SKA-Mid Band 6
Science Motivation & Performance Update

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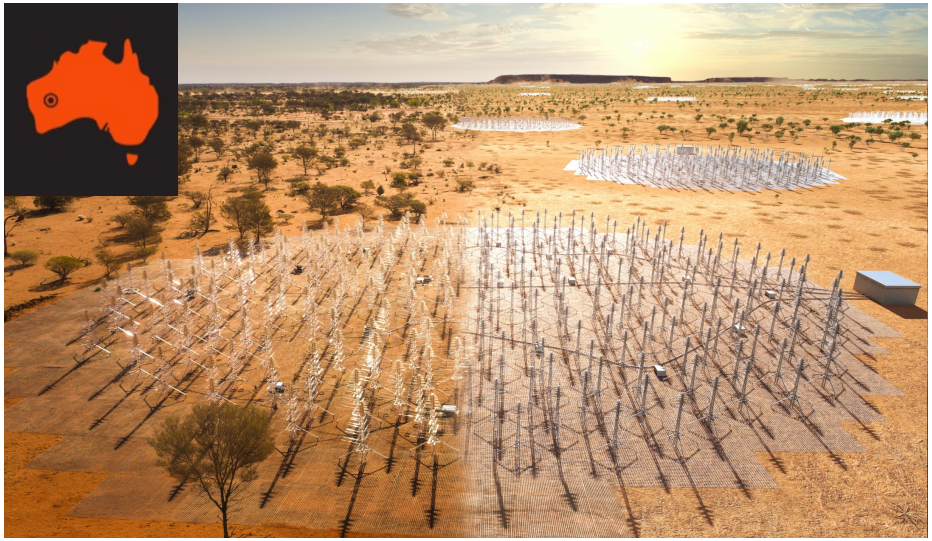
Swiss SKA Days – 7 September 2023

The Telescopes

SKA-Low

131,072 log-periodic antennas
(512 stations each with 256 dipoles)
50 – 350 MHz
74 km baselines (9.5” @ 110 MHz)
Murchison, **Western Australia**



SKA-Mid

197 steerable 15-m class dishes
(133 x SKA + 64 x MeerKAT dishes)
0.35 – 15 GHz (goal: up to 30 GHz)
150 km baselines (0.22” @1.7 GHz; 34 mas @15 GHz)
Karoo, **South Africa**

Aspirational future expansion: > 500,000 dipoles across Australia; > 2000 dishes across Africa

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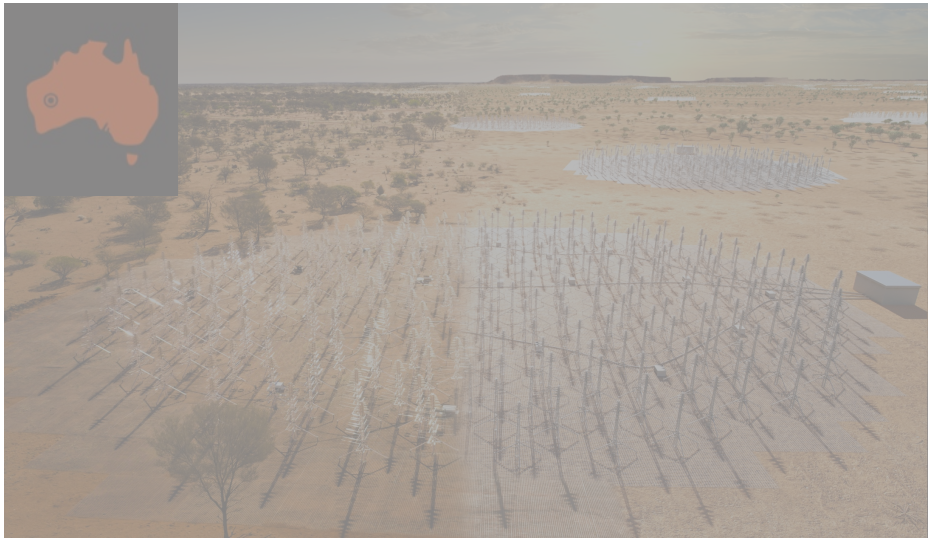

