Commissioning SKA-Low

First results and future plans towards Science Verification

Giulia Macario (on behalf of the SKA-Low Science Commissioning team)

Fifth National Workshop on the SKA Project, Bologna, Italy
24th November 2025

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.

SKAO Science Commissioning in the big picture

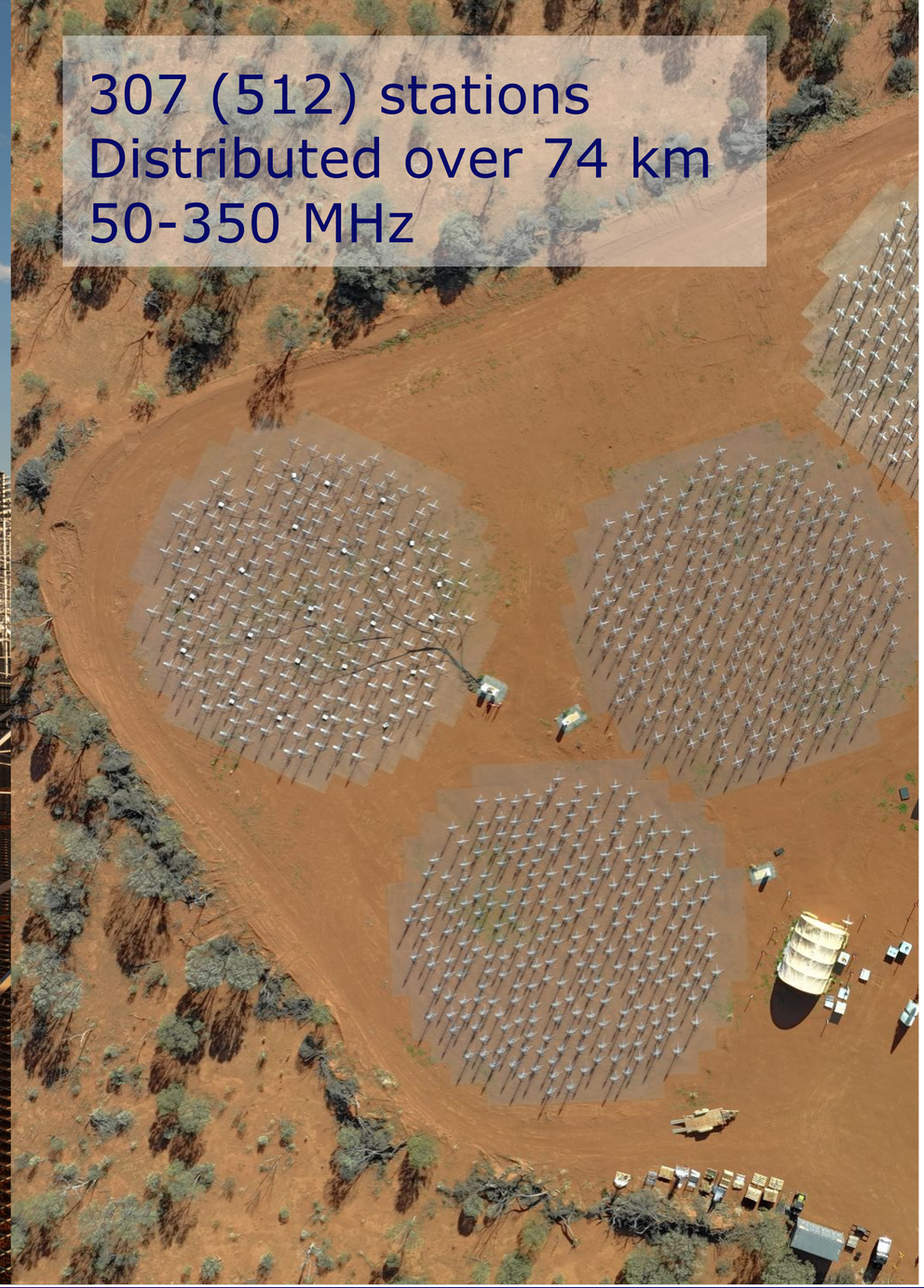
Internal activity that focuses on tests of science capability, using astronomical observations

Includes Short Functional Tests (SFTs)

Includes Test Cases, Verification Events, …

Structured around a Commissioning Plan for each Array Assembly

Ensuring the telescope meets the needs of the science & operational users



307 (512) stations
Distributed over 74 km
50-350 MHz

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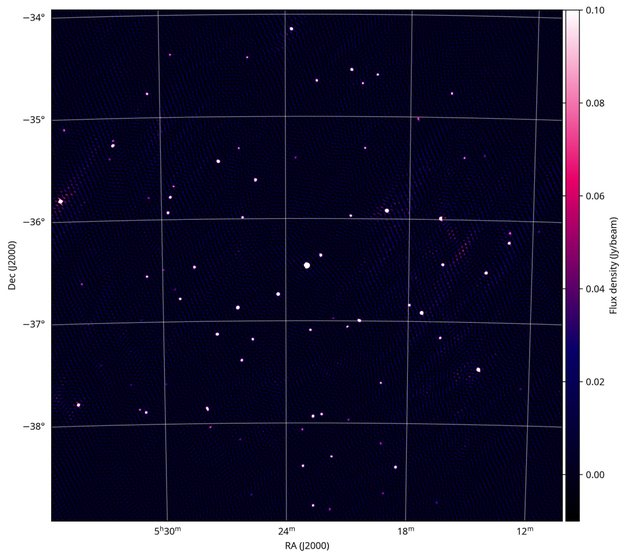
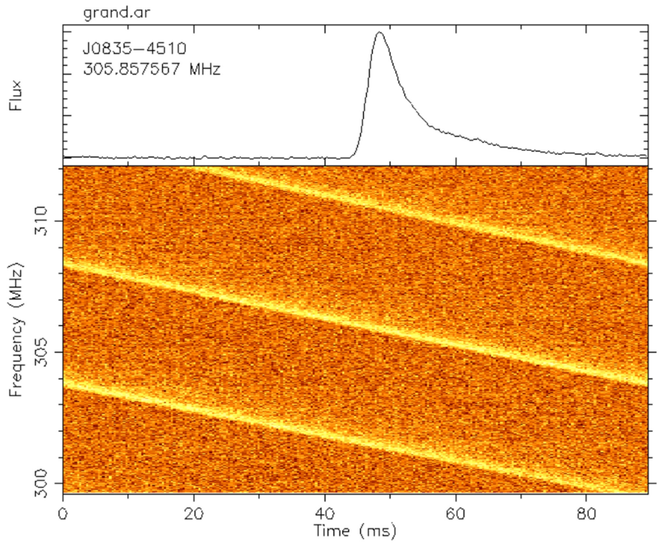


Images

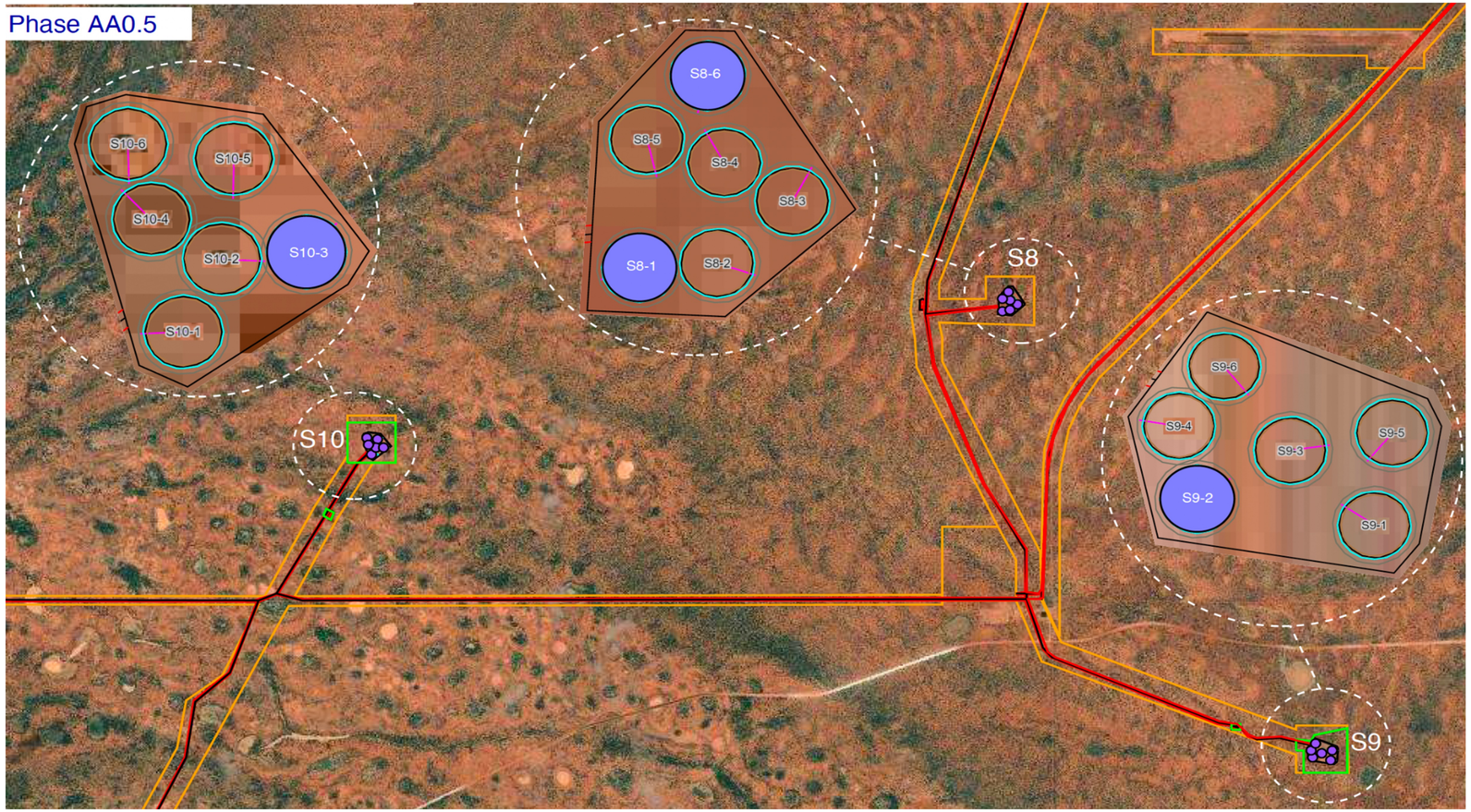
Tied-array beams



SKA-Low Array Assembly 0.5 - layout

AA0.5 Complete!

