Producing the first image from SKA-Low AA0.5

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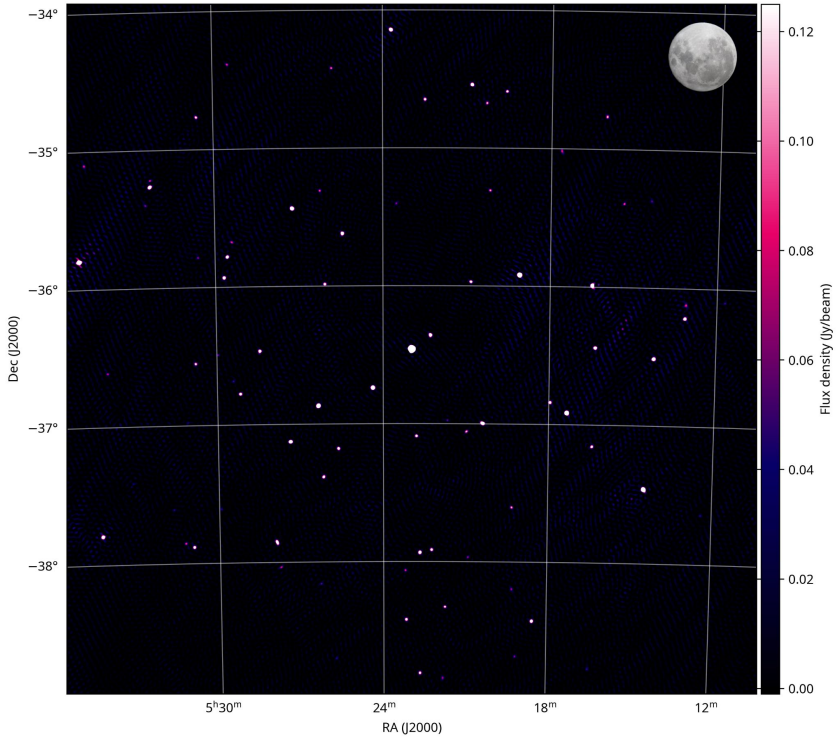
29 May 2025

Outline

- Overview of SKA-Low AA0.5
- Initial commissioning challenges
  - Can we point the stations?
  - Does the correlator fringe stop?
  - Can we calibrate the array?
- First image - a closer look



We recognise and acknowledge the Traditional Owners of the lands on which our facilities are located, and pay our respects to their Elders past and present.

Australia's Indigenous people are the first scientists and have long standing knowledge of the Universe that we continue to build on today.

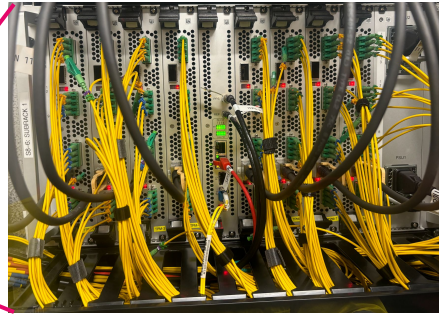
We acknowledge the Wajarri Yamaji as the Traditional Owners and native title holders of Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, where we are building the SKA-Low telescope in Australia.

We acknowledge the Whadjuk Noongar as the traditional owners of the land where our Science Operations Centre is situated in Perth, and the Southern Yamatji as the traditional owners of the land where our Engineering Operations Centre is situated in Geraldton.

I also pay my respects to all First Nations people in attendance.

A collaborative painting from Aboriginal Yamaji artists from WA for the SKAO *Shared Sky* exhibition. Credit: Yamaji Arts Centre.

What does a station look like?

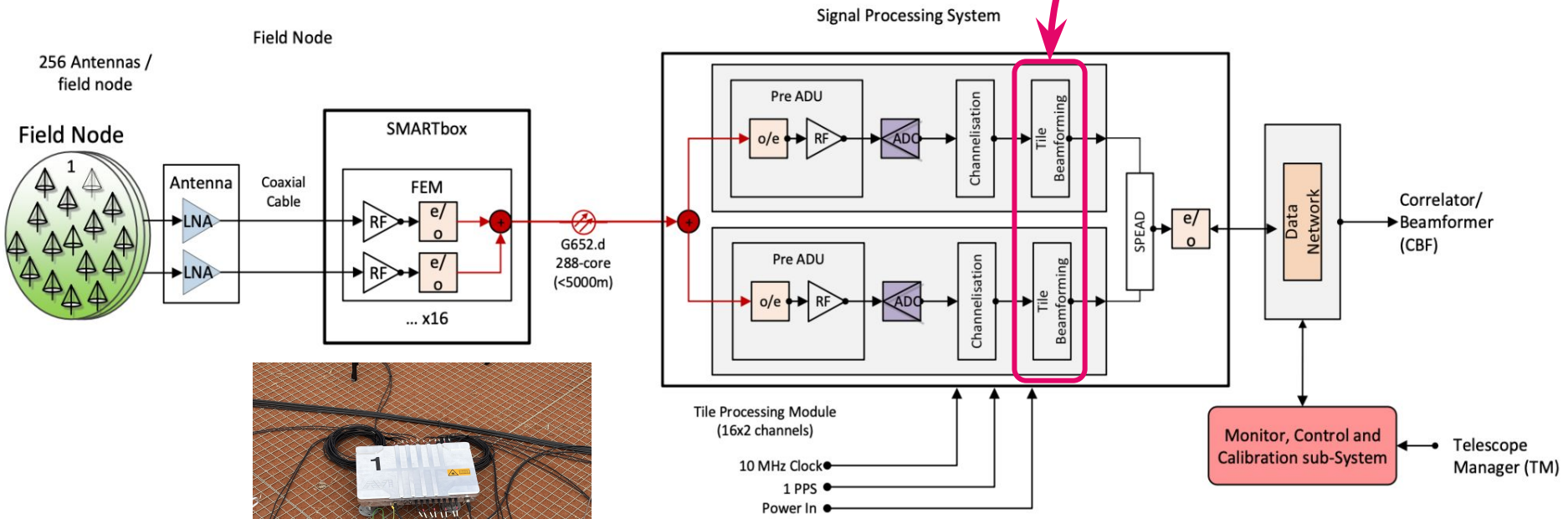


Few 100m of fibre (not really in a tangled mess)

What does a station look like?

This bit "points" the station somewhere

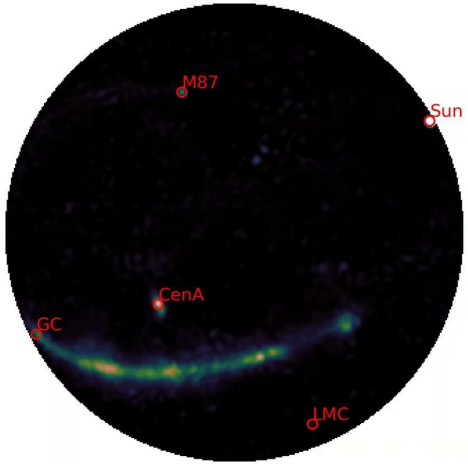
(or we can record the antenna data in other ways…)

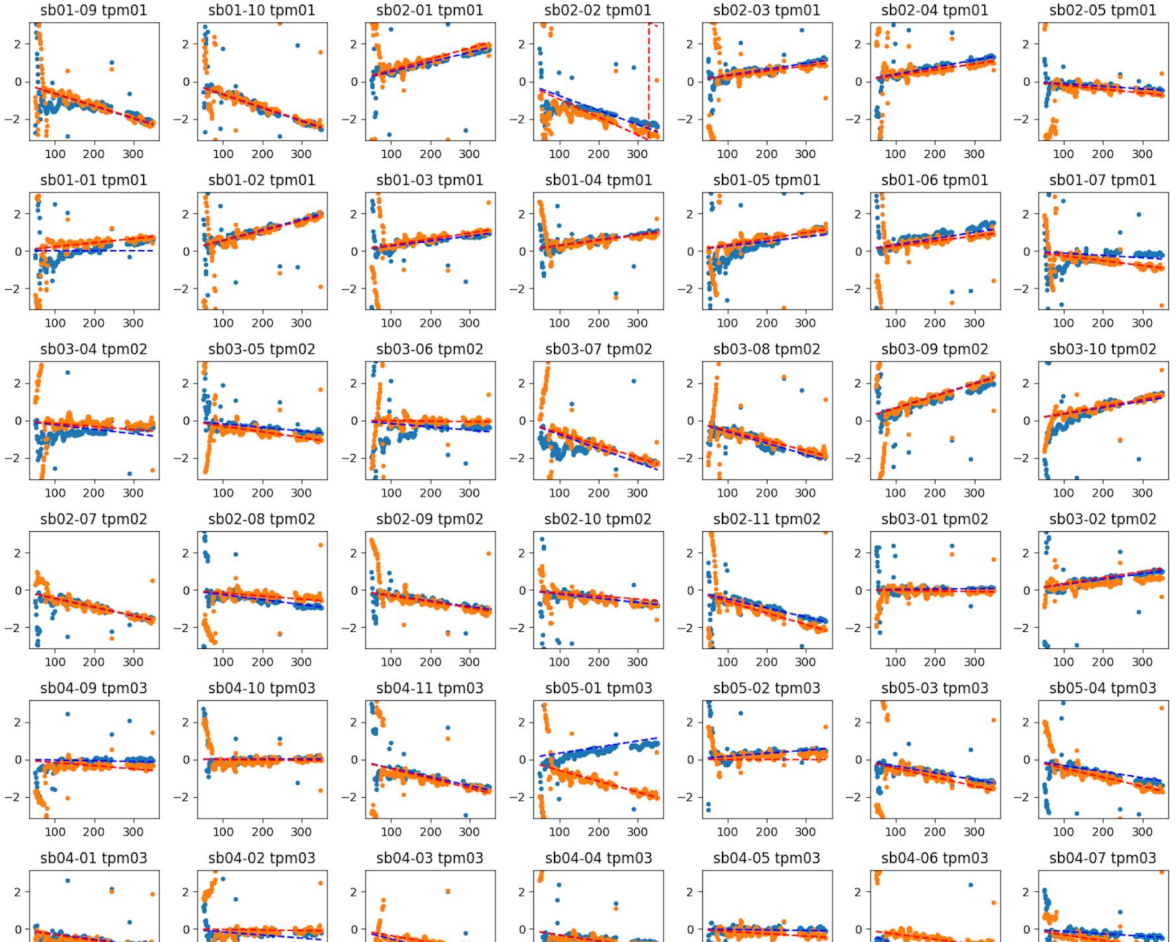


New SMARTbox design

Challenge 1: can we point the stations?

