Science with the SKA Observatory

Dr A. Bonaldi, SKAO Project scientist

SKA Swiss days

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.

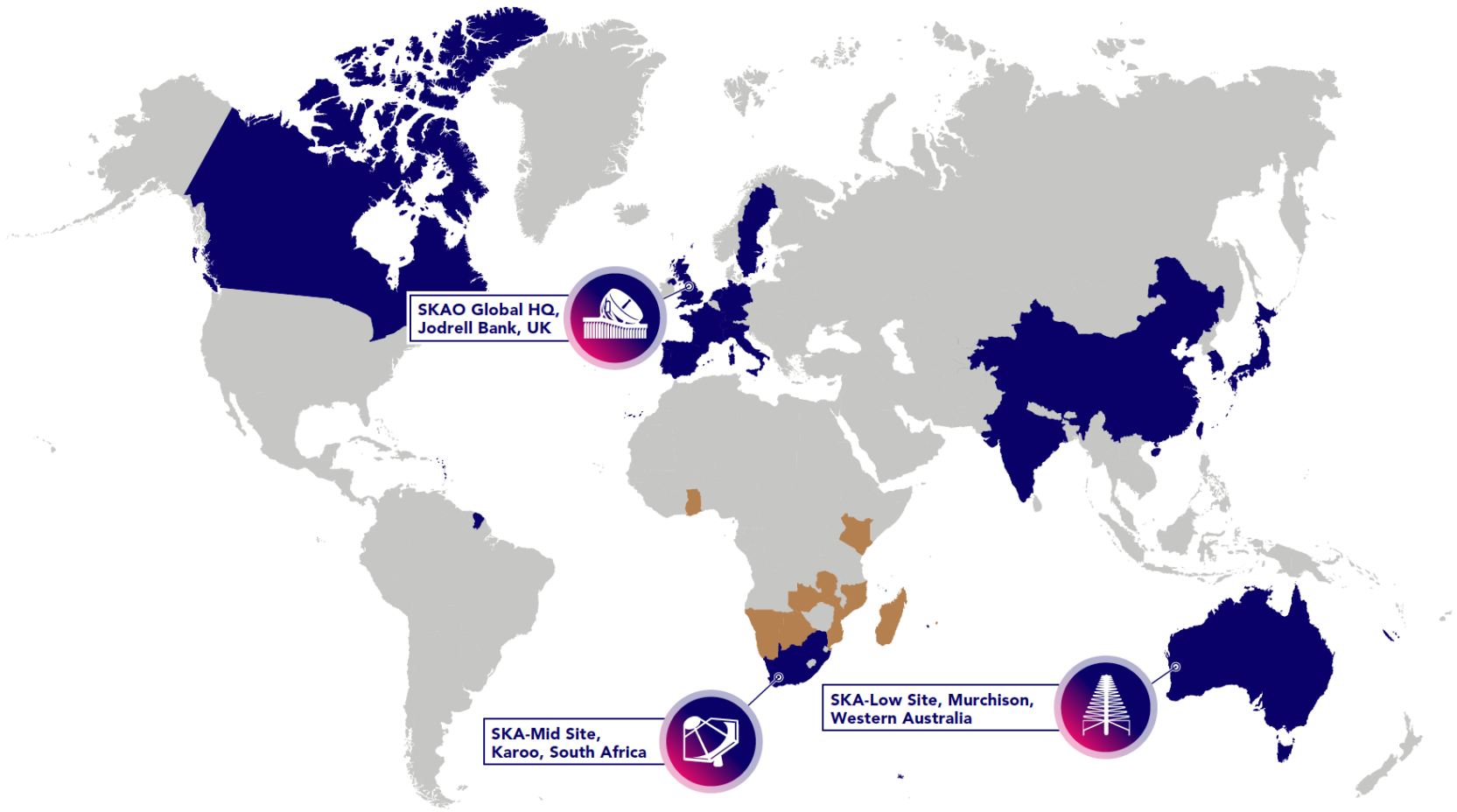
Membership negotiations:

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."

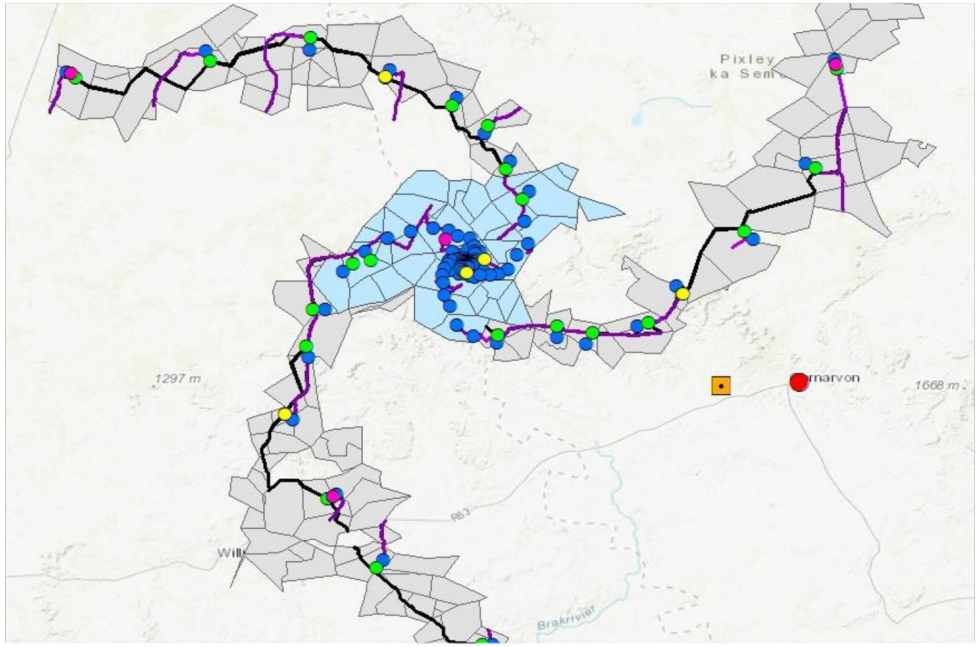


SKAO Partnership - includes SKAO Member States* and SKAO Observers (as of June 2022)

* * * * * * * *

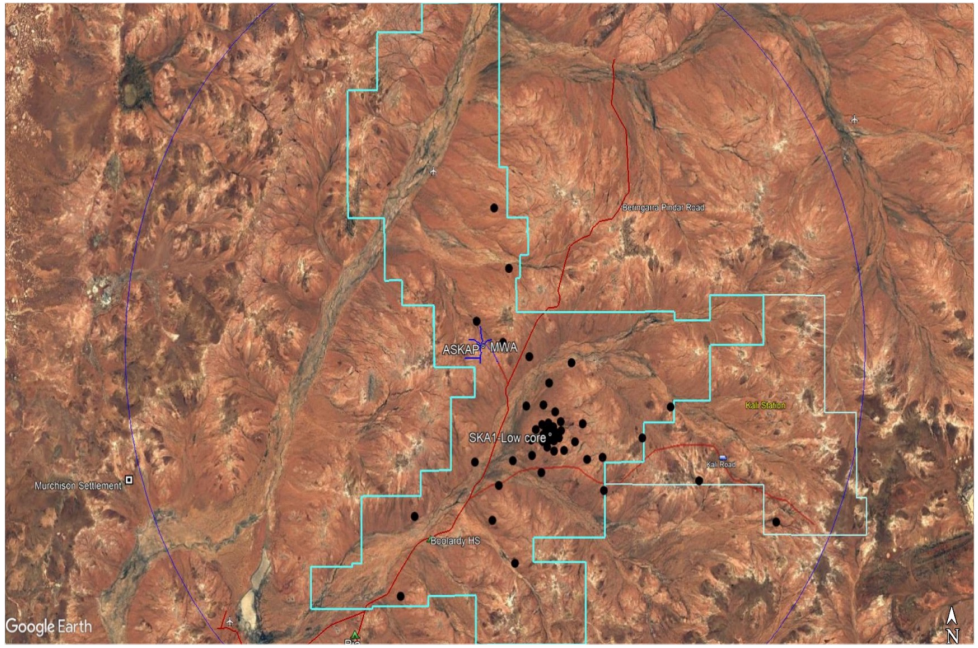
African Partner Countries

SKA-Mid in South Africa



- 197 fully steerable dishes, including the existing MeerKAT dishes
- Frequency range: 350 MHz - 15.4 GHz
    - See Tyler's presentation on B6
- Wavelength range: 0.85 m – 2 cm
- Maximum distance between dishes: 150km

SKA-Low in Australia



- 131,072 log-periodic antennas, spread across 512 stations
- Frequency range: 50 MHz - 350 MHz
- Wavelength range: 6 m – 0.85 m
- Maximum distance between antenna stations: 74km

The SKA project in numbers

€1.3 BILLION
CONSTRUCTION COST (2021 €)

131,072 ANTENNAS
IN WESTERN AUSTRALIA

710 PETABYTES
OF SCIENCE DATA DELIVERED TO SCIENCE USERS

€0.7 BILLION
FIRST 10 YEARS OF OPERATIONS COST (2021 €)