- Four stations: S8-1, S8-6, S9-2 and S10-3
- Shortest baseline ~120m, longest ~5.5km
- Stations are rigidly rotated relative to each other
- Next milestone: AA1 (16 stations)



AA0.5: Four operational stations spread across the Southern spiral arm
AA1: 16 operational stations in the same three clusters

SKA-Low Science Commissioning main focus areas

AA0.5 (40 tests, 95% completed); **AA1** (47 tests, already started)

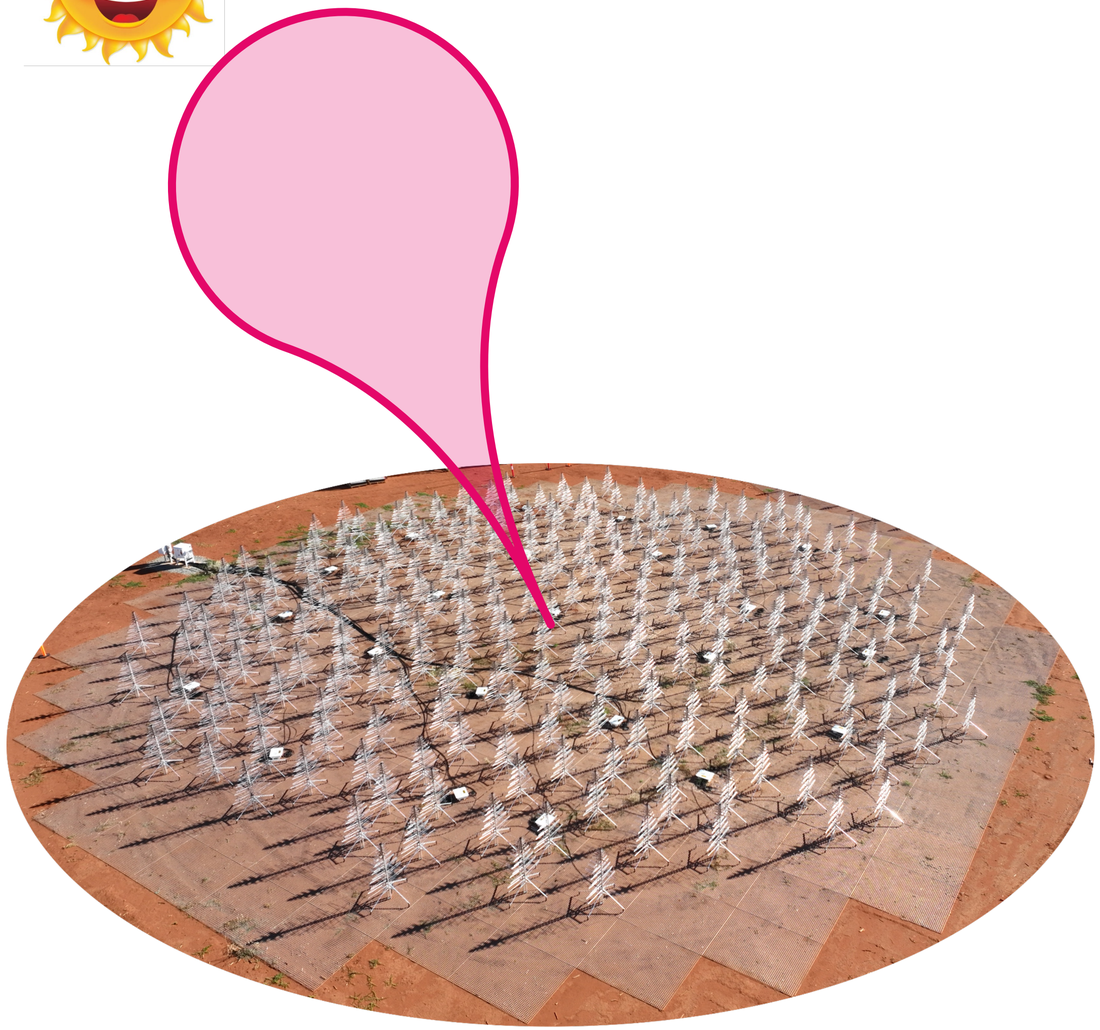
Single station
(system performance and pulsars detections)

Array beamforming
(tied array beams)

Array calibration and imaging performance
(continuum, polarization, spectral line)

Development of **SKA-Low Calibrator Database**
(and cal. survey plans)

Single station: behaviour



Commissioning outcomes so far:

- Good calibration solutions for each antenna within a station
- Stable performance with time and varying environmental conditions
- Per-antenna delays for pointing and tracking are fit for purpose
- Beam shape and sensitivity are approximately as expected

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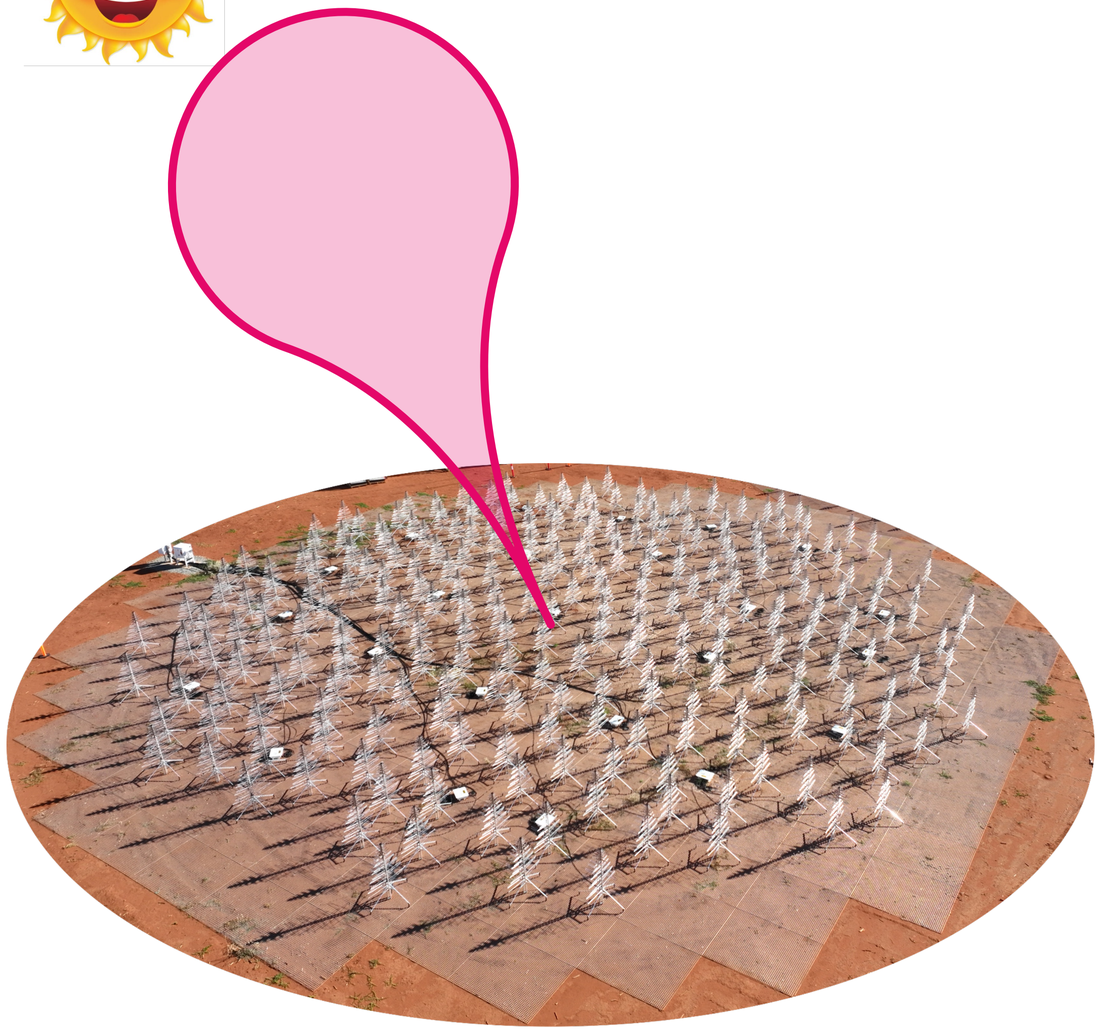

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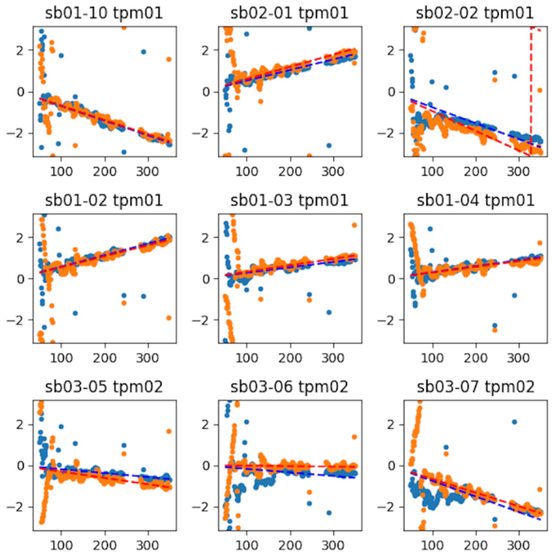

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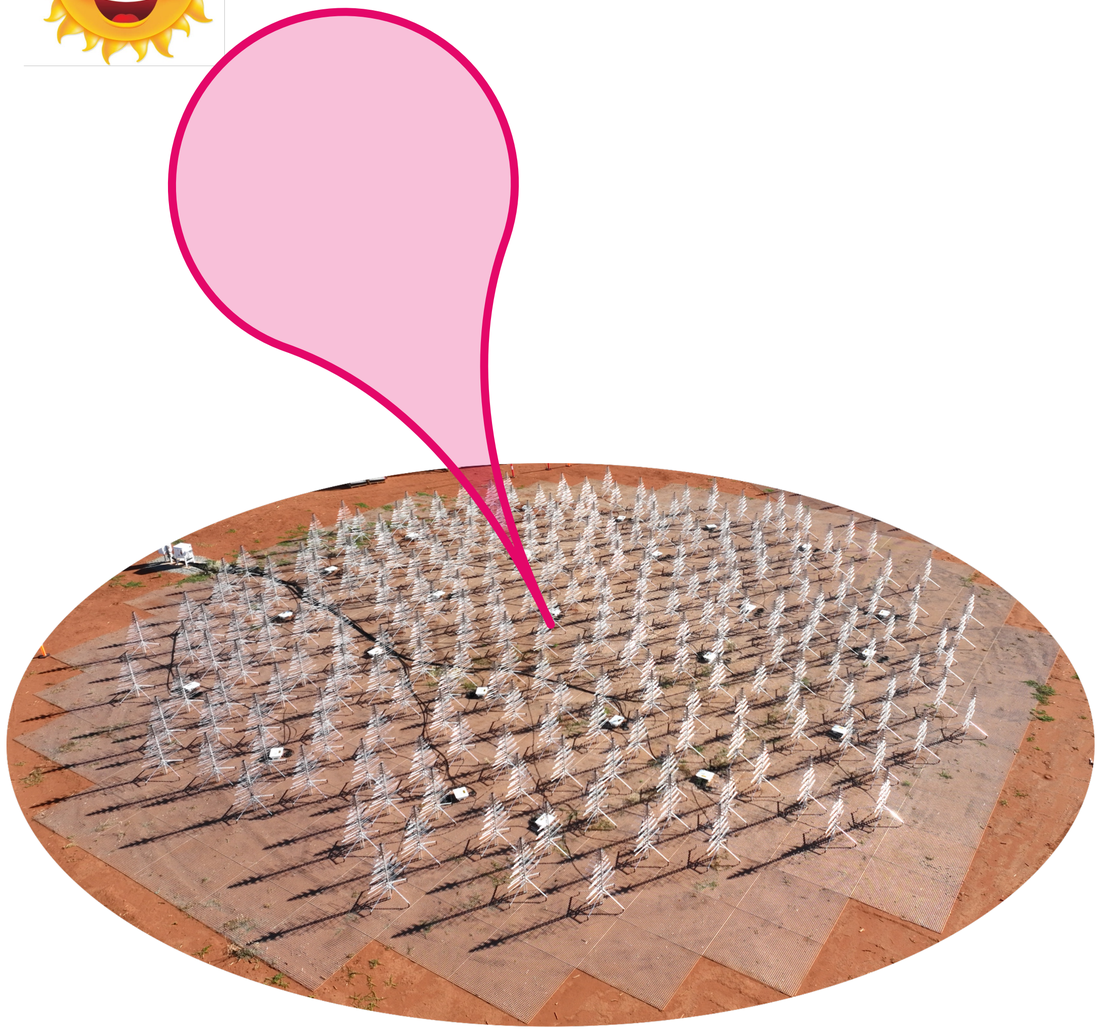

