

Preparing for the first cycle of SKA-LOW Science Verification

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Slide credits: SKAO sci. webinar repository (S. Breen, G. Heald, I. Heywood, N. McClure-Griffiths)

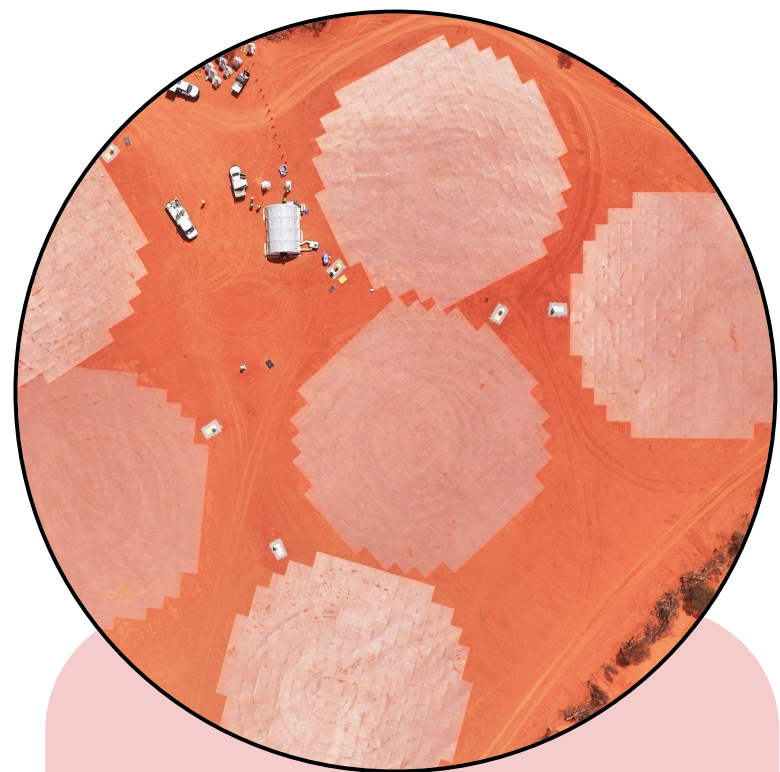
Workshop agenda

- Time line I: construction, science verification, KSPs
- Time line II: roll-out of capabilities/observing modes
- Highlights from commissioning observations
- Science verification: aims, procedure, capabilities on offer
- Your pathway to SV data:
 - Current status of your plans: questionnaire
 - The importance of SKACH involvement in the SV process
 - Targets for SV: in search of the winning combination of capability demonstration and science potential

SKAO milestones

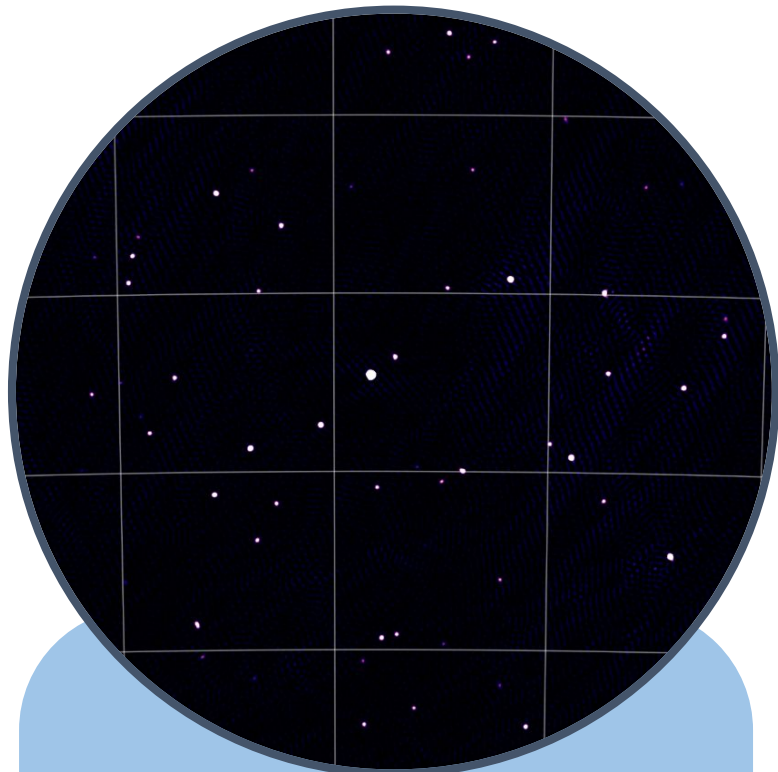
Community involvement starts

Credit: I. Heywood, SARA0



Construction

- Building antennas, dishes, roads...
- Followed by Assembly, Integration and Verification



Commissioning

- SKAO activity
- Collaborative across system verification and science commissioning



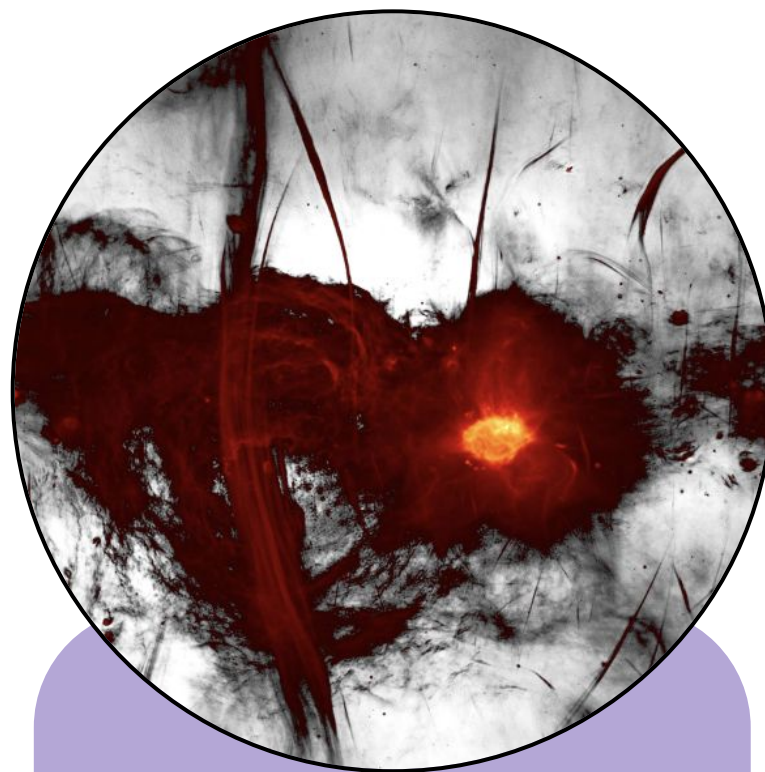
AA2

Science Verification

- **Primary purpose of SV is verification of the scientific capability, overall workflow and usability of the system** → science is a bonus, not guaranteed.
- Provide an end-to-end test of the system for each mode/ODP
- Must not place unnecessary burden on the SKA user community
- Build trust in operational model and excitement on our way to science



AA*



Cycle 0

- Shared-risk PI projects
- SRCNet resources ready for user
- proprietary periods