197 DISHES
IN SOUTH AFRICA (INCLUDING 64 MEERKAT DISHES)

1 GLOBAL NETWORK
OF DATA CENTRES TO DELIVER SCIENCE-READY DATA PRODUCTS TO END-USERS

8 YEARS
OF CONSTRUCTION ACTIVITIES

16 COUNTRIES
PARTICIPATING IN 2022

50+ YEARS
OF TRANSFORMATIONAL SCIENCE

Construction Schedule

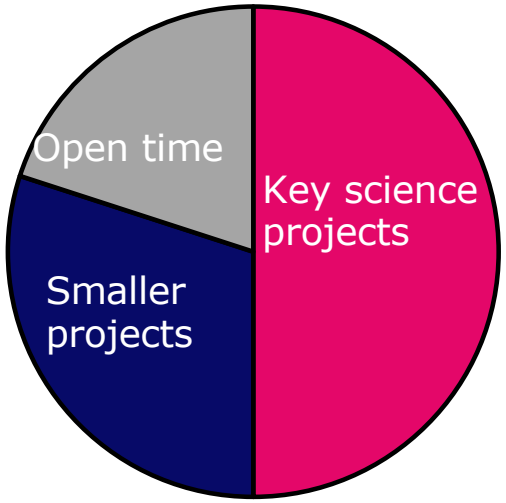
Construction commencement ceremonies, Dec 5-6 2022

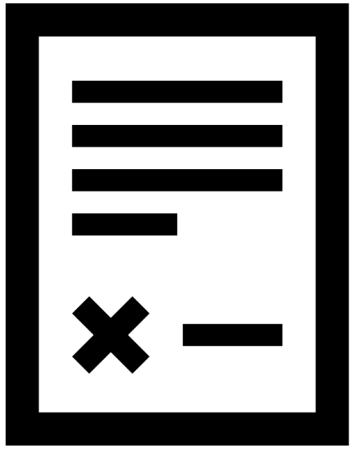
Milestone Event		SKA-Mid	SKA-Low
AA0.5	4 dishes 6 stations	2025 Q1	2024 Q4
AA1	8 dishes 18 stations	2026 Q1	2025 Q4
AA2	64 dishes 64 stations	2027 Q1	2026 Q4
AA*	144 dishes 307 stations	2027 Q4	2028 Q1
Operations Readiness Review		2028 Q1	2028 Q2
End of staged delivery programme		2028 Q3	2028 Q3
Full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

First science verification expected in 2026/27

Funding model

- SKAO member countries contribute to the SKAO construction and operations cost at an agreed level
- Telescope access is based on contribution level
- Construction contracts awarded to member countries whenever possible, to guarantee fair return of investment





March 2023: 48 contracts awarded, totalling ~€475M; more major contracts being prepared

Examples of impact of investment in radio astronomy

THE INVENTION OF WIFI

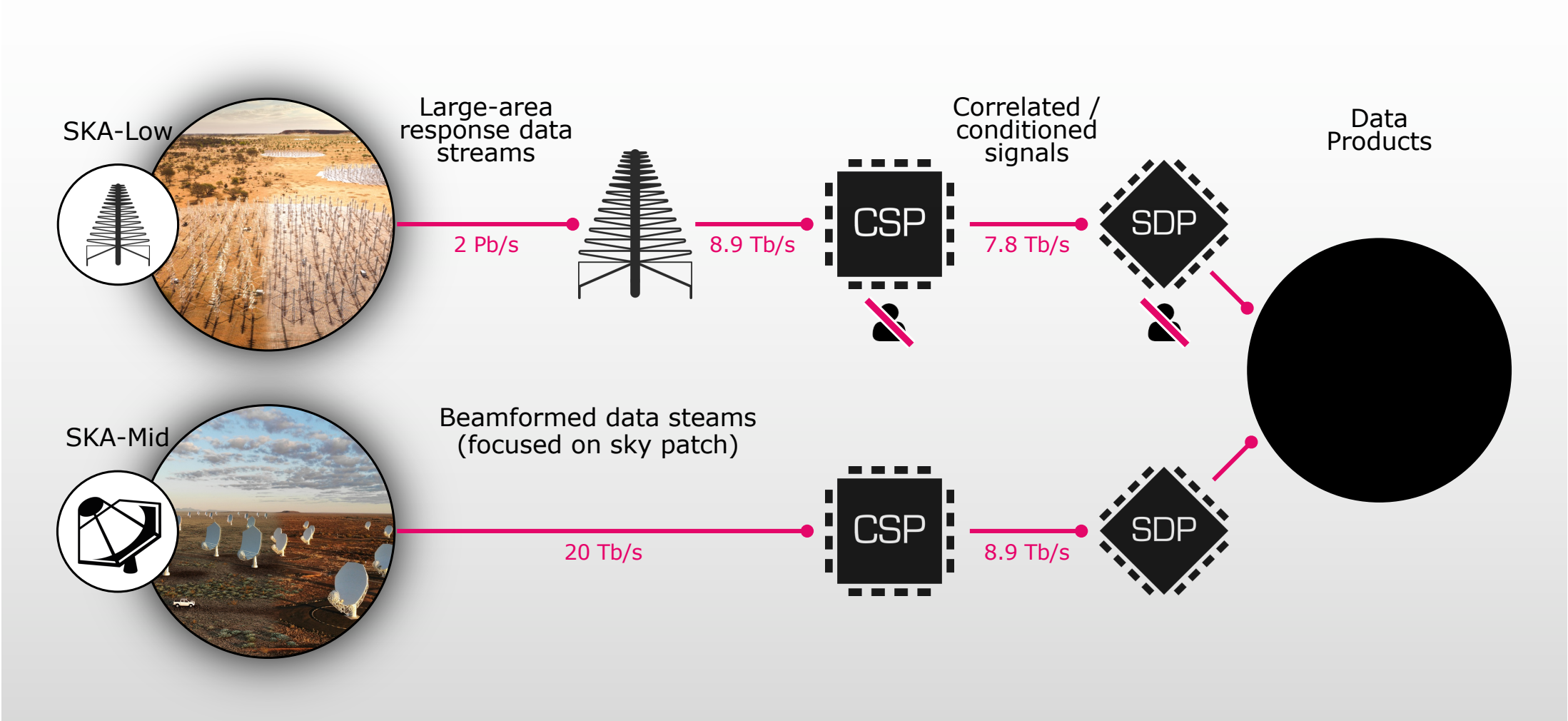
MAGNETIC RESONANCE IMAGING (MRI)

REFERENCE SYSTEMS FOR SPACE NAVIGATION AND GP:

HIGH-PRECISION MONITORING OF TECTONIC PLATE MOVEMENTS

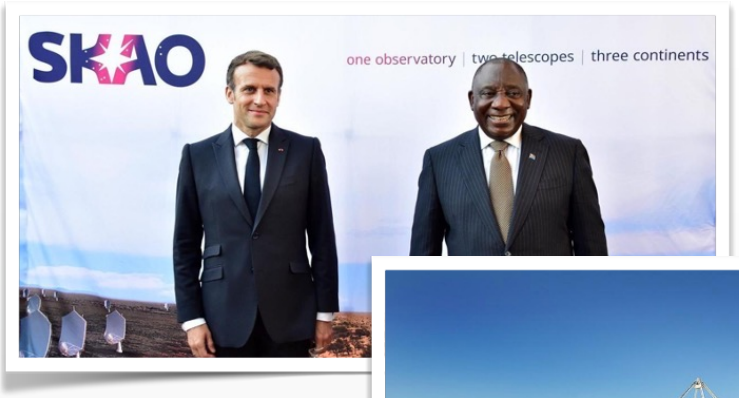
SPACE TRACKING

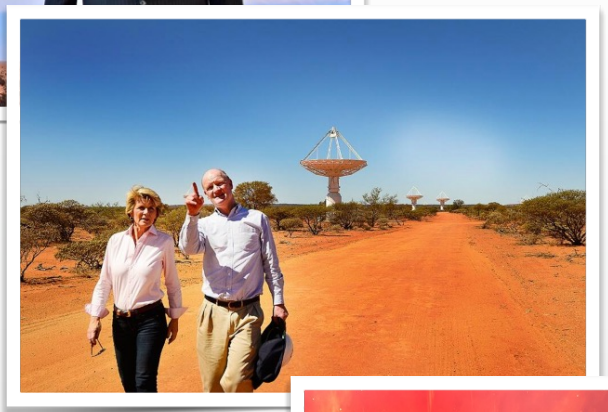
SKAO data processing stages



SKAO partnership as a science diplomacy tool

- Build international connections
- Encouraging government-level interaction
- A vehicle for collaboration





Access to SKA Resources

- SKAO resources are made available to scientists from Member and non-Member states
  - For members, allocation is proportion to their share in the project
  - For non-members, allocation is capped at a percentage defined as Open Time
  - Time allocation for all is based on scientific merit and technical feasibility, evaluated by a common proposal review process
- Calibrated data will be automatically generated by SKAO, these are called Observatory Data Products (ODPs) ✗ Raw Data
- Scientists will access ODPs via SKA Regional Centres (SRCs)
  - may require further processing (e.g., co-adding) to produce Advanced Data Products (ADPs) for analysis

