



# An Introduction to ASKAP

Bringing Radio Interferometers Into the Multi-pixel Era

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CSIRO ASTRONOMY AND SPACE SCIENCE

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# Introducing ASKAP

- The Australian SKA Pathfinder is a radio telescope array that uses **new receiver technology** to improve **field of view** and provide unprecedented **survey speed**.
- Covers a section of the radio spectrum surrounding rest-frame neutral Hydrogen emission (700 MHz to 1.8 GHz).
- Consists of 36 individual 12m antennas fitted with PAF receivers.
- Currently under construction at MRO, a **radio quiet environment**.
- Begins early science operations with a subset of antennas in 2015.
  - Some science is already being done with a prototype 6-antenna array (BETA).
- It will be Australia's third major national radio astronomy facility.
  - Total collecting area is similar to Parkes or the Compact Array.

# ASKAP Science Priorities

- Most of the observing time will be spent on major survey projects.
  - ASKAP will cater for large international science teams.
  - Observations will be highly automated and done by facility operators.
- 10 major projects were selected to receive time during this first 5 yrs:
  - **Evolutionary Map of the Universe (EMU)**
  - **Widefield ASKAP L-Band Legacy All-Sky Blind Survey (WALLABY)**
  - **The First Large Absorption Survey in HI (FLASH)**
  - **An ASKAP Survey for Variables and Slow Transients (VAST)**
  - **The Galactic ASKAP Spectral Line Survey (GASKAP)**
  - **Polarization Sky Survey of the Universe's Magnetism (POSSUM)**
  - **The Commensal Real-time ASKAP Fast Transients survey (CRAFT)**
  - **Deep Investigations of Neutral Gas Origins (DINGO)**
  - **The High Resolution Components of ASKAP (VLBI)**
  - **Compact Objects with ASKAP: Surveys and Timing (COAST)**

# ASKAP Science Priorities

- Understanding galaxy formation and gas evolution in the nearby universe through extragalactic surveys of neutral hydrogen.
- Determining the evolution, formation and population of galaxies across cosmic time through radio continuum surveys.
- Characterise the radio transient sky through detection and monitoring of transient and variable sources.
- Exploring evolution of magnetic fields in galaxies over cosmic time.

# Contribution to Astrophysical Knowledge

- Spectral Line:
  - Survey two-thirds of the sky to  $z = 0.25$  in neutral hydrogen.
  - Detect 600,000 galaxies in neutral Hydrogen in 1 year .
  - Derive distance, gas mass, total mass, dark matter content, star-forming rates and identify likely optical/IR counterparts.
- Continuum:
  - Survey two-thirds of sky to RMS  $10 \mu\text{Jy}$ .
  - Detect 70 million galaxies, probe evolution of star forming galaxies  $z < 2$ .
  - Deep Field: 30 square degree field to RMS =  $1\mu\text{Jy}$ .
  - Detect 0.5 million galaxies, probe evolution of star-forming galaxies  $z < 5$ .

# ASKAP Timeline

- Equipment is being deployed in stages.
  - The first 6 antennas were given “Mk I” prototype hardware. This sub-array is called BETA.
  - BETA is primarily an engineering test and will be used to develop techniques.
- The remaining antennas will be fitted out with “Mk II” electronics.
  - New hardware is being constructed now, based on lessons learned from BETA.
- **2012**
  - Three BETA antennas operational. First images formed.
- **2013**
  - BETA fully deployed, with 6 PAFs, beamformers and correlator.
- **2014**
  - BETA does some very early science.
  - Initial deployment of Mk II hardware to antenna 29.
- **2015**
  - Beginning of early science with Mk II hardware on 12 antennas.

# Overview of ASKAP Systems

- The Murchison Radio Observatory.
- ASKAP 3-axis antennas and array layout.
- Phased Array Feeds (see earlier talk).
- Data flow from antenna to correlator.
- Data flow from correlator to science data archive.
- Summary of results from BETA.

# Murchison Radio Observatory

- Radio telescopes are highly susceptible to interference from signals of human origin.
  - Astronomers call this Radio Frequency Interference (RFI).
  - Similar to the problem of light pollution for optical observatories.
- Current radio observatories are in rural NSW, but civilisation has expanded to the point where some bands are unusable.
- The MRO is a part of Boolardy Station in Western Australia that has been set aside as a special radio quiet zone.
  - It is one of the least-populated areas in Australia (and the world).
  - Now has federal government protection over the use of radio transmitters within a large radius of the core site.

# The Murchison Radio Observatory (MRO)



US Dept of State Geographer  
© 2012 Whereis® Sensis Pty Ltd  
© 2012 Google  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
27°07'55.46" S 126°00'36.04" E elev 458 m

Google earth

Eye alt 4821.48 km



Photo taken by Alex Cherney

# Murchison Radio Observatory

- Isolation is a good defence, but we must still avoid generating our own radio noise!
- All systems installed at the MRO must comply with stringent requirements, and will be housed in shielded structures.

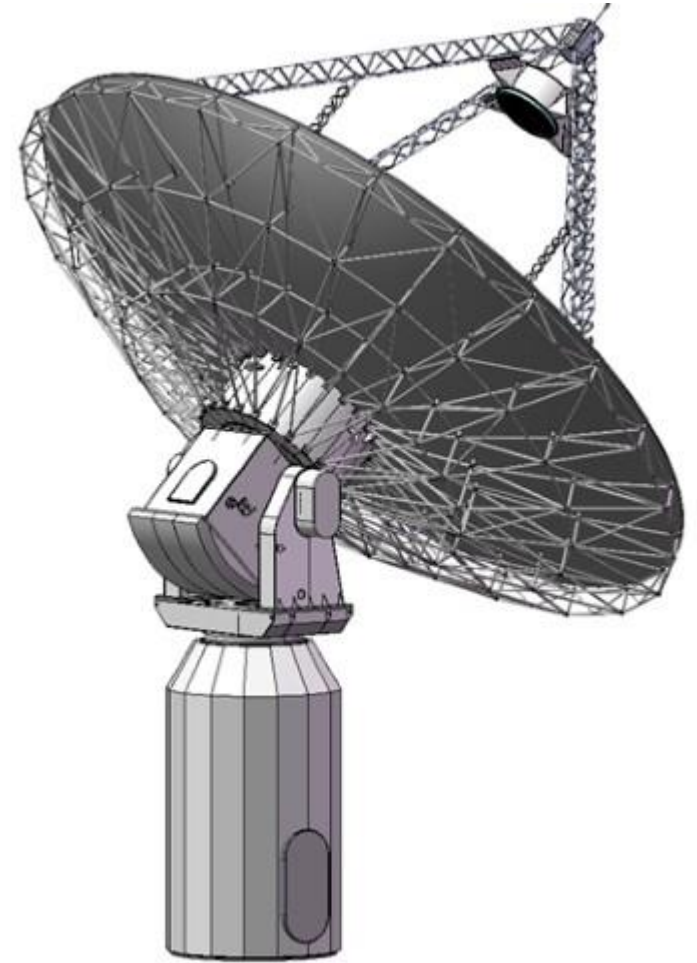


The only windows!

Two layers of 80 dB RF shielding, only optical fibre goes in or out.

