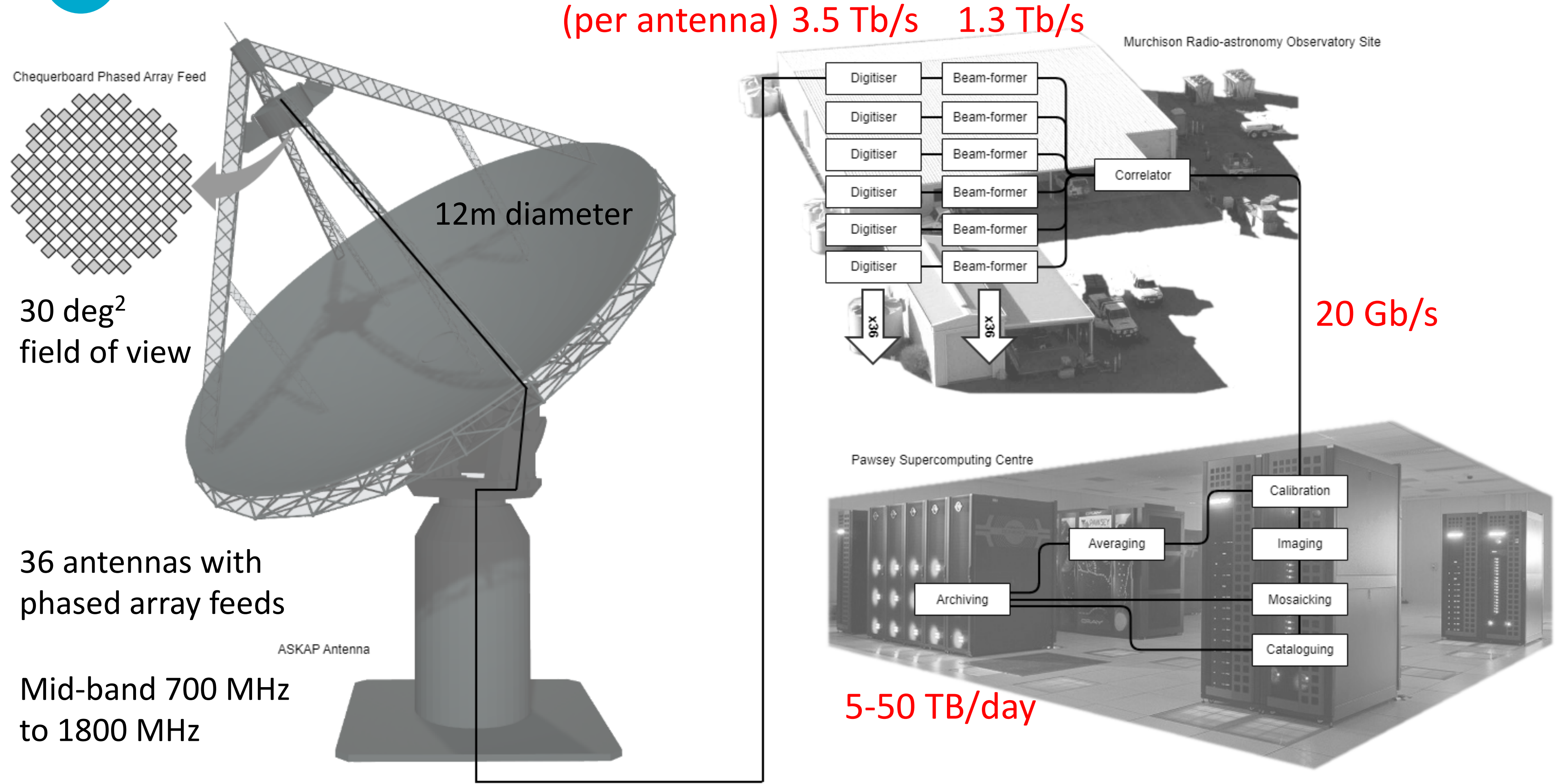
# ASKAP commissioning

## Verification and Early Science

Aidan Hotan | 26-11-2019

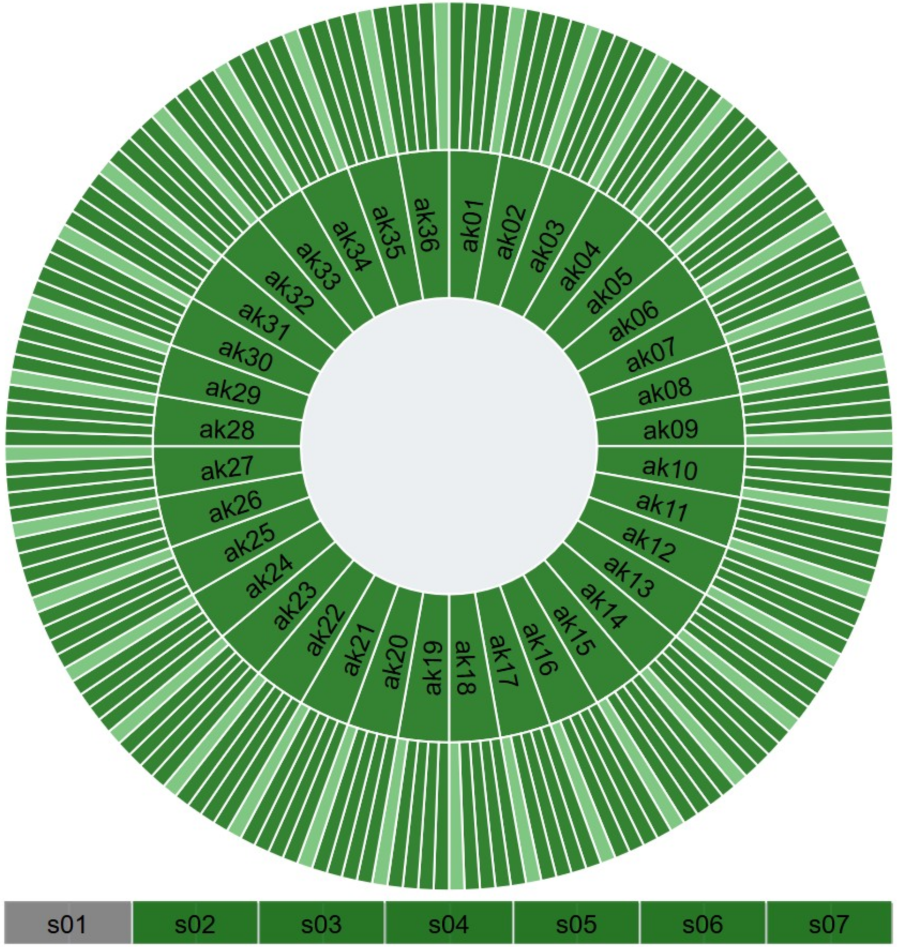
Australia's National Science Agency

# ASKAP system summary



# ASKAP current status

- Started operations this year, conducting pilot surveys now
- Commissioning efforts spanned nearly a decade
- System still actively evolving from operational experience
- Producing excellent science
- Many lessons already reflected in SKA plans