Proposal Types

Key Science Projects (KSPs)

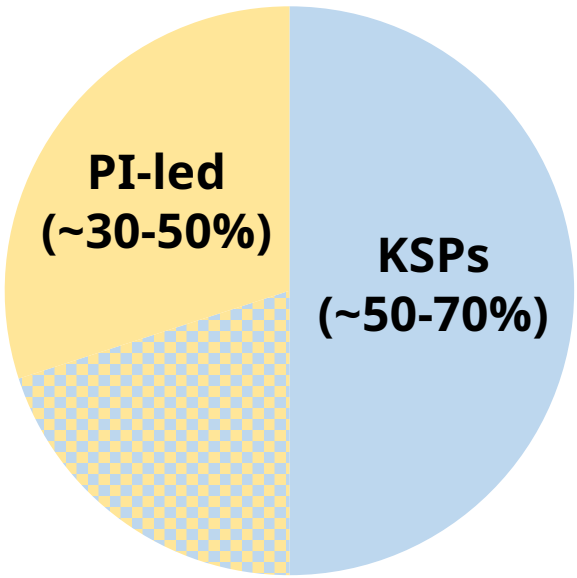
- Large programs that require the allocation of significant observing time (at least a few x 100h ? - TBC) and resources, performed over multiple cycles (nominally 1 cycle = 1 year)
- Leadership team from SKA-member countries; co-Is from any country (latter may be limited)
- Expected to provide added-value data products and tools back to SKAO
- Regular reviews to track progress toward goals

Principal Investigator (PI) Projects

- Smaller programs (< KSP) performed within a single cycle

Director-General's Discretionary Time

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



Indicative allocation split over first 5 years of normal operations

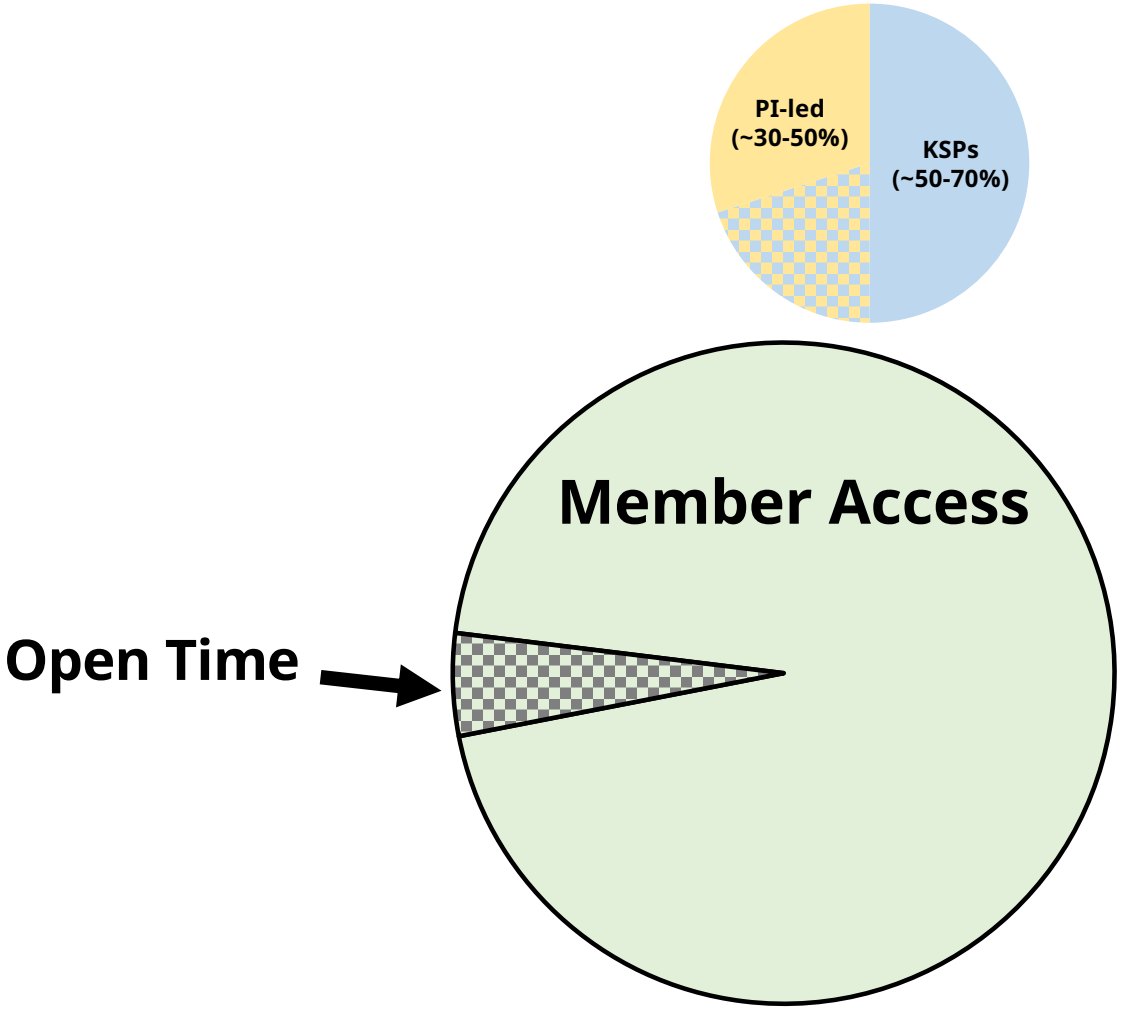
Telescope Access

Members (and Associate Members)

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

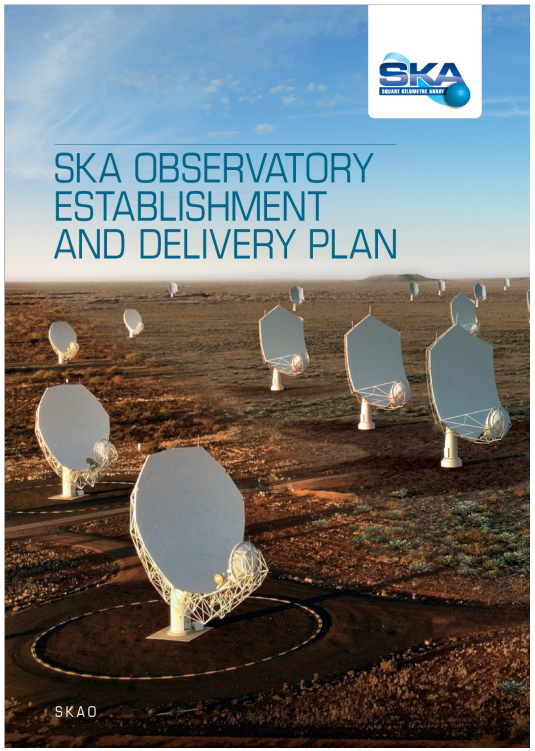
Non-Members

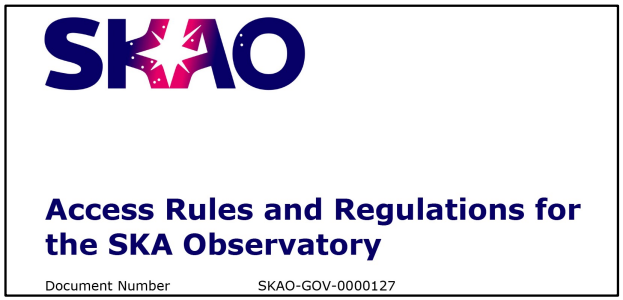
- Can lead PI programs
- Can be team members of KSPs, but not part of leadership team
- Access capped at **5% ("Open Time";** TBC by Council)
- Access to any individual non-member entity may be capped



Important Documents

- SKA Observatory Establishment and Delivery Plan
  - describes Observatory Operations in practice
- SKA Observatory Access Policy
  - Council policy document outlining the high-level principles that will be followed to enable access to SKA telescope time and computing resources during routine operations
- SKAO Access Rules and Regulations
  - describes the implementation of the Access Policy, with rules and procedures on how scientists will gain access to SKA telescope time and computing resources during routine operations





Science drivers and requirements

Cradle of Life	Cosmology and the Cosmic Dawn/EOR	Evolution of Galaxies	Strong-field tests of gravity; transient radio sky	Exploring the unknown

High Spatial, Spectral & Temporal Resolution

Imaging, Spectral Sensitivity, Speed (Pulsar Timing)

Polarimetry

Broad Frequency Coverage

IMPACT •Understand how rocky planets form •Understand the origins of life •Understand exoplanet characteristics	**IMPACT** •Understand the first 700 M years of the universe •Understand when the first stars formed	**IMPACT** •`Understand how galaxies replenish their gas •Understand relationship between HI and AGN	**IMPACT** •Understand gravity in extreme environments •Understand multi-messenger astrophysics	**IMPACT** •Open new radio science windows •Provide next generation radio telescope


