The MWA's importance as an SKA precursor

Sarah Pearce, SKA Low Telescope Director

MWA Project Meeting, 23 July 2023

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

We acknowledge the Wajarri Yamatji as the traditional owners and native title holders of Inyarrimanha Ilgari Bundara, CSIRO’s Murchison Radio-astronomy Observatory, the land on which we will build the SKA-Low telescope.

We acknowledge the Whadjuk Noongar people as the traditional owners of the SKA-Low Science Operations Centre site.

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

Who are we?

The SKA Observatory (SKAO)

An inter-governmental organisation, governed by a treaty. SKAO was born on 4 February 2021.

Only second IGO in astronomy, after ESO

Full membership:

Australia, China, Italy, Netherlands, Portugal, South Africa, Spain, Switzerland, United Kingdom.

Accession stage:

Canada, France, Germany.

Membership negotiations:

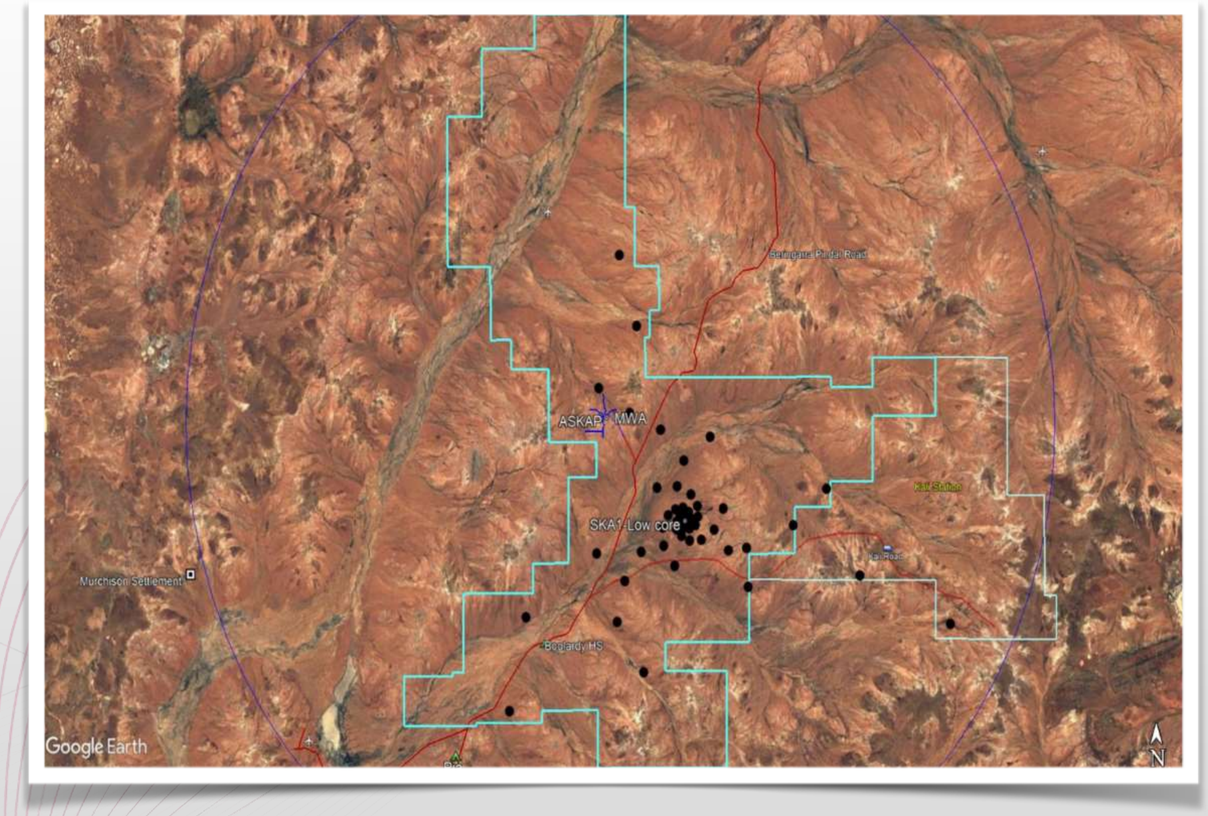
India, Sweden.

Early stages:

Japan, South Korea.

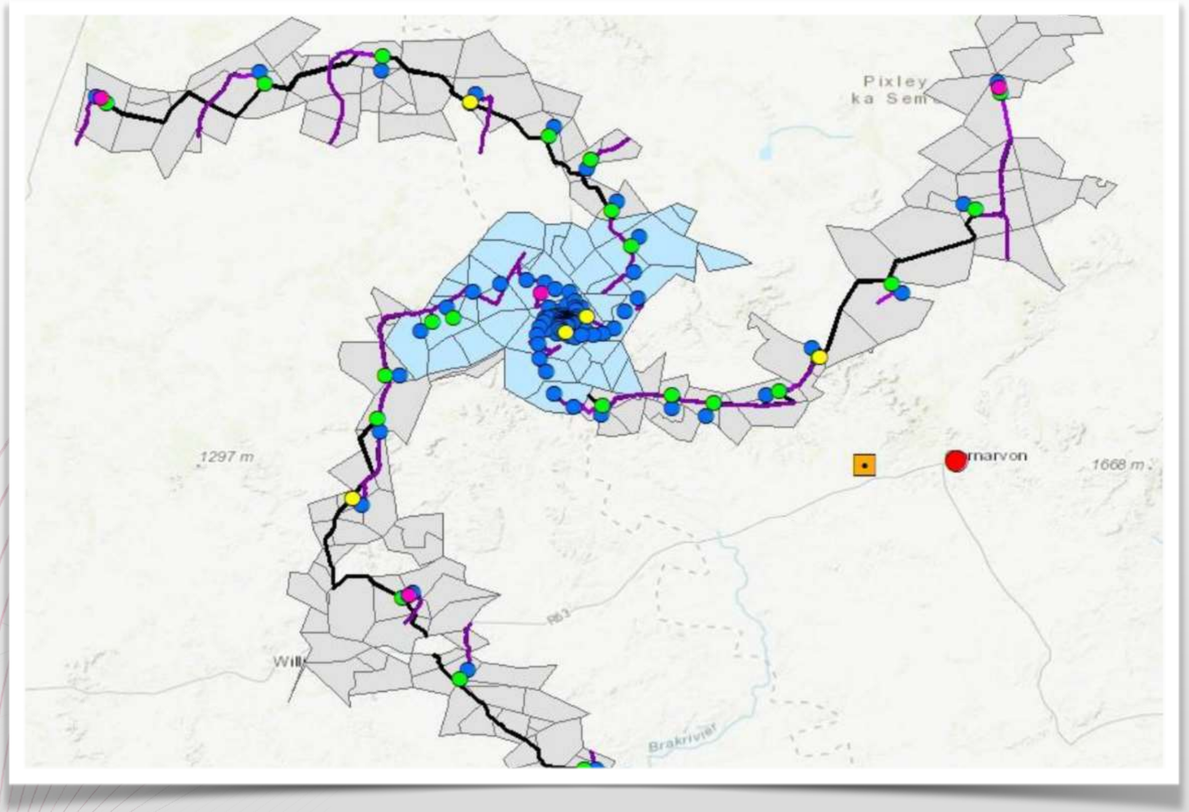
"SKAO's mission is to build and operate cutting-edge radio telescopes to transform our understanding of the Universe and deliver benefits to society through global collaboration and innovation."