# Lessons from commissioning

- The first deployment will have major issues (despite all the CDRs)
  - Real-world performance and problems are extremely difficult to predict
    - Deploy prototypes *in the field* and expect production performance to differ
    - *Integrate* prototype systems as soon as possible and *allow time for testing*
- High-level systems with many links are very difficult to integrate and test
  - e.g. Telescope manager software, data processing pipelines
  - These exist in the *"chaotic"* complexity domain when first deployed!
- Issues of scale are difficult to predict and arise late in construction
  - Tests may pass for one or two units, but fail in the field with hundreds
  - Investigating such issues usually needs to be done on the full system

ASKAP test platform at Parkes (below) and early deployment at MRO (right)

Mk I PAFs did not meet performance specifications when tested on-sky, but the first 6 production units were already being built

# The path to operations


Engineering acceptance tests need commissioning-level depth

Commissioning develops the first operational procedures

- Different constraints, goals and procedures in each phase
  - These come into conflict and need to be balanced carefully
- Each phase overlaps the next and knowledge should be retained
  - Operational improvements may need significant engineering effort

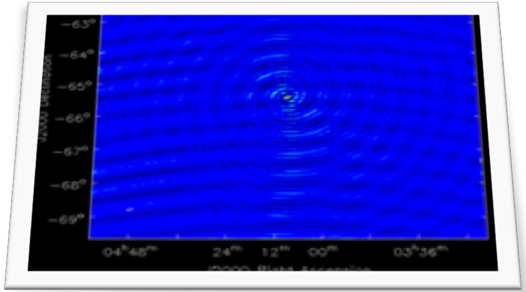
# Planning to commission a new telescope

- Start early, build the commissioning team during design
  - Make sure commissioning work can provide feedback into designs
  - Involve designers in commissioning newly deployed hardware
- Test everything, visualise outputs, *do unexpected things*
  - Commissioning requires tools that may not be obvious from requirements
- Develop a culture of *shared responsibility* instead of “hand over”
- Build support for partial systems at all levels of complexity
  - This is a hardware consideration as well as software/firmware

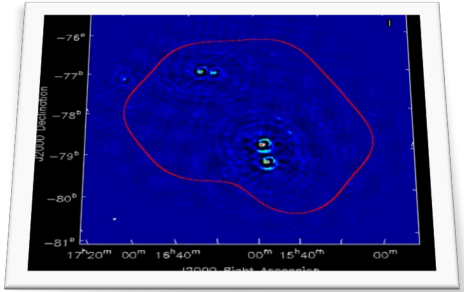
# Attempting science during commissioning

- Science observations are the ultimate system test
  - Simulations prepare for scale, but not robustness – *real data are messy*
- Long term science planning is risky in the absence of data
  - Strategies can change – e.g. EMU moving frequency bands due to RFI
- Science working groups need links to commissioning
  - ASKAP Commissioning and Early Science (ACES) integrated model
  - Tracing science data quality issues to engineering solutions is difficult
    - Even *communicating the nature of a problem* is challenging
- Early science reacts to opportunities and identifies new priorities
  - Small amounts of data can be hugely beneficial to the science community

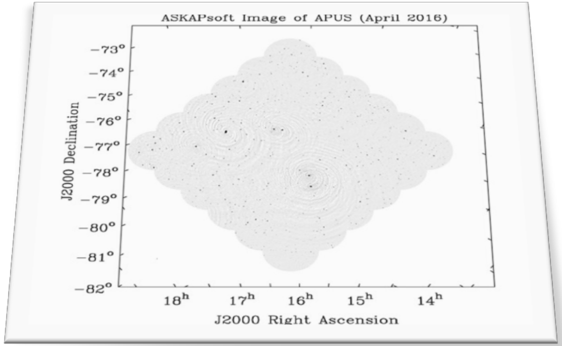
# Growth of ASKAP reflected in image quality



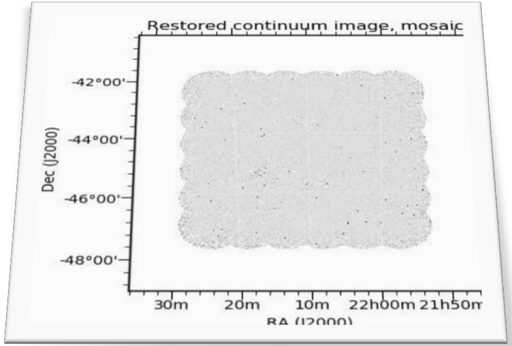
1 beam, 3 antennas



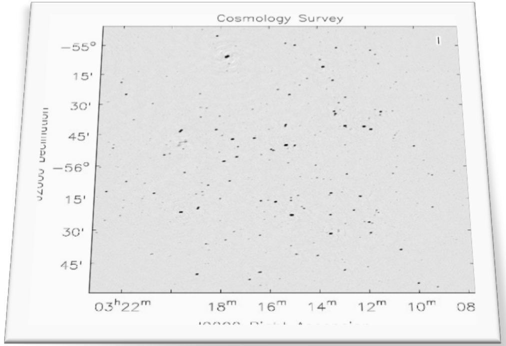
9 beams, 6 antennas



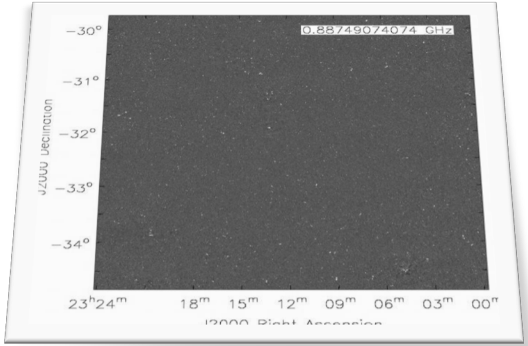

36 beams, 9 antennas




36 beams, 12 antennas




36 beams, 16 antennas




36 beams, 36 antennas

# ASKAP's early science program

- Survey-scale operations with an early array release of 12 antennas
  - Verify continuum and spectral line observing and processing modes
  - Search for *unexpected features and systematics* (e.g. beamforming boundaries)
  - Two moderate-scale surveys planned for the whole science community
    - – This evolved into a more flexible series of small observations
    - – Science teams actively involved in data processing using observatory software

- Highlighted gaps between commissioning and operations
  - Additional tools needed (beam management, visualisation, etc.)
  - Commissioning requires *getting the right answer once*, operations requires automation, robustness, efficiency and *sustainable procedures*

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# ASKAP Early Science Public Data Release

10-07-2017: In this update, we announce the first public release of ASKAP early science data via the CSIRO ASKAP Science Data Archive (CASDA). This document provides an overview of the released observations, along with some important notes for users.

