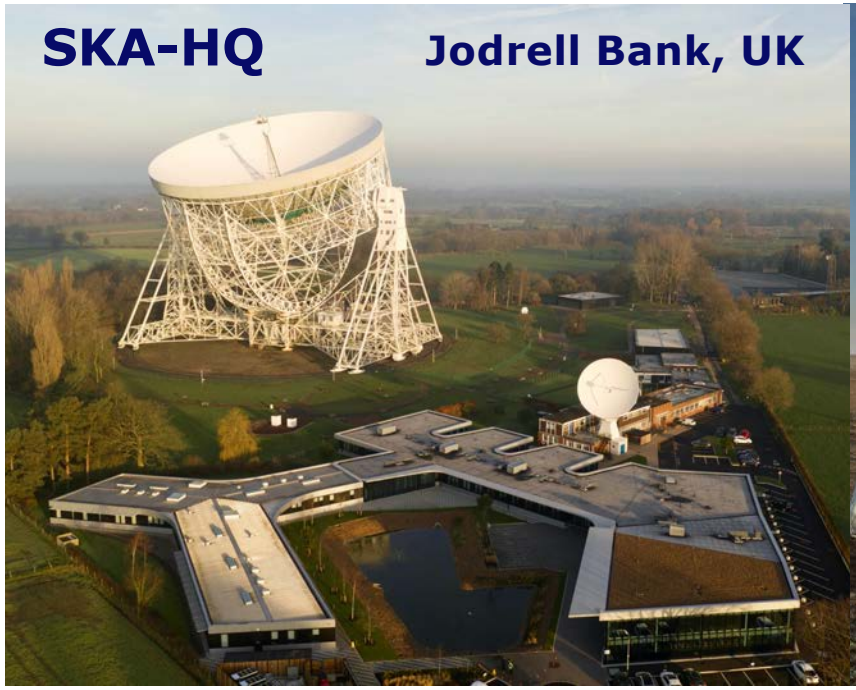
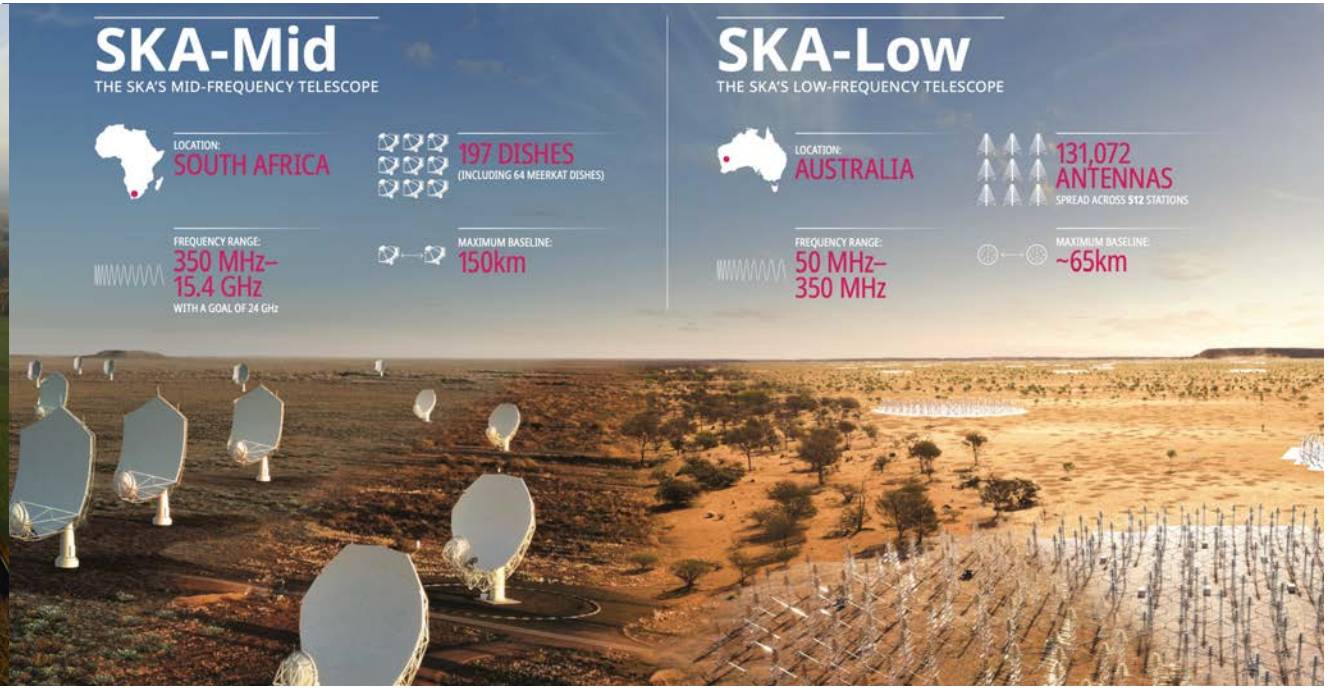
SKAO Update