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First and Future (?) Generation Feeds/Receivers

Band	Frequency Range	Bandwidth
Mid Band 1	**0.35 – 1.05 GHz**	**700 MHz**
Mid Band 2	**0.95 – 1.76 GHz**	**810 MHz**
Mid Band 3	1.65 – 3.05 GHz	1.4 GHz
Mid Band 4	2.80 – 5.18 GHz	2.4 GHz
Mid Band 5a	**4.6 – 8.5 GHz**	**3.9 GHz**
Mid Band 5b	**8.3 – 15.4 GHz**	**2 x 2.5 GHz**

65k channels maximum across any band, zoom windows possible with 16k channels

Initial Deployment

Original Plan:
Bands 1, 2, 3

Science Prioritisation:
Bands 2, 5, 1

Future upgrades? (Observatory Development Programme)		
Mid Band "A"	1.6 – 5.2 GHz	2 x 2 GHz
Mid Band "B"	4.6 – 24 GHz	(2 x 2.5 GHz)
Mid Band 6	15 – (28) GHz	(2 x 2.5 GHz)

Bands 3+4

Bands 5+6

Band 7 27-50 GHz?

SKA Anticipated Performance

SKA-Mid aperture efficiency requirements

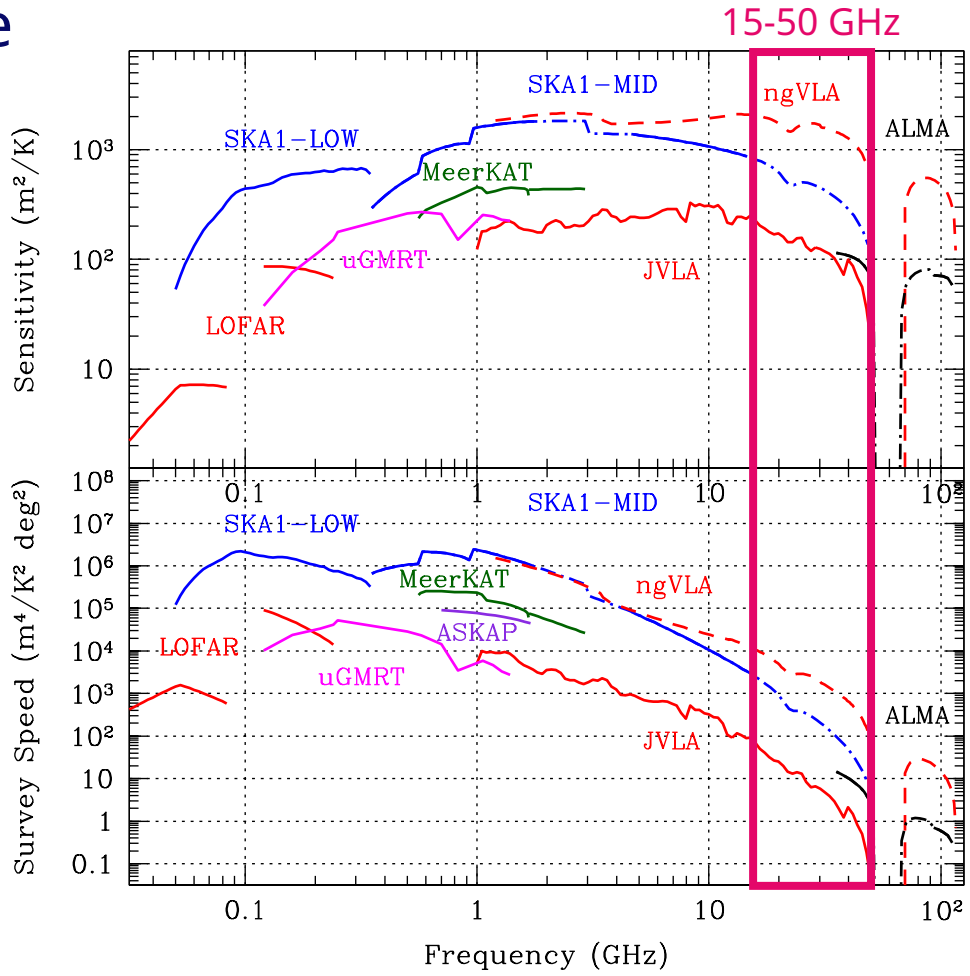
- 60% @ 350 MHz
- 65% @ 400 MHz
- 78% from 600 to 8000 MHz
- 70% from 8 to 15 GHz (B5b)
- **65% from 15 to 20 GHz**