## The ASKAP early science program

ASKAP early science involves a series of observations made with a sub-array of nominally 12 antennas equipped with Mk II phased array feeds. It occurs while installation and commissioning of additional hardware is ongoing. These observations are designed to verify all components of the system including the science data pipeline and public archive. As experience is gained, early science observations will evolve into precursor surveys that have the potential to make new scientific discoveries.

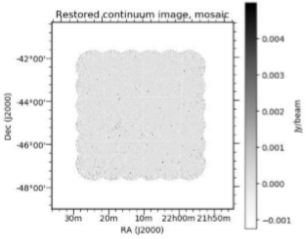
Observations began in October 2016. Since then, members of the ASKAP Commissioning and Early Science (ACES) team and the Survey Science Teams (SSTs) have been busy tuning the ASKAPsoft imaging pipeline to produce the best possible output.

We have defined a suitable set of quality metrics to assess the data and are now satisfied that any major issues have either been solved or documented, with work-arounds provided where appropriate.

## NGC7232 observations

The first data release consists of several observations of the interacting galaxy pair NGC7232/3 and other sources in the surrounding field. ASKAP was configured with 48 MHz of bandwidth at a centre frequency of 1.4 GHz using 36 beams in a 6x6 square configuration with 0.9-degree beam spacing. Visibilities were recorded with 18.5 kHz frequency resolution and 10 second time resolution, but this release has been averaged to 1 MHz.

Observations typically ran overnight, for periods of up to 12 hours. To better sample the field of view, we observed using two different field centres (labelled A and B) on different nights. Note that although we observed "interleaved" positions (beam centres from the B-field footprint placed on the inter-beam positions of the A-field footprint), these field centres were observed on different nights using different scheduling blocks. We have released mosaiced images from each block individually and combining the interleaved blocks is left to the user.




**An example Stokes-I continuum image of the observed field.**

### Accessing the data archive

Released ASKAP data can be obtained from the CSIRO Data Access Portal. While the number of scheduling blocks remains small, users can feasibly browse the collection by performing a null search for all released data. It is also possible to access the archive via a Virtual Observatory Table Access Protocol interface. Some quick instructions are given below and more detailed documentation is available in the CASDA Users Guide.

### Web interface instructions

Once a search query has returned, tabs at the top of the listing page can be selected to view different types of data products. The list currently includes *catalogues* created by the Selavy source finding software, *continuum images* in FITS format and tar archives of calibrated *visibilities* stored as CASA measurement sets (one file per beam).

The CASDA index can be viewed by anyone but users must obtain an OPAL account to download files.

Hovering over the rows in the list will cause an entire row to highlight – clicking anywhere within the row will open a summary page for that data product, with a more extensive description that includes FITS headers and an image preview where available.

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# ASKAP Early Science Public Data Release

In this update, we announce the public release of a new ASKAP early science data set – a subset of fields from the "cosmology survey". This document provides an overview of the released observations, along with some important notes for users.

## The ASKAP early science program

These data were observed during the ASKAP early science program using a sub-array of 16 antennas equipped with Mk II phased array feeds. Observations occurred during installation and commissioning of additional hardware and do not represent the full capability of the telescope.

## Cosmology observations

The cosmology survey was designed by the EMU science team as a first attempt at a wide-area continuum survey, with the primary goal of using radio galaxy population statistics to measure cosmological parameters.

The planned survey covered 2000 square degrees, using 68 fields to tile a rectangular region in equatorial coordinates (RA 20:30 to 05:30 and Dec -60 to -45).

Observations began in February 2018. The first round of observing captured 16 of these fields and then paused to assess the quality of the resulting images. This revealed that we were not reaching the required RMS noise level and the survey was not continued in its initial form.

However, 10 of the 16 observed fields produced good quality images, released with the expectation that they will be useful for other science projects.

### Telescope configuration

This data release consists of 10 fields of roughly 30 square degrees each. They were selected according to hour angle from the full set of 68 survey fields (see below) and do not form a continuous region. ASKAP was configured with 240 MHz of bandwidth at a centre frequency of 912 MHz using 36 beams in a 6x6 square configuration with 0.9-degree beam spacing. Visibilities were recorded with 18.5 kHz frequency resolution and 10 second time resolution.

Each field was observed for 200 minutes without interleaving. The RMS noise level is 150 μJy/beam using the default ASKAPsoft pipeline and robust -0.5 weighting.

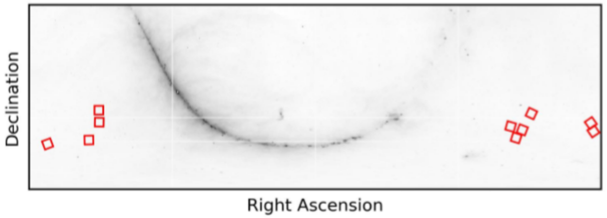
In the interests of allowing additional spectral line processing, this release includes the calibrated visibilities as CASA measurement sets at 18.5 kHz resolution. This is possible due to the small number of antennas available for early science and may not be possible with larger file sizes from the full array in future.

