


# Planning for Science with the SKA

Tyler Bourke  
SKA Project Scientist



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The background of the slide is a vibrant, multi-colored cosmic scene. It features a bright white star in the upper left, a large orange and red nebula or galaxy structure in the center, and a field of yellow and green stars in the lower right. The overall color palette is dominated by warm oranges, reds, and yellows, contrasted with deep blues and blacks of space.

# SKA- Key Science Drivers

## The history of the Universe

Testing General Relativity  
(Extreme Gravity, Gravitational Waves)

Cosmic Dawn & Reionisation  
(First Stars and Galaxies)

Cradle of Life  
(Planets, Molecules, SETI)

Galaxy Evolution  
(Normal Galaxies  $z \sim 2-3$ )

Cosmic Magnetism  
(Origin, Evolution)

Cosmology  
(Dark Matter, Large Scale Structure)

Our Galaxy  
(Star Birth & Death, Matter Evolution, Structure)

Exploration of the Unknown

**Huge range of transformational science enabled by the SKA**

# SKA Big 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?*

## ➤ **Our Galaxy, The Milky Way**

*How does matter cycle between stars and the Interstellar Medium?*

## ➤ **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 and Radio Continuum**

*How do normal galaxies form and grow? What is their star-formation history?*

## ➤ **The Transient Radio Sky**

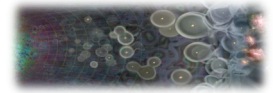
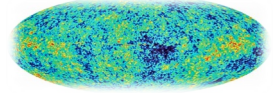
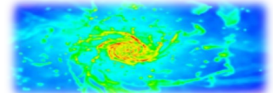
*What are Fast Radio Bursts and how can we utilise them? What haven't we discovered?*

