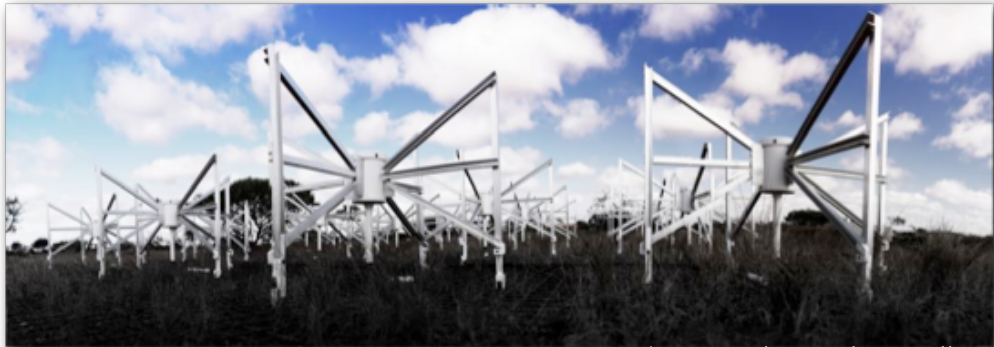
Murchison Widefield Array



Credit: Natasha Hurley-Walker

Randall Wayth

MWA Staff Scientist, ICRAR – Curtin University

On behalf of the international MWA consortium

Update scope

- What are we?
- What have we done?
- What are we doing?
- What are we going to do?
- What do we enable and support?

What are we?

- The MWA is a low-frequency radio telescope operating between 80 and 300 MHz. It is located at the Murchison Radio-astronomy Observatory (MRO) in Western Australia, the planned site of the future SKA_LOW telescope, and is one of three telescopes designated as a Precursor for the SKA

- Tingay et al. 2013, PASA, 30, 7

  MWA system description paper

- Bowman et a. 2013, PASA, 30, 31

  MWA science description paper

MWA MURCHISON WIDEFIELD ARRAY

What are we?

