Science Operations with the Square Kilometre Array

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Outline

Introduction to the SKA

Science Programme

Operational Model

Data Flow
Introduction to the SKA

One Observatory
The Square Kilometre Array

Two Telescopes
SKA-LOW
SKA-MID

Three Sites
Australia (LOW)
South Africa (MID)
UK (GHQ)
SKA Distributed Operations

Exploring the Universe with the world's largest radio telescope
SKA Distributed Operations

Telescope Operator sits ~600 km away from the telescope at the Science Operations Centre in Cape Town.

Correlator located at the telescope and data transferred to Cape Town to the Science Processing Facility.
SKA Distributed Operations

Telescope Operator sits ~ 300 km away from the telescope at the Engineering Operations Centre in Geraldton.

Correlator located at the telescope and data transferred to Perth to the Science Processing Facility.
Introduction to the SKA

Why build our telescopes at these remote locations?

• at the our operating frequencies (0.05 – 20 GHz) radio frequency interference is our biggest enemy

Background radiation at 131 MHz (mv/m)
Murchison Radio-Astronomy Observatory

Shire of Murchison

- 50,000 km² (~NY State)
- no towns
- 29 sheep/cattle stations
- population 110
SKA1 MID - Karoo, South Africa

133 SKA1 dishes (15m), 64 MeerKAT (13.5m), core + 3 spiral arms, 150km baseline, $0.35 \rightarrow 15$-GHz covered in 5 bands
SKA1 LOW - Western Australia

131,072 antennas : 512 stations of 256 antennas, core + 3 spiral arms, 65km baselines, 50 → 350-MHz full instantaneous bandwidth
(Distributed) Technical Progress

Sweden: Band 1

RSA/Canada: Band 2

UK: Band 5
5a: 4.6 – 8.5 GHz
5b: 8.3 – 15.3 GHz

UK/AUS: Prototype NIP

NL/AUS: LOW CBF

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(Distributed) Technical

Chinese (CETC54)/German (MTM) Dish Design

Spec: rms surface of 350 µm

Individual panels: 80 - 110 µm

South Africa: DSH test foundation

China: Subreflector mould

Italy: Feed indexer
Technical Progress

SKA-LOW prototype antenna station deployed

Solar power station: 2.6 MW-hr Lithium-ion battery
SKA Organisation: 10 countries, more to join

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Australia
Canada
China
India
Italy
Netherlands
New Zealand
South Africa
Sweden
UK

Interested Countries:
- France
- Germany
- Japan
- Korea
- Malta
- Portugal
- Spain
- Switzerland
- USA

Contacts:
- Mexico
- Brazil
- Ireland
- Russia

Full members
- SKA Headquarters host country
- SKA Phase 1 and Phase 2 host countries

African partner countries
(non-member SKA Phase 2 host countries)

This map is intended for reference only and is not meant to represent legal borders

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Current Governance

Board of Directors

SKA Organisation

UK limited company

9 Design Consortia

> €170M funding

Distributed in Operations - Distributed in Design
Negotiations to Establish SKA as an IGO
Science Driven Design

SKA Science Case

- 135 Chapters
- more than 1200 authors
- 31 countries
- 9-kg of science
Science Programme

Blend of large surveys and conventional PI projects
  • in the range 50:50 to 70:30

Key Science Projects
  • coordinated approach to ensure key science objectives for SKA are addressed efficiently and effectively
  • delivery of derived data products back to the wider user community
  • encourage scientific and technical collaboration among SKA partner countries

Total allocated time to each country (KSPs and PI projects) to be proportional to share in the project
  • countries can focus on one or the other

A small amount of Open Time
  • for members and non-members on basis of merit

Data to be made openly available following a proprietary period
SKA – Key Science Drivers