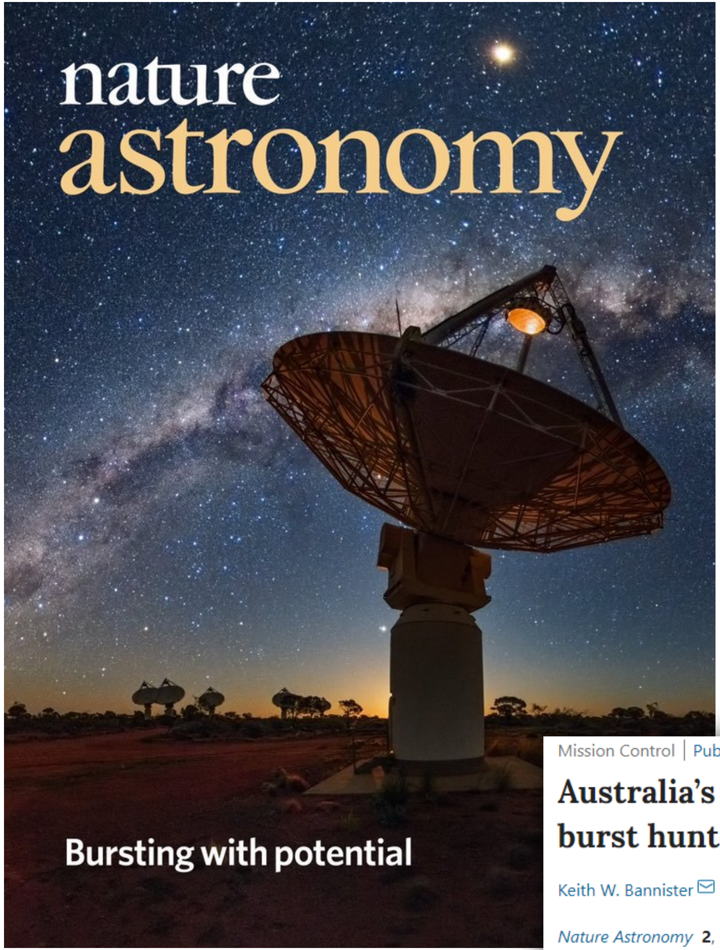
## Image processing strategy

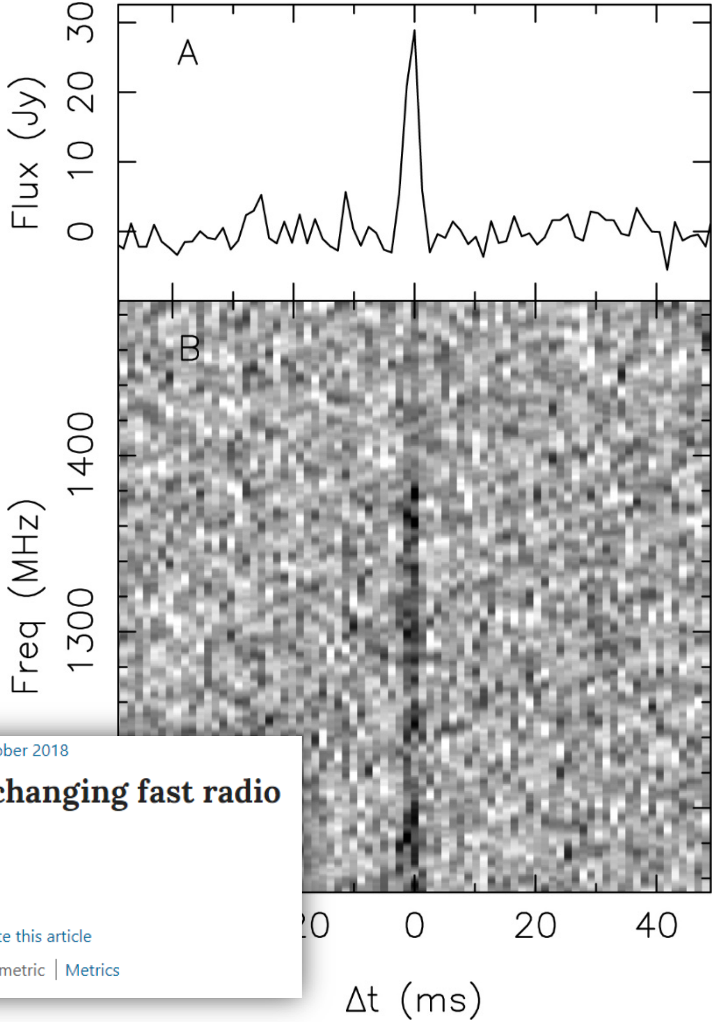
Data were calibrated for flux and bandpass shape using observations of the reference source PKS B1934-638. Phase calibration was performed using self-calibration on sources in each beam before mosaicking together the full field using an idealised Gaussian primary beam correction.

## Accessing the data archive

Released ASKAP data can be obtained from the CSIRO Data Access Portal. Users can find the cosmology survey by searching for project ID AS034. It is also possible to access the archive via a Virtual Observatory Table Access Protocol interface. Some quick instructions are given below and more detailed documentation is available in the CASDA Users Guide.