Now

Now

Mid 2027

First half 2029

2030



Now

Now

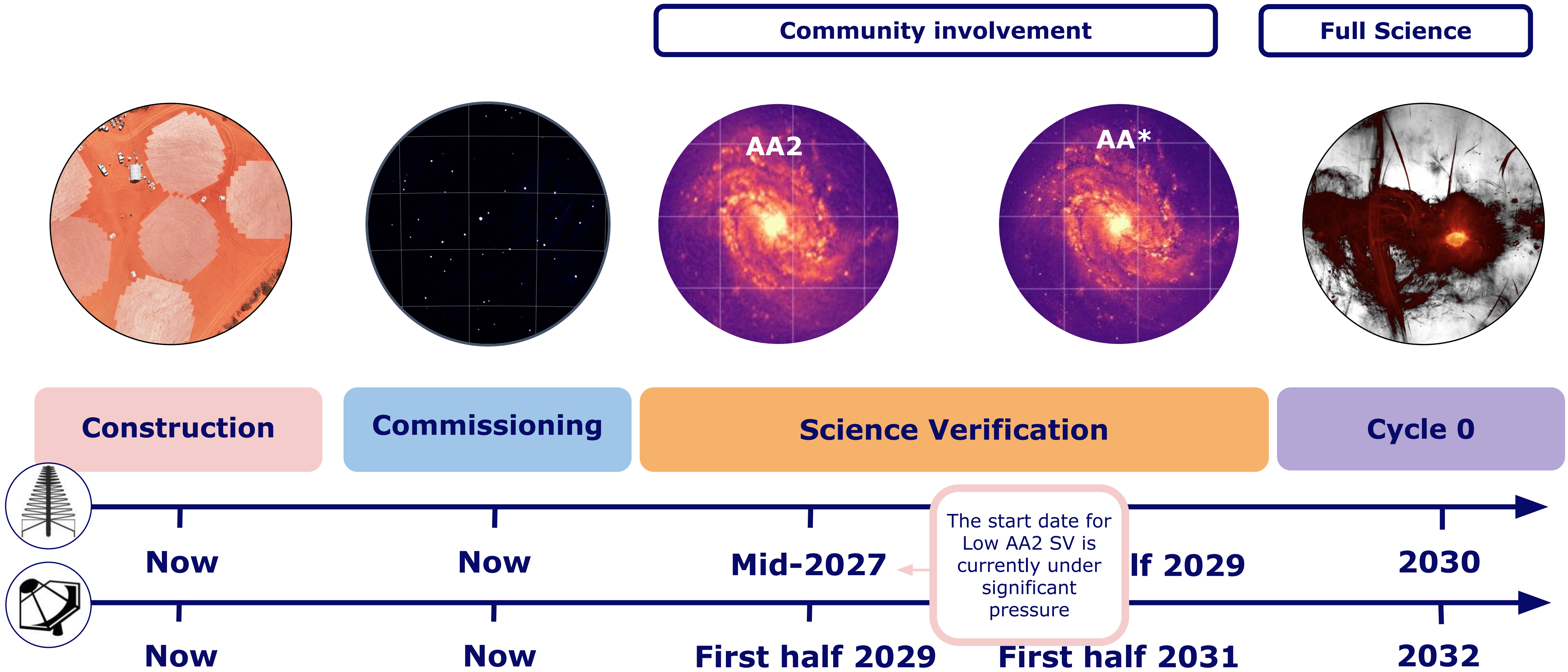
First half 2029

First half 2031

2032



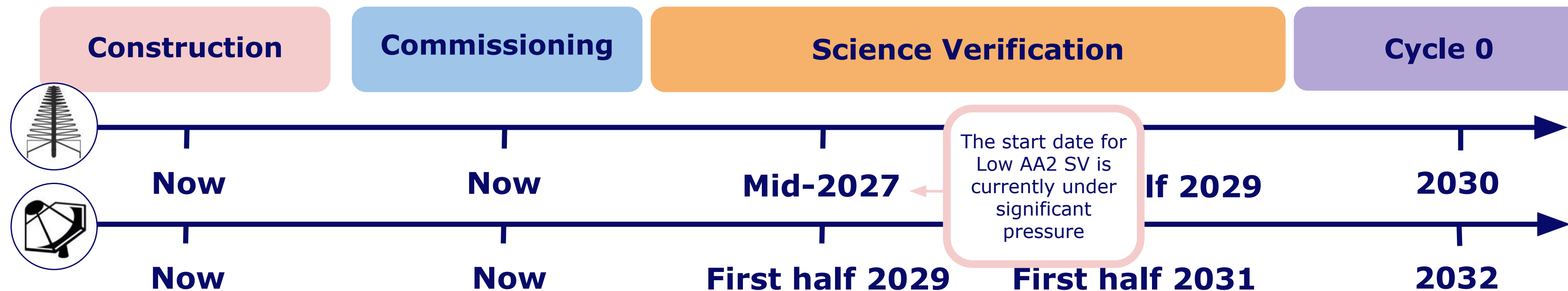
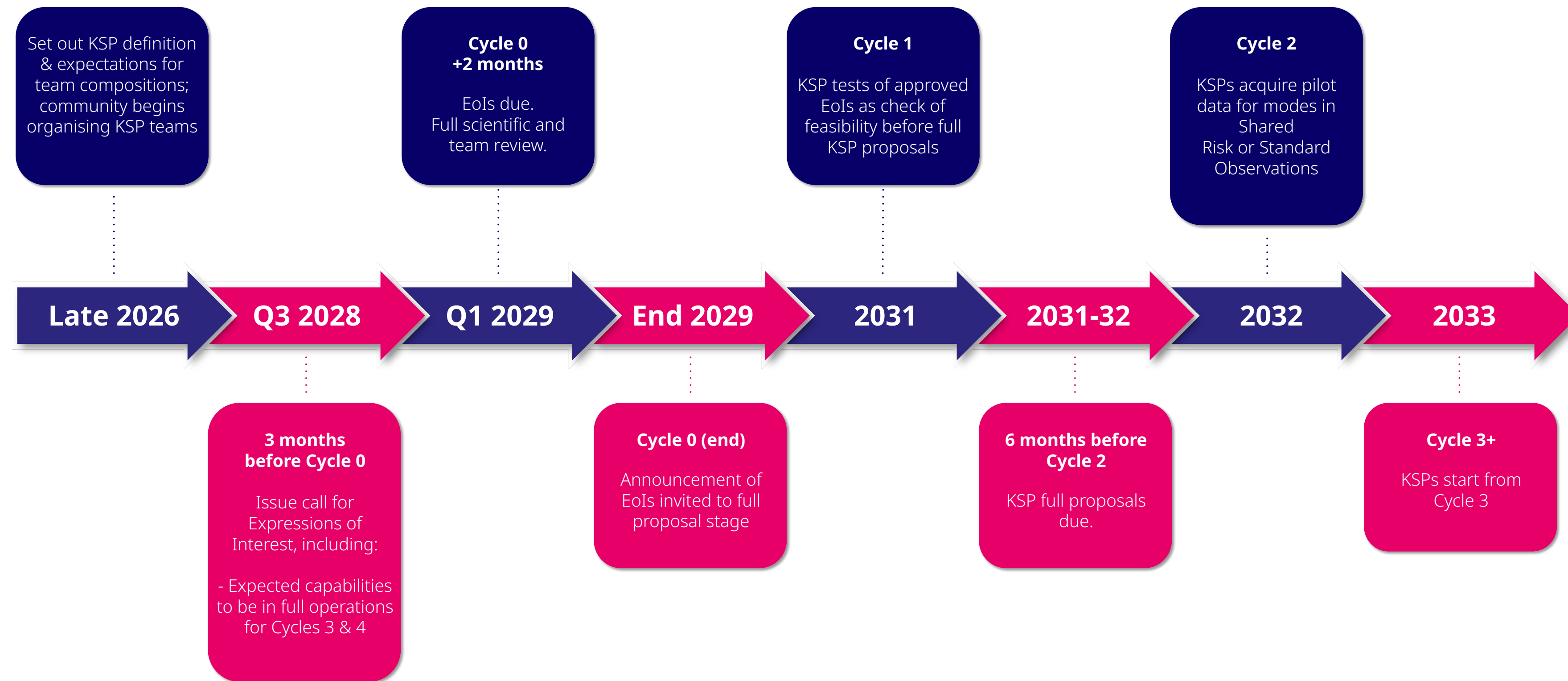
The SKA Timeline to Science



Credit: I. Heywood, SARAO



A timeline to the first round of KSPs applicable for SKA-Low



SKA-Mid Construction Progress

- 13 dish “Big Lifts”
 - Lifting ~3 dishes/month
- 4 Dishes operating
 - Phase & Amplitude closure
- New Engineering Operations Centre nearly complete
- By the end of 2026:
 - all roads, fibre & power infrastructure will be complete

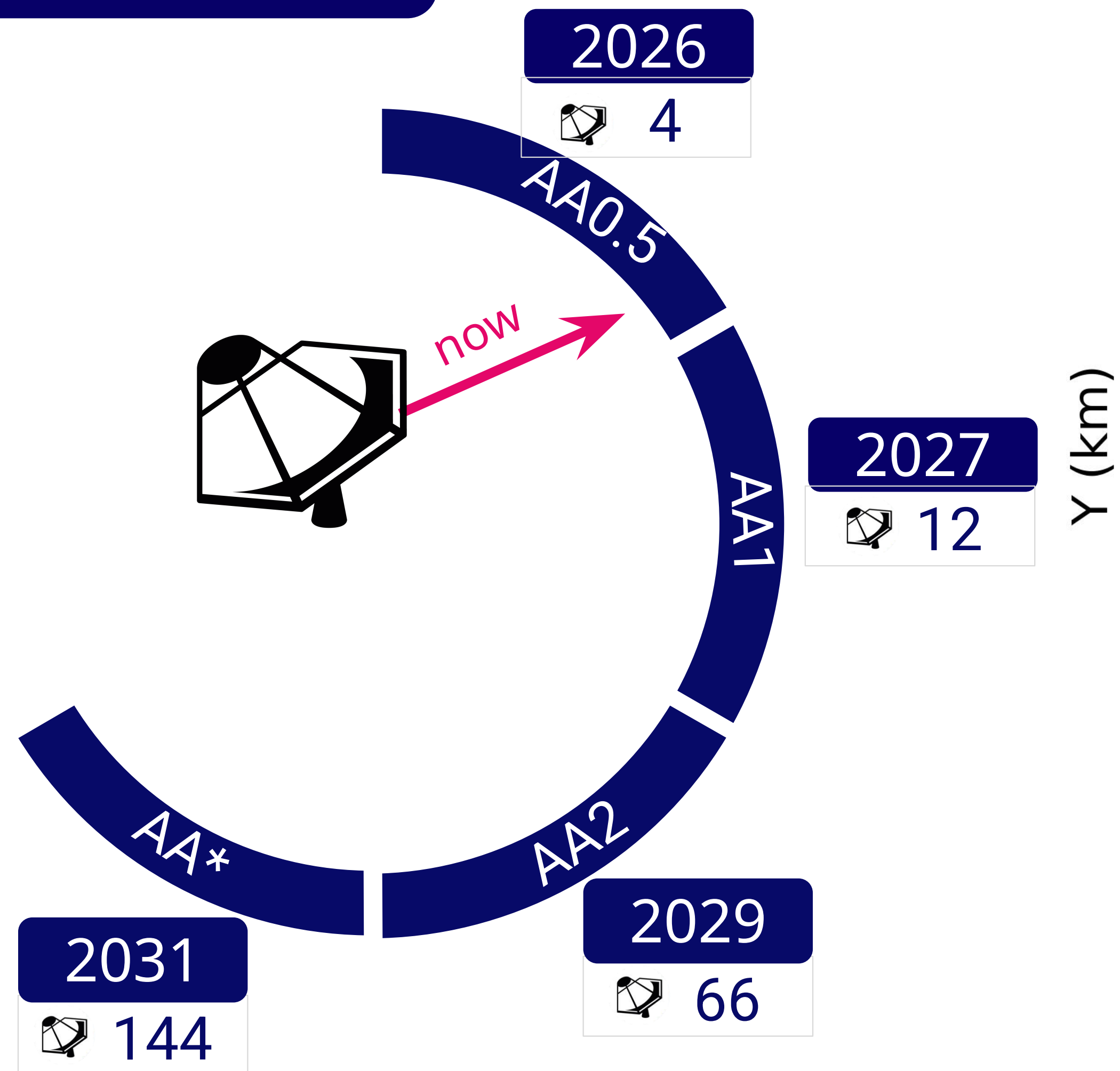
Another “big lift”



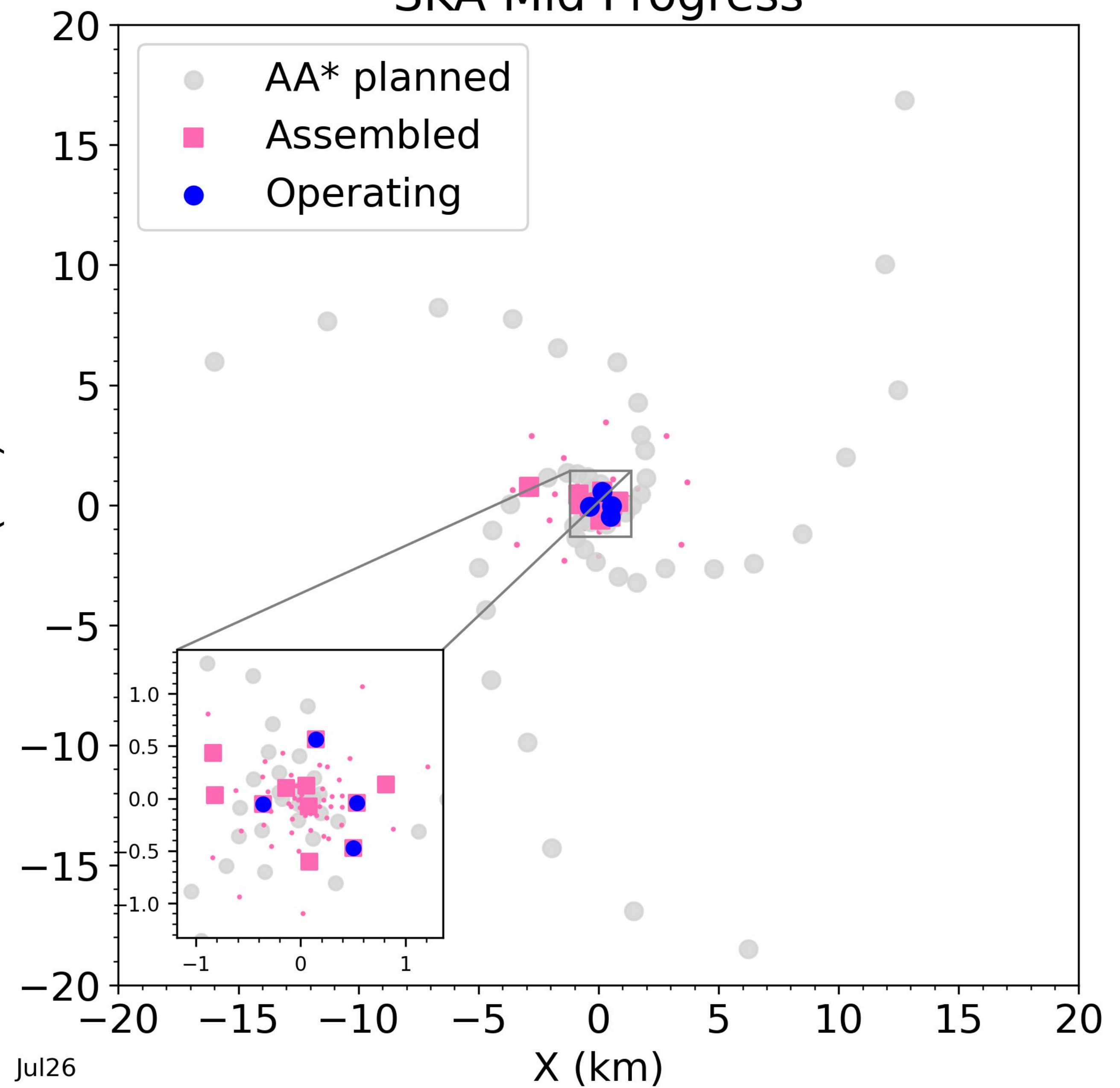
Engineering Operations Centre



SKA-Mid



Y (km)



Jul26



SKA-Low Construction Progress

The trenchers have left the site!