# ASKAP Antennas

- 12m parabolic reflectors, prime focus.
- ASKAP antennas were designed with a unique feature – the ability to **rotate the reflector about the optical axis**.
- This is necessary, because Altitude-Azimuth telescopes do not naturally track the *orientation* of a source on the sky, only its position.
- Some existing telescopes allow feed rotation, but full reflector rotation better preserves the pattern of all beams on the sky.



# The Value of the Roll Axis

- For offset beams, the roll axis allows the use of fixed weights for extended observations as a source moves across the sky.
- Even for the boresight beam, it improves image fidelity.
  - See below: Image of a single beam containing 4 bright sources. Phase-only self calibration, with and without the roll axis tracking. Other parameters fixed.

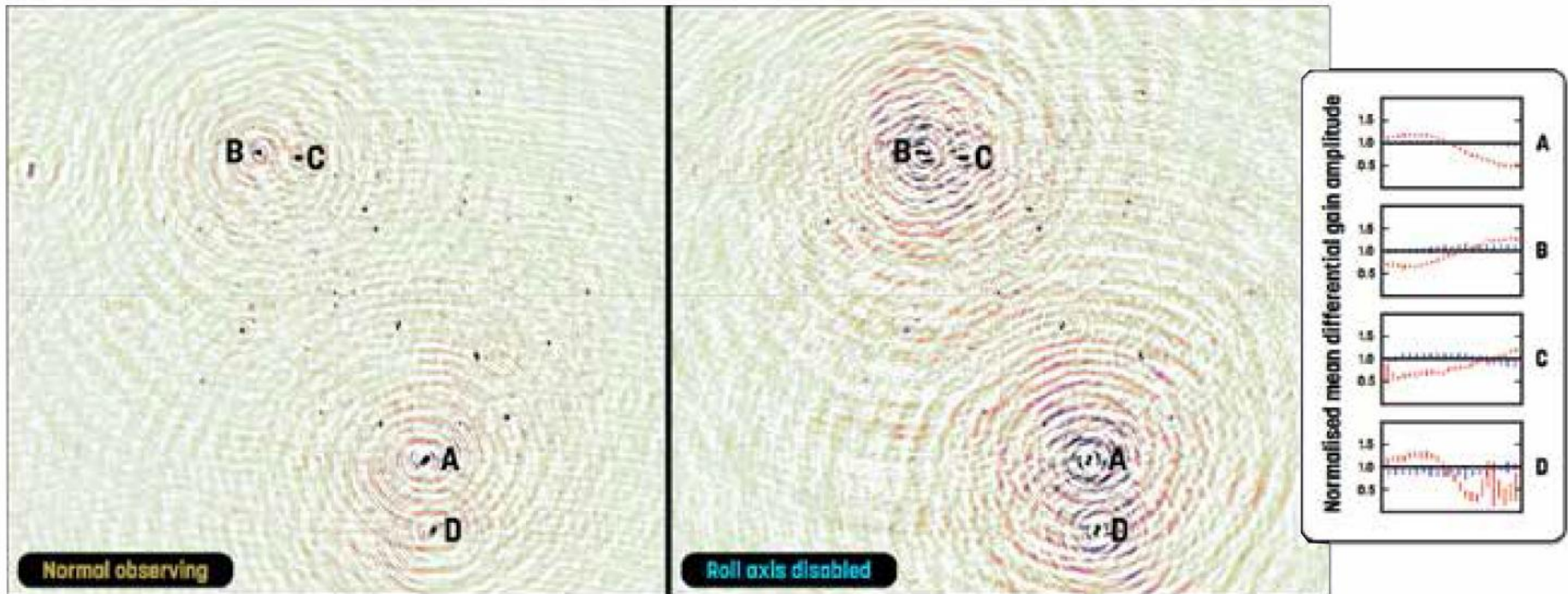
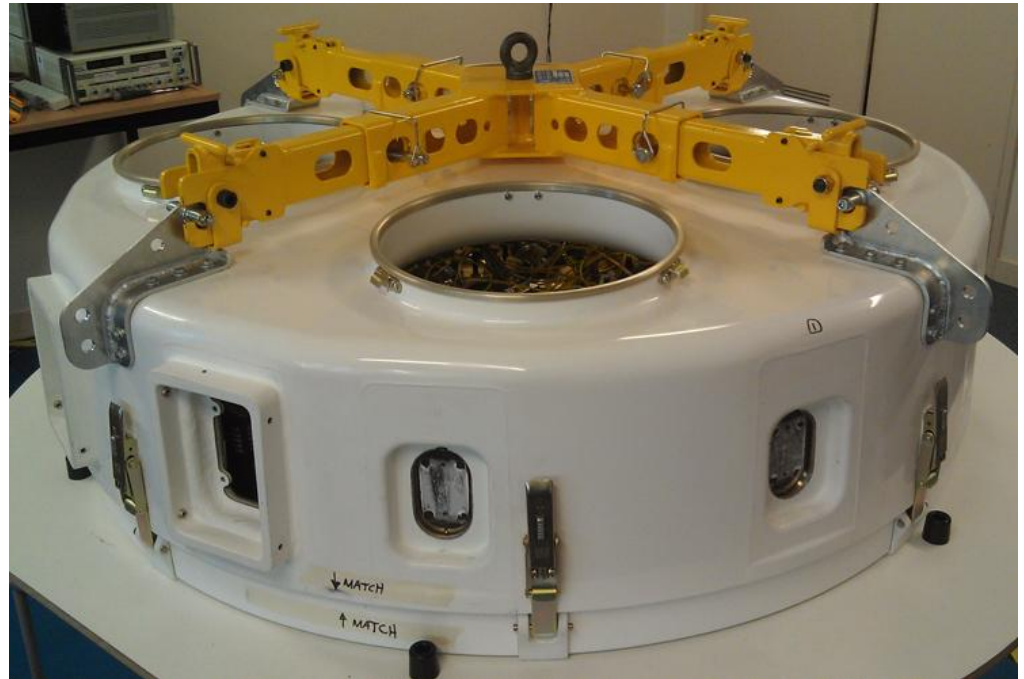
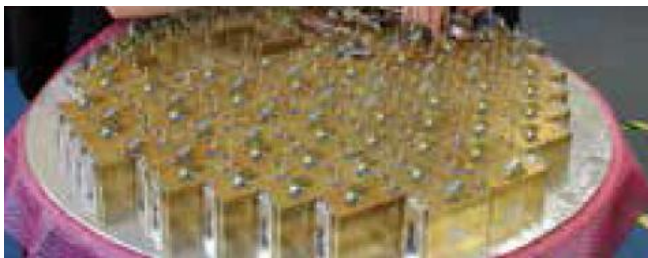
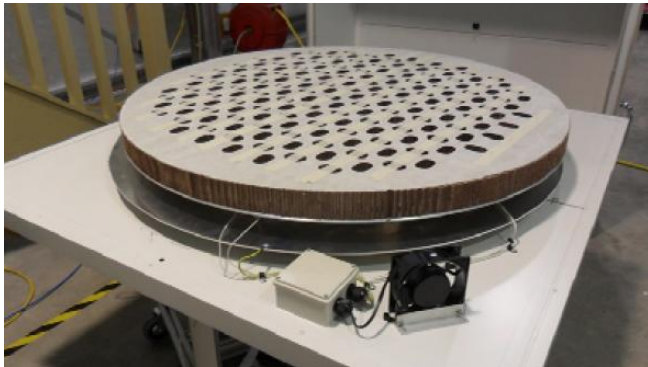