## ➤ **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?*

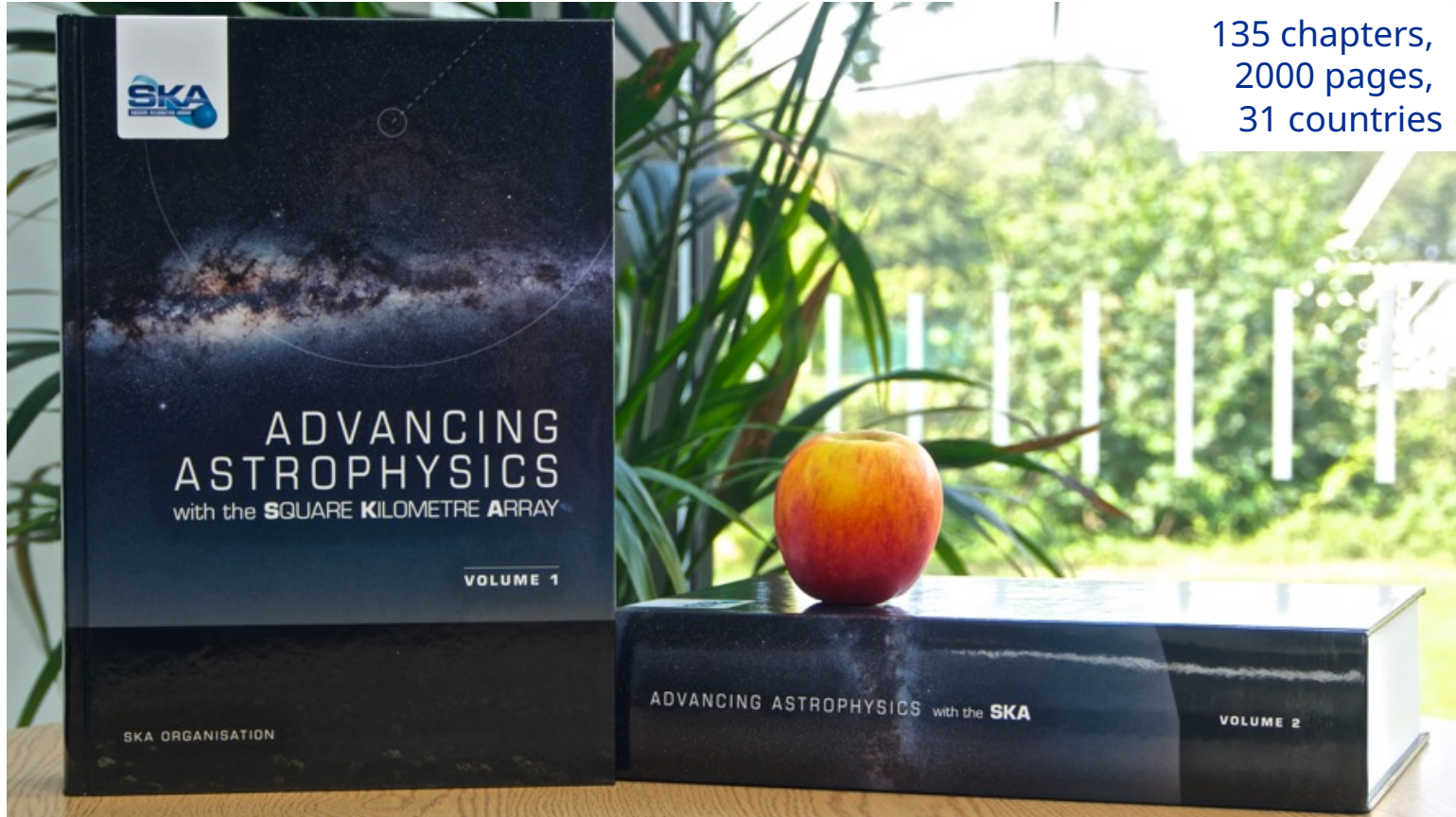


# SKA Science Case

(2015 snapshot ; continuous evolution)

<https://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=215>

135 chapters,  
2000 pages,  
31 countries



# SKA Science Case – White Books, Red Books, Memos

## The Spanish Square Kilometre Array White Book

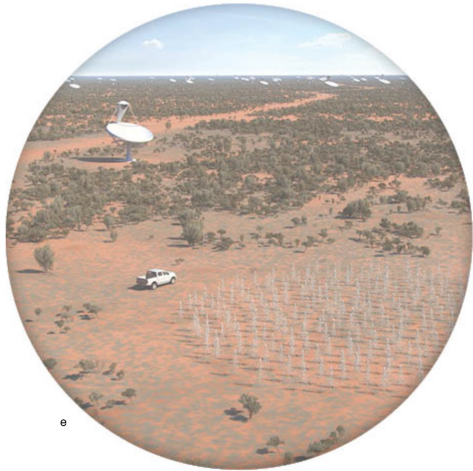
### Editors

Miguel Pérez-Torres  
Lourdes Verdes-Montenegro  
José Carlos Guirado  
Antonio Alberdi  
Jesús Martín-Pintado  
Rafael Bachiller  
Diego Herranz  
Josep Miquel Girart  
Simone Migliari  
José Miguel Rodríguez-Espinoza



## Italian SKA White Book

Editors: L. Feretti & I. Prandoni  
On behalf of the SKA-Italy WG



## French SKA White Book

The French community towards the Square Kilometre Array



## Portuguese SKA White Book



日本 SKA コンソーシアム

科学検討班

# SKA Science Case – White Books, Red Books, Memos



THE SQUARE  
KILOMETRE  
ARRAY (SKA)

SWISS INTERESTS  
AND CONTRIBUTION

Publications of the Astronomical Society of Australia (PASA)  
doi: 10.1017/pas.2018.xxx.