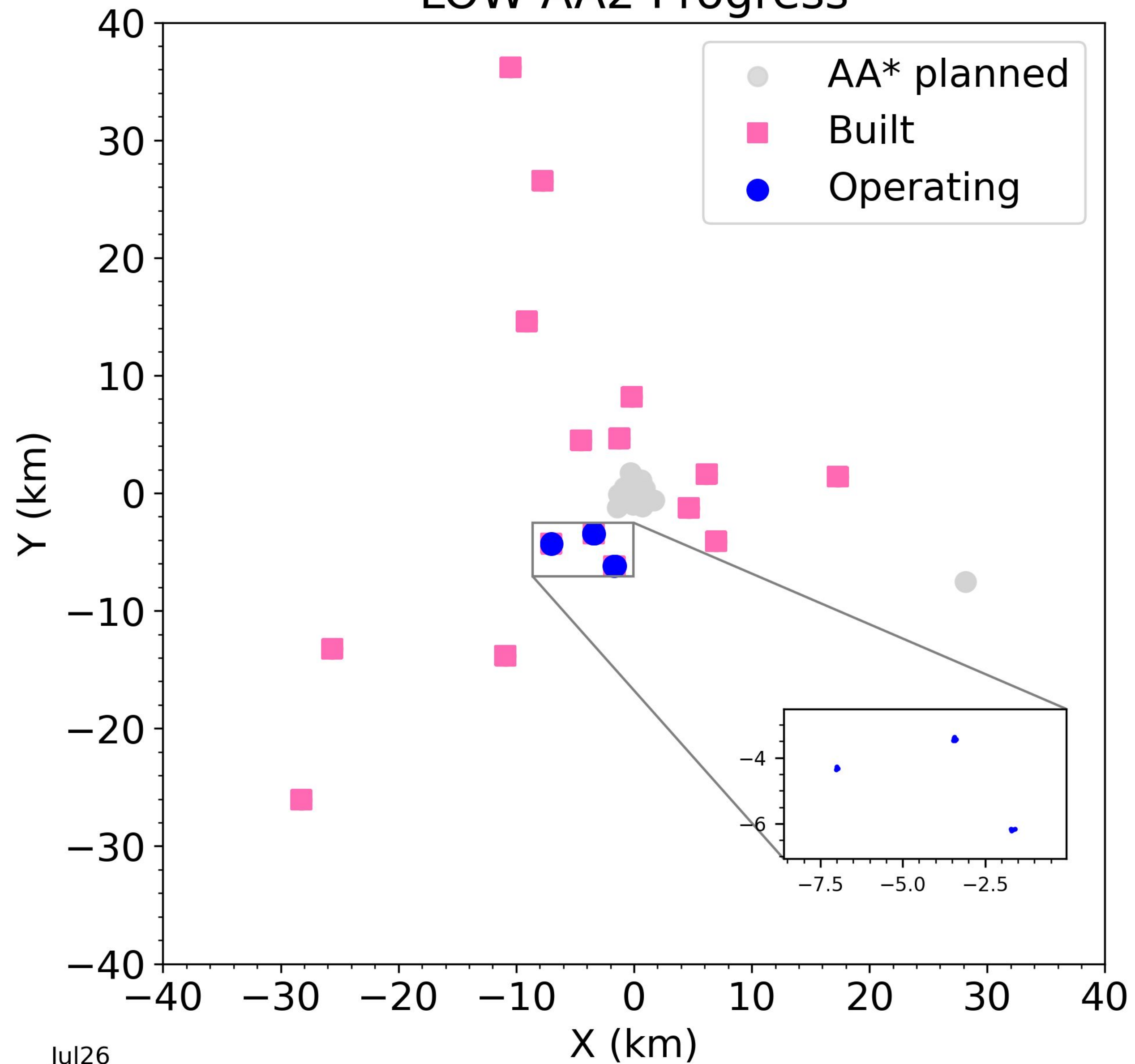


Laying mesh at one of the most distant station, E15

- Moved into the Central Processing Facility
- 69 stations fully assembled; 15 stations “connected up”
- Central power station operational

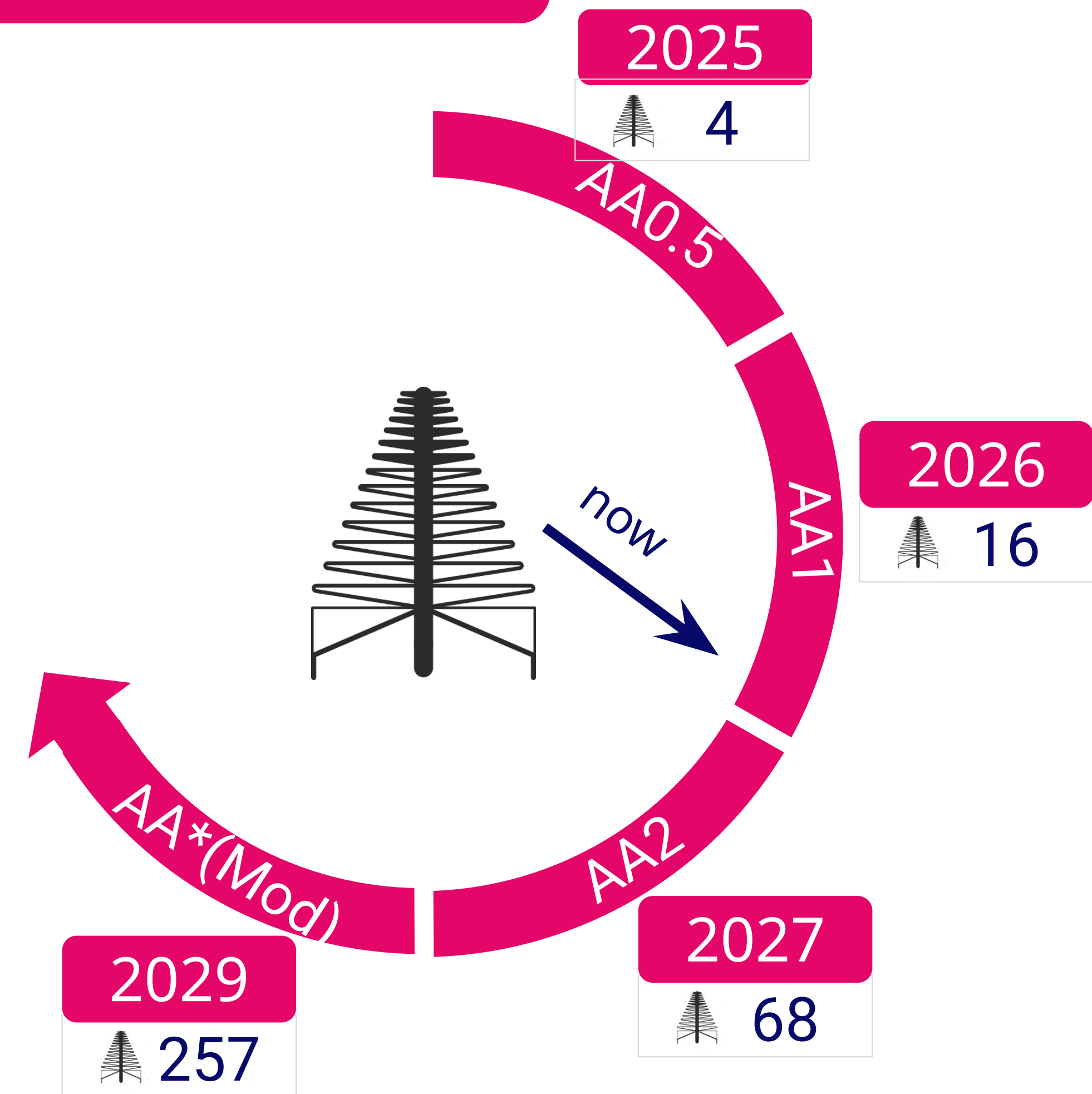


LOW AA2 Progress



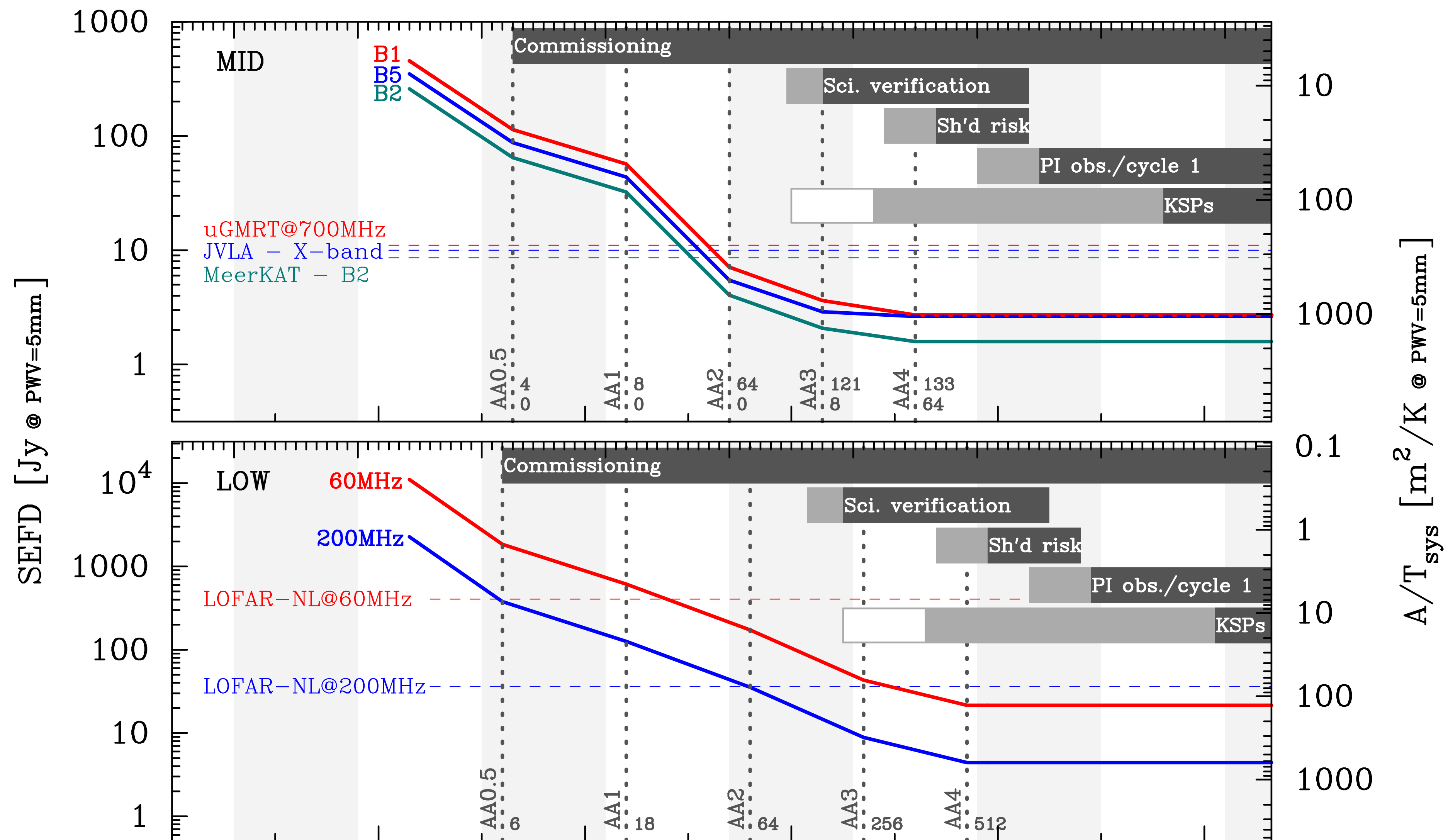
Jul26

SKA-Low



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In terms of raw sensitivity, AA2 (SV) is the point in time when the growing SKA matches/outperforms present-generation observatories.

