SKA SWG Update

SWG Chairs Meeting – 20 February 2024

Tyler Bourke
SKA Project Scientist
SKAO Senior Scientist
START RECORDING

Agenda

• Progress toward science
• SWG Chair rotation
• SKAO Membership Status
• Science Data Challenges
• Meetings
• AOB (chairs roundtable etc)
**SKA Design Baseline**

**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 dishes (133 x SKA + 64 x MeerKAT dishes)
- 0.35 – 15.4 GHz
- 150 km baselines (0.22” @1.7 GHz; 0.034” @15 GHz)
- Karoo, South Africa

---

**Major dates**

- **2021**: Start of construction activities
- **2024**: Start of science commissioning
- **2027**: Start of science verification
- **2027-29**: Key Science Project (KSP) planning & proposals
- **2028**: Commencement of PI-led programmes (shared risk)
- **2030**: Commencement of KSPs
Construction Strategy
(Staged Delivery - **Target: Design Baseline**)

- **Goal** – SKA-Mid with 197 dishes & SKA-Low with 512 stations
- Roll out the array in stages (Array Assemblies – AAs)
- Not all funding yet secured, therefore following Staged Delivery Plan (AA*)
- Maintain a continuously working and expanding facility that demonstrates the full performance capabilities of the SKA Design.
- **AA 0.5** – test array for interferometry, using prototypes; discover system level issues and develop procedures (e.g., pointing, tracking, holography)

First data release to community during SV in 2027 time-frame
(similar to ALMA SV model)
Some test data released during Commissioning

<table>
<thead>
<tr>
<th><strong>Milestone Event (earliest)</strong></th>
<th><strong>SKA-Mid (date)</strong></th>
<th><strong>SKA-Low (date)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>AA0.5 (test array)</td>
<td>2025 Q2</td>
<td>2024 Q4</td>
</tr>
<tr>
<td>AA1</td>
<td>2026 Q2</td>
<td>2025 Q4</td>
</tr>
<tr>
<td>AA2</td>
<td>2027 Q2</td>
<td>2026 Q4</td>
</tr>
<tr>
<td><strong>Science Verification begins</strong></td>
<td><strong>2027+</strong></td>
<td><strong>2027+</strong></td>
</tr>
<tr>
<td>AA*</td>
<td>2028 Q1</td>
<td>2028 Q1</td>
</tr>
<tr>
<td>Operations Readiness Review</td>
<td>2028 Q2</td>
<td>2028 Q2</td>
</tr>
<tr>
<td>End of Staged Delivery Programme</td>
<td>2028 Q3</td>
<td>2028 Q3</td>
</tr>
<tr>
<td><strong>Early Operations begin (shared risk)</strong></td>
<td><strong>2029+</strong></td>
<td><strong>2029+</strong></td>
</tr>
<tr>
<td>AA4</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Construction Strategy
(Staged Delivery - Target: Design Baseline)

Array Assemblies (AA)

- Capable as acting as an end-to-end telescope system with pre-defined functionality
- Used to commission and verify the telescopes
- Different objectives for different assemblies
- **Science commissioning**: on-sky observations for testing and debugging the system (some data may be released to community)
- **Science verification**: observations to ensure the system meets the needs of the science users (e.g., test observing modes, verify science requirements)
- **AA2 – Start science verification (SV)**: Community suggests targets & observations, data made publicly available

<table>
<thead>
<tr>
<th>Milestone Event (earliest)</th>
<th>SKA-Mid (date)</th>
<th>SKA-Low (date)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA0.5 (test array)</td>
<td>2025 Q2</td>
<td>2024 Q4</td>
</tr>
<tr>
<td>AA1</td>
<td>2026 Q2</td>
<td>2025 Q4</td>
</tr>
<tr>
<td>AA2</td>
<td>2027 Q2</td>
<td>2026 Q4</td>
</tr>
<tr>
<td><strong>Science Verification begins</strong></td>
<td><strong>2027+</strong></td>
<td><strong>2027+</strong></td>
</tr>
<tr>
<td>AA*</td>
<td>2028 Q1</td>
<td>2028 Q1</td>
</tr>
<tr>
<td>Operations Readiness Review</td>
<td>2028 Q2</td>
<td>2028 Q2</td>
</tr>
<tr>
<td>End of Staged Delivery Programme</td>
<td>2028 Q3</td>
<td>2028 Q3</td>
</tr>
<tr>
<td><strong>Early Operations begin (shared risk)</strong></td>
<td><strong>2029+</strong></td>
<td><strong>2029+</strong></td>
</tr>
<tr>
<td>AA4</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Updated December 2023
### The Road to Science