S8-6 (XX+YY) 2024-07-05 08:54:55.0 UTC





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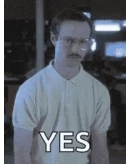
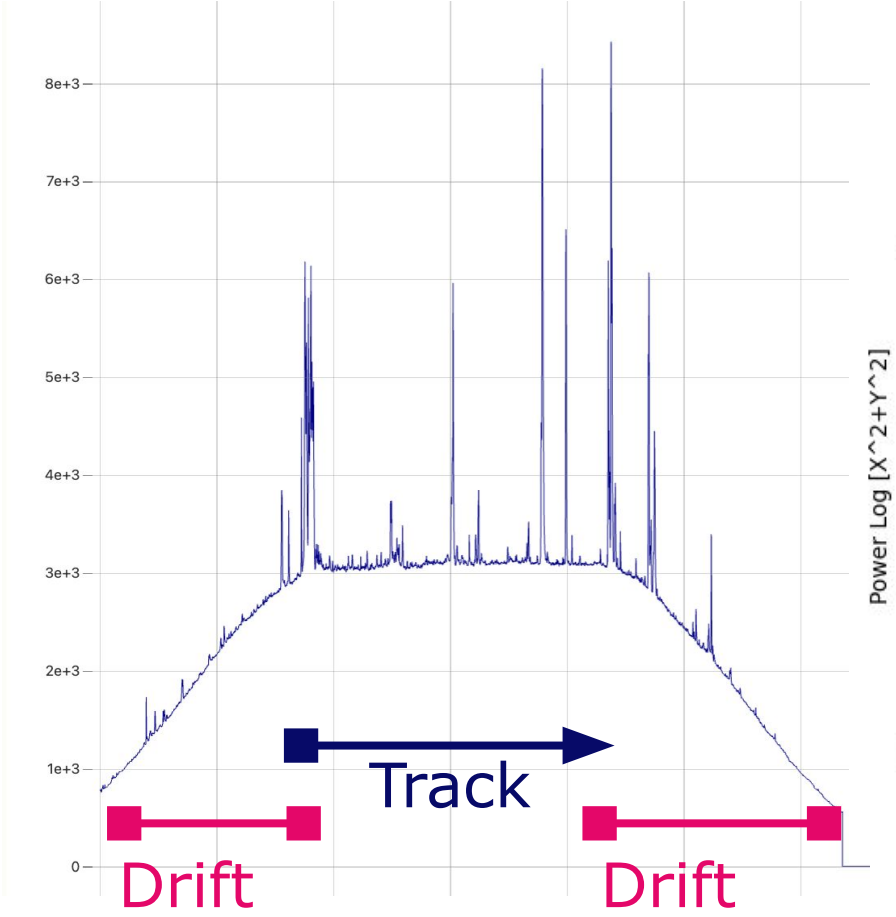
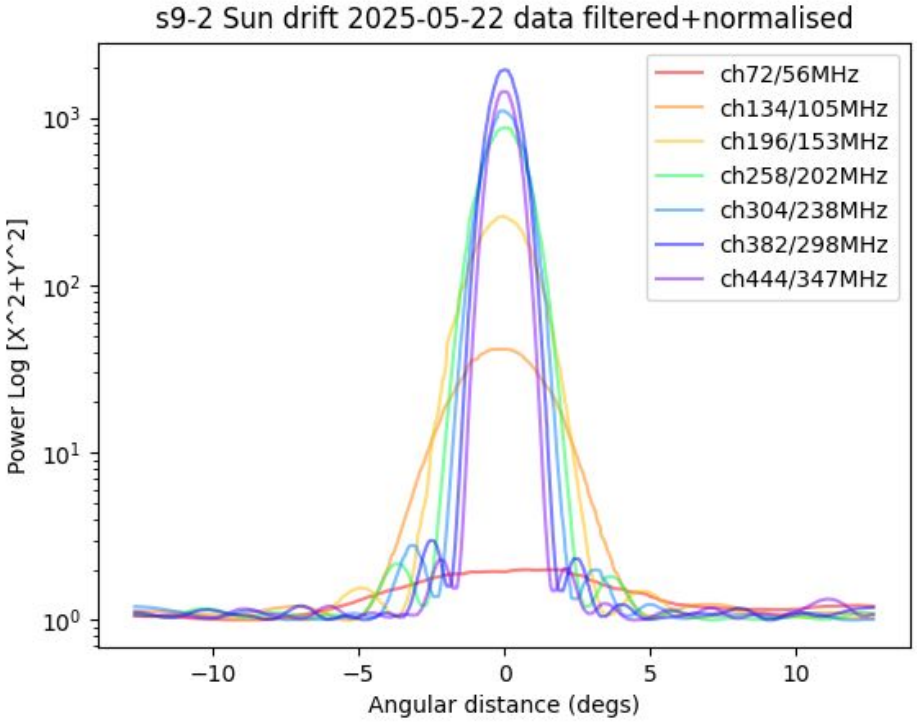
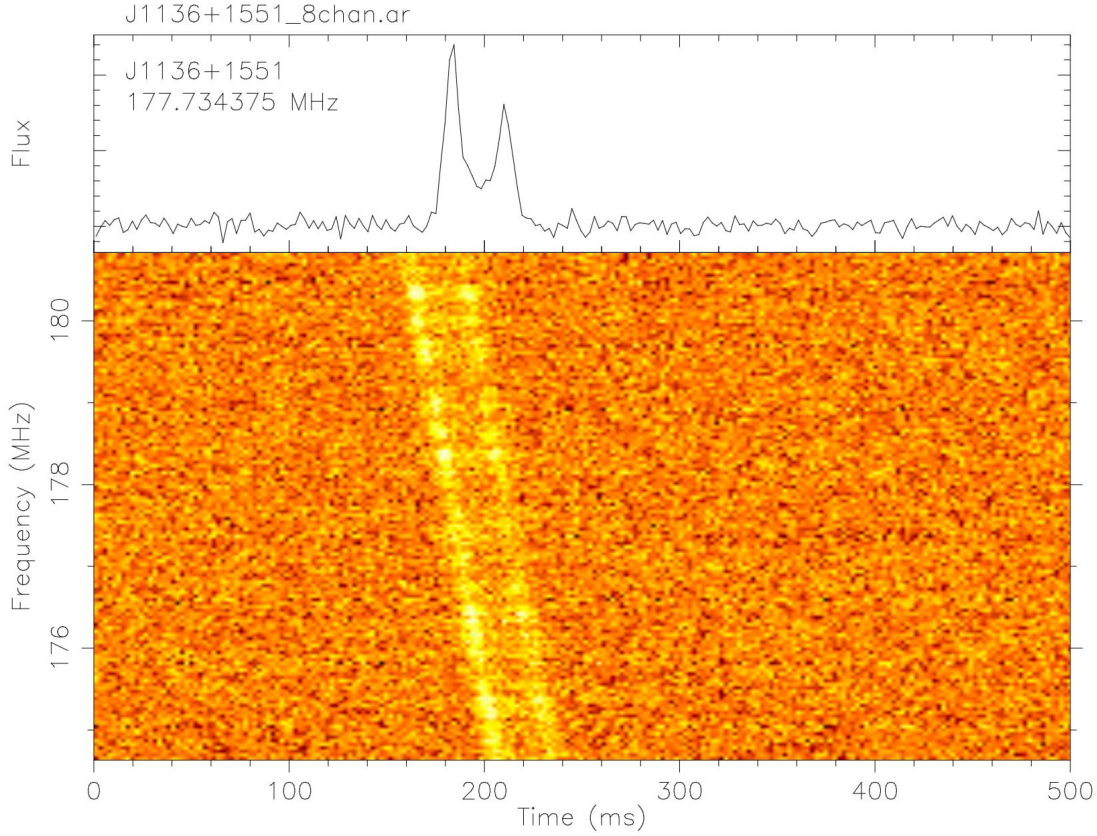