Baseline distribution (imaging characteristics) of SKA stations/dishes in AA2 often differs from current radio telescopes.

SKA-Low: Delivery of observing modes and ODPs to the astronomy community

AA2 SV 2027	AA* SV 2029	Cycle 0 2030		Cycle 1 2031			Cycle 2 2032			Cycle 3 2033		
Science Verification (SV)		AA* SV	Shared risk	AA* SV	Shared risk	Standard ops	AA* SV	Shared risk	Standard ops	AA* SV	Shared risk	Standard ops
Single subarray Both sidereal and non-sidereal tracking		4 subarrays Drift scanning capped at a few mins		16 subarrays Drift scanning capped at a few mins			Full drift scanning capabilities				Full drift scanning capabilities	
Calibrated and averaged visibilities, image cubes Full BW (150MHz), FoV Single beam, single pointing 40 channel max 4h max integration	Full BW (300MHz) At least one substation arrangement, capped by data rates Up to 16 station beams 8h max integration, up to 16 images (either in time i.e. 30min pointings or station beams) Gridded visibilities	VLBI at least 2 beams 50 PSS beams	Two substation arrangements, capped by data rates Up to 24 station beams 50h max integration Basic image-based mosaicing	PLDP generation tests Joint deconvolution Limited support for PLDP generation testing Limited joint deconvolution Transient buffer triggered by PSS observations	Source finding (& associated image cutouts) Source finding (& associated image cutouts) PSS full basic capability VLBI full basic capability	Multiple pointings processed independently Greater than 2 substation arrangements, capped by data rates Up to 48 station beams 50h max integration 64k channel max Greater than 2 substation arrangements, capped by data rates Multiple pointings processed independently Increased number of channels Up to 48 station beams 12h max integration PST full 8 beam capability	Improved PSS machine learning for improved triggering Fast imaging Transient buffer triggered by fast imaging	Limited PLDP generation Joint deconvolution Limited PLDP generation Joint deconvolution Transient buffer triggered by PSS observations	Full substation capabilities Improved source finding (& associated image cutouts) Full substation capabilities PSS full basic capability VLBI full basic capability	Autocorrelation processed data products Autocorrelation processed data products	Improved PSS machine learning for improved triggering Fast imaging Transient buffer triggered by fast imaging	Full PLDP capabilities Joint deconvolution Full joint deconvolution capabilities Full PLDP capabilities Transient buffer triggered by PSS observations
Calibrated and averaged visibilities, image cubes Early implementation of the continuum subtraction possible Single beam, single pointing Full FoV, 4k channel max, up to full BW 4h max integration	At least one substation arrangement, capped by data rates Continuum subtraction Up to 8 station beams 4h max integration, up to 8 images (either in time i.e. 30min pointings or station beams) Gridded visibilities		Two substation arrangements, capped by data rates 16k channel max Up to 24 station beams 12h max integration Basic image-based mosaicing PST full 8 beam capability									
PST at least one beam in flowthrough or detected filterbank mode	PST at least 2 beams, full processing VLBI at least one beam 9 PSS beams fully processed											

Telescope mode

Observatory Data Products (ODPs) and their capabilities

Continuum

Spectral

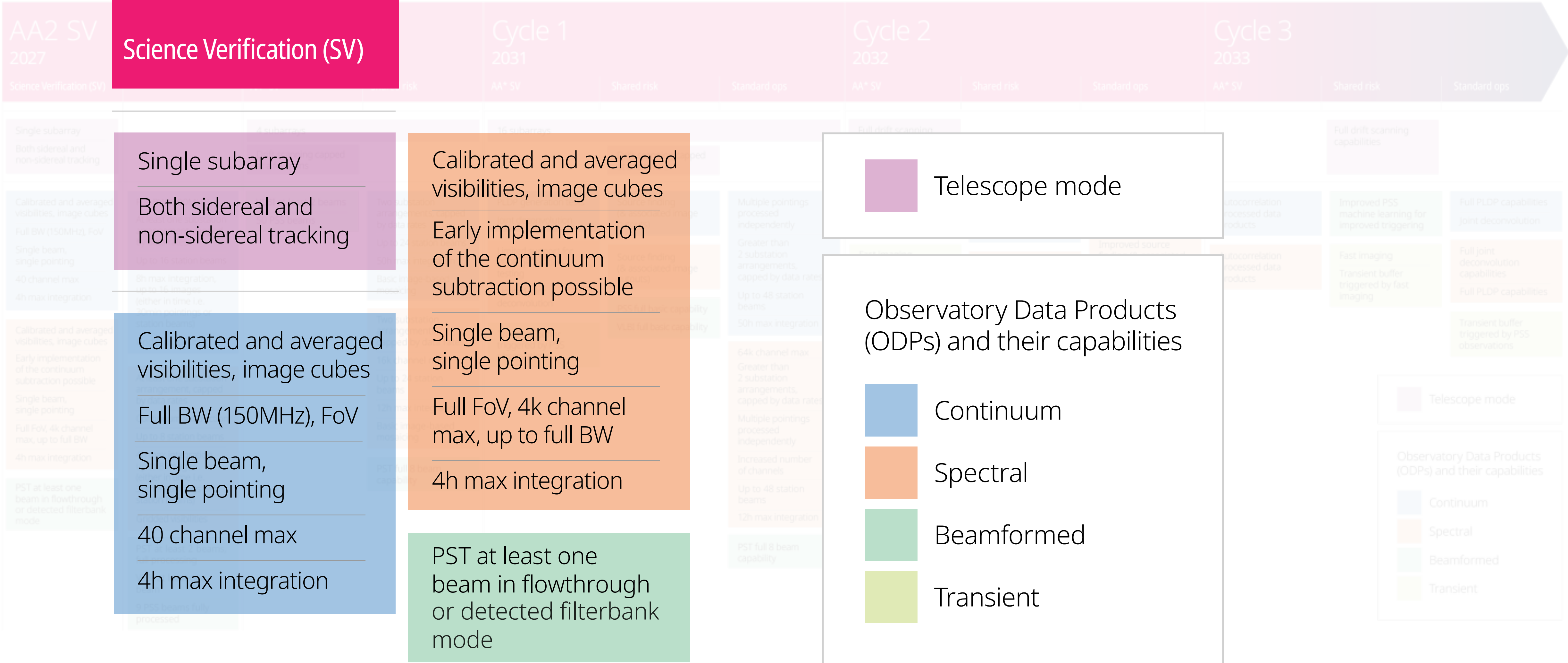
Beamformed

Transient

AA2 SV 2027

Science Verification (SV)

observing modes and ODPs to the astronomy community

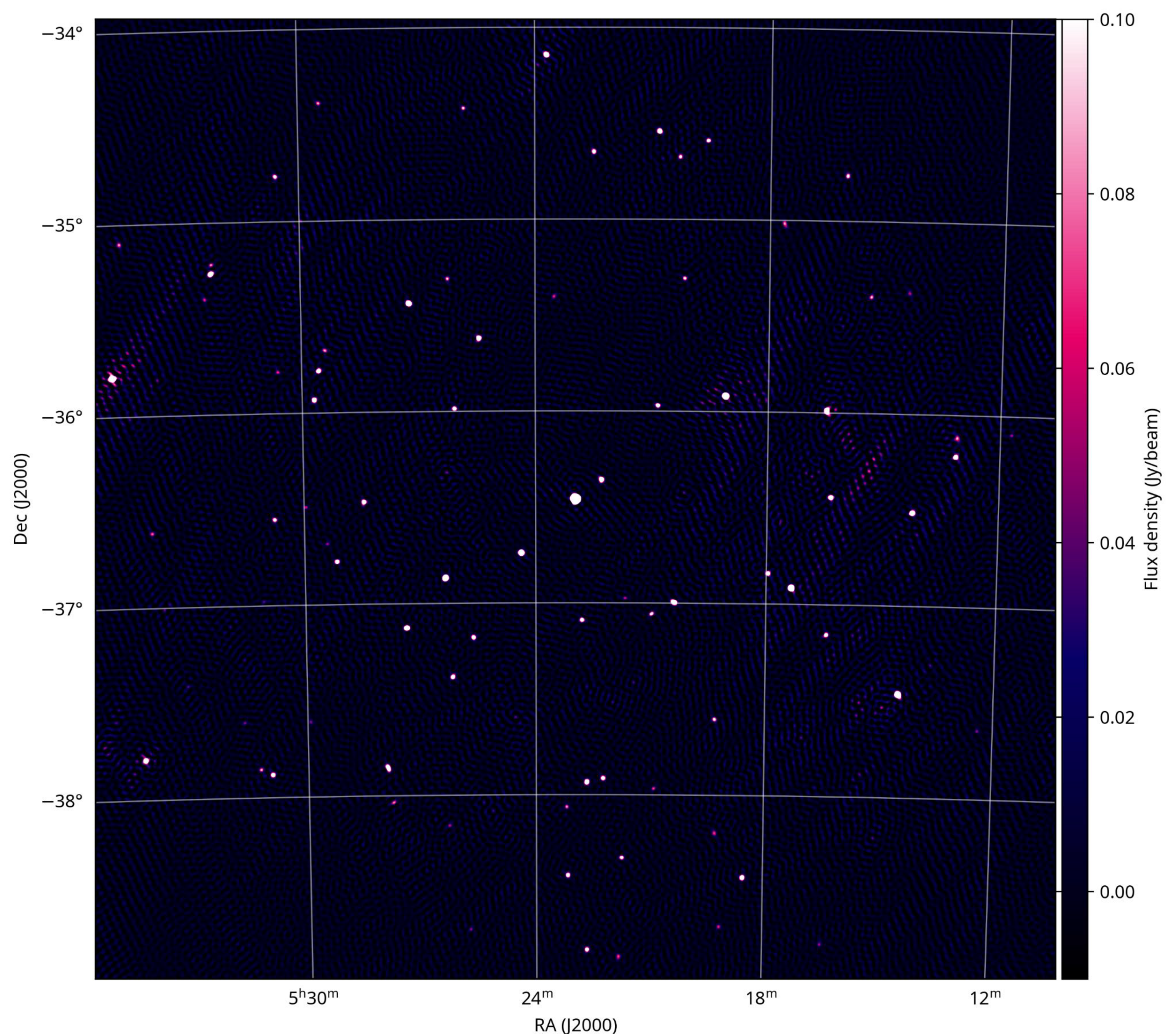


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First SKA-Low AA0.5 image!