**Expectant Astronomers**

**Science Commissioning**
- Some test data may be available

**Science Verification**
- Suggests targets and observations
- Calibrated data publicly available

### Shared Risk PI
- Calls for proposals
- Observing cycles

<table>
<thead>
<tr>
<th>Milestone Event (earliest)</th>
<th>SKA-Mid (date)</th>
<th>SKA-Low (date)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AA0.5</strong> (test array)</td>
<td>2025 Q2</td>
<td>2024 Q4</td>
</tr>
<tr>
<td><strong>AA1</strong></td>
<td>2026 Q2</td>
<td>2025 Q4</td>
</tr>
<tr>
<td><strong>AA2</strong></td>
<td>2027 Q2</td>
<td>2026 Q4</td>
</tr>
<tr>
<td><strong>Science Verification begins</strong></td>
<td>2027+</td>
<td>2027+</td>
</tr>
<tr>
<td><strong>AA</strong></td>
<td>2028 Q1</td>
<td>2028 Q1</td>
</tr>
<tr>
<td><strong>Operations Readiness Review</strong></td>
<td>2028 Q2</td>
<td>2028 Q2</td>
</tr>
<tr>
<td><strong>End of Staged Delivery Programme</strong></td>
<td>2028 Q3</td>
<td>2028 Q3</td>
</tr>
<tr>
<td><strong>Early Operations begin (shared risk)</strong></td>
<td>2029+</td>
<td>2029+</td>
</tr>
<tr>
<td><strong>AA4</strong></td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

*Updated December 2023*
Construction Update – AA 0.5

4 Stations
2 x S8
1 x S9, S10

SKA-Low
AA 0.5

3.2 km
Construction Update

SKA-Low
Construction Update – AA 0.5

SKA-Mid

- MeerKAT
- SKA dish locations

MeerKAT

SKA036
SKA063
SKA001
SKA100

1.36 km
Construction Update – AA 0.5

SKA-Mid
SKA063
SKAO – global partnership (IGO since 2021)

One Observatory
Two Telescopes
Three Continents

Various stages of joining:
France, Germany, Canada, Sweden, India, S.Korea: Some will be almost complete by end 2024, others in 2025

Japan: uncertain, a few years away now (internal infrastructure roadmap)

Ireland: discussions renewed, no timeline just yet

Ratified Members:
Australia
China
Italy
The Netherlands
Portugal
South Africa
Spain
Switzerland
United Kingdom
Membership Update

• Germany
  • December cabinet approval
  • Discussions on further commitment (beyond MeerKAT+ contribution)

• India
  • December cabinet approval
  • Contribution of €110M, including additional ~€25M to expected Staged Delivery budget

• Japan
  • Low priority on national roadmap (TMT, CTA, Icecube)
  • formal talks on hold until 2027/8?

• Canada
  • Parliamentary approval being completed

• France
  • Parliamentary process in preparation
  • SKAO-CNRS agreements continue

• Sweden
  • Govt. process toward membership
  • SKAO-Chalmers agreement continues. Contribution of €26M secured.

• South Korea
  • SKAO included in national space agenda
  • discussions on agreement with KASI underway, then membership
## SWG Chair rotation