Extragalactic Continuum
Science Working G
Cosmology
Science Working G
Cradle of Life
Science Working G
Pulsars
Science Working
Epoch of Reionization
Science Working G
HI Galaxy Science
Science Working G
Extragalactic Spectral Lines
Science Working G
Transients
Science Working G
Cosmic Magnetism
Science Working G
Solar and Heliospheric Physics
Science Working G
Our Galaxy
Science Working G
High Energy Cosmic Particles
Focus Group
SQUARE KILOMETRE ARRAY
ADVANCING ASTROPHYSICS
with the SQUARE KILOMETRE ARRAY
VOLUME 1
SKA ORGANISATION
ADVANCING ASTROPHYSICS with the SKA
VOLUME 2

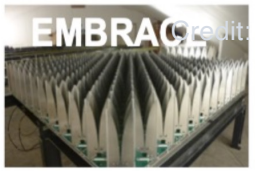
Paving the way

Precursors

Located at future SKA sites (South Africa and Australia)

Pathfinders

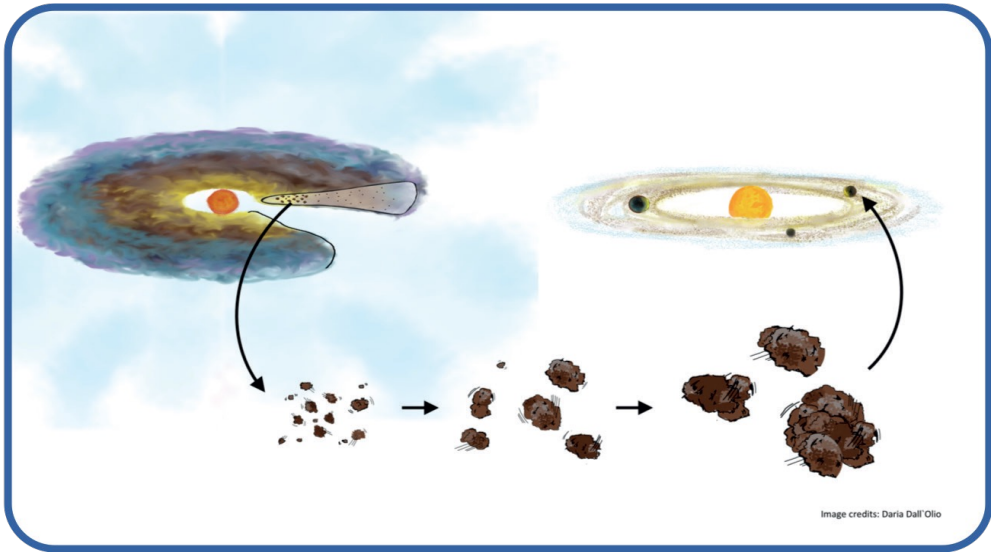
Engaged in SKA related technology and science studies

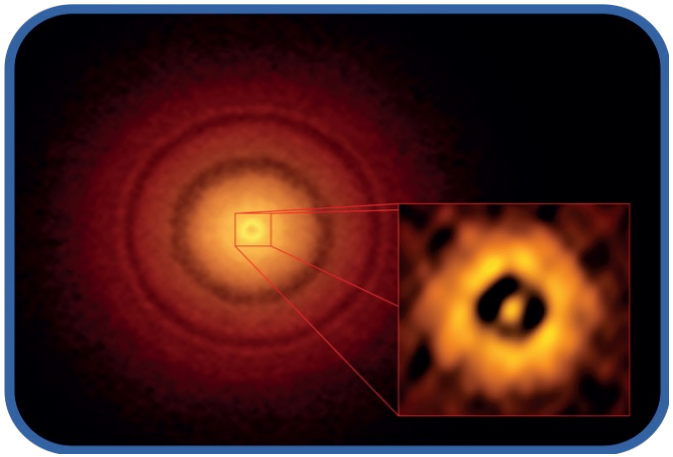


Credit: SARAO

Cradle of life

What makes life possible? From planet formation to life and intelligent life on other planets!

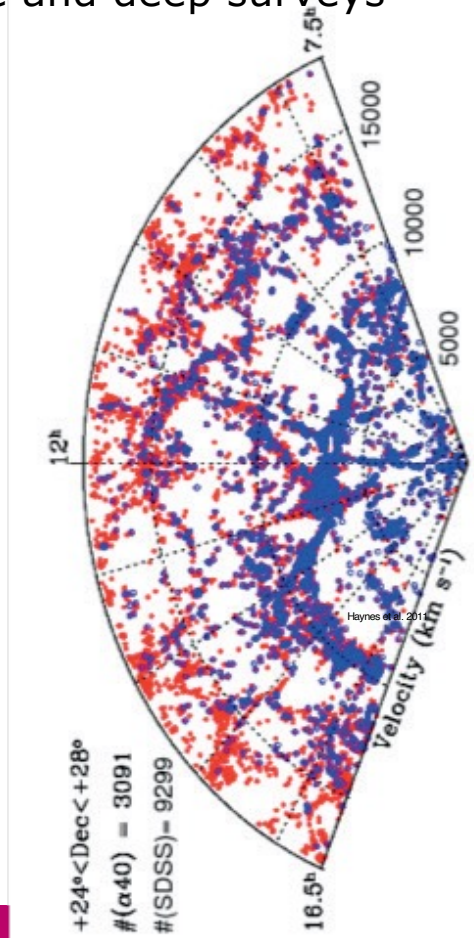




Credit: S. Andrews (CfA), ALMA (ESO/NAOJ/NRAO)