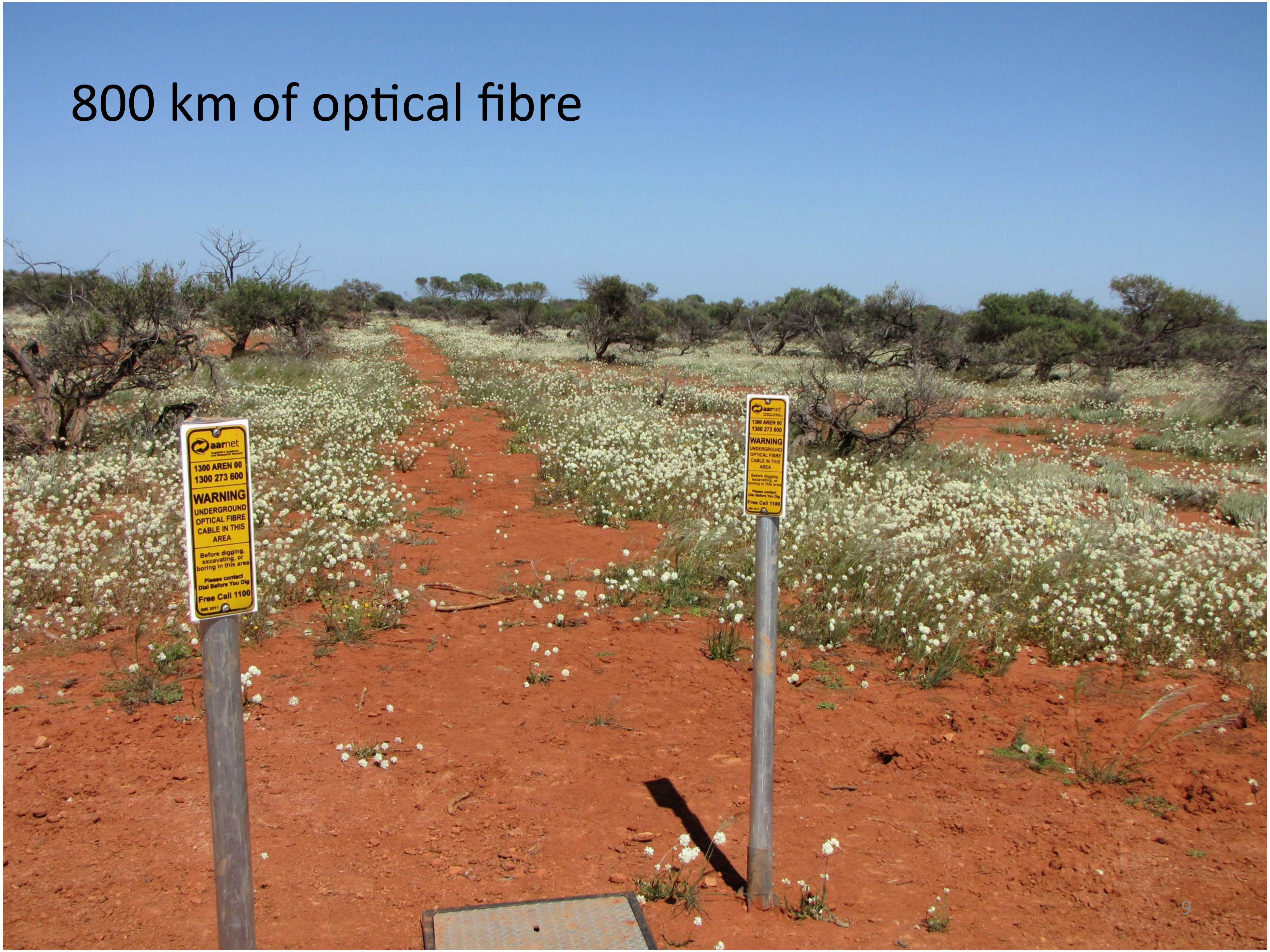

Murchison Shire Boundary
MRO (operated by CSIRO)
On site: data rate into central building ~60 Gbps
41,000 sq. km = The Netherlands
Population density = 0.002 people/sq. km
Geraldton
Off site: data rate into science archive ~3 Gbps
~200 km
Perth
Pawsey Centre 9 PB storage for MWA