NB: lower limits linearly interpolated (B5 estimate is 0.83 at Zenith)

Site characteristics TBD (no in-situ yet)

- pwv (particularly 22 GHz water line)
- phase stability (tropospheric)
- pwv = 5mm assumed (winter)

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



SKA-Mid Band 6 Science Case

Aperture Efficiency requirement + Anticipated Performance

➡ observations above > 15 GHz may be feasible

Science motivation?

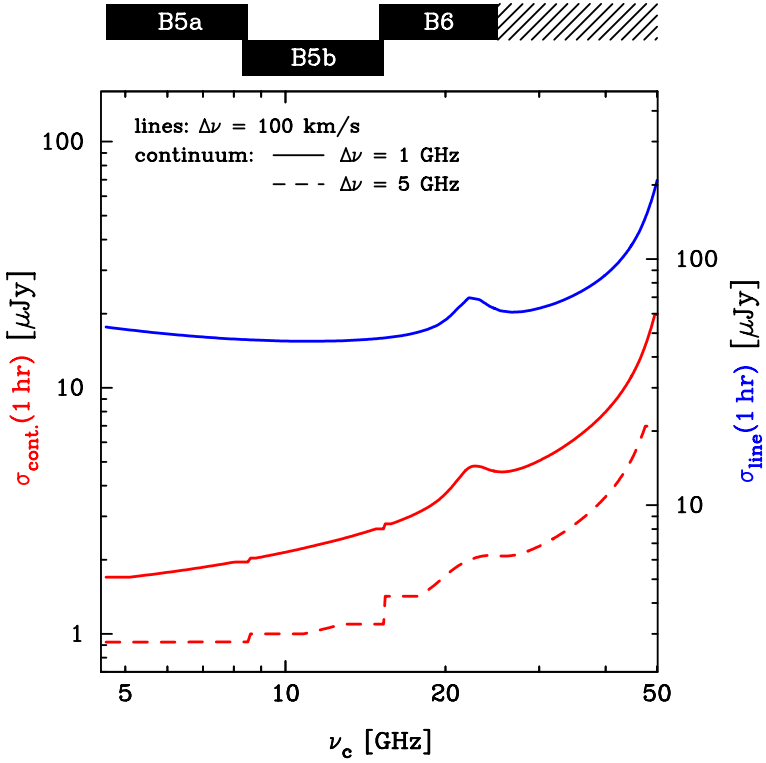
- SKA Science up to 24 GHz (2015; Andrew Walsh)
- B6 focus session at 2019 SKA Science meeting in UK
  - significant community interest and input
- 2020 SKA Memo – many chapters and contributors

Memo 20-01

SKA1 Beyond 15GHz:
The Science case for Band 6

J. Conway, R.Beswick, T.Bourke, M.Coriat, C.Ferrari,
I.Jimenez-Serra, S.Muller, M.Sargent

February 2020



Many thanks to Jeff Wagg for shepherding this through
Particular thanks to Rob Beswick, John Conway, & Mark Sargent

https://www.skao.int/sites/default/files/documents/ScienceCase_band6_Feb2020_0.pdf

SKA-Mid Band 6 Science Cases

Solar System
(Trans-Neptune Objects; solar flares)

Star Formation
(disks; exoplanets; astrochemistry; SETI;
star-forming gas; magnetic fields)

Stellar Evolution
(AME; Galactic Centre; evolved and old stars)

Nearby Galaxies
(dense gas; masers; AGN; star formation)

Cosmology
(AGN/SF at high-z; molecules at high-z; water masers; SZ effect)

Transient Phenomena
(FRBs; SNe; Magnetars; AGN; jets; TDE/GRB)

SKA-Mid Band 6 High Priority Science Drivers

Solar System
(Trans-Neptune Objects; solar flares)

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Top 5 science drivers?

(should enable as many of the science cases as possible)

?