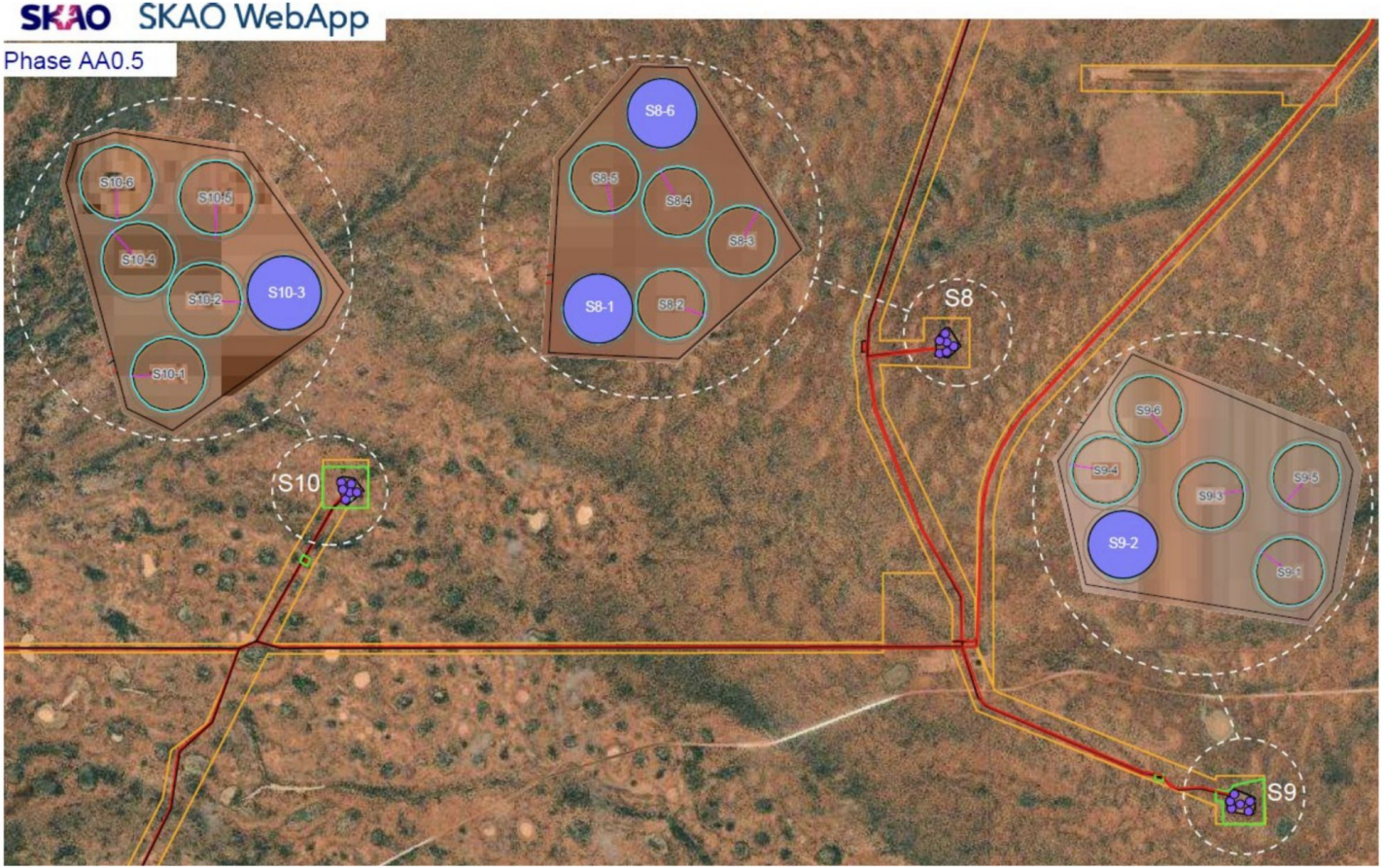




Single station pulsar detections

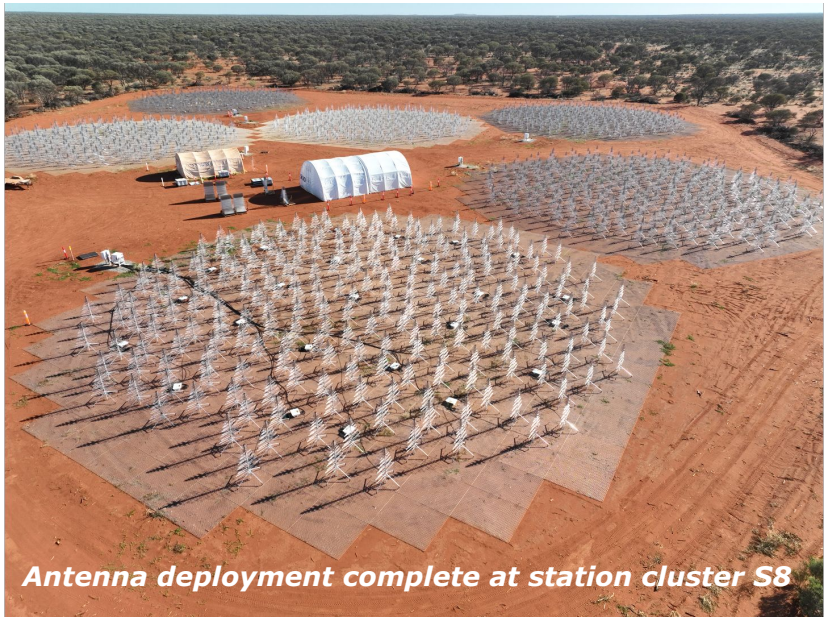


What does the array (AA0.5) look like?

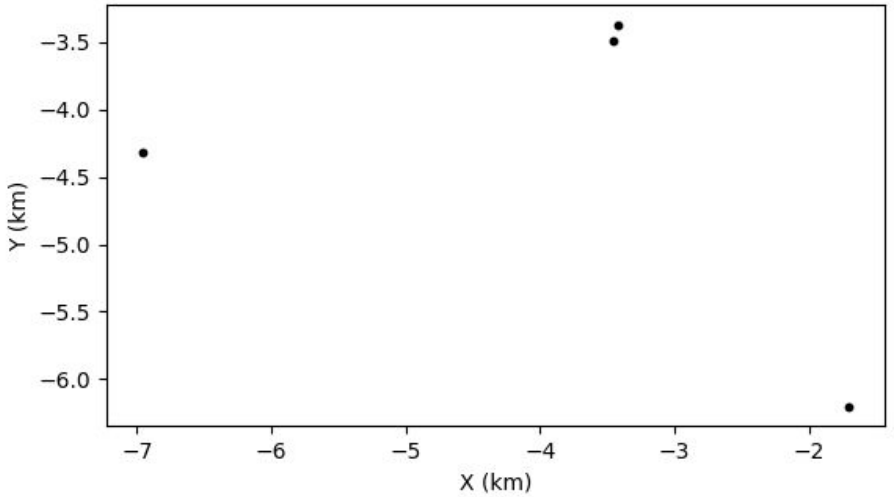


What does the array (AA0.5) look like?

Antenna deployment now complete for 21+ stations (AA1+)
Expecting 16+ stations online for observations later this year