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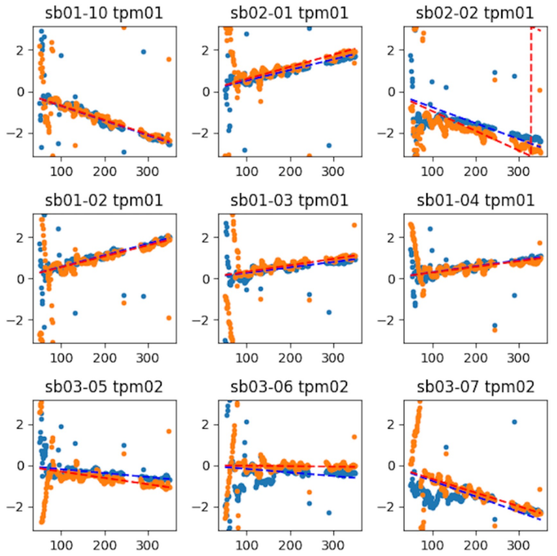

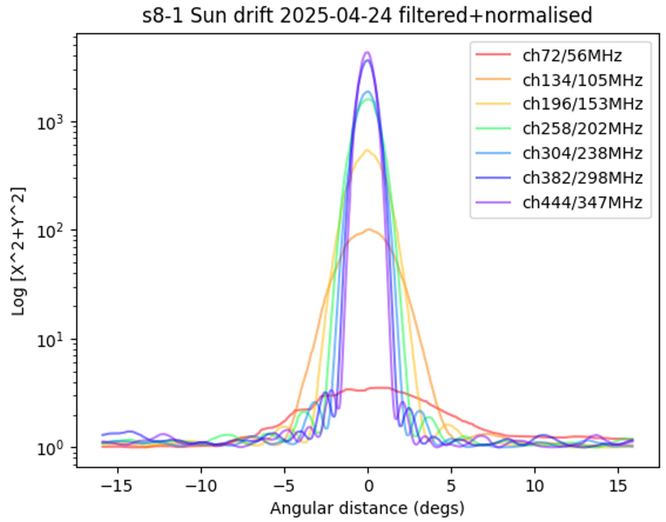

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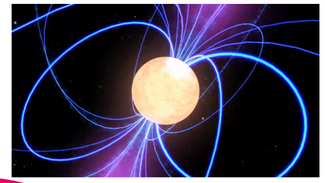

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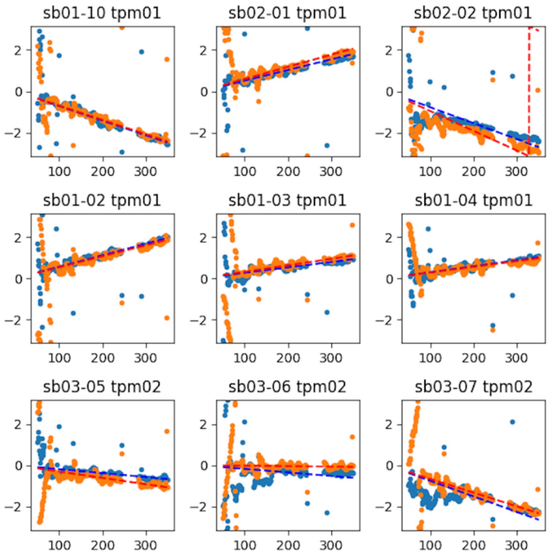
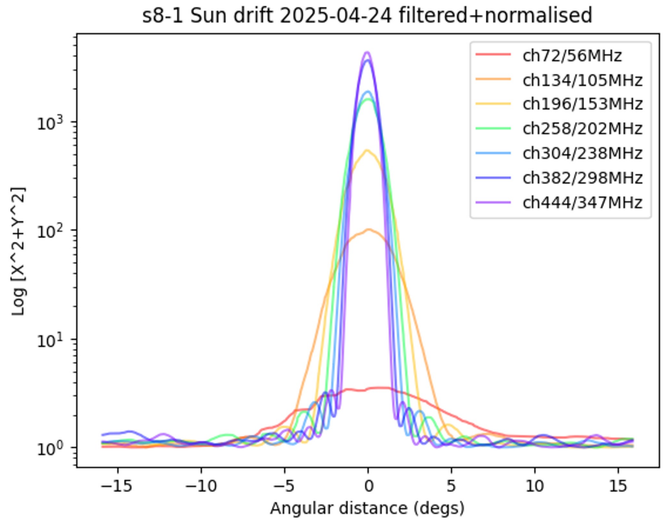
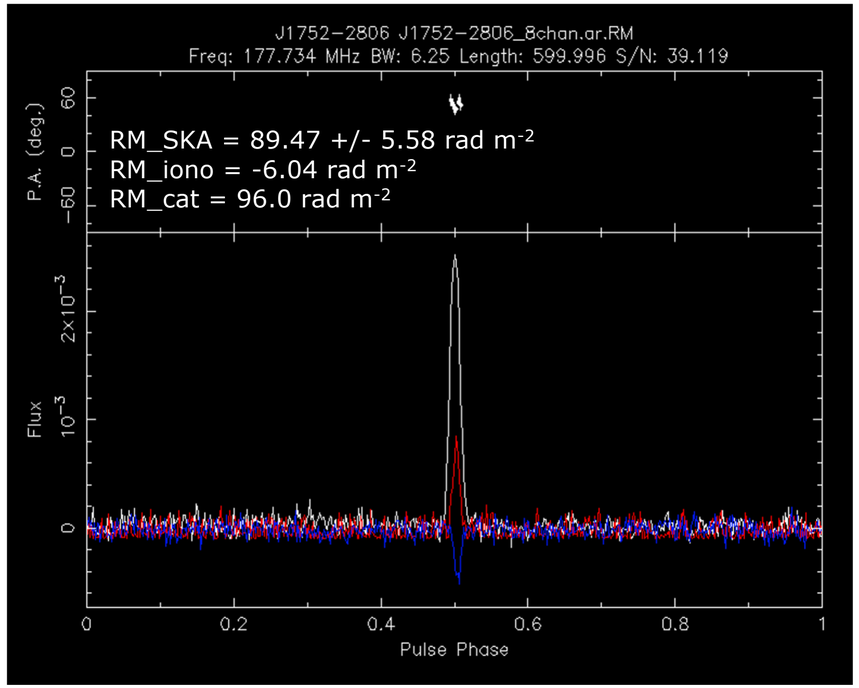
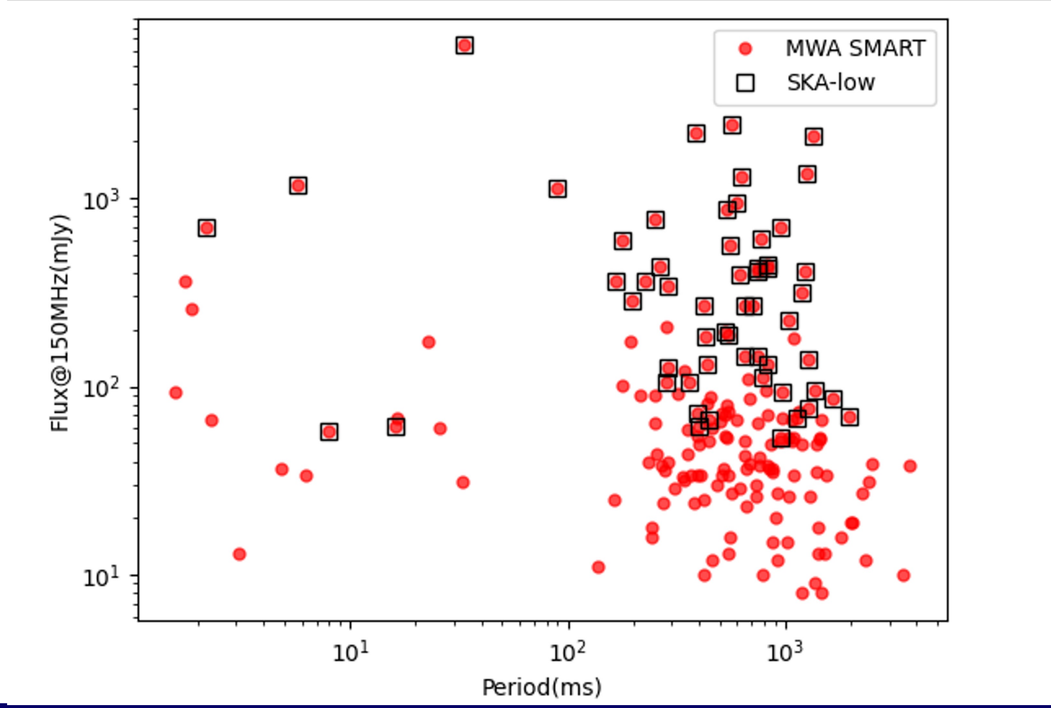