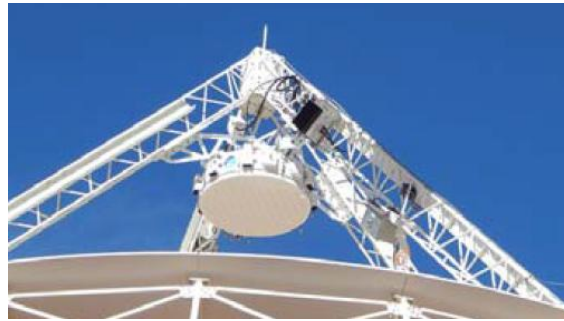
Image made by Ian Heywood

# PAF Assembly

- The ASKAP PAF is a high-tech composite structure.
  - BETA versions were difficult to maintain and labour intensive to build.
  - The final version is much more modular – amplifiers encased in “dominoes”.

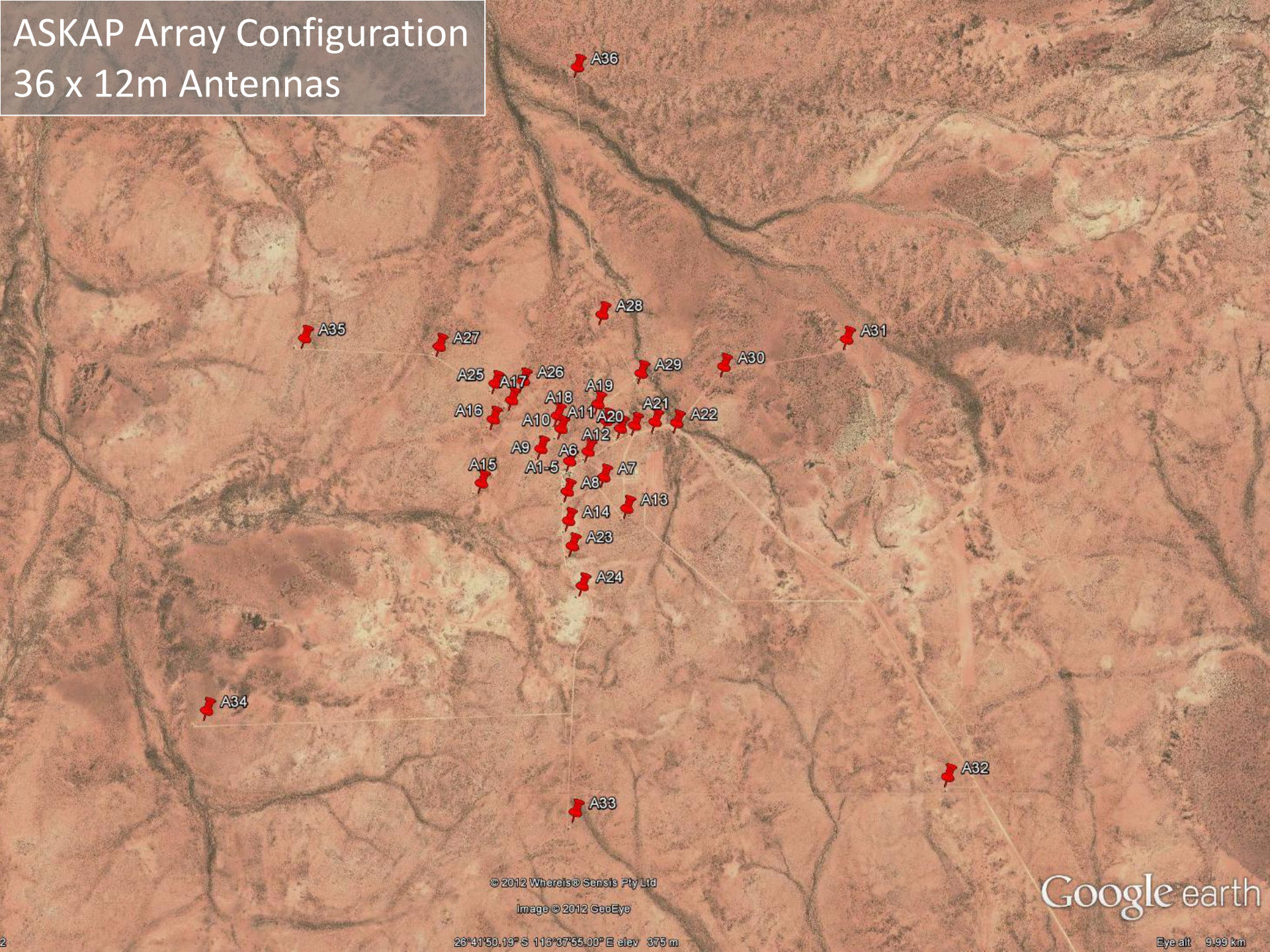


# Antennas and PAF Installation



# ASKAP Array Configuration

## 36 x 12m Antennas



© 2012 Whereis© Sensis Pty Ltd