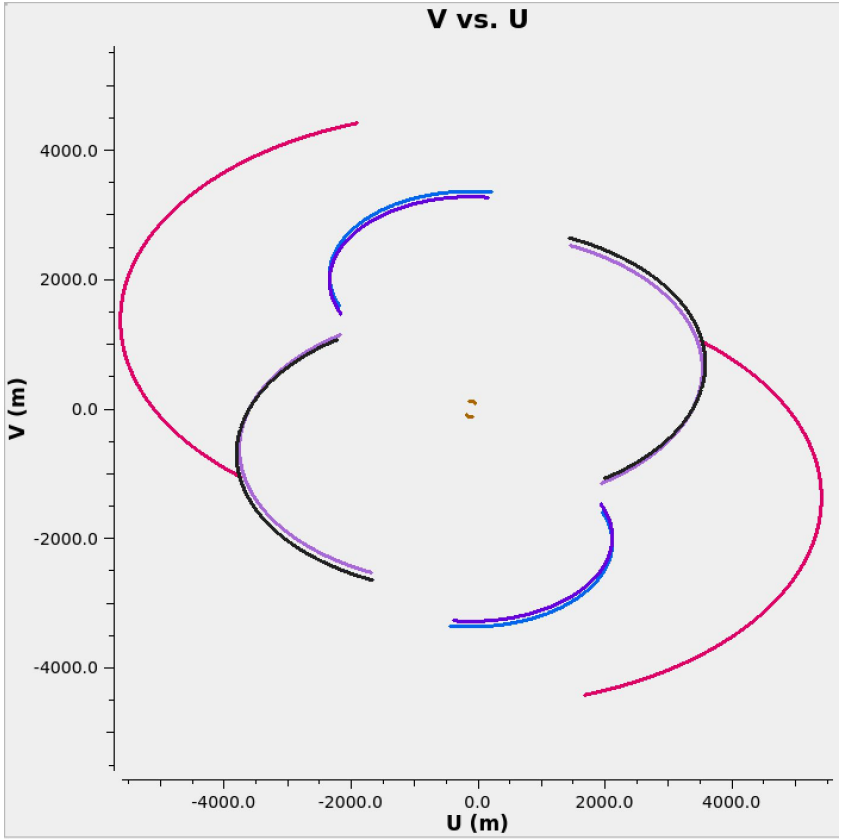


Antenna deployment complete at station cluster S8

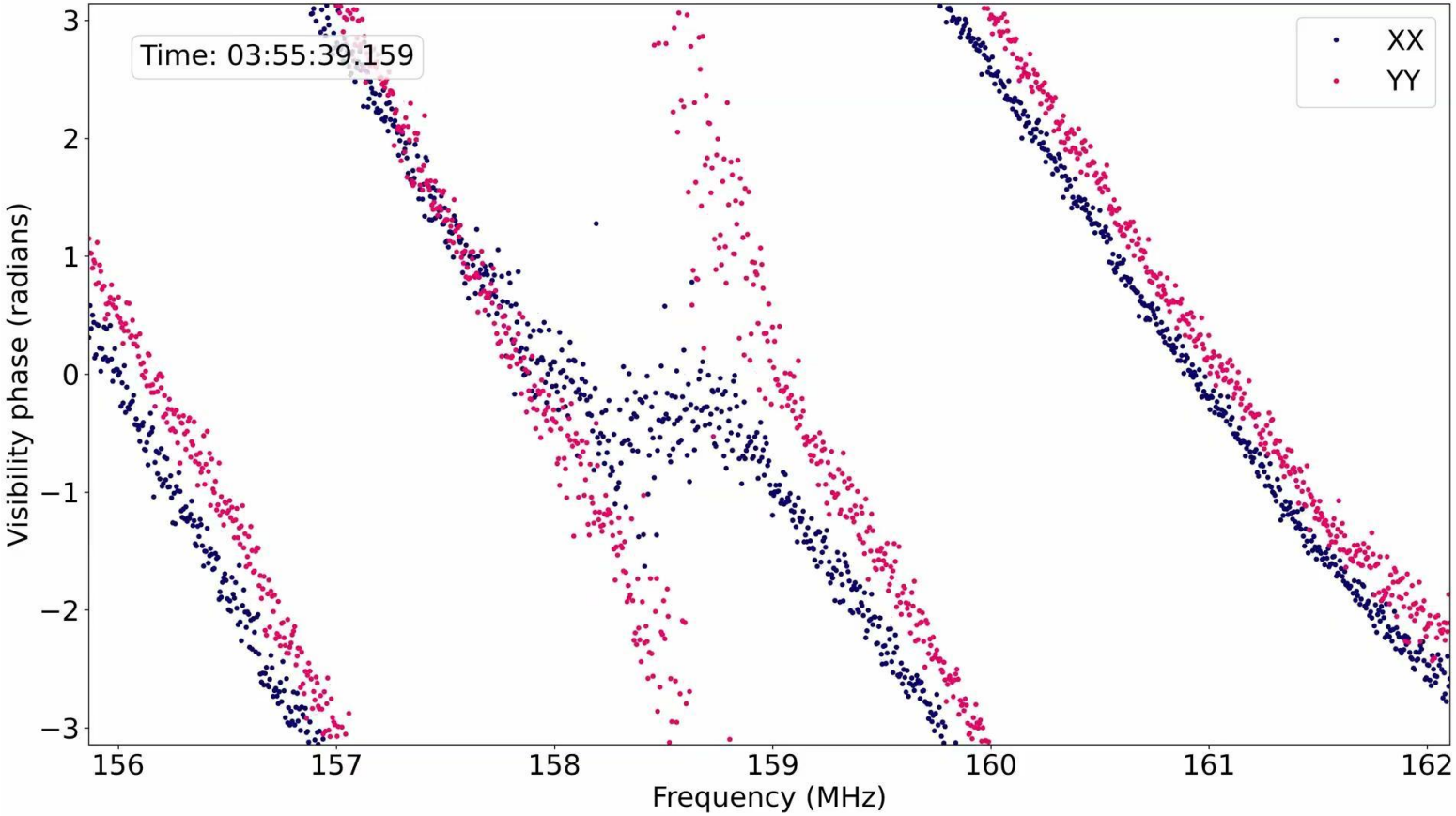


What does the array (AA0.5) look like?

- Limited imaging capability due to sparse uv coverage
- Limited calibration capability due to so few stations
- But this is not a blocker
- Bandwidth helps quite a bit, so recent progress to unlock the full 75MHz is quite important for our next steps (mentioned later)

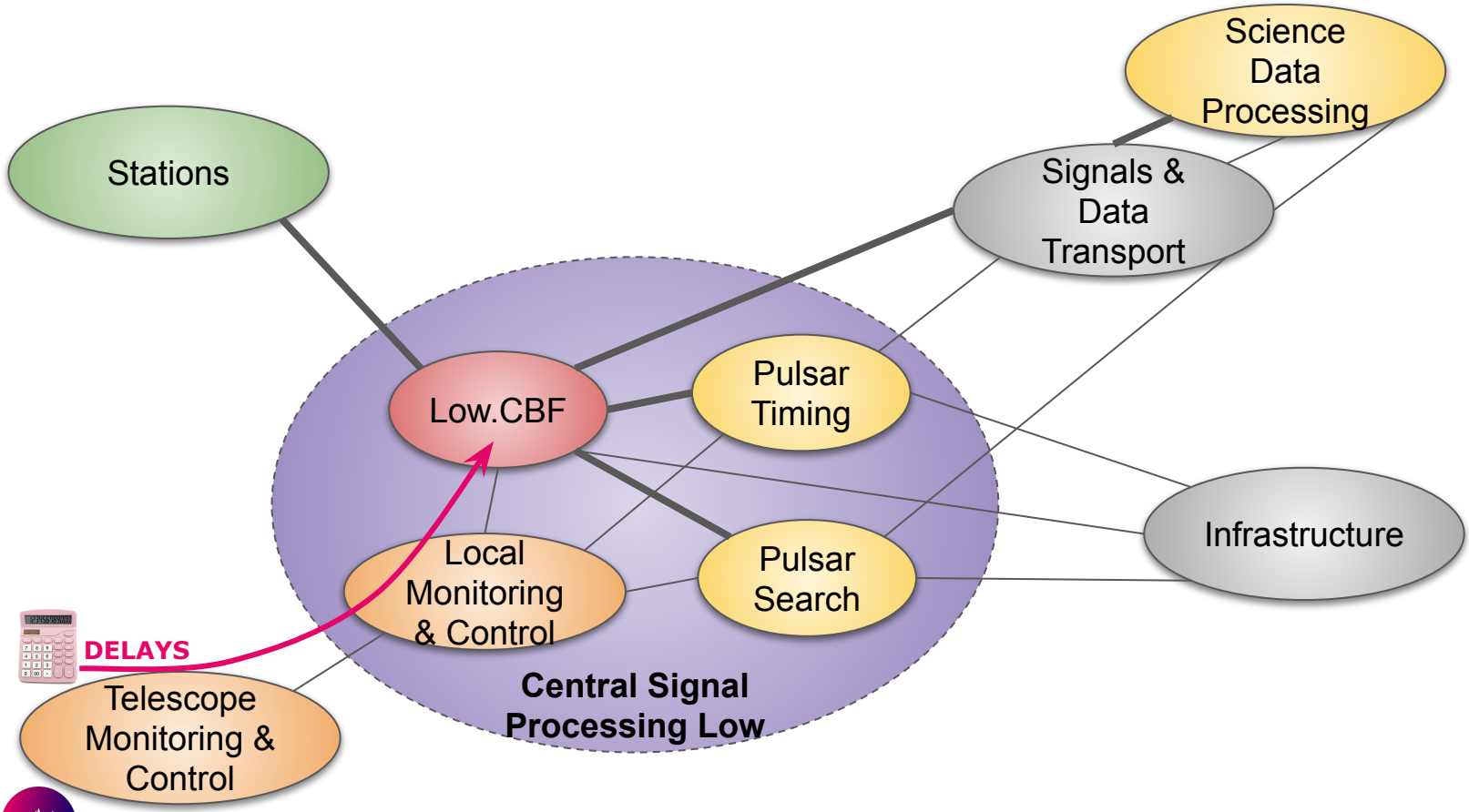


Challenge 2: can we fringe stop?



Challenge 2: can we fringe stop?

