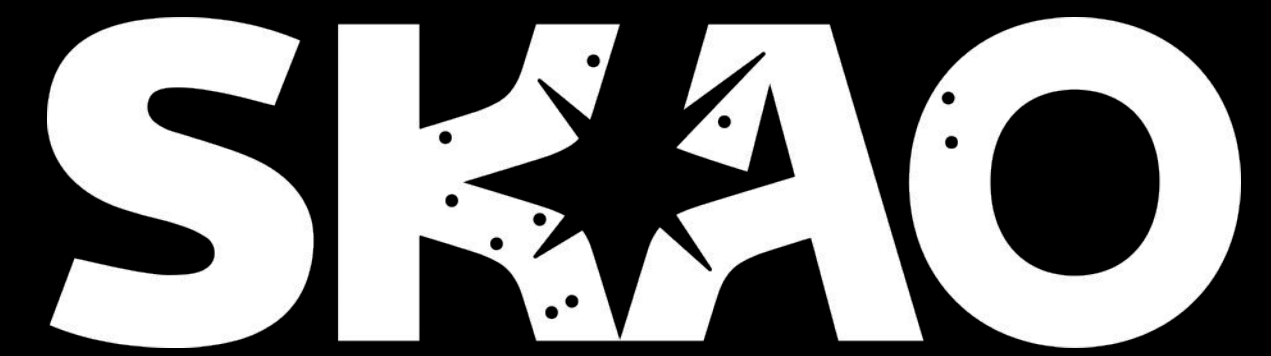




Progress on Construction and Science Commissioning of SKA-Low

George Heald, SKA-Low Lead Commissioning Scientist
(on behalf of the SKA-Low Science Commissioning team)

LOFAR Annual Meeting

9 June 2026



SKA Observatory

SKAO HQ,
Jodrell Bank, UK



1 Observatory
2 telescopes
3 continents
A mega-science project

*Two telescopes, frequency coverage of
50 MHz up to 15.4 GHz.*

SKA-Mid telescope, Karoo, South Africa

SKA-Low telescope, Murchison, Western Australia



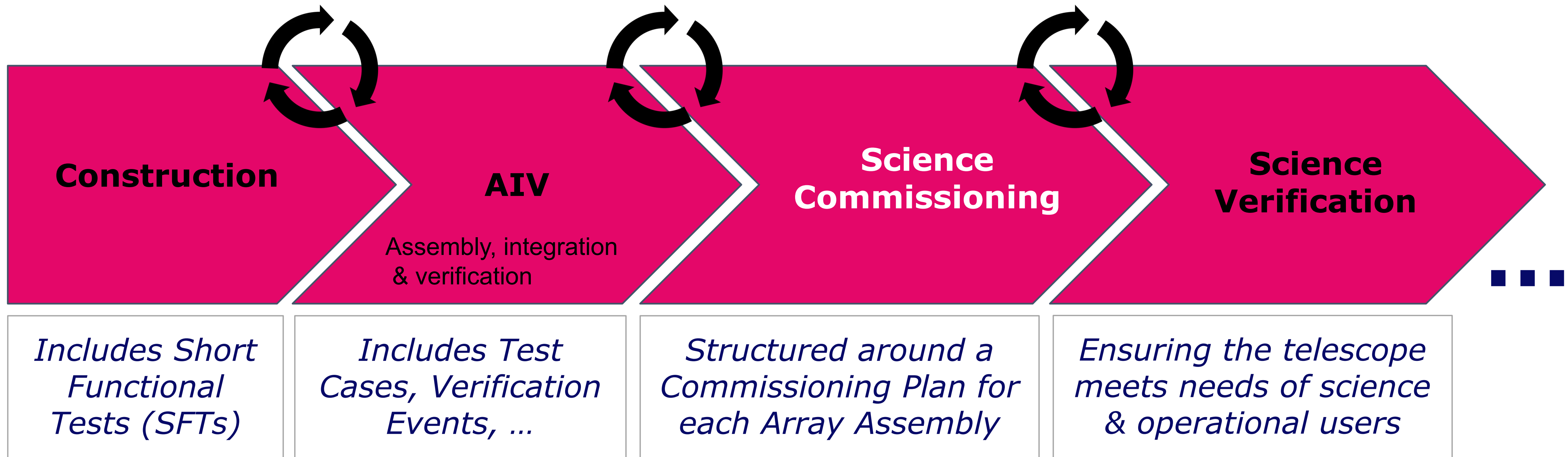
AA*

- 307 stations for SKA-Low (257 prior 2030)
- 144 dishes for SKA-Mid



SKAO Science Commissioning in the big picture

Internal activity that focuses on tests of science capability, using astronomical observations - separately organised for each telescope, by linked teams



Close collaboration between all involved teams
All activities are taking place at the same time



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.



SKAO



SKA-Low

THE SKA'S LOW-FREQUENCY TELESCOPE



LOCATION:
AUSTRALIA



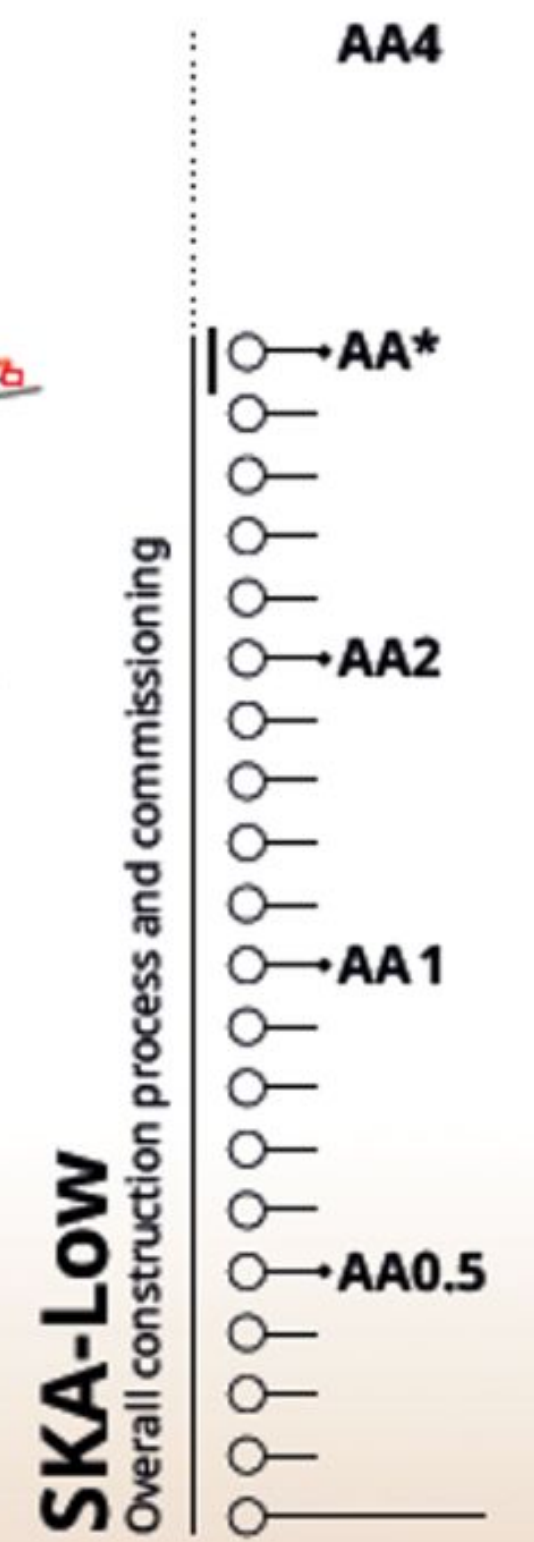
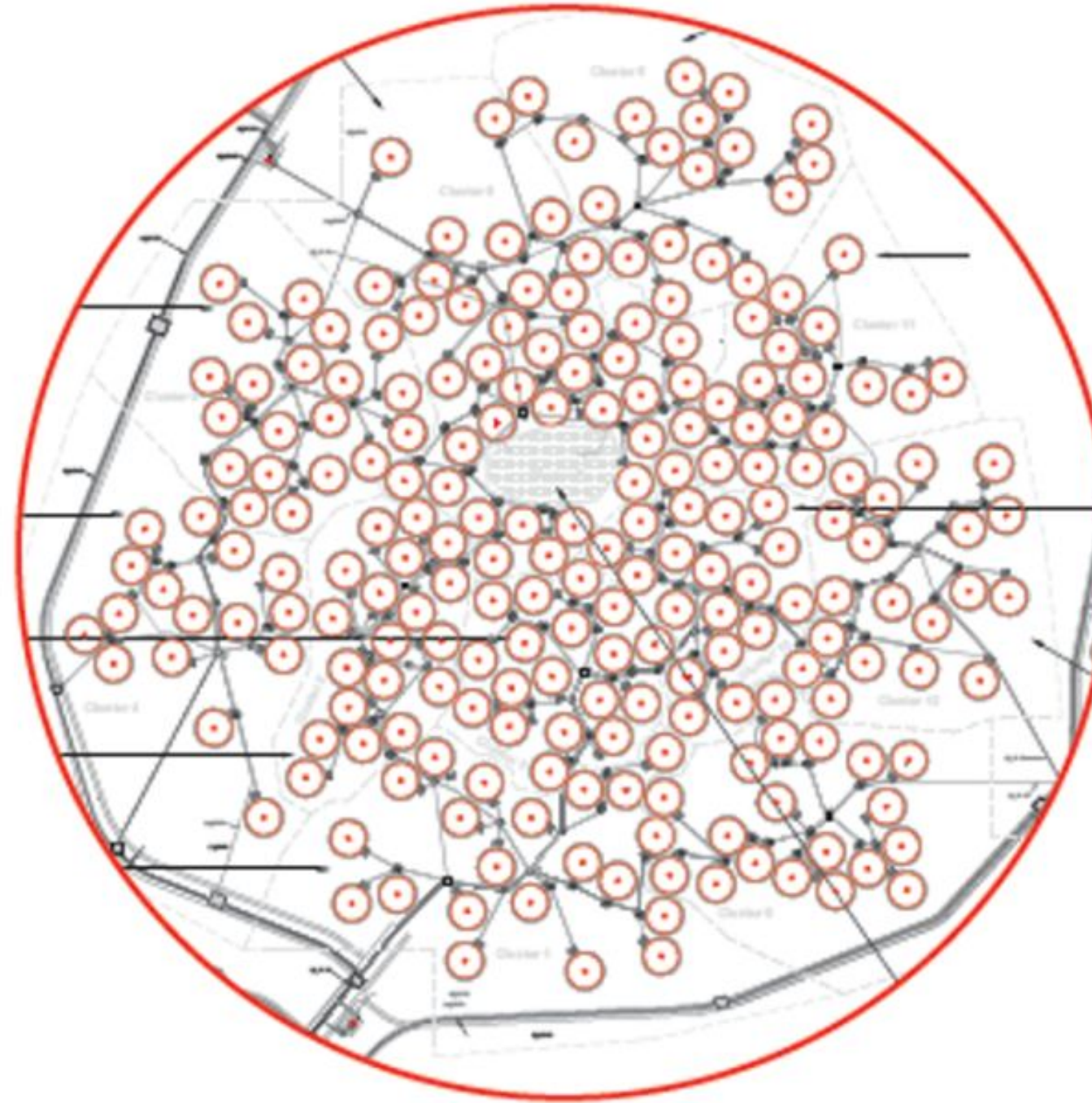
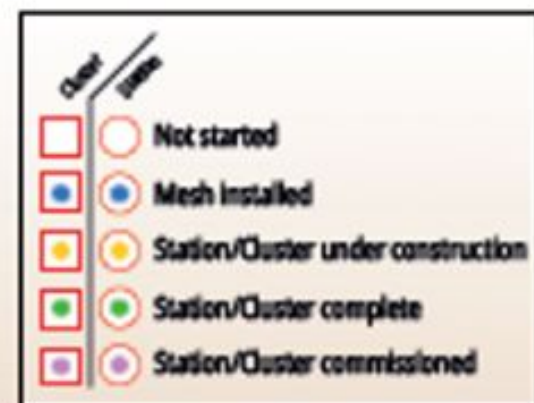
FREQUENCY RANGE:
**50 MHz-
350 MHz**



**131,072
ANTENNAS (AA4)**
SPREAD ACROSS 612 STATIONS



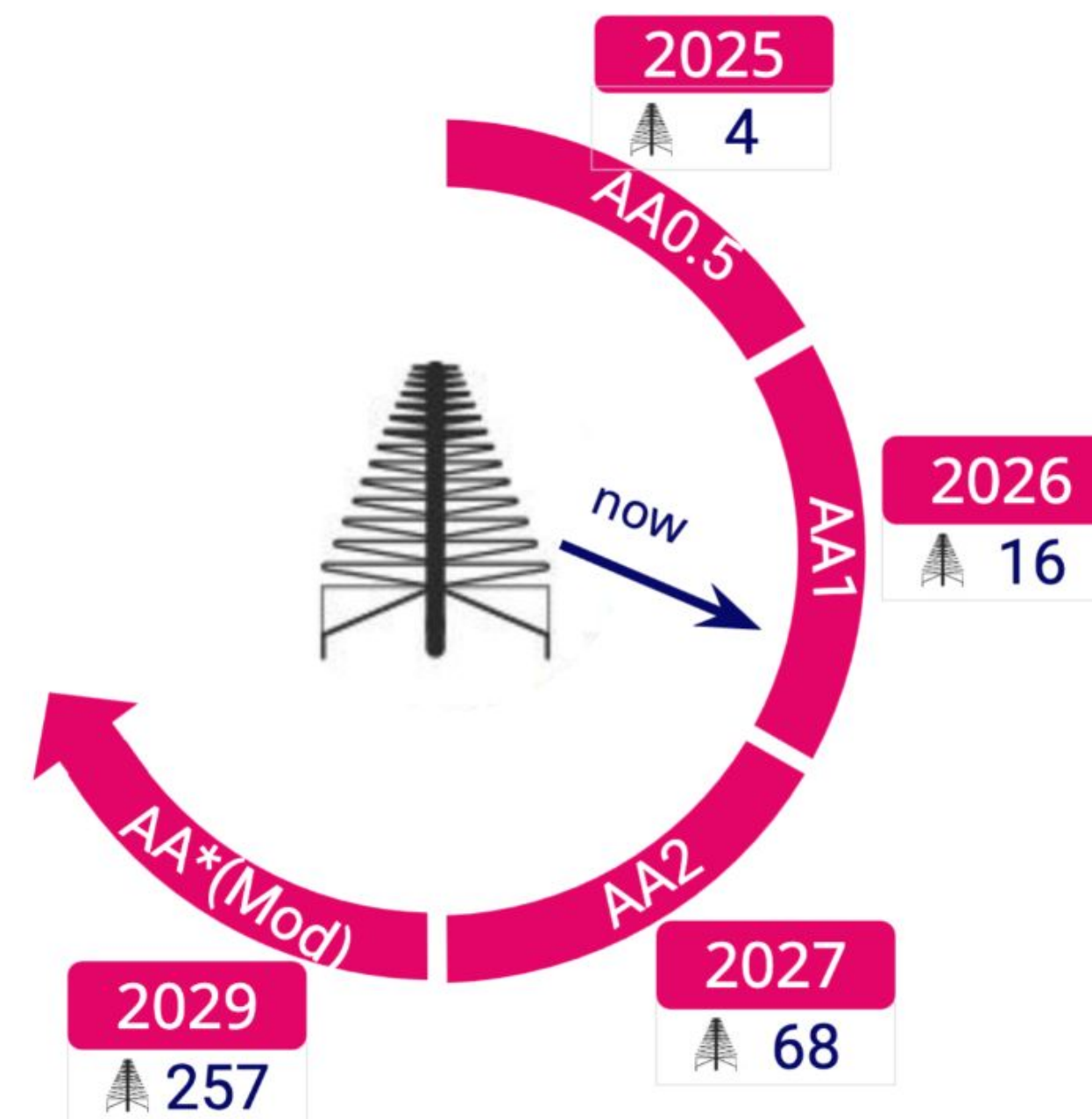
MAXIMUM BASELINE:
~74km



Staged delivery plan: the Array Assemblies

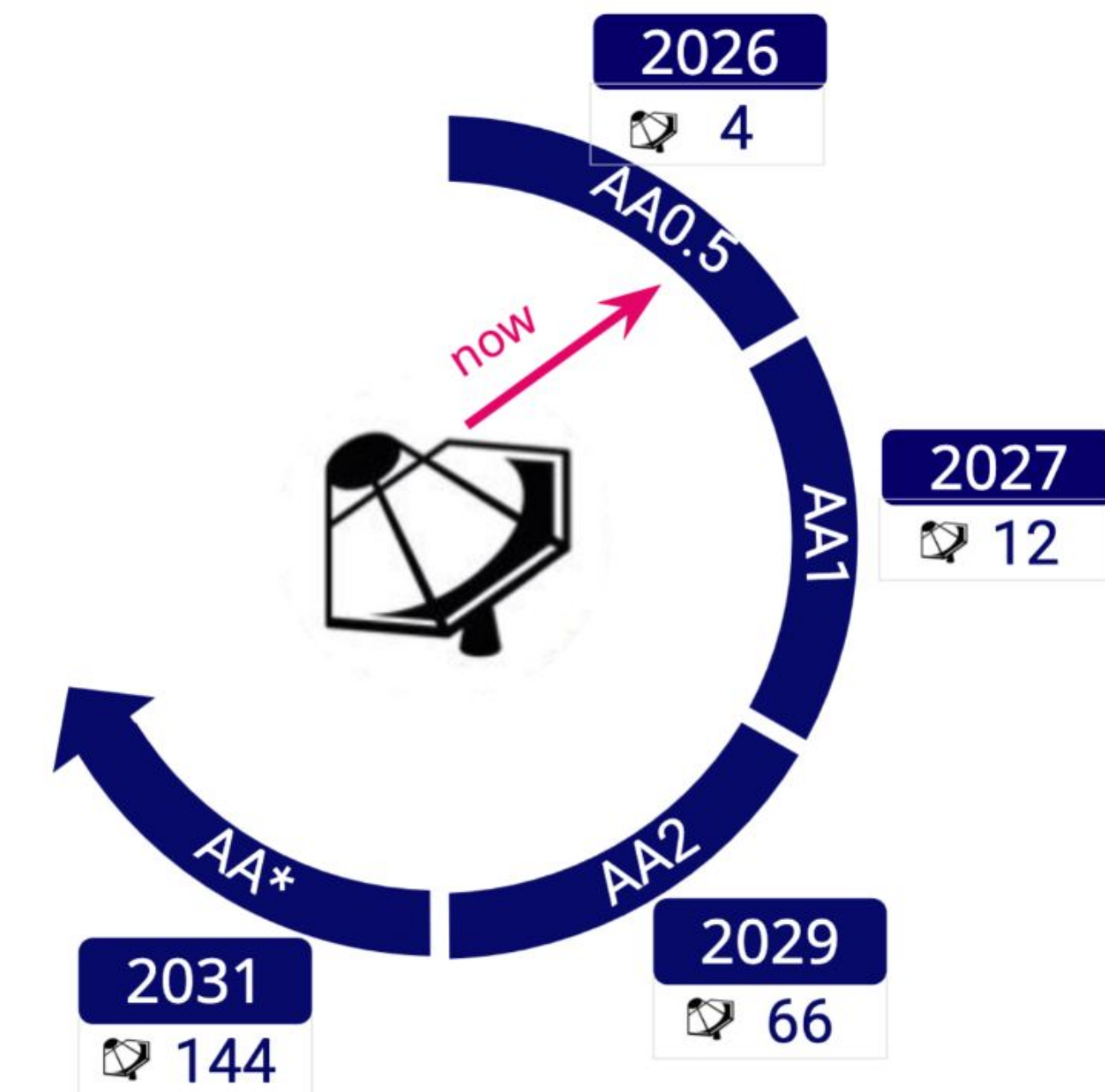
- Both telescopes are constructed and verified in stages called Array Assemblies (AA)
- Computing/network resources follow AAs to accommodate the increased data rates
- AAs ensure the full functionality of all the software and hardware is tested and verified at the earliest possible stage during construction

SKA-Low



Highlight results:
later in this presentation

SKA-Mid



- Highlight results:
- Fringes between 4 dishes
 - Phase and amplitude closure
 - Preliminary imaging



SKA-Low Array Assemblies (AAs)

Progression is not just numbers, it's about functionality

AA0.5

4 stations
Bmax ~ 5.5 km

Intent:

Get things working, no matter how

AA1

16 stations
Bmax ~ 5.5 km

Intent:

Stabilise and ensure reliable systems

AA2

68 stations
Bmax ~ 65 km

Intent:

Scale up, higher resolution, early science

AA*
...