SKA-Low in Australia



- 131,072 log-periodic antennas, spread across 512 stations
- Frequency range: 50 MHz - 350 MHz
- Maximum distance between antenna stations: 74km

SKA-Mid in South Africa



- 197 fully steerable dishes, including the existing MeerKAT dishes
- Frequency range: 350 MHz - 15.4 GHz (potentially 30 GHz)
- Maximum distance between dishes: 150km

SKA Science Community
14 Working Groups
over 1000 scientists

High Energy Cosmic Particles
Focus Group

Extragalactic Continuum
Science Working Group

Our Galaxy
Science Working Group

Extragalactic Spectral Lines
Science Working Group

Cosmology
Science Working Group

VLBI with the SKA
Science Working Group

Pulsars
Science Working Group

HI Galaxy Science
Science Working Group

Cosmic Magnetism
Science Working Group

Epoch of Reionization
Science Working Group

Solar and Heliospheric Physics
Science Working Group

Cradle of Life
Science Working Group

Transients
Science Working Group

+ Gravitational Waves
(banner in progress)

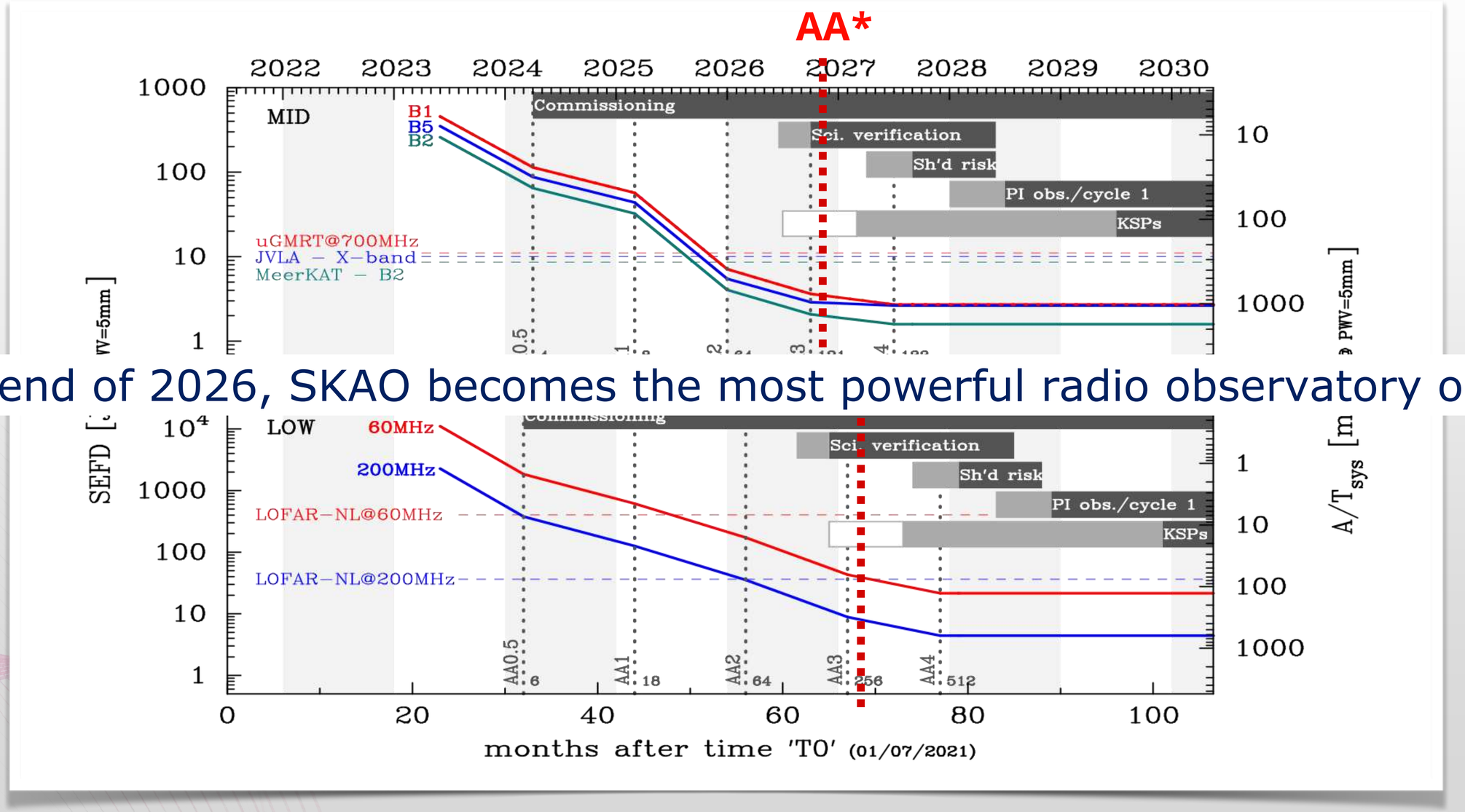
Construction Strategy

- **Target**: build the SKA Baseline Design (197 Mid dishes; 512 Low stations: AA4)
- Not all funding yet secured, therefore following Staged Delivery Plan (AA*)
- Develop the earliest possible working demonstration of the architecture and supply chain (AA0.5)
- Then maintain a continuously working and expanding facility that demonstrates the full performance capabilities of the SKA Design.

