Are we there yet?

Experiences developing and commissioning the HPC System for ASKAP Telescope

Juan Carlos (JC) Guzman | Head of ATNF Software and Computing
Perth HPC Advisory Council Conference – 31 July – 1 August 2017

CSIRO ASTRONOMY AND SPACE SCIENCE
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We acknowledge the Wajarri Yamatji people as the traditional owners of the Observatory site and the Noongar people as the traditional owners of the land where this meeting is being held.

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Outline

Overview of ASKAP

ASKAP Computing System history, challenges and future

Lessons Learned
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Lessons learned
Australian SKA Pathfinder - overview

• 36-antenna multi-beam interferometer in a radio-quiet zone
  • Frequency range: 700 MHz – 1.8 GHz, baselines from 23m to 6km
• Survey instrument – pushing wide instantaneous field of view
  • 2nd generation phased-array feed (PAF) receiver + flexible beamformer
  • 3-axis mount (whole antenna can rotate) – can fix or rotate beam pattern
  • Automatic processing eventually – necessary for the full instrument
• Early science with 12 antennas started in October 2016
  • Most reported science was with BETA (6-antenna array with MkI PAF)
  • 18 antennas have already been integrated into the array
Phased Array Feed – 188 single pol receivers
Wide field of view
Murchison Radio Observatory (MRO)

- 126 km²
- 32 km roads and tracks
- 16 000 km optic fibre
  - >8000 fibres
- Control Building
- Power station
  - Under construction
MRO power station
ASKAP – system architecture

Combined data rate ~ 21 Tb/s

~ 2.5 GB/s
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Lessons learned
Indirect imaging of the sky

Synthesis telescopes measure correlations between received voltages for each pair of antennas.

To the first order (narrow FOV), the measurement equation is a 2D Fourier Transform.

Three different types of images are required:

- **Continuum image**
  - Very accurate image
  - Need multiple iterations
  - Hard to parallelize

- **Spectral line cube**
  - 16200 independent images
  - Each at slightly different frequency
  - Embarrassingly parallel task
  - One iteration may be sufficient

- **Transient image**
  - Very coarse image
  - Made every 5 seconds

We need to make images in near real time, ideally all three types in parallel.
Indirect imaging of the sky

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ASKAP Key Computing Requirements

• 90% Computational Cost in gridding/degridding
  • [Link](https://www.skatelescope.org/uploaded/59116_132_Memo_Humphreys.pdf)
  • Developed stand-alone benchmarking gridding code for testing in multiple platforms
• 10,000 cores (80% efficiency), 4 GB/core ▶️ **200 TFLOPs Peak**
• Data Ingest from Correlator ~ 2.8 GB/s = ~ 10 TB/h (Raw Visibilities)
• Processing of raw visibilities (calibration & imaging) needs to keep up
  • Cannot afford to keep raw visibilities
  • Multiple science products after observations ~ 5 PB/year
The Pawsey High Performance Computing Centre for SKA Science

- AUD$80M super-computing centre
- 25% resources to support operational requirements of storage and processing of data from ASKAP and MWA
- Construction completed April 2013
ASKAP Central Processor @ Pawsey Centre

**Ingest cluster**
- 16 nodes, 2 sockets per node
- 8 cores CPUs, 64 Gb of RAM per node

**Central Processor (Galaxy)**
472 x Cray XC30 Compute Nodes
- 200 TFlop/s Peak
- 64 Gb of RAM per node
- 2 sockets per node, 10 cores each

**Shared storage**
Cray Sonexion Lustre Storage
- 1.3 PB usable
- 480 x 4TB Disk Drives
- Peak I/O performance: 30 Gb/s
ASKAPsoft

• In development since 2007
  • Extensive re-use of core libraries
  • Re-written Synthesis (parallel) code C++/MPI

• Assumptions
  • Instrument stable (relatively easy to calibrate)
  • Good global sky model
  • Imaging model adequate

• Automated calibration and imaging (pipeline)
  • ASKAP is one of the pathfinders in this domain (streaming + batch)
  • Treat processing software as a part of the telescope
  • Requires paradigm shift in the science community

• Commissioning requires different things to the full telescope
ASKAPsoft for Commissioning & Early Science

- Smaller datasets!
  - 1 TB/hr (ASKAP-12) vs 10 TB/hr (ASKAP-36)
  - Larger natural resolution (maximum baseline = 2.18km)

- Able to do manual processing – still hard (many beams, large cubes), but tractable
  - Processing team will run pipelines manually upon completion of observation
  - Needed to understand and learn about the instrument!!