- Field surrounding PKS 0521-36 (~ 56 Jy at 150 MHz)
- 150-175 MHz BW
- 7 hours effective integration time
- Image noise ~ 5 -6 mJy/beam at $70''$ final resolution
- 85 sources detected and matched to GLEAM-X catalog



SKA-Low imaging

PKS 0521-36

11 stations (“path to AA1”)

150-175 MHz

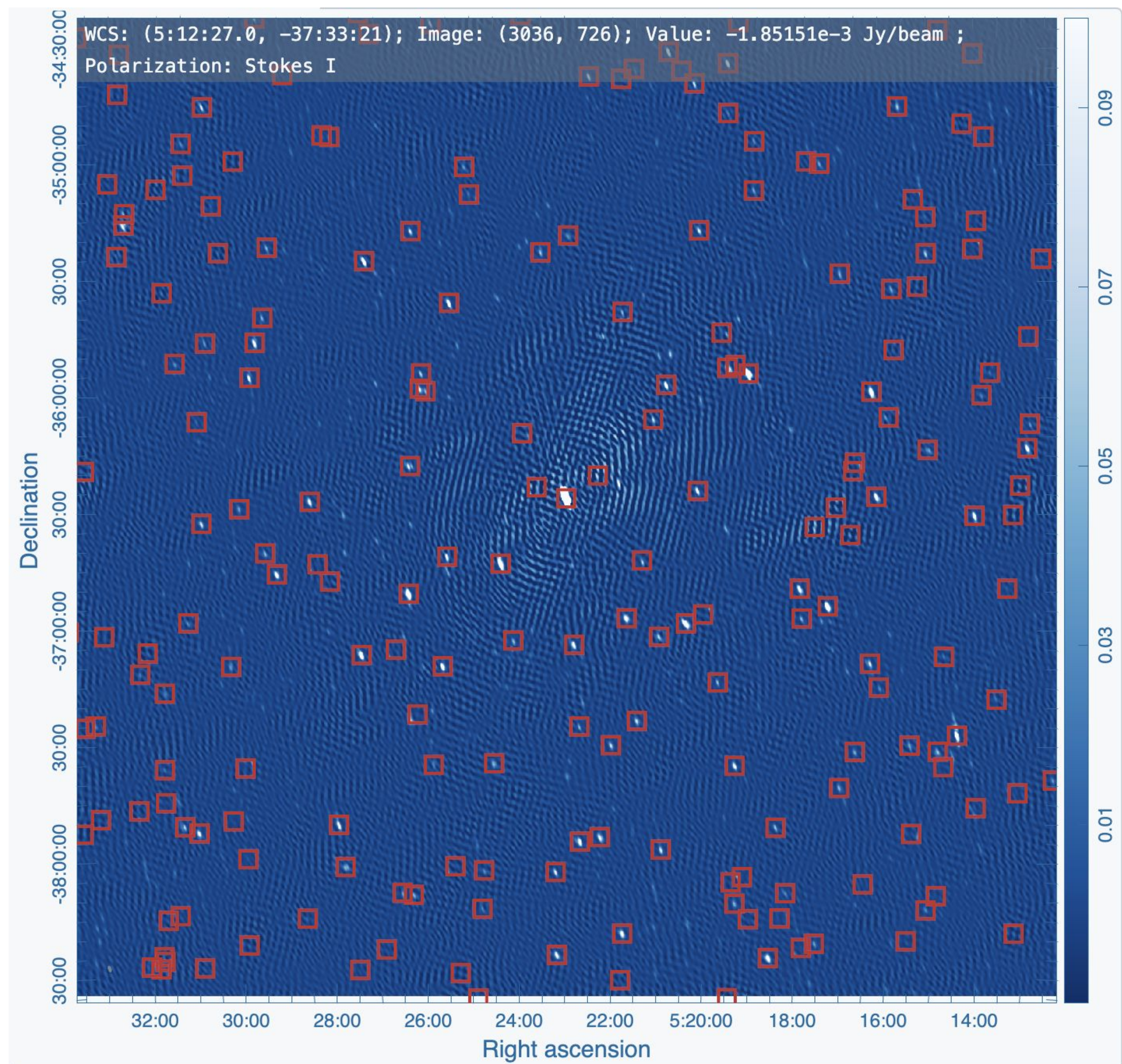
~3 hr track

Direction-independent
self-calibration applied

$\sigma \sim 4$ mJy/beam (83" x 29")

DR ~ 10,000

Red boxes: GLEAM-X > 50 mJy



SKA-Low imaging - complicated fields

Abell 3667

15 stations (“close to AA1”)

170-225 MHz

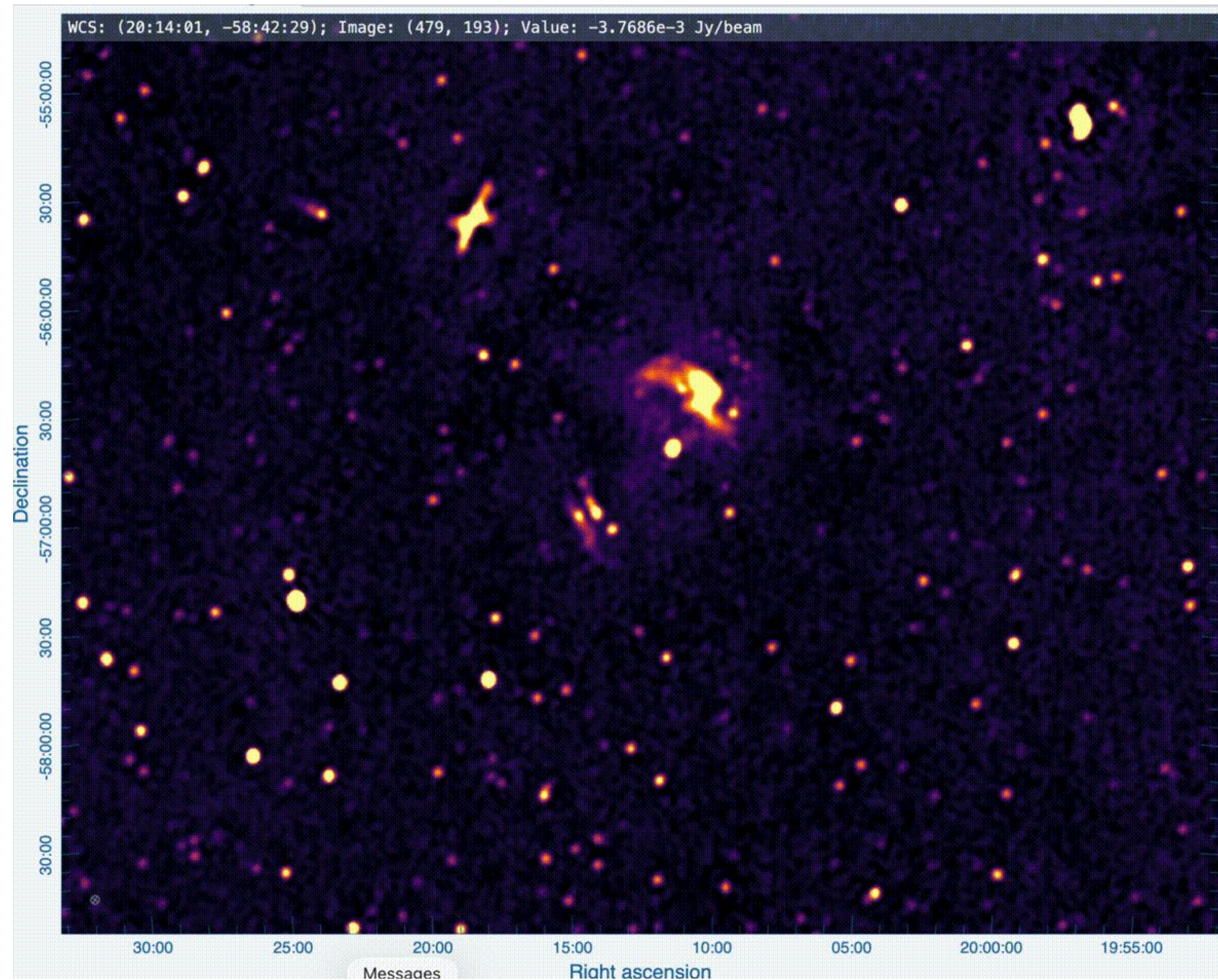
~1 hr track

Primary solutions transferred
from 3C283

Direction-independent
self-calibration applied

$\sigma \sim 12$ mJy/beam ($80'' \times 21''$)

Baselines < 500 m excluded (!)