<table>
<thead>
<tr>
<th>SWG</th>
<th>First</th>
<th>Last</th>
<th>Country</th>
<th>Rotation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmology</td>
<td>Stefano</td>
<td>Camera</td>
<td>Italy</td>
<td>under discussion</td>
</tr>
<tr>
<td>EoR</td>
<td>Abhirup</td>
<td>Datta</td>
<td>India</td>
<td>under discussion</td>
</tr>
<tr>
<td>EoR</td>
<td>Andrei</td>
<td>Mesinger</td>
<td>Italy</td>
<td>under discussion</td>
</tr>
<tr>
<td>Exgal Cont</td>
<td>Fatemeh</td>
<td>Tabatabaei</td>
<td>Iran</td>
<td>replaced Natasha</td>
</tr>
<tr>
<td>Exgal Cont</td>
<td>Mark</td>
<td>Sargent</td>
<td>Switzerland</td>
<td>Catherine Hale (UK) 2024/05</td>
</tr>
<tr>
<td>Exgal Line</td>
<td>Viviana</td>
<td>Casasola</td>
<td>Italy</td>
<td>replaced Fraincoise</td>
</tr>
<tr>
<td>Exgal Line</td>
<td>Sebastien</td>
<td>Muller</td>
<td>Sweden</td>
<td>Jacco van Loon (UK) 2024/03</td>
</tr>
<tr>
<td>GW</td>
<td>Samaya</td>
<td>Nissanke</td>
<td>Netherlands</td>
<td>under discussion</td>
</tr>
<tr>
<td>GW</td>
<td>Alvise</td>
<td>Raccanelli</td>
<td>Italy</td>
<td>under discussion</td>
</tr>
<tr>
<td>HI Galaxy</td>
<td>Neeraj</td>
<td>Gupta</td>
<td>India</td>
<td>replaced Barbara</td>
</tr>
<tr>
<td>High Energy</td>
<td>Katie</td>
<td>Mulrey</td>
<td>Germany</td>
<td>replaced Anna</td>
</tr>
<tr>
<td>Magnetism</td>
<td>Jennifer</td>
<td>West</td>
<td>Canada</td>
<td>replaced Valentina</td>
</tr>
<tr>
<td>Our Galaxy</td>
<td>Jan</td>
<td>Forbrich</td>
<td>UK</td>
<td>Ke Wang (China) 2024/03</td>
</tr>
<tr>
<td>Our Galaxy</td>
<td>Adriano</td>
<td>Ingallinera</td>
<td>Italy</td>
<td>Marc Audard (Switzerland) 2024</td>
</tr>
<tr>
<td>Pulsars</td>
<td>Bhal Chandra</td>
<td>Joshi</td>
<td>India</td>
<td>replaced Natasha</td>
</tr>
<tr>
<td>SHI</td>
<td>Eduard</td>
<td>Kontar</td>
<td>UK</td>
<td>Rohit Sharma (India) 2024/03</td>
</tr>
<tr>
<td>SHI</td>
<td>Pietro</td>
<td>Zucca</td>
<td>Netherlands</td>
<td>replaced Divya</td>
</tr>
<tr>
<td>Transients</td>
<td>Jason</td>
<td>Hessels</td>
<td>Netherlands</td>
<td>Due</td>
</tr>
<tr>
<td>VLBI</td>
<td>Jack</td>
<td>Radcliffe</td>
<td>South Africa</td>
<td>replaced Cormac</td>
</tr>
<tr>
<td>VLBI</td>
<td>Tao</td>
<td>An</td>
<td>China</td>
<td>Jun Yang (Sweden) 2024/06</td>
</tr>
</tbody>
</table>

### SWG (incl. Chair) Terms of Reference ([Link](#))
Science Data Challenges

• Prepare Science Community
  • Science extraction from SKA Observatory Data Products (ODPs)
  • Stimulate advance of state-of-the-art in source finding, source characterisation and reliable inference of astrophysical parameters
  • Promote reproducibility and analysis pipeline sharing

• Develop proto-SRC Network
  • Test increasingly realistic data transfer, user access and customised user processing in proto-SRC environment

• Constrain SDP Pipeline development
  • Identify gaps in sky, telescope and error models
  • Determine necessary calibration quality and identify any other factors that might inhibit science extraction from ODPs
Science Data Challenge 3

Developed in collaboration with SKA EoR SWG members

- SDC3a "Foregrounds" (SDC3a; SWG Coordinators: C. Trott, V. Jelic)
  - Foreground removal exercise
  - SDC3a started 1 March 2023, closed 30 September 2023
  - 20 team submissions
  - Winner – team HIMALAYA (China)
  - Journal paper in preparation

- SDC3b “Inference” (SDC3b; SWG Coordinators: A. Mesinger, G. Melema)
  - Extraction of cosmological parameters
  - SDC3b launching Q2 2024

sdc3.skao.int
Science Data Challenge 3a – Dataset

• General
  • Observation track length HA = -2 to +2 hours
  • Thermal noise equivalent 1000 h
  • Field of View: one SKA1-Low pointing at RA, Dec = 0h, -30deg