First data release to the community expected in 2026/27 (for science commissioning and verification)

Milestone Event (earliest)		SKA-Mid (date)	SKA-Low (date)
AA0.5	4 dishes 6 stations	2024 Dec	2024 Aug
AA1	8 dishes 18 stations	2025 Nov	2025 Oct
AA2	64 dishes 64 stations	2026 Oct	2026 Sept
AA*	144 dishes 307 stations	2027 Aug	2028 Jan
Operations Readiness Review		2027 Nov	2028 Apr
End of Staged Delivery Programme		2028 Jul	2028 Jul
AA4	197 dishes 512 stations	TBD	TBD

The Evolution of Performance



At the end of 2026, SKAO becomes the most powerful radio observatory on Earth

Credit:
Mark Sargent

Anticipated Science Performance: https://arxiv.org/abs/1912.12699

Construction Commencement Ceremony (05 Dec 22)

SKA-Low on site: Recent milestones, activities,

Left : installation of first water bores
Lower right: AAVS3 antenna deployment
Right: construction of “turkeys nest”

Precursors

Located at future SKA sites (South Africa and Australia)

Pathfinders

Engaged in SKA related technology and science studies

MWA influence on SKA - Prototyping

- Series of prototypes on MWA site - making use of existing power and signal infrastructure
  - AAVS0.5 - 16 SKALA antennas – 2014
  - AAVS1 – 256 SKALA2 antennas - 2016
  - EDA2 – 256 MWA diploes – 2108
  - AAVS2 – 256 SKALA4.1 antennas – 2019
  - AAVS3 – 256 SKA4.2 antennas – 2023
- Critical for developing and testing all aspects of SKA stations – engineering, reliability, deployment, operations, calibration, data processing, science…

Image credit: ICRAR

MWA influence on SKA – Engineering

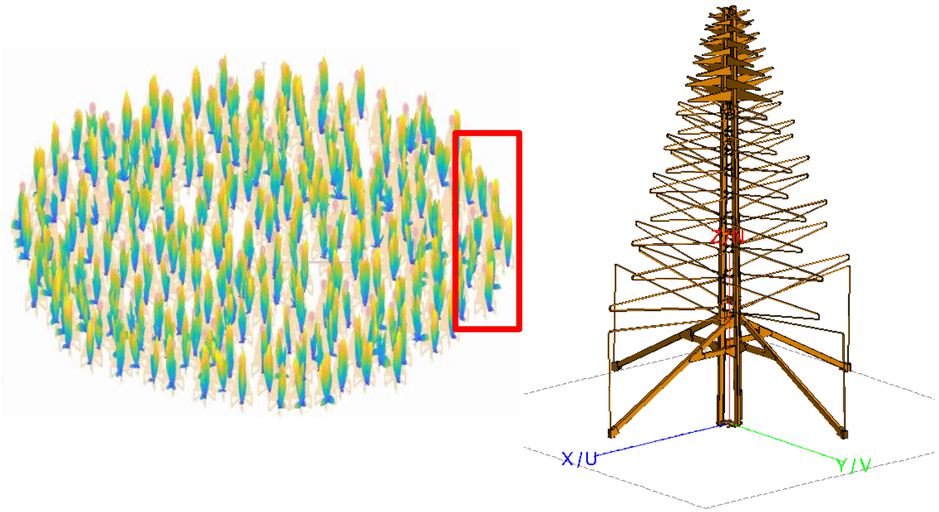
- Strong influence on station design of SKA-Low
- Antenna attachment to the mesh
  - MWA solution
  - Removal of concrete bases – critical cost and operations saving
- Antenna material (steel to aluminium)
- Power and signal distribution
  - Moved from one single box to smaller smartboxes
  - Smartbox evolved from MWA beamformer
- Coaxial cable for power and monitoring data to smartboxes
  - Improved reliability, operations
  - MWA reflections → length of cables
- RFI compliance
  - PaSD based on experience with MWA

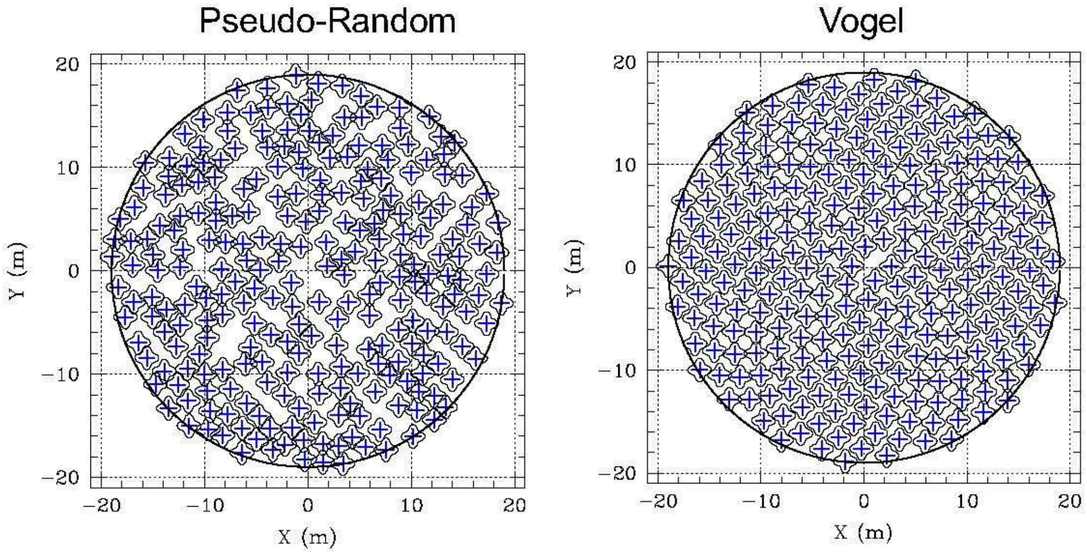
MWA influence on SKA – Calibration and modelling