Image © 2012 GaoEye

26°41'50.19" S 116°37'55.00" E elev 375 m

Google earth

Eye alt 9.99 km

# Layout of MRO Central Core

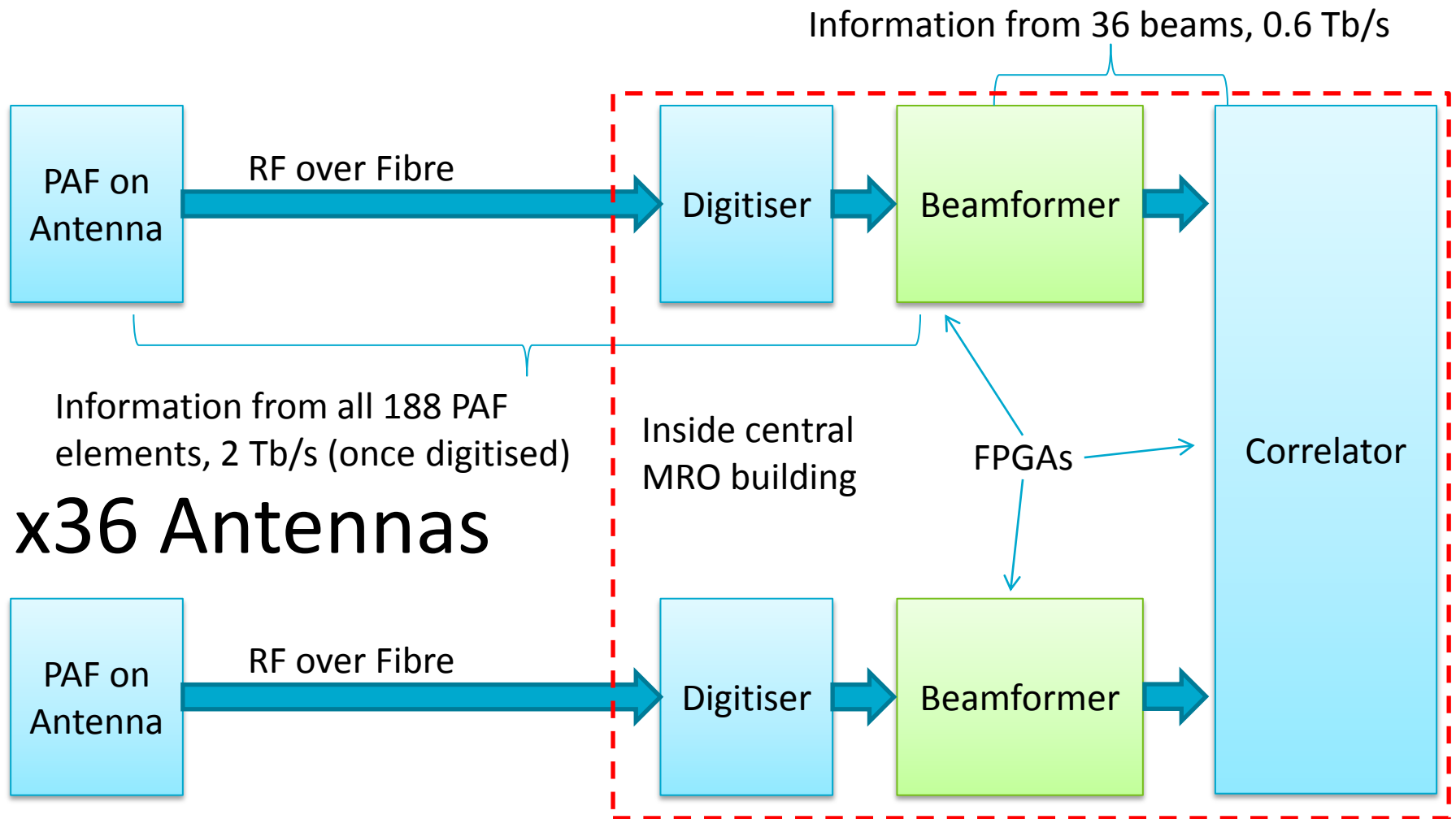
BETA antennas circled in red.

Central control building.

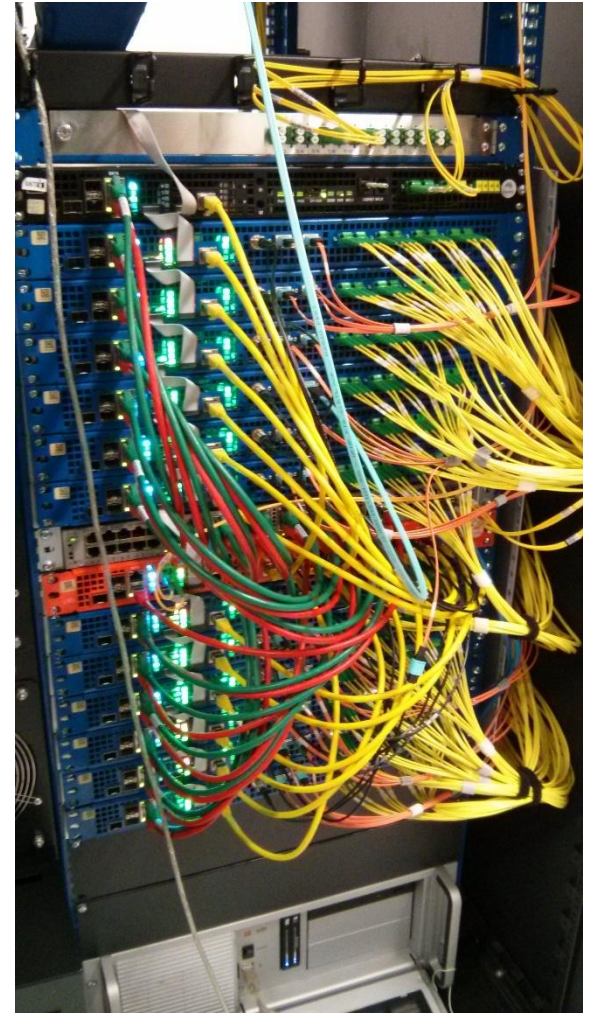
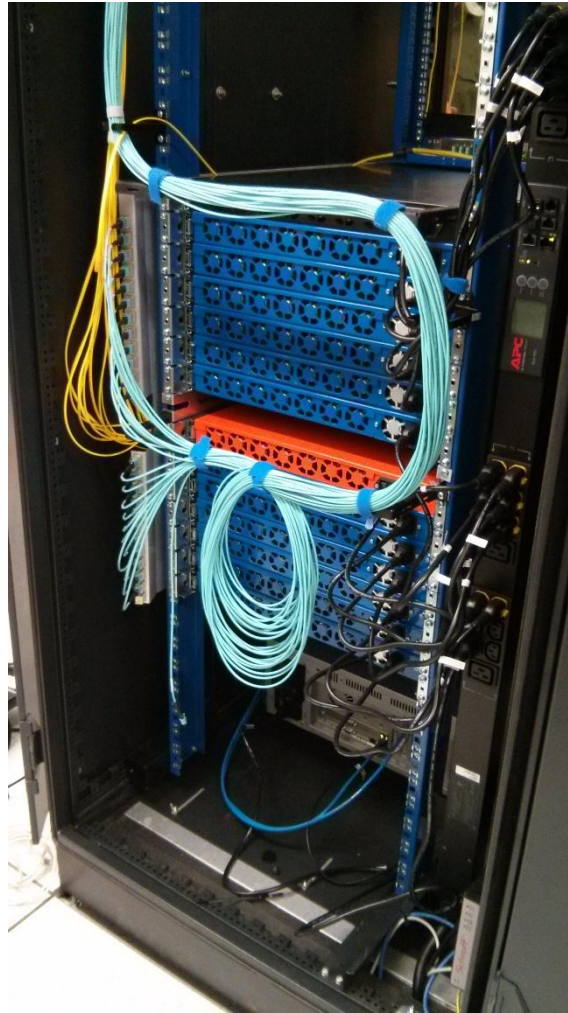
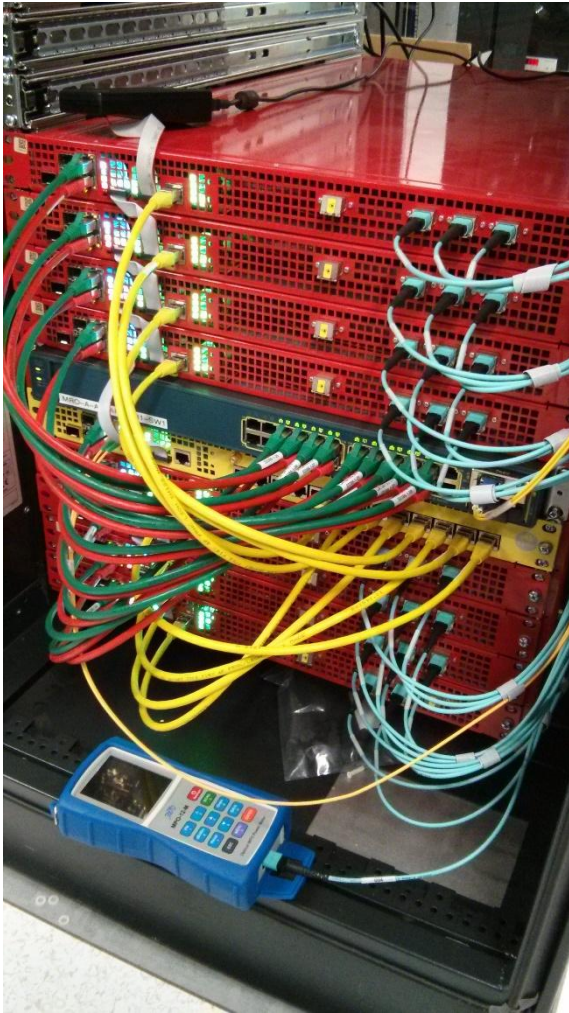
Geothermal cooling field.