• Visibilities
  • Size 7.5 TB
  • Integration time 10 s
  • Channel width 100 kHz
  • Frequency coverage 106 - 196 MHz

• Image cube → 2048 x 2048, 16 arcsec pixels, natural weighting

• The Challenge:
  • Determine intrinsic power spectrum of EoR fluctuations as function of scale and frequency despite foregrounds that are $10^5$ times brighter and presence of various residual calibration errors (DI, DD, bandpass) of specific magnitude
The Challenge in Numbers

Teams analysing
7.5 TB of simulated telescope data and a corresponding
60 GB of image cubes representing different radio frequencies

234 registered participants
12 supercomputing centres providing resources globally

Swiss National Supercomputing Center / CSCS
Lausanne, Switzerland

UC-LCA
Columbia, Portugal

UCS
IRIS-CAM
Cambridge, UK

UKS (RIO / Manchester, IRIS-ETF)
Manchester, UK

ASTRON / SURF
Amsterdam, Netherlands

GENCI / CRICS
Grenoble, France

INAF
Bologna - Trieste - Catania, Italy

INAF
Granada, Spain

SPSRC / IAA-CSIC
Granada, Spain

Galicia Supercomputing Center / CESGA
Santiago de Compostela, Spain

AustSRC
Australia

JPSRC
Tokyo, Japan

China SRC
Shanghai, China

Teams are analysing data which simulates observations of the Epoch of Reionisation signal (left: bright areas are neutral hydrogen, and dark patches are ionised gas). It is obscured by foreground emission (right: orange dots are galaxies, and the ribbon-like shape is diffuse gas in our galaxy). While the features of each image appear equally bright here, in the data cube the background is millions of times fainter than the foreground.
Reproducibility awards – SDC3

- Awarded to all teams who prepare software pipelines that can be reproduced and reused by others.
- Based on Software Sustainability Institute’s six steps to reproducibility
- Award system revised since SDC2
- Simpler for teams to follow and achieve
- SKAO reproducibility ‘badges’ can be added to team’s code repository
Reproducibility awards – SDC3

• Motivation:
  • Recognise that it can take extra time and effort to prepare codes into a shareable state
  • Align with FAIR principles for scientific data management and software

• Benefits
  • Easier for teams to share and learn analysis techniques → potential boost from combination of techniques
  • Pipelines (with SDC datasets) can be used as test cases for SRCNet development
Reproducibility awards – SDC3a Winners

<table>
<thead>
<tr>
<th>Team</th>
<th>Published codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOTSS</td>
<td><a href="https://gitlab.com/flomertens/dotss21_sdc3_pipeline">https://gitlab.com/flomertens/dotss21_sdc3_pipeline</a></td>
</tr>
<tr>
<td>ERWA</td>
<td><a href="https://github.com/zzh0616/SKA-DECONV">https://github.com/zzh0616/SKA-DECONV</a></td>
</tr>
<tr>
<td>FOREGROUNDS-FRIENDS</td>
<td><a href="https://github.com/espsrc/FOREGROUNDS-FRIENDS">https://github.com/espsrc/FOREGROUNDS-FRIENDS</a></td>
</tr>
<tr>
<td>Hausos</td>
<td><a href="https://github.com/CEA-jiangming/Hausos-sdc3a/tree/v1.0">https://github.com/CEA-jiangming/Hausos-sdc3a/tree/v1.0</a></td>
</tr>
<tr>
<td>HIMALAYA</td>
<td><a href="https://github.com/553445316/HIMALAYA.git">https://github.com/553445316/HIMALAYA.git</a></td>
</tr>
<tr>
<td>KORSDC</td>
<td><a href="https://github.com/Kj-Ahn/KORSDC_FGremove">https://github.com/Kj-Ahn/KORSDC_FGremove</a></td>
</tr>
<tr>
<td>SROT</td>
<td><a href="https://github.com/AkashRadio/SDC_SDC3">https://github.com/AkashRadio/SDC_SDC3</a></td>
</tr>
<tr>
<td>Wizards of Oz</td>
<td><a href="https://github.com/d3v-null/sdc3-pipeline">https://github.com/d3v-null/sdc3-pipeline</a></td>
</tr>
</tbody>
</table>