## Cosmology with Phase 1 of the Square Kilometre Array

Red Book 2018: Technical specifications and performance forecasts

Square Kilometre Array Cosmology Science Working Group: David J. Bacon<sup>1</sup>, Richard A. Battye<sup>2,\*</sup>, Philip Bull<sup>3</sup>, Stefano Camera<sup>4,5,6,2</sup>, Pedro G. Ferreira<sup>7</sup>, Ian Harrison<sup>2,7</sup>, David Parkinson<sup>8</sup>, Alkistis Pourtsidou<sup>3</sup>, Mário G. Santos<sup>9,10,11</sup>, Laura Wolz<sup>12,\*</sup>, Filipe Abdalla<sup>13,14</sup>, Yashar Akrami<sup>15,16</sup>, David Alonso<sup>7</sup>, Sambatra Andrianomena<sup>9,10,17</sup>, Mario Bonvin<sup>22</sup>, Michael L. Brown<sup>2</sup>, Emma Chapman<sup>23</sup>, Song Chen<sup>9</sup>, Xuelei Chen<sup>24</sup>, Anna Bonaldi<sup>21</sup>, Camille Bonvin<sup>22</sup>, José Luis Bernal<sup>18,19</sup>, Daniele Bertacca<sup>20,36</sup>, Carlos A.P. Bengaly<sup>9</sup>, Steven Cunningham<sup>1</sup>, Tamara M. Davis<sup>26</sup>, Clive Dickinson<sup>2</sup>, José Fonseca<sup>9,36</sup>, Keith Grainge<sup>2</sup>, Stuart Harper<sup>2</sup>, Matt J. Jarvis<sup>7,9</sup>, Roy Maartens<sup>1,9</sup>, Natasha Maddox<sup>27</sup>, Hamsa Padmanabhan<sup>28</sup>, Jonathan R. Pritchard<sup>23</sup>, Alvise Raccanelli<sup>18</sup>, Marzia Rivi<sup>13,29</sup>, Sambit Roychowdhury<sup>2</sup>, Martin Sahlén<sup>30</sup>, Dominik J. Schwarz<sup>31</sup>, Thilo M. Siewer<sup>31</sup>, Matteo Viel<sup>32</sup>, Francisco Villaescusa-Navarro<sup>33</sup>, Yidong Xu<sup>24</sup>, Daisuke Yamauchi<sup>34</sup>, Joe Zuntz<sup>35</sup>

Affiliations listed after references

## 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





# The Road to Science

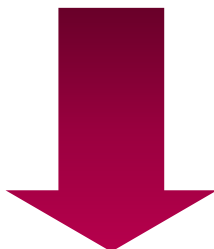
Science Commissioning



Science Verification



Shared Risk PI  
Normal PI  
KSP



Event	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





# Definitions

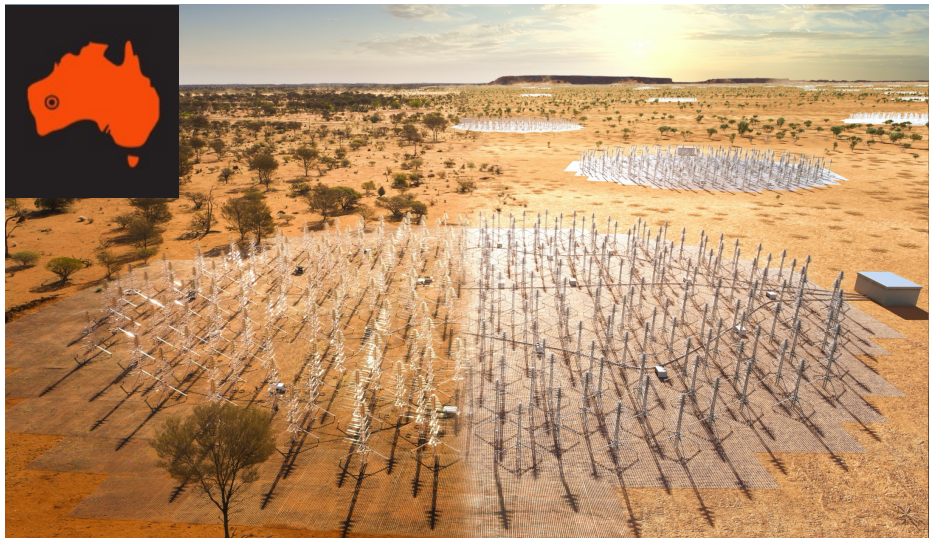
Science Commissioning (SC)	Execution & analysis of science observations, with the aim of testing and debugging the system
Science Verification (SV)	<ul style="list-style-type: none"><li>• Activities to verify the telescope system against the science requirements (to ensure the system meets the needs of the science users).</li><li>• Verifies one or more observing modes (e.g. deep imaging in B1)</li><li>• SV data will be publicly released</li><li>• Community may be involved in project/target selection</li></ul>
Shared Risk PI Projects	PI projects that carry a risk of not being successful or not being scheduled. No guarantee of re-observing or re-scheduling. Will be used to exercise end-to-end operations (e.g. new modes; KSP preparation)
Principal Investigator Projects	Science Projects of modest time requests that can typically be completed within a single time allocation cycle using already commissioned modes
Key Science Projects (KSPs)	KSPs are observing projects that require the allocation of significant observing time and resources (ie compute) over a period longer than one time allocation cycle. It is anticipated that KSPs will take up 50-70% of available time during the first 5 years of full operations.