Mission Control | Published: 31 October 2018

## Australia's game-changing fast radio burst hunter

Keith W. Bannister

*Nature Astronomy* **2**, 922(2018) | Cite this article

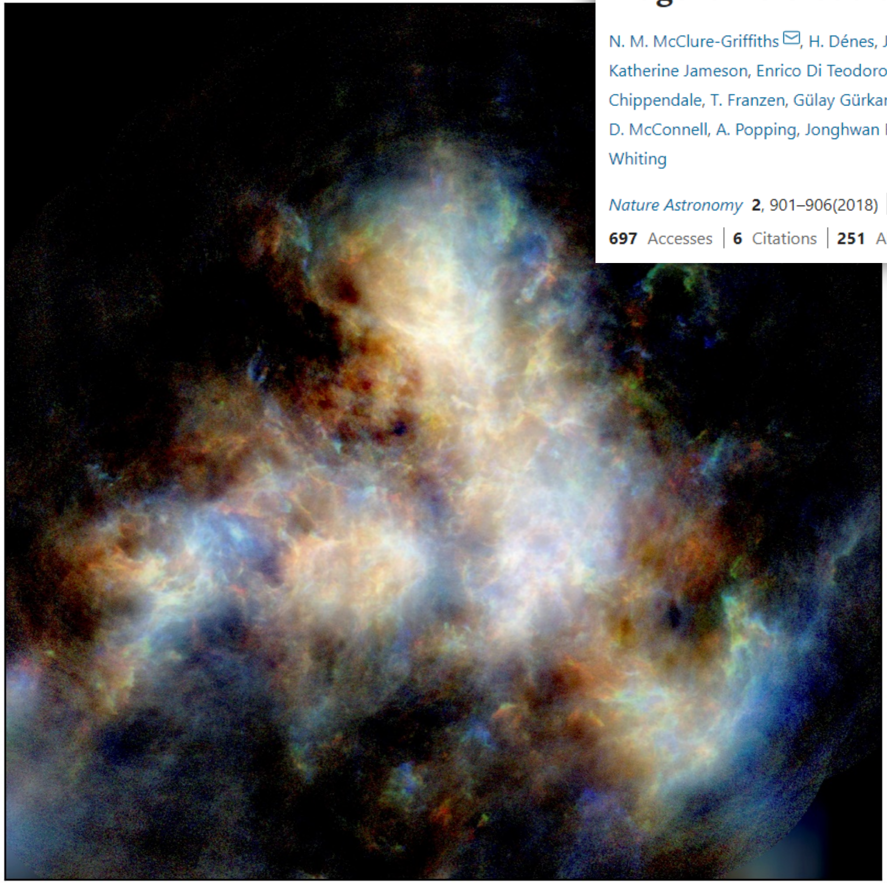
Letter | Published: 29 October 2018

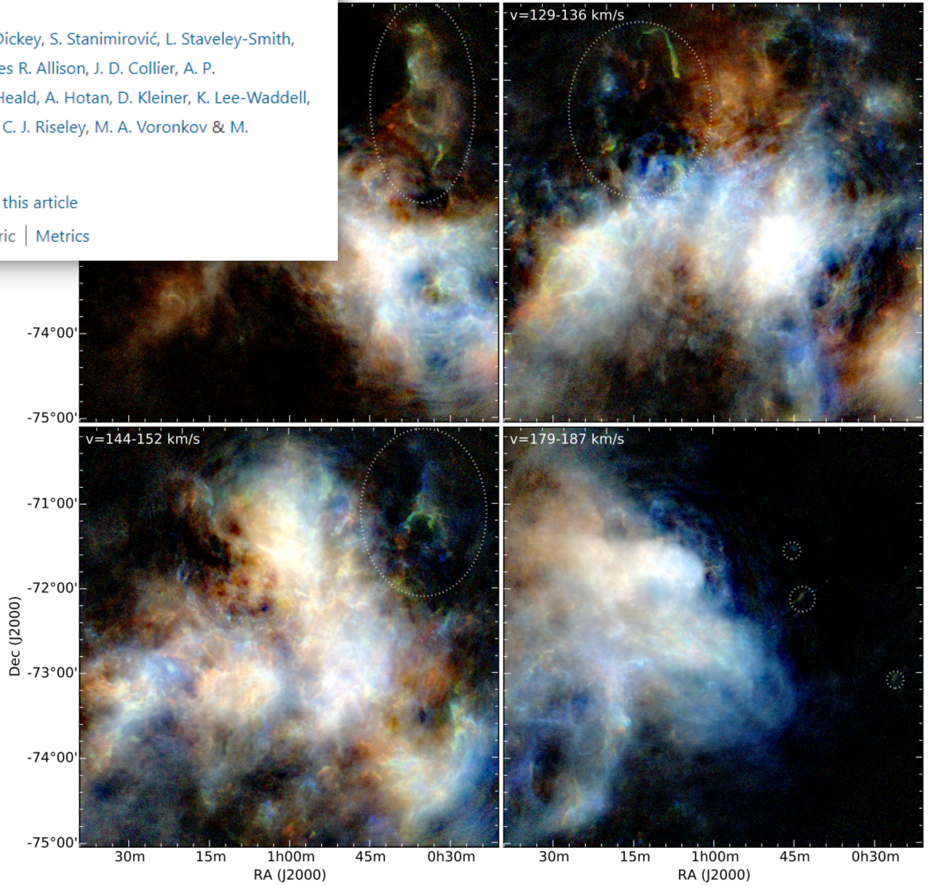
# Cold gas outflows from the Small Magellanic Cloud traced with ASKAP

N. M. McClure-Griffiths, H. Dénes, J. M. Dickey, S. Stanimirović, L. Staveley-Smith, Katherine Jameson, Enrico Di Teodoro, James R. Allison, J. D. Collier, A. P. Chippendale, T. Franzen, Gülay Gürkan, G. Heald, A. Hotan, D. Kleiner, K. Lee-Waddell, D. McConnell, A. Popping, Jonghwan Rhee, C. J. Riseley, M. A. Voronkov & M. Whiting

