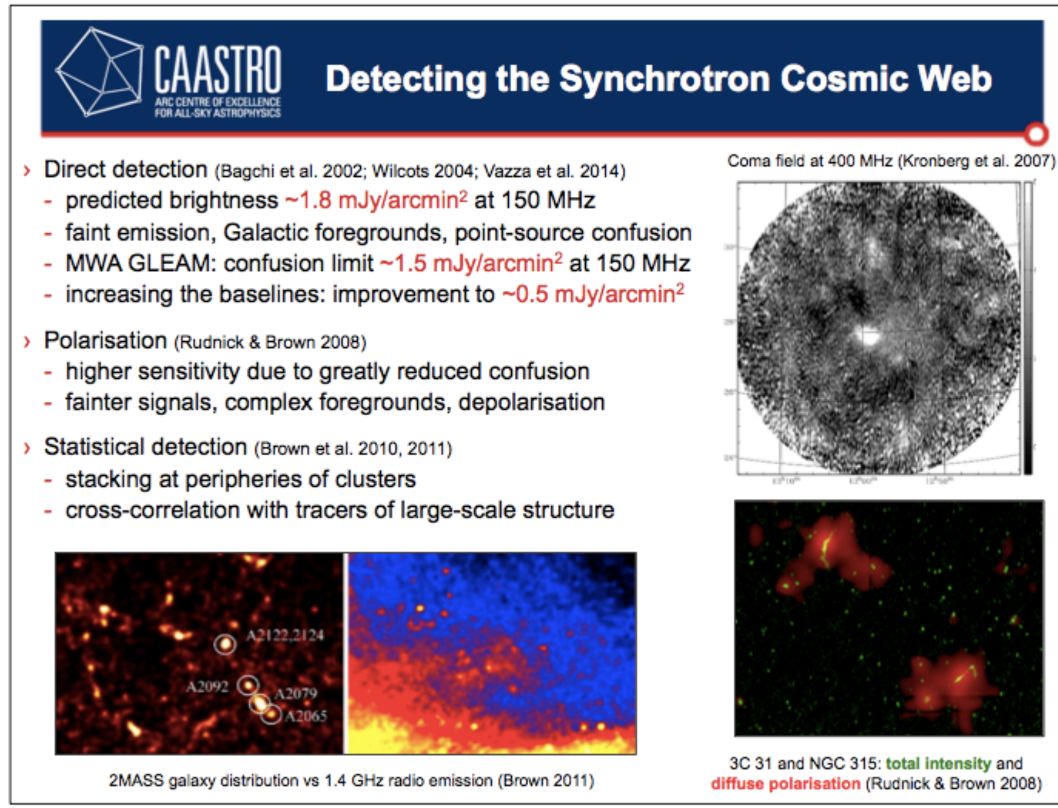
- The optical astronomers are meeting us half way
  - We’re entering the age of optical near IR IFU multi-object spectroscopy
  - Working up to reionisation from low z



Science priorities and issues

Cosmic web

- New frontier
- "The only game in town with this image quality"
- "In box seat to make huge progress on the cosmic web"
- Faraday rotation from background AGN. (B field)
- 21cm emission from the WHIM (neutral gas)
- Fast radio bursts (ionised gas)
- Ron: "Transformational"



Array requirements very similar to EoR

Science priorities and issues

Survey

- Long baselines! Goals:
  - beat confusion
  - Resolve components of complex sources
  - 12 km-> similar res to NVSS. Not going to happen in phase1
- New science: find fading and/or rotating radio lobes
- Exotic sources: find high redshift counterparts of GPS sources due to negative k-correction factor

Science priorities and issues

Survey

- Supertile! (aka correlating individual dipoles)
- Looks good on paper
- Ron: What are the effects of packing tiles in close together? Has anyone looked at that?
    - We already know there is significant mutual coupling between bowties. OK for beamforming/PB modelling. Not good for correlation?

Science priorities and issues

Survey

- Processing and storage requirements for 256 with long baselines gets formidable
- Need to get smarter about most aspects of processing
- Doing a limited chunk of sky (e.g. zenith drift) makes life easier

GLEAM-X: MWA-X Phase2

Pipelines

- Phase 1:
  - Cotter **800** kSU
  - ~~CASA 288 kSU~~
- Phase 2:
  - WSClean & self-cal: **50,000+** kSU

Some comparisons...