# The Telescopes – Phase 1

**SKA1-Low:** 131,072 low-freq antennas  
(512 stations each with 256 dipoles)  
50 – 350 MHz  
65 km baselines (11" @ 110 MHz)  
Murchison, **Western Australia**

**SKA1-Mid:** 197 dishes  
(133 x 15m + 64 x 13.5m dishes)  
0.35 – 15.4 GHz MeerKAT  
150 km baselines  
(0.22" @ 1.7 GHz; 34 mas @ 15 GHz)  
Karoo, **South Africa**



Phase 2 (aspiration): > 2000 dishes across Africa; > 500,000 dipoles across Australia



# First and Future (?) Generation Feeds/Receivers

Band	Frequency Range	Bandwidth
<b>Low</b>	<b>50 – 350 MHz</b>	<b>2 x 150 MHz</b>
<b>Mid Band 1</b>	<b>0.35 – 1.05 GHz</b>	<b>700 MHz</b>
<b>Mid Band 2</b>	<b>0.95 – 1.76 GHz</b>	<b>810 MHz</b>
Mid Band 3	1.65 – 3.05 GHz	1.4 GHz
Mid Band 4	2.80 – 5.18 GHz	2.4 GHz
<b>Mid Band 5a</b>	<b>4.6 – 8.5 GHz</b>	<b>3.9 GHz</b>
<b>Mid Band 5b</b>	<b>8.3 – 15.3 GHz</b>	<b>2 x 2.5 GHz</b>

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

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?



# Capabilities & Performance Estimates

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 [ $\mu$ Jy/beam] <sup>a</sup>	26	14	4.4	2	1.3	1.2
Line rms, 1hr [ $\mu$ Jy/beam] <sup>b</sup>	1850	800	300	140	90	85
Resolution range for Cont. & Line rms. [arcsec] <sup>c</sup>	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