Why am I here?

LOFAR is an SKA pathfinder! And we're both undertaking science commissioning as the telescopes grow.

- Important that we continue to learn from LOFAR experience
 - Including organisation of the commissioning activity
 - More obviously: common gotchas, key tests and checks, etc
- Share our progress to date and forward plans
- Chance to capture feedback from you on what we have done, and what we plan to do

There's more to say than what I can present here, I'm very happy to talk throughout the week!



Progress toward AA1

- AA0.5 stations
- AA1 “early access” stations
- AA1 stations partially available

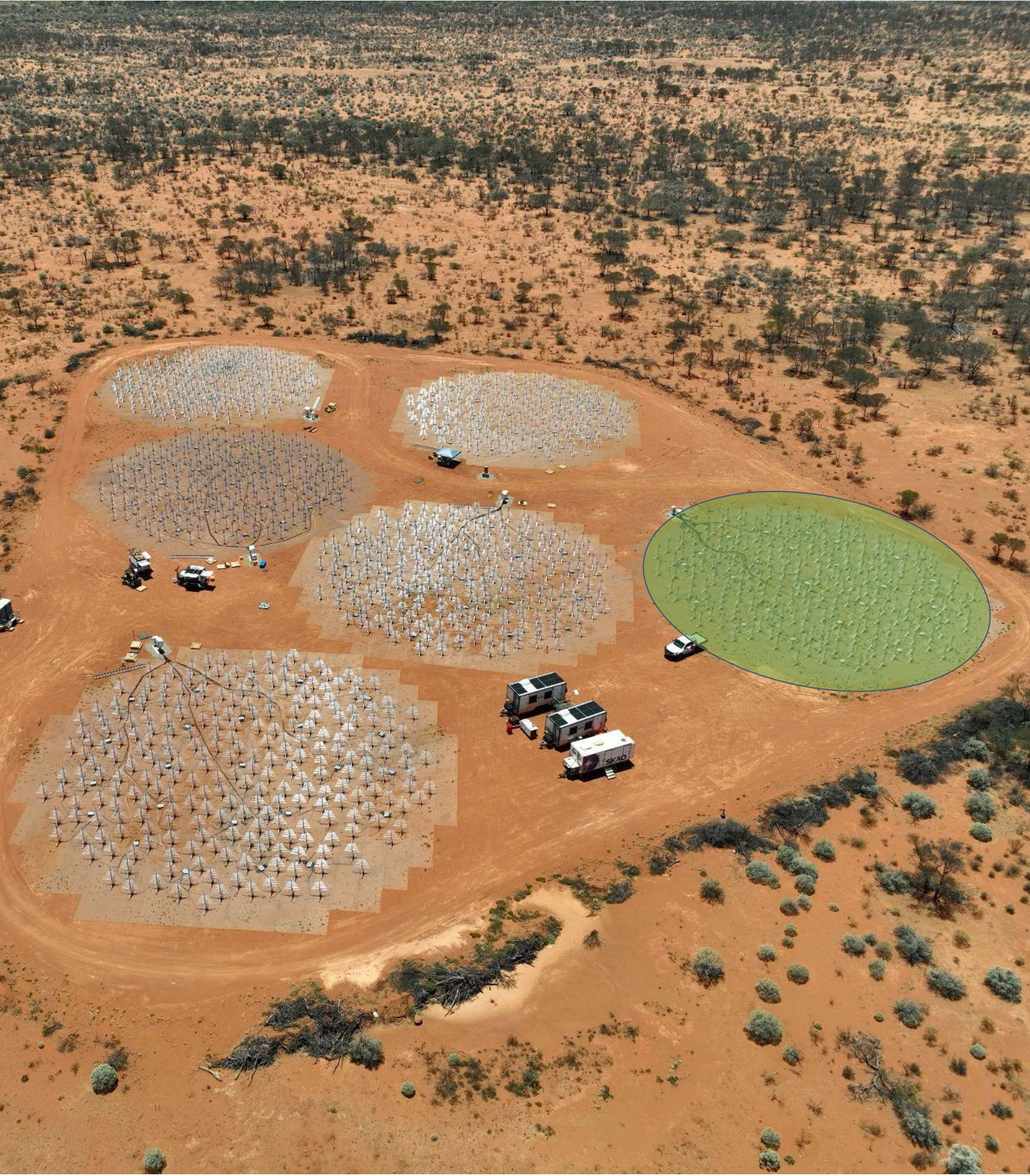
Min BL ~ 40 m
Max BL ~ 5.5 km



S8



S9



S10



Progress toward AA1

- AA0.5 stations
- AA1 “early access” stations
- AA1 stations partially available

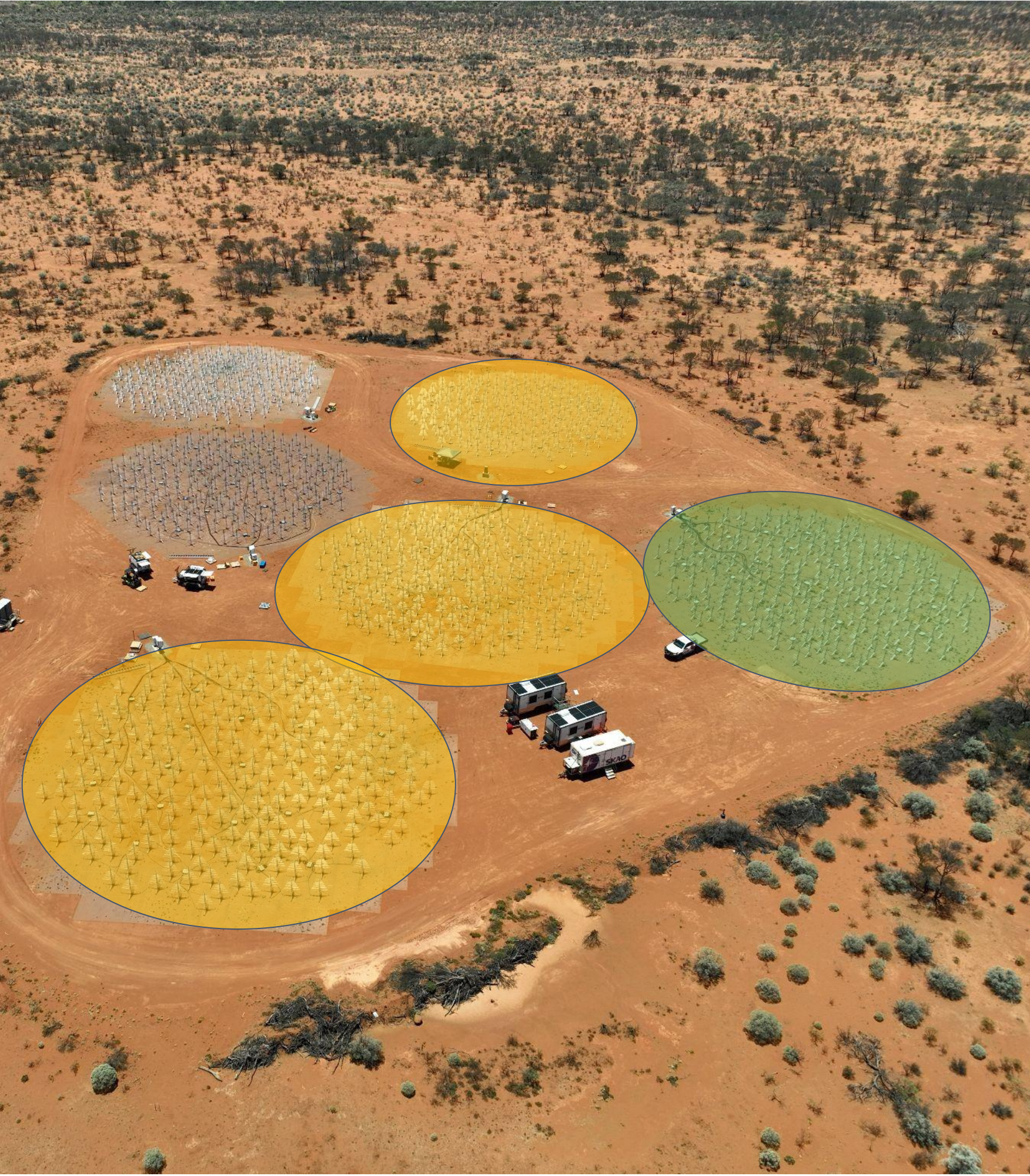
Min BL ~ 40 m
Max BL ~ 5.5 km



S8



S9



S10



Progress toward AA1

- AA0.5 stations
- AA1 “early access” stations
- AA1 stations partially available