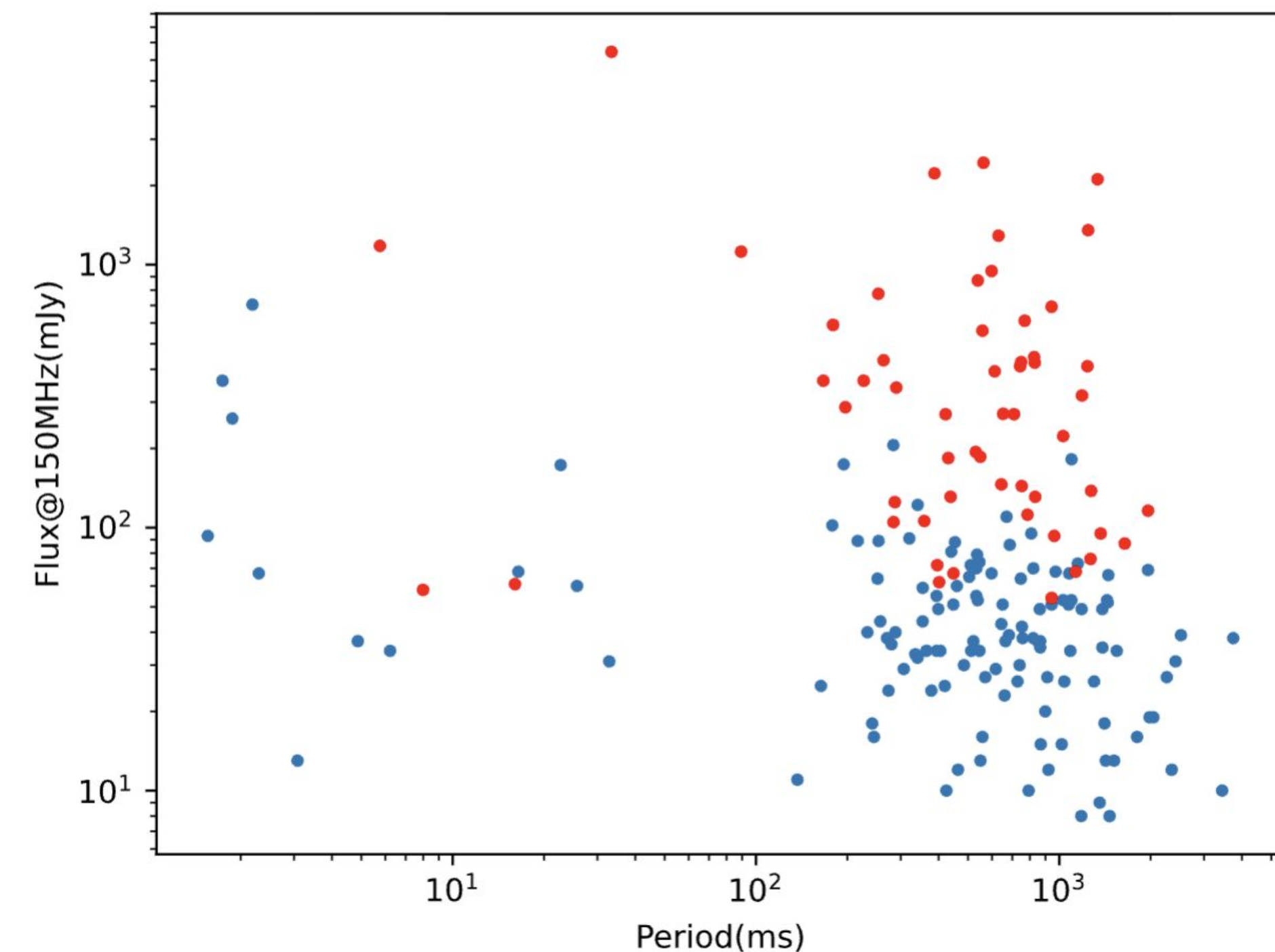
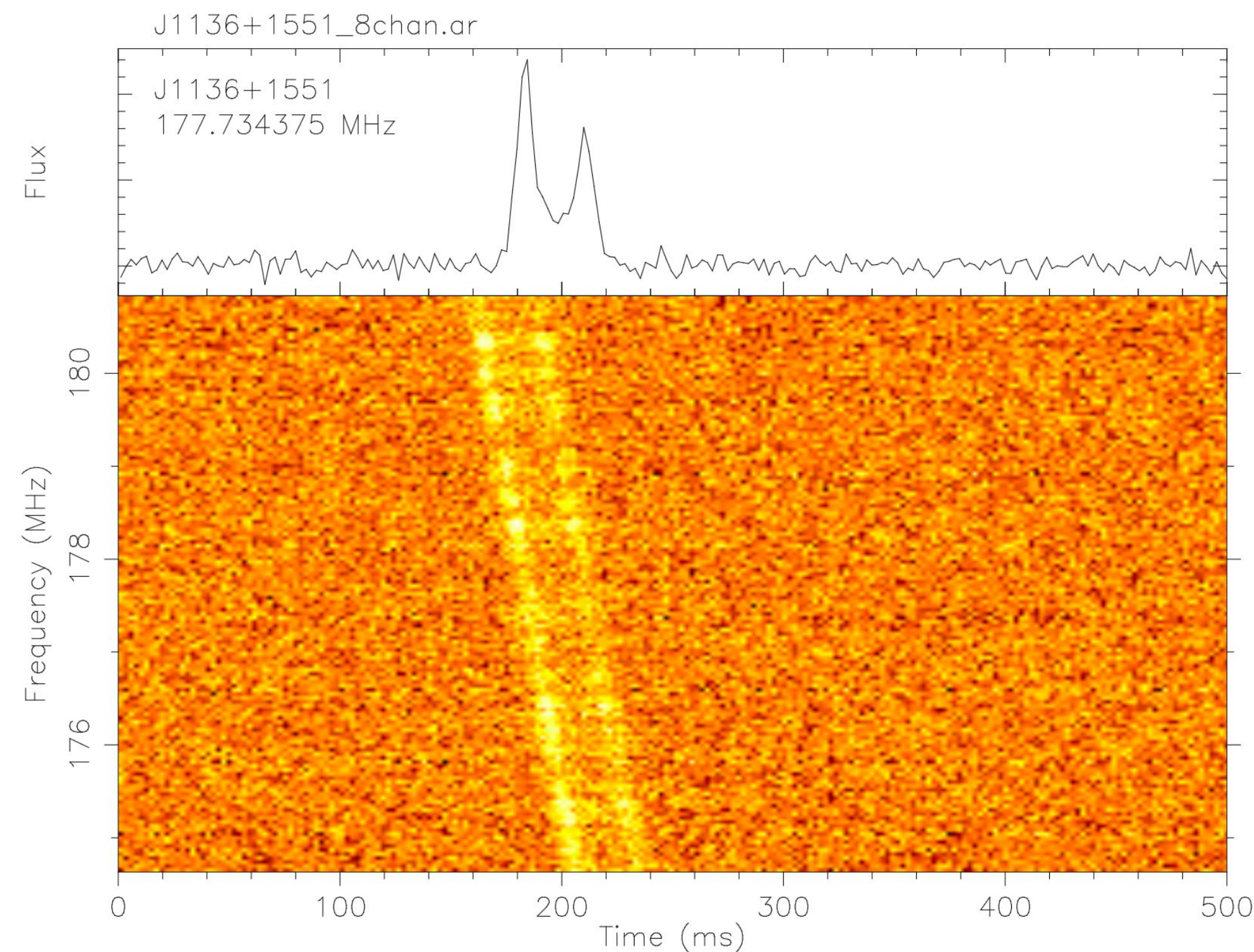


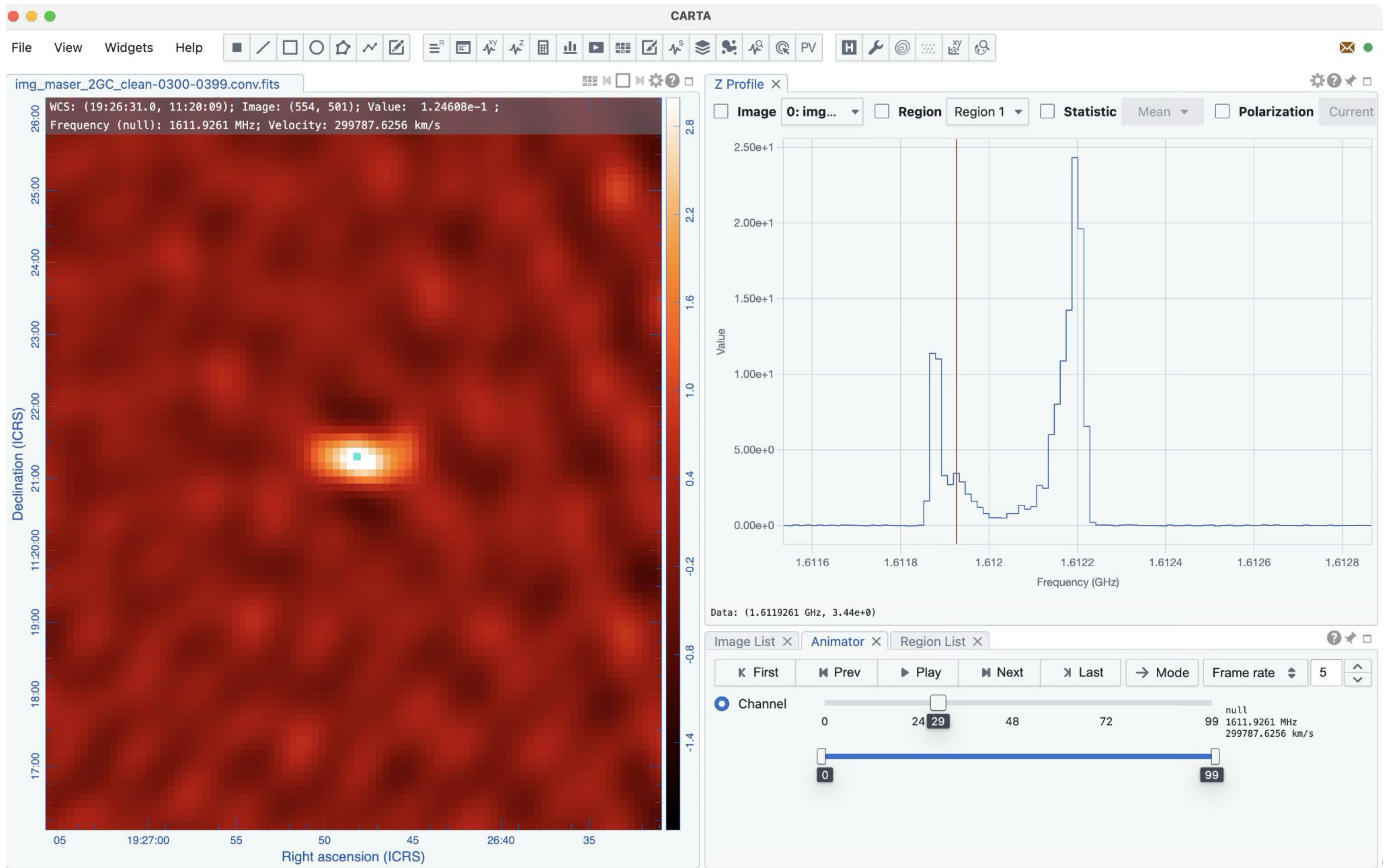
Alternating: GLEAM image and SKA-Low almost-AA1 image



Low Science Commissioning: Pulsar detections

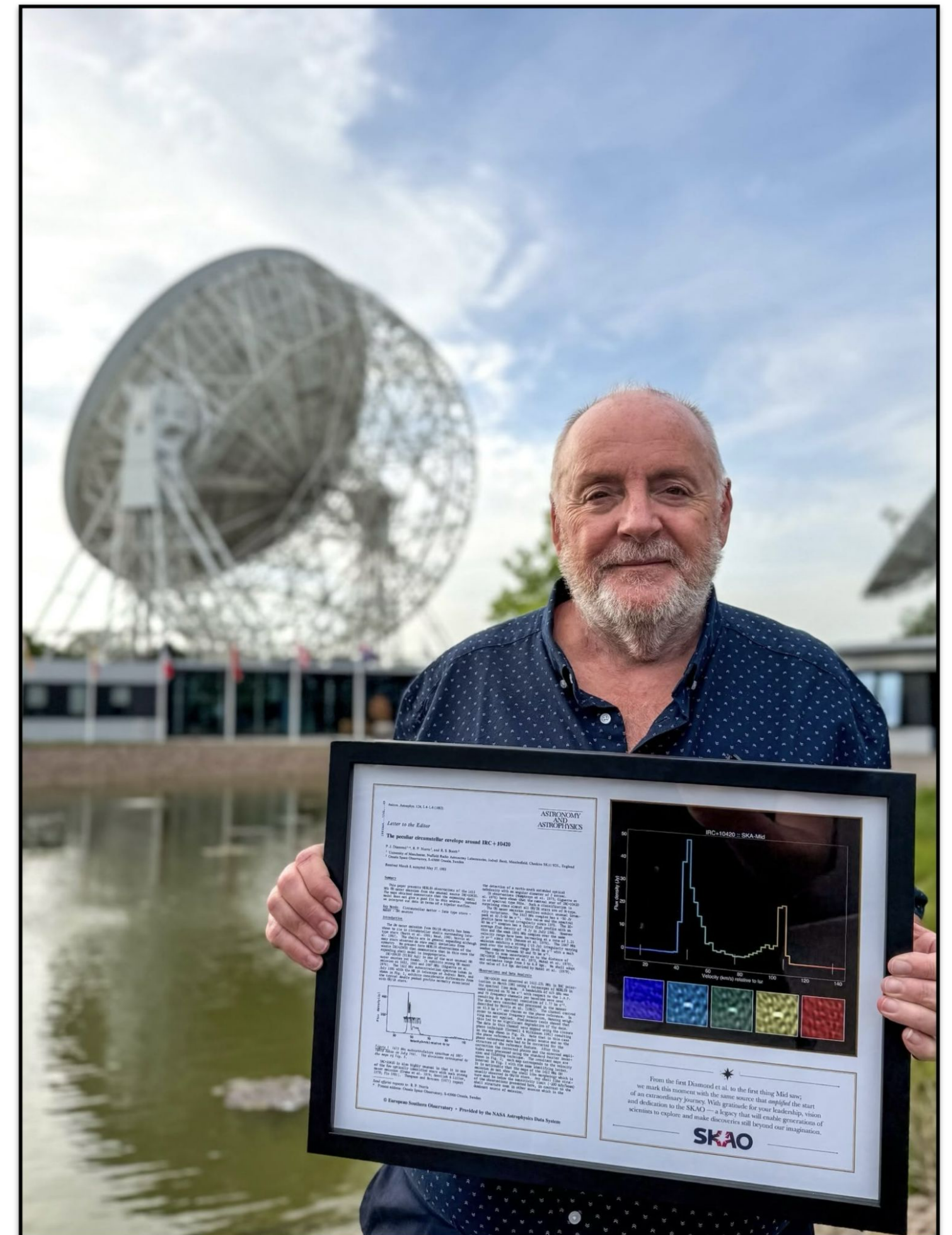
- Detected **56** known pulsars and an RRAT using single stations and tied arrays
- Sneak peek at full polarization properties, with promising results
- Initial testing of tied-array performance is very encouraging - realtime calibration loop in development now, so full coherence is coming soon





IRC+10420

- On 14 May we observed the hypergiant star IRC+10420, calibrated using a scan of PKS B1934–638.
- This was completely jumping the gun from a commissioning perspective, but a plan was hatched to observe this target as a goodbye gift for our outgoing D.G.
- Maser emission from IRC+10420 was the subject of Phil's very first refereed paper.
- Still, we learned a lot about the system, and the quality of the SKA-Mid spectrum is very encouraging.