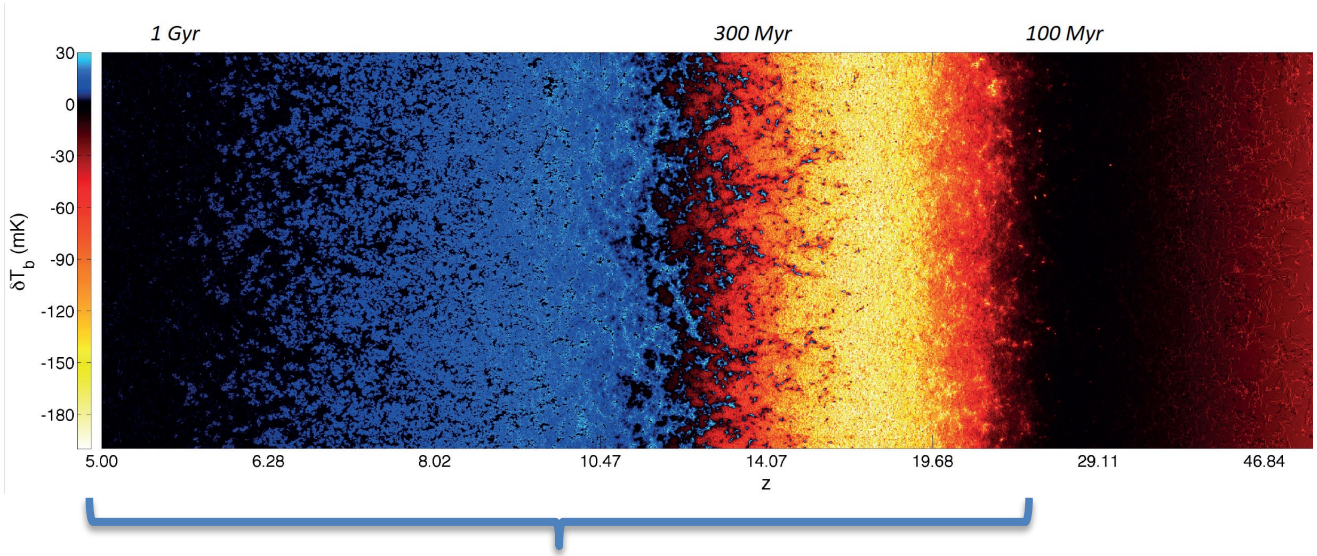
Cosmology

Studying the Universe as a whole with wide and deep surveys



Cosmic Dawn and Epoch of reionization

Exploring the formation of the first stars and galaxies in the Universe

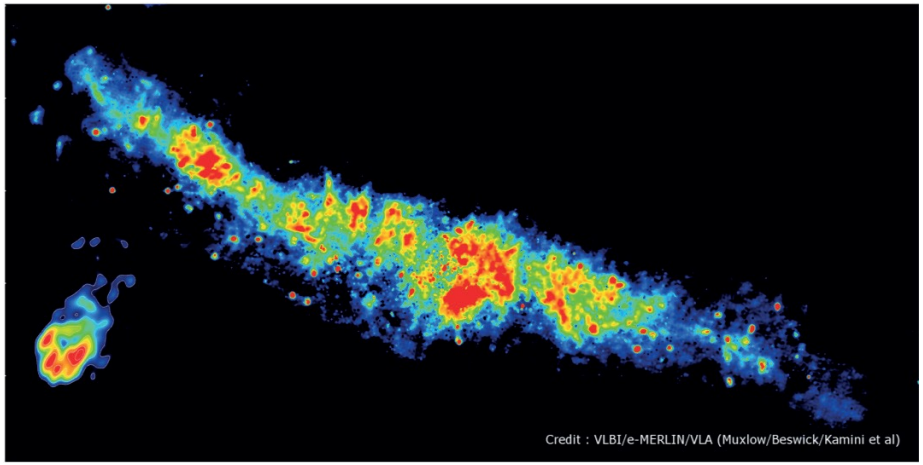


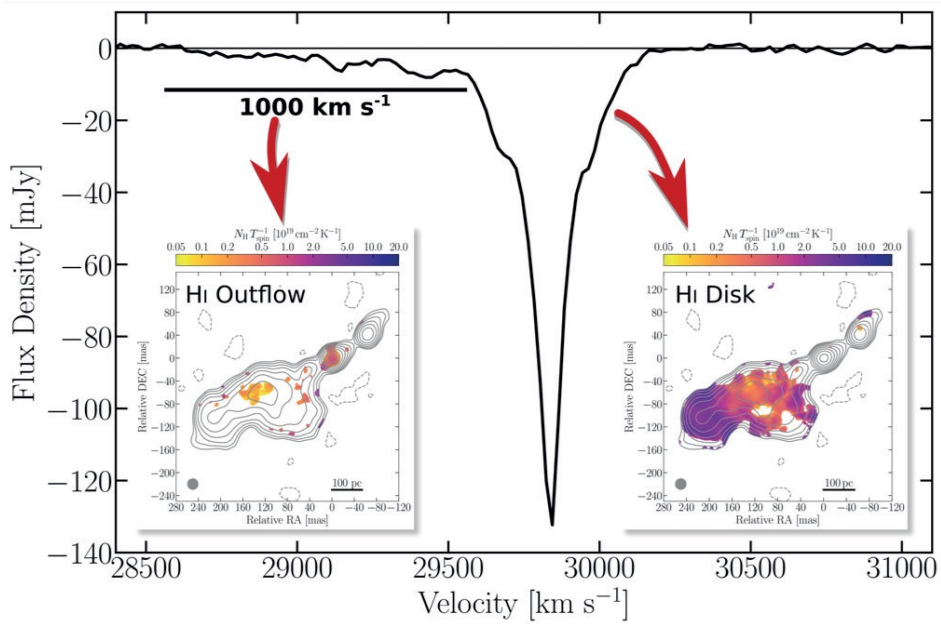
230-50 MHz, SKA Low

Evolution of galaxies:

Extragalactic continuum
HI galaxy science

The whole lifecycle of a galaxy, from gas, to stars, to accretion into a central black hole

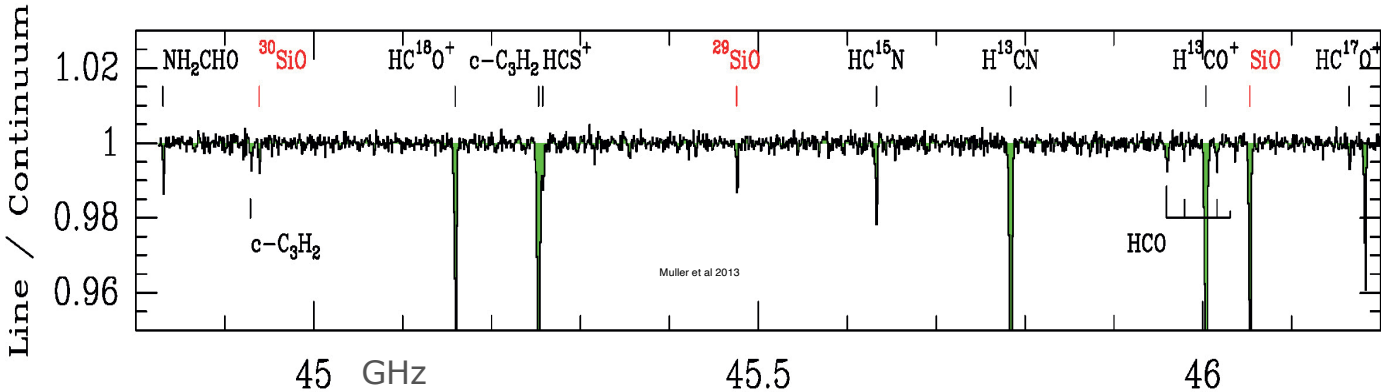


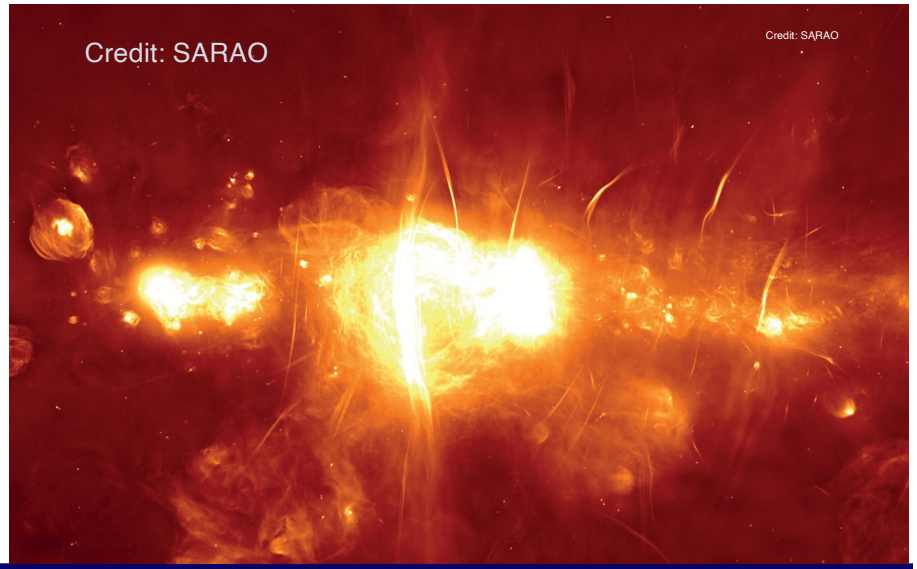


Evolution of galaxies:

Extragalactic spectral line
Our Galaxy

The spectra of galaxies reveal their composition, and there's much more than hydrogen!