# Data Flow at the Telescope



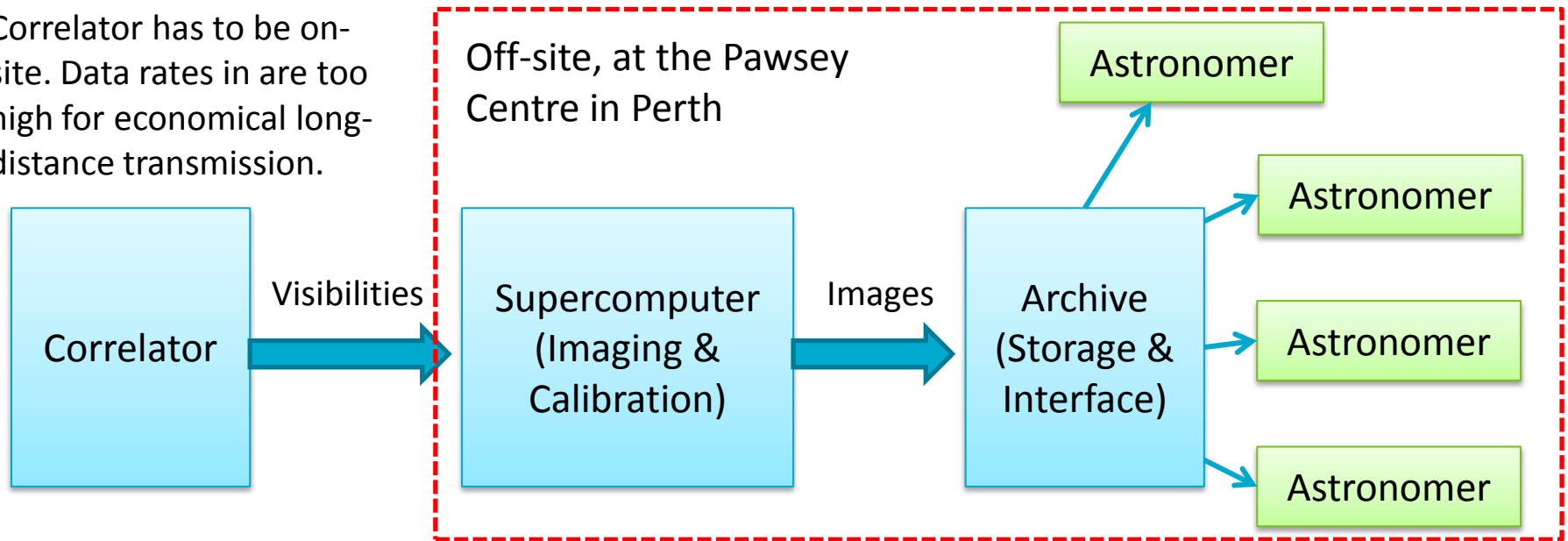
# Digitisers and Beamformers



# Data Flow out of the Correlator

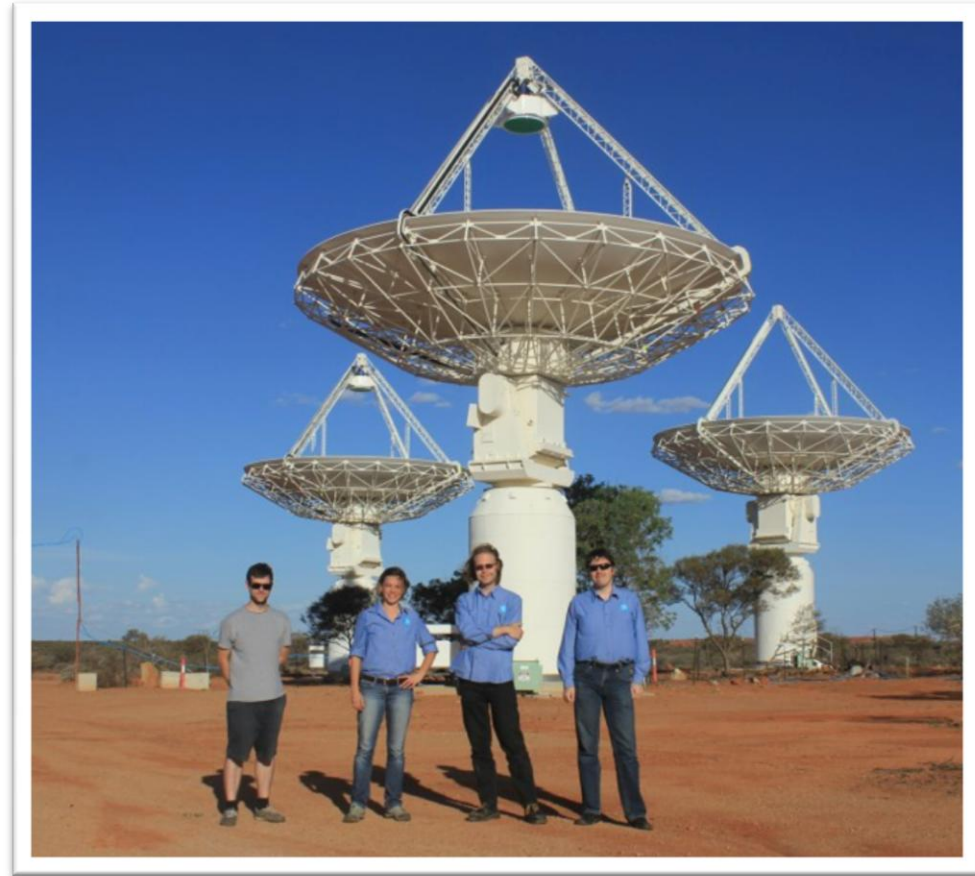
- Data rate out of the correlator is roughly 2.5 Gb/s, requiring a dedicated high-speed optical fibre link to a supercomputer.
- Imaging occurs via an automated pipeline. Raw visibilities are too large to archive, so processing needs to be right first time!

Correlator has to be on-site. Data rates in are too high for economical long-distance transmission.