*Nature Astronomy* **2**, 901–906(2018) | Cite this article

**697** Accesses | **6** Citations | **251** Altmetric | Metrics



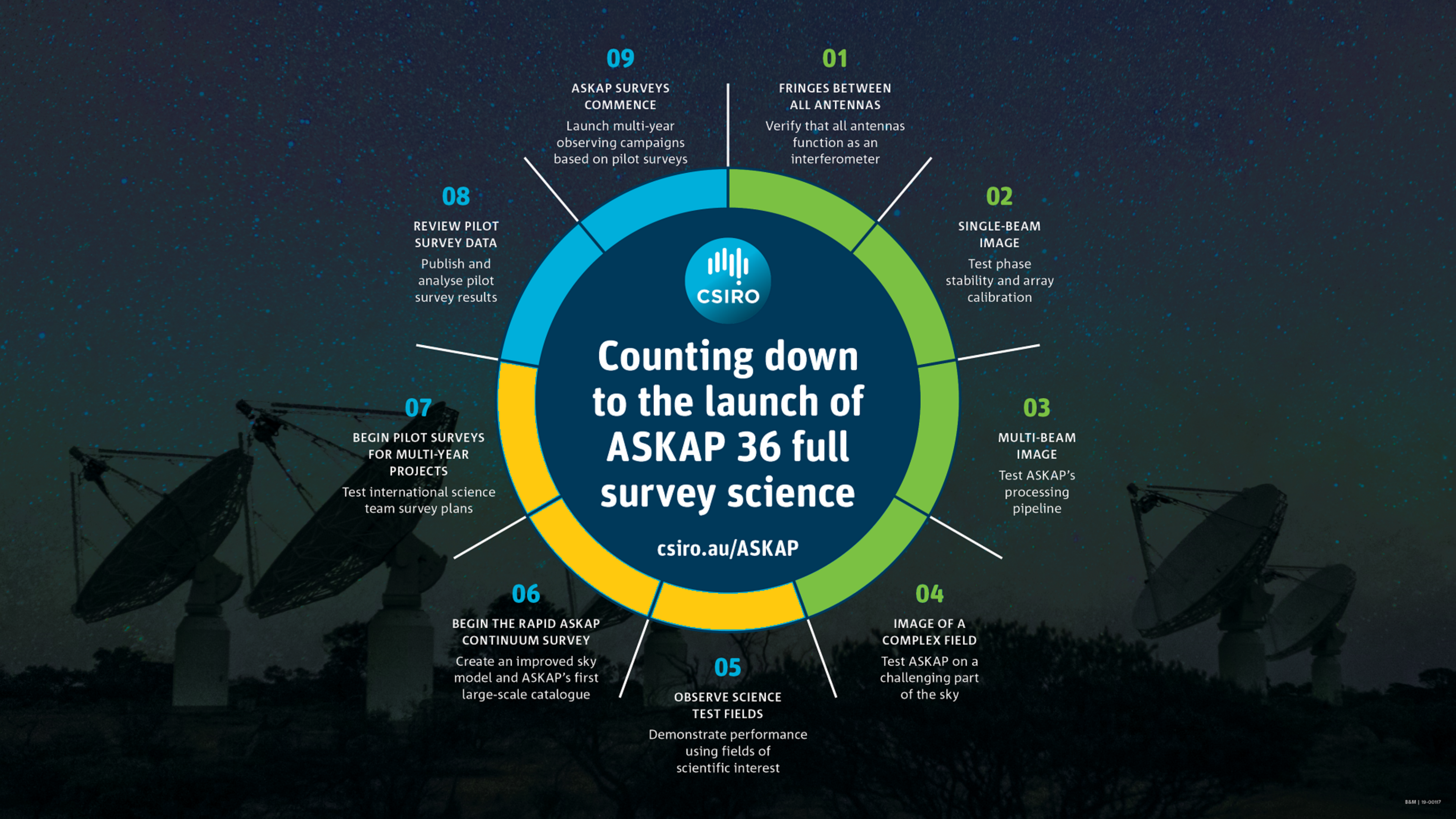


# Full-scale test observations with 36 antennas

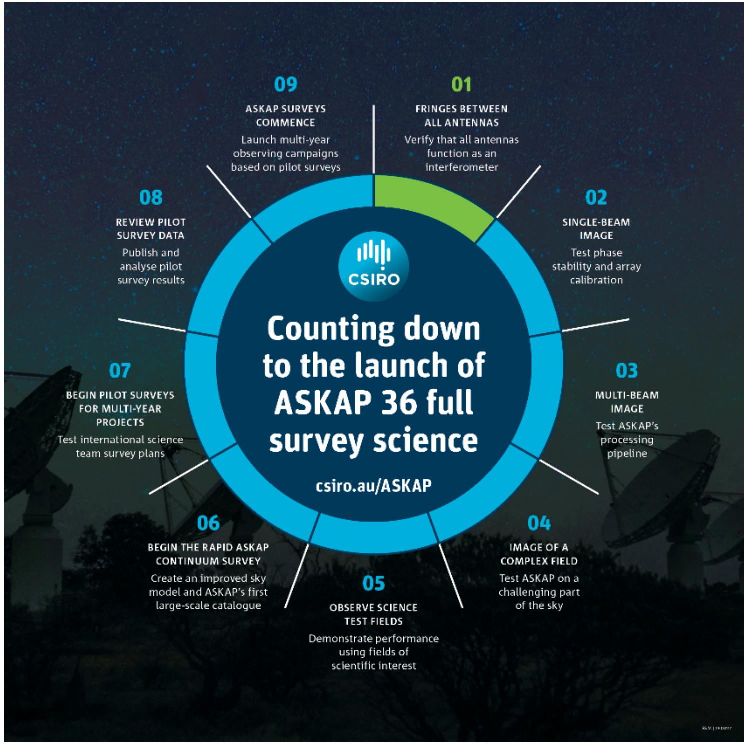
- Science teams asked to nominate individual test fields
  - Designed to verify telescope performance for exact modes of operation

- Observatory responsible for data processing
  - Manage supercomputing resources and triage issues reported by science teams
    - Science teams still experimenting directly, but using small amounts of data

- Processing parameters determined iteratively with ACES input
  - Test field data challenges were extremely important for progress
    - Identified issues with flagging, continuum subtraction, calibration, etc.

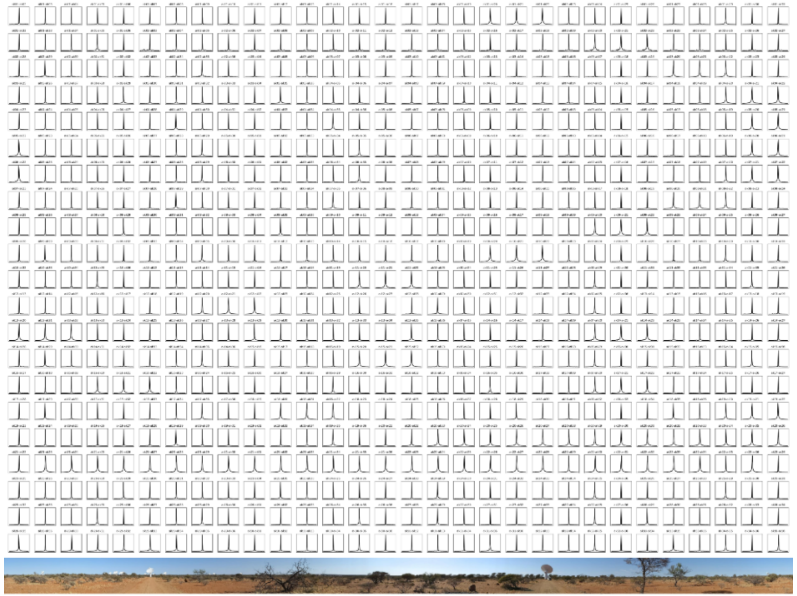

CSIRO
Counting down to the launch of ASKAP 36 full survey science
csiro.au/ASKAP
01
FRINGES BETWEEN ALL ANTENNAS
Verify that all antennas function as an interferometer
02
SINGLE-BEAM IMAGE
Test phase stability and array calibration
03
MULTI-BEAM IMAGE
Test ASKAP's processing pipeline
04
IMAGE OF A COMPLEX FIELD
Test ASKAP on a challenging part of the sky
05
OBSERVE SCIENCE TEST FIELDS
Demonstrate performance using fields of scientific interest
06
BEGIN THE RAPID ASKAP CONTINUUM SURVEY
Create an improved sky model and ASKAP's first large-scale catalogue
07
BEGIN PILOT SURVEYS FOR MULTI-YEAR PROJECTS
Test international science team survey plans
08
REVIEW PILOT SURVEY DATA
Publish and analyse pilot survey results
09
ASKAP SURVEYS COMMENCE
Launch multi-year observing campaigns based on pilot surveys