Robert Braun, Director of Science

January 2023

One Observatory, Two Telescopes, Three Sites



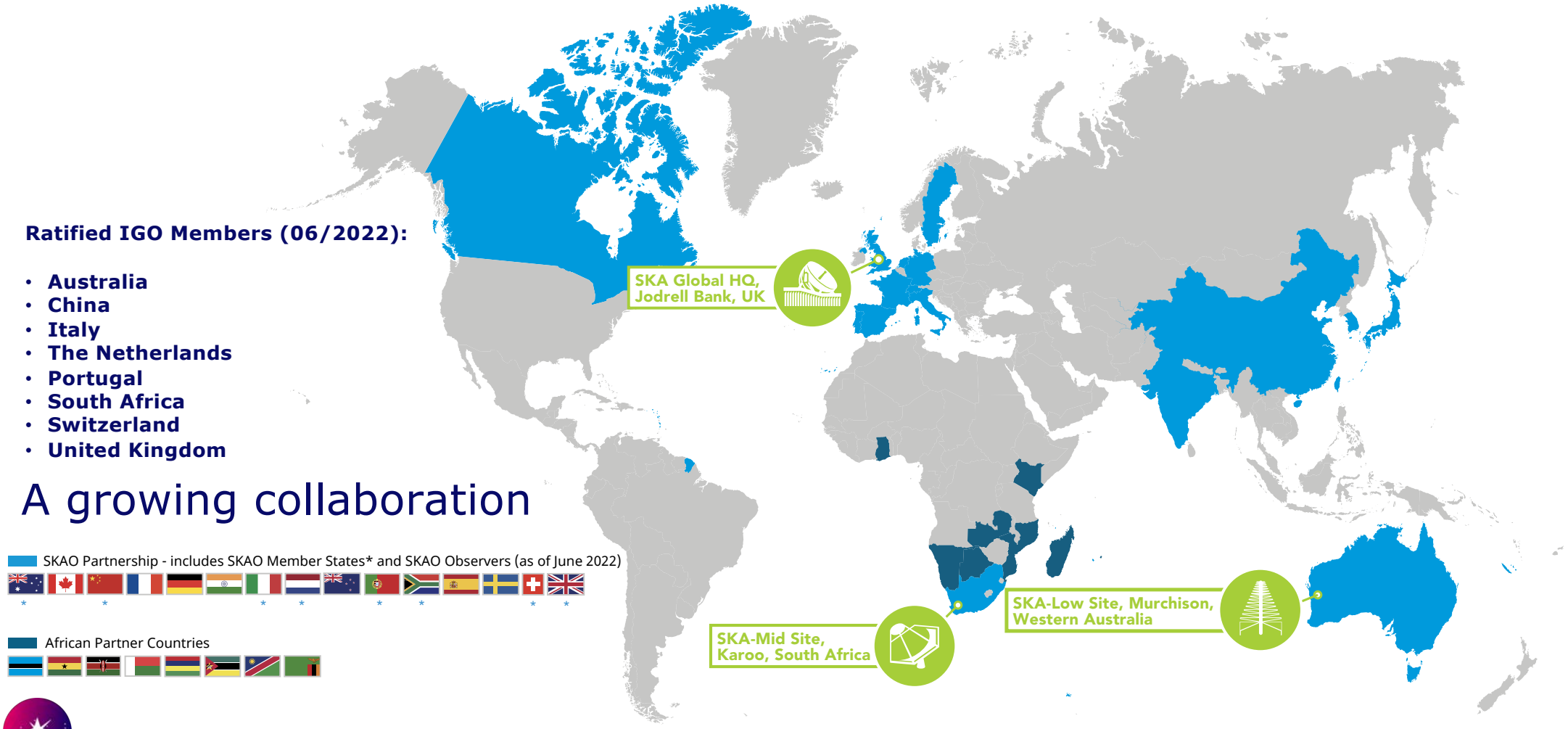


One Observatory, Two Telescopes, Three Sites

Ratified IGO Members (06/2022):

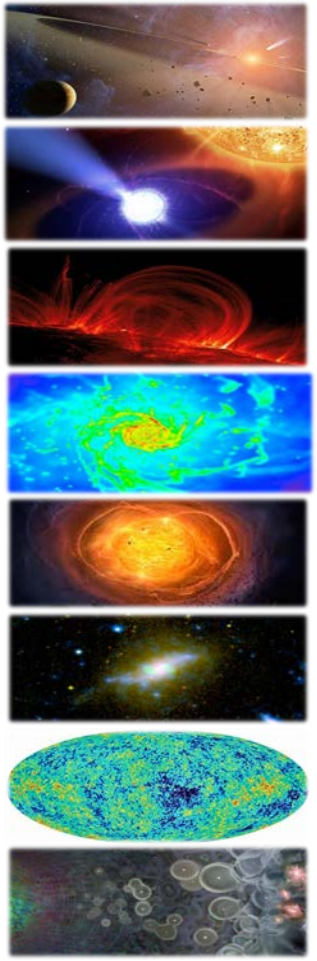
- **Australia**
- **China**
- **Italy**
- **The Netherlands**
- **Portugal**
- **South Africa**
- **Switzerland**
- **United Kingdom**

A growing collaboration



Some of the big SKA Science questions

- **The Cradle of Life & Astrobiology**
  - *How do planets form? Are we alone?*
- **Strong-field Tests of Gravity with Pulsars and Black Holes**
  - *Was Einstein right with General Relativity?*
- **The Origin and Evolution of Cosmic Magnetism**
  - *What is the role of magnetism in galaxy evolution and the structure of the cosmic web?*
- **Galaxy Evolution probed by Neutral Hydrogen**
  - *How do normal galaxies form and grow?*
- **The Transient Radio Sky**
  - *What are Fast Radio Bursts and how can we best utilise them? What haven't we discovered?*
- **Galaxy Evolution probed in the Radio Continuum**
  - *What is the star-formation history of normal galaxies?*
- **Cosmology & Dark Energy**
  - *What is dark matter? What is the large-scale structure of the Universe?*
- **Cosmic Dawn and the Epoch of Reionization**
  - *How and when did the first stars and galaxies form?*