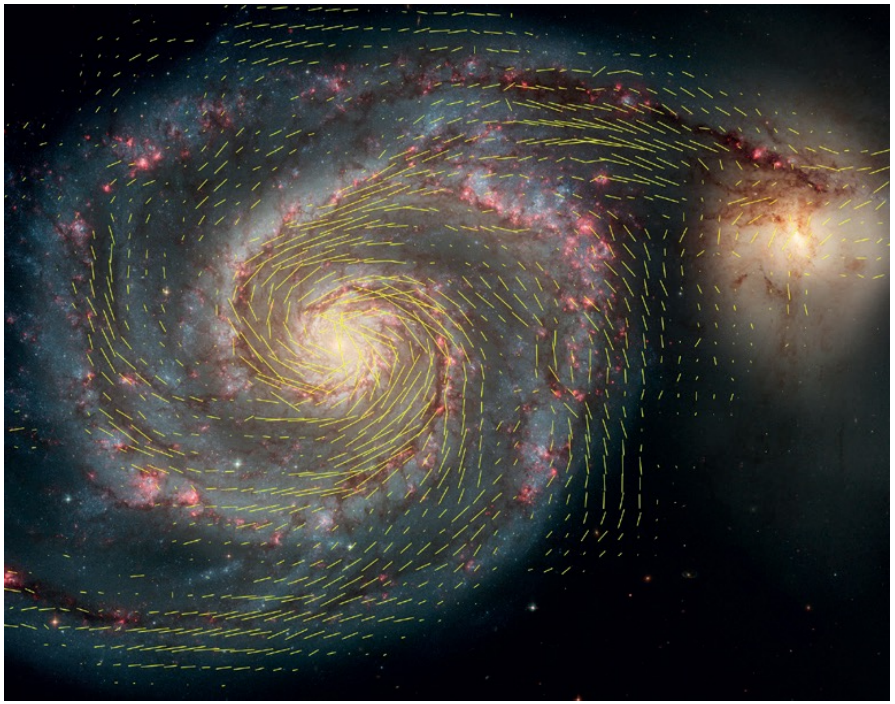


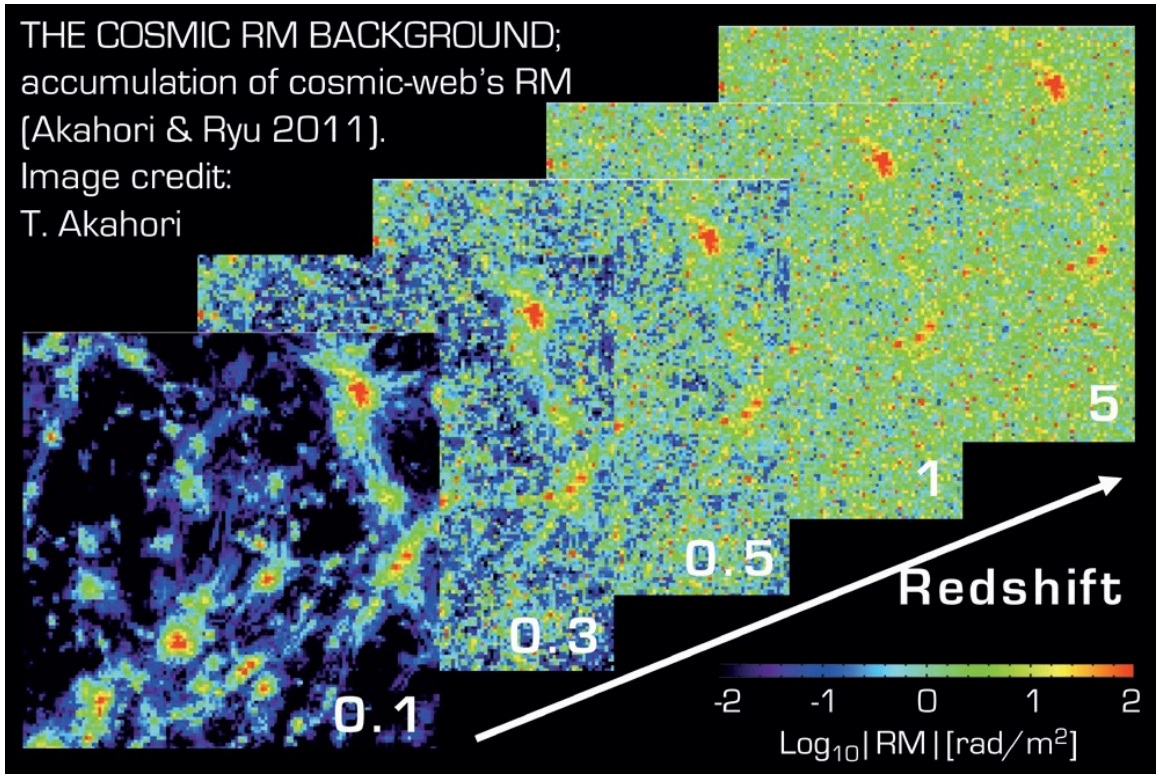


And, of course, our own Galaxy, the Milky Way, has VIP status!

Cosmic magnetism

We can measure the magnetic fields in galaxies and clusters

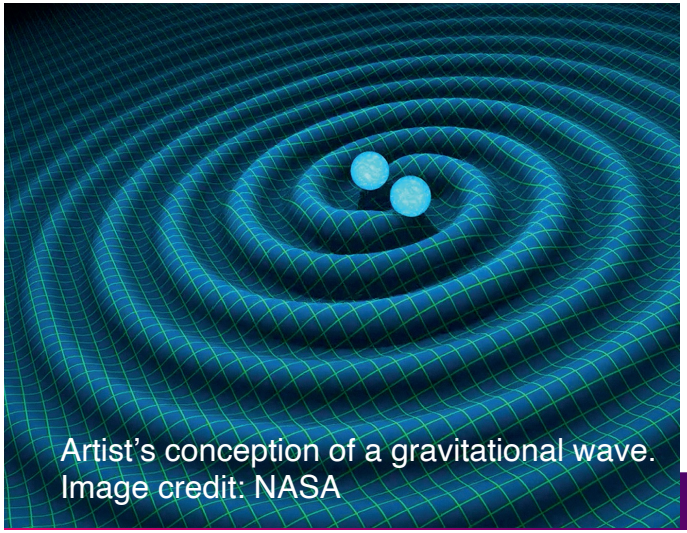


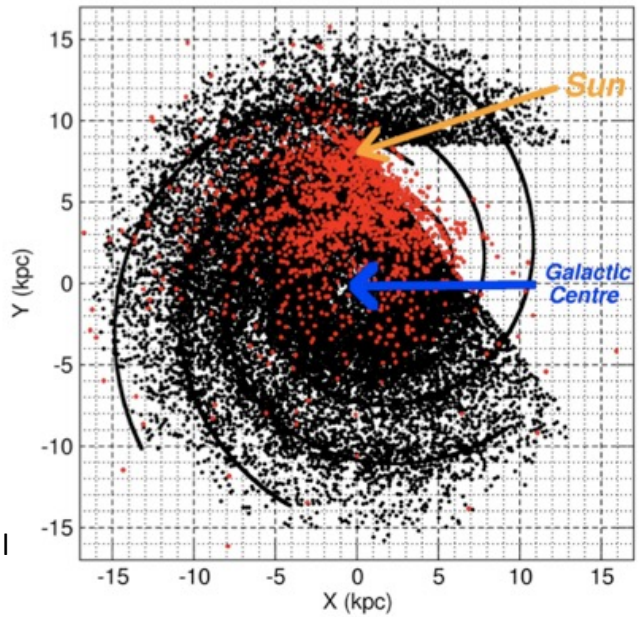


The Transient radio sky

Pulsars
Transients
Gravitational waves


Artist's conception of a long gamma-ray burst. Image credit: NASA


Artist's conception of a gravitational wave. Image credit: NASA



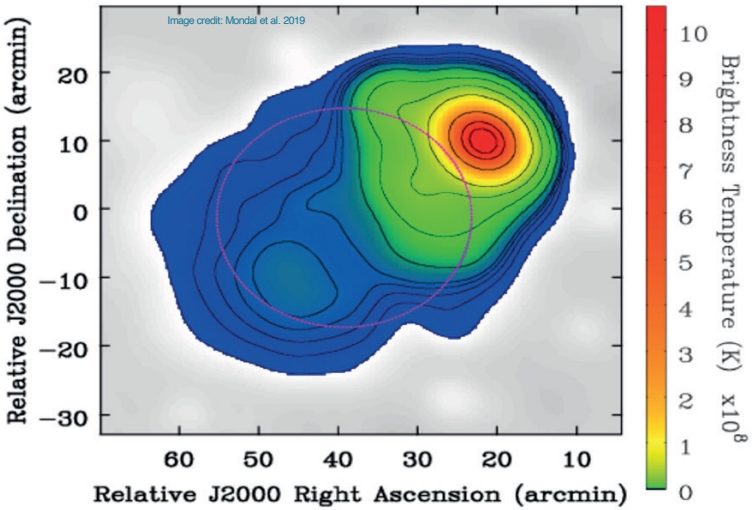
Pulsar survey of the galaxy – 50% of all Galactic pulsars detectable with SKA

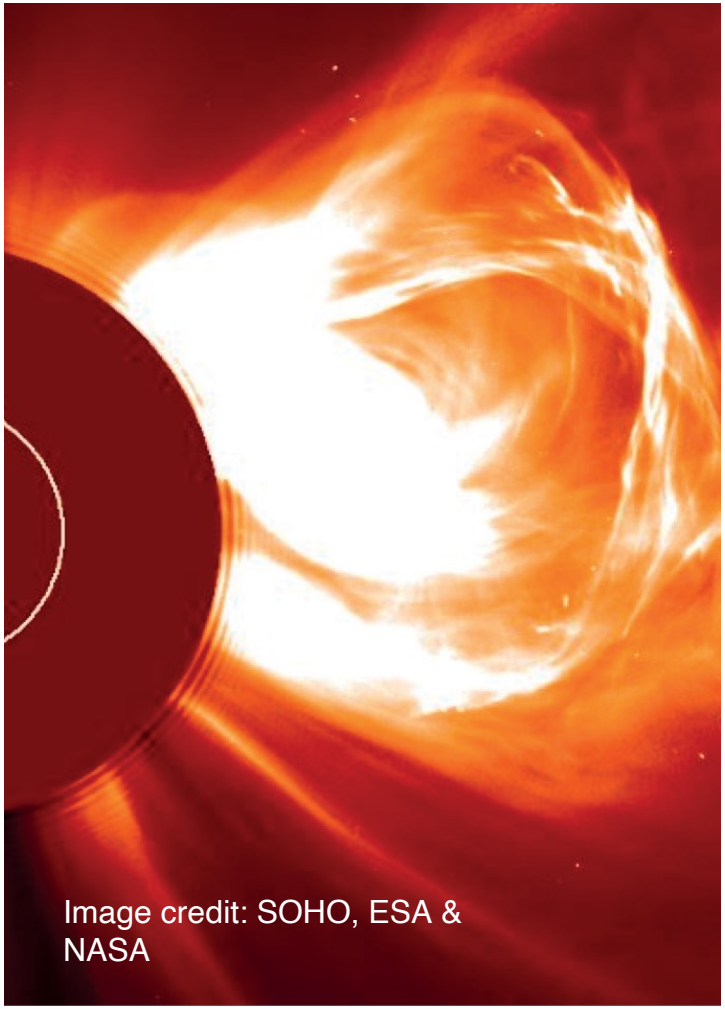
Pulsars are incredible tools to study the theory of Gravity and much more…