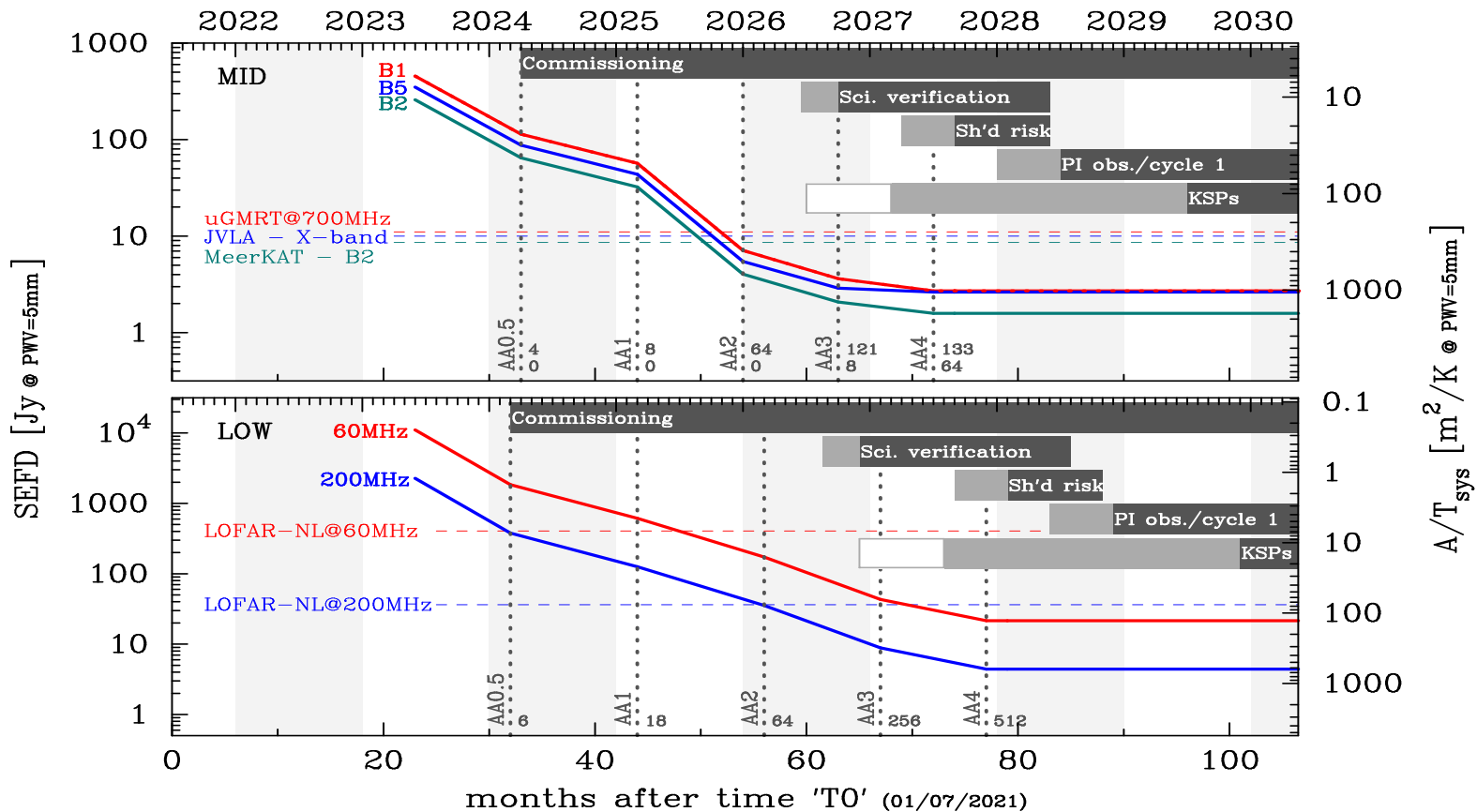
## One hour integrations

### Table Notes:

- (a) Line sensitivity assumes fractional bandwidth per channel of  $\Delta\nu/\nu = 10^{-4}$  ( $>10^{-6}$  will be possible)
- (b) Continuum sensitivity assumes fractional bandwidth per channel of  $\Delta\nu/\nu = 0.3$
- (c) The sensitivity numbers apply to the range of beam sizes given by Min. and Max. beam sizes

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

# The Evolution of Performance



# Telescope Access

## Key Science Projects (KSPs)

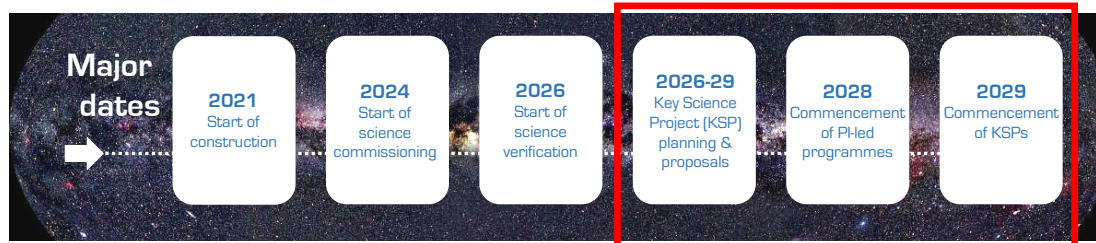
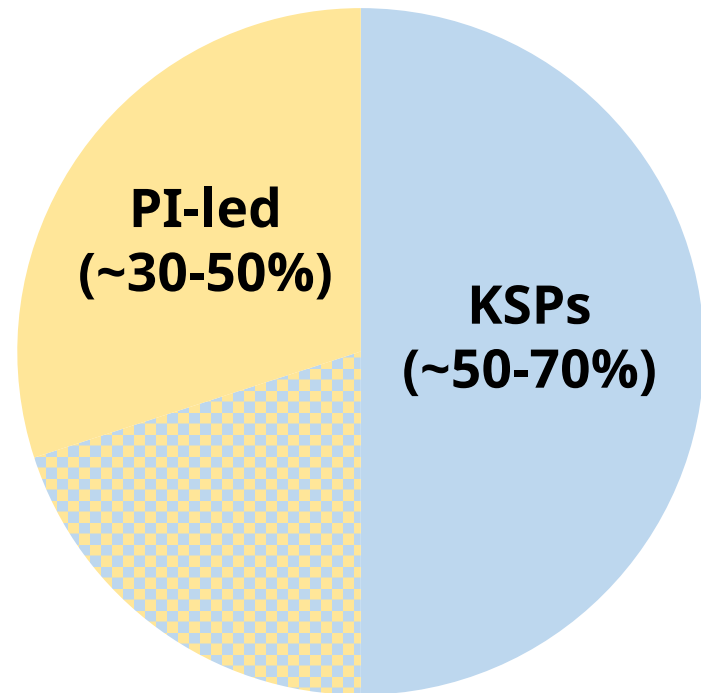
- Large programs (>500 h ?) performed over multiple cycles (nominally 1 year)
- PI & leadership team from SKA-member countries; co-Is from any country (latter may be limited)
- Expected to provide added-value data products and tools back to SKAO
- Regular reviews to track progress toward goals