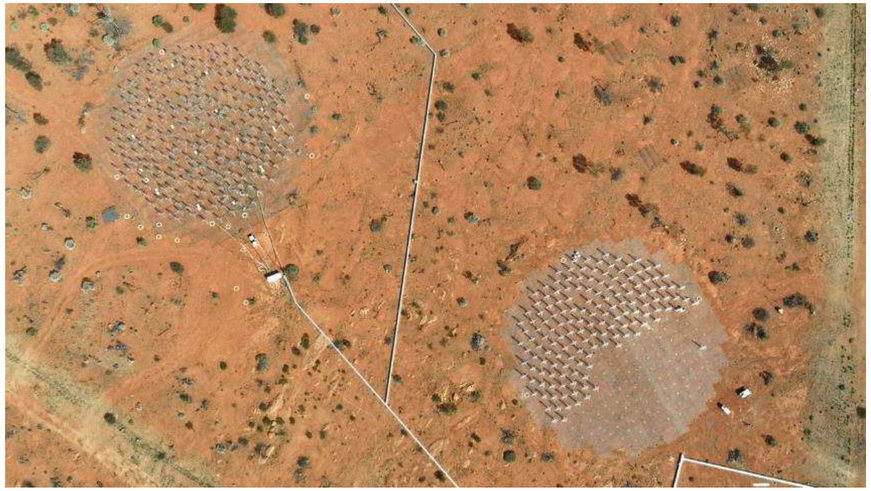
- Curtin engineering team, in collaboration with INAF
- First simulations used AAVS0.5 and MWA tiles
- AAVS2/3 simulations
  - 1 million+ degrees of freedom, 5 MHz intervals
  - Run on supercomputer: hours/days of time
- Models validated with drone measurements

- AAVS3 will trial Vogel layout

Image credit: D Ung, ICRAR







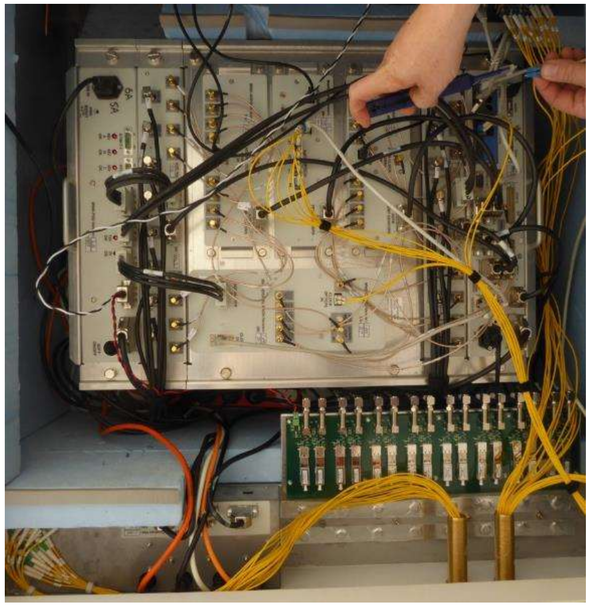
MWA influence on SKA – Operations

- Learning from the experience of deploying, operating and maintaining MWA

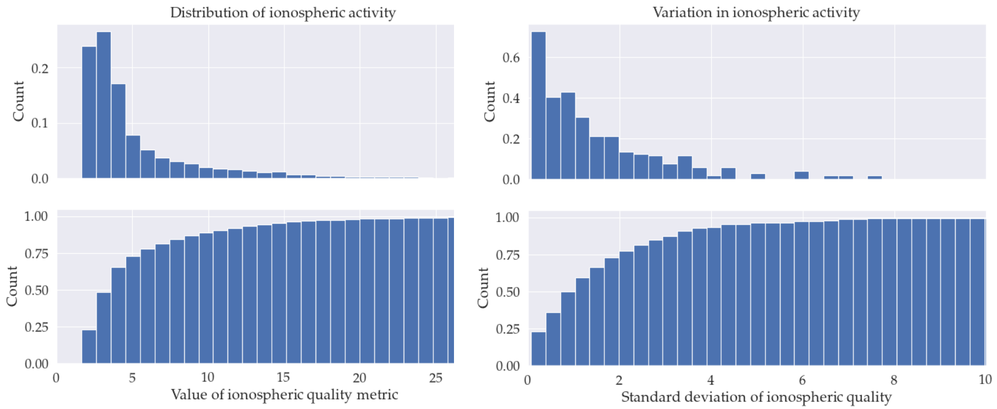
- Work with local industry contractors
  - Building relationships and expertise for SKA-Low construction and operations

- Understanding the MRO environment
  - Ionospheric monitoring and characterisation
  - Soil, wind, temperature
  - RFI environment: satellites, ducted TV and radio
  - Failure modes

- Developing science operations



Ionospheric activity at the MRO (Chris Jordan)



327 nights (9,811 snapshots) over four years

AAVS3

- Final single station test before AA0.5
- On MWA site – in collaboration with Curtin and INAF
- Test and verify (pre)-production hardware and software
- Refine the design (to the extent this is still feasible)
- Prototype robust and automated calibration procedures