- thermal continuum emission
- (redshifted) spectral lines
- GC pulsars
- higher resolution imaging/astrometry

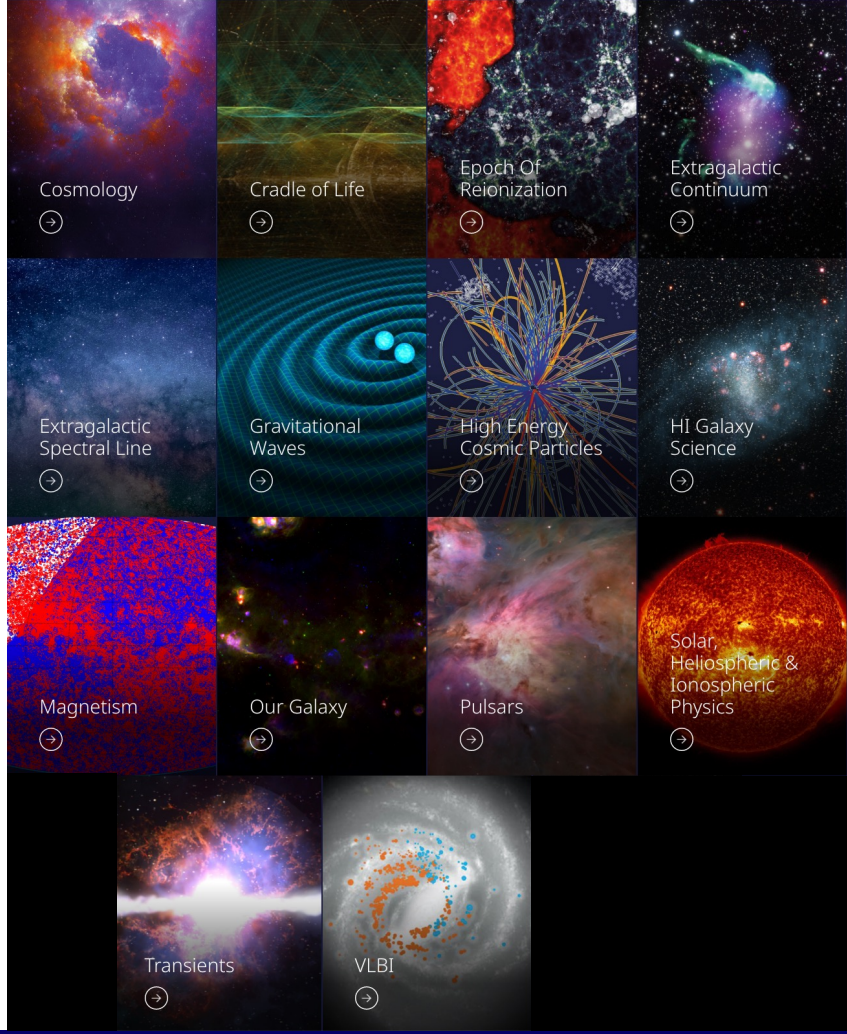
SKA Science Working Groups (SWGs)

SWGs …

- provide a forum for discussion on possible SKA science projects, primarily the Key Science Projects (KSPs)
- will facilitate KSP collaborations
- are the best way to receive up-to-date information regarding the road to science and operations