Antenna tiles


eceivers

Central Signal Processing

800 km of optical fibre

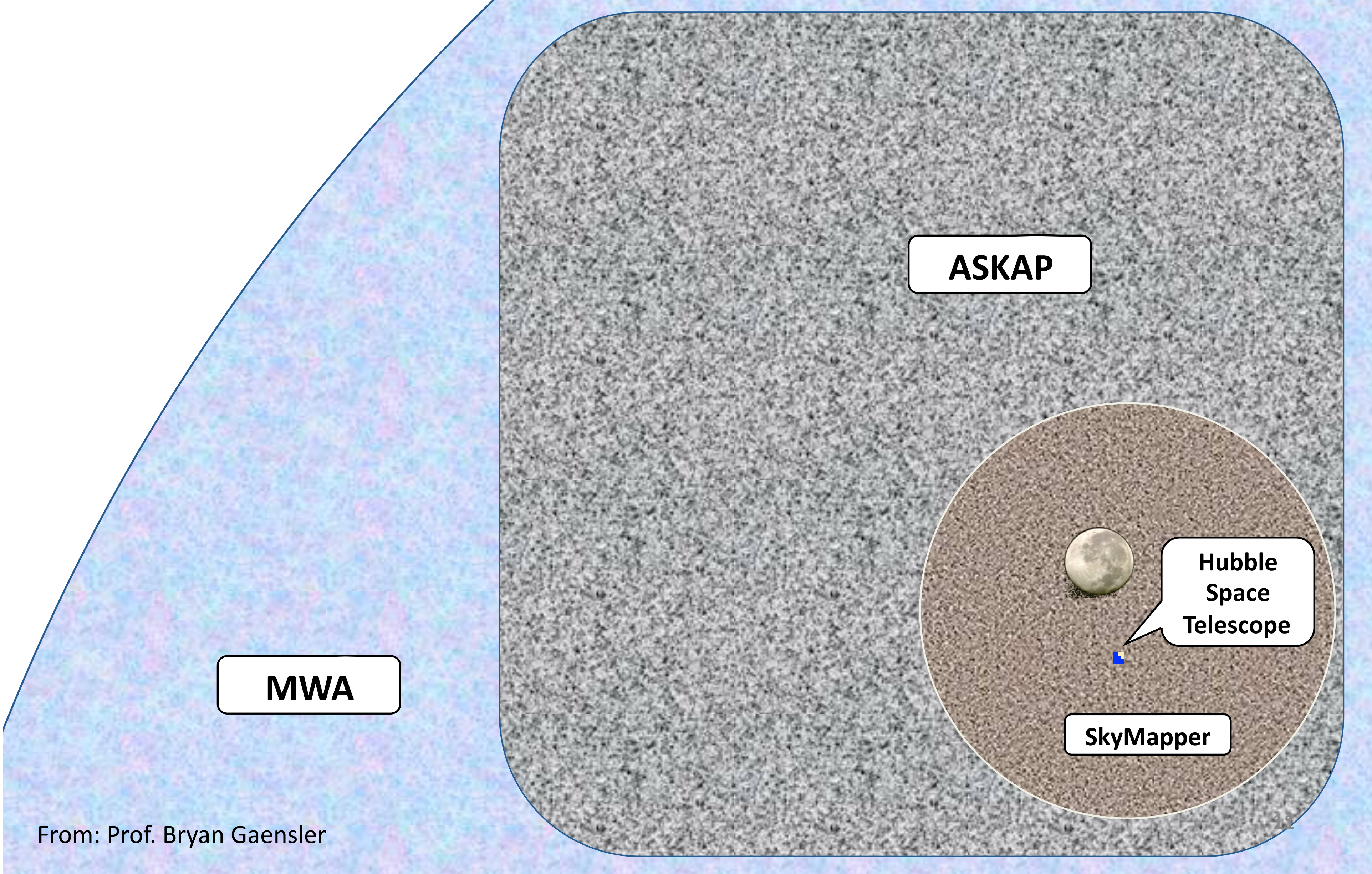


Pawsey Supercomputing Centre

www.pawsey.org.au

Field of view!

~15 - 50 deg. (200 - 2500 sq. deg.)