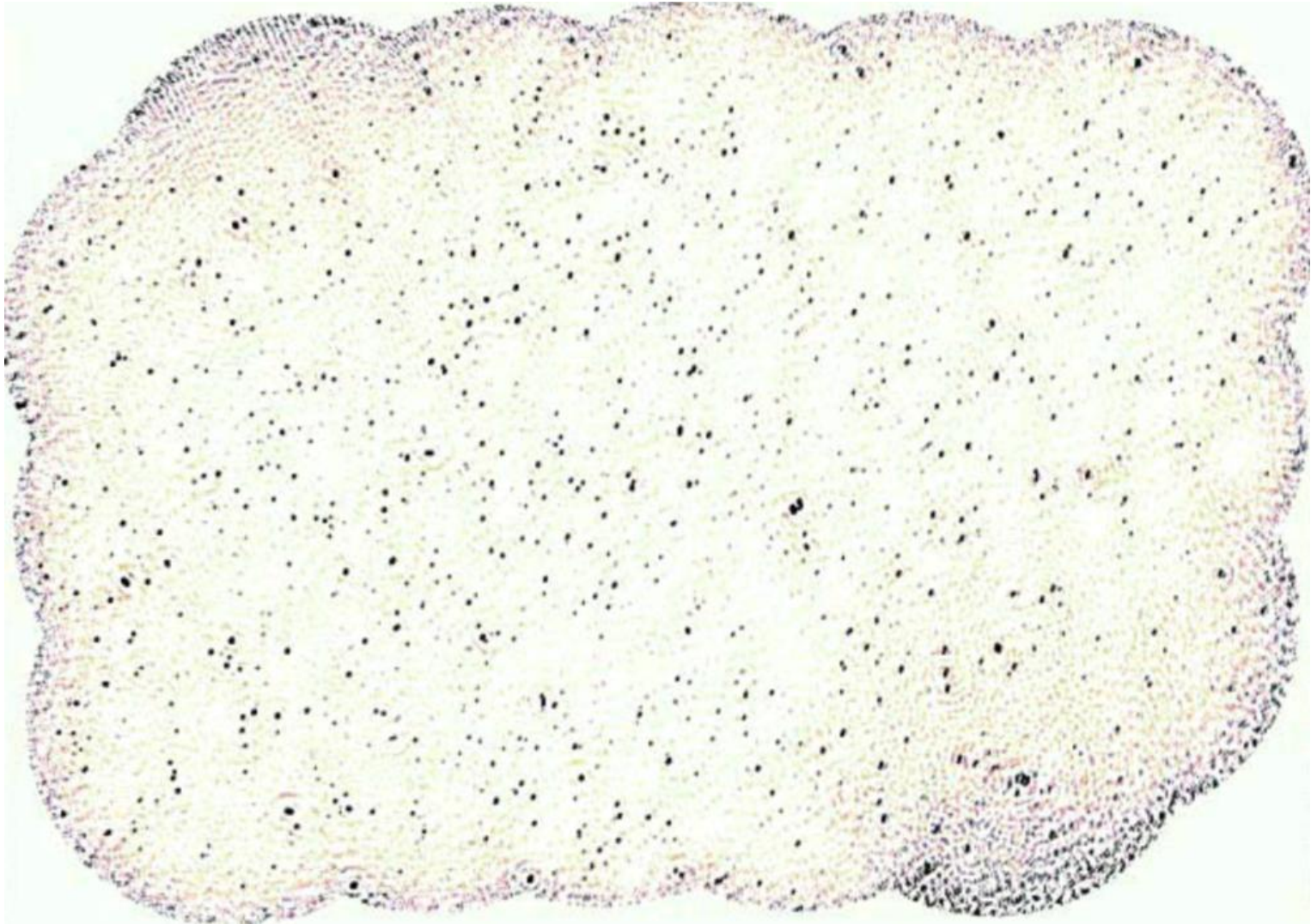


# Commissioning Results from BETA

- Six antennas with first-generation PAFs and electronics.
- Total bandwidth 304 MHz.
  - 1 MHz or 18.5 kHz spectral resolution (up to 16,416 spectral channels).
- 9 dual-pol beams available.
- Degraded Tsys above 1 GHz.
- Commissioning team of 14 astronomers and engineers.