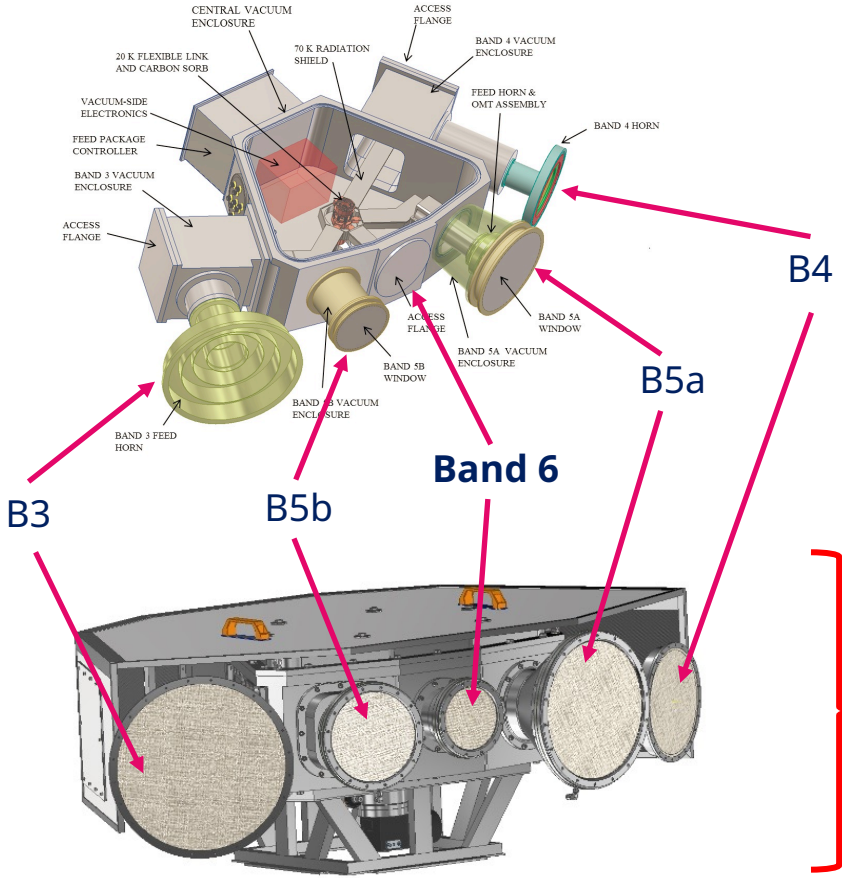
Membership is open to any actively publishing researcher (see Terms of Reference), regardless of SKA-member status.

If you wish to join … contact the relevant SWG chair or SKAO Project Scientist



SKA-Mid Band 345 Receiver Cryostat

Afternoon presentation by Angela Taylor



Design by Oxford U. and JLRAT/CETC54

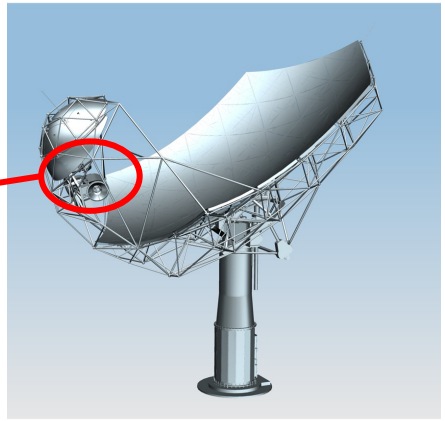
Will initially be populated by

- B5a (4.6-8.5 GHz)
- B5b (8.3-15.4 GHz)

as first-generation bands

Allows for expansion:

- Band 3
- Band 4
- Band 6?



Outline Schedule – Staged Delivery (Target: Design Baseline)

- **Goal – SKA-Mid with 197 dishes & SKA-Low with 512 stations**
- Not all funding yet secured, therefore following Staged Delivery Plan (AA*)
- Roll out the array in stages (Array Assemblies – AAs)
- **AA0.5** – test array for interferometry, using prototype dishes and (in some cases) receivers; discover system level issues and develop procedures **(pointing, tracking, holography)**
- **AA2 – Start science verification**: observations to ensure the system meets the needs of the science users (e.g., test observing modes, verify science requirements)

First data release to community after AA2 in 2026/27 time frame
(similar to ALMA SV model)

Milestone Event (earliest)		SKA-Mid (date)	SKA-Low (date)
AA0.5	**4 dishes** **6 stations**	**2025 Q1**	**2024 Q4**
AA1	8 dishes 18 stations	2026 Q1	2025 Q4
AA2	64 dishes 64 stations	2027 Q1	2026 Q4
AA*	144 dishes 307 stations	2027 Q4	2028 Q1
Operations Readiness Review		2028 Q1	2028 Q2
End of Staged Delivery Programme		2028 Q3	2028 Q3
Full SKA	197 dishes 512 stations	TBD	TBD

SKA Monthly Construction Report July 2023 update

SKA-Mid Progress Update

- New prototype SKA dishes are currently being produced for AA0.5 (CETC-54)
- SKA-compliant dishes are being produced for MeerKAT+ (CETC-54)