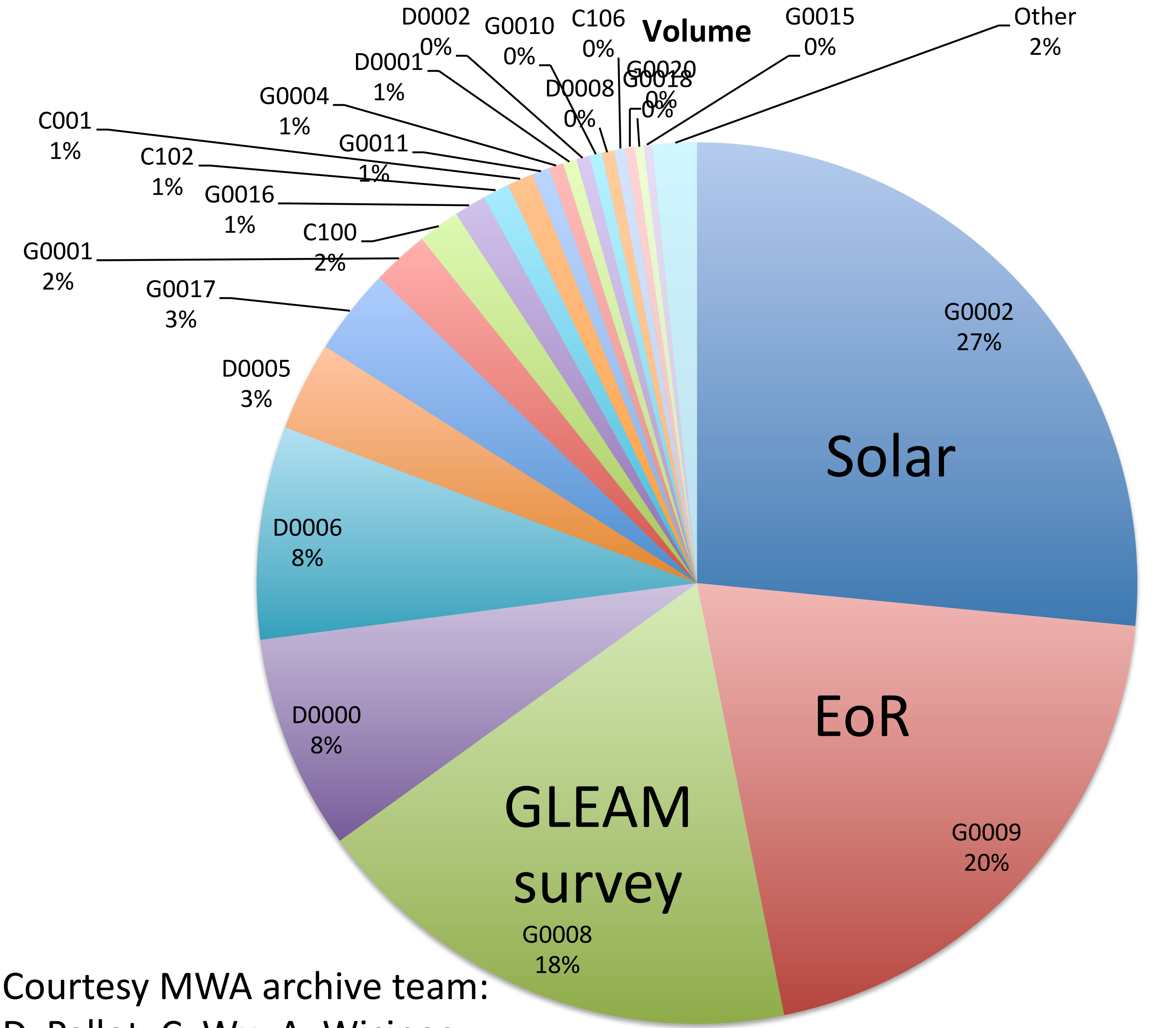


From: Prof. Bryan Gaensler

What have we done?

- We will complete our fifth 6-month operational observing campaign at the end of CY15
- ~8000 hours of observing have been conducted in support of >36 different projects (@20151104)
- >7.5 PB of data are archived at the Pawsey Centre (@20151104)
- Completed a design study and implementation plan for an MWA node of the All-Sky Virtual Observatory (www.asvo.org.au)
- First public release of MWA data (www.mwatelescope.org)
- Learned a lot about building, commissioning and operating a low-frequency aperture array at the MRO
- Science

Archive volume breakdown



Project	Volume (TB)
G0002	1807.97
G0009	1380.62
G0008	1241.30
D0000	537.01
D0006	531.27
D0005	222.57
G0017	215.48
G0001	141.26
C100	104.51
G0016	79.34
C102	66.98
C001	65.52
G0011	43.81
G0004	35.94
D0001	34.57
D0002	33.05
G0010	31.37
D0008	30.70
C106	28.15
G0020	23.86
G0018	22.21
G0015	19.78
Other	111.70