Commissioning highlights from the last webinar

- Interferometric fringes detected on a single baseline
 - SKA001 – SKA100
 - Observing standard calibrator source PKS B1934–638
- Galactic HI line detected in the dish autocorrelations
- Closure phase achieved with a three antenna system
 - SKA001, SKA036, SKA100
 - Again observing PKS B1934–638
- Field with two strong sources in the beam yields expected fringe patterns
 - PKS 1718-649



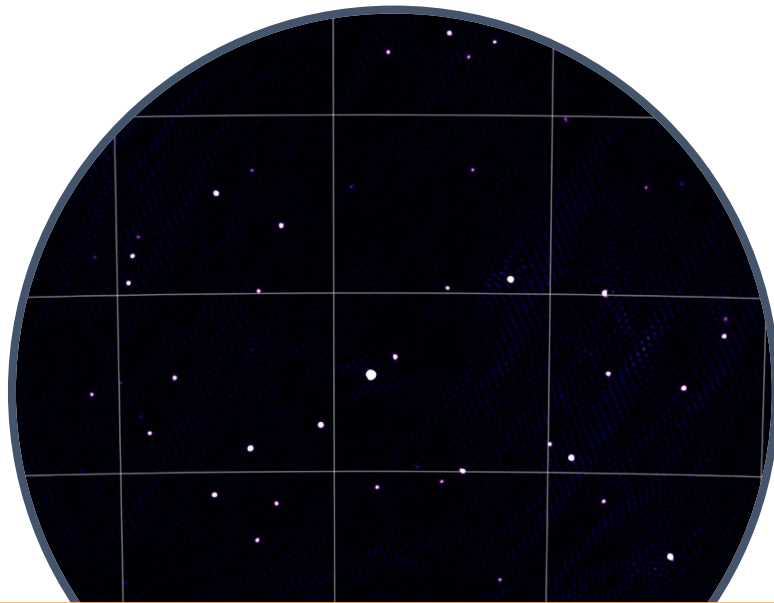
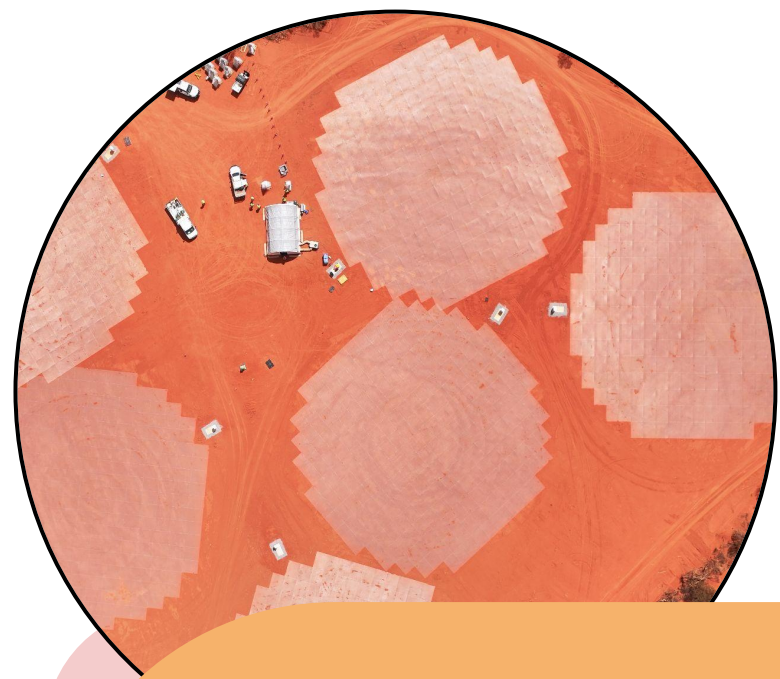
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Community involvement starts

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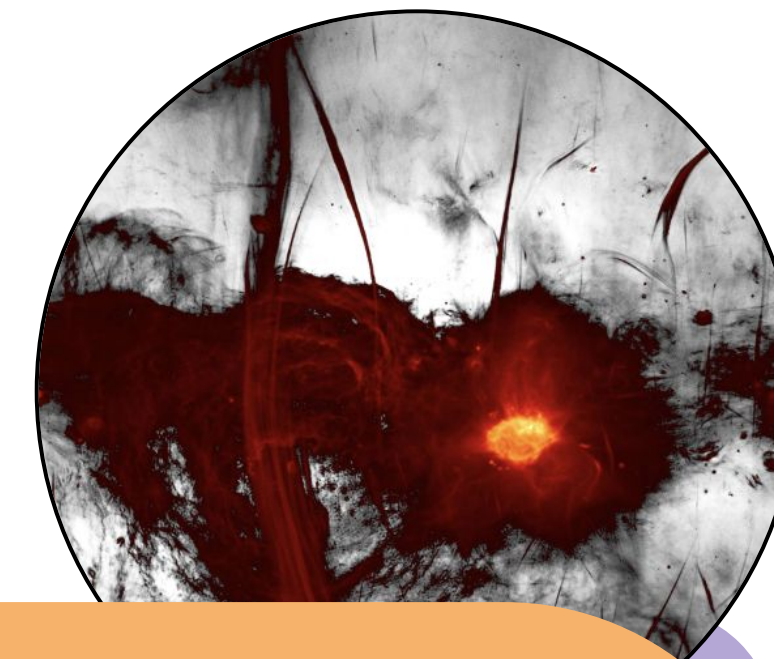


AA2

Science Verification



AA*



- Starts when Mid and Low are comparable to current state-of-the-art telescopes (66 dishes, 68 stations in AA2)
- **Primary purpose of SV is verification of the scientific capability, overall workflow and usability of the system → science is a bonus, not guaranteed.**
- Provide an end-to-end test of the system for each mode/ODP
- Must not place unnecessary burden on the SKA user community
- Goal to get broad feedback on SKA data, SKAO operational model and SRCNet from a diverse user community → data will be publicly available for thorough scrutiny
 - SV data will not be owned by any person/group.
- Build trust in operational model and excitement on our way to science

NOW

NOW

First half 2029

First half 2031

2032

Science Verification - How will it work?



Call for ideas

Call(s) issued to the (entire) community for verification ideas to test specific modes and capabilities (integration times, number of beams etc). Open for 2 months. SKAO plans for SV targets and Observatory-led data products will be included.



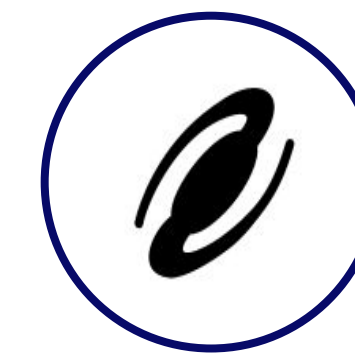
Idea submission

Submit a verification idea through the SV idea submission tool. Will require title, mode to be tested, summary of idea and verification opportunities, target.



Idea Assessment

A light touch internal appraisal providing us with a pool of well suited, prioritised targets and ideas to test the modes and capabilities. Breadth of science coverage will be considered to ensure diverse user engagement.



Announcement of SV target set

SV targets announced, including Observatory-led data product plans



Call for SRCNet resource requests

Expecting restricted resource availability to begin, building as we go through SV stages. Resource request will include plan for verification of SV target, intention of providing feedback, feasibility.

-6 months

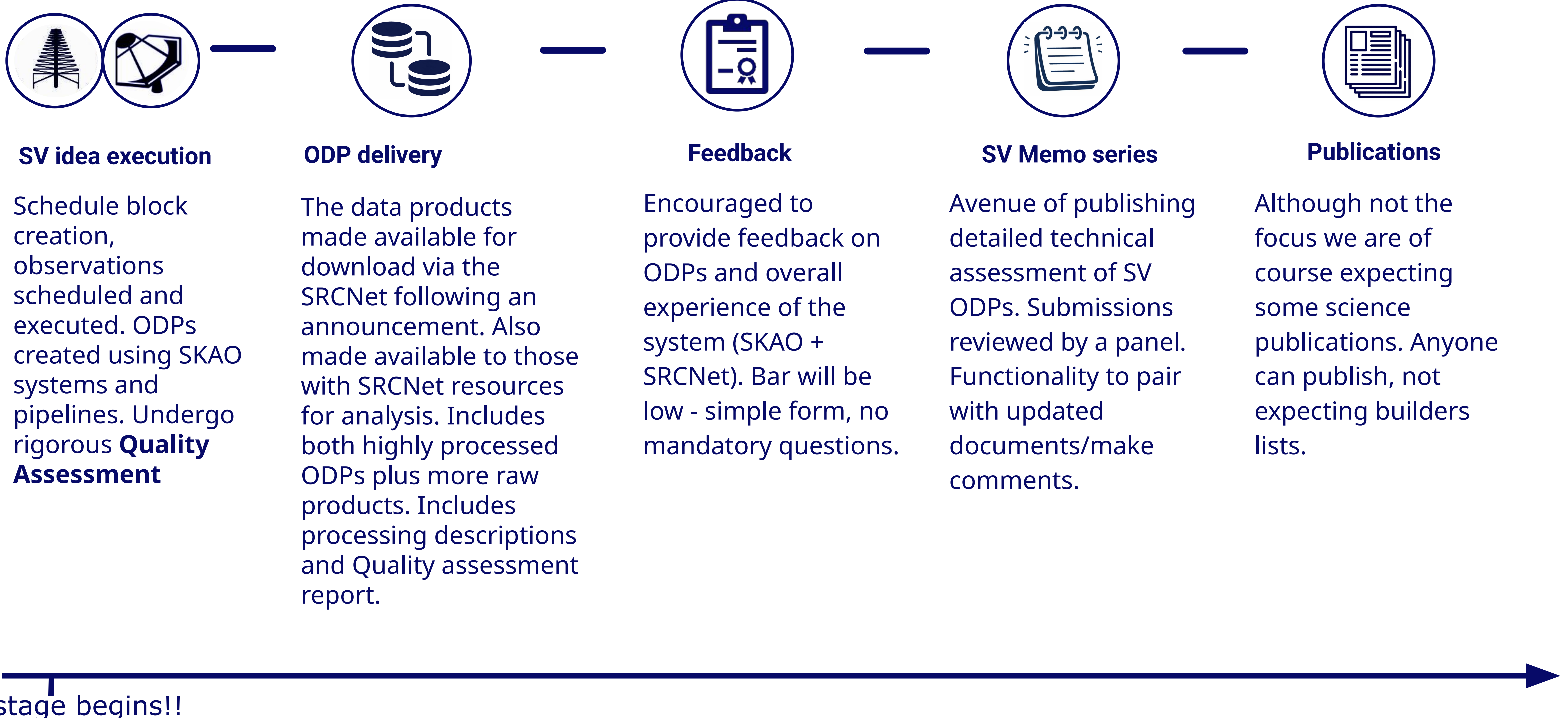
-4 months

-3 months

-2.5 months



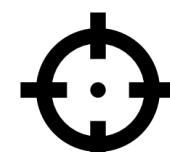
Science Verification - How will it work?