- Prototype dishes will initially be tested at CETC-54 (very bad RFI environment)
  - e.g., photogrammetry as part of structure testing
- and on site by CETC-54 & SKA AIV teams (Dish Verification System)
  - photogrammetry, holography (with uncooled Ku system paired with an MK or SKA dish), pointing/tracking

- AA 0.5 – a 4 dish array as a Minimal Viable Product
  - aim to have all fitted with prototype B5 feeds paired with limited bandwidth analogue downconverters (800 MHz, 16k channels per 200 MHz?)
  - interferometric pointing and imaging (bright objects of known flux/structure, ”empty” fields)

Meeting the Pointing and Tracking requirements will be challenging
Possible high-frequency limitation

SKA Observatory Development Programme (SODP)

Goal is to enhance the SKA science output (not expanding to SKA2)

- enable new science (adapting to changing science priorities)
- improve the science output
- reduce operational costs
- restore lost (or deferred) capability

Requires science prioritisation and evaluation of TRL (and trade-offs against cost and disruption to the science program

- SKAO will develop science and technology road-maps, in consultation with the community, with review by the Science and Engineering Advisory Committee (SEAC)

Indicative Example: What is the relative science return (hence prioritisation) of deploying any of:

- Band 3
- Band 4
- Band 6 (15+ GHz)
- Wideband to cover Bands 3+4
- Wideband to cover Bands 5a+5b (the original Band 5) or higher (8 – 24 GHz?)

SODP – Indicative Upgrades & Improvements

- Improved frequency coverage
  - Additional receiver bands (Mid)
  - increased instantaneous RF bandwidth
- Higher sensitivity
  - More dishes/stations
  - Improved receivers/LNAs (lower noise)
- Digitisation and correlator
  - More bandwidth/channels/bits
  - Integrated receivers
  - RFI resilience
- Spatial multiplexing
  - Phased-array feeds (dishes)
  - More beams (aperture arrays)
- Higher spatial resolution
  - longer baselines (Mid/Low)
  - higher frequencies (Mid)

- Upgraded computer hardware and software
  - Algorithms: RFI rejection, direction-dependent calibration, …
  - Storage
  - Networks
  - Data processing hardware (over and above refresh)
  - improved power consumption, cooling
  - Major OMC/SDHP upgrades
- Better access to data
- Environmental monitoring
- Increased reliability
  - Power
  - Remote diagnostics
  - Alarm systems
  - More effective predictive maintenance

SODP will be very focused on delivery of enhancements for SKA. It will not be a blue-sky R&D program

SODP – Status and Plan

More details:
see the SKAO Establishment & Delivery Plan (OEDP)
https://www.skao.int/en/resources/402/key-documents

1. Science Roadmap
   - Prioritisation of new science enabled by SODP
   - developed by external advisory group, chaired by SKAO
2. Technology Roadmap
   - Survey of new technologies relevant to SKA, with light TRL assessment
   - developed by external advisory group, chaired by SKAO
3. Development Plan
   - Evolving plan informed by roadmaps
   - Balance restoration of capabilities against new capabilities
   - externa advisory group, chaired by SKAO
   - approved by SEAC and Council, publicly viewable.

Enabled by (open calls):

Studies: small-scale feasibility studies, 2-3 year cycle, co-funding encouraged (SKAO + national/EU/etc)

Projects: delivery of major capability, 1-5 year cycle, up to €20M, cp-funding required

Timeline: Roadmaps and initial studies likely to start during construction phase (this decade).
Currently on-hold, pending SKAO Council go-ahead.

Budget: Might start around €4M per year initially, ramping up to €20M in steady state

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It will not be a blue-sky R&D program

Final Remarks

https://www.skao.int/en/science-users

A large range of key science would be enabled by Band 6

SKA dishes likely to perform well at 15 GHz < ν < 30 GHz

(Pointing and Tracking may be limiting factors, particularly > 30 GHz)

Construction of the SKA telescopes has begun!

Real performance numbers from late 2024 into 2025

GET INVOLVED – Join one or more of the Science Working Groups!

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