Courtesy MWA archive team:
D. Pallot, C. Wu, A. Wicinec

MWA
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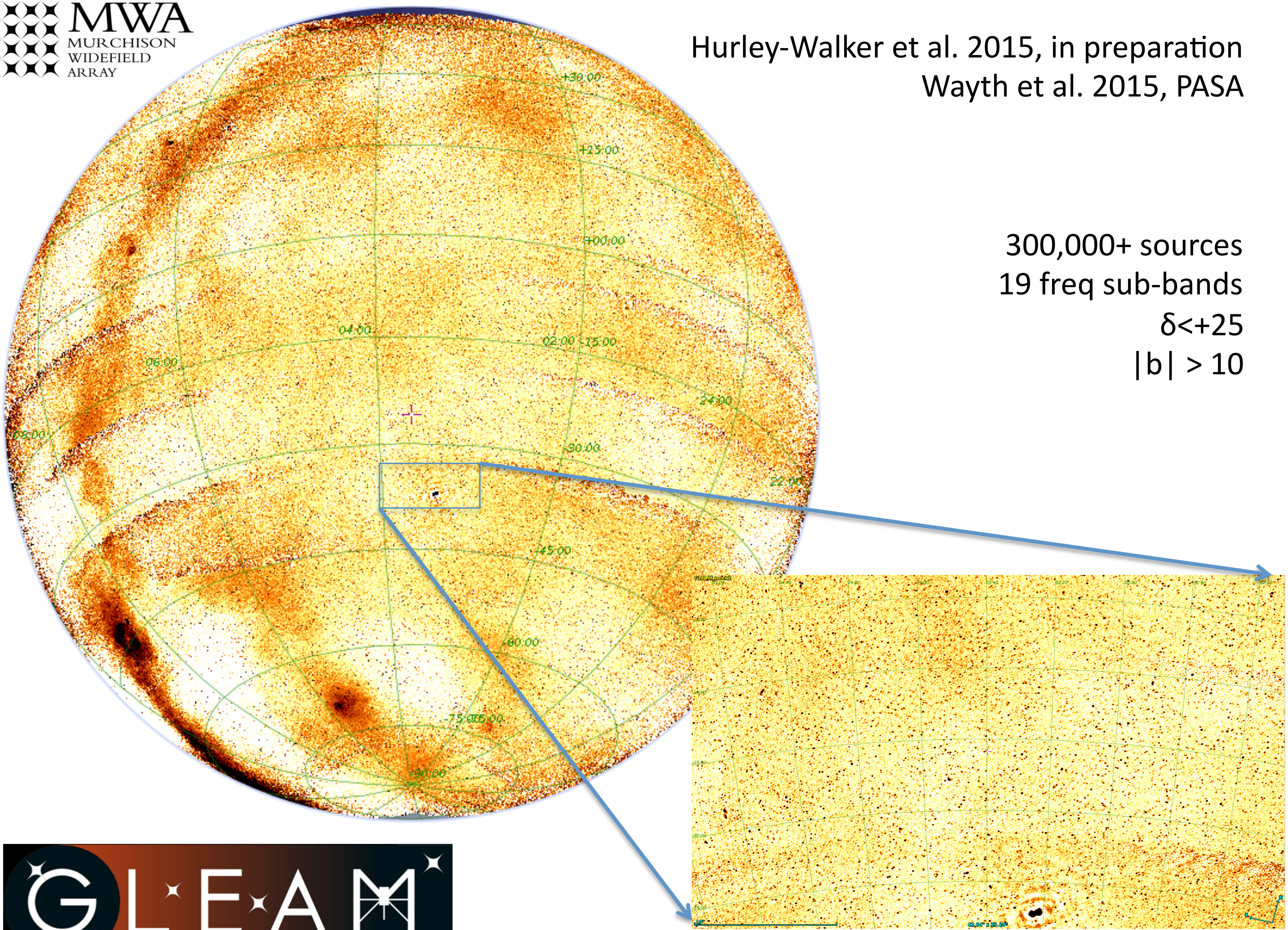
ARRAY

Hurley-Walker et al. 2015, in preparation
Wayth et al. 2015, PASA

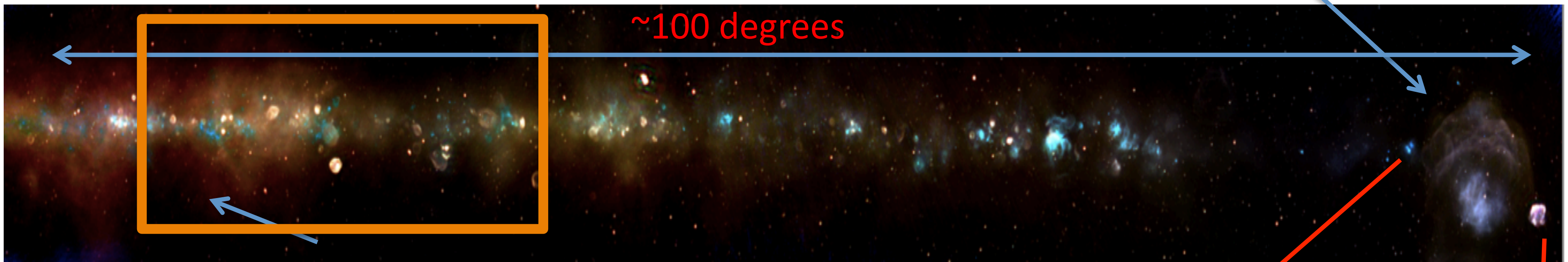
300,000+ sources
19 freq sub-bands
δ<+25
|b| > 10