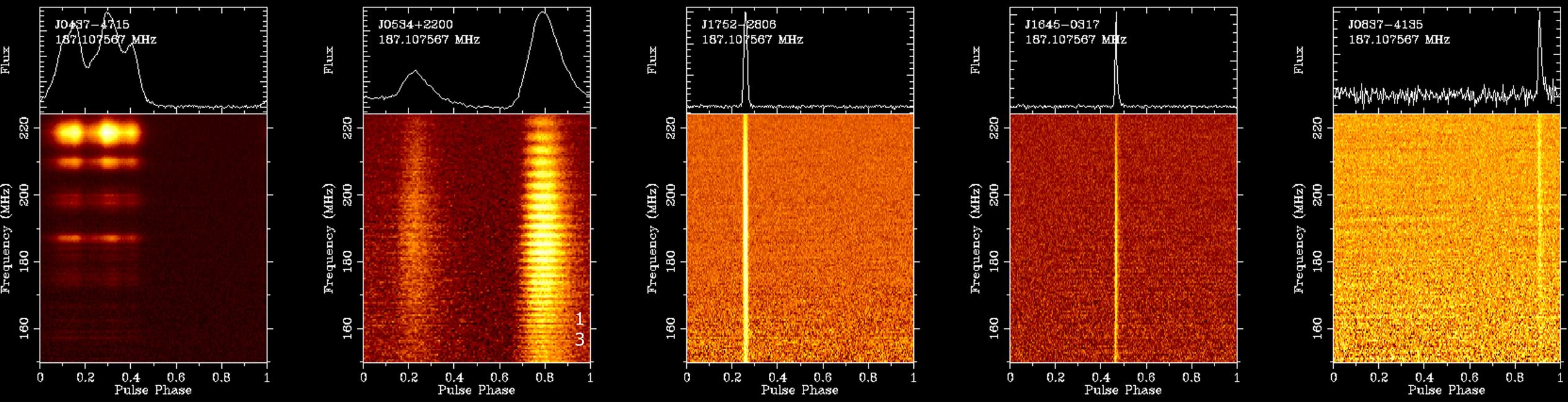


Single station: pulsar detections

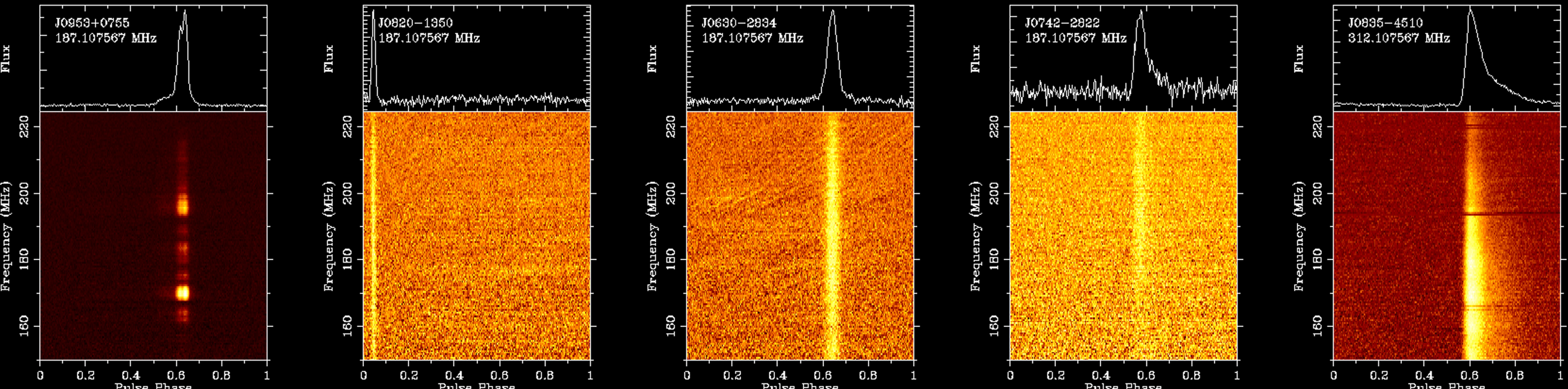
- Detected **56** known pulsars using *single* stations raw voltages (6.25 MHz bandwidth) and Pulsar Timing Subsystem (up to 75 MHz)
- Sneak peek at full polarization properties, with promising results
- Initial testing of tied-array performance is very encouraging - realtime calibration loop in development now, so full coherence is coming soon







Testing tied array observation (2 stations), 75 MHz: excellent data quality !!



Basic array performance

Commissioning outcomes so far:

- Interferometric fringes detected
- Per-station delays determined to be stable and match fibre lengths
- Closure phase verified (indicating that visibilities can be calibrated)
- Station sensitivities measured
- First images produced
- Station bandpasses determined

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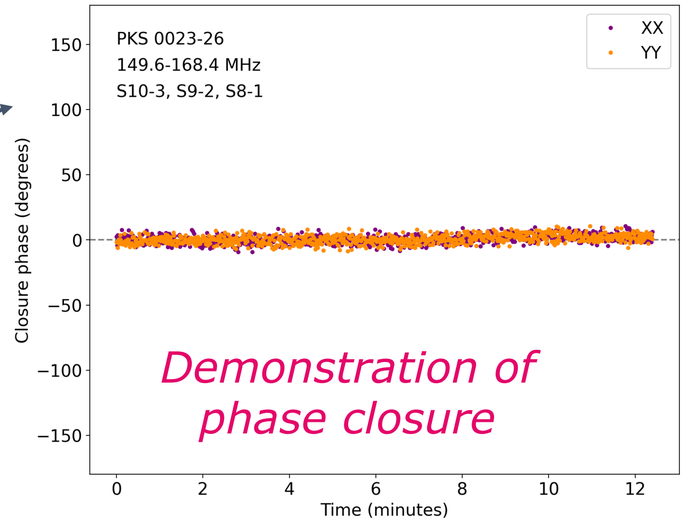

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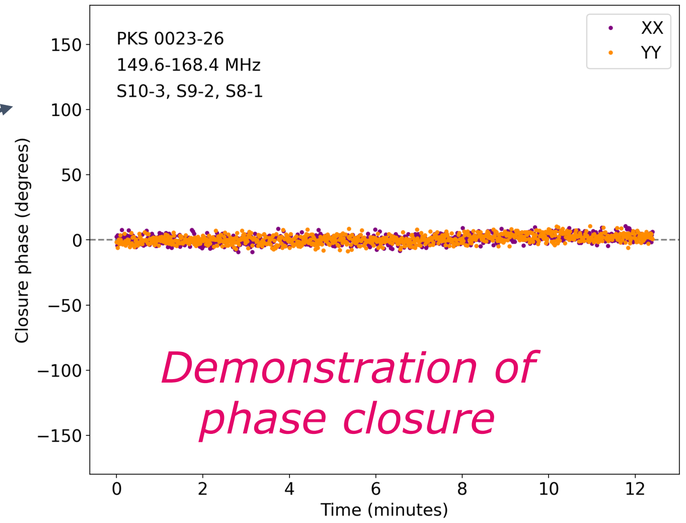

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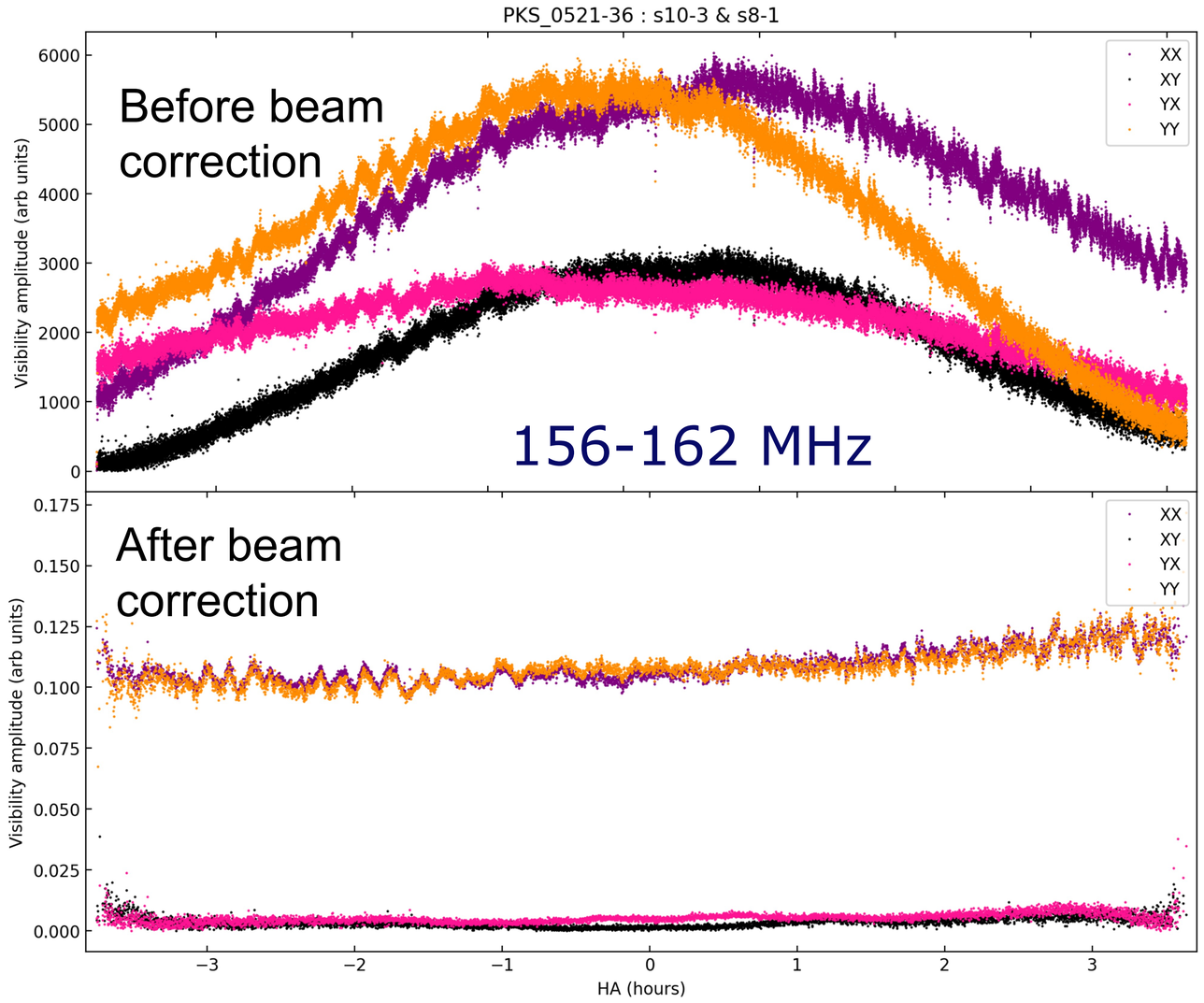

Unflagged(!), delay calibrated & averaged visibilities

Beam correction compensates for antenna response and relative station rotations

First SKA-Low AA0.5 image!

- Field surrounding PKS 0521-36 (~56 Jy at 150 MHz)
- 150-175 MHz BW
- ~7h effective int.