Subsystem map courtesy of: perentie SKA Low Correlator & Beamformer



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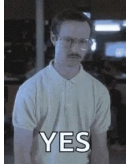
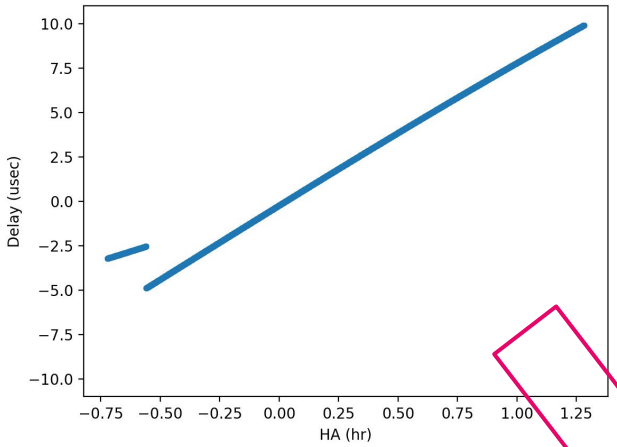
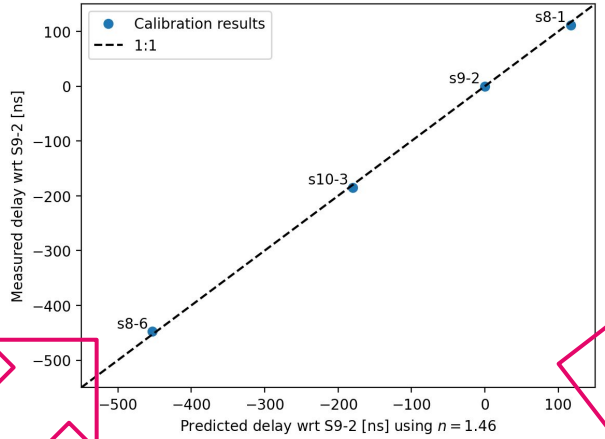
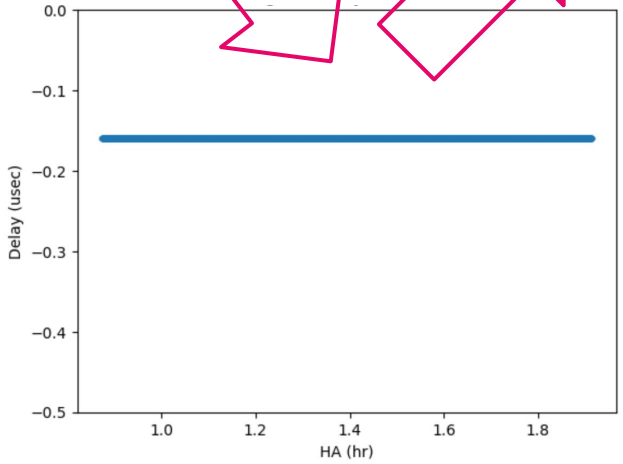
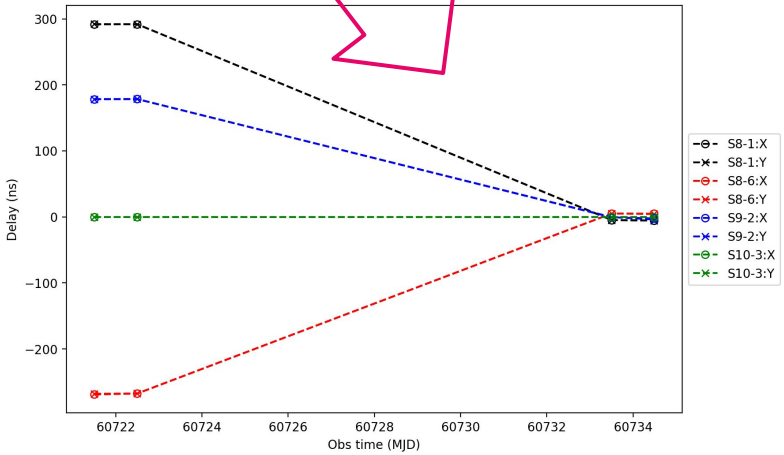










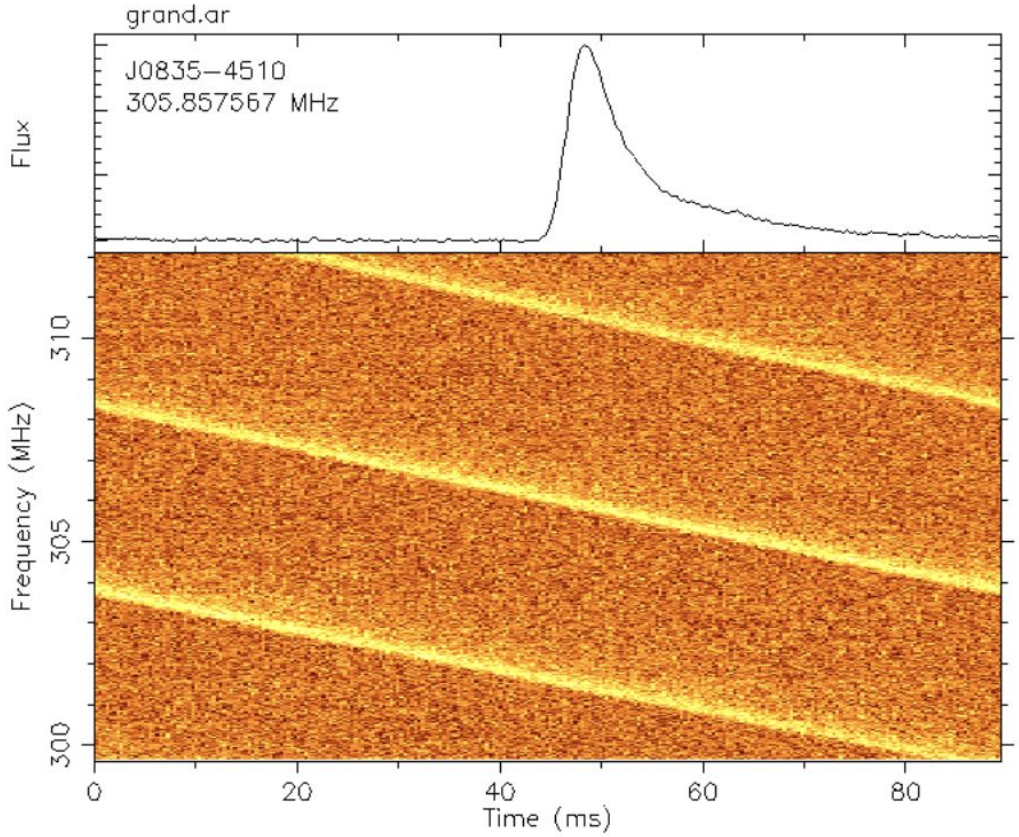
Side point: tied array beamforming (WIP)

Vela

Four stations in tied array (semi coherently)

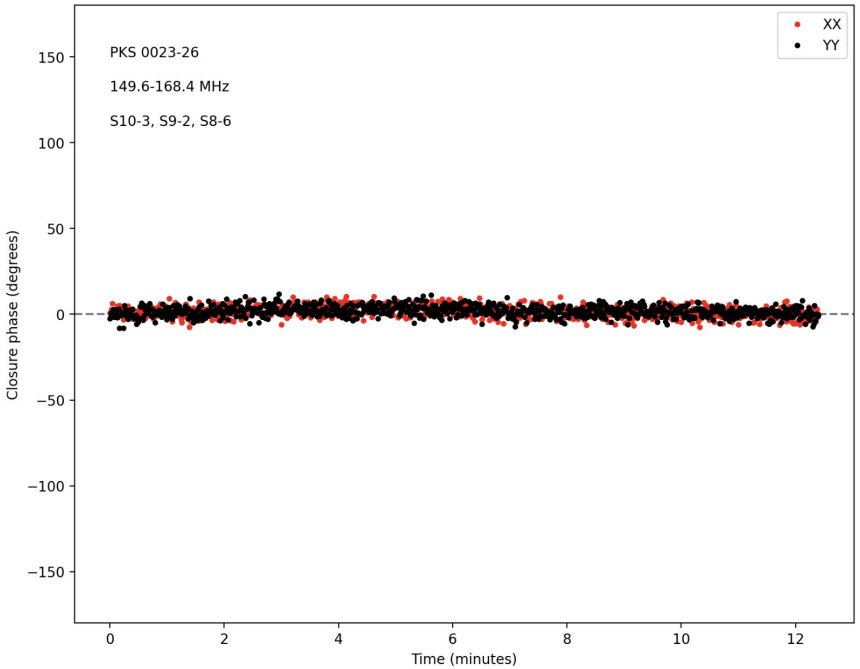
12.5 MHz bandwidth

SNR ~ 650



Challenge 3: can we calibrate the array?

Initial signs promising, phase closure achieved early on



Observations toward first image

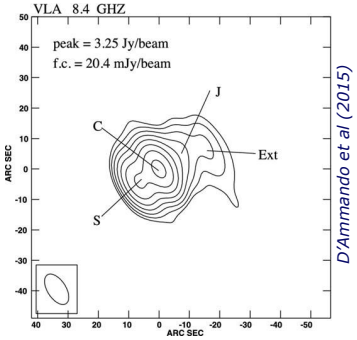
75 MHz bandwidth was not yet reliable, so stitched together 4x 6.25 MHz tracks to build up some aggregate bandwidth

Objective: demonstrate array (self-)calibratability

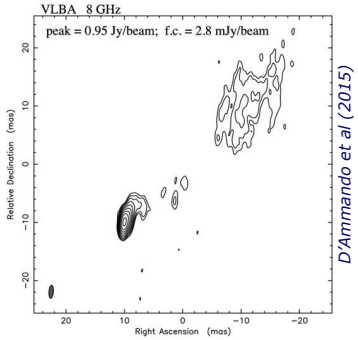
Date / UTC time range	Coarse channel range	Frequency range (MHz)	Elapsed time
2025-02-15 / 09:02:05 - 15:02:01	192 - 199	149.63 - 155.84	6 hr
2025-02-16 / 07:57:53 - 15:57:47	200 - 207	155.88 - 162.09	8 hr
2025-02-27 / 08:53:53 - 15:23:48	208 - 215	162.13 - 168.34	6.5 hr
2025-02-28 / 07:42:39 - 15:42:35	216 - 223	168.38 - 174.59	8 hr

First image: target source = PKS 0521-36

Compact, bright source - ideal for first tests

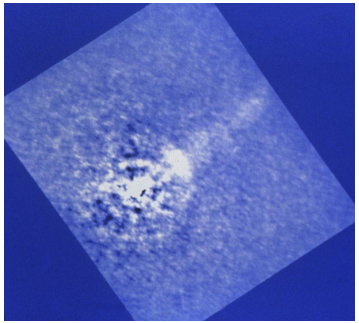


D'Ammando et al (2015)