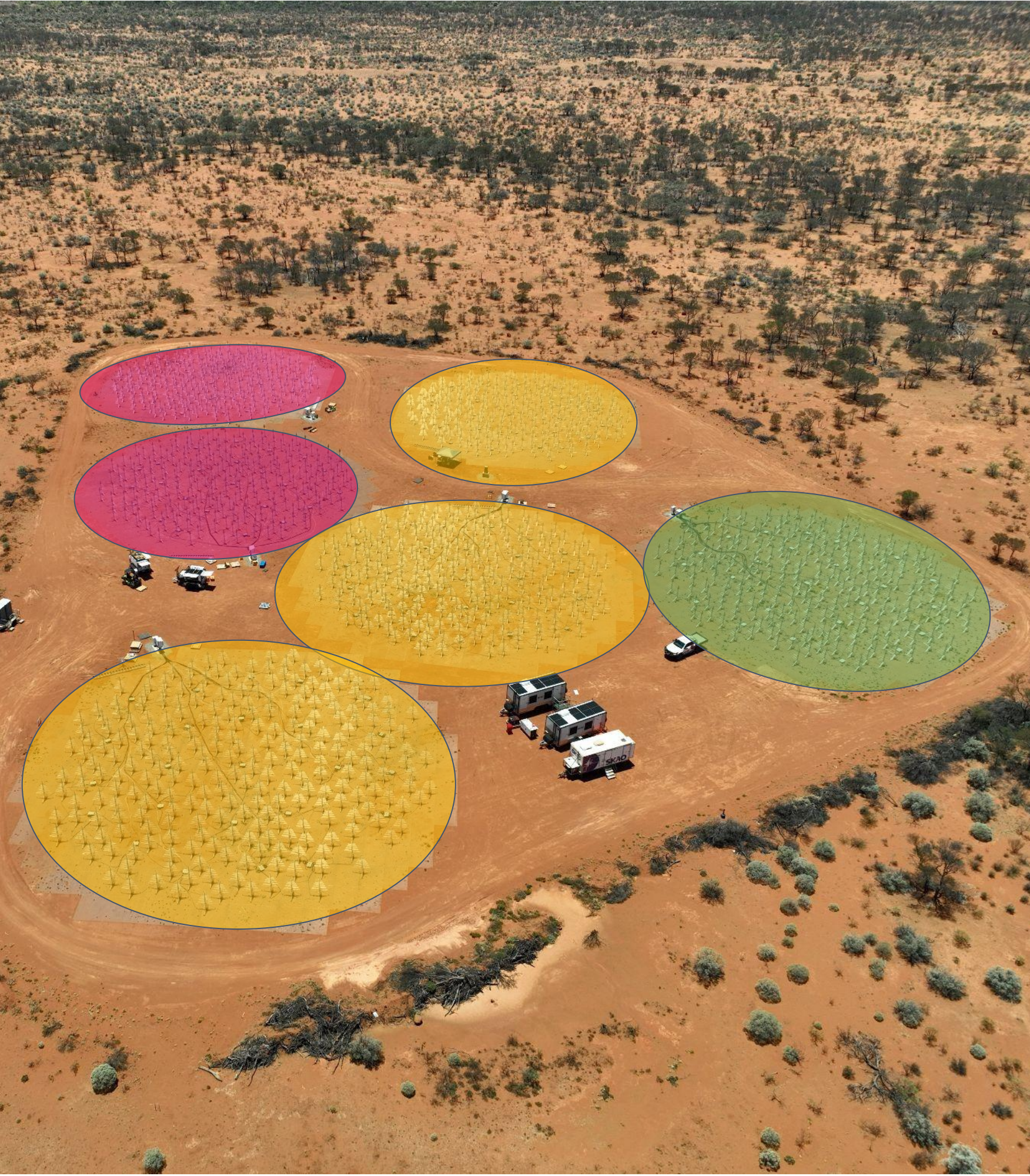
Min BL ~ 40 m
Max BL ~ 5.5 km



S8



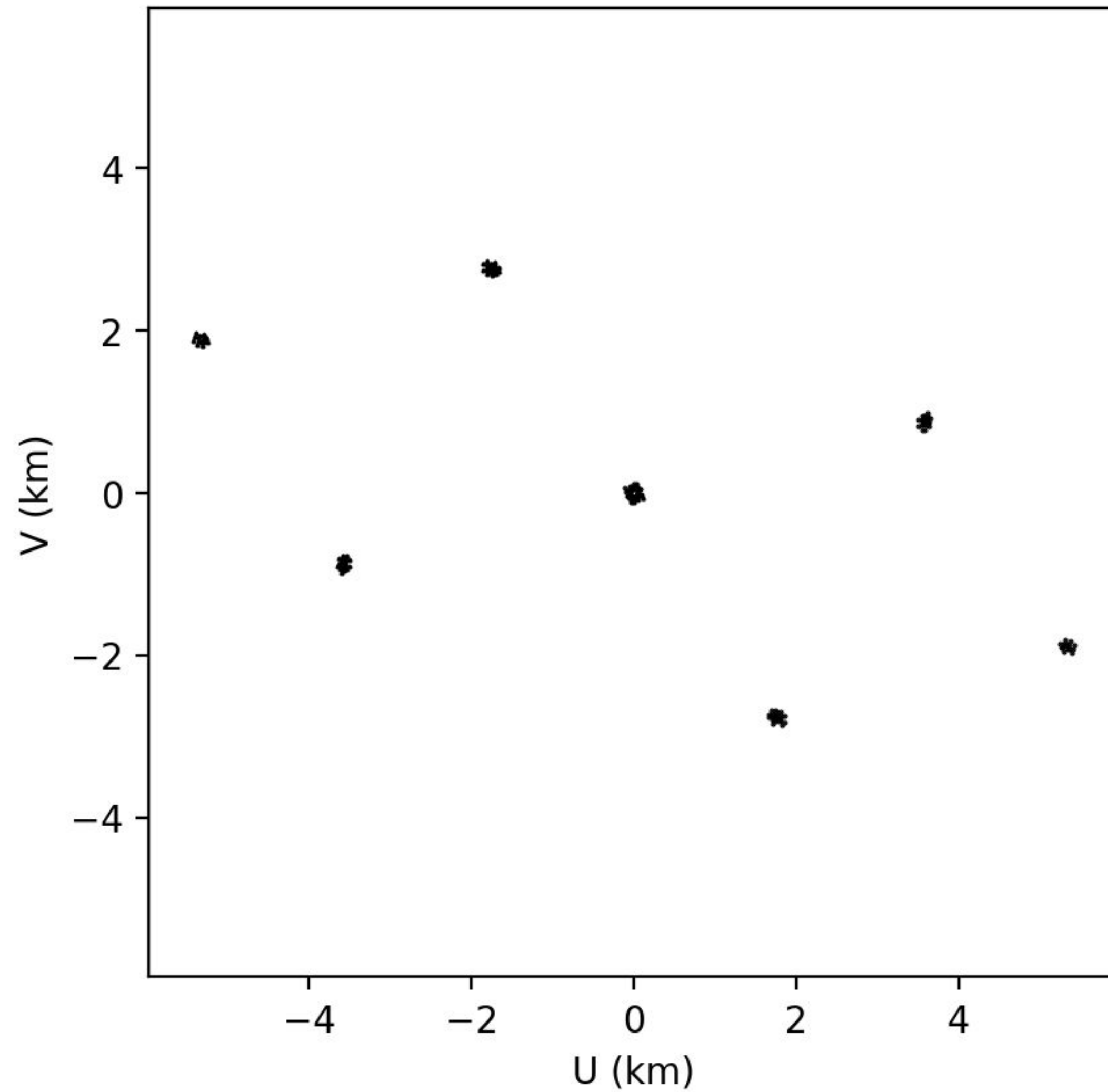
S9



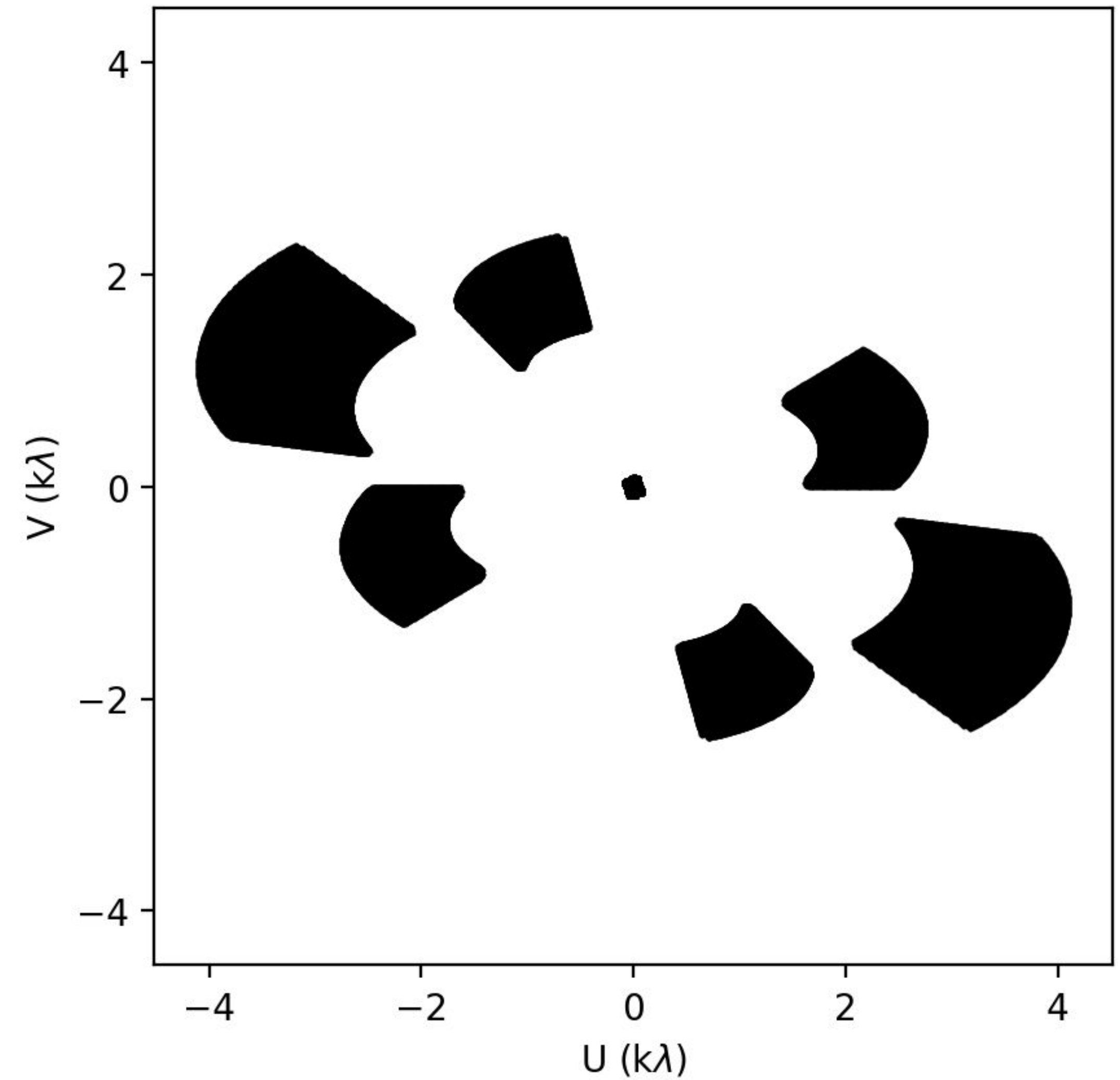
S10



Current ($\sim$ AA1) uv coverage



Zenith snapshot



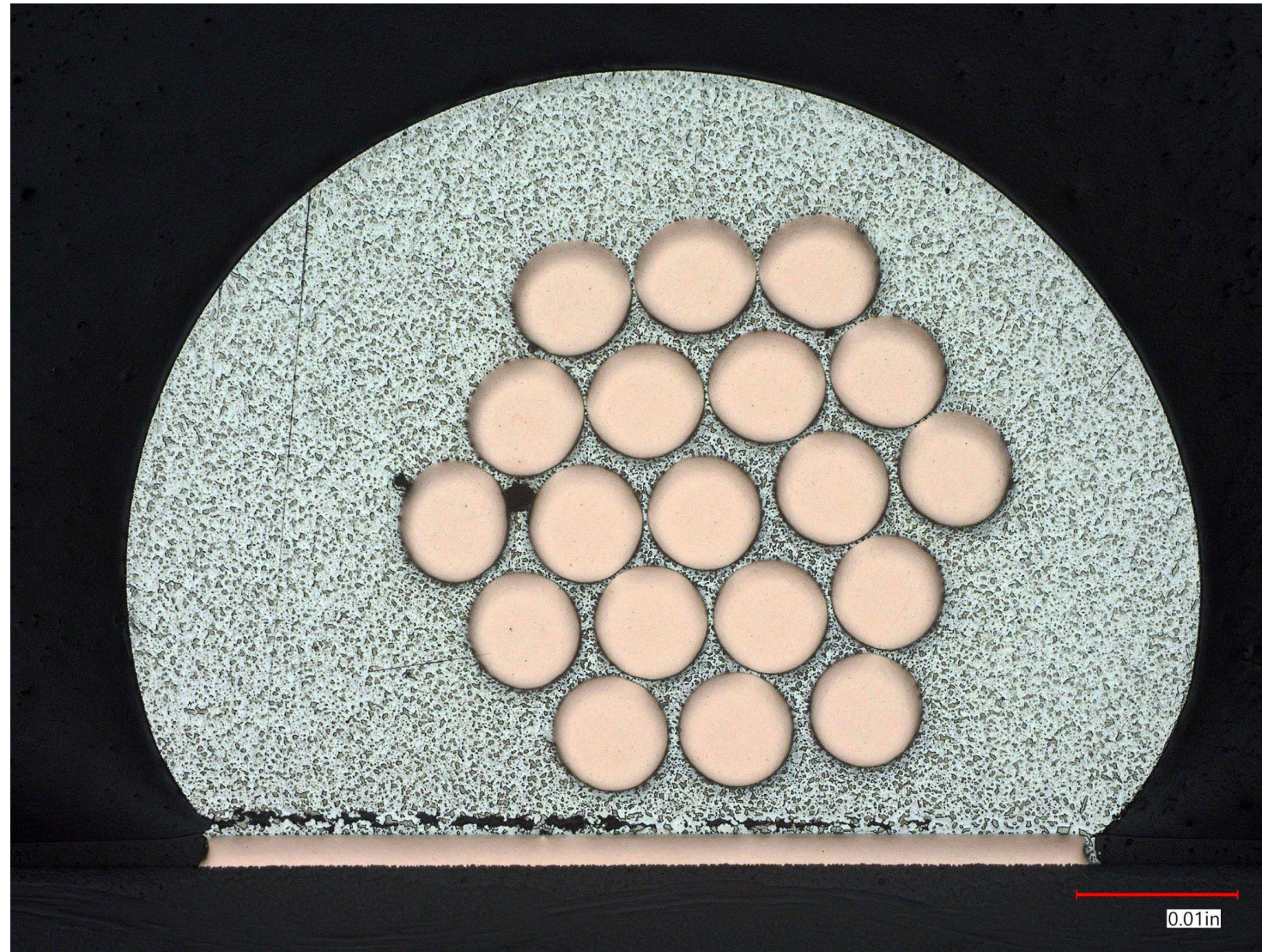
Long track, 4hr, 150-225 MHz, dec=-25.3°



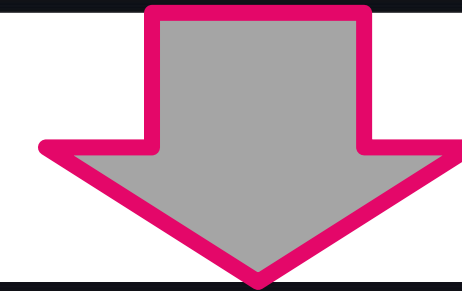
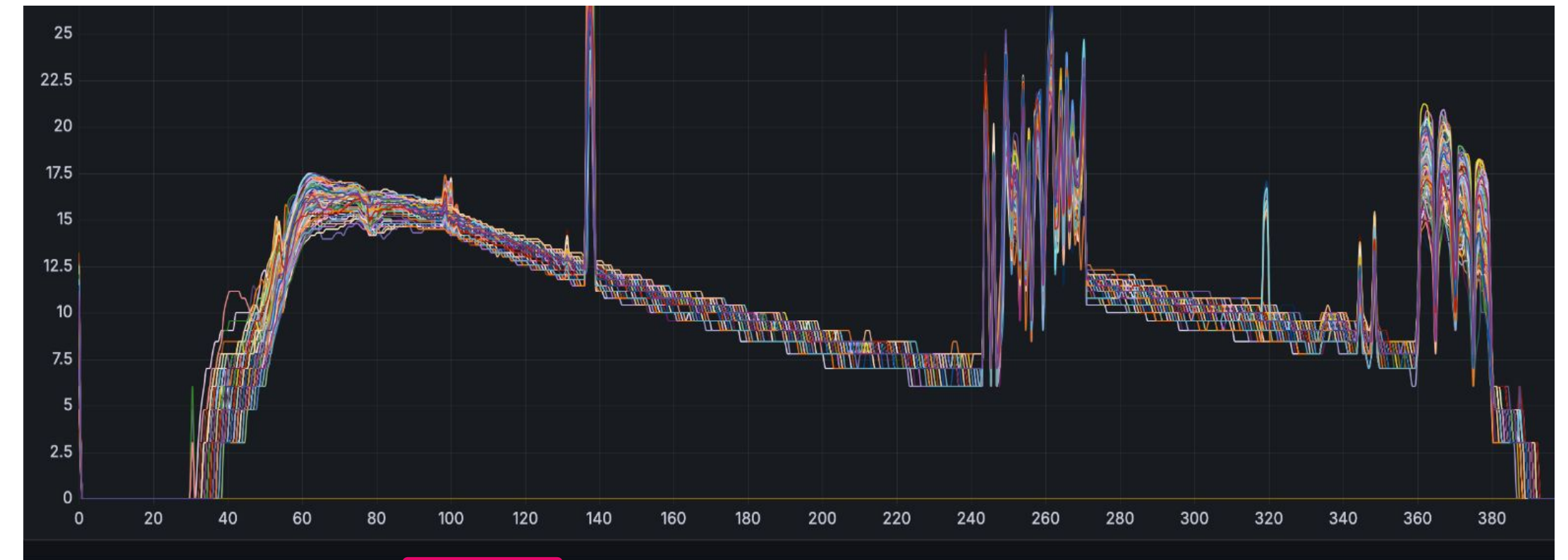
Upcoming activity (in lead up to AA2): replace
~35,000 LNAs with hardware issue



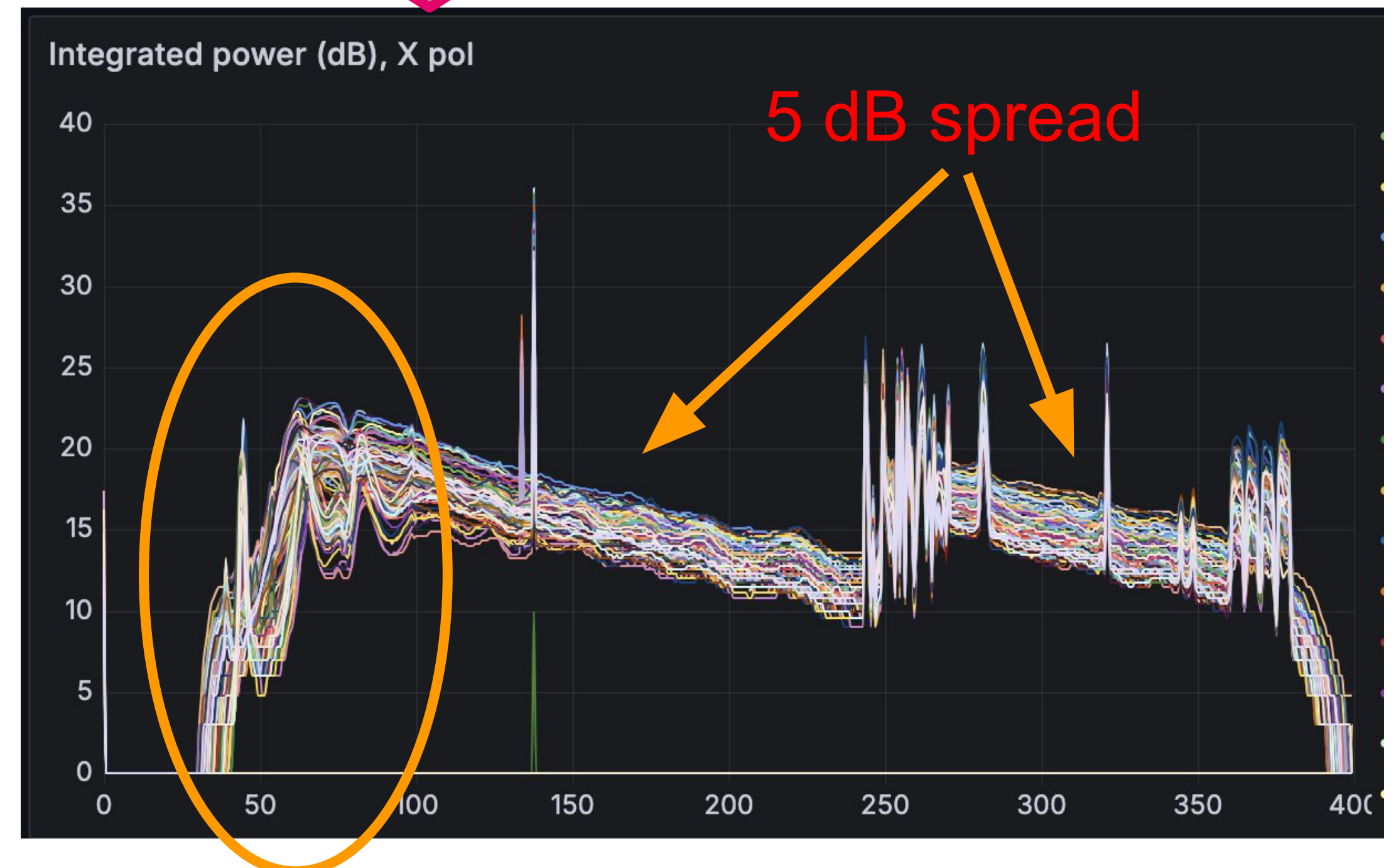
LNA degradation issue: symptoms and impact



- Fluctuations in amplitude and phase, thus moderate defocus of station beam
- Below 100 MHz, bandpass degradation is extreme - much larger impact
- Now: intensive testing of new design
- Soon: rollout of new devices at scale
- Commissioning work can proceed for most of our test cases, some will have to wait



Over the course of minutes/hours



Summary of SKA-Low Science Commissioning

Organisation

- Use of Jira tickets to define, track and document commissioning tests & tasks
- Tests are grouped within 'domains' of telescope capability, led by team members

Completion of AA0.5 Science Commissioning

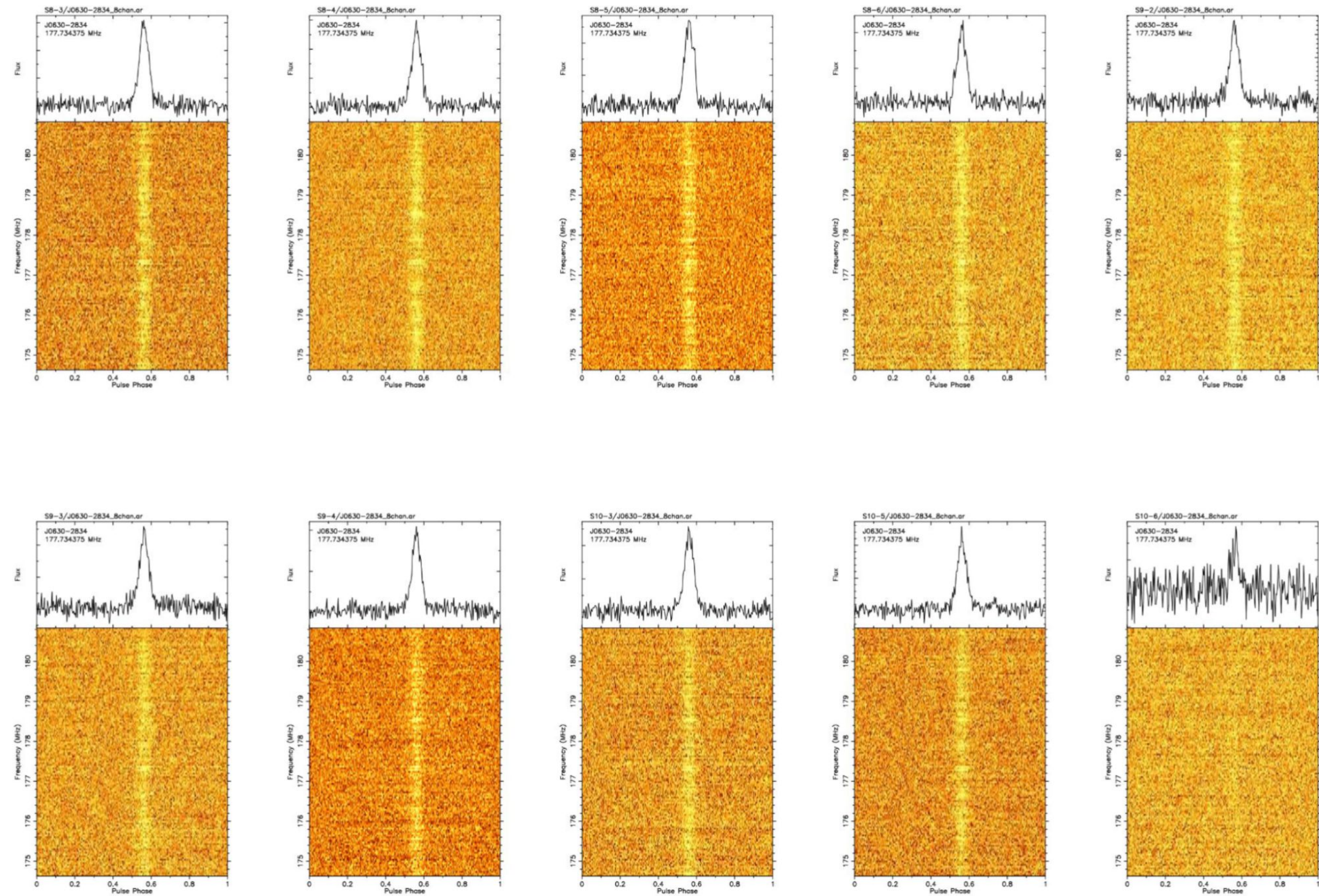
- Determined best practice for station calibration & performance monitoring
- Measured station beam width and SEFD (~ 2000 Jy at intermediate frequencies)
- Reconciled station delays (geometric and static), phase closure & basic calibration
- First (4-station) image, detections of 57 known pulsars with single stations & PST