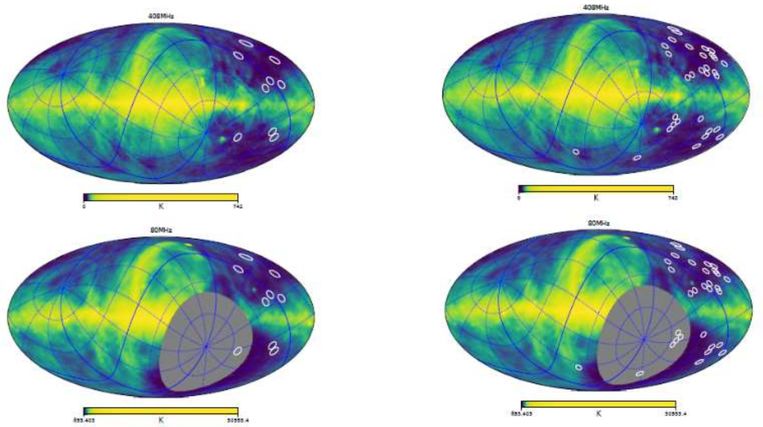
AAVS3 deployment

- Collaboration SKAO, MWA
- First time SKAO has deployed equipment at site
- Many lessons for deployment team for AA0.5+
  - Safety – planning, ergonomics
  - Logistics
  - Process and design for antenna assembly and installation
  - Quality control, testing
  - Scheduling
  - Waste removal

MWA influence on SKA – Science I

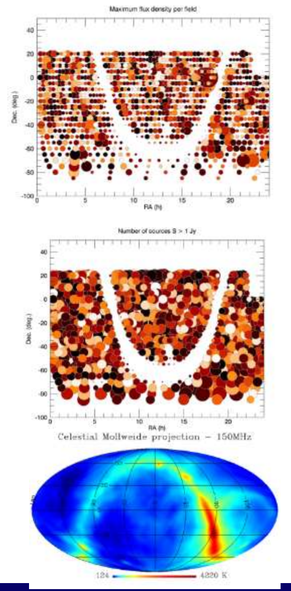
- **EoR**
  - Key science project for SKA-Low
  - MWA view of the Southern Sky used to determine observing fields
  - Also experience of how to run an EoR experiment
- **Pulsars**
  - Pulsar survey of southern sky
    - Input data for SKA
    - Discovery of new pulsars
    - Ultra-long period magnetars
    - Value of the archive

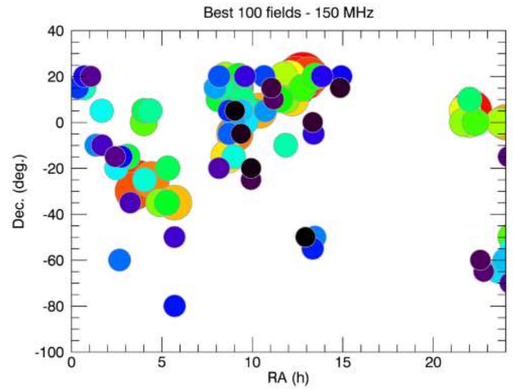
Pre-selection of the Candidate Fields for Deep Imaging of the EoR with SKA1-Low - Qian (Cathie) Zheng (SHAO)



S<6 Jy, 40 square degrees

S<3 Jy, 20 square degrees

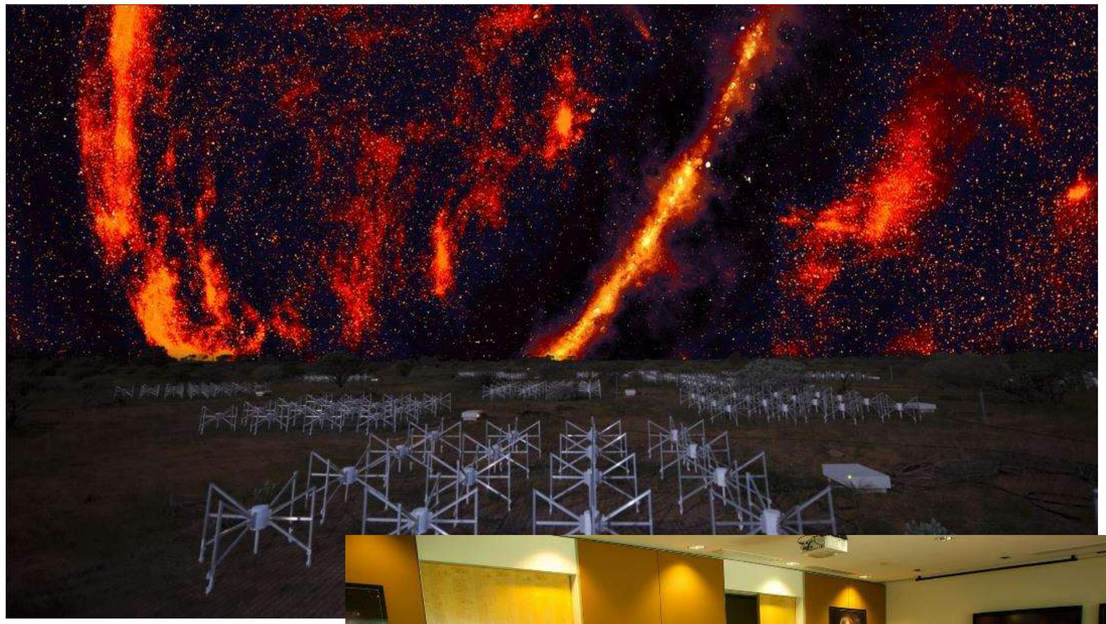




Trott 2017 (IAU proc.)