# First fringes with the full ASKAP array



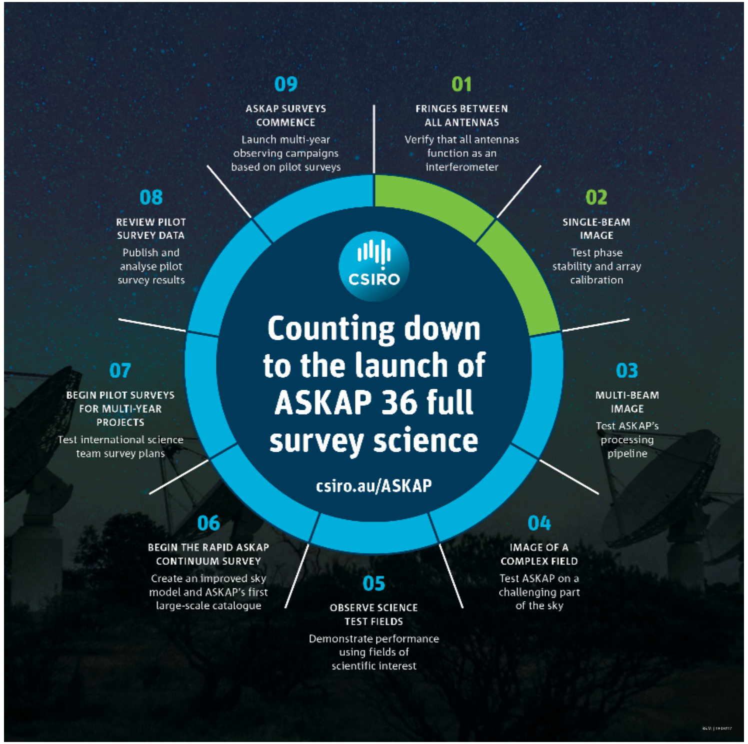

First fringes between all 36 ASKAP antennas

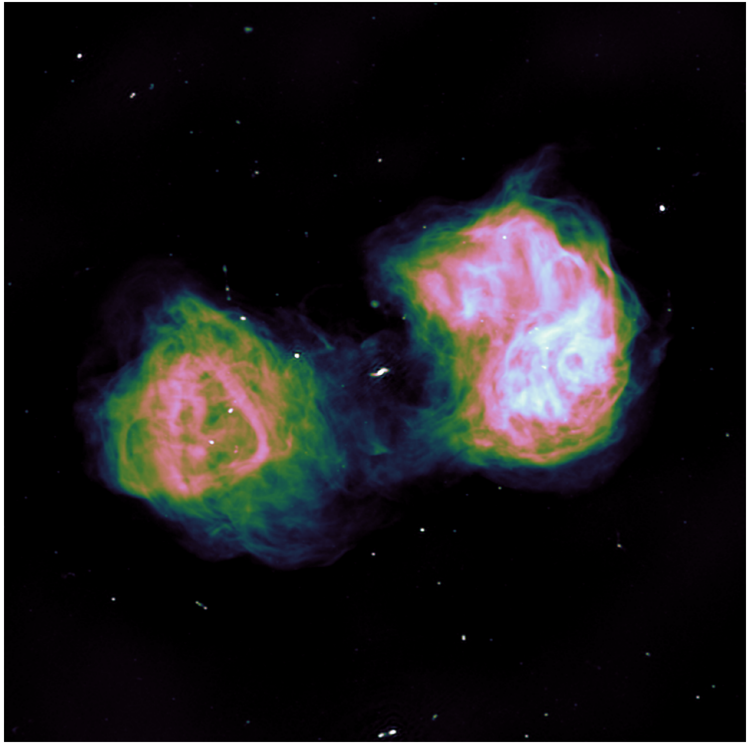
February 22nd, 2019: Correlated signal from PKS B1934-638 detected on 630 baselines



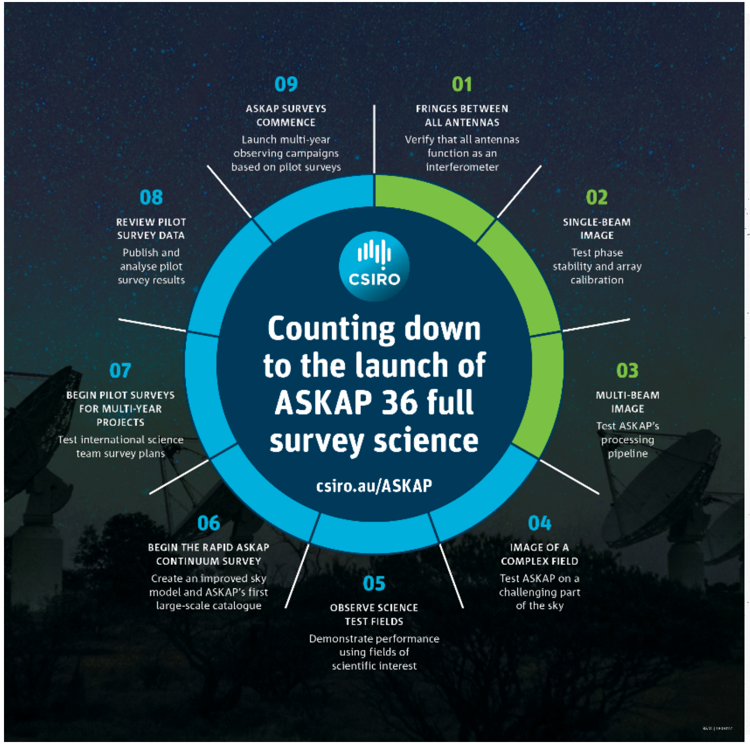
360-degree panoramic photograph showing all visible antennas tracking the radio galaxy PKS B1934-638 during the first calibration observations made with the full array

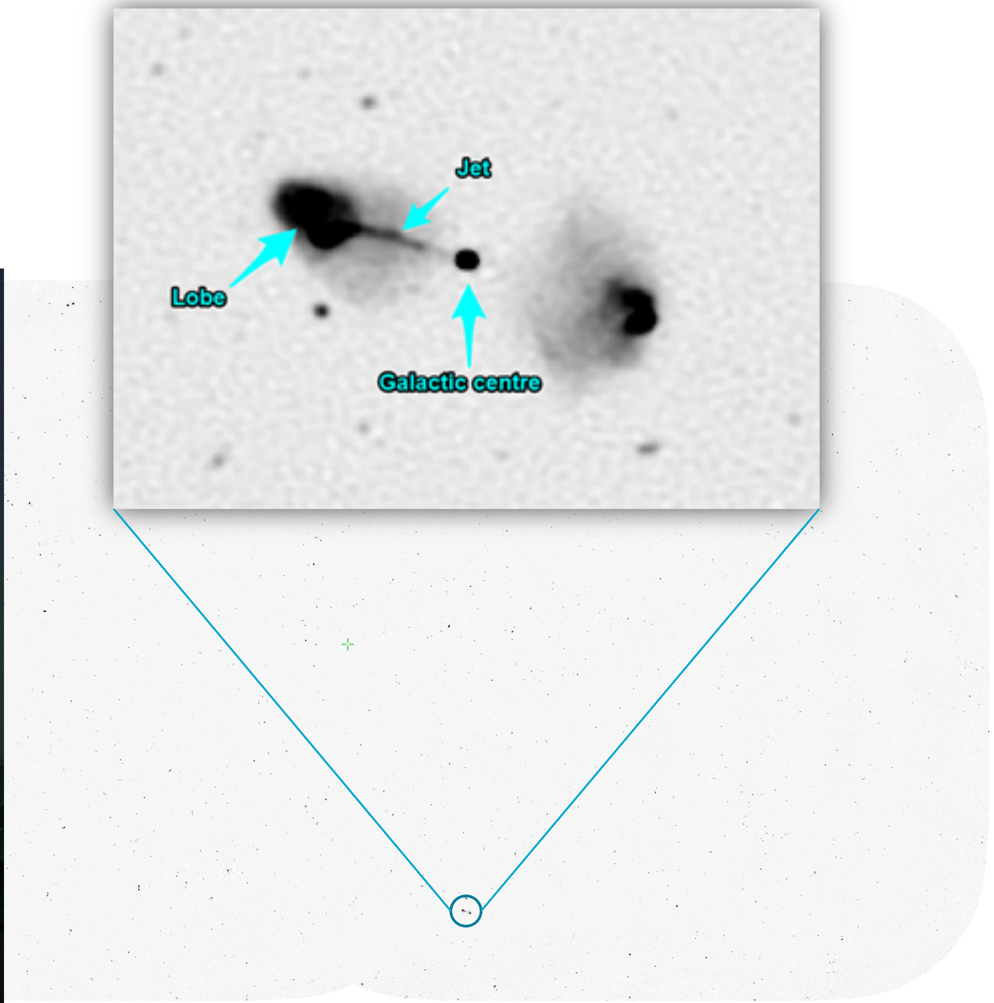
# First single beam image with the full array