The transient Universe is still largely unexplored

Solar and Heliospheric and Ionospheric Physics

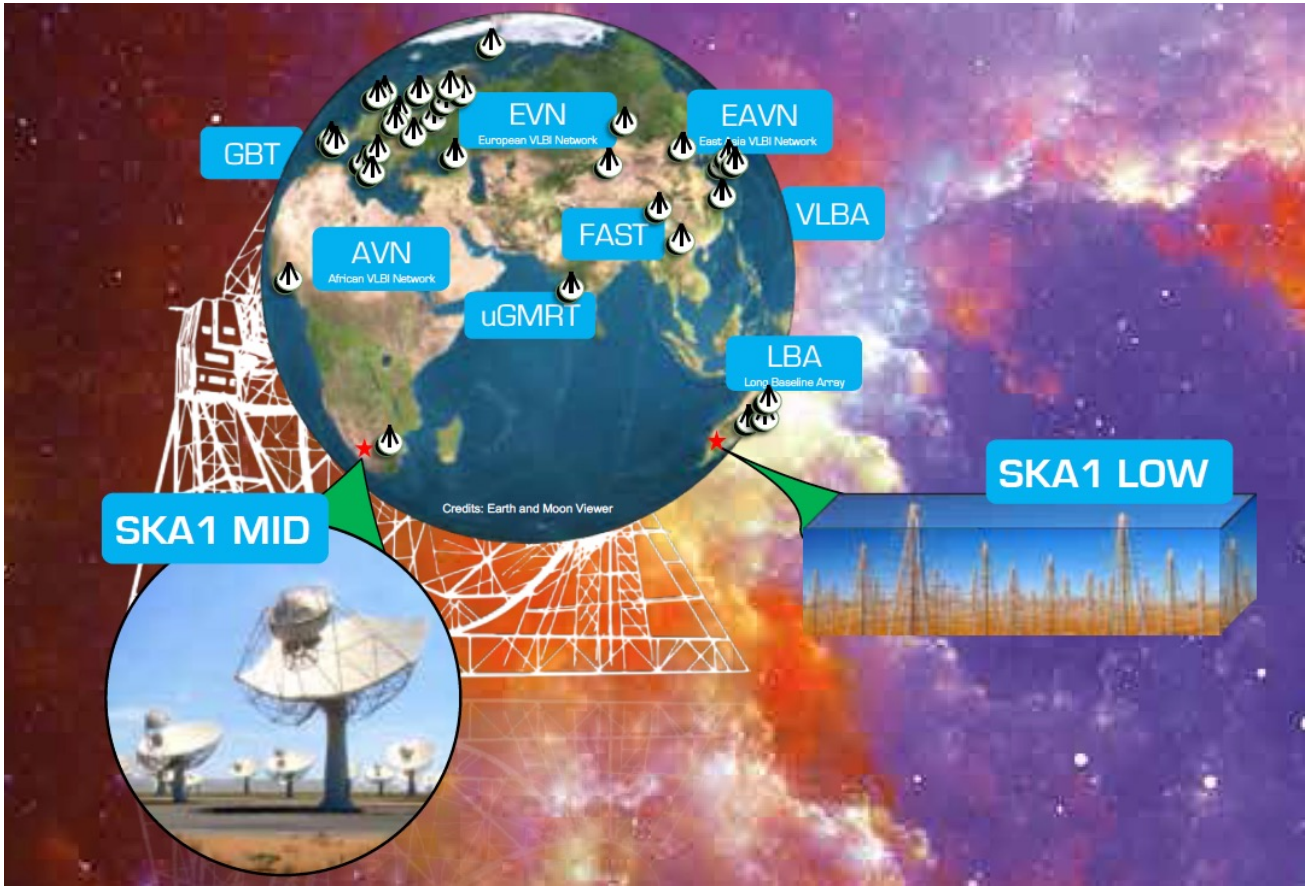
…and finally home, to our own Sun



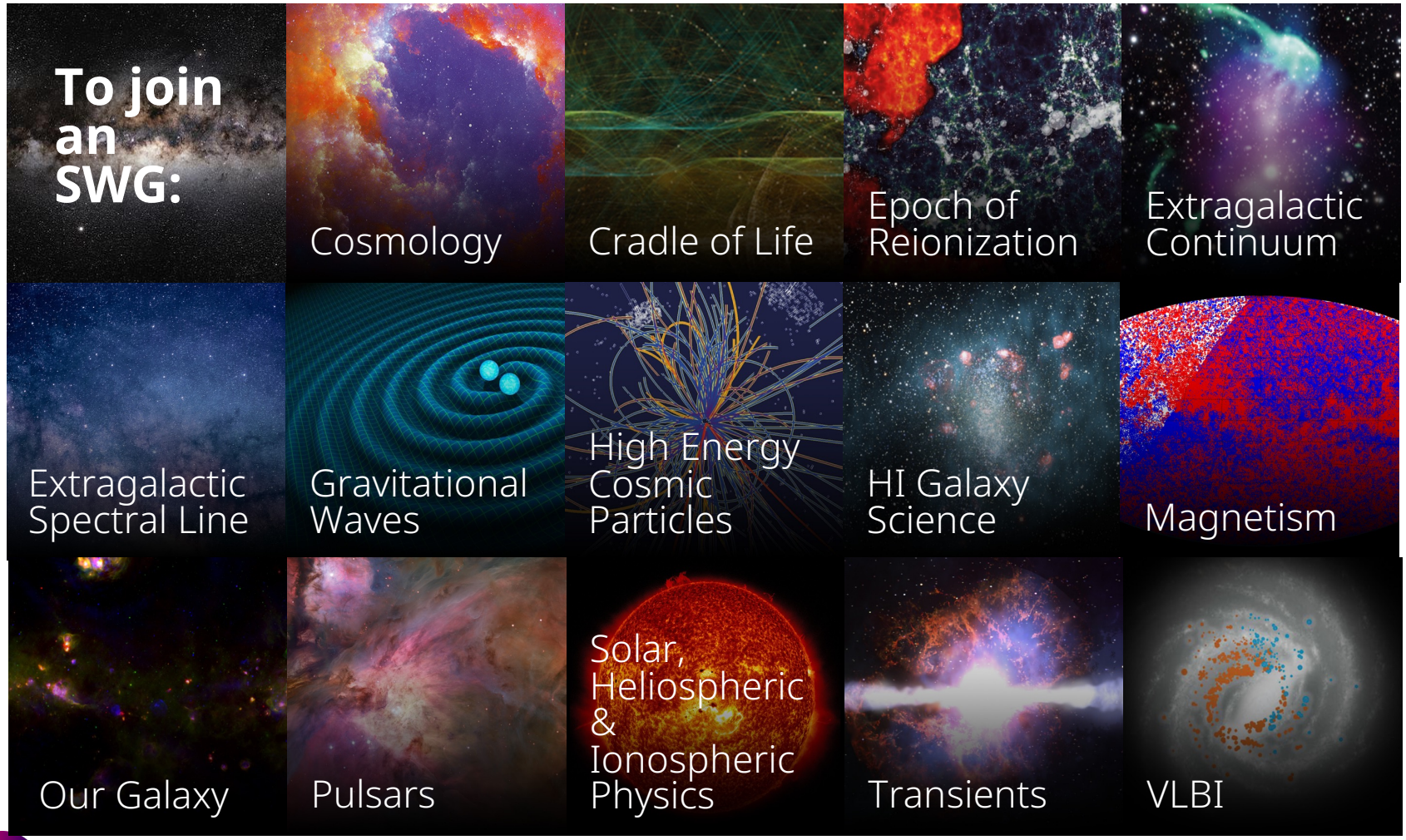


VLBI

The sharpest and deepest view of the Universe



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



- Send a request via email to the relevant SWG co-chairs
- Contact details of the co-chairs available on the website

Thank you for your time…

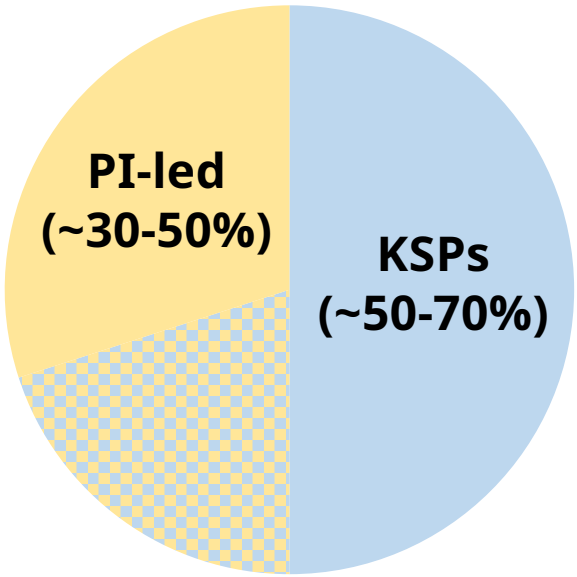
We recognise and acknowledge the Indigenous peoples and cultures that have traditionally lived on the lands on which our facilities are located.