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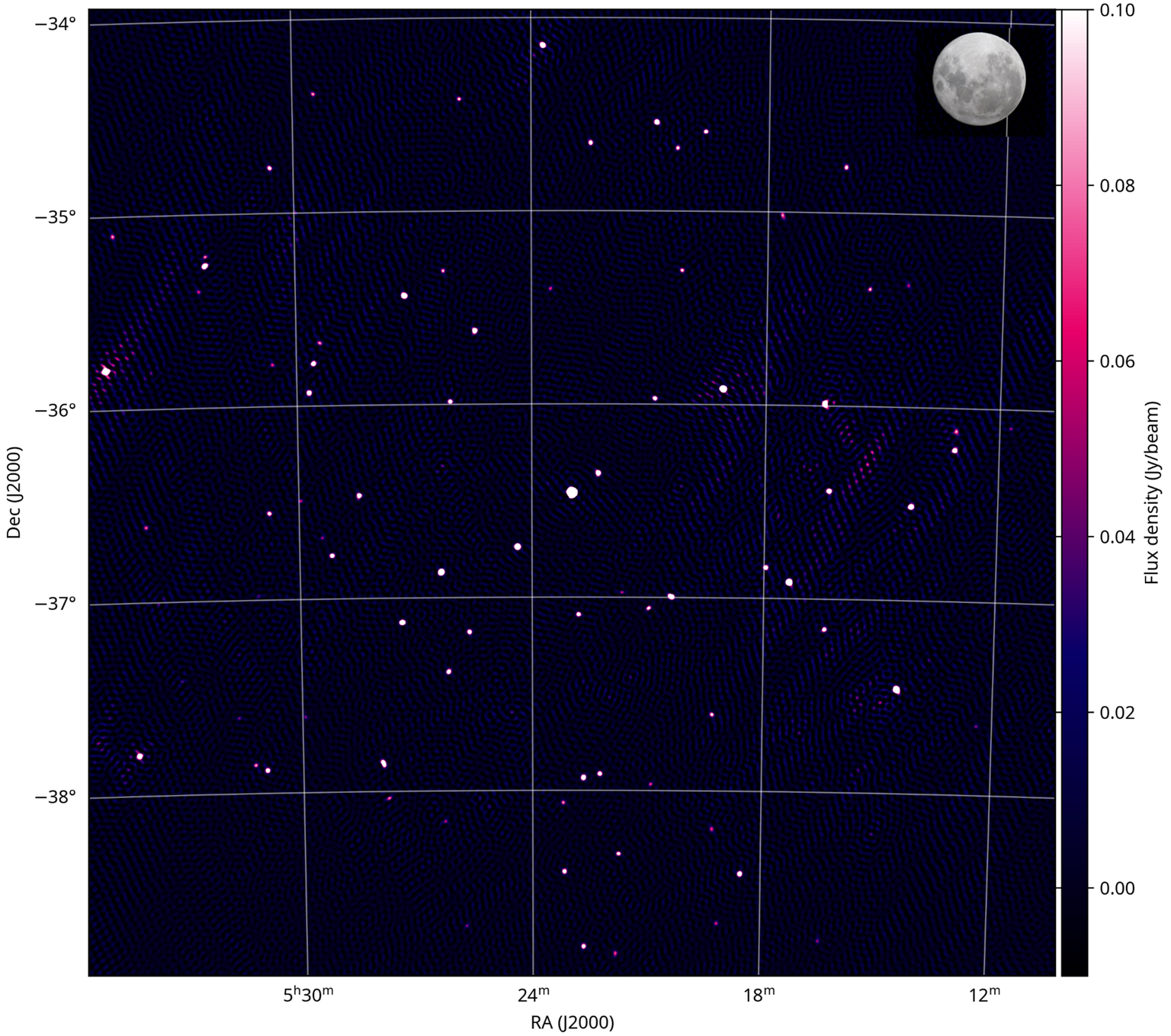
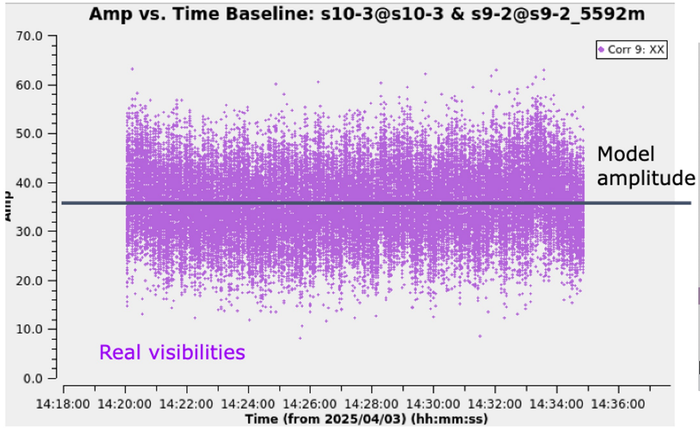
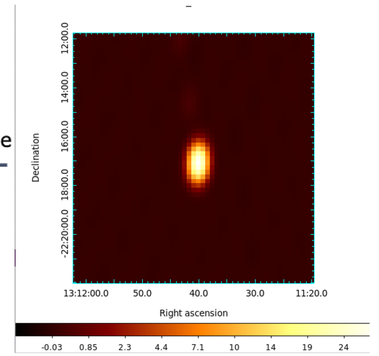
- Field surrounding PKS 0521-36 (~56 Jy at 150 MHz)
- 150-175 MHz BW
- ~7h effective int.
- Image noise: ~5-6 mJy/beam at 70” final resolution
- 85 sources detected
- Very good match to GLEAM-X catalog (with mostly unguided self-cal!)



SKA-Low station SEFD

SEFD estimates from rms noise of point source calibrated visibilities





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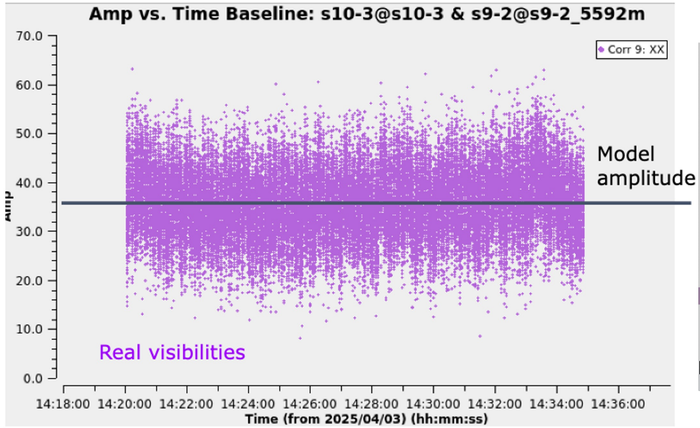
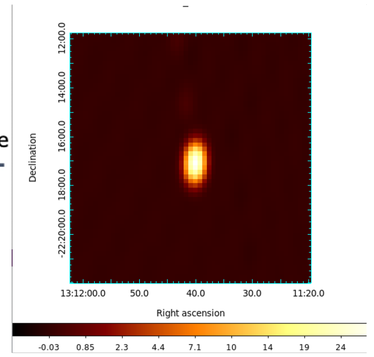
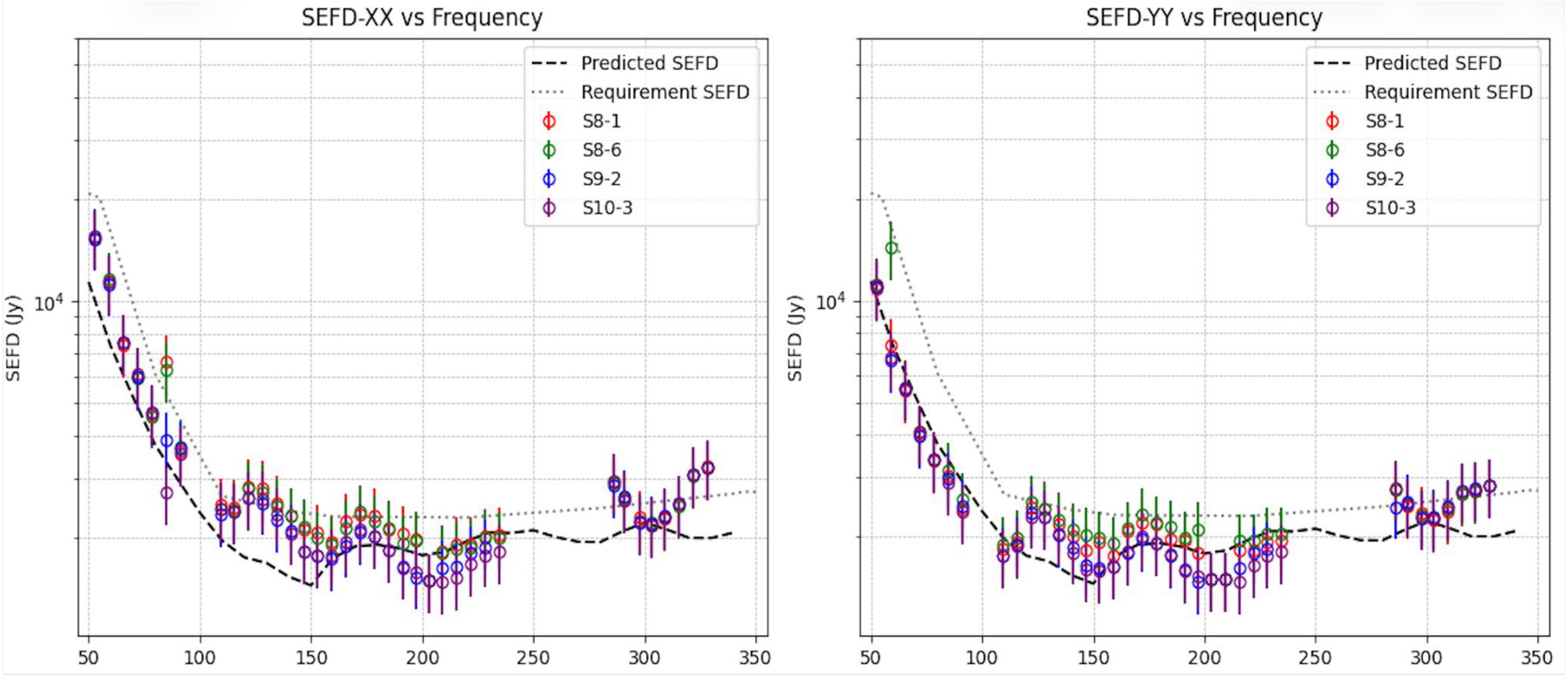
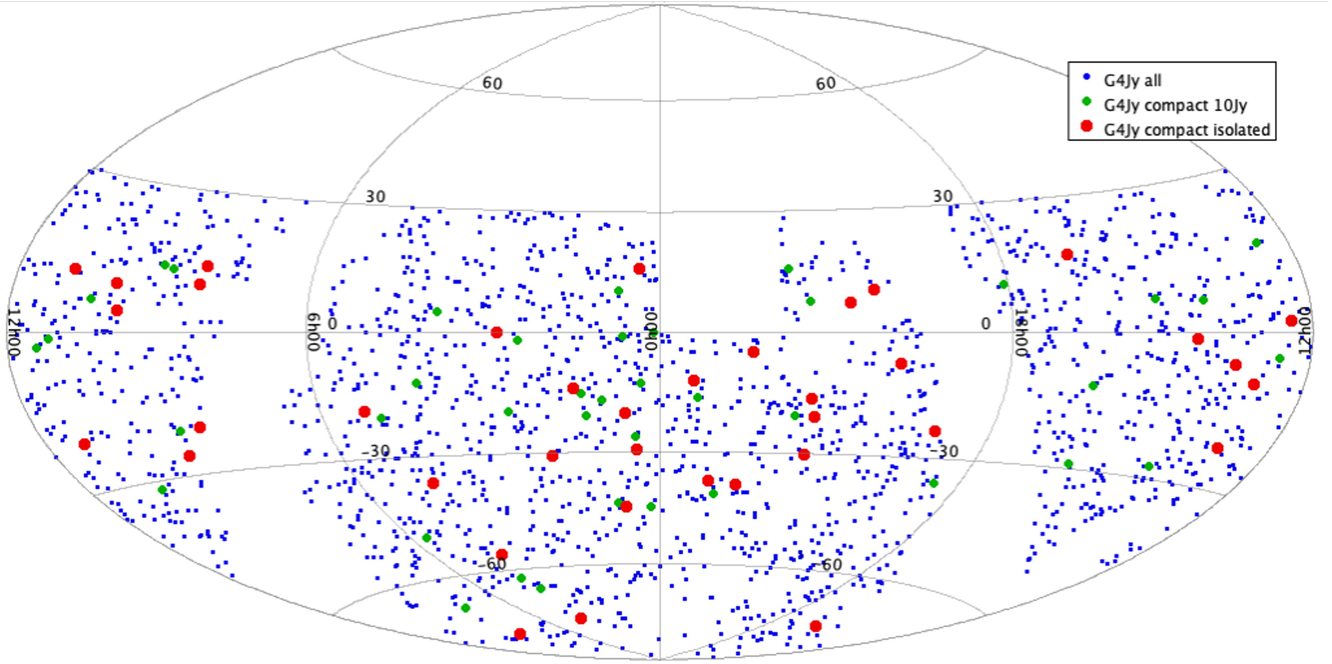
Lower SEFD = **better** sensitivity!