MWA influence on SKA – Science II

- **Sky catalogues**
  - GLEAM, GLEAM-X and LoBES will be primary catalogues for initial SKA-Low calibration
  - POGS (GLEAM polarisation catalogue)
    - First all-sky low-frequency polarimetry survey
    - Influential in SWG planning for SKA-Low
  - GLEAM has also developed a cohort of ECRs
- **Cosmic web**
  - Role in first statistical detection of cosmic web filaments
    - Value of low frequency surveys, publicly available data, large scale



Images: E Lenc, ICRAR

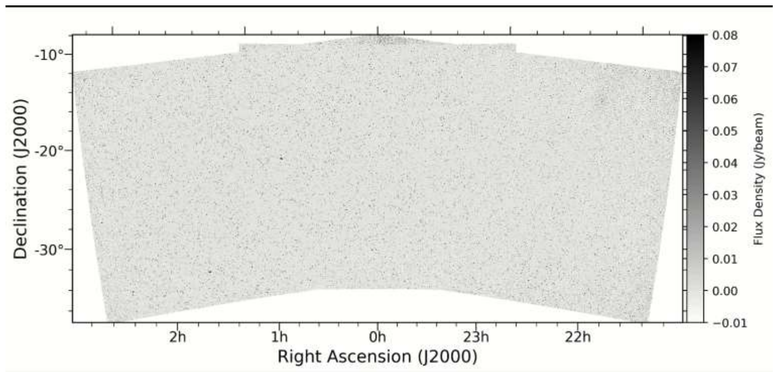
Computing and data

- MWA partnership with Pawsey has grown capability in HPC for low frequency radio astronomy (see previous talk)
- MWA projects part of early stage AusSRC
  - Experience in supporting science teams, users, telescope teams
- MWA data core to SKAO Science Data Challenge 3

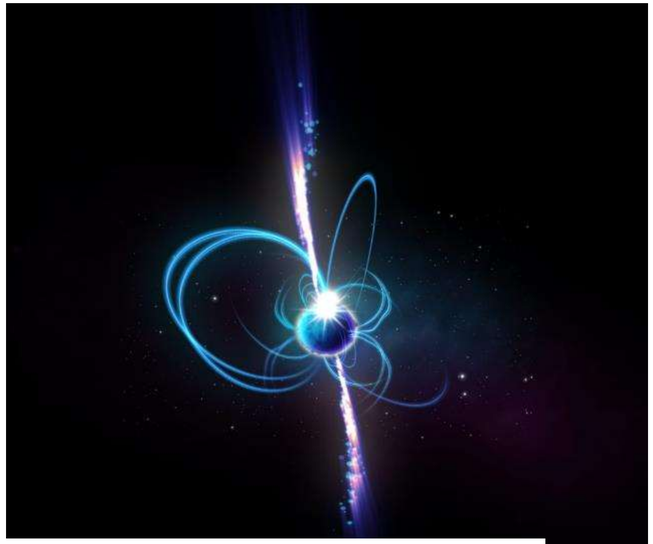
SKAO Science Data Challenge # 3 : First SKA-Low based one

LoBES – Long-baseline survey in EoR fields. Used in SDC3 Data Challenge

Lynch et al (2021)
Lynch et al (2023, in prep)



Communications and outreach



The West Australian | for 190 years

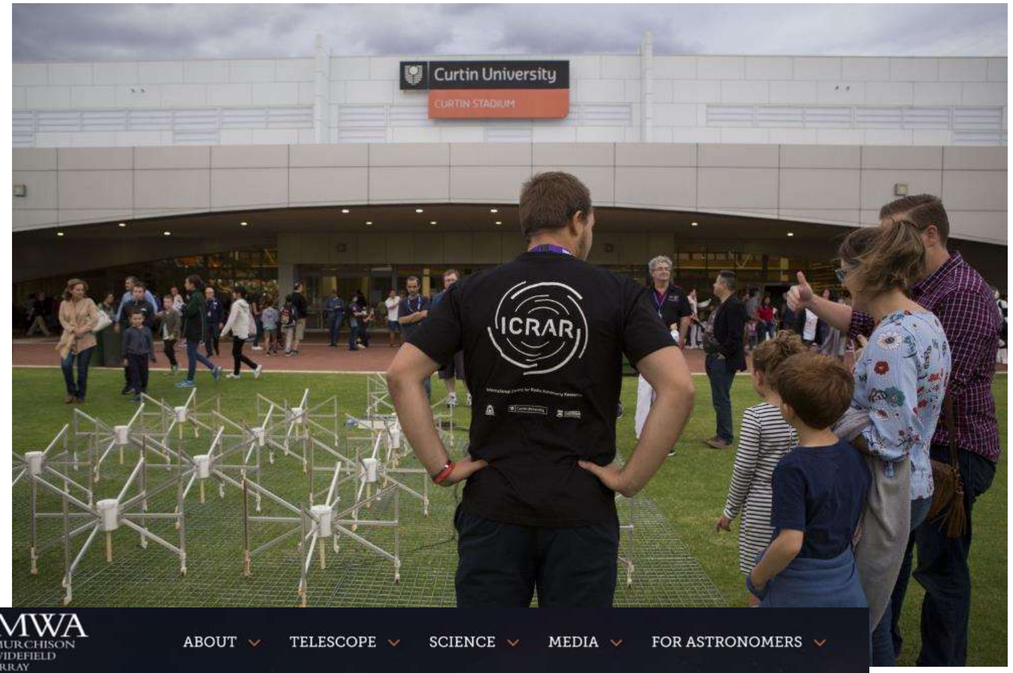
WA News | Opinion | Science | Space

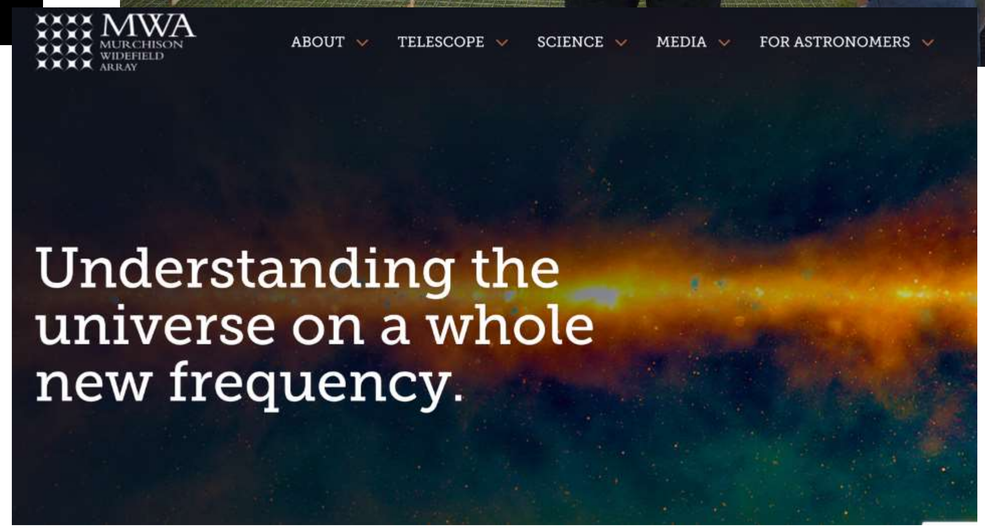
OPINION

Steven Tingay: WA takes its place at centre of astronomy universe with Murchison Widefield Array project