SKA-Low AA2



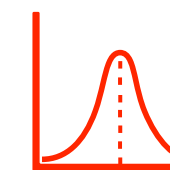
1 subarray



1 pointing, **1** beam



Max **4 hrs**



7.5" FWHM (100 MHz)
2.4" FWHM (300 MHz)

Bandwidth



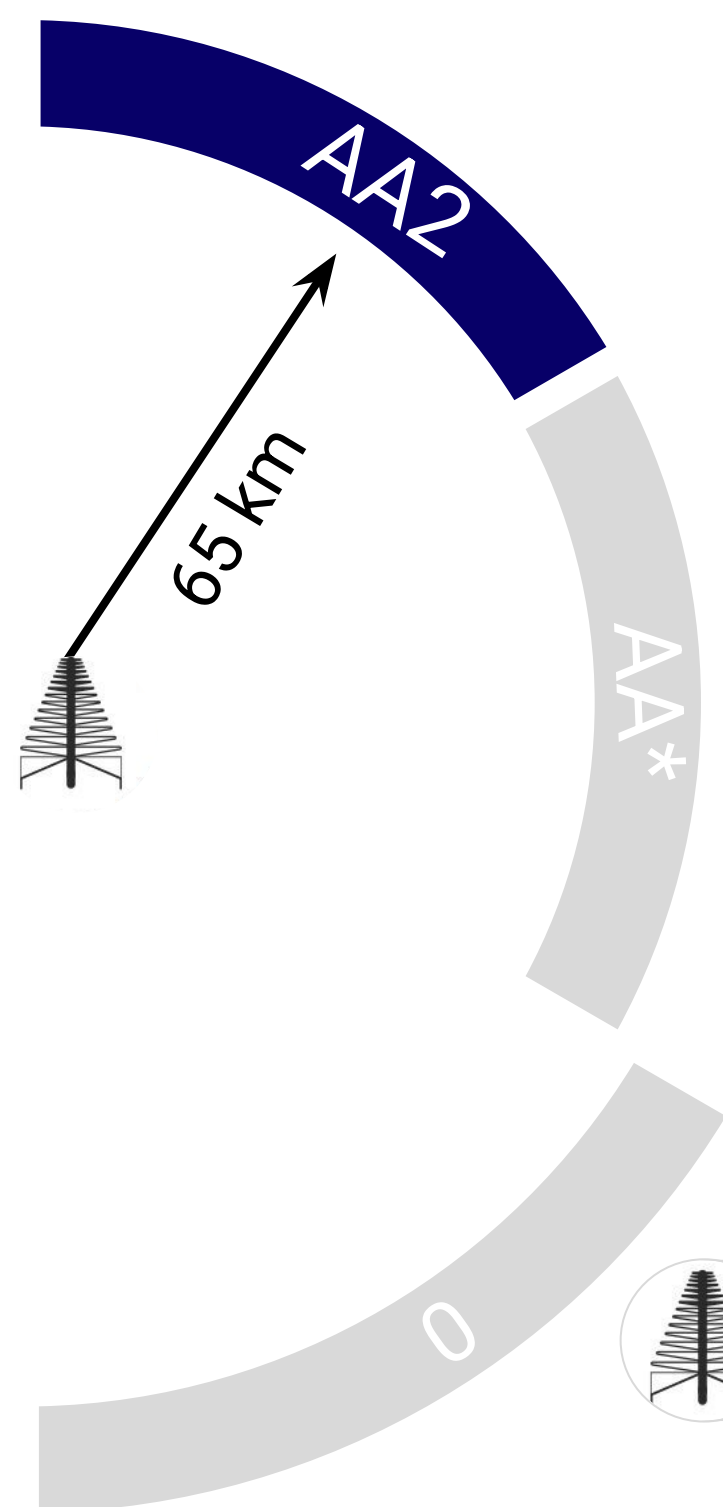
150 MHz

50%

2027 - 2029



68



2029



257*

2030

Science Verification

Continuum

Up to **40** channels imaged

Expecting to exclude (all?)
Galactic observations at this
stage as we build the GSM

Spectral Line

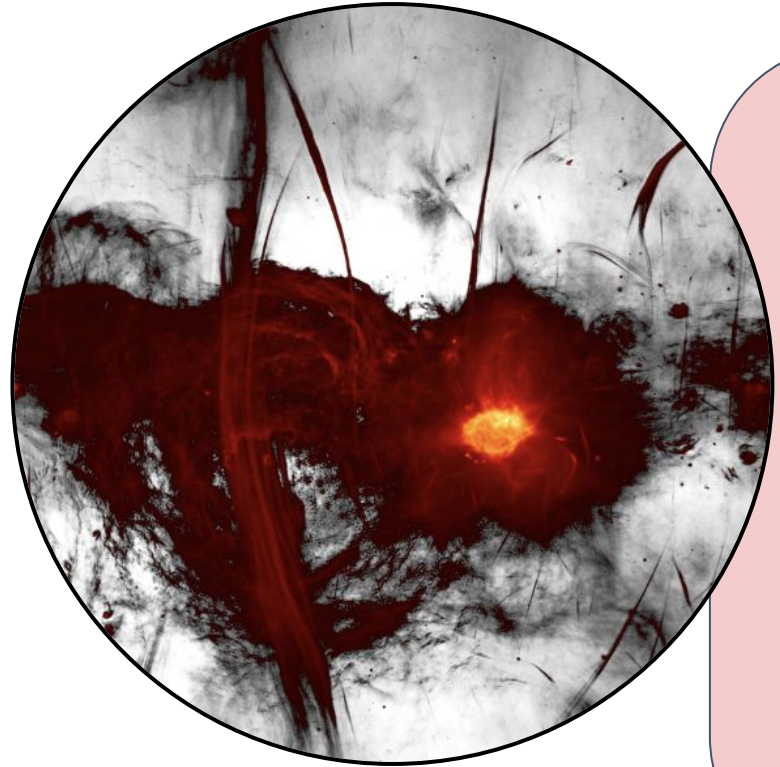
Up to **4000** channels

Continuum subtraction
(early implementation)
Spectral resolution up to
226 Hz

PST

At least **1** beam
Flow through + detected
filterbank

What data will provide in Science Verification?



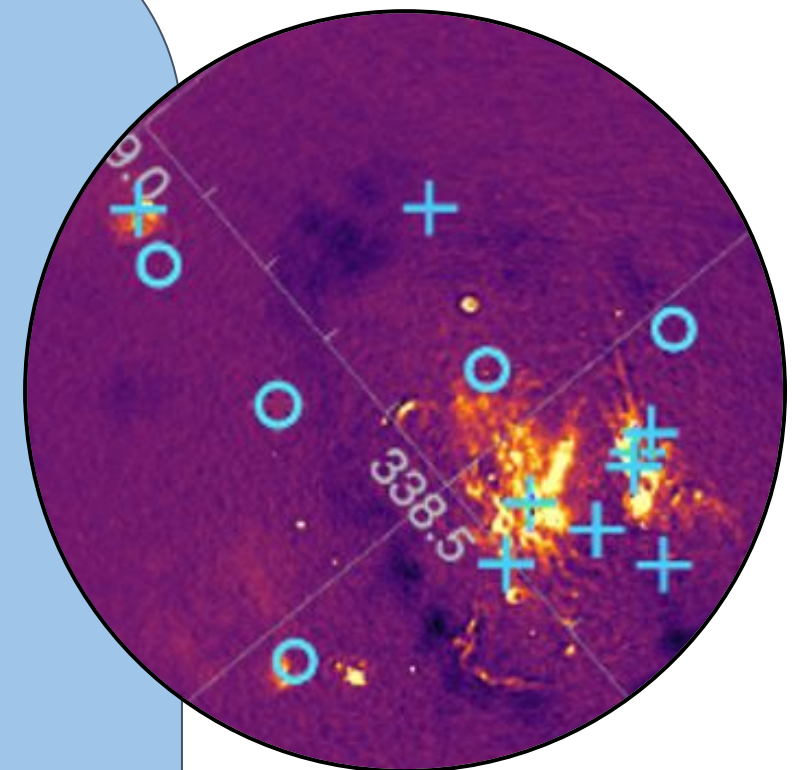
Data products

- Highly processed Observatory Data Products (ODPs) e.g. images
- Less processed data products e.g. calibrated, averaged visibilities (including calibration solutions) → **Needed for verification of ODPs and to build trust in our ODPs**
- Supporting ancillary data products
- During AA2, most files $\lesssim$ a few TB, spectral visibilities $\sim$ a few 10s of TB. In AA* spectral visibilities a few 100 TB

Continuum image cube of a single source, single image, 4 hours integration

- bandwidth-averaged multi-frequency synthesis (MFS) image plus a cube of 10 evenly spaced channels covering the full bandwidth by default (max of 40 channels if required). Full polarisation.
- Calibrated visibilities, averaged to 3.4 s time resolution and 21.7 kHz
- Ancillary data products including detailed QA, local sky model and description of processing

AA2 Low continuum example



Questions?

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A quick survey on your SV plans/needs:



The importance of SKACH involvement in the SV process

- Build observer community and hands-on expertise with SKA data from outset
- Build track record to support KSP ramp-up process
- Hands-on testbed of the chSRC user experience for observational projects
- Evidence (rising) demand by SKACH community for compute allocations at CSCS
- Demonstrate importance and reliability of capabilities/resources provided by chSRC
- Offer inspirational projects at Swiss research institutions

(N.B.: ODPs from all SV projects will be made public, so many of these objectives do not uniquely depend on SKACH PI-ship of SV observations.)

Targets for SV - discuss/brainstorm in small groups...

SKA sensitivity calculator



Community update on SV (by SKAO/S. Breen)



The winning combination of capability demonstration and science potential - an (incomplete) checklist

- How many capabilities will your proposed observation test?
- Is there a well-defined data set that can serve as a reference when verifying SKA SV observations?
- Will the visualization of your observation produce inspirational/marketable image material?
- Can you offer processing via a custom pipeline to flag potential improvements over standard ODPs?
- Is your target suited best to the specific obs. mode under SV?
- Has the chSRC developed resources that are particularly well suited to processing your project?
- Will your SV observation enable original science? Does the analysis lend itself to MSc/PhD projects?

Next steps

- Wait for information re. timeline for LOW SV
- Exploit tools for generating mock SV data of candidate targets (KARABO, skasim) — the chSRC might organise a dedicated hack day to facilitate this.
- How can we help you explore/plan?
- ...

Thank you!