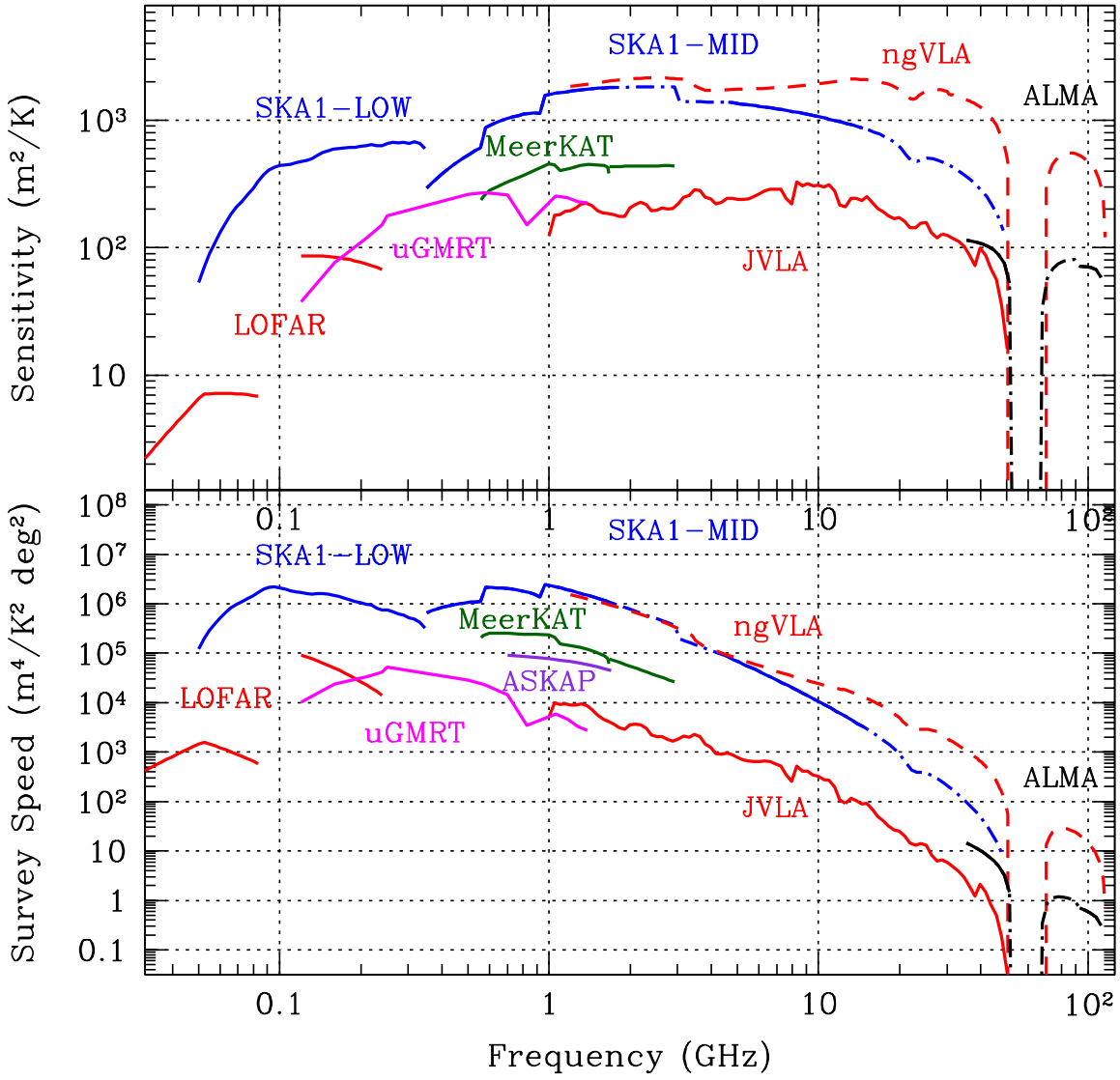


- **14 SKA Science Working Groups**
- **More than 1100 members**

+Gravitational Waves

SKA Sensitivity and Survey Speed

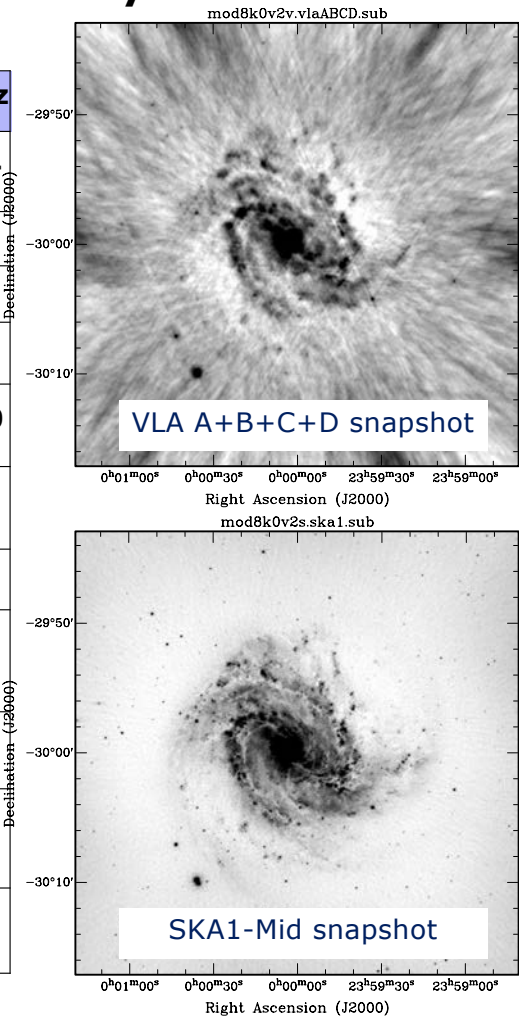
- Proto-type verified performance predictions now available at most frequencies
- Opportunity for seamless interface of SKA to ALMA capabilities
- uGMRT, MeerKAT and ASKAP already starting to open up new parameter space
- ngVLA would supplement high frequency capabilities



SKAO Capabilities

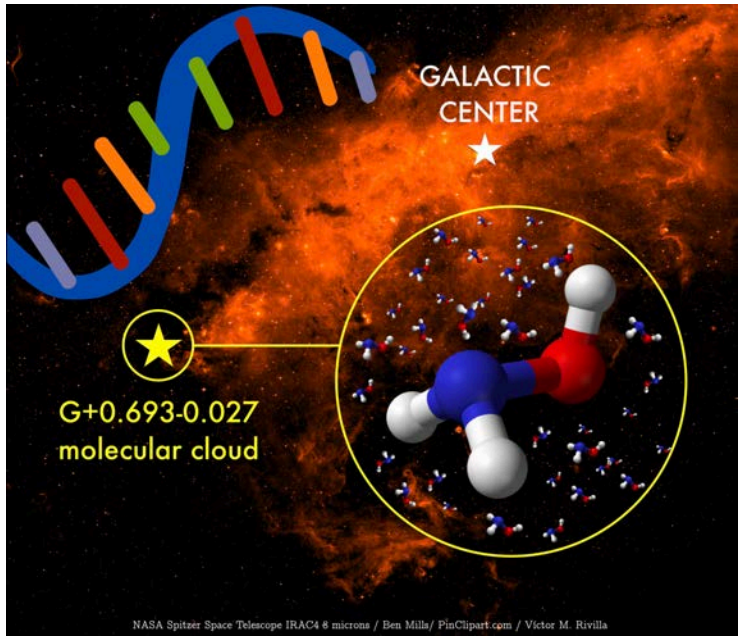
Nominal frequency	110 MHz	300 MHz	770 MHz	1.4 GHz	6.7 GHz	12.5 GHz
Range [GHz]	0.05-0.35	0.05-0.35	0.35-1.05	0.95-1.76	4.6-8.5	8.3-15.4
Telescope	Low	Low	Mid	Mid	Mid	Mid
FoV [arcmin]	327	120	109	60	12.5	6.7
Max. Resolution [arcsec]	11	4	9.5	0.3	0.06	0.03
Max. Bandwidth [MHz]	300	300	700	810	3900	2 x 2500
Cont. rms, 1hr [microJy/beam] [a]	26	14	4.4	2	1.3	1.2
Line rms, 1hr [microJy/beam] [b]	1850	800	300	140	90	85
Resolution range for Cont. & Line rms. [arcsec] [c]	12-600	6-300	1-145	0.6-78	0.13-17	0.07-9
Channel width [kHz]	5.4	5.4	13.4	13.4	80.6	80.6
Spectral zoom windows x narrowest bandwidth [MHz]	4 x 3.9	4 x 3.9	4 x 3.1	4 x 3.1	4 x 3.1	4 x 3.1
Finest zoom channel width [Hz]	226	226	210	210	210	210

Between 10-100 times image **fidelity** of current facilities



Pre-biotic Molecules in Star-forming Regions

- Building blocks for life on Earth may have arrived from space (panspermia hypothesis)
- Detection of key pre-biotic molecules (e.g. amino acids, complex sugars) in interstellar space is a "holy grail" of Cradle of Life studies

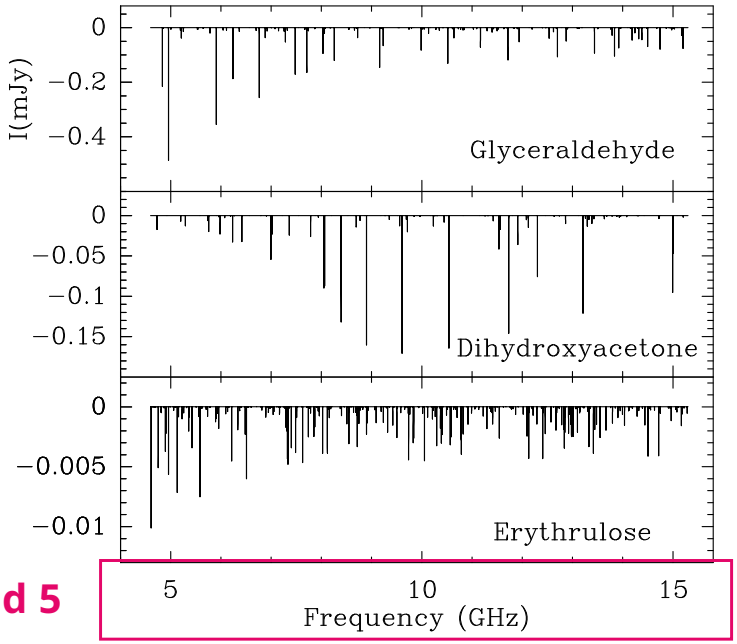


Detection of hydroxylamine (NH_2OH), key precursor to RNA
(IRAM 30-m; Rivilla et al. 2020ApJ...899L..28R)