Progress toward AA1 Science Commissioning

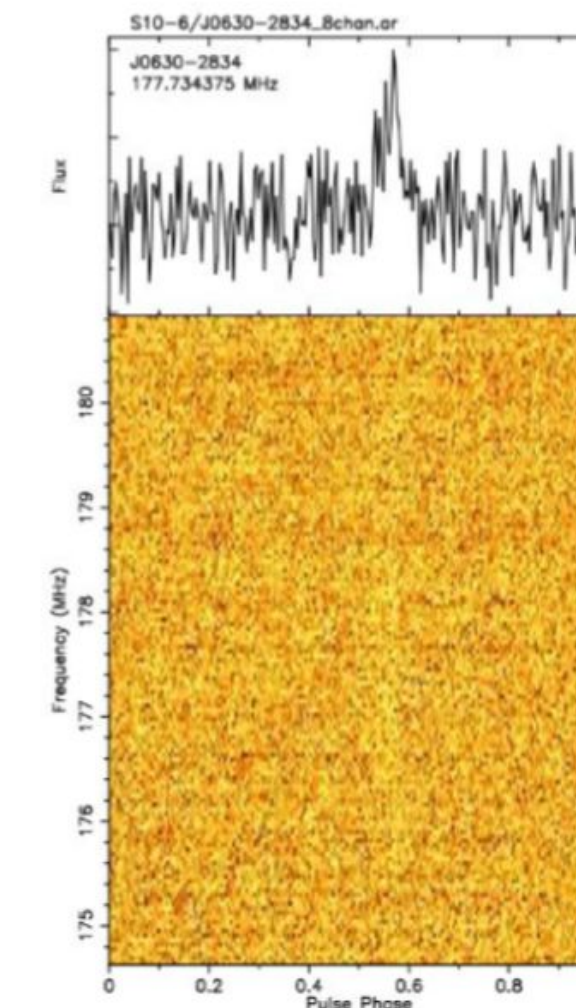
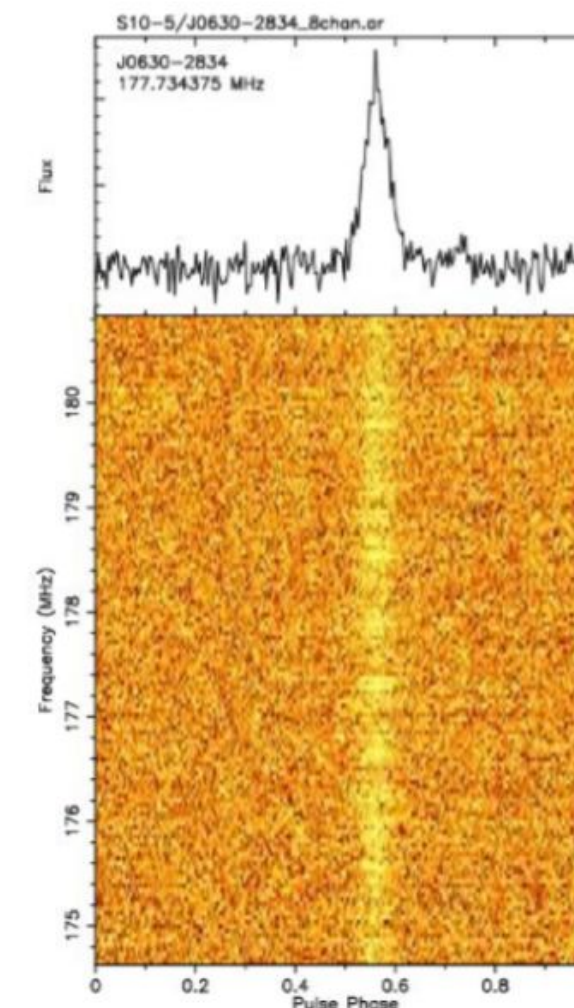
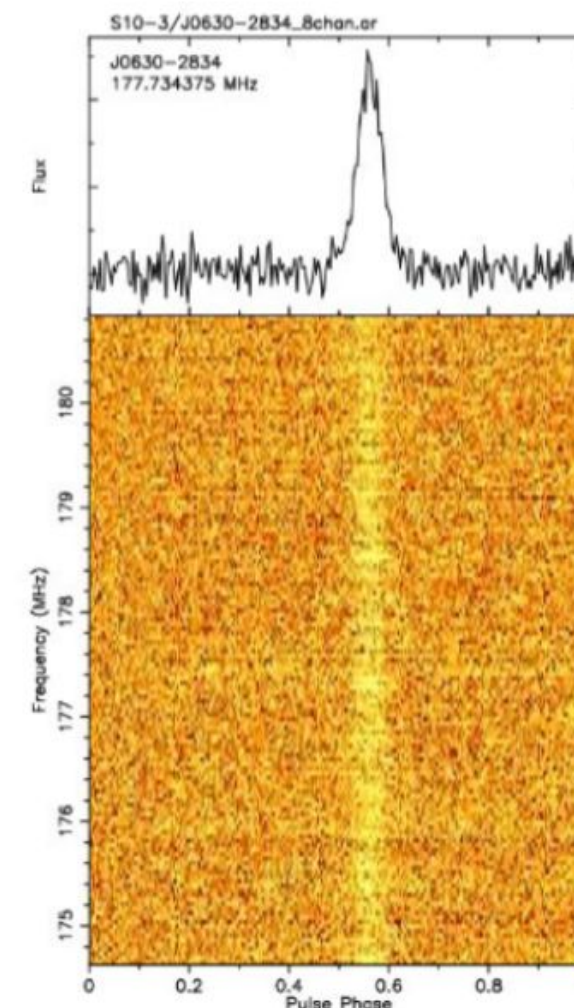
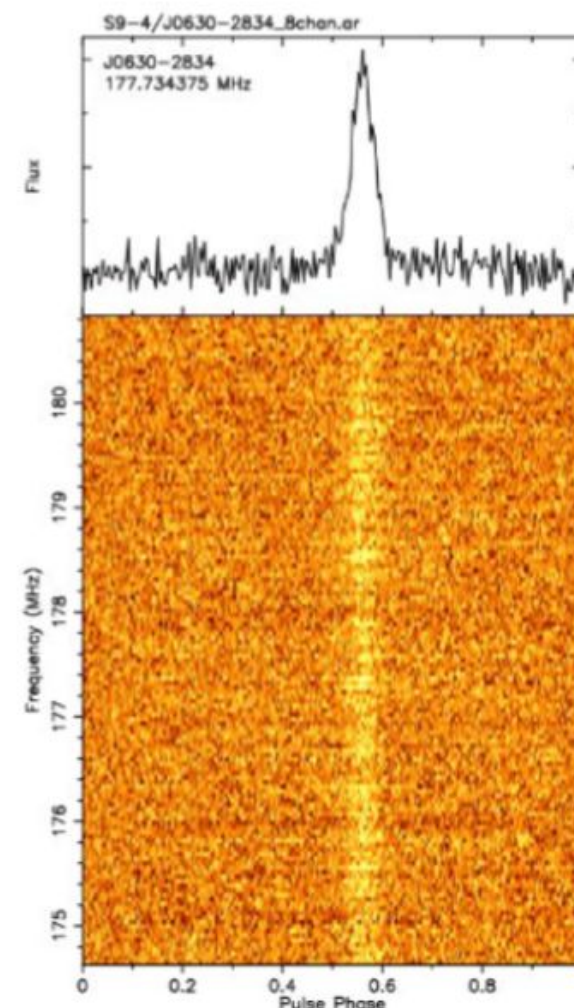
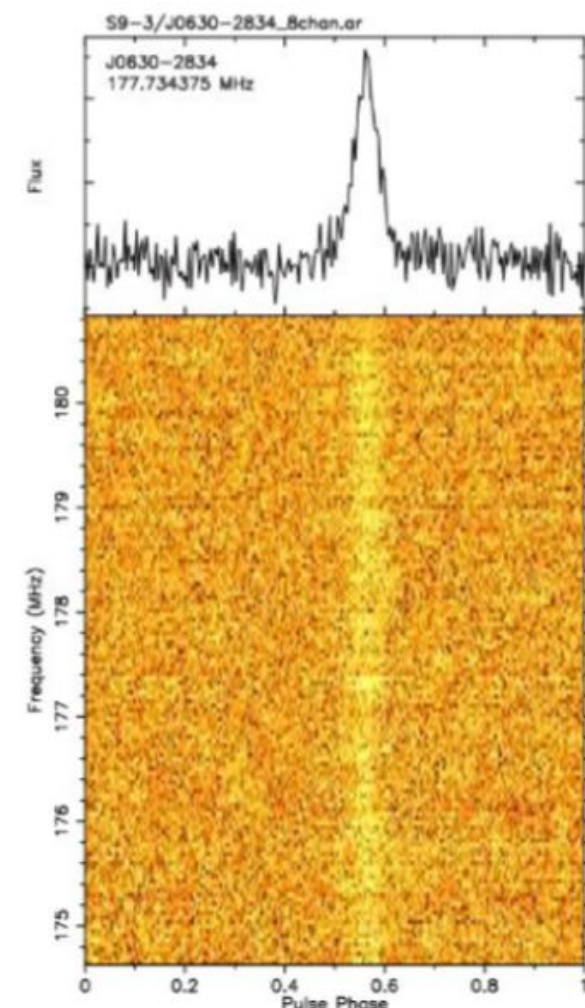
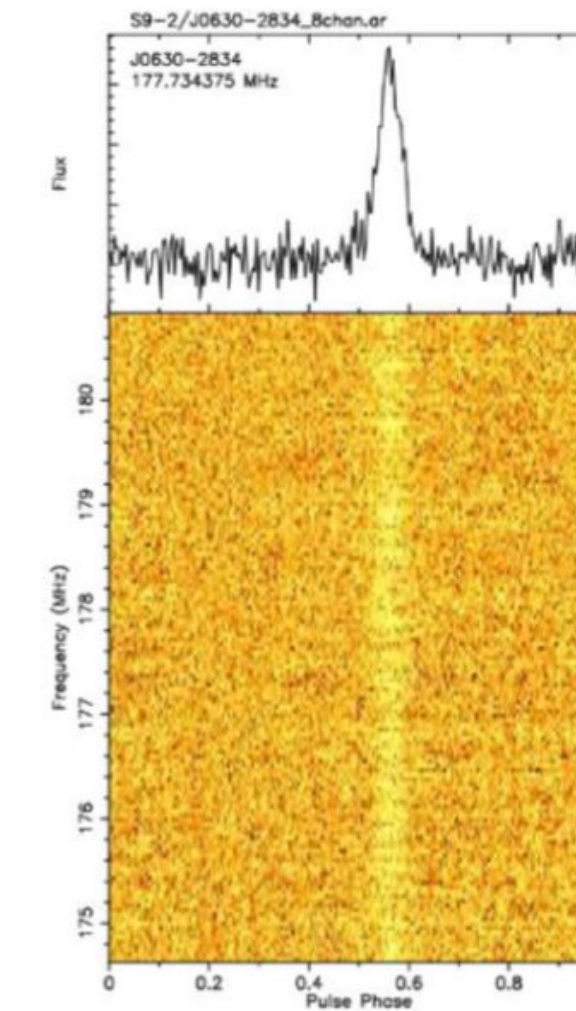
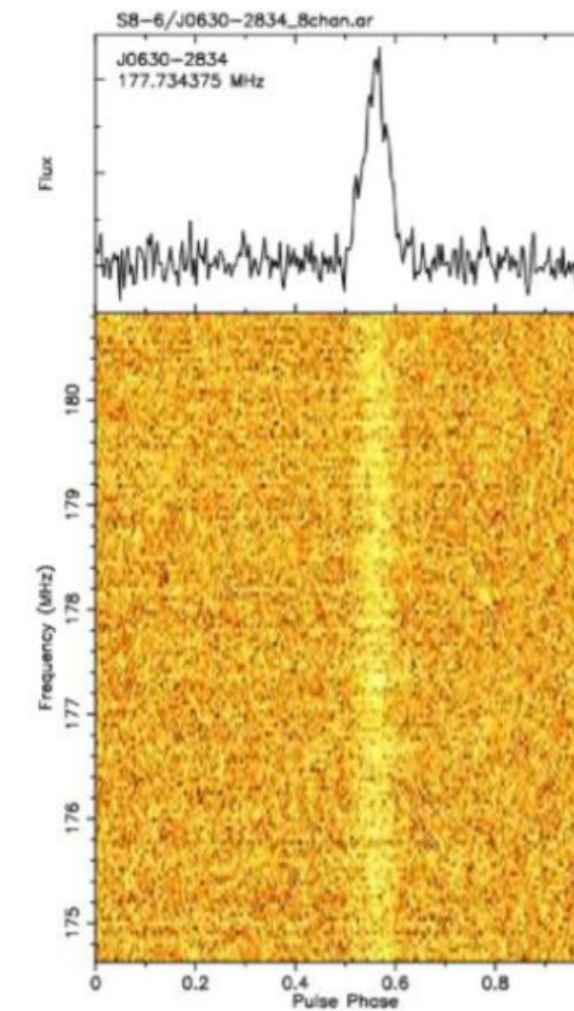
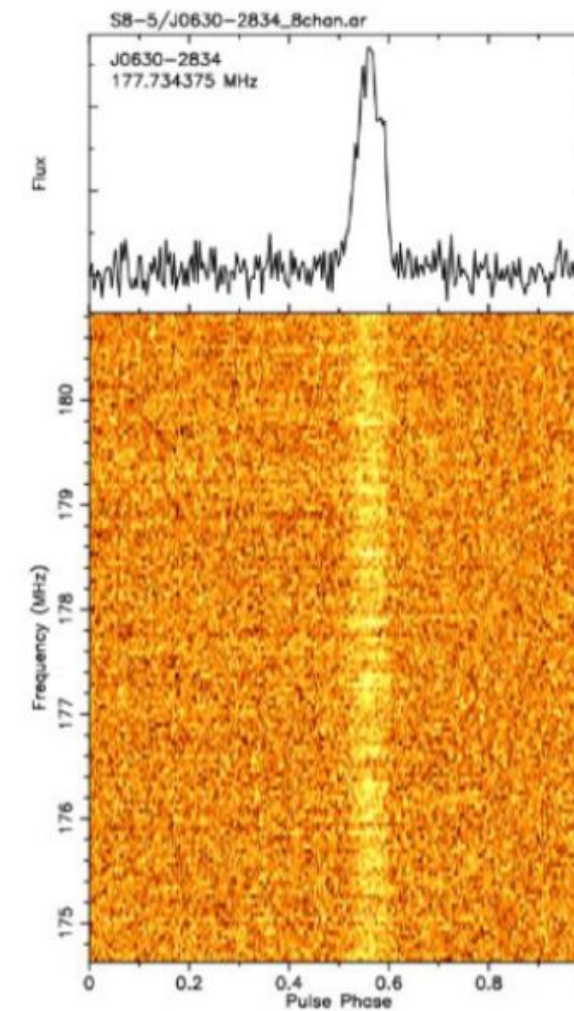
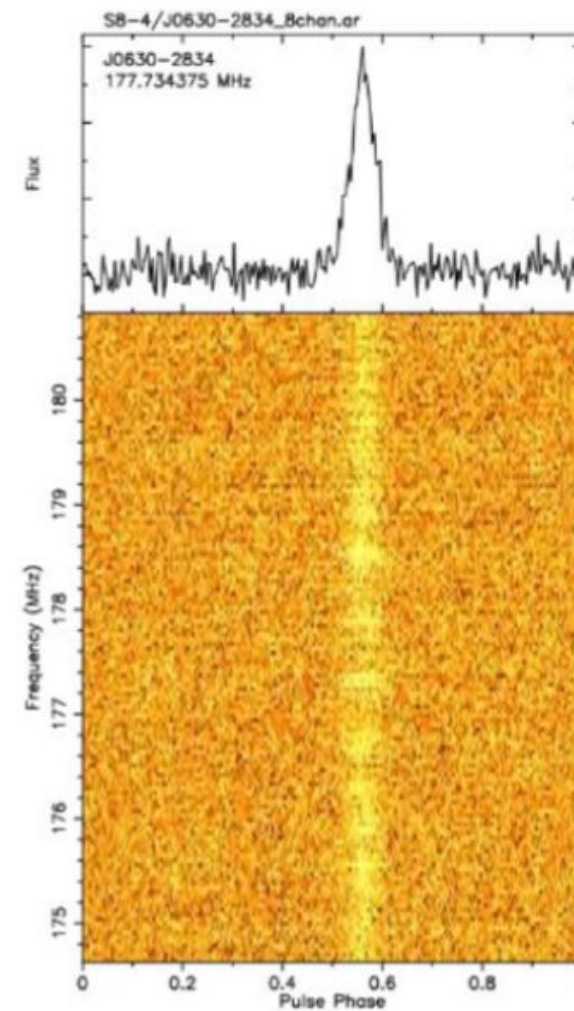
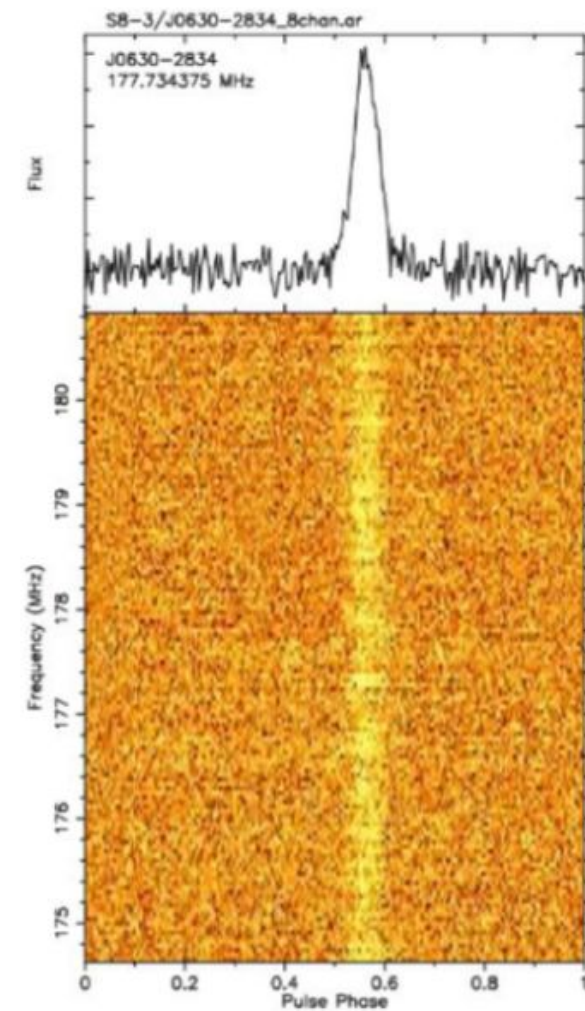
- Further tests of closure, measured relative station positions within the array
- Testing of "real time calibration" and pulsar timing (PST) and search (PSS) modes
- Further tests of array calibration and imaging capability, manual self-calibration
- Testing of batch processing software components and pipelines



