Big Data and Extreme Computing for the Square Kilometre Array

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Tuesday, 30 April 13
The Square Kilometre Array

- 2020 era radio telescope
- Very large collecting area (km²)
- Very large field of view
- Wide frequency range (70MHz - 25 GHz)
- Large physical extent (3000+ km)

- International project
- Telescope sited in Australia and South Africa
- Headquarters at Jodrell Bank, UK
- Multiple pathfinders and precursors now being built around the world
- Now entering pre-construction phase

<table>
<thead>
<tr>
<th>SKA Element</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dish Array</td>
<td>SKA1_Mid : 190 x 15m dishes + SPFs</td>
</tr>
<tr>
<td>Low Frequency Aperture Array</td>
<td>SKA1_Low : 280 Aperture array array stations</td>
</tr>
<tr>
<td>Survey Instrument</td>
<td>SKA1_Survey : 60 x 15m dishes + PAFs</td>
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</tbody>
</table>

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<thead>
<tr>
<th>SKA Element</th>
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<tbody>
<tr>
<td>Low Frequency Aperture Array</td>
<td>SKA2_Low</td>
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<tr>
<td>Mid Frequency Dish Array</td>
<td>SKA2_Mid</td>
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<tr>
<td>Mid Frequency Aperture Array</td>
<td>SKA2_Mid_AA</td>
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</tbody>
</table>

Exploring the Universe with the world’s largest radio telescope
SKA1 data products and transformations

0.3 to 3 TB/s

Enhanced data products e.g. Source identification and association

Validated science data products (released by Science Teams)

Calibrated data, images and catalogues

Visibility data

Correlator output

Beam-former output

ADC outputs

0.3 to 3 TB/s

10 - 500 TB/s

~ 100 PB data set read multiple times over several days

e.g. 1 year

Redshifted Hydrogen survey ~ 4EB

Low frequency aperture array

Dish arrays

1. ADC outputs
2. Beam-former output
3. Correlator output
4. Visibility data
5. Calibrated data, images and catalogues
6. Validated science data products (released by Science Teams)
7. Enhanced data products e.g. Source identification and association

Level

Definition

Responsibility

ST

SKA

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Example of cost model

### 2019 costs
- Based on four kernel model of processing
- Expect to update this model continuously over preconstruction
- Poor on cost of data movement

<table>
<thead>
<tr>
<th>Baseline (m)</th>
<th>Ingest</th>
<th>Calibration</th>
<th>Continuum</th>
<th>Spectral_Line</th>
<th>Transient</th>
<th>All</th>
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<tbody>
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<td>€73,835</td>
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<td>€3,282,435</td>
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</tbody>
</table>

**Processing costs of SKA1_Low, diameter 53m, vs baseline**

- Exploring the Universe with the world’s largest radio telescope

**Tuesday, 30 April 13**
• What architectural changes are needed?
  – Tighter integration of storage, computing and networking.
    • The classical split between storage and computing requires that large amounts of data have to be moved even for very little computing.
  – More intelligent, hierarchical object storage and application driven networking
    • Could potentially perform in-storage filtering and/or on-stream transformations.
  – Dynamic integration of several memory and cache levels into intelligent data movement/pre-fetch agents.
  – Cassandra and Hadoop work well for some use cases
Workflows

• Describe a forwarding-looking workflow
  – Our workflows are mainly data reduction
    • Ingest, editing, calibration, imaging, source finding, analysis, archiving
    • With some iteration
    • Run constantly (as the telescope observes)

• What software is missing to support your workflow?
  – Tighter integration between data movement services and compute scheduling
  – Observability tools (monitoring) for data flow within systems
  – Something like Infosphere streams, Twitter Storm,...
• Outline how you use your data
  – BDEC system is part of the telescope
  – Telescope becomes adaptive to cancel calibration effects
  – Steps are: acquire, edit, calibrate, transform, analyse, with iterative cycles
  – Too much data to allow guiding by humans
  – But analysis step requires some human guidance and performance
  – Analysis rich in visualization, feature identification, catalog queries
  – Survey science
Taxonomy

• Data-driven mini-application?
  – Not yet but will be developed

• Cross cutting concerns
  – Advanced I/O optimised data formats (e.g. ADIOS: http://www.olcf.ornl.gov/center-projects/adios/)
  – Usability of systems for astronomers. Barrier to entry is getting ever higher. Astronomers spending more time wrestling with systems and less doing core research.
  – Turnaround time, the ability to do quick iterations on petascale datasets just like we do on gigascale datasets.
    • Fast iteration == productivity
• **Data flow**
  – Waterfall with successive phases of refinement and lossy compression
  – Processes simple at beginning of flow, less so at end
  – Some phases (calibration and imaging) required multiple (10?) passes through data
  – Analysis requires long residency of result in “working set”: days to weeks
  – Arithmetical complexity low throughout
Software

- What software are you currently using to manage and explore your data?
  - Software is largely bespoke
    - CASA, CFITSIO, WCSLIB
    - ASKAPSoft
    - SKA expects to spend about 150 FTE-years

- What algorithms and software libraries/tools need development and improvement to address your big data needs?
  - Synthesis calibration and imaging algorithms must scale up ~ 10,000

- Problems without a full solution
  - Fault tolerance
Interoperability challenges

- Provenance, etc.
  - Well in hand from IVOA work

- Semantics
  - There is a semantics working group in the IVOA and they have produced a complete ontology of astronomical object types
  - All of the IVOA standards use the UCD standard vocabulary.
    - A UCD does not define the units nor the name of a quantity, but rather "what sort of quantity is this?"
  - Implementation slow
  - Need a proper, controlled mechanism of machine-readable semantic tagging of quantities and data objects