$CHOCHOHCH_2OH$

$CH_2OHCOCH_2OH$

$C_4H_8O_4$



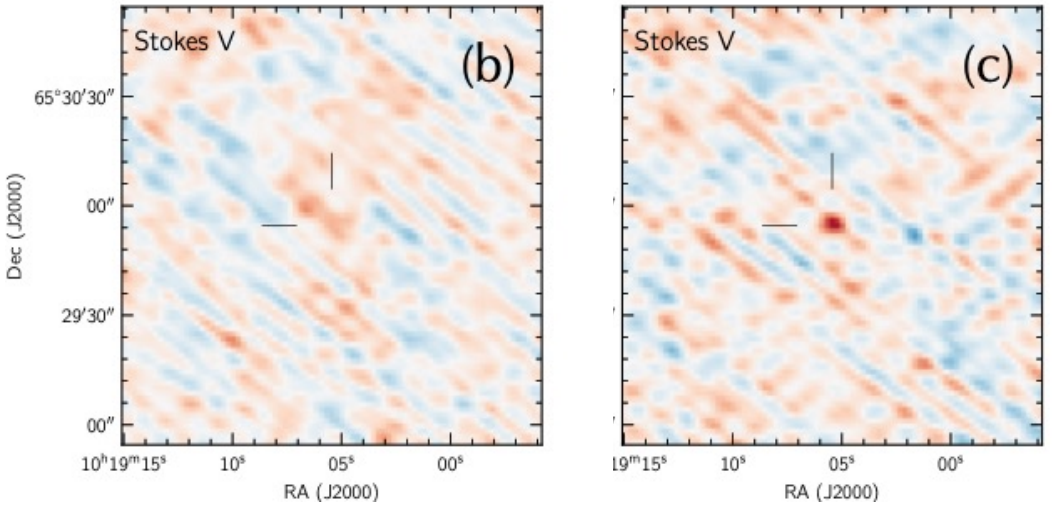
SKA Band 5

Predicted spectrum of key large sugars toward G+0693.
Detection of the brightest (ie. deepest) lines requires 10s of hours integration with SKA1
(Jimenez-Serra et al. 2022FrASS...943766J)

Characterisation of Exoplanets via Direct Detection

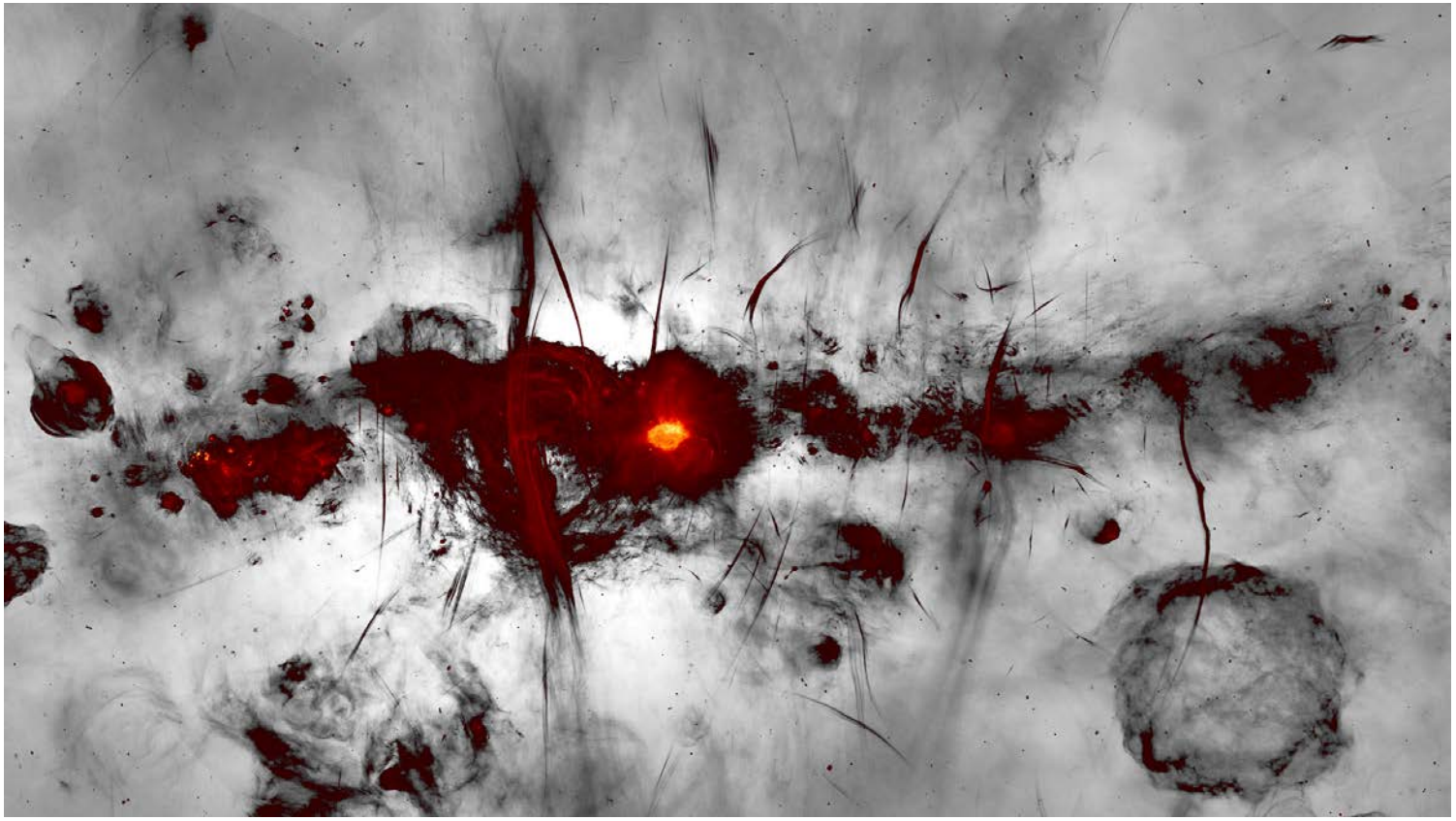
- Low frequency radio emissions from planetary aurora are very bright and highly polarized
- LOFAR detecting Brown Dwarfs – higher mass proxy (mass ~13-80 MJ) for exoplanets (<13 MJ)
- SKA-Low sensitivity will enable direct detection of exoplanets (host star not polarized so not detected)

Aurora on Jupiter (credit: NASA)



Circularly polarised images (Stokes V; 30s) of radio bursts from the Brown Dwarf WISEPA J101905.63+652954.2 observed with LOFAR at 144 MHz (LoTSS) (Vedantham, Callingham, Zarka et al. submitted)

Magnetically Driven Galactic and Cosmic Web Evolution



https://www.sarao.ac.za/media-releases/new-meerkat-radio-image-reveals-complex-heart-of-the-milky-way/