Highlight - multistation quality checks



Highlight - multistation quality checks



Lower S/N in station S10-6:

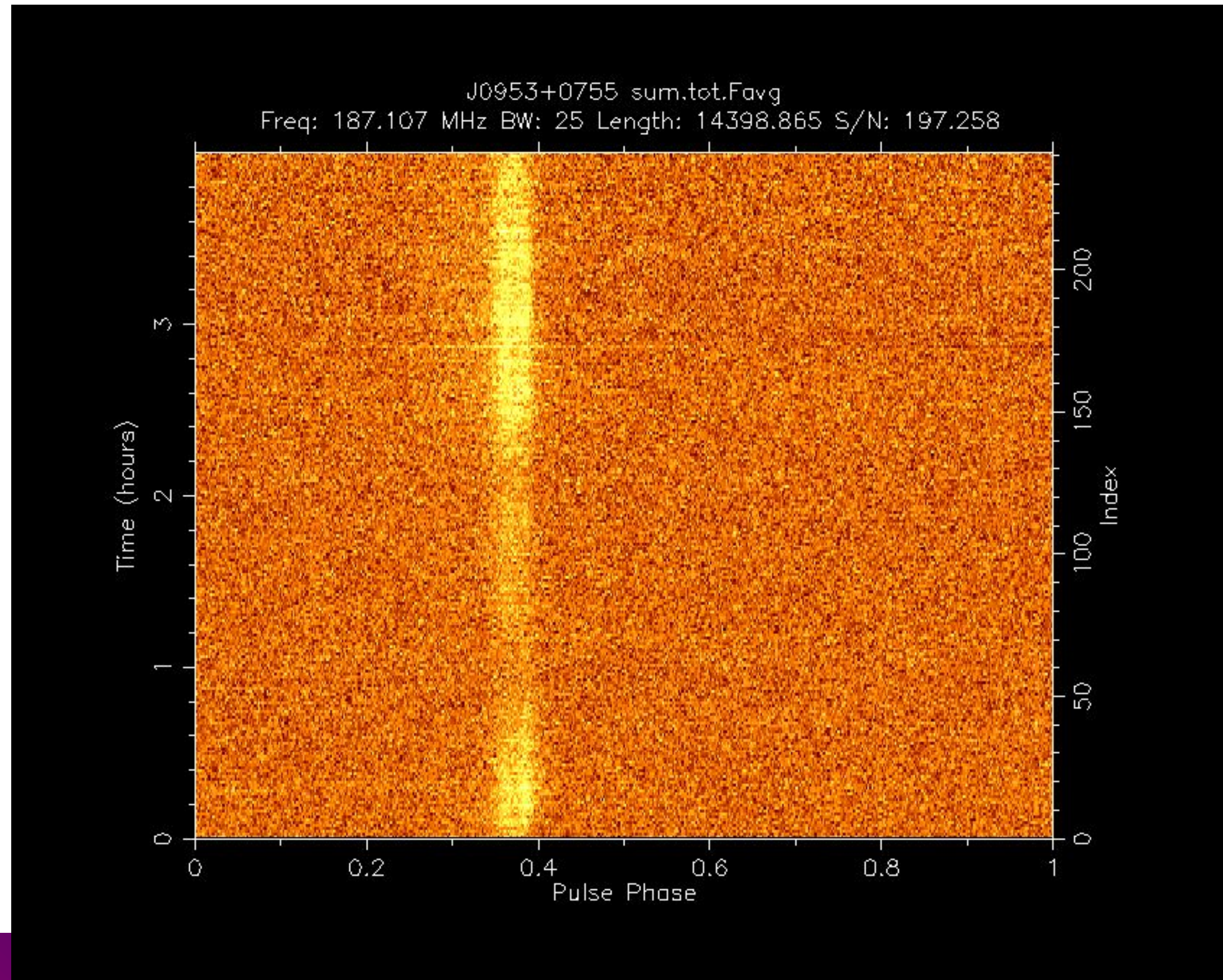
Suboptimal station calibration, while this station was still in the assessment phase for “early access”

Ongoing value in such tests

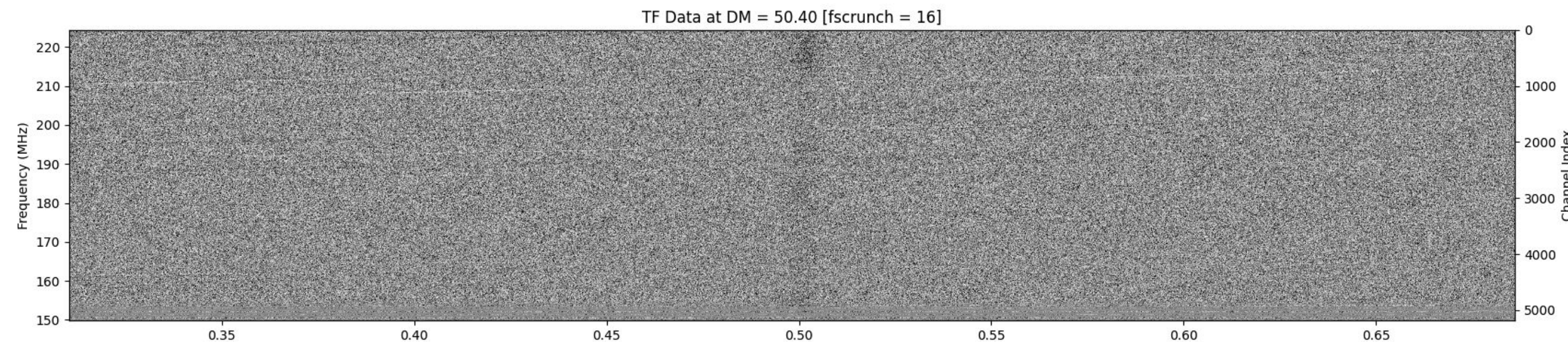


Highlight - PST flowthrough mode

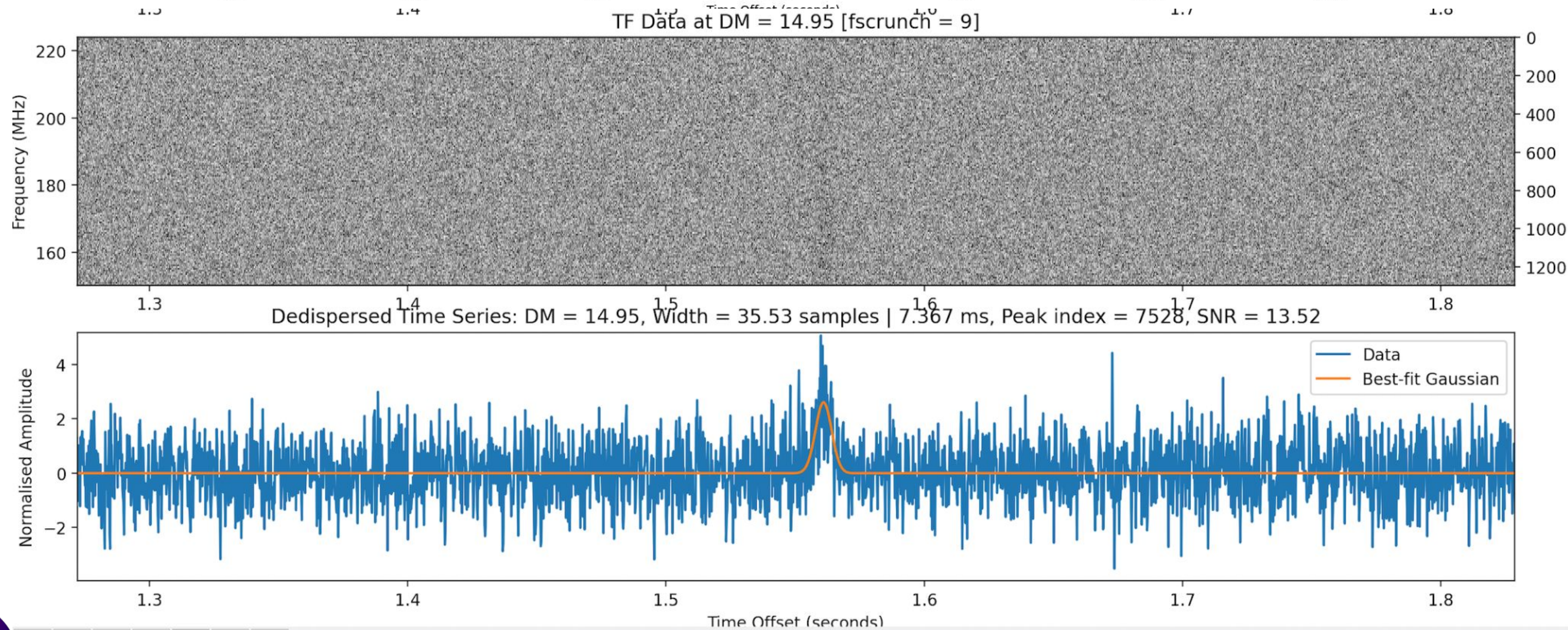
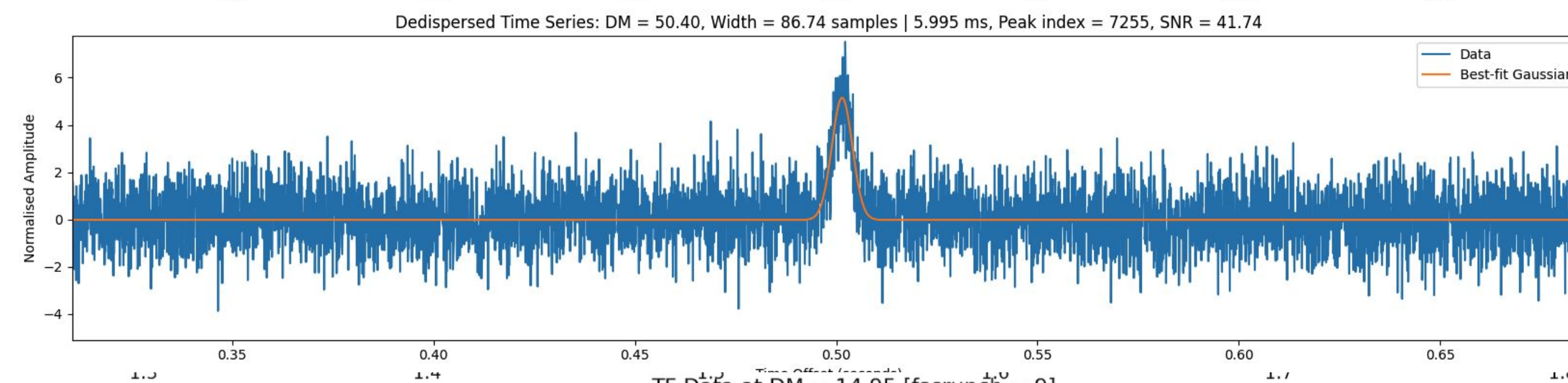
Can record PST data at reduced bit rate ➡ longer scans
Here, brightness dips are real (scintillation + intrinsic)



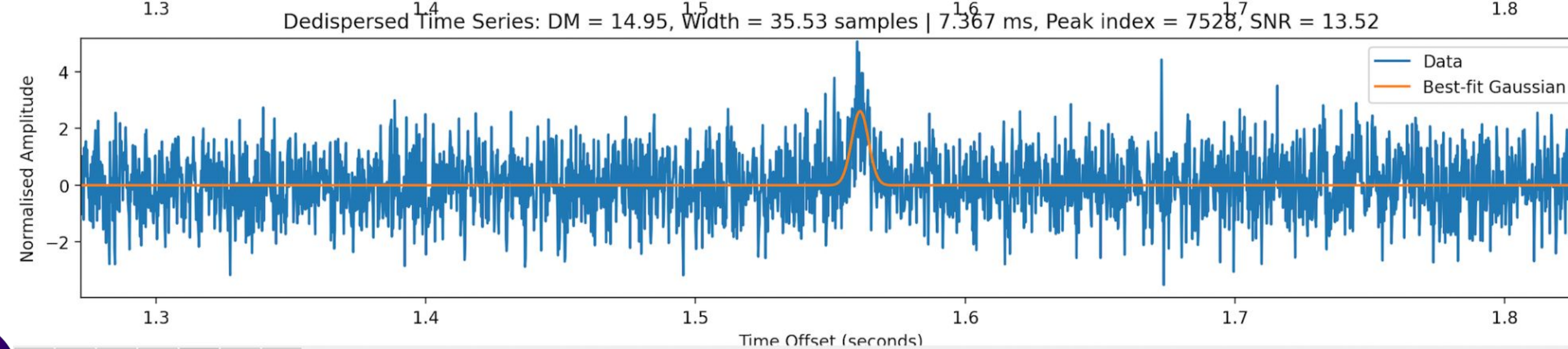
First PSS detections!



Single pulse from J1752-2806
over 75 MHz bandwidth



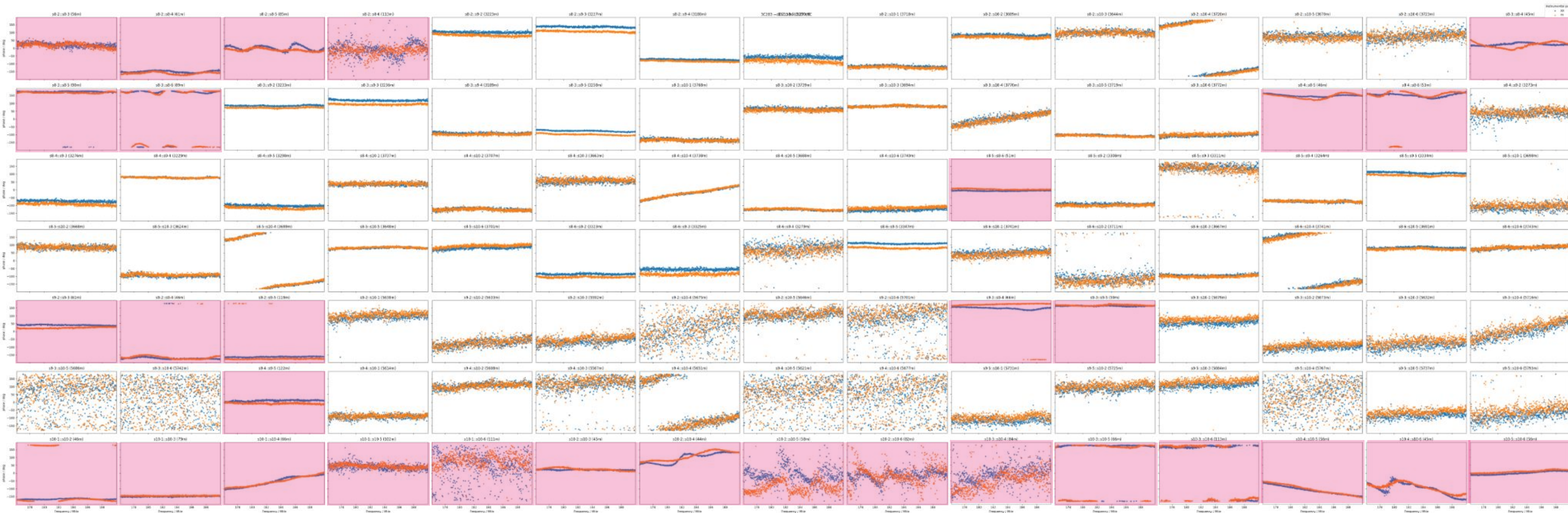
A pulse from J2325-0530! – A
rotating radio transient (RRAT)