# Observing Large Areas of the Sky (50 square degrees)



5.5 degrees

Image made by Ian Heywood

# Detecting HI Absorption

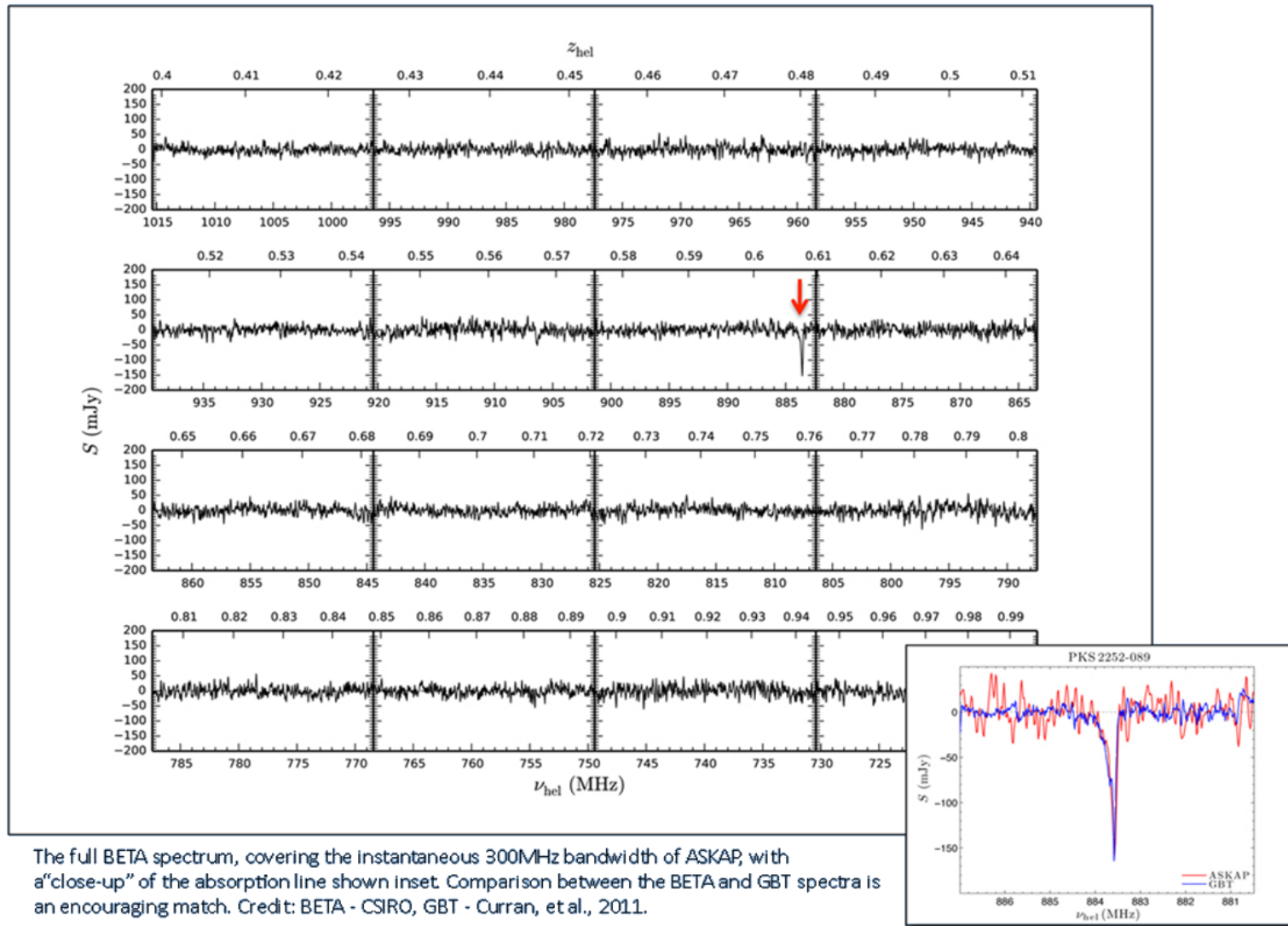


Image made by James Allison

# Widefield Spectral Line Observations

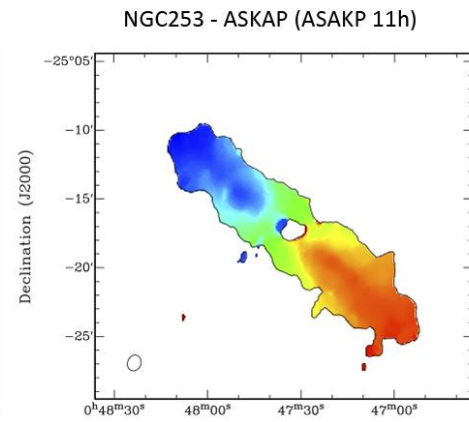
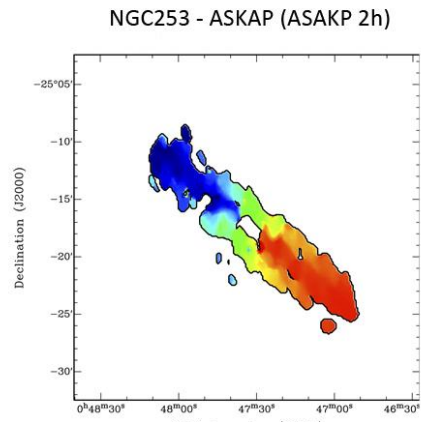
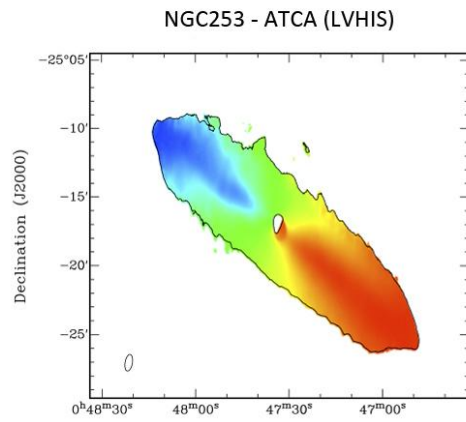
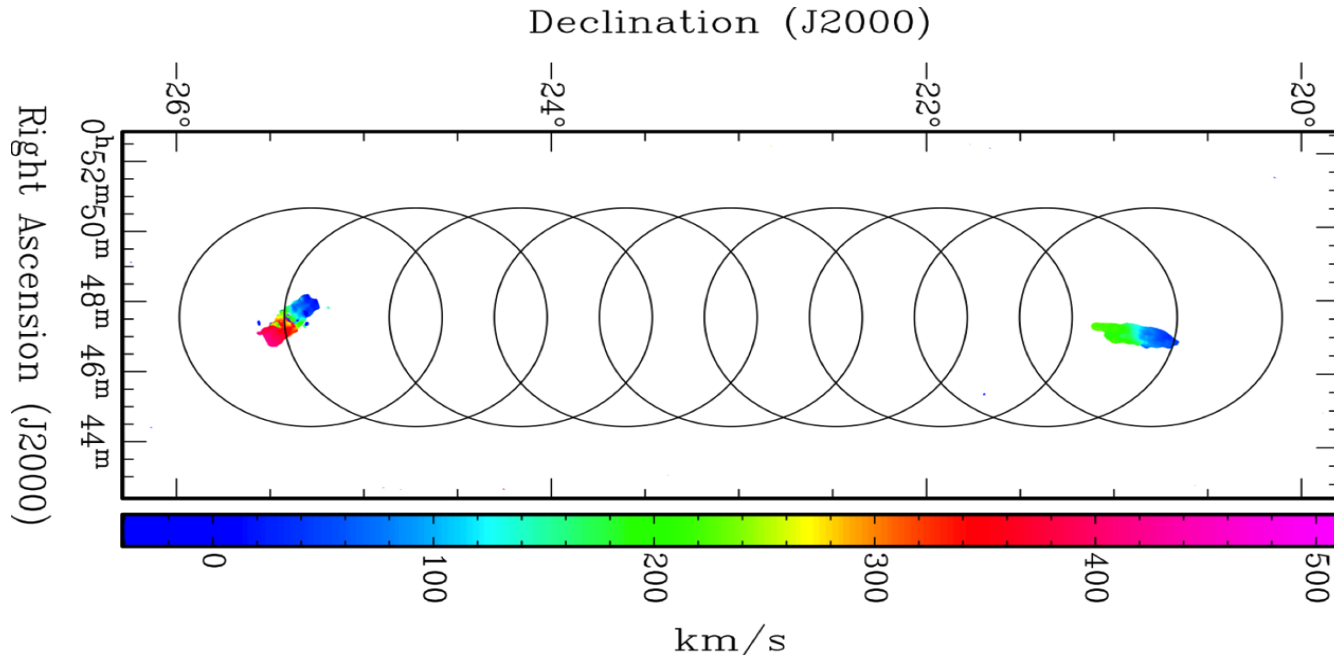