- Some features not available
  - Processing is not automated
  - No Sky Model available, nor calibration service applied in ingest
  - Transient pipeline not yet developed
Results: ASKAPsoft: First 36 beam image

- Continuum image with 9 antennas at 939.5 MHz
- Processing resembles an early-science experiment
- Each beam calibrated separately
- Individual deconvolution of different beams

- Only ASKAPsoft used

Image credit: Wasim Raja
Results: NGC 7232 WALLABY Early Science

Credit: Juan Madrid – 14 Sep 2016
ASKAP Computing Project

• Team of 7 people distributed between Perth & Sydney
• Iterative software development process ~ 2 months cycles
• Continuous Integration Tool (Jenkins)
• Confluence & JIRA
• Subversion soon to be moved to git
Issues

• 1.3 PB Fast storage (Lustre filesystem) aka /scratch2
  • Multiple users doing manual processing needed during commissioning and Early Science
  • Shared with MWA users
  • Shortage of space and non-deterministic performance affected the data ingest software (ingest pipeline)
  • Underestimate scratch space of Early Science Program

• New 1.9 PB filesystem in May 2017
  • Procured by Pawsey
  • 1 PB dedicated to ASKAP real-time and 0.9 PB to MWA

• Still have a shortage of 0.5 – 1 PB to support Early Science program depending on the fate of /scratch2
Issues

• Need stable instrument to validate our assumptions
  • PAF beams stable (relatively easy to calibrate)
  • Good Global Sky Model (continuum)
  • Imaging performance adequate (high dynamic range)

• Early Science and Commissioning different use case as full (automated) pipeline -> Scope Creep

• Under-estimate effort on software integration, verification and support

• Sharing resources with ASKAP Commissioning and SKA pre-construction
Next steps

• Software Development for basic modes for full ASKAP
  • Scaling testing and debugging
  • Real-time services development and integration (calibration)
  • Automated continuum and spectral line pipelines

• Additional Science Pipelines
  • Full Polarisation Calibration
  • ”Postage Stamps” – small regions (10” spatial resolution)
  • Transient and Zoom-mode pipeline

• Upgrade of the Galaxy platform in 12 – 24 months (TBD)
  • Testing, profiling in Athena (benchmarking & data challenges)
  • Evaluating GPU code
  • Updating ASKAP Computing Requirements
Next steps – Towards SKA1 in Australia

- **SKA1_LOW ~ 100 times larger than ASKAP**

- **Joint ICRAR/CSIRO SKA Science Data Processing Project (named Rialto)**
  - Continue our involvement in SDP consortium towards CDR
  - Next generation of calibration and imaging processing software as a prototype for SKA1_LOW, ASKAP and MWA
  - Re-use of ASKAPsoft and DAliuGE Execution Framework
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Lessons learned
Lessons learned (for SKA1)

• ASKAP operations model does not follow traditional HPC (batch) user/support model
  • Build strong relationship with service providers: Service Agreements, co-location
  • Dedicated resources at all levels for Radio Astronomy: People, Software, Hardware

• Commissioning of telescopes takes long time, significant resources and is different to full operations of the telescope
  • Support the transition period was underestimated

• Isolate fast shared storage (Lustre filesystem) from “traditional” HPC user model and include more storage if you can
Are we there yet?

ASKAPsoft is already working!

Still lots of work to do, many challenges ahead and more to learn!

When software is really finished?...
...Never?
Thank you

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