Total national provision for 2015: **137,000 kSU**

Resulting data products:

- **16** PB raw visibilities (gpubox fits files)
- **10** PB calibrated visibilities
- **600** TB image products
- **6** TB Stokes I 30MHz snapshots (minimal image product)
- (Neglecting RM synthesis, spectral line products)

Total MWA Operations data in 1.5 yr: **2.5 PB**

Current GLEAM archive storage capacity: **200 TB**

Assuming we simply repeat GLEAM's observing strategy

Thermal noise: **1.2** mJy
Confusion noise: **0.1** mJy

Science priorities and issues

Spectral lines

- 10 kHz OK for HI abs, Carbon RRLs
- 1 kHz needed for other lines
- Edges of coarse channels bad (and for EoR)

Science priorities and issues

Slow transients/variables

- Various science programs
- Stokes V a way around confusion
- Imaging and calibration hard

Spinoff science: ionosphere

(likewise polarisation data)

- *Only possible due to MWA's wide field of view*

Science priorities and issues

Fast transients & pulsars

- Higher time resolution (~5 microsec) desired
- More core tiles = more powerful pulsar instrument

Future MWA capabilities

Tingay et al. 2013, PASA, 30, 7
(MWA system description paper)

- 128 tiles; MORE!
- 3 km maximum baseline; MORE!
- Configuration balanced between short baselines for EoR and longer baselines for surveys/solar; Important!
- 80 – 300 MHz frequency range; MORE!
- 30 MHz processed bandwidth. MORE!

Plus…

- Finer time resolution, pulsar beams
- Finer spectral resolution

But… don't stuff it up

- Current MWA snapshot images appear to be exquisitely balanced between classical and sidelobe confusion
- Longer baselines with poorer u,v coverage == sidelobe confusion dominant
- If so, MUCH harder imaging problem (ala LOFAR), snapshots will not be better

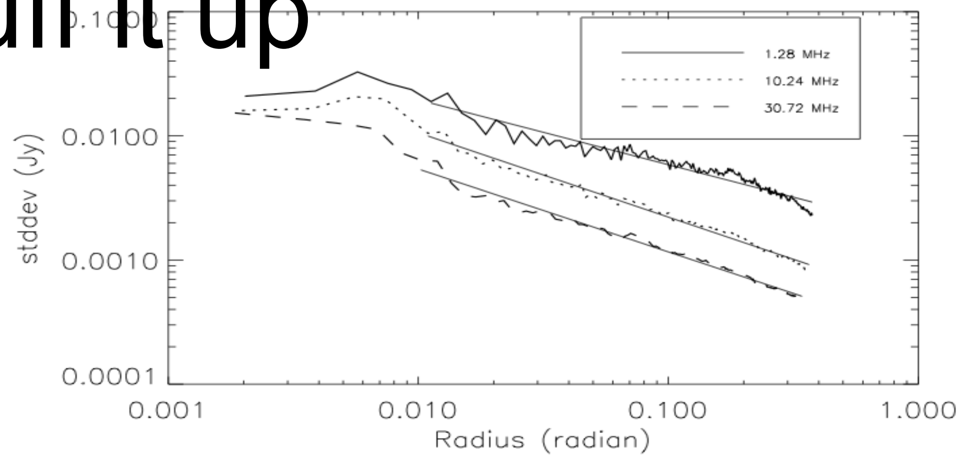


Figure 1. The standard deviation of the MWA synthesised beam vs radius for a 112 s snapshot centred on 155 MHz. Shown are the synthesised beams for 1.28, 10.24 and 30.72 MHz multi-frequency synthesis images with robust=0.