## Principal Investigator (PI) Projects

- Small programs (<500 h ?) performed within a single cycle

## Director-General's Discretionary Time

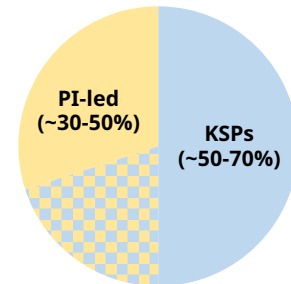
- Time allocated by the D-G outside of the normal TAC process



# Telescope Access

## Commensal Science

- Different observing projects utilizing the same telescope time (pointing direction); may use same or different observing mode (i.e., continuum imaging, spectral line imaging, pulsar/transient search)
- Maximizes the use of SKA resources
- Commensal science is not “free”, will be counted against member share



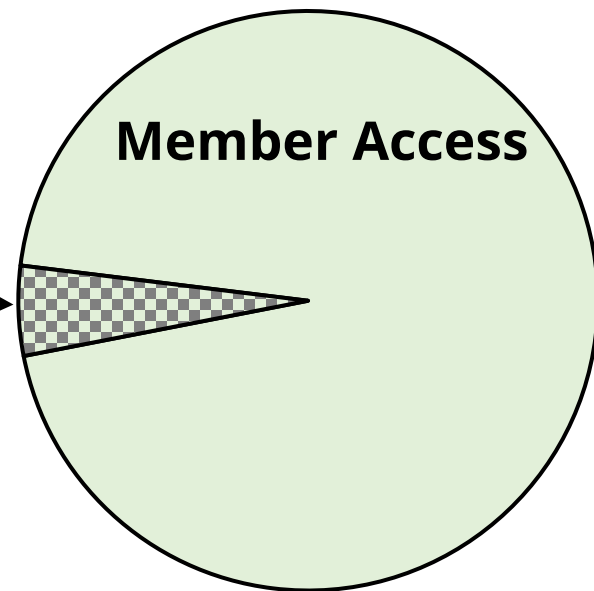
## Members (and Associate Members)

- Can lead any program (KSP, PI)
- Can be part of KSP leadership teams
- Access in proportion to member share

## Non-Members

- Can lead PI programs
- Can be team members of KSPs, but not part of leadership team
- Access capped at **5%** (“**Open Time**”; TBC by Council)
- Access to any individual non-member entity may be capped

**Open Time** →



# Telescope Access

**NO time has been allocated for ANY project**

SWG's are NOT proto-KSPs

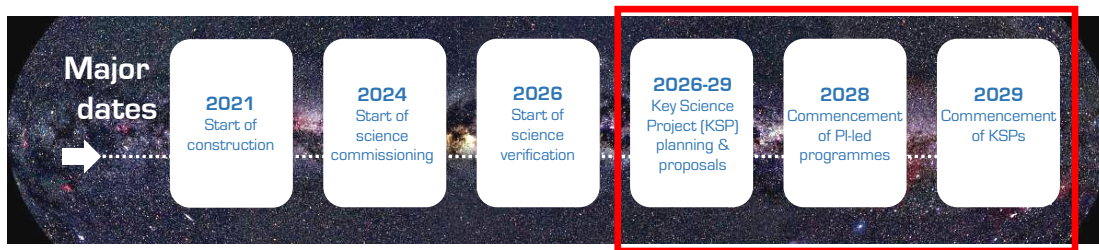
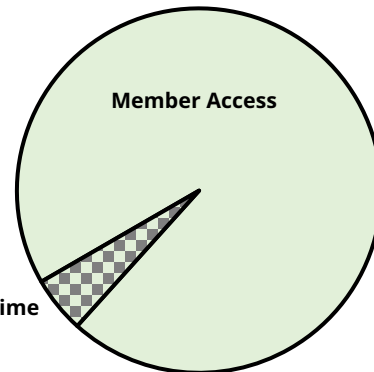
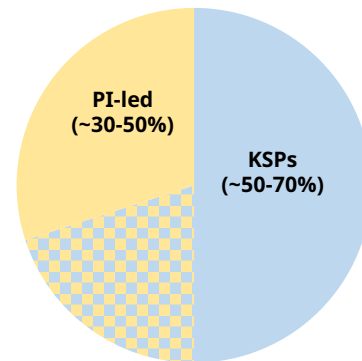
High Priority Science Objectives are NOT KSPs