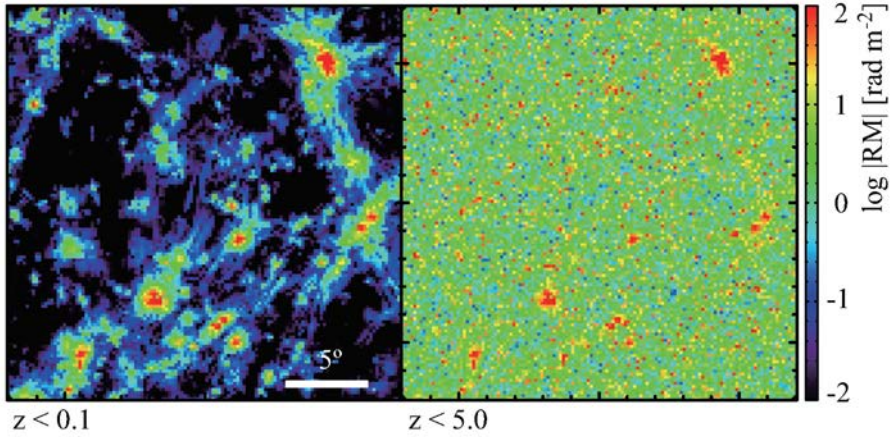
- Magnetic filaments in the central 500 pc of the Galaxy as imaged by MeerKAT

  Heywood et al. 2022ApJ...925..165H

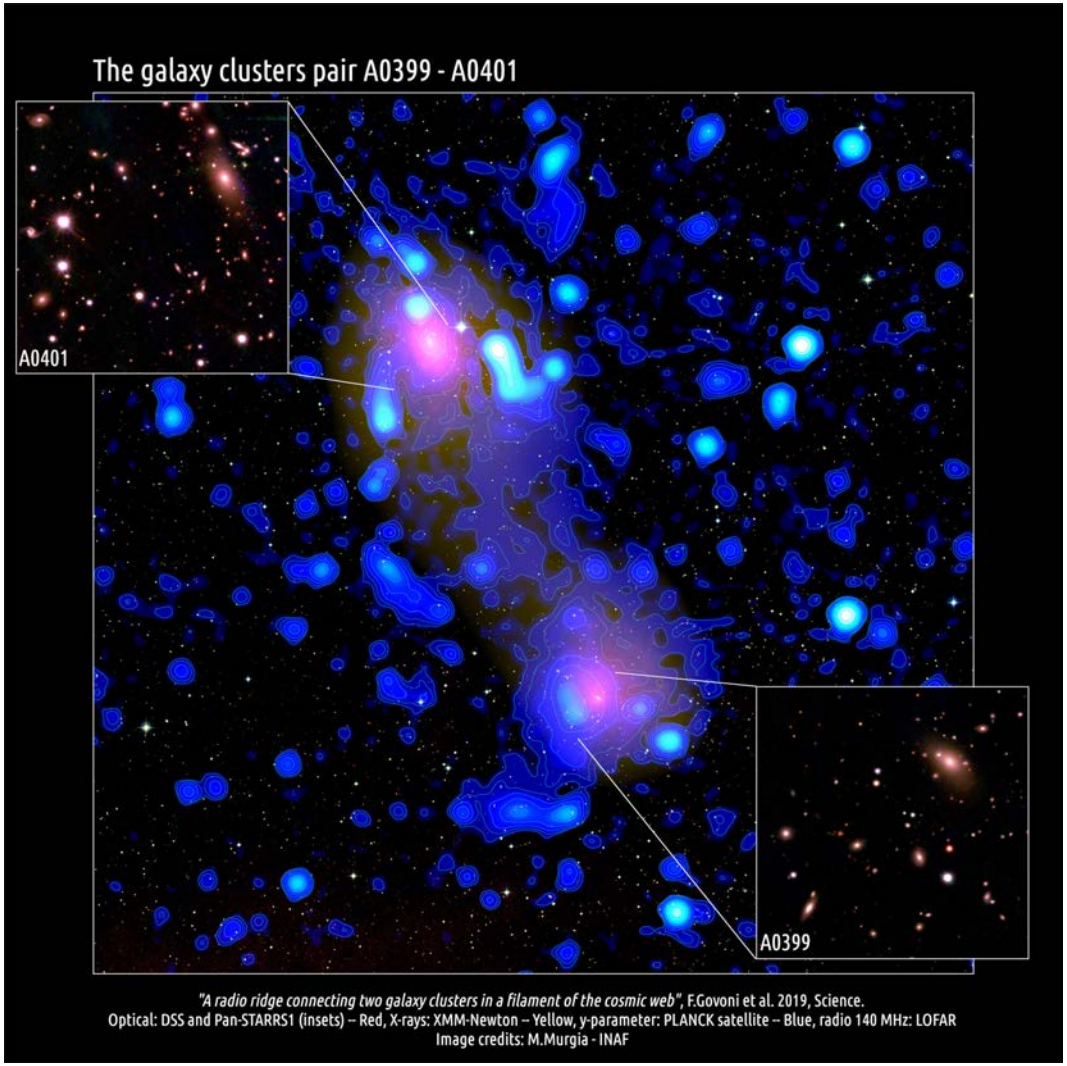
Magnetically Driven Galactic and Cosmic Web Evolution

- The magnetic cosmic web filament connecting the galaxy cluster pair A0399 – A0401 (at z=0.07) as imaged by LOFAR

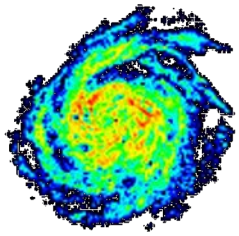
  Govoni et al. 2019Sci...364..981G

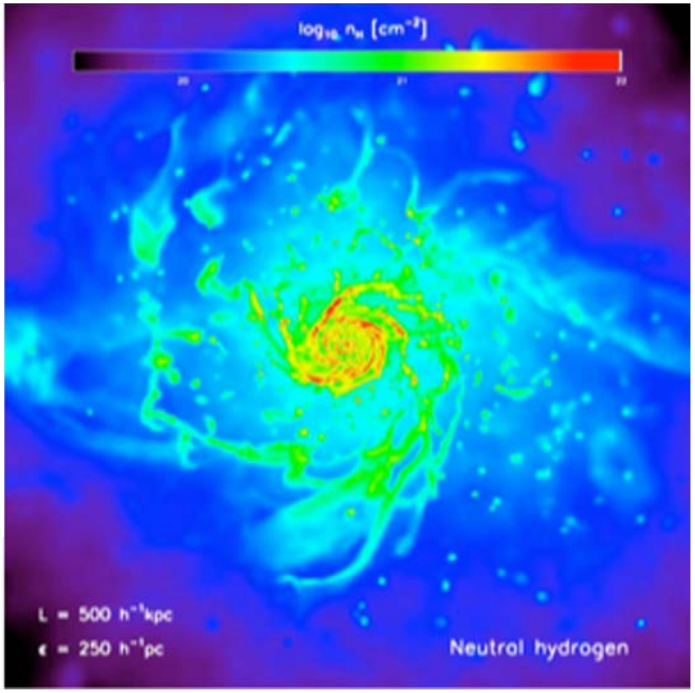


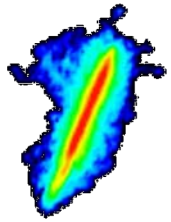
Magnetised cosmic web simulation
Akahori 2018Galax...6..118A