SKA-Low Calibrator Database (ongoing effort)



38 compact isolated sources identified from existing catalogs (GLEAM, TGSS…)

Current status

- 23/38 observed across full 50-350 MHz
- Q&A plots of raw visibilities to support Operators
- Bandpass calibration tests for *all* sources (150-200 MHz only)
- Full bandwidth calibration tests
- Sky model tests with single point source, also with field sources
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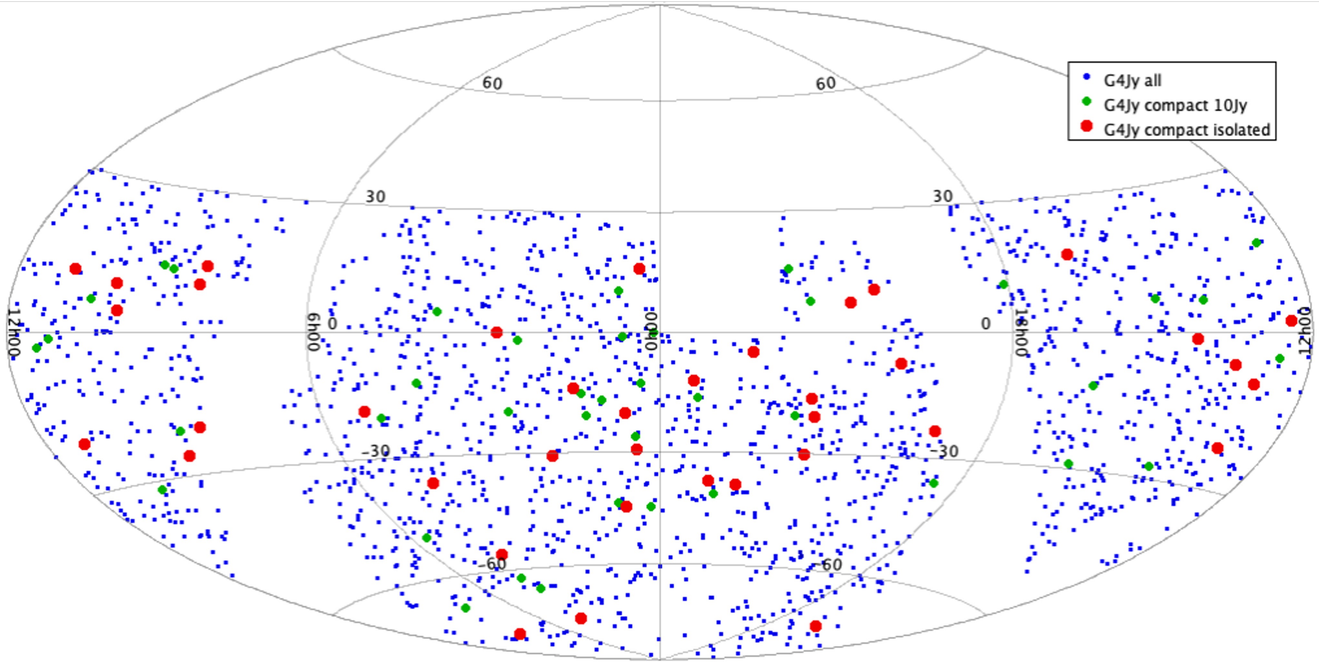

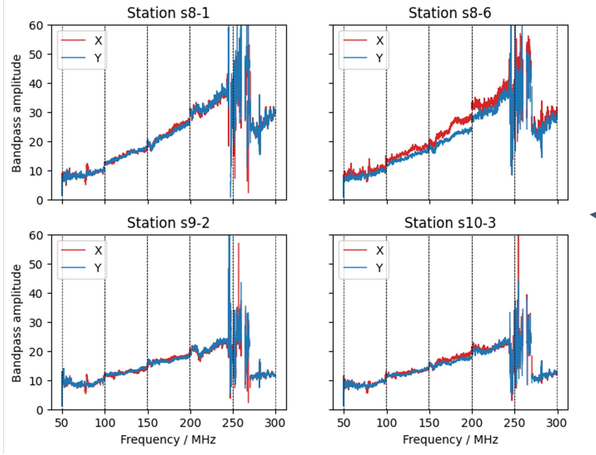

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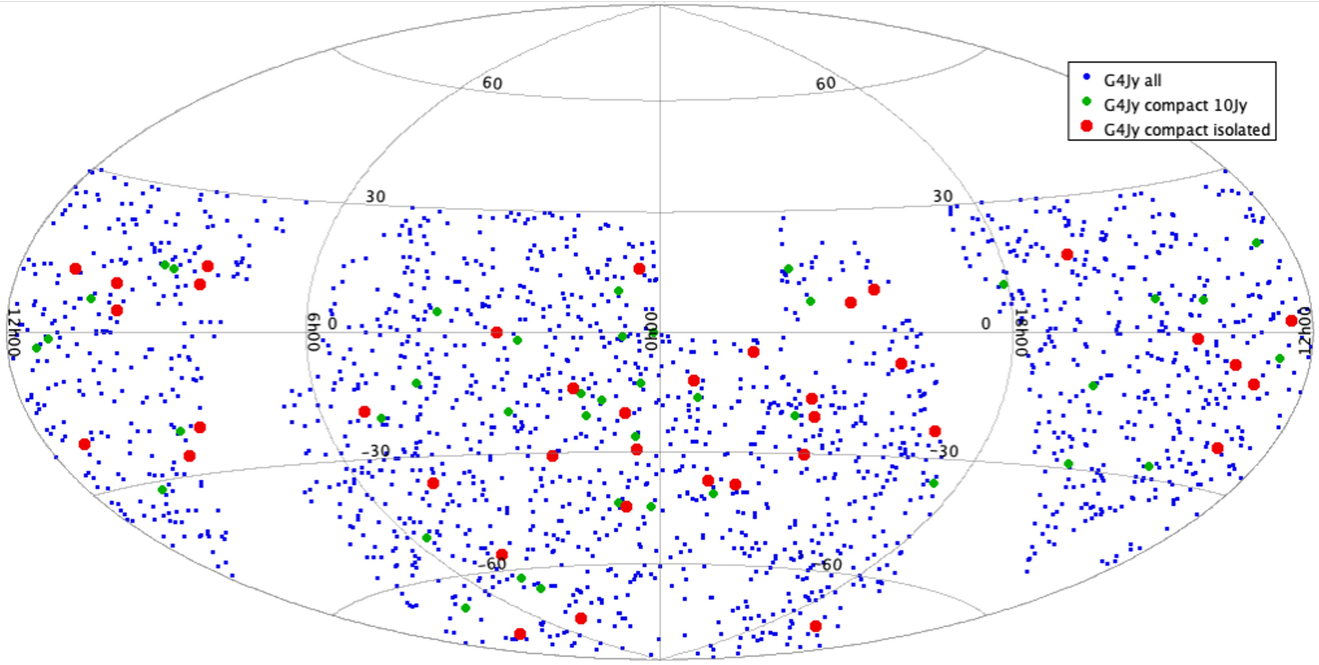

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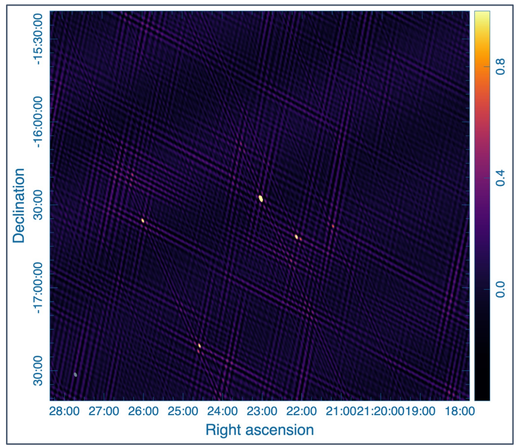