- Cosmic Dawn (First Stars and Galaxies)
- Galaxy Evolution (Normal Galaxies z~2-3)
- Cosmology (Dark Matter, Large Scale Structure)
- Exploration of the Unknown
- Cosmic Magnetism (Origin, Evolution)
- Cradle of Life (Planets, Molecules, SETI)
- Testing General Relativity (Strong Regime, Gravitational Waves)
Image fidelity – simulated snapshot images
Transients and the SKA

Pulsars and Transients are an important part of the SKA science case

- High Priority Science Objectives (HPSOs)
- Pulsar Searches
- Pulsar Timing
- Transients – FRBs
- Precision Astrophysics
- Gravitational Waves

Keane et al., 2016, Nature, 530, 453
Transients and the SKA

There is a big emphasis on Pulsars and Transients in the SKA science case

- High Priority Science Objectives (HPSOs)
- Pulsar Searches
- Pulsar Timing
- Transients – FRBs
- Precision Astrophysics
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- Data Flow
Operational Model

Mission of the SKA is to enable transformational science

• conventional operational and scientific performance metrics
• complexity for SKA ⇒ can multiplex observations by use of subarrays

Conventional features:

• periodic proposal cycles
• service observing
• automated, flexible observing queue
• 24-hour operation

Complex features for SKA:

• time domain: fast response to transients and ToOs
• subarrays and commensality
• telescope operations at a distance
Availability

An SKA telescope is defined to be operationally capable when it can perform astronomical observations with at least 95% of its collecting area.

Operational availability is the probability that the system is operationally capable at any point in time when used in a realistic supporting environment.

Each telescope is required to have an operational availability of at least 95%.

95% of each SKA telescope has to be operationally available for 95% of the time.
SKA Observatory Organisation

Principles:

- one observatory
- optimal operation
- minimal duplication
- co-location of science and engineering staff
- autonomy & authority
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Data flow

SKA1-LOW

~ 2 Pb/s

~ 7 Tb/s

~ 5 Tb/s

~ 260 PFlops (130+130)

~ 5 Tb/s

~ 9 Tb/s

SKA Regional Centres

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SKA Distributed Science Operations

Observatory Data Products flow from the Science Data Processors in Perth and Cape Town to SKA Regional Centres around the globe.
SKA Distributed Science Operations

Observatory Data Products flow from the Science Data Processors in Perth and Cape Town to SKA Regional Centres around the globe.
Ordinarily, the science data processor is not considered a part of the telescope

- data reduction should never hamper or obstruct data acquisition
- data rates and volumes emerging from central signal processor are so high that we will not be in a position to store the raw data from the CSP
- it will be cheaper to re-observe than store the raw data indefinitely

The science data processor becomes a schedulable resource of the telescope for observation planning
Data flow

this schematic does not take into account any power restrictions
A collaborative model for SKA Regional Centres

There are three main factors that lead to a model of a collaborative alliance of SKA Regional Centres (SRCs):

1. The science data products that emerge from the SKA observatory are not in the final state required for science analysis. The generation of advanced data products not in scope of project. SDP must maintain throughput matched to input data rate. Combination & further analysis of data products outside of observatory boundaries.

2. The data volumes are so large that direct delivery to end users is unfeasible.

3. The community of scientists working on SKA science data products will be geographically distributed.
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does not account for possible future "discovery" archive final data volume for each project will exceed that delivered by the observatory downloading data to local machines/cluster expensive and unfeasible in long term

"take the processing to the data"

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KSPs with 1000s of hrs of observing time will dominate the science programme. Large international teams drawn from across the membership need new methods, algorithms and techniques driven by the community so they need a platform on which to do this.
A collaborative model for SKA Regional Centres

Simplified description

- a collaborative alliance
- transparent and location agnostic interface to SRCs for users
  - no SKA user should care where their data products are
  - all SKA users should be able to access their data products, irrespective of whether their country or region hosts a regional centre
CERN-SKA Collaboration

This summer saw the establishment of a Collaboration Agreement between CERN and the SKA

Kick-off meeting was held at SKAO in Oct17
SQUARE KILOMETRE ARRAY
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