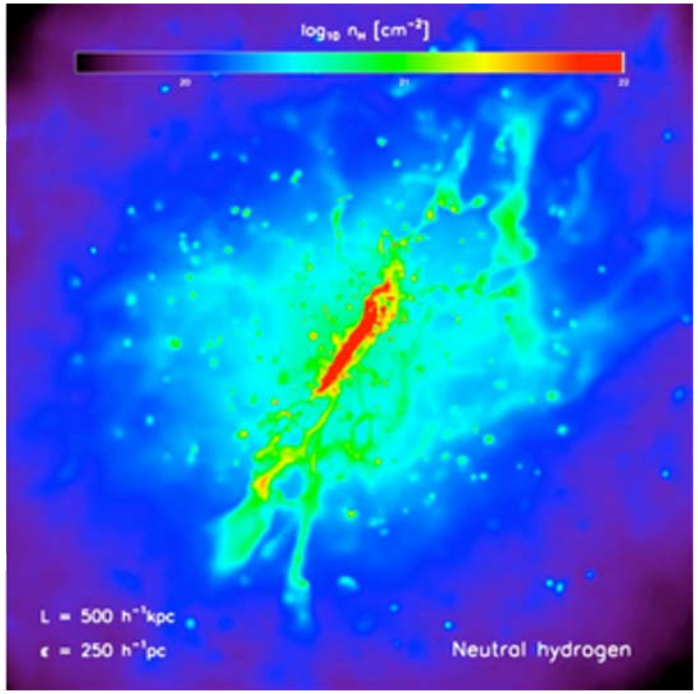


Probing Galaxy Assembly and Evolution with Neutral Hydrogen



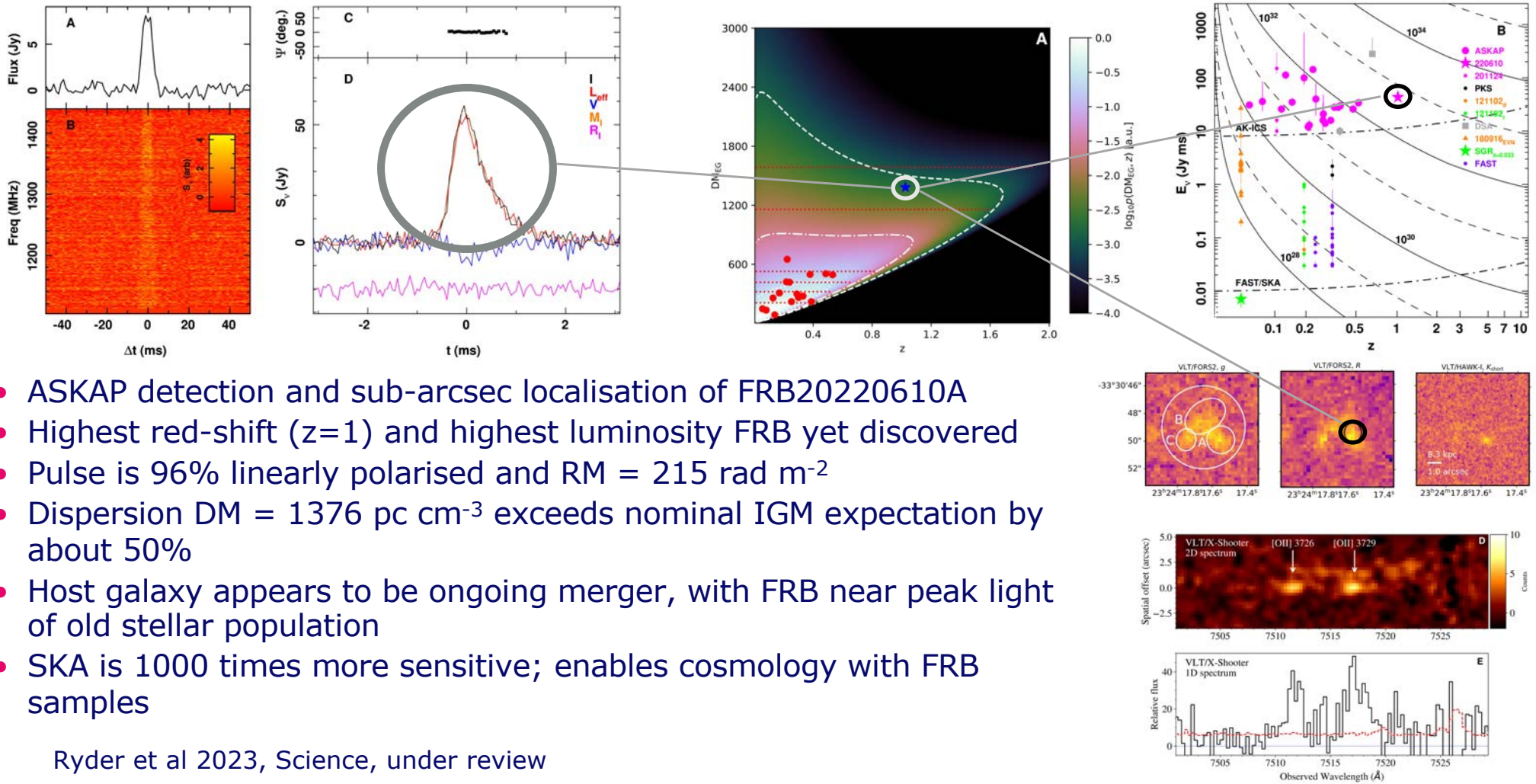






- Contrast of current detection limits (left hand observations, Oosterloo et al.) with predicted galaxy environments (right hand simulations, Schaye et al.) accessible to the SKA

Using Fast Radio Bursts as Cosmological Probes



- ASKAP detection and sub-arcsec localisation of FRB20220610A
- Highest red-shift (z=1) and highest luminosity FRB yet discovered
- Pulse is 96% linearly polarised and RM = 215 rad m^{-2}
- Dispersion DM = 1376 pc cm^{-3} exceeds nominal IGM expectation by about 50%
- Host galaxy appears to be ongoing merger, with FRB near peak light of old stellar population
- SKA is 1000 times more sensitive; enables cosmology with FRB samples

Ryder et al 2023, Science, under review

Construction timeline (Design Baseline):

- Now at T_0 + 18 months
- Procurement well underway
- 46 contracts awarded, with aggregate committed value of ~€470M, (per Dec 2022)
- 44 contracts still to award, most in 2023
- Still aligned (+/- months) with procurement schedule

	SKA-Low	SKA-Mid
Start of construction (T0)	1ST JULY **2021**	1ST JULY **2021**
Earliest start of major contracts (C0)	AUGUST **2021**	AUGUST **2021**
Array Assembly 0.5 finish (AA0.5) SKA-Low = 6-station array SKA-Mid = 4-dish array	FEBRUARY **2024**	MARCH **2024**
Array Assembly 1 finish (AA1) SKA-Low = 18-station array SKA-Mid = 8-dish array	FEBRUARY **2025**	FEBRUARY **2025**
Array Assembly 2 finish (AA2) SKA-Low = 64-station array SKA-Mid = 64-dish array, baselines mostly <20km	FEBRUARY **2026**	DECEMBER **2025**
Array Assembly 3 finish (AA3) SKA-Low = 256-station array, including long baselines SKA-Mid = 133-dish array, including long baselines	JANUARY **2027**	SEPTEMBER **2026**
Array Assembly 4 finish (AA4) SKA-Low = full Low array SKA-Mid = full Mid array, including MeerKAT dishes	NOVEMBER **2027**	JUNE **2027**
Operations Readiness Review (ORR)	JANUARY **2028**	DECEMBER **2027**
End of construction	JULY **2029**	JULY **2029**

Construction Strategy

- Target: the SKA Baseline Design (197 Mid dishes; 512 Low stations: AA4)
- Not all funding yet secured, therefore follow Staged Delivery Plan (AA*)
- First Milestone: Develop the earliest possible working demonstration of the architecture and supply chain (AA0.5).
- Then maintain a continuously working and expanding facility until achieve the baseline design.