Highlight - interferometry

3C283, ~14 min scan, 15 stations, 176-239 MHz

This plot: raw data, “derotated” (XX,YY), 176-190 MHz

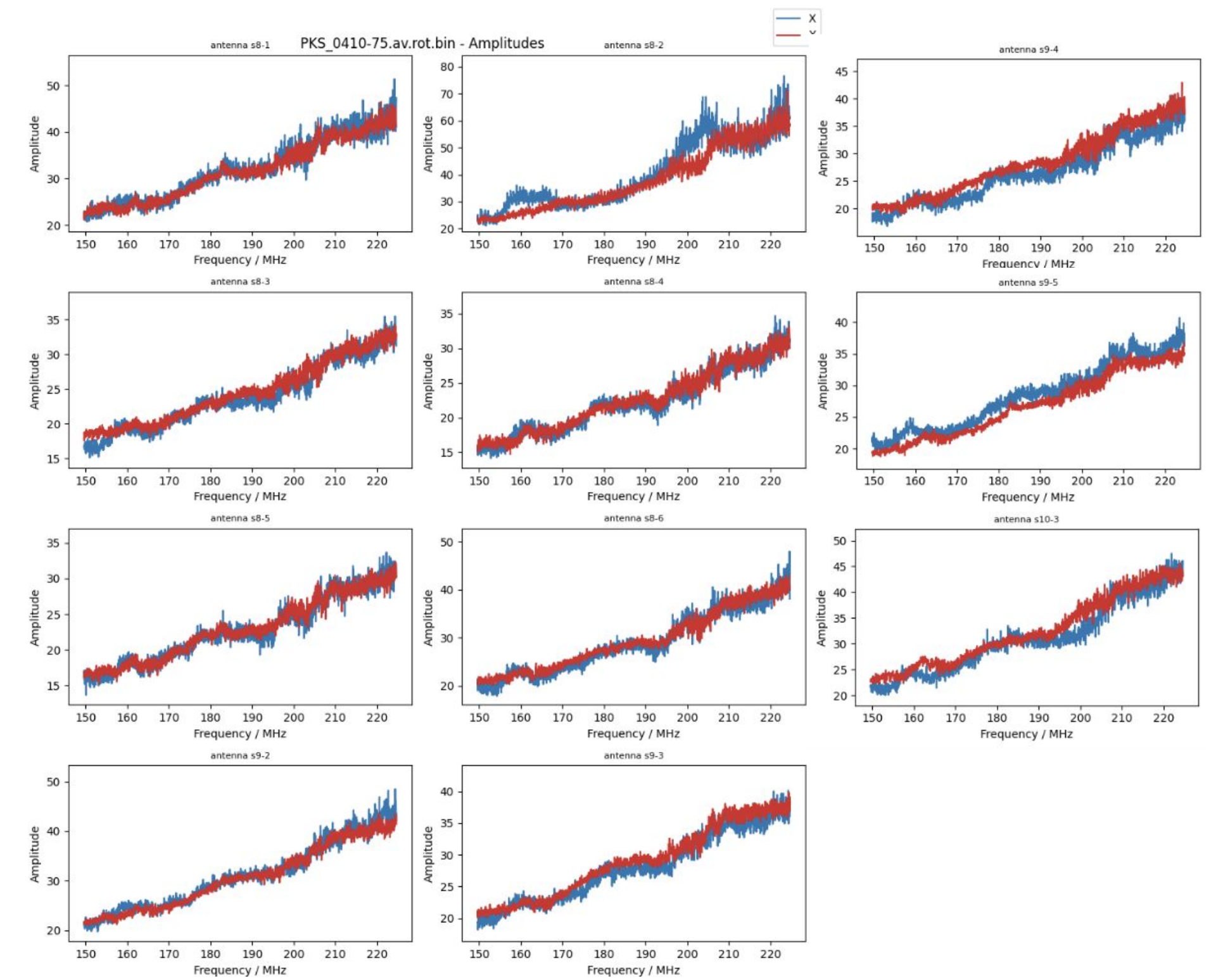
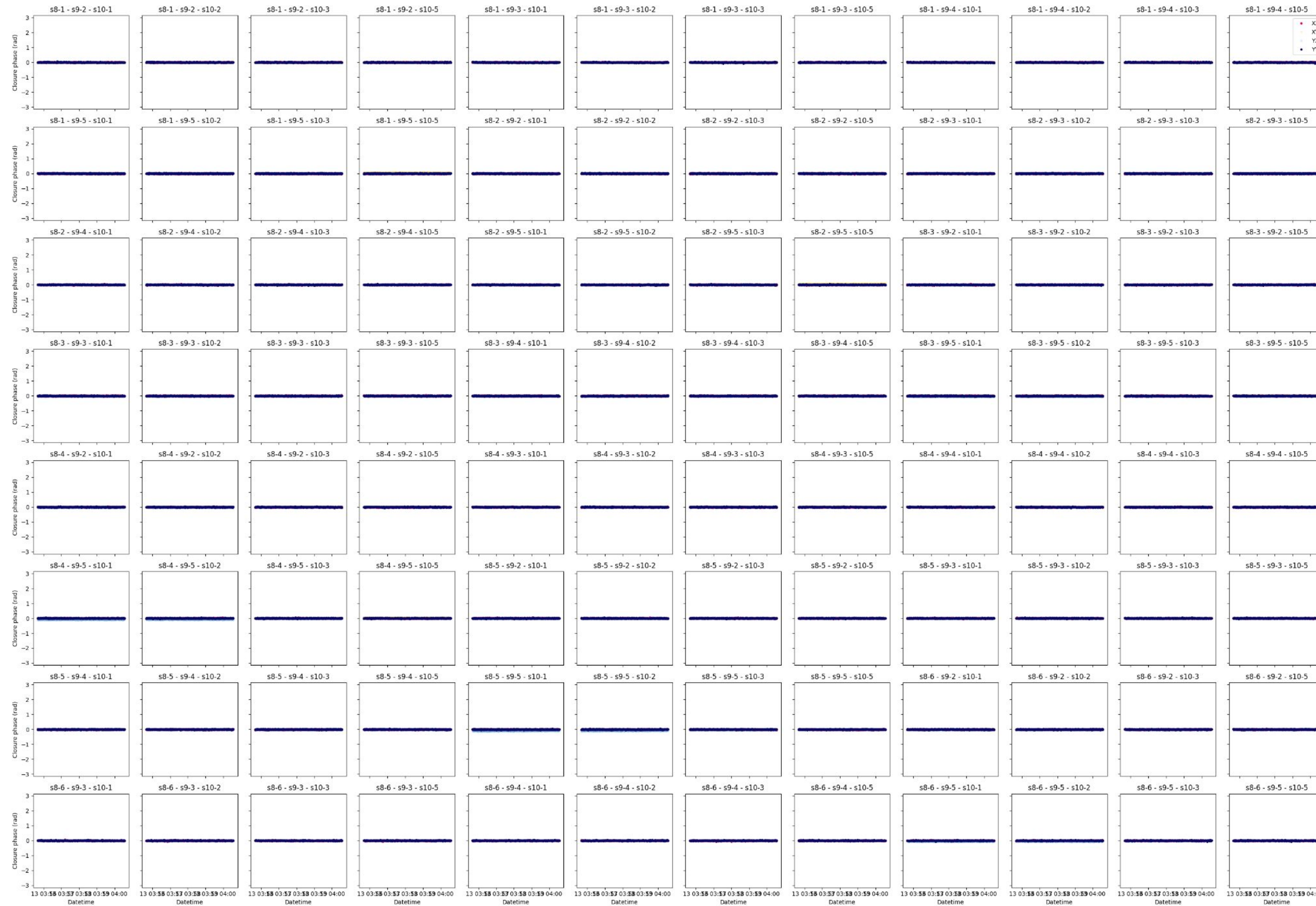


Pink-highlighted panels: short (intracluster) baselines, typically excluded for calibration purposes



Highlight - Interferometry

Closure, basic (bandpass) calibration - looking very good



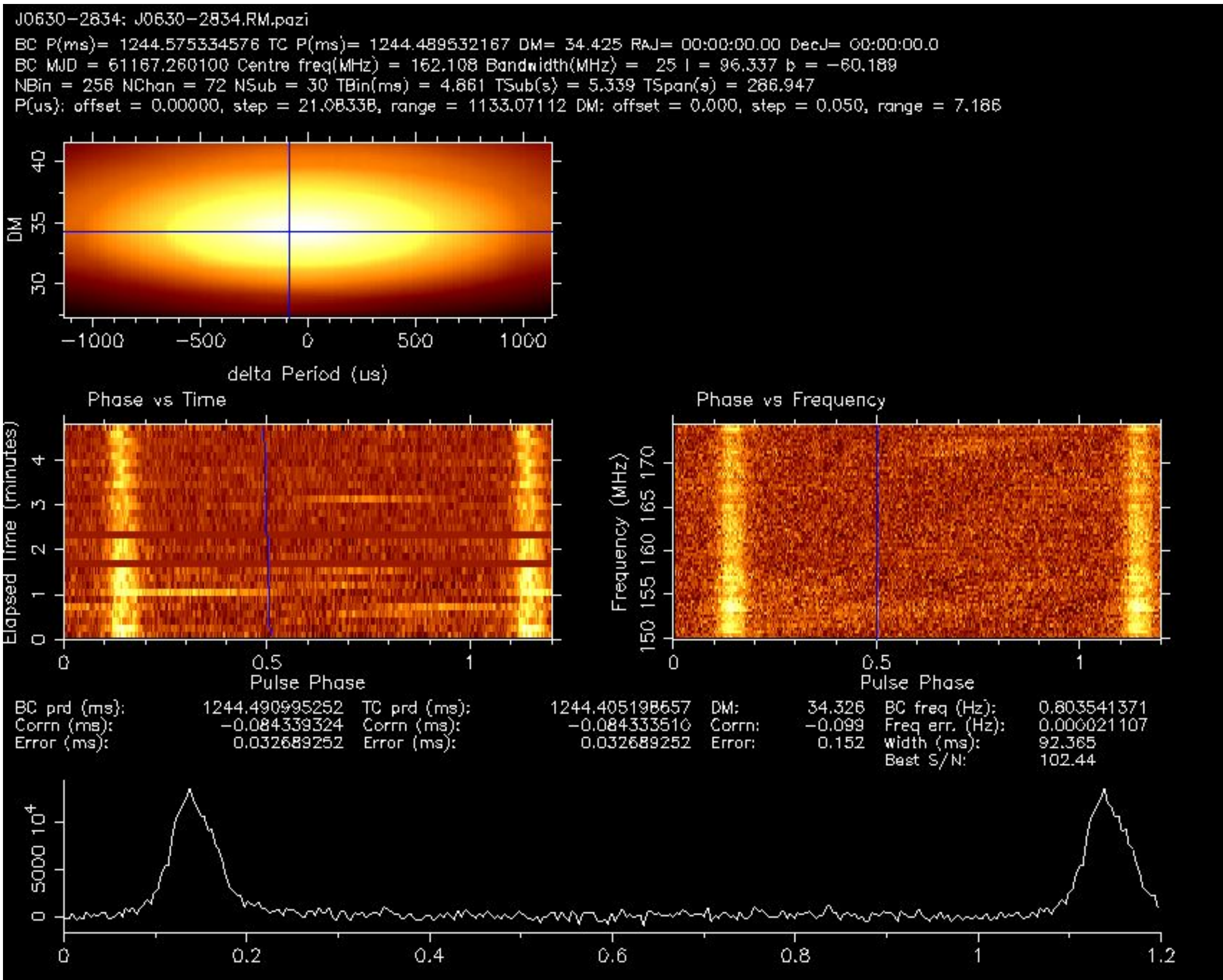
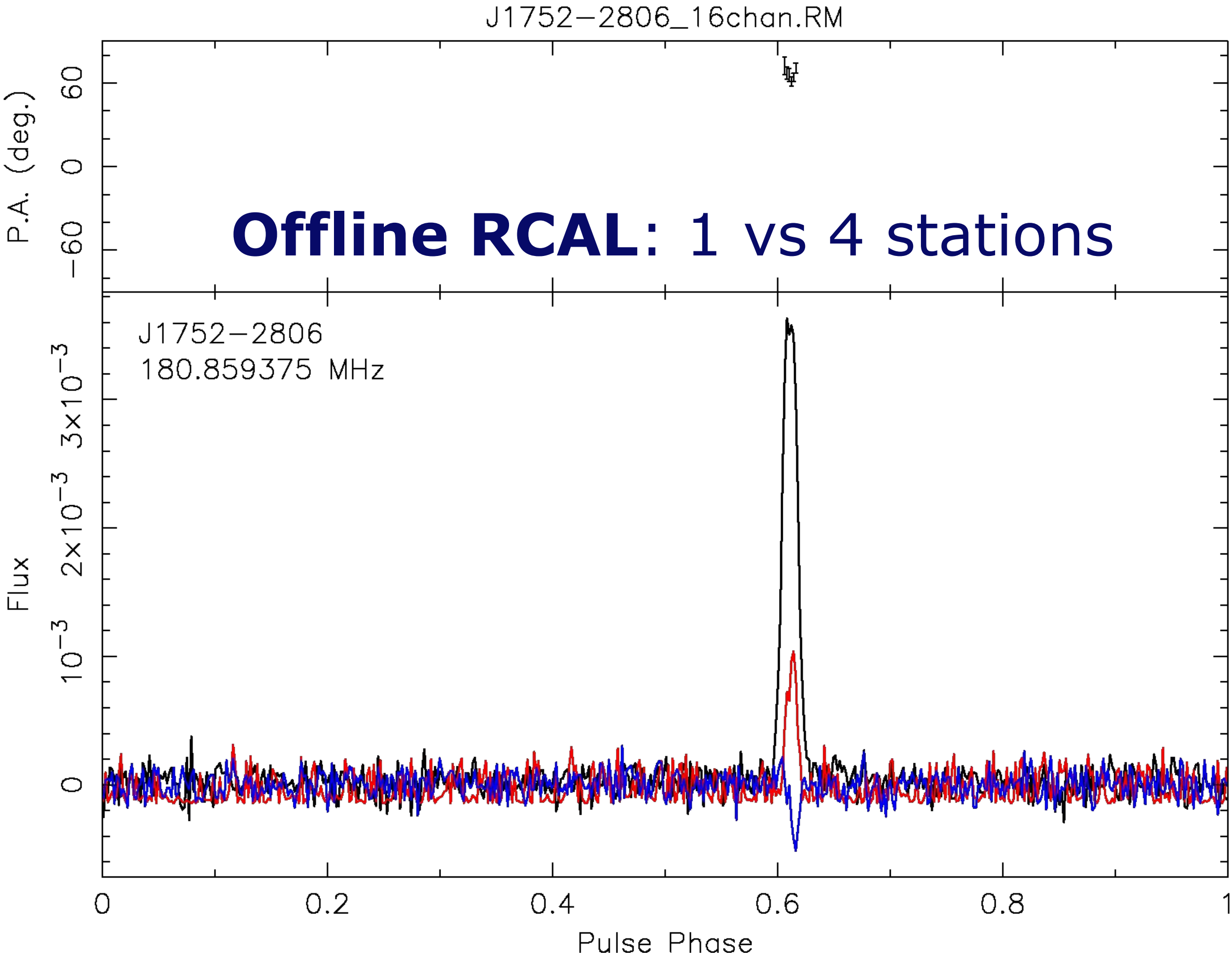
*Station beam bandpass amplitudes
(PKS 0410-75, 150-225 MHz)*