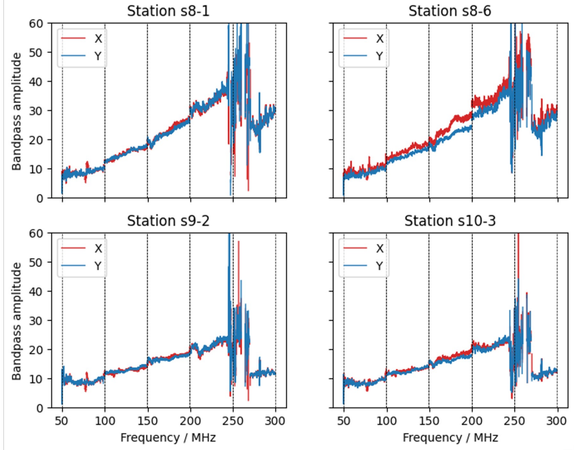

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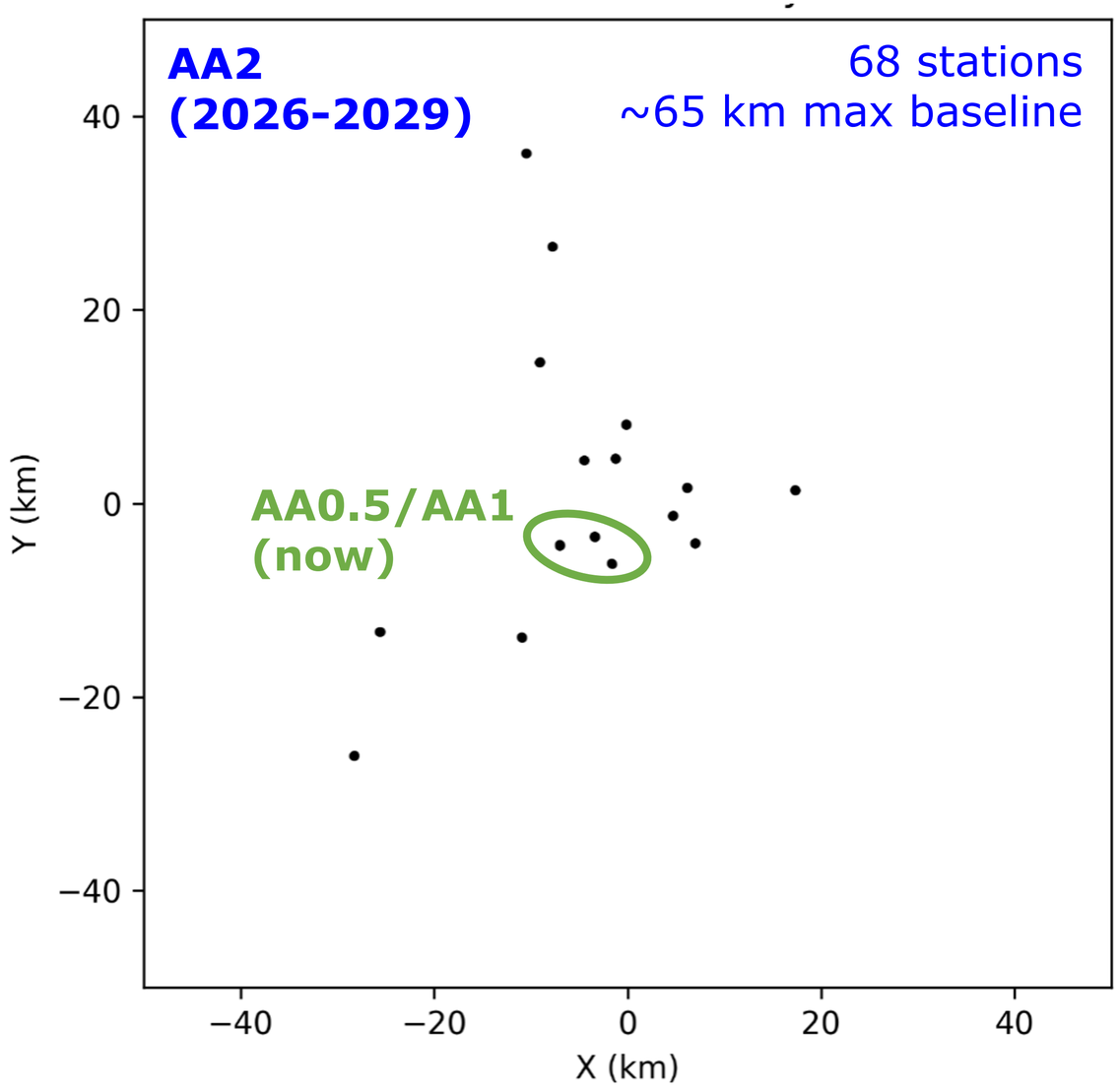
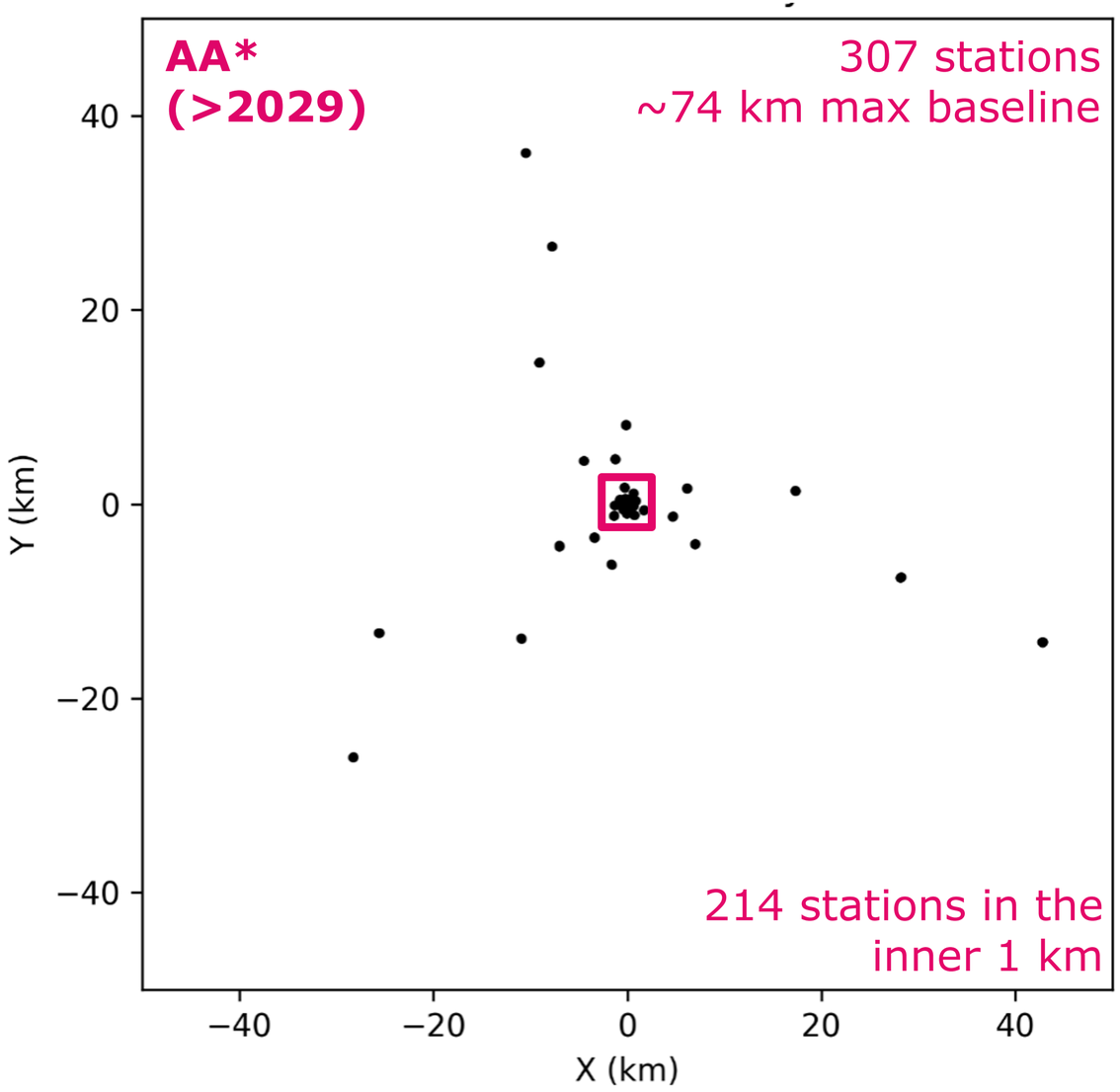
*Stage 1 of SKA-Low **G**lobal **S**ky **M**odel (GSM) to kick off the **S**cience **D**ata **P**rocessor pipelines!*

SKA-Low Array Assemblies

SKAO tools for your science!





SKA-Low Calibrator Surveys

Progression of observational campaigns to establish calibrator database for basic array calibration, enabling Science Verification

These surveys are *not* designed for science, but resulting Observatory Level Data Products expected to be made public in Science Verification

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Within 3 clusters
Bmax = 5.5 km