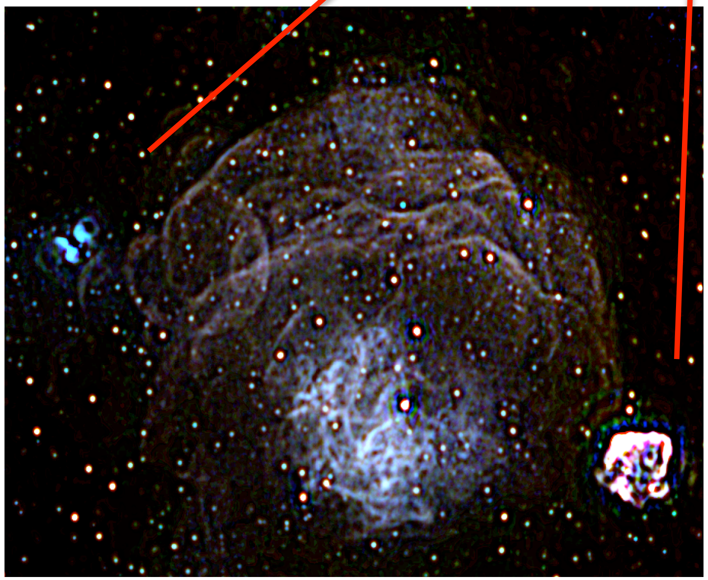


GLEAM

Multi-frequency imaging of the Galactic plane

"Three-colour" image: ~120 – 200 MHz



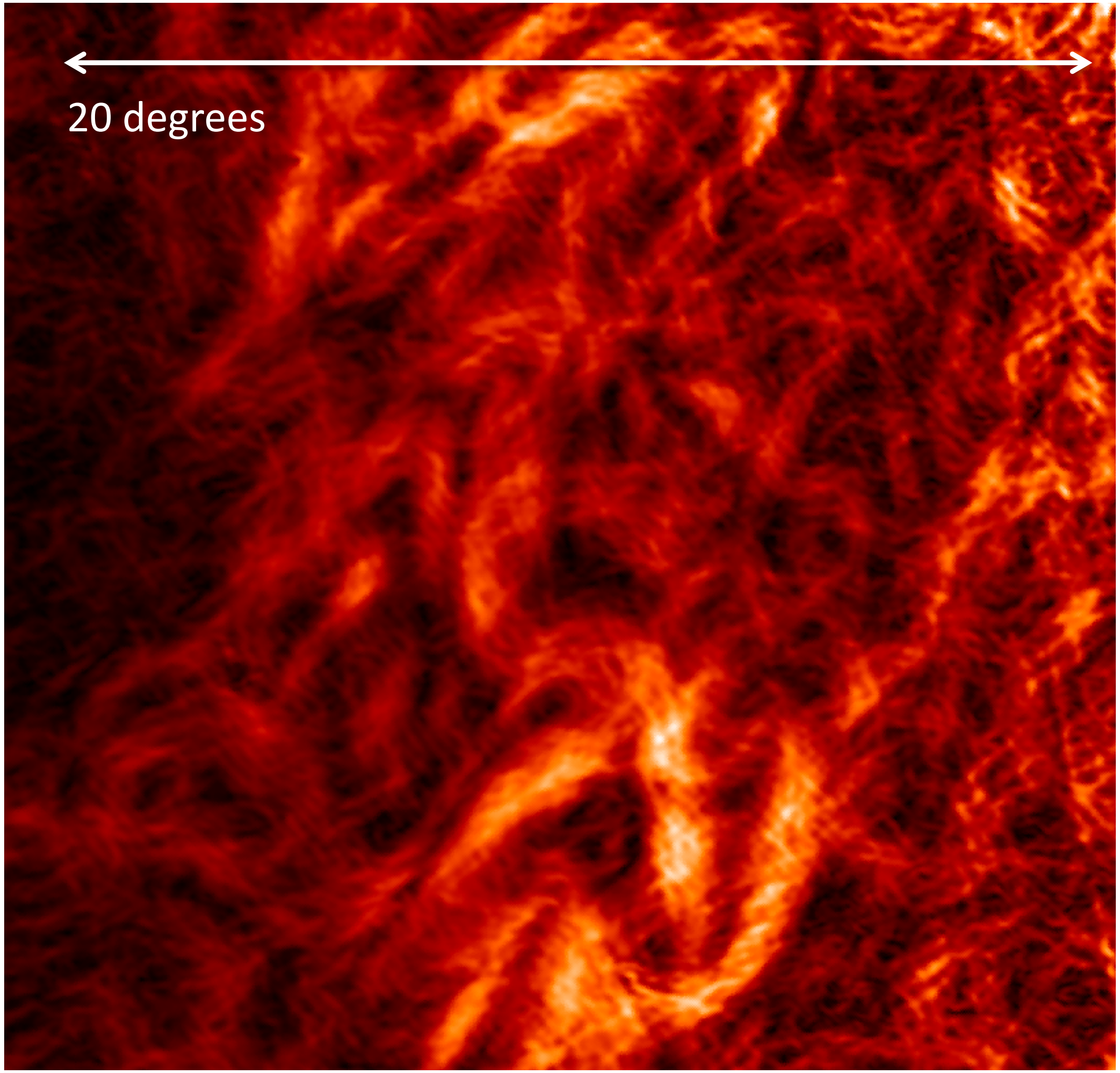


Images: Luke Hindson et al.
(Victoria University of Wellington). 2015 in prep

Unsharp mask (Melanie Johnston-Hollitt)

Snakes out of the plane