We warmly congratulate all teams who took part in this part of the Challenge!
Science Data Challenge 4 – Magnetism

• Developed in collaboration with Magnetism SWG (Akahori, Vernstrom, Vazza, ...)
  • Scope still being refined, but full Stokes compact plus diffuse sky model with IGM, ISM, and ionosphere propagation
  • 10 square deg, 950 – 1760 MHz, 3 arcsec beam, source finding and characterisation, $\text{RM}_{\text{Max}} \sim 5000 \text{ rad m}^{-2}$, $N_{\text{chan}} \sim 650$
  • 100 square deg, 100 – 350 MHz, 350 – 1760 MHz, 10 arcsec beam, source finding and characterisation, $\text{RM}_{\text{Max}} \sim 500 \text{ rad m}^{-2}$, $N_{\text{chan}} \sim (9350 + 650)$
  • Thermal noise equivalent few 1000 h, AA* telescope model
• Sky and Propagation Models nearing completion and looking good
  • Fully propagated models will require several months of local server time to run
• Telescope and Error Models
  • Under development, but already clear these will be image-based rather than visibility-based due to prohibitive computing cost
Science Data Challenge 4 – Magnetism

- IGM RM Sky Model of 100 deg$^2$ extending from $z = 0.01$ to 3.2 using Vazza et al simulations
- Red-shift space built up of 70 slices of 100 Mpc depth
- Each slice is the simulation at that redshift tiled as needed to fill 10x10 deg, with an offset and rotation to randomize projected distribution
Science Data Challenge 4 – Magnetism

- Galaxy clusters at $z = 0.1 - 0.3$ in the simulation to have RM up to +/- 8000 rad m$^{-2}$
- Polarised IGM emission also included in sky model out to $z = 0.3$
- ISM and Ionosphere RM Sky Model of 100 deg$^2$ from Akahori et al simulations
- Also include ISM polarised emission from Akahori et al model
- Sky Emission Model consists of:
  - T-RECS (all z)
  - IGM emission ($z < 0.3$)
  - ISM emission
- Propagation Model consists of:
  - IGM RM ($z < 3.15$)
  - ISM RM
  - Ionosphere RM

Stokes $I$ Sky Model
Science Data Challenge 4
Magnetism

- Close-up view of Galaxy cluster at $z = 0.1$ with RM up to +/- 8000 rad m$^{-2}$
- Good prospects for rich polarimetric phenomena in SDC4 data products
Science Meetings (2024 unless indicated)

- **THIS WEEK:** MeerKAT @ 5, 20-23 February, Stellenbosch, SA
- **Interstellar Frontiers:** Bridging SETI, Astrobiology, and SKA, 11-14 March, Perth AU
- **Cosmology in the Alps:** 18-22 March, Les Diablerets, CH
- **African Astronomical Society (AfAS) Conference:** 15-20 April, Marrakech, Morocco
- **Raising the veil on star formation:** conference in honour of Richard Hills, 22-28 April, Cambridge UK
- **SPARCS XII:** Pushing toward the final frontier, 6-10 May, Bologna, IT
- **New Telescopes and major upgrades to existing telescopes:** URSI AT-RASC, 19-24 May, Gran Canaria, ES
- **Cosmic Magnetism in the pre-SKA Era:** 27-31 May, Kagoshima JP
- **EAS SS31:** The SKAO: pathway to science operations, 1-5 July, Padova, IT
- **IAU GA:** 6-15 August, Cape Town. **SKAO Day 9 August,** and various SKA-related Symposia
- **SKA Science Conference, June 2025, Gorlitz, Germany,** planning underway
Outreach & Engagement

- **CONTACT** is the SKAO magazine aimed at the entire SKA community

- Ideas for articles for CONTACT are always welcome (email Tyler). These include:
  - Let’s Talk About (Feature length ... science focussed)
  - Pathfinders (& precursors. Short pieces on recent results)
  - SKA-related events (e.g. SPARCS, etc)
  - any other news of SKA relevance (award/honours, jobs, ...)

- Encourage your SWG members to sign up
AOB

- SWG News?

Reminder:
- SWG Chairs meetings 3\textsuperscript{rd} Tuesday each month
- Alternating between 09.00 UT (March, May, ...) and 15.00 UT (Feb, Apr, ...)

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