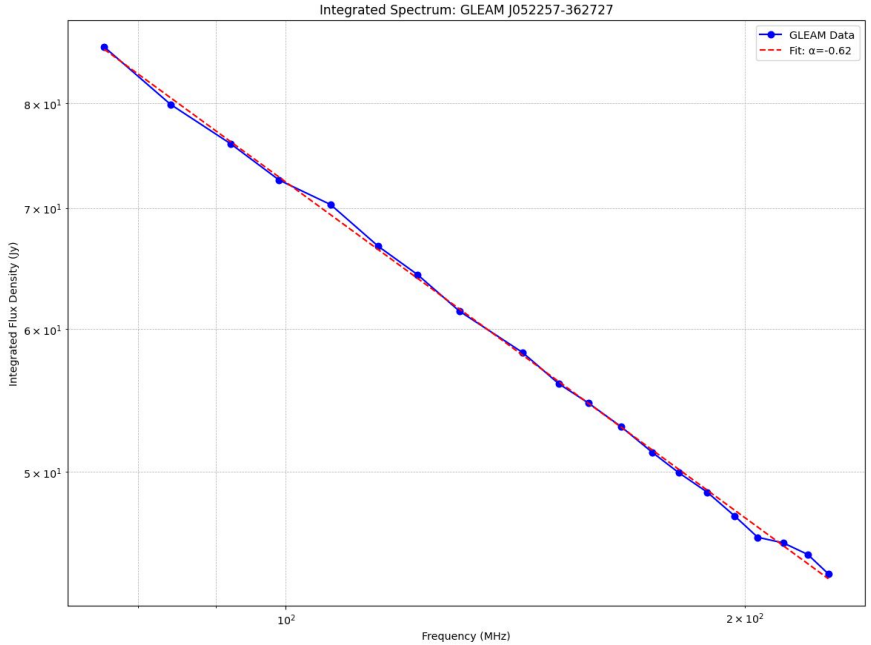


D'Ammando et al (2015)

Of note: jet seen in radio and optical, like M87 !



NASA, ESA, and STScI



Calibration process

In summary:

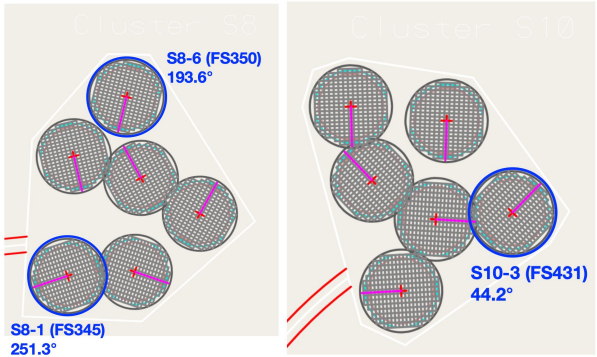
- Delay calibration
- Data averaging
- Station “derotation”
- Bandpass calibration
- Gain calibration on local sky model
- Imaging and source finding
  - Sky model complexity increasing in selfcal loop
  - Sky model constrained by GLEAM-X
- Final imaging (combining all 4 epochs)

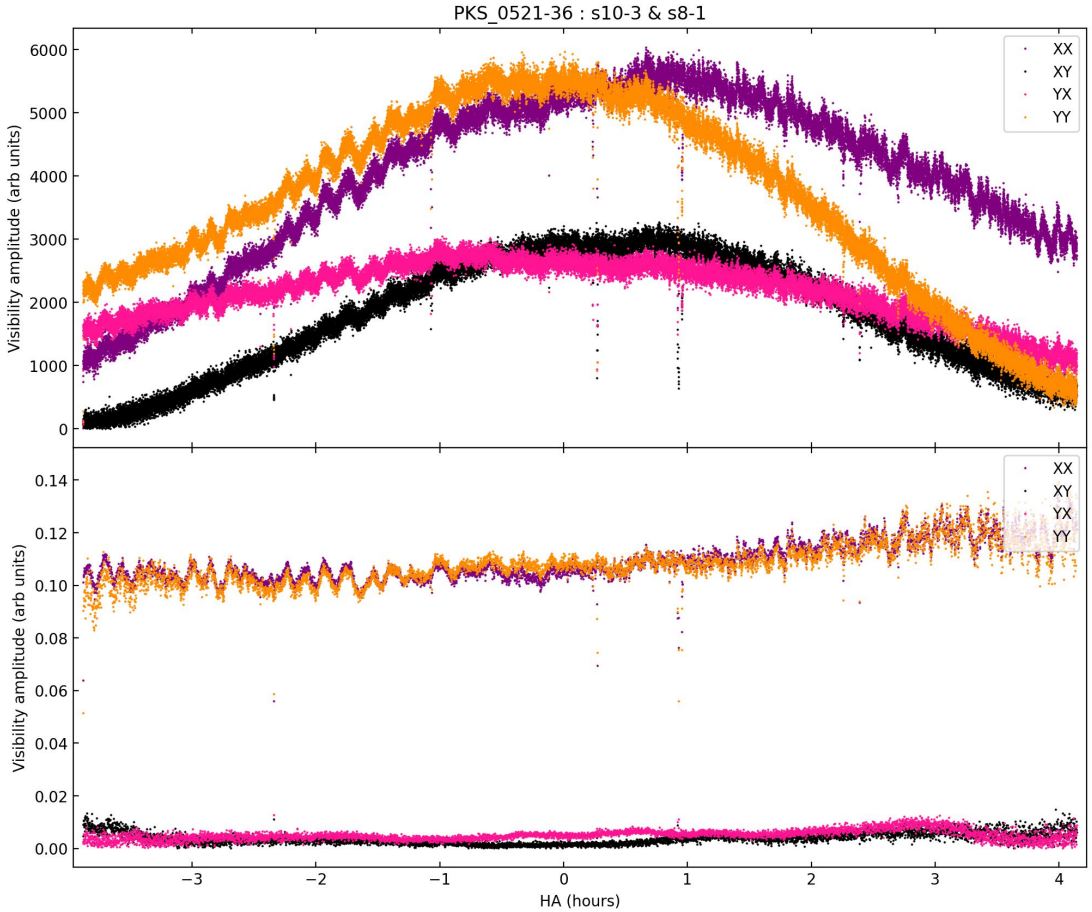
This was a manual process (CASA and bespoke scripts)

SDP pipelines are now becoming available for testing and basis for future work

Station derotation

Shown here for the baseline between S8-1 and S10-3 (relative angle 27.1°) ~3.6 km baseline





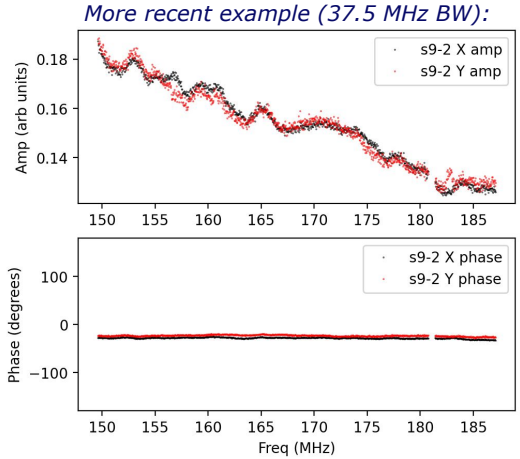
Bandpass calibration

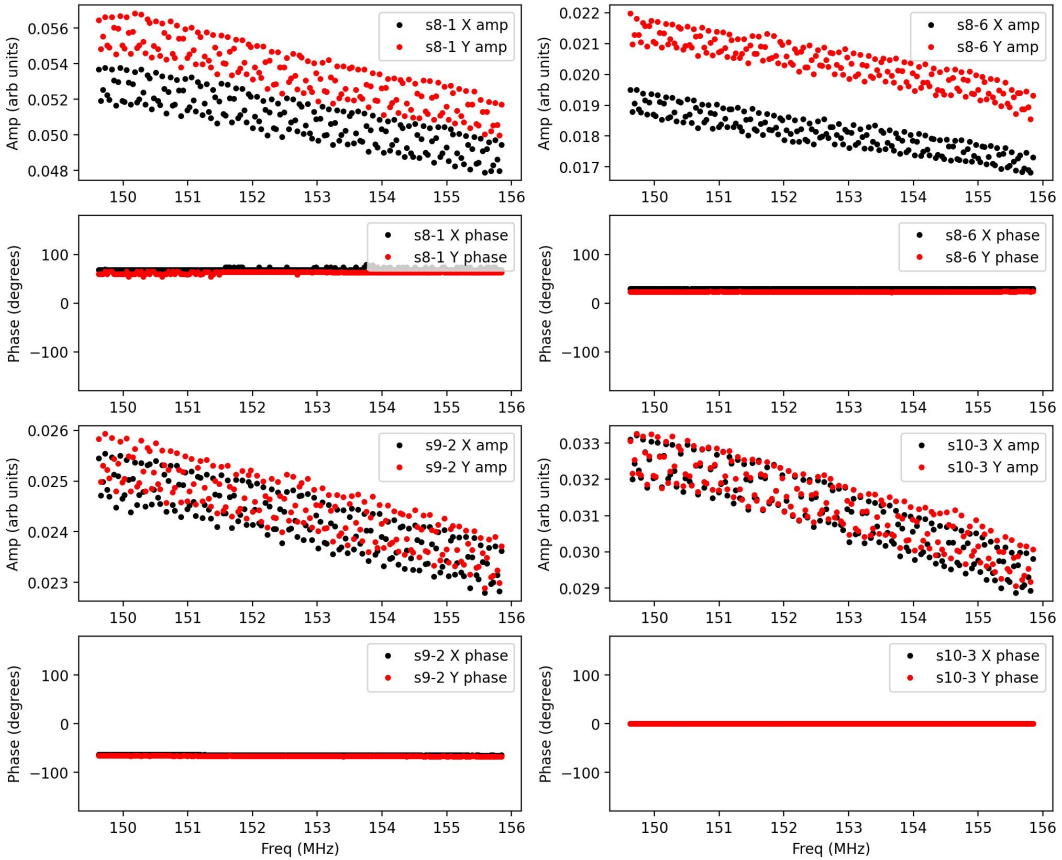
Major feature at the time:

Coarse channel ripple from PFB

(Now corrected in CBF)

More recent example (37.5 MHz BW):

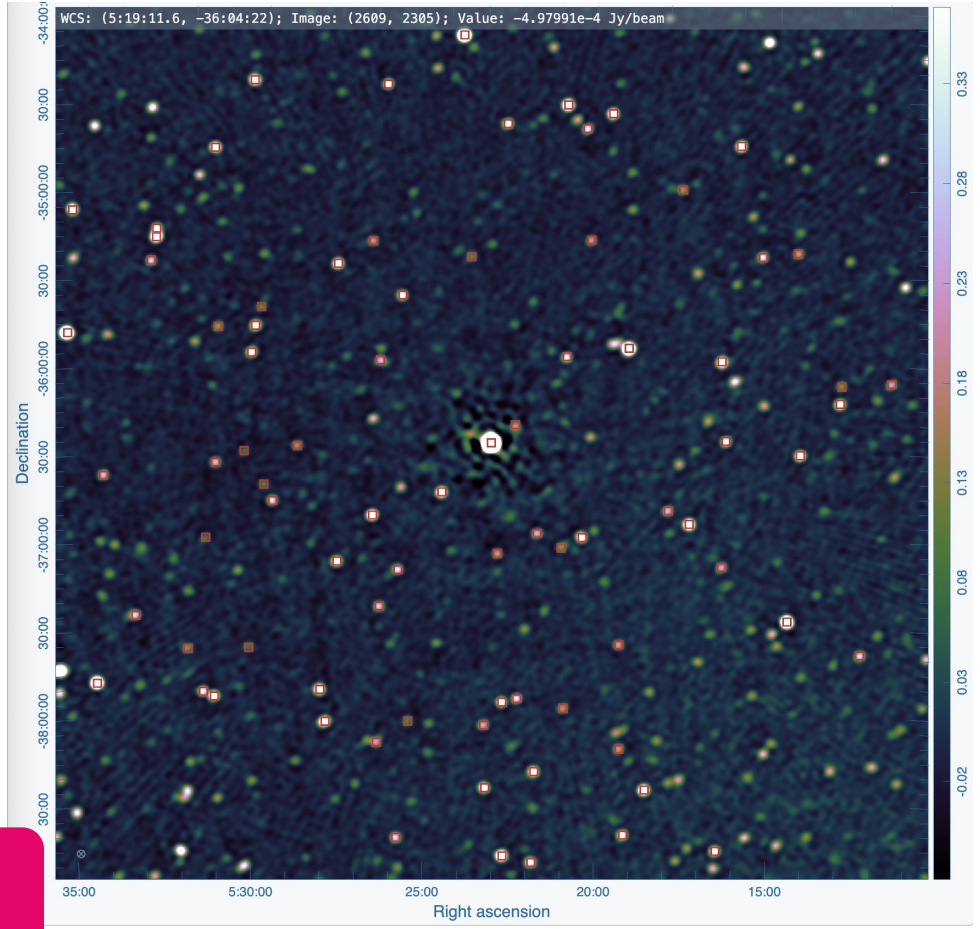




Selfcal loop

At each stage:

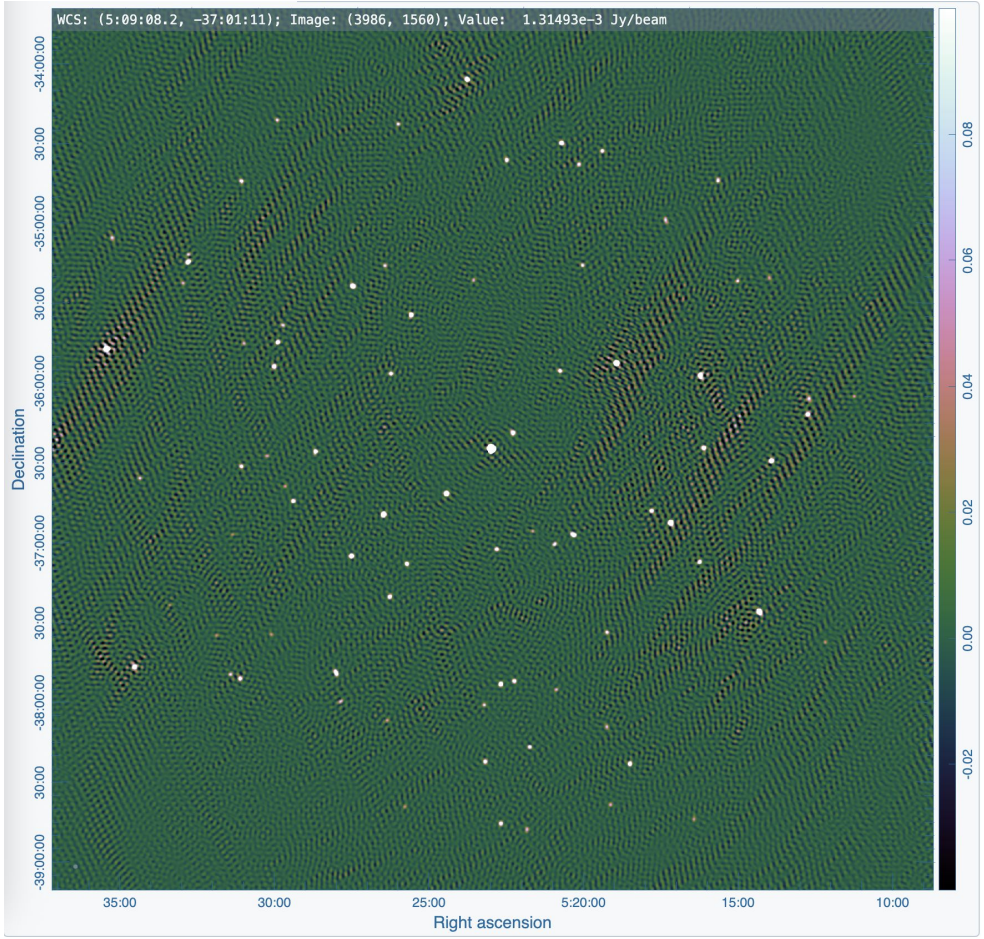
- Imaging/cleaning (wsclean)
- Source finding
- Cross match w/ GLEAM-X
- Create mask from xmatch
- Deconvolve, gain cal
  - Phase+amp, eventually
- Repeat …



GLEAM image of the field, with final sky model overlaid

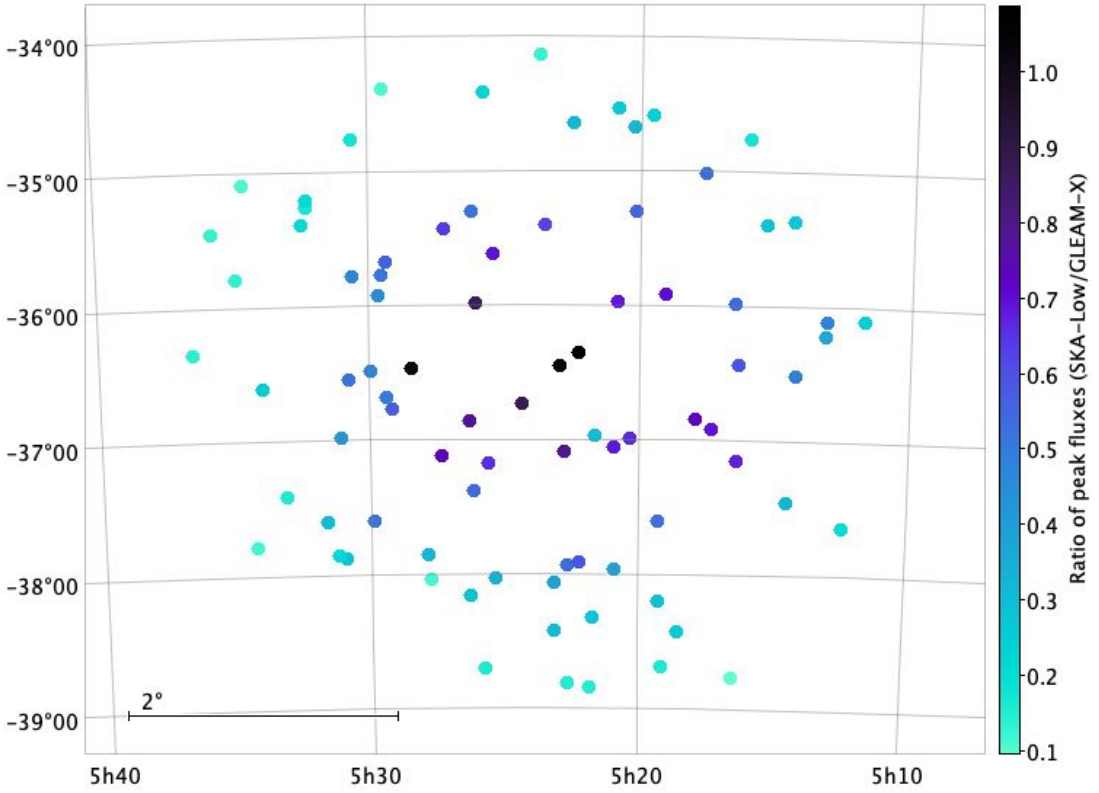
First image, deeper look

- Natural weighting
- Convolved to 70”
- Image noise ~5-6 mJy/beam
  - Nominal thermal noise ~ 0.8 mJy/beam
- 85 sources detected and matched to GLEAM-X catalog
- Clear artifacts remaining
- Some overfitting here
  - Room for improvement