Steven Tingay | The West Australian
Sat, 22 July 2023 2:00AM | Comments

Tile 107, against the breakaways, under the night sky. Credit: Pete Wheeler,





Images: MWA, ICRAR

Shared sky

Image:
The West Australian

Image:
Creation of the Sun, by the First People Artists

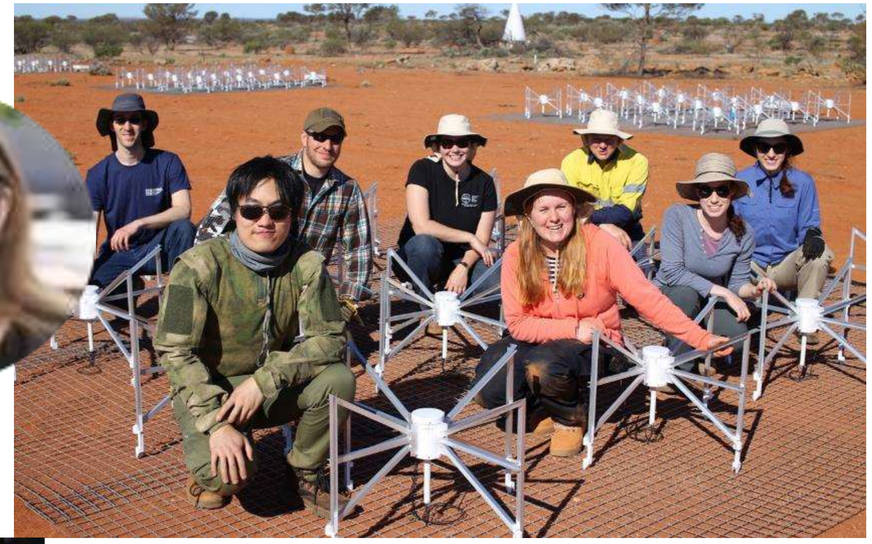
Image: SARAO

Image: The Jewellery Box, by Barbara Merritt

Image: Leiden Observatory/
Elinoor Veldman Photography

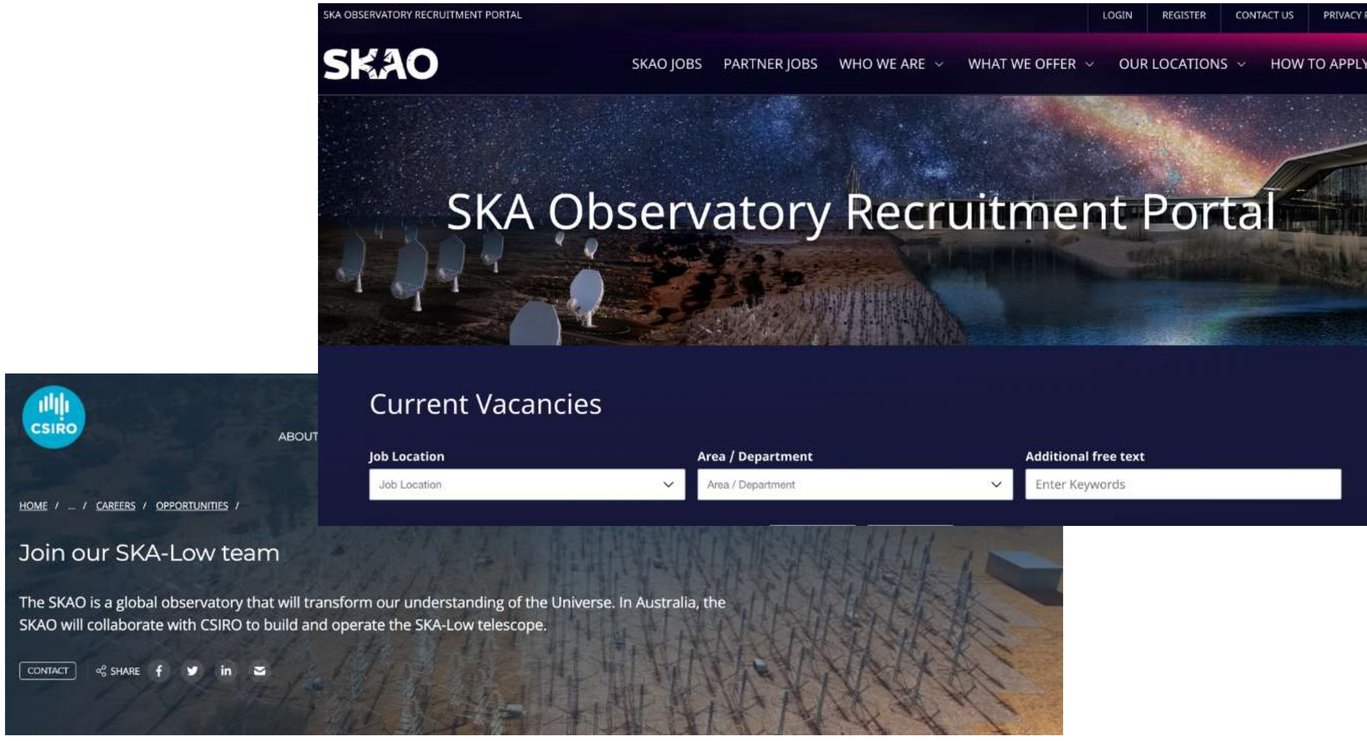
People

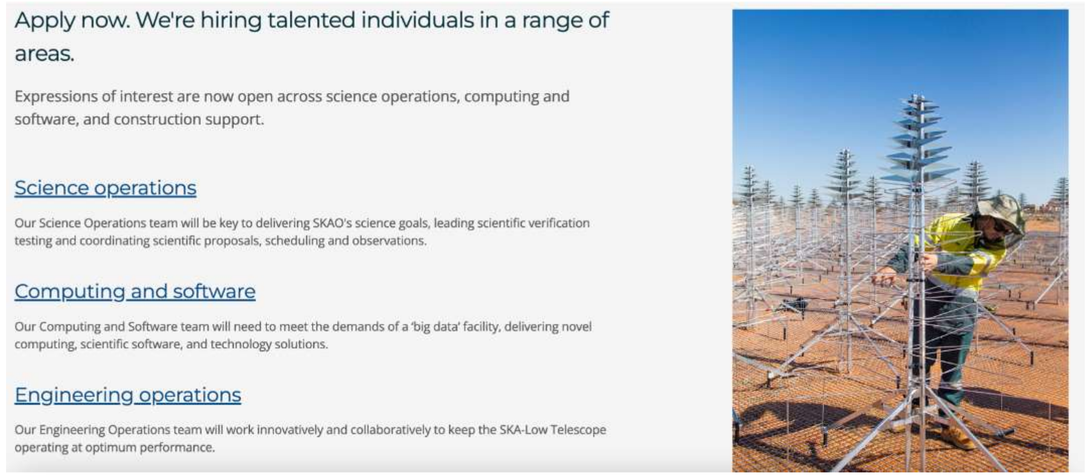
- MWA has helped build a low-frequency radio astronomy community worldwide - with a core in WA