Milestone Event	SKA-Mid (date)	SKA-Low (date)
AA0.5	2024 Dec	2024 Aug
AA1	2025 Nov	2025 Oct
AA2	2026 Oct	2026 Sep
AA*	2027 Aug	2028 Jan
Operations Readiness Review	2027 Nov	2028 Apr
End of Construction	2028 Jul	2028 Jul

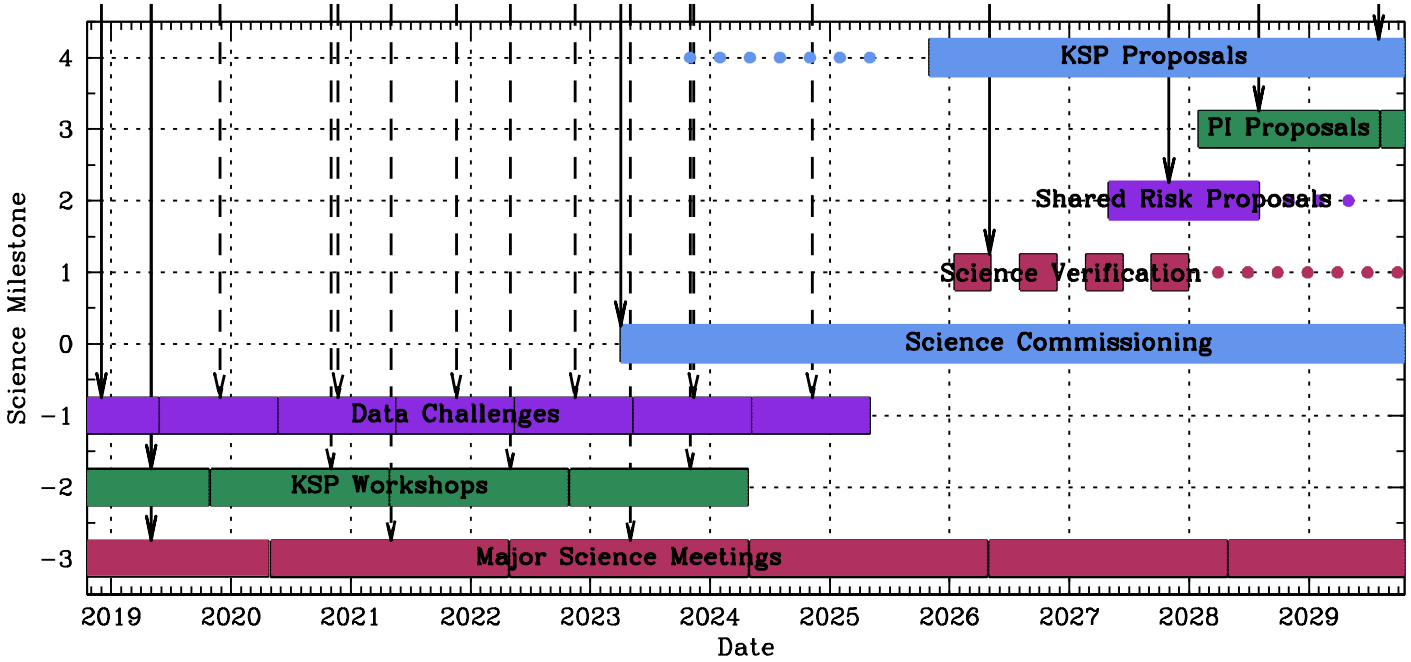
Science Timeline

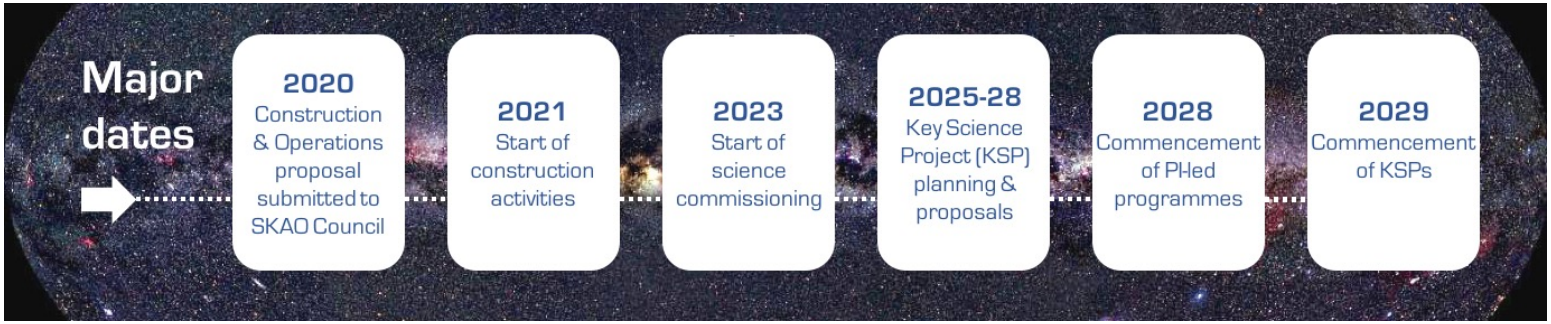
- Early Science Verification
  - Worthwhile from AA2, when capabilities become competitive
  - Interspersed with science commissioning
- Preparation for Cycle 0: first open call, shared risk
  - Observing Modes Review to decide what to offer in Cycle 0
  - Dedicated block of SV observations scheduled to inform this review (end 2026)
- Handover to Operations
  - Follows successful Operations Readiness Review (ORR).
- Cycle 1 Proposal Round

Milestone Event	SKA-Mid (date)	SKA-Low (date)
AA0.5	**2024 Dec**	**2024 Aug**
AA1	**2025 Nov**	**2025 Oct**
AA2	**2026 Oct**	**2026 Sep**
AA*	**2027 Aug**	**2028 Jan**
Operations Readiness Review	**2027 Nov**	**2028 Apr**
End of Construction	**2028 Jul**	**2028 Jul**

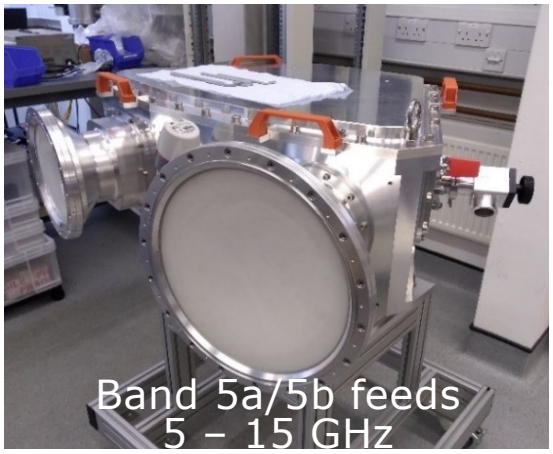
The SKA Science Timeline (*approximate!*)