Image made by Paolo Serra

# Multiple Objects in One Field

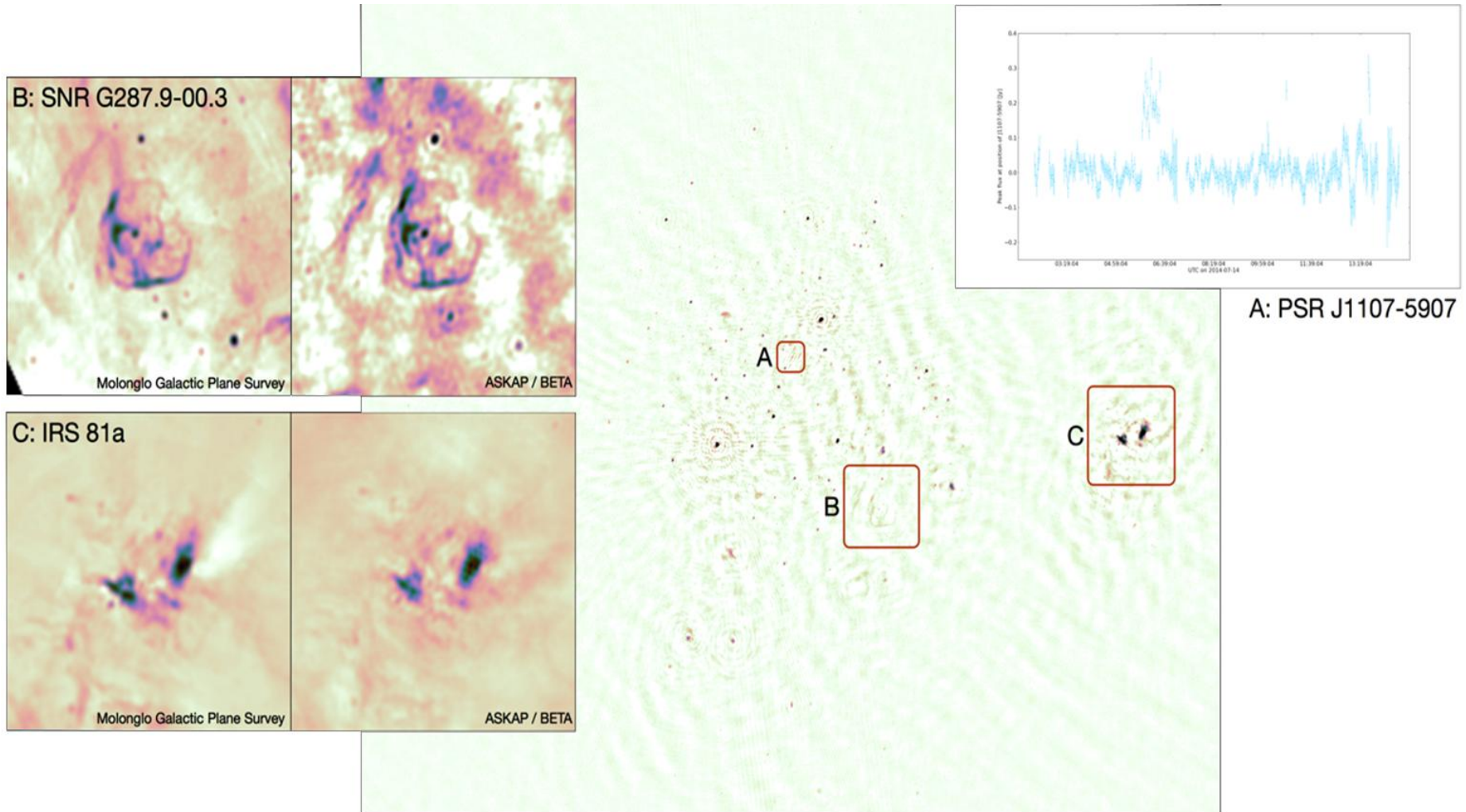
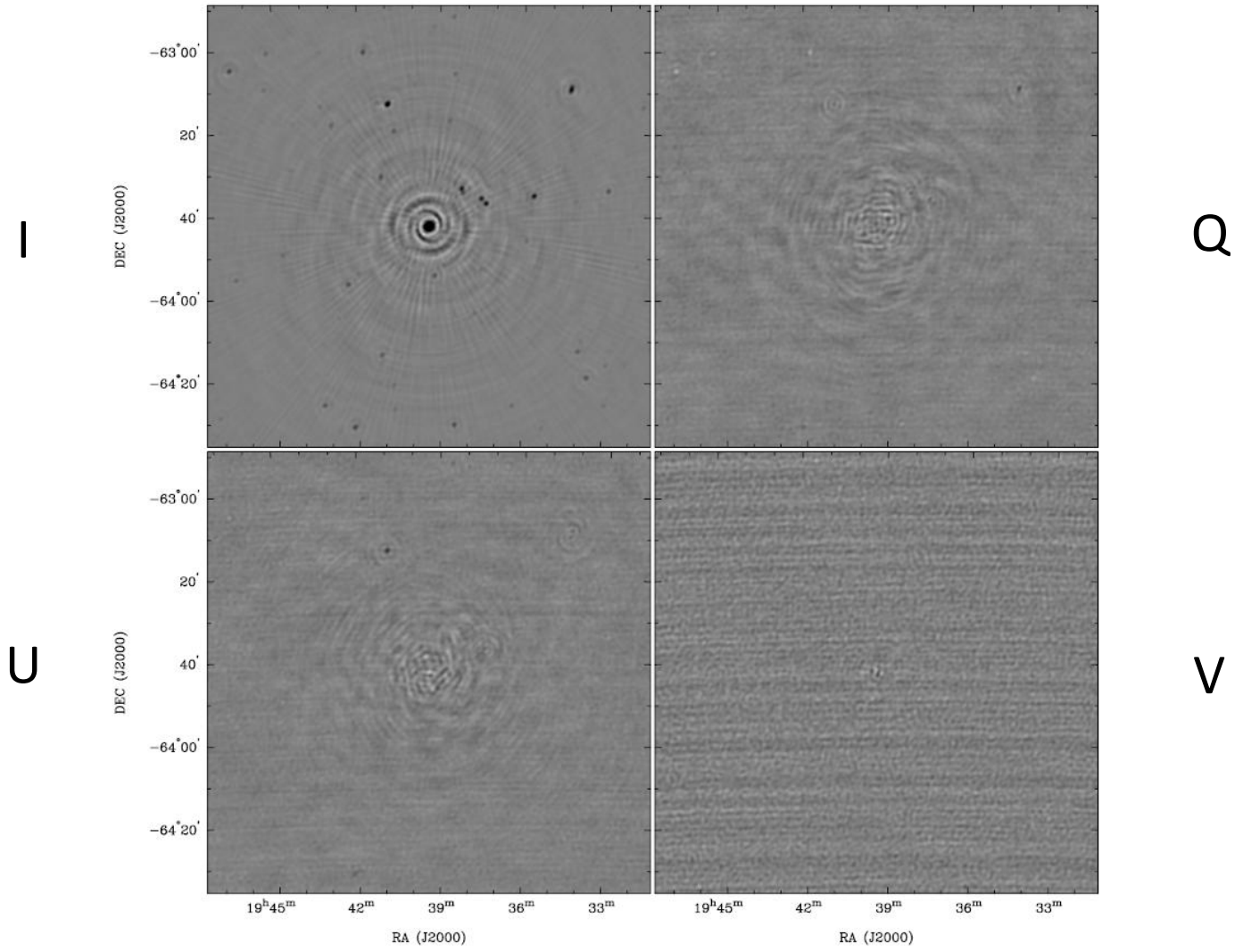


Image made by Ian Heywood

# Testing Beam Polarisation Characteristics



1934-638

Image made by Bob Sault

# Conclusions

- BETA is already doing science!
  - The flexibility of adaptive beamforming is a huge advantage.
  - We are learning many technical lessons to do with beamforming, PAF polarisation characteristics and data processing strategies.
  - See <http://arxiv.org/abs/1409.1325> for details of the BETA system.
  - Contact [Dave McConnell](#) if you are interested in working with us on BETA.
- ASKAP will add rapid survey capabilities to the existing world-class radio astronomy facilities in Australia.
- Survey science data should be reaching the astronomy community in the next year or two (PhD / post-doc opportunities!).

# Thank you

**CSIRO Astronomy and Space Science**

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