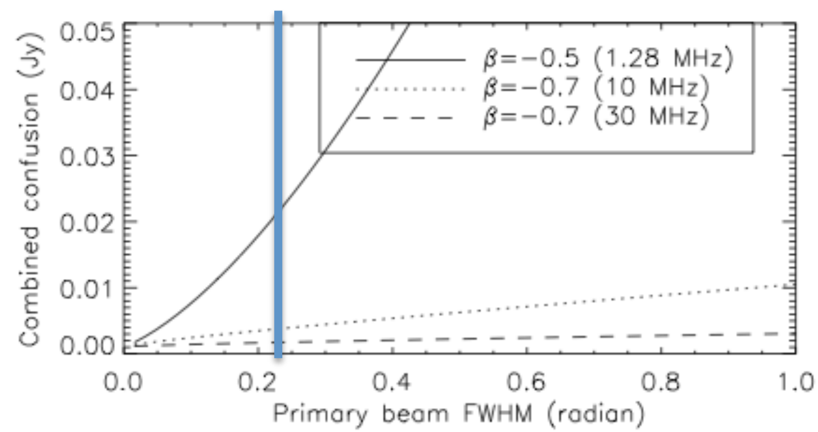
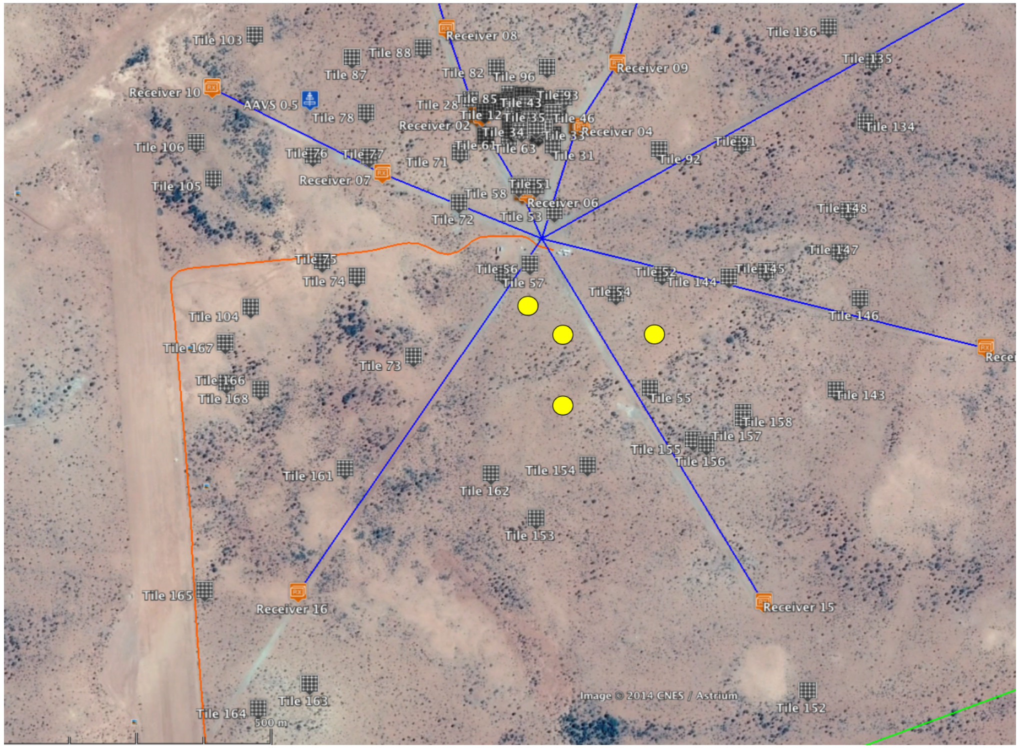


Figure 3. Total combined confusion noise for a snapshot 155 MHz, robust 0 MWA synthesised beam with varying hypothetical primary beam sizes. Values of β = -0.5 and -0.7 are used to represent the 1.28, 10.24 and 30.72 MHz synthesised beam properties. $q = 8$. The classical confusion for this case is 5 mJy.

MWA -- SKA-low linkage

- AAVS1 to add SKA-low station(s) in MWA infrastructure
- Intent is to integrate signal into MWA signal path, hence correlate
- AAVS1 mutually beneficial with MWA



New software pipeline?

New software pipeline!

people!

- Right team of people, critical mass
- One location
- Real data
- Well defined goals
  - realistic
  - No shifting goalposts
  - Do no aim to solve everything at the start
  - Resist bells and whistles

What you said…

“Box seat”

“hard to stuff-up”

“Shirtfronting the opposition”

“The only game in town”

“Transformational”

“The best is yet to come”

“Simply blows everybody else out of the water”