- Growing capability critical to SKA-Low
- Substantial proportion of SKA-Low team worked on MWA
- Opportunities for co-supervised students and postdocs
- Continue to develop capability together through SKA constriction and operations

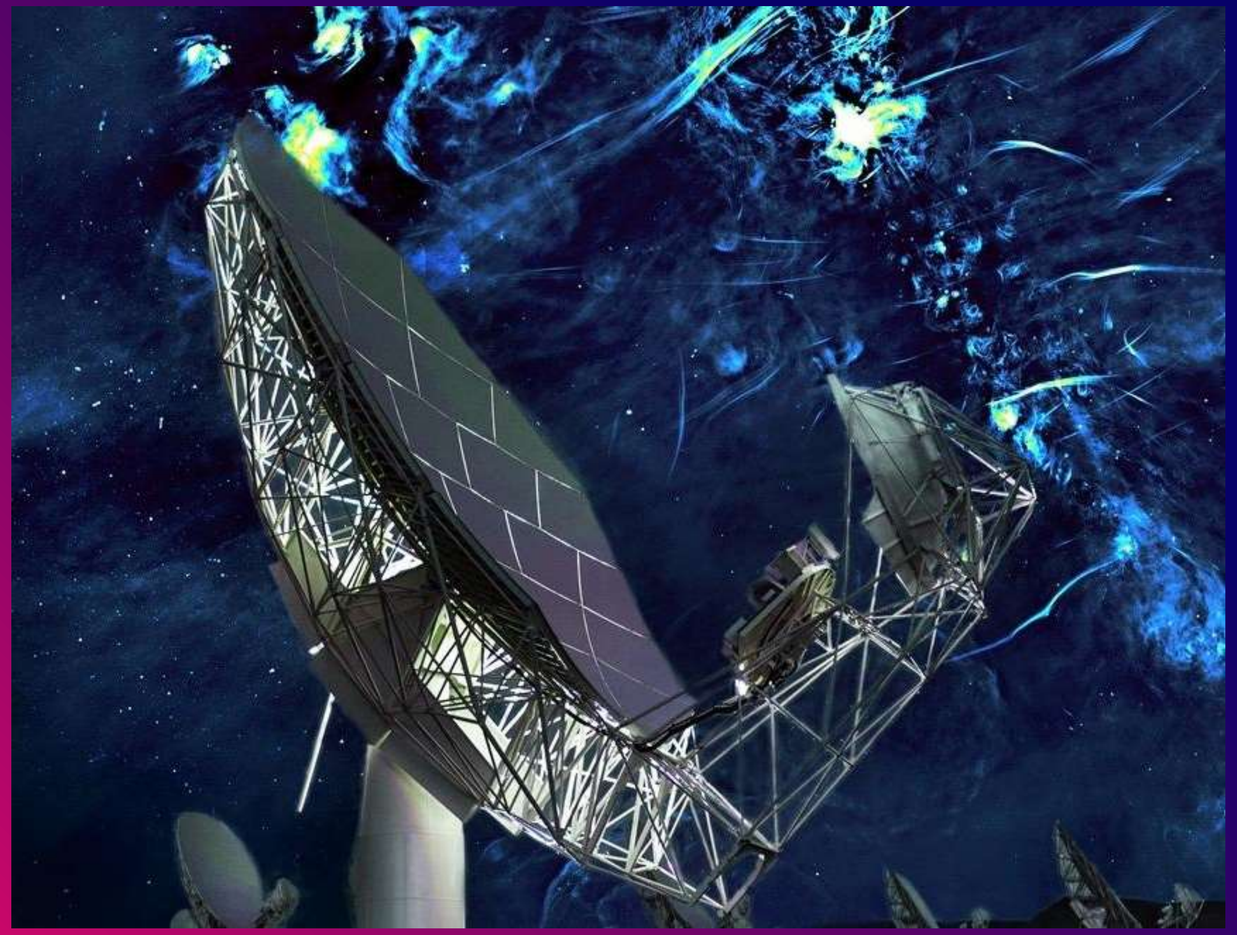


Recruitment

- 32 roles planned in next 12 months
- New web pages for SKAO and CSIRO recruitments
- Expression of interest process for CSIRO roles: identified 100+ candidates for roles in engineering ops, science ops and software & computing.







SKAO

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