Closure phases on "long baseline triangles", PKS 0410-75

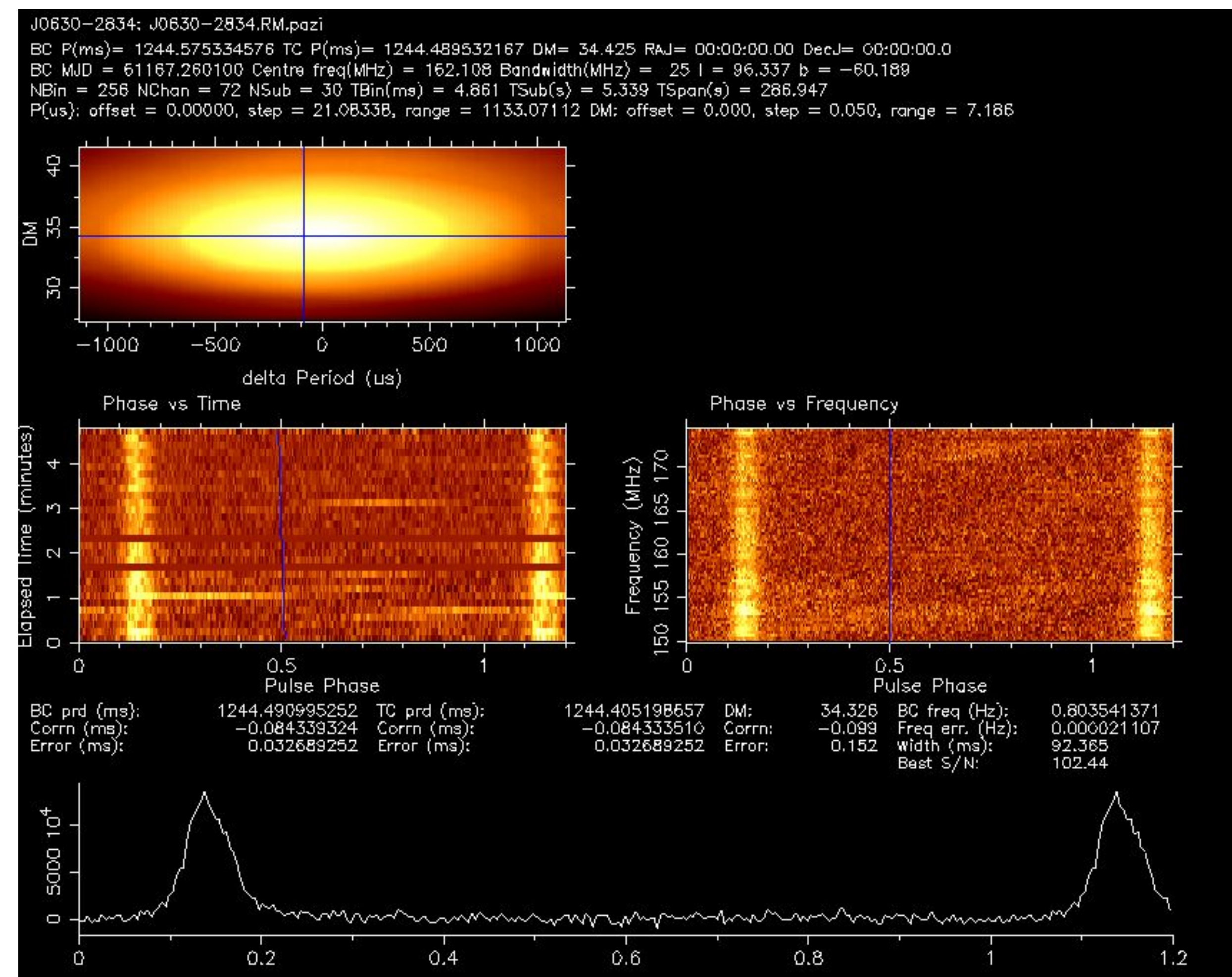
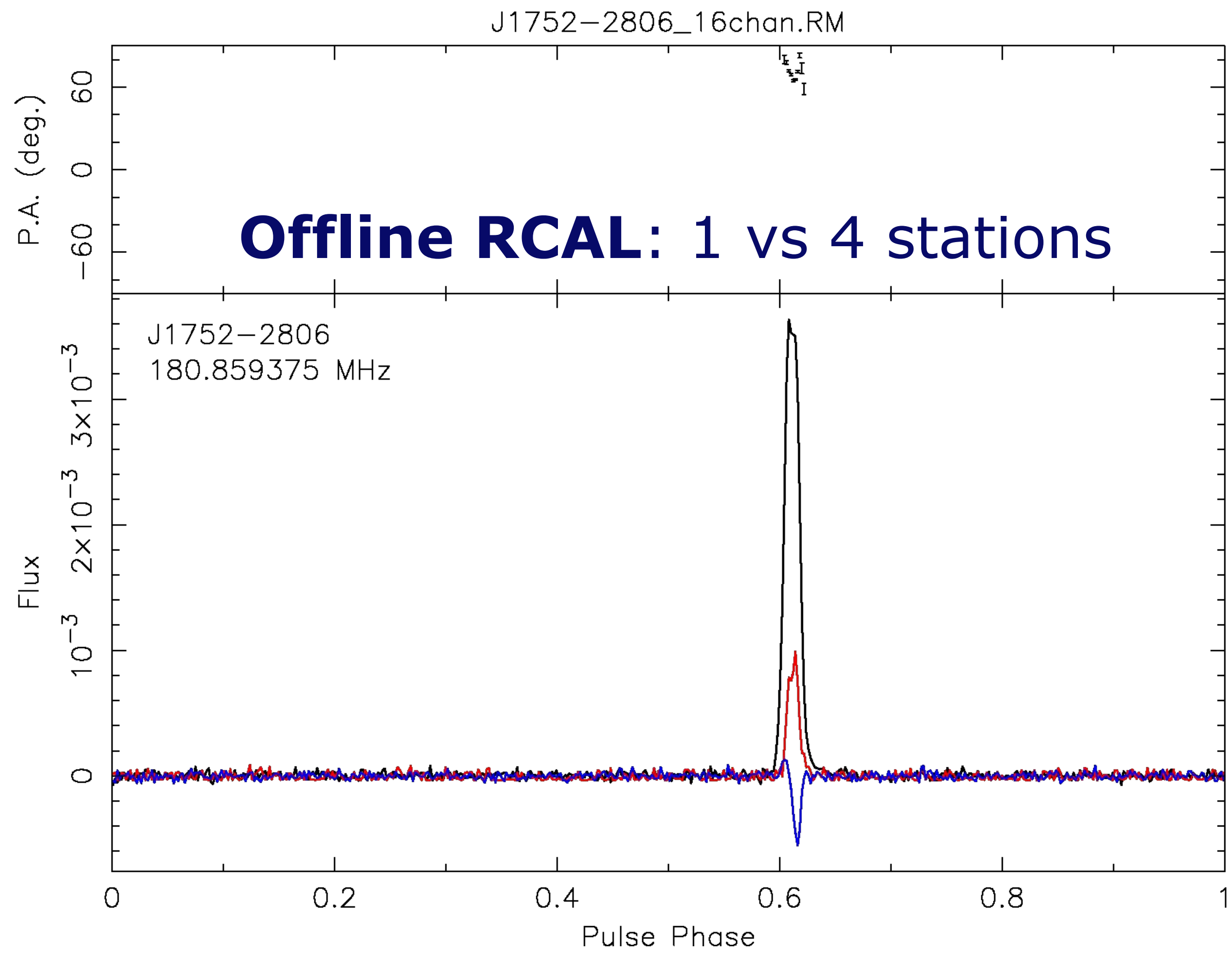
Highlight - RCAL

Right: J0630-2834, RCAL+PST, 10 stations, 150-175 MHz
Resulting data are not yet ideal, but suitable for testing



Highlight - RCAL

Right: J0630-2834, RCAL+PST, 10 stations, 150-175 MHz
Resulting data are not yet ideal, but suitable for testing



Highlight - Interferometry

PKS 0521-36

11 stations ("path to AA1")

150-175 MHz

~3 hr track

Direction-independent
self-calibration applied

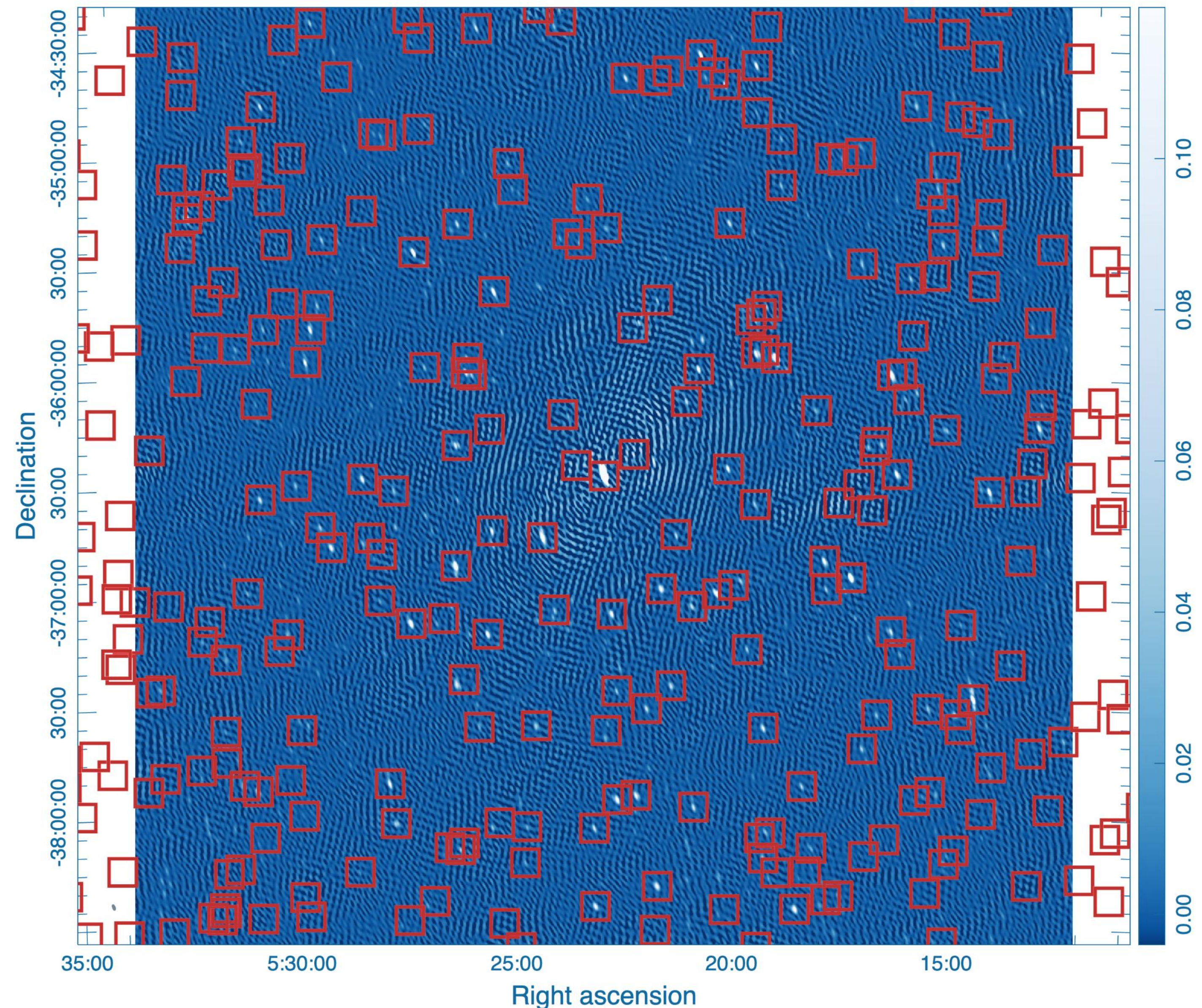
Processing with legacy tools

$\sigma \sim 4$ mJy/beam (83"x29")

DR $\sim 10,000$

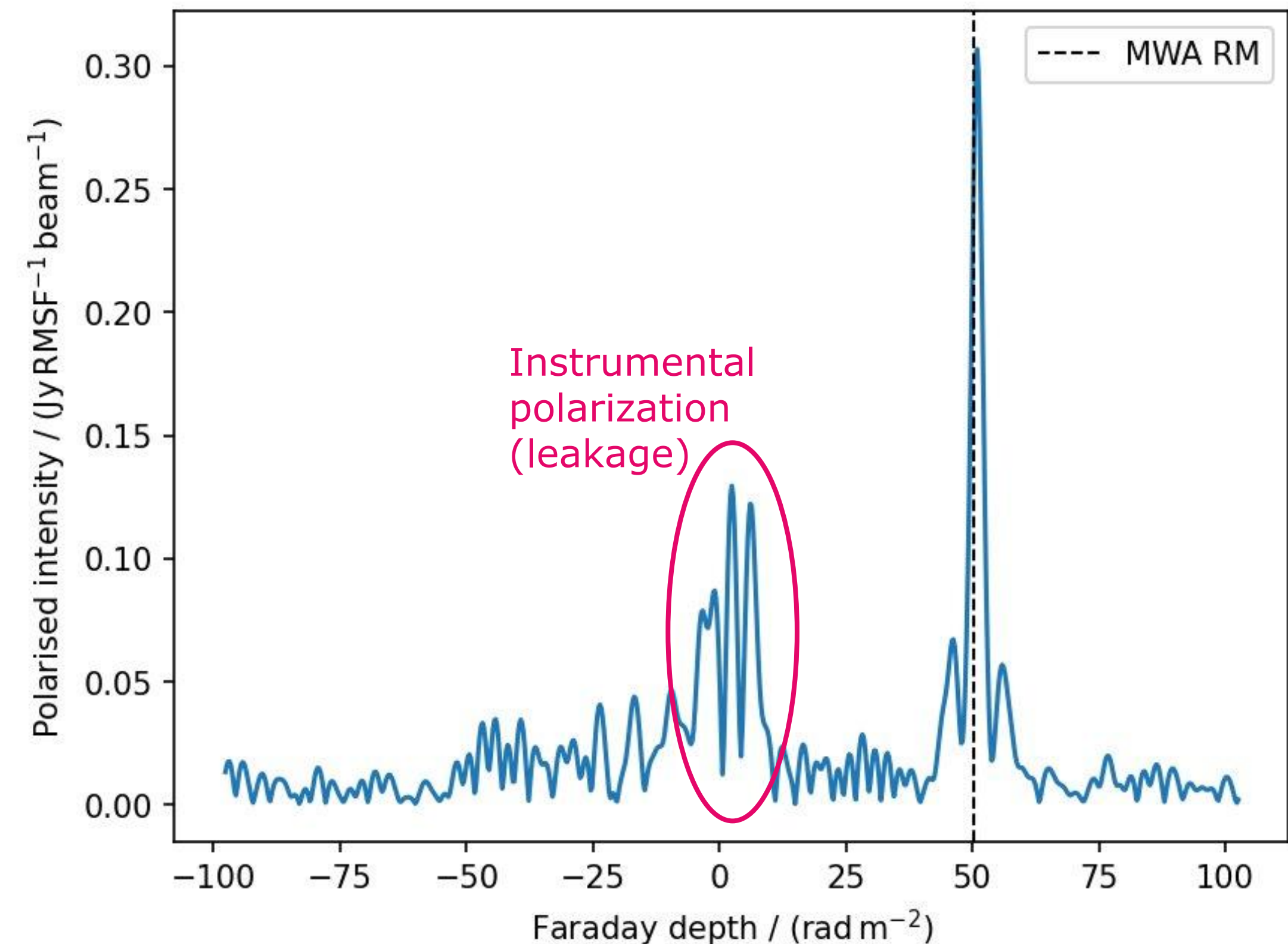
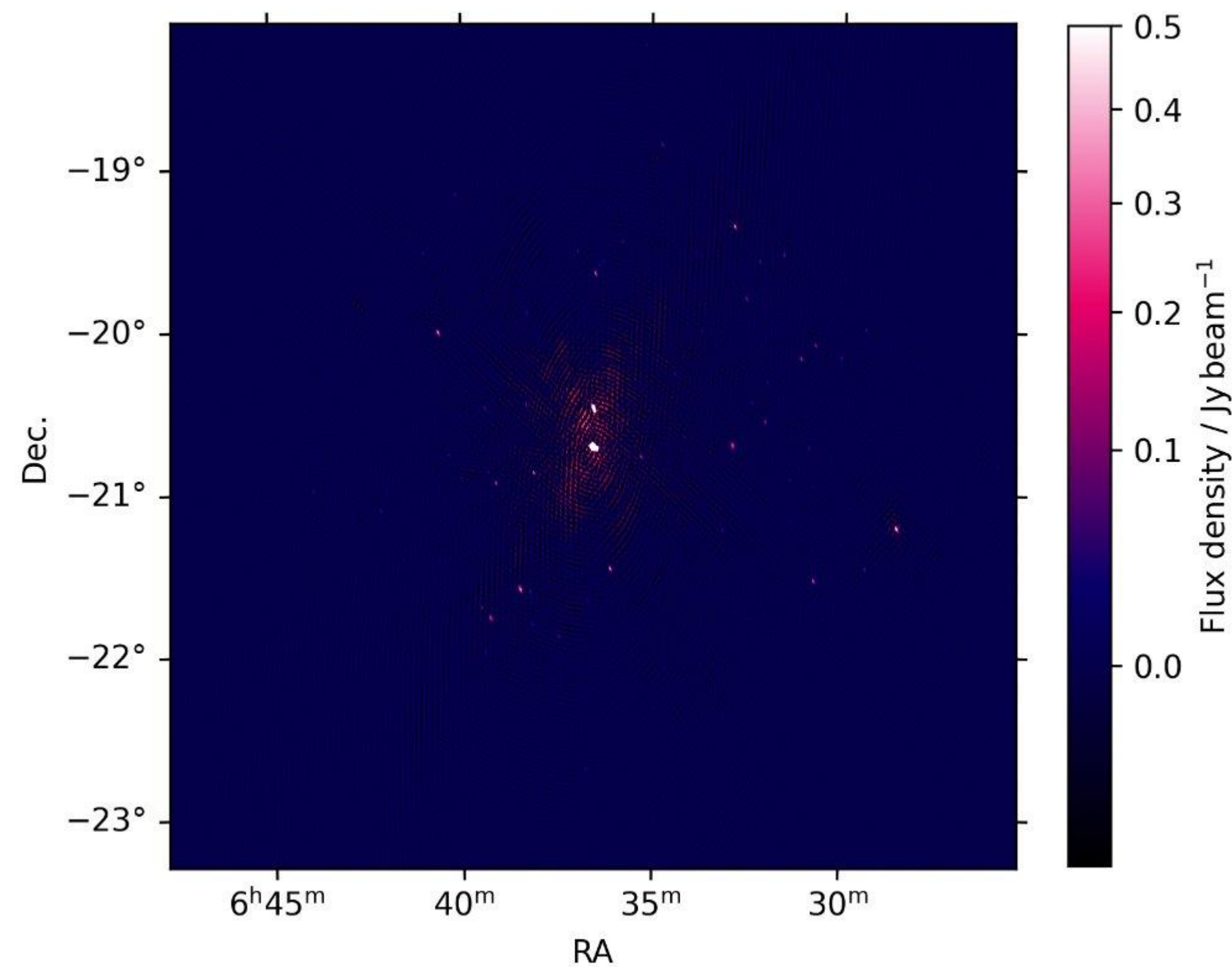
Image: sqrt stretch ($-1 \rightarrow 30\sigma$)

Red boxes: GLEAM-X > 40 mJy



Polarization

Initial linear polarization tests on single-station pulsar data, and interferometric data, indicate alignment with MWA results



Planning for AA2: global sky model (GSM) survey

We will require our own GSM from AA2 onward. Key unique requirements include:

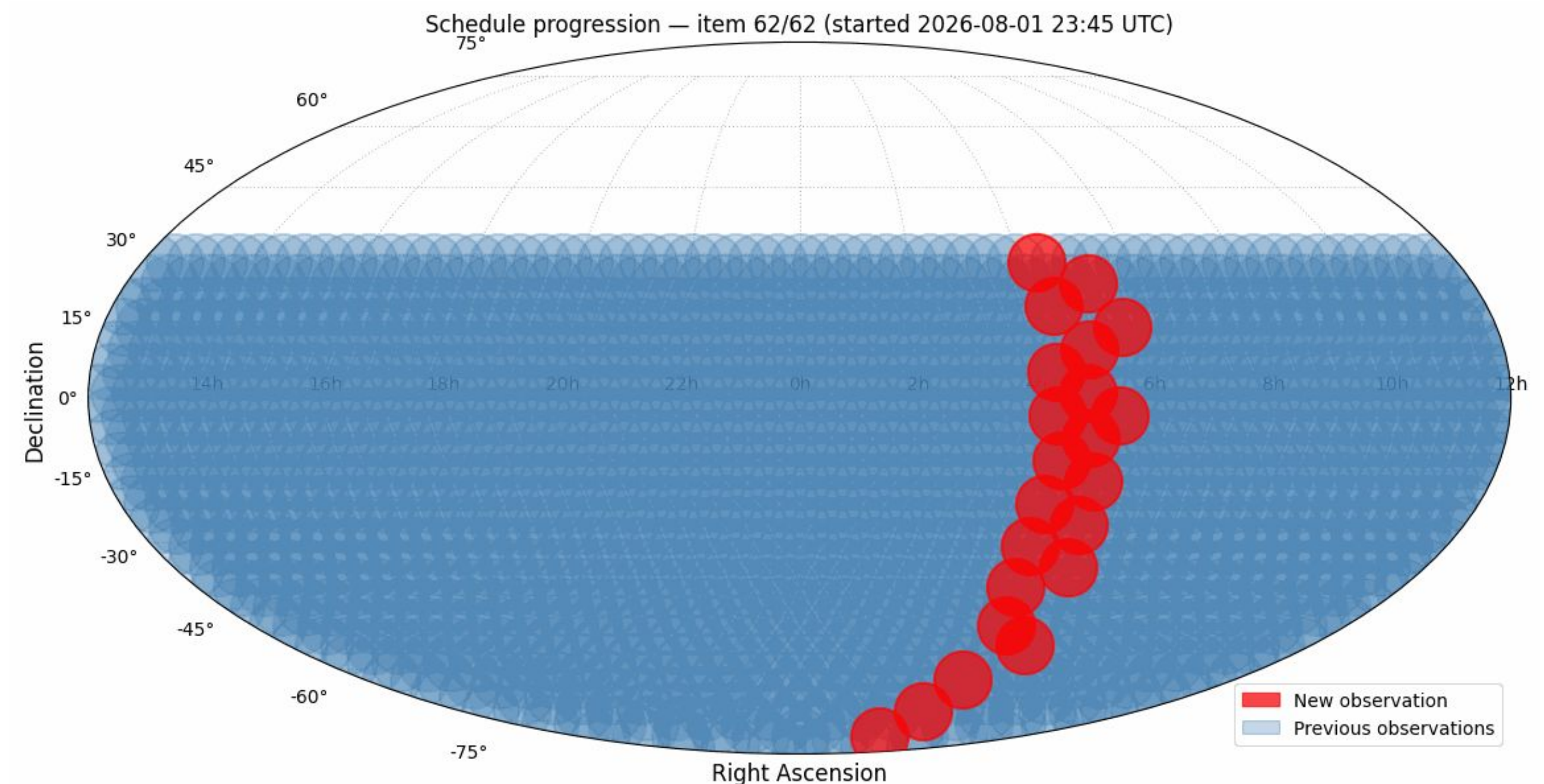
- Spectral index/curvature information in the 50-350 MHz range
- Source components and structures on angular scales $\ll 1\text{-}2'$ (GLEAM/GLEAM-X)

Planned features include:

- All-sky with short snapshots
- HA segments for better uv coverage
- Clean frequencies spanning range
- Small fractional bandwidth (~ 6.25 MHz) with 24-48 beams

Preparatory steps underway:

- Scheduling simulations, and implementation into front-end observing tools
- Generation of interim GSM catalog that synthesises existing best-in-class catalogs
- Detailing data/computing requirements



Summary and next steps

- We are now able to capture high-quality 10+ station datasets
 - Calibration/imaging, initial real time calibration, pulsar timing
- Progress comes in fits and starts, and reliability is our biggest issue
- Software (suitability and scalability) is our biggest worry
- Our commissioning test campaign is ready to go once we are able to begin collecting data with the full AA1 (all 16 stations)
- Further operator interface requirements will be needed, e.g. improvements to monitoring/QA, and scheduling
- Upcoming (tomorrow): disruption to telescope availability, caused by transition of the onsite Central Processing Facility from a temporary enclosure to the final building near the core
 - Commissioning work will continue throughout, on the basis of data recorded in a recent high-cadence commissioning campaign
- Next: commission AA1, start testing AA2 to enable Science Verification (currently targeting this in 2027)



Questions?

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



www.skao.int

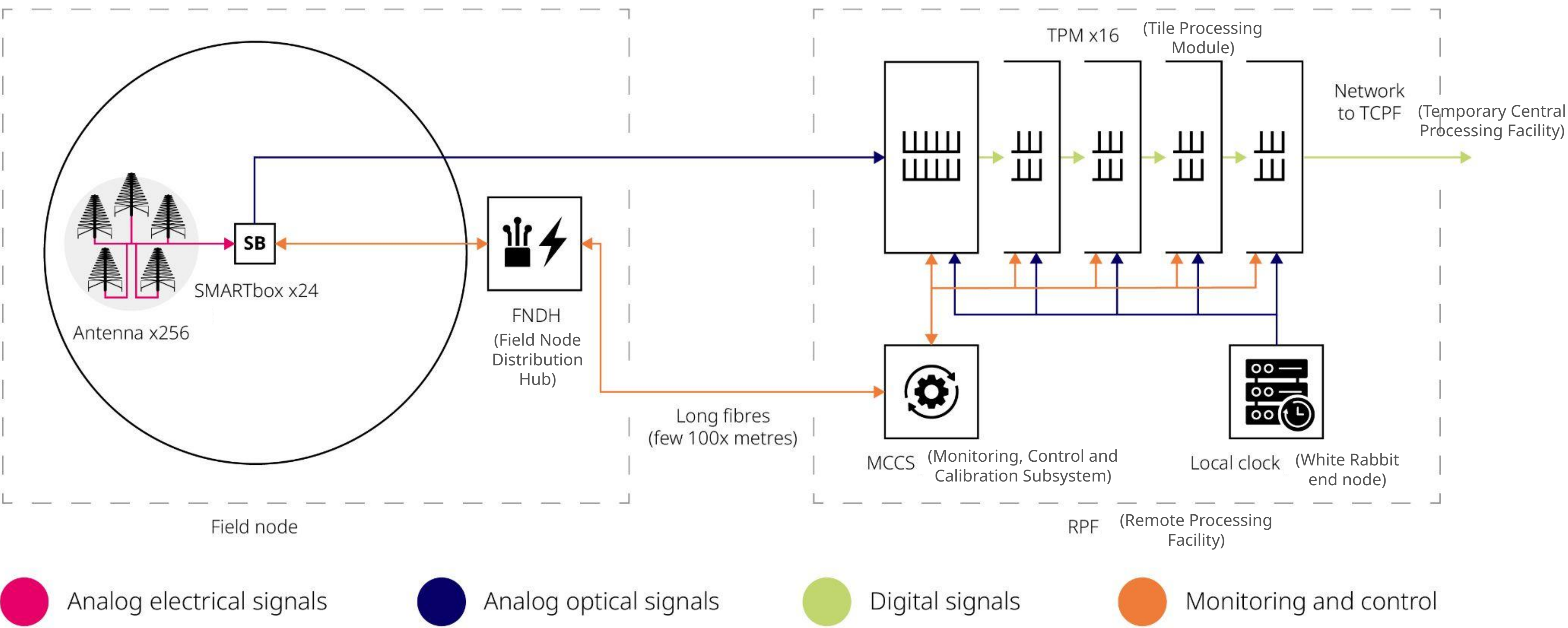
*We recognise and acknowledge the
Indigenous peoples and cultures that have
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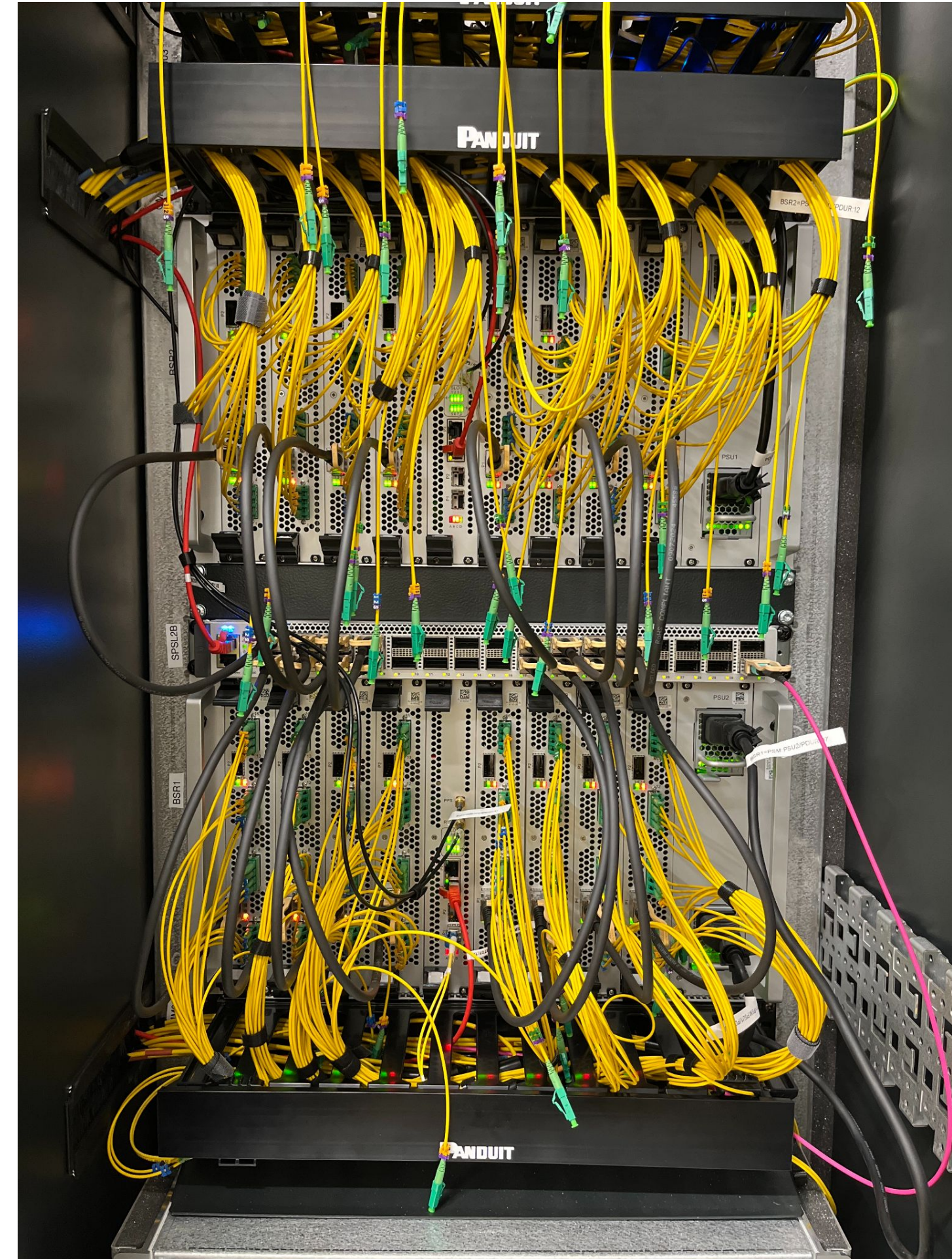
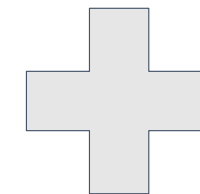
www.skao.int

SKA-Low: system overview (1)

Station level diagram - SIGNAL PATH AND M&C

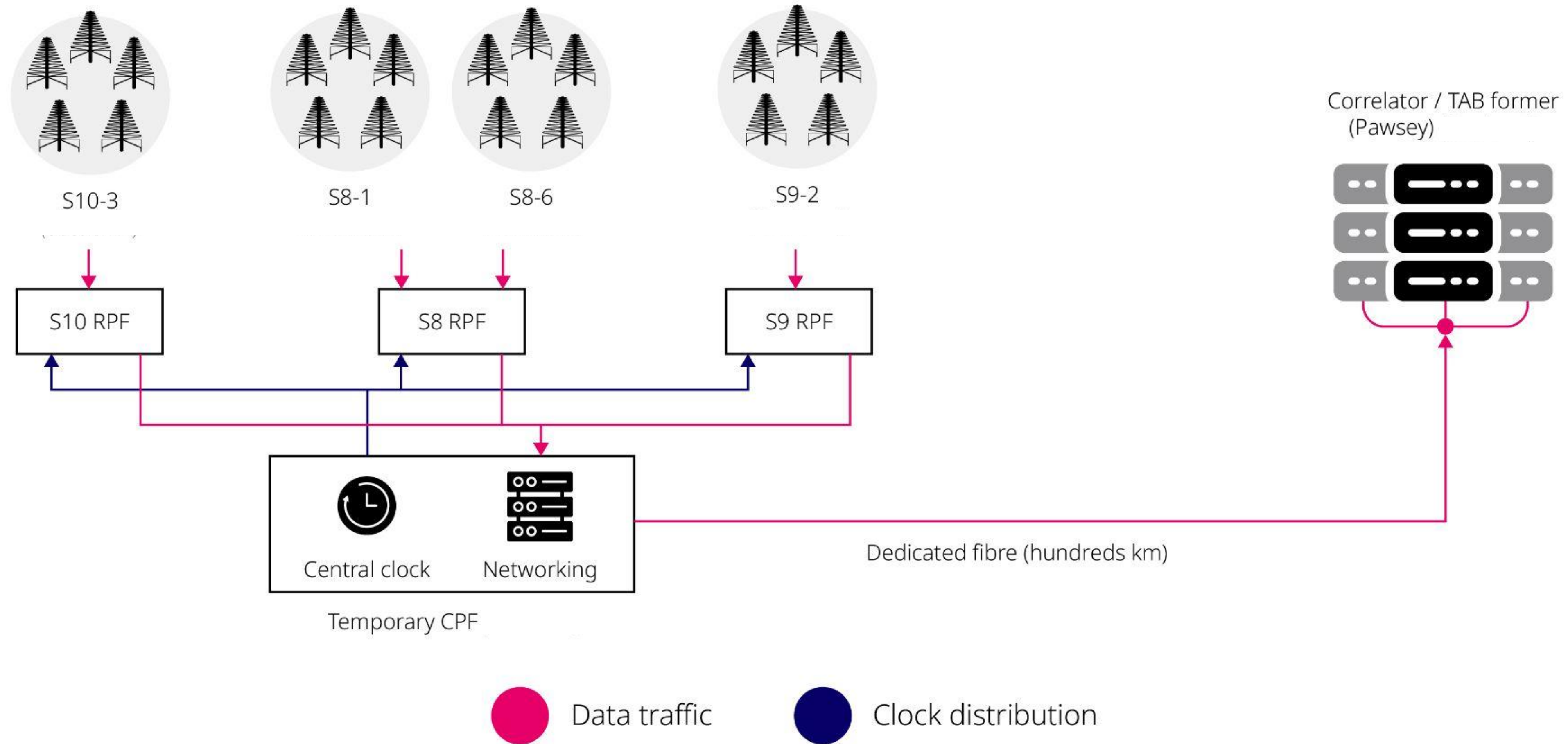


SKA-Low station = Field node + “beamformer” (TPMs)



SKA-Low: system overview (2)

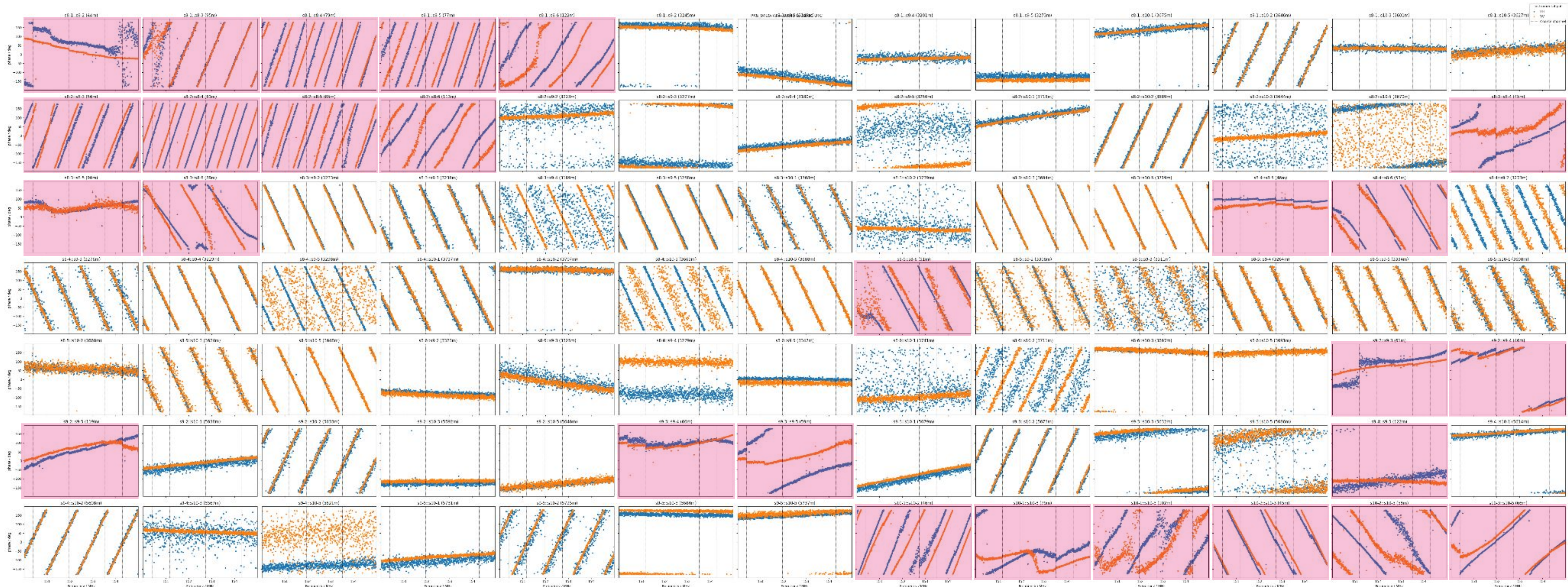
High level diagram - SCIENCE DATA FLOW (AA0.5)



Highlight - Interferometry

PKS 0410-75, 5 min scan, 14 stations, 150-225 MHz

This plot: raw data, parallel hands (XX,YY), 150-155 MHz



Pink-highlighted panels: short (intracenter) baselines, typically excluded for calibration purposes