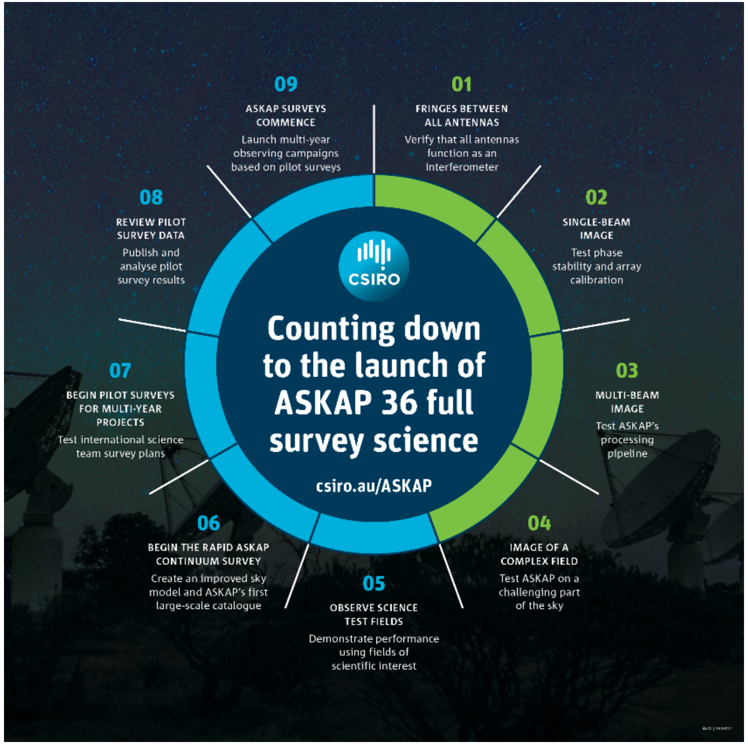



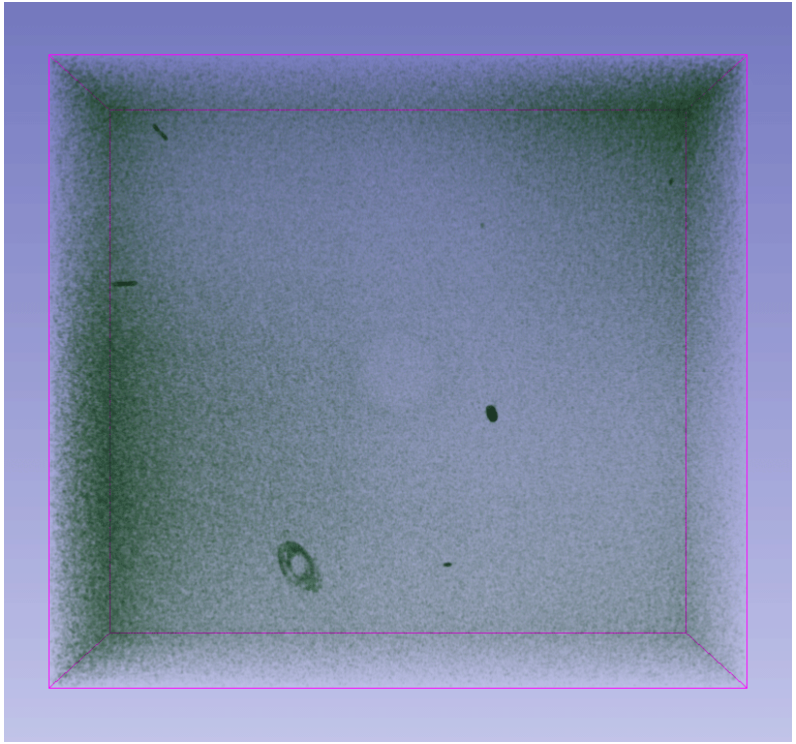
# GAMA23 test field



# Eridanus neutral Hydrogen test field



# ASKAP pilot surveys

- ASKAP’s science goals involve multi-year survey projects
  - Experience with early science suggested ramping surveys up in stages

- An initial 100 hours allocated to each science team for a pilot
  - Check that we reach required sensitivity levels and dynamic range
  - Confirm that footprint and tiling strategy are suitable
  - Ensure that all required data products are provided to end users

- Pilot surveys are also helping to develop operational procedures
  - Logging, reporting, fault tracking and recovery, maintenance scheduling, etc.

# Lessons from science verification

- Re-processing is unavoidable when commissioning imaging software
  - Use batch processing, incorporate checkpoint stages and *allow inspection*
  - New tools will be needed and *evolve outside the project* if necessary
  - Support *multiple methods for everything* e.g. bandpass calibration

- Building in fault tolerance can save more time than optimisation

- Input and analysis from astronomers is essential
  - Science ready data products need to be verified by scientists, however:
    - Diverse science goals lead to proliferation of (conflicting) requirements
    - Software needs to be flexible to cope with multiple modes

# Thank you

*The Australian SKA Pathfinder is part of the Australia Telescope National Facility which is managed by CSIRO.*

*Operation of ASKAP is funded by the Australian Government with support from the National Collaborative Research Infrastructure Strategy.*

*ASKAP uses the resources of the Pawsey Supercomputing Centre.*

*We acknowledge the Wajarri Yamatji people as the traditional owners of the Observatory site.*