- Compact point sources only
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- Full sky coverage, but not expecting GSM entries in MW plane
- Focus: morphology, astrometry, flux scale
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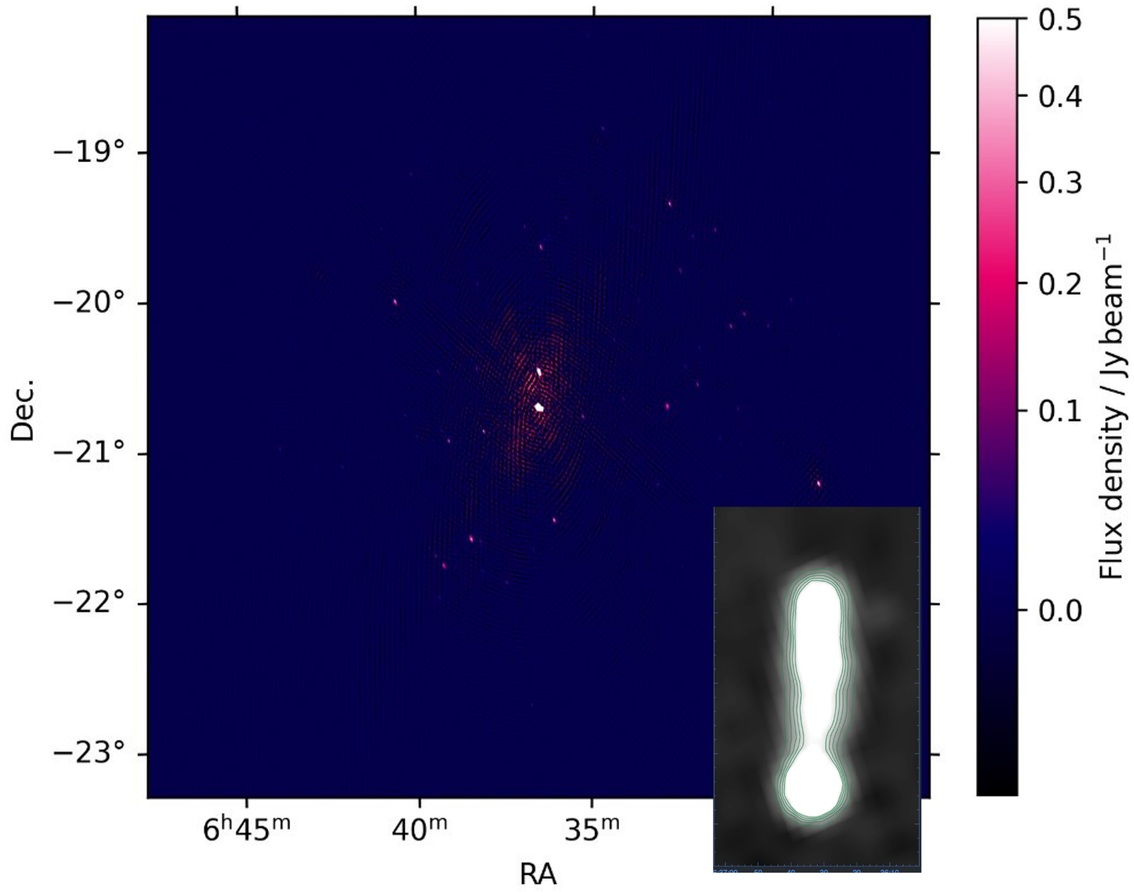
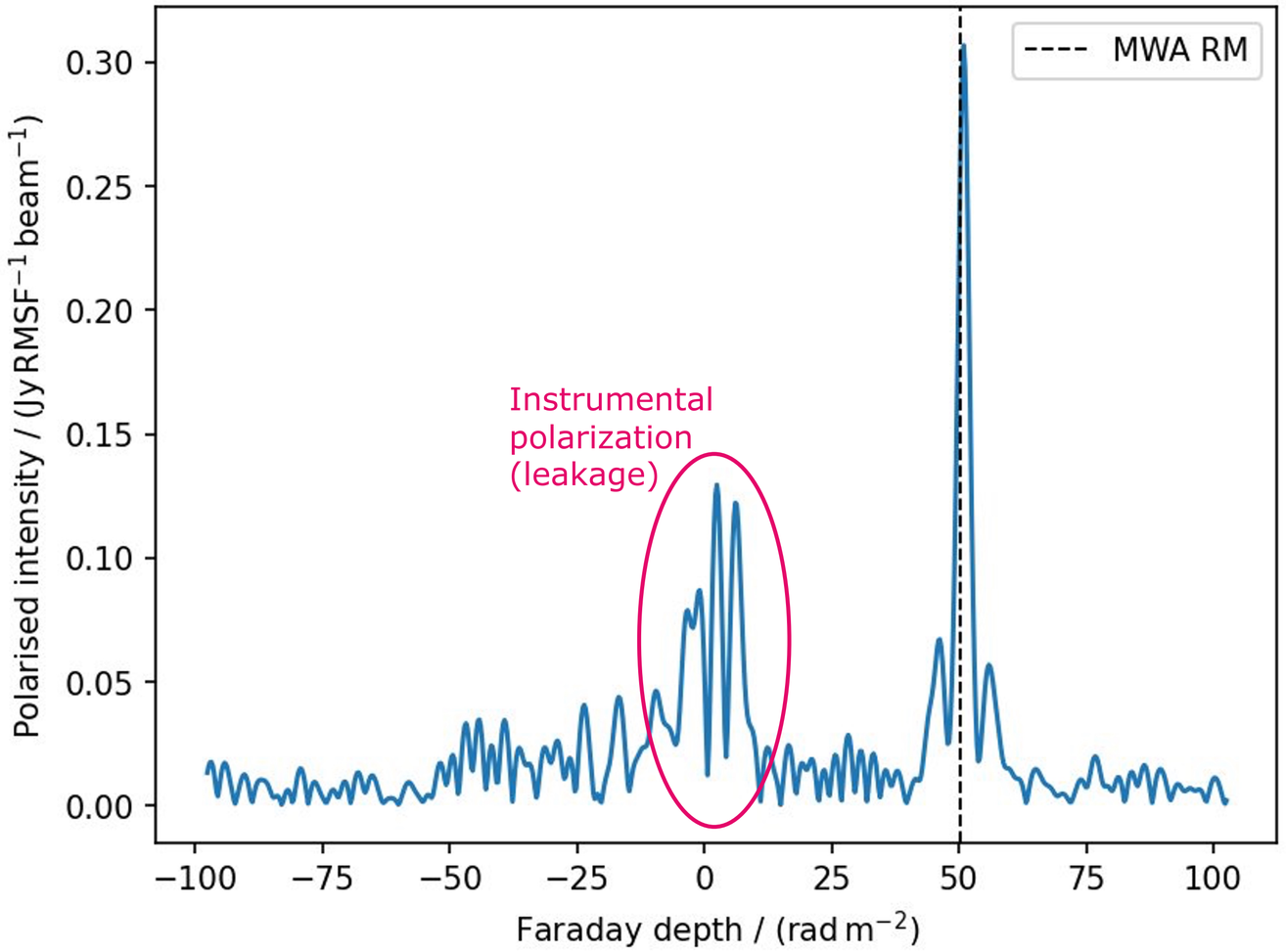
AA*
307 stations
Spiral arms and core
Bmax = 74 km

- Full sky coverage, adding MW plane
- Better morphologies
- Better astrometry
- Deeper imaging
- Indicative depth: <1 mJy/beam (TBC)

Polarization

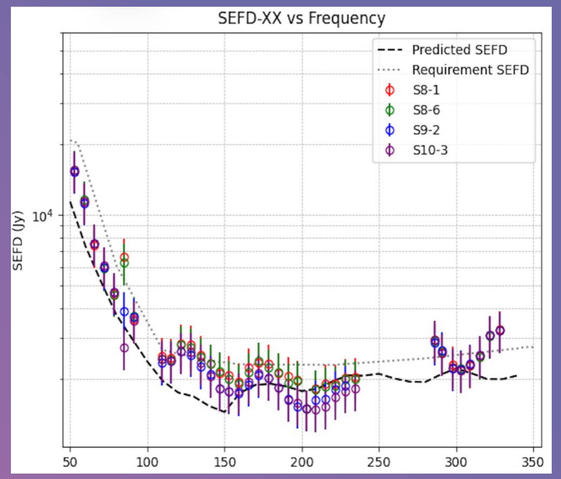
Initial polarization tests from interferometric imaging as well, with RM also aligned with MWA results

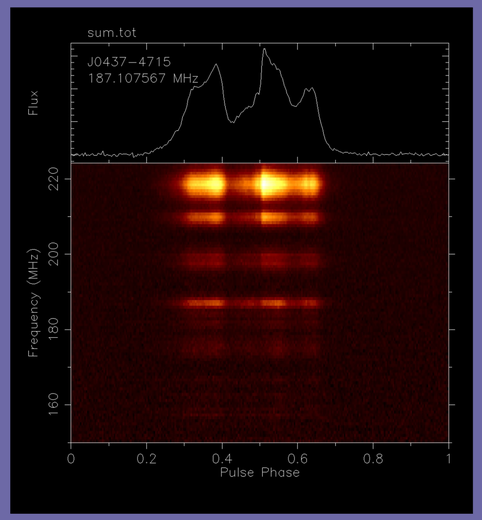




Recap: Science Commissioning outcomes

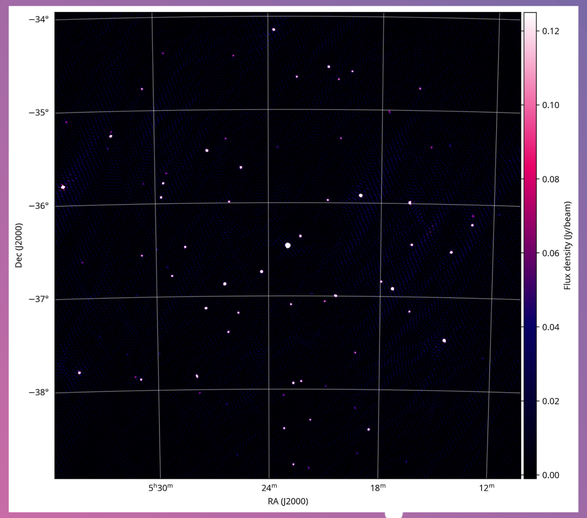
Good single station calibration, pointing, tracking, sensitivity

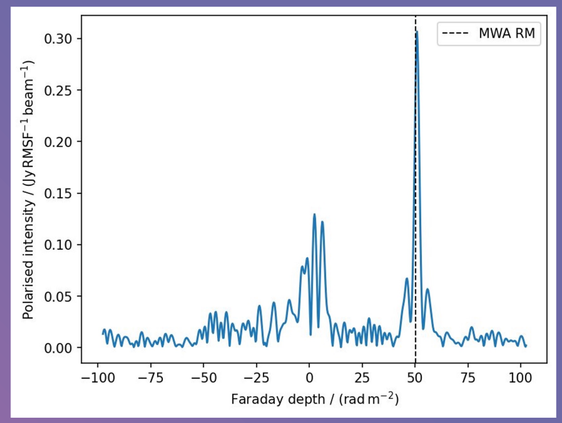




Initial tied-array beam results in pulsar timing (PST) mode, with full coherence coming soon

Good array calibration demonstrated, with first images being produced





Good results for polarimetry, both from pulsar and imaging observations

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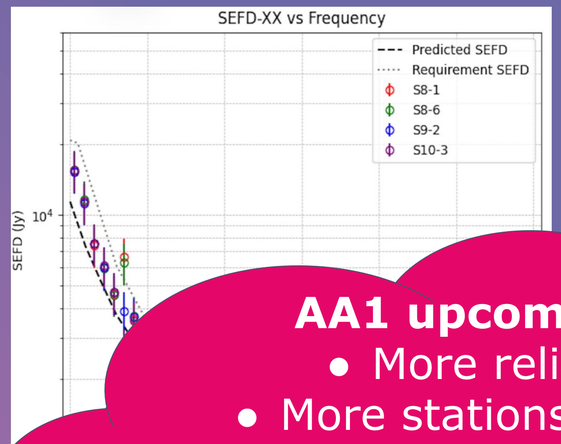

Initial tied-array beam results in pulsar timing (PST) mode, with full coherence coming soon

AA1 upcoming shortly!

- More reliable uptime
- More stations → much better calibration & sensitivity
- Better understanding of systematics
- Improved team processes
- 1st calibrator database

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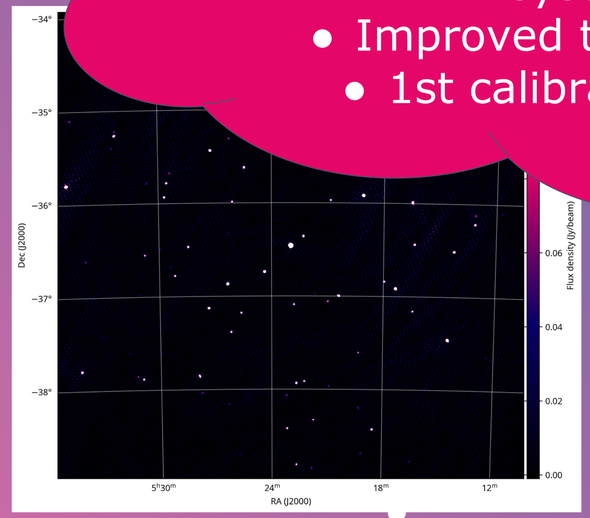

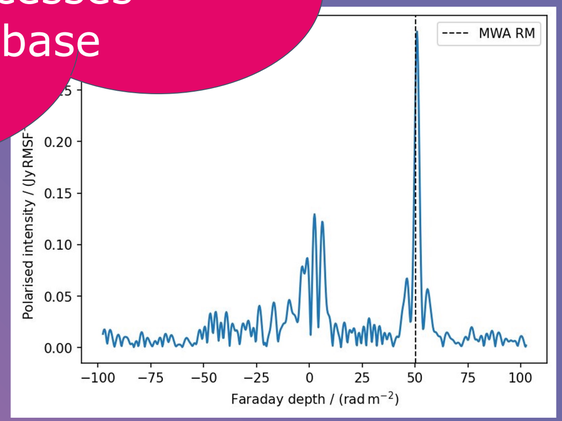

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Feedback:

sciops@skao.int

Science User Q&A :

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

SKAO

The Low Science Commissioning Team (left to right):
Sam Mcsweeney, Giulia Macario, George Heald (team leader), Alec Thomson, Shivani Bhandari, Randall Wayth and Xiang Zhang

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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.