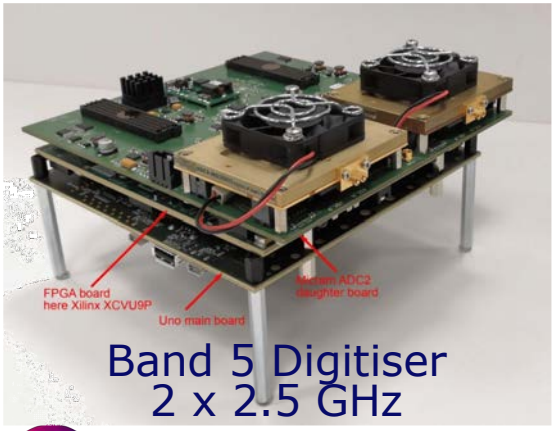
- Dates will depend on when funding for full Design Baseline is secured





Recent Prototype and Construction Progress


Band 5a/5b feeds
5 – 15 GHz



Band 5 Digitiser
2 x 2.5 GHz

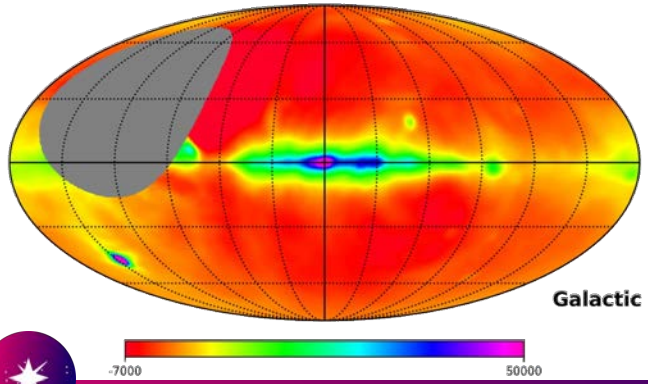
Improved dish stiffness
and pointing


First SKA dish foundations

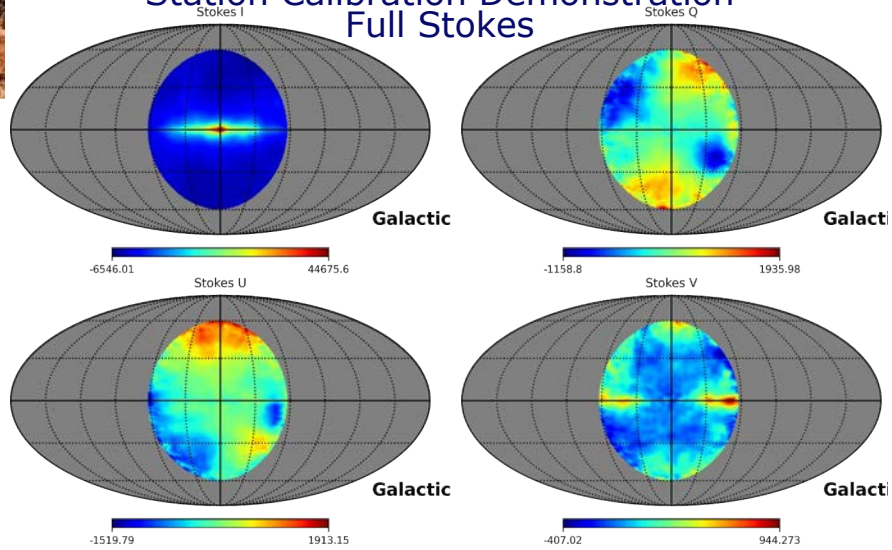
Recent Prototype and Construction Progress

Model for on-site storage and antenna assembly

Station Calibration Demonstration
Stokes I



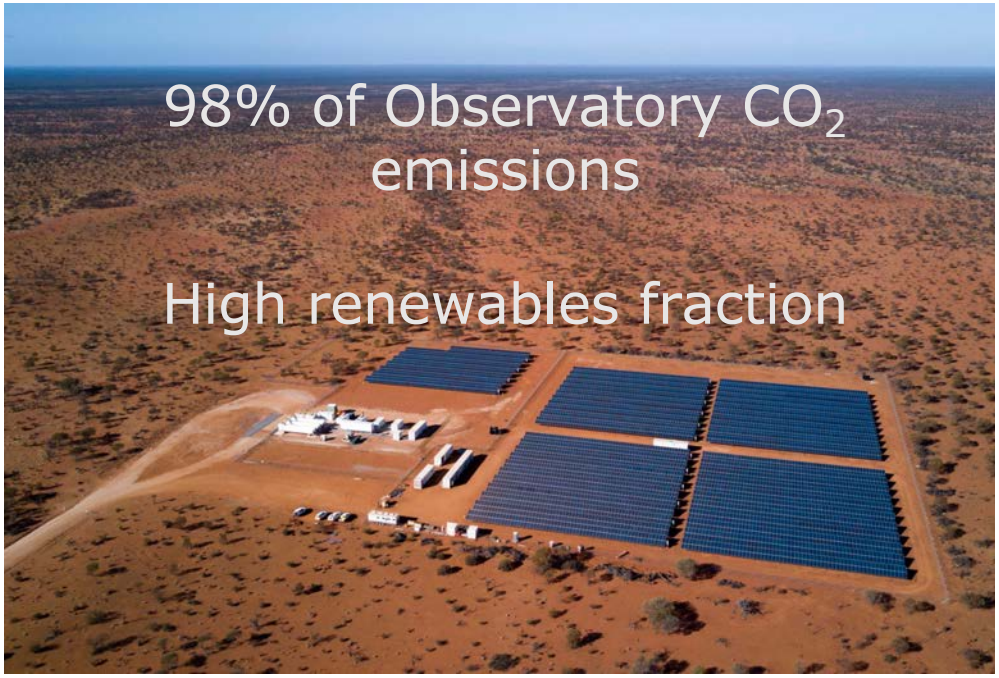
Station Calibration Demonstration
Full Stokes



SKA Power

- SKA Energy requirements are significant
  - ~13 MW total continuously (24/7/365 @ >95% availability)
- Contracts worth €100's of millions

- SKA-Low Murchison
  - 9 Remote stations ~25kW ea
  - Central Power Station (CPS) ~3.3MW
- SKA-Low Perth
  - SPC Requirements (Pawsey) ~3MW
- SKA-Mid Karoo
  - 21 Remote stations 8 – 12 kW ea
  - New 132kV transmission line ~3.4MW
- SKA-Mid Cape Town
  - SPC Requirements + Ref Design (SARAO/iThemba) ~3.5MW
  - On-site PV (2.2MW) + Battery + Backup Generators



Establishing SKAO in Australia and South Africa

- Staff in Australia: currently ~30, eventually ~140.
- Staff in South Africa: currently ~30, eventually ~140
- [Staff in UK: currently ~150, eventually ~170]

- Facilities in host countries:
  - Science Operations Centres (Perth, Cape Town)
  - Engineering Operations Centre (Geraldton, Klerefontein)
  - Australia only: Boolardy Accommodation Facility

Summary

- SKAO is now an operational inter-governmental organisation, only the second in astronomy after ESO
- SKAO's mission is to build and operate the two largest and best radio telescopes on earth
- The scientific capability of SKAO will cover a huge range from the dawn of the Universe to the origins of life
- SKAO Council approved the start of construction: T_0 was 1st July 2021; procurement is now well underway

Thank you

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