Comparison to GLEAM-X

- Calibration included bandpass and gains
- No source info included other than flux density of central calibrator source
- Deconvolution step did include exclusion of mask regions with no GLEAM-X counterpart
- Self-calibration process led to source fluxes that mainly line up very well with expectations!
- Cal process to be refined…



Comparison of SKA-Low sources to MWA catalog shows the effective response pattern of the SKA-Low station digital beam

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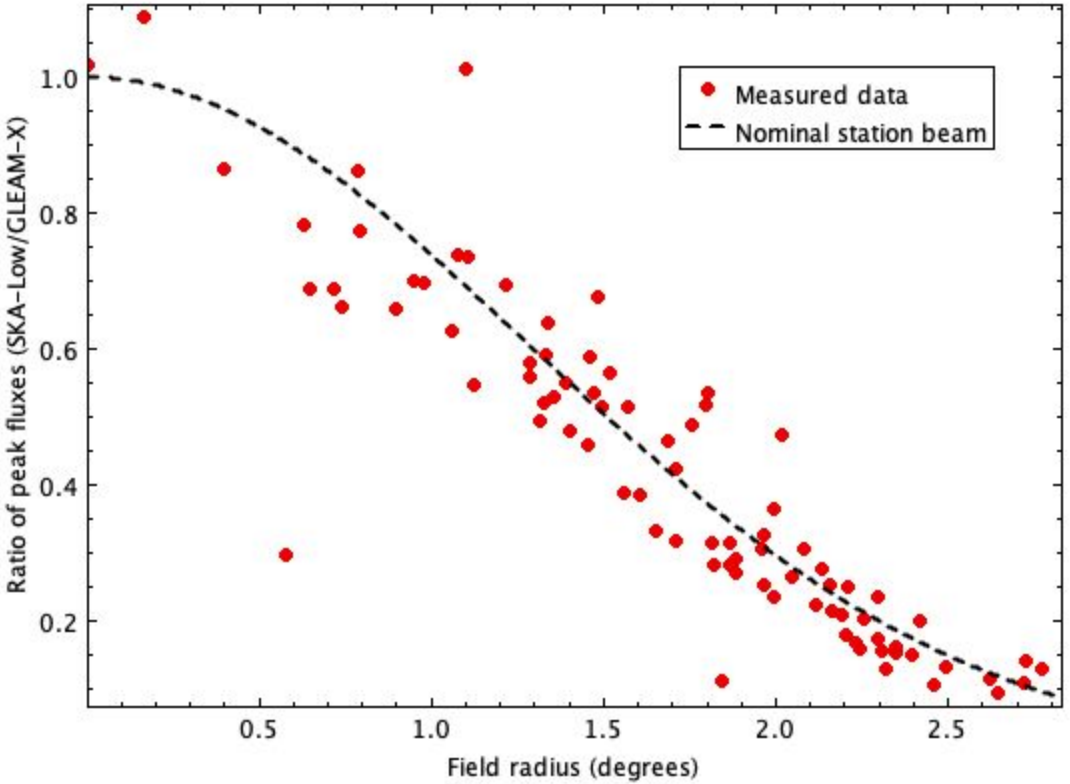


Comparison of SKA-Low sources to MWA catalog shows the effective response pattern of the SKA-Low station digital beam

Next steps

- Broader bandwidth
- Use components of SDP pipeline, now becoming available
  - Correct ordering of terms in Measurement Equation
  - More efficient sky modeling
- Begin process with GLEAM-X field (not source) model
  - Demonstrate better calibration/imaging performance
- Repeat process at other frequency ranges
- Additional fields with and without bright central source
- Calibration transfer from field to field
- etc etc - commissioning plan!

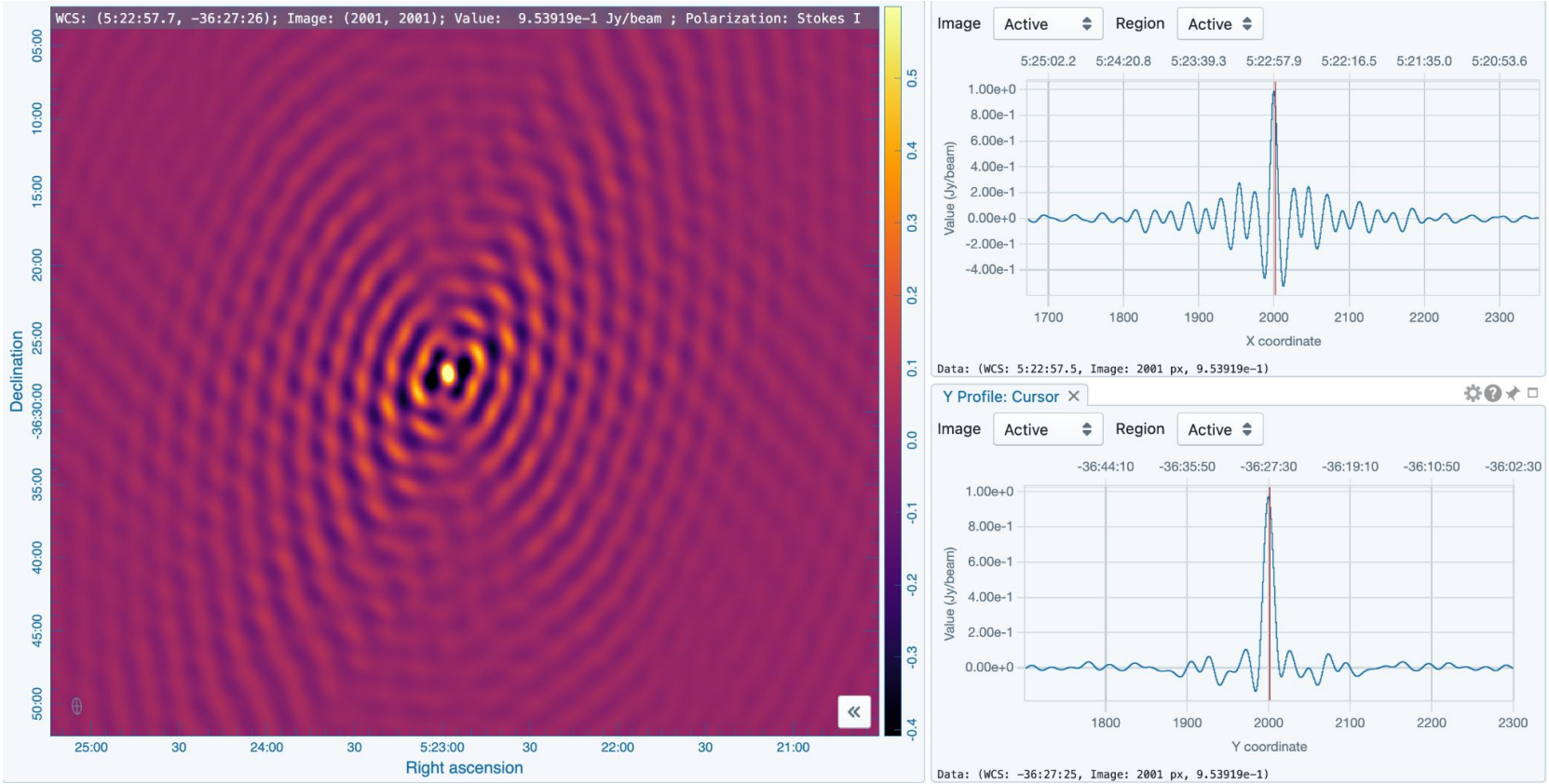
Questions?

We recognise and acknowledge the Indigenous peoples and cultures that have traditionally lived on the lands on which our facilities are located.

SKAO

www.skao.int

PSF


WCS: (5:22:57.7, −36:27:26); Image: (2001, 2001); Value: 9.53919e−1 Jy/beam ; Polarization: Stokes I
Declination
Right ascension
Image
Active
Region
Active
X coordinate
Value (Jy/beam)
Data: (WCS: 5:22:57.5, Image: 2001 px, 9.53919e−1)
Y Profile: Cursor
Y coordinate
Data: (WCS: −36:27:25, Image: 2001 px, 9.53919e−1)