There are NO guaranteed KSPs

Time allocation will be based on

**SCIENTIFIC MERIT**

and technical feasibility through a common proposal review process





# Science Community Engagement

## Regular Science Meetings

- Refresh of the science case
- New science from Precursors and Pathfinders
- Bring early career researchers into the family
- Keep everyone excited for SKA science

## Science Working Group Activities

- Internal Data Challenges
- KSP planning (Obs. using precursors, etc)
- Webinars, SWG meetings, Updated science cases
- Monthly SWG Chairs updates, circulated to all SWGs

## Science Data Challenges

- Allow science community to become familiar with SKA-like data products (synthetic, precursors)
- Test their analysis/extraction techniques against truth sets
- **See talk by Philippa Hartley**
- **for SKA Regional Centres see talk by Rosie Bolton**

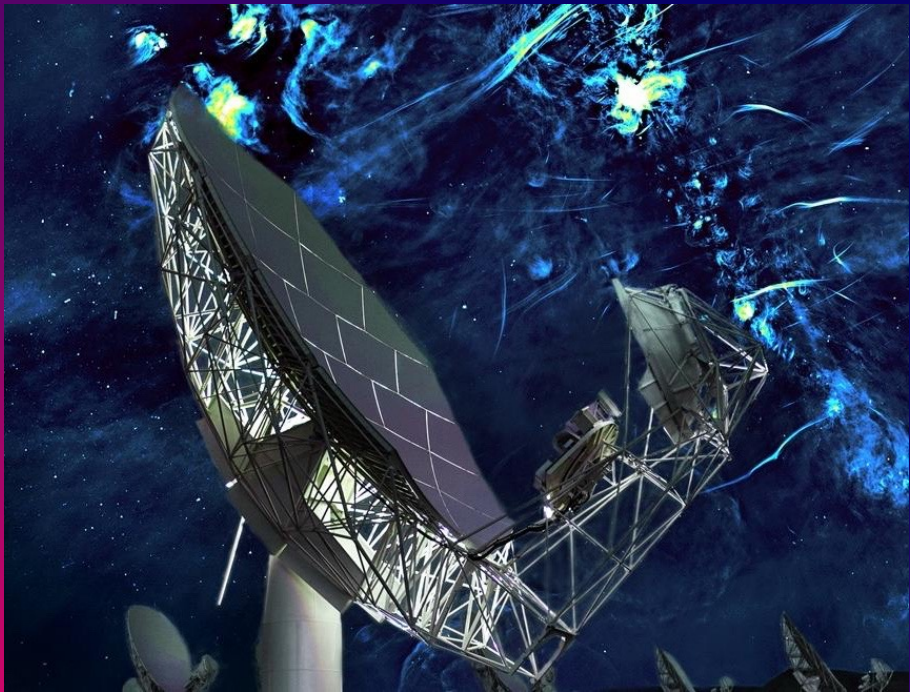
## KSP Planning

- Will run a planning workshop and issue a call for Letters of Intent (preliminary co-ordination), starting > 2 years before first KSP observations
- Workshop provides a forum for co-ordination and perhaps collaboration of proposals with similar science goals and technical needs

## Science Verification

- Similar to ALMA SV
- Data to community early (AA2) – public data
- Community involvement in source selection (like ALMA)
- Prepare for Shared Risk (cycle 0)
- Confidence that Level 0 Science Requirements will be met





**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](http://www.skao.int)