SKAO

www.skao.int

Key Science Projects (KSPs)

- must demonstrate they address **extremely compelling science questions**
- may take up to 5 proposal cycles to complete (nominally 1 cycle = 1 year)
- requires a **Leadership Team** to oversee the delivery of the scientific outcomes
- Leadership Team will be no more than 10 individuals (one member will be the main contact for communications with SKAO, in place of a PI)
- Leadership roles are only **open to scientists from Member countries**; co-Investigators may come from any country
- Progress will be reviewed regularly by an expert panel; if the science goals are unlikely to be achieve the D-G may terminate or reduce the project

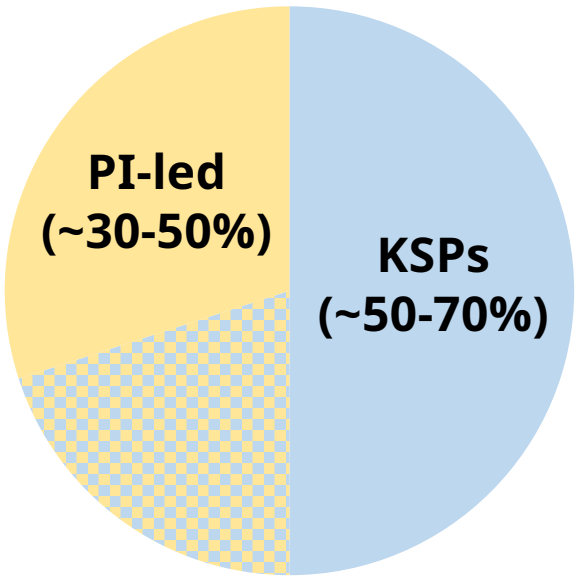


Indicative allocation split over first 5 years of normal operations

Key Science Projects (KSPs)

Each KSP proposal will be required to include:

- a detailed management plan describing the roles and responsibilities of each member of the KSP Leadership Team and the qualities they bring to the proposed science
- a plan for the reduction and analysis of Observatory Data Products (giving details of any secured resources at SRCs)
- a plan for the dissemination of scientific results to emerge from the project
- a justification for any investigators on the KSP proposal from non-Member countries[1]
- a plan for the submission of ADPs into the SKAO Science Archive.



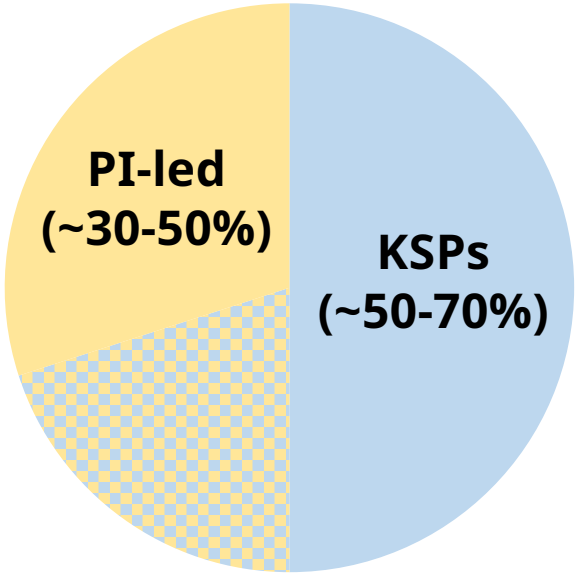
Indicative allocation split over first 5 years of normal operations

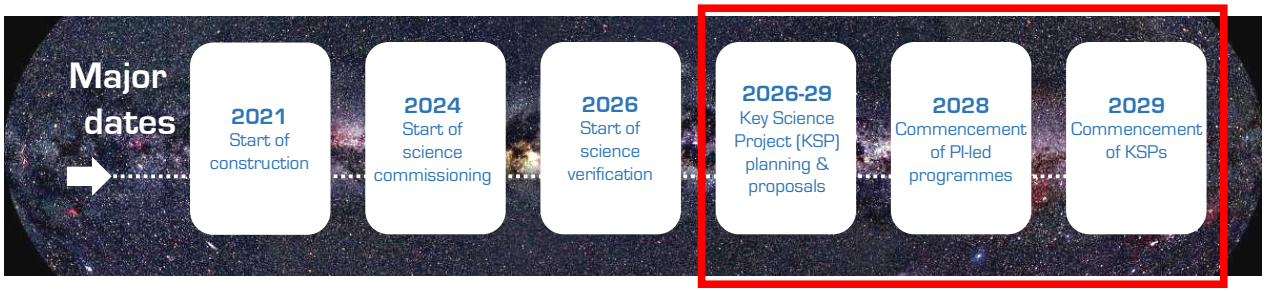
[1]a limit may be set on the fraction of investigators from non-Member countries.

Key Science Projects (KSPs)

Planning for KSPs:

- SKAO will run at least one planning workshop and issue a call for Letters of Intent (preliminary co-ordination), starting > 2 years before first KSP observations
- Workshops provide a forum for co-ordination and perhaps collaboration of proposals with similar science goals and technical needs
- Data Challenges, to help the community get used to working with SKA sized data





Telescope Access

Commensal Science

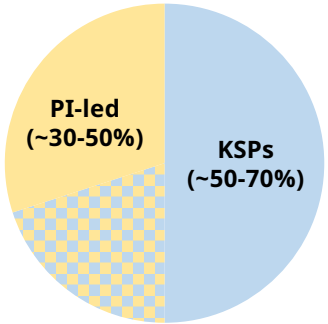
- Maximizes the use of SKA resources
- Commensal science is not "free", will be counted against member share
  - Data: different projects use same data products for different science goals
  - Observing: difference projects use same signal/data for different data products (e.g., cont., line)
  - Multiplex: different subarrays observing at the same time

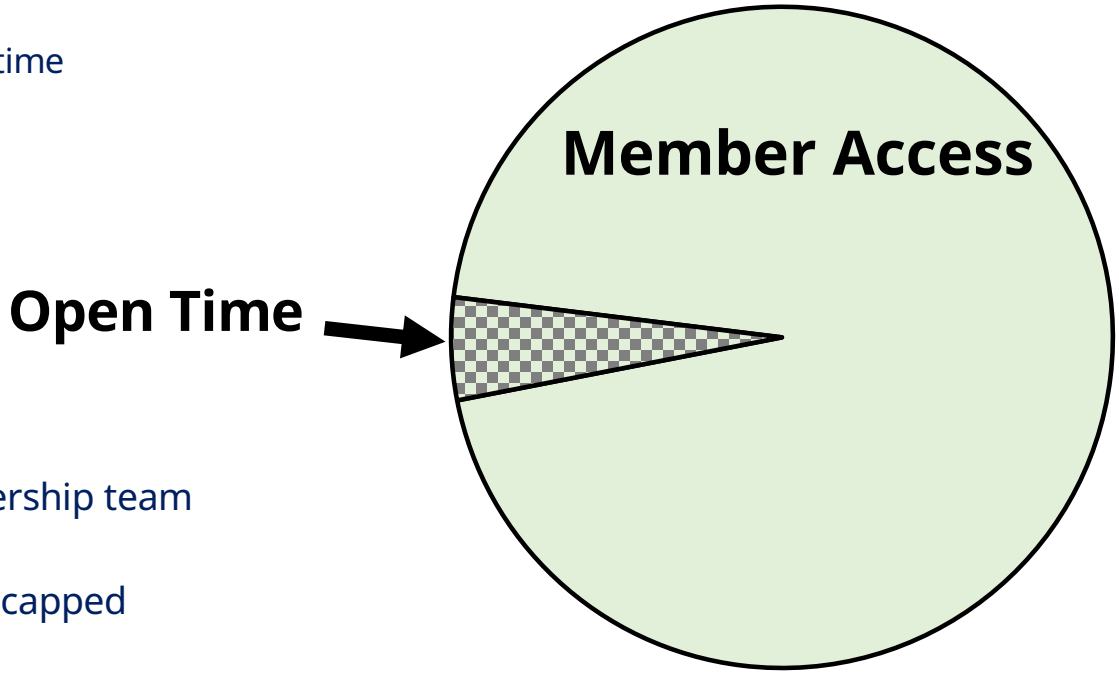
Members (and Associate Members)

- 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

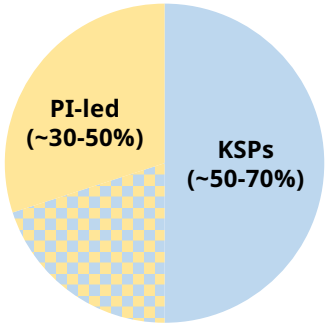


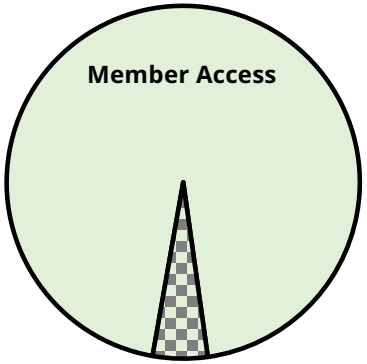


Proposal Submission & Review

Proposal Review

- All proposed reviewed and assessed by a Time Allocation Committee (TAC)
- SKAO will undertake a technical feasibility review, including evaluation of SRC resources that will be required
- TAC members appointed by D-G with advice from SKAO staff
- Proposal assessment shall be:
  - driven by scientific merit and technical feasibility
  - be fair and transparent, informed by peer review
  - be able to resolve conflicts of interest
- The TAC shall:
  - rank each proposal according to scientific merit and technical feasibility
  - provide a recommendation of telescope time and resources for each proposal
  - present a ranked list of proposals to the D-G
- The SKAO shall construct the science program, considering:
  - sky coverage
  - scheduling feasibility
  - observatory resources
  - opportunities for commensality
  - members' share of the project





Open Time