- Linear polarisation gradient maps from 200-230 MHz (20 x 20 degs)
- The maps highlight turbulence in the local ISM and are the first to be made in these frequency bands
- Large angular scale structures -> very important foreground to account for in EoR experiment



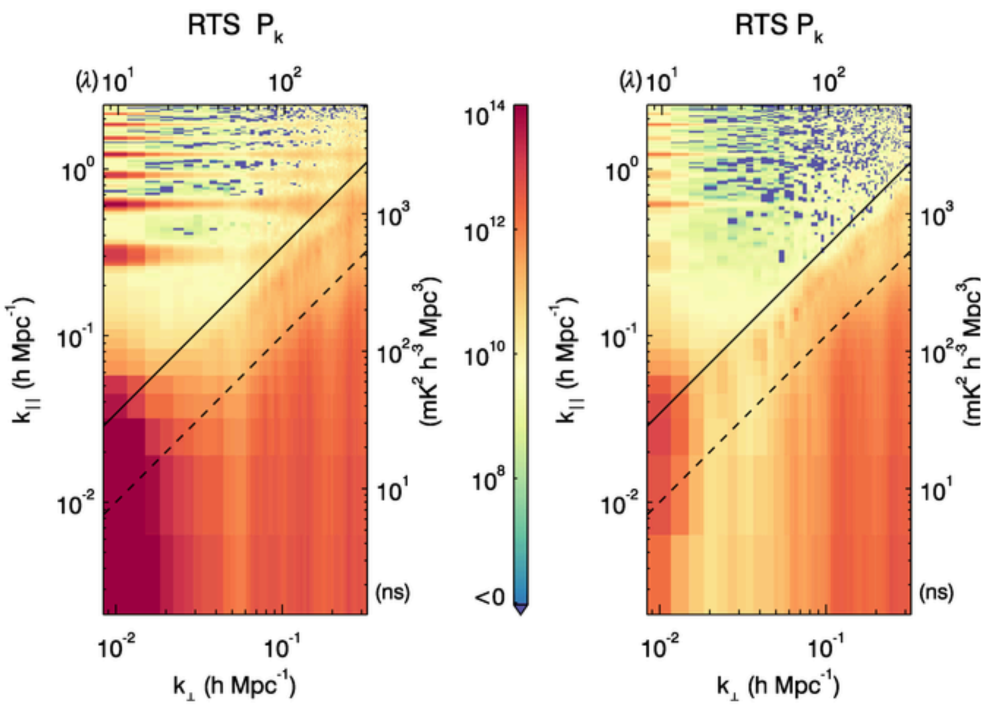
Emil Lenc et al. 2015, in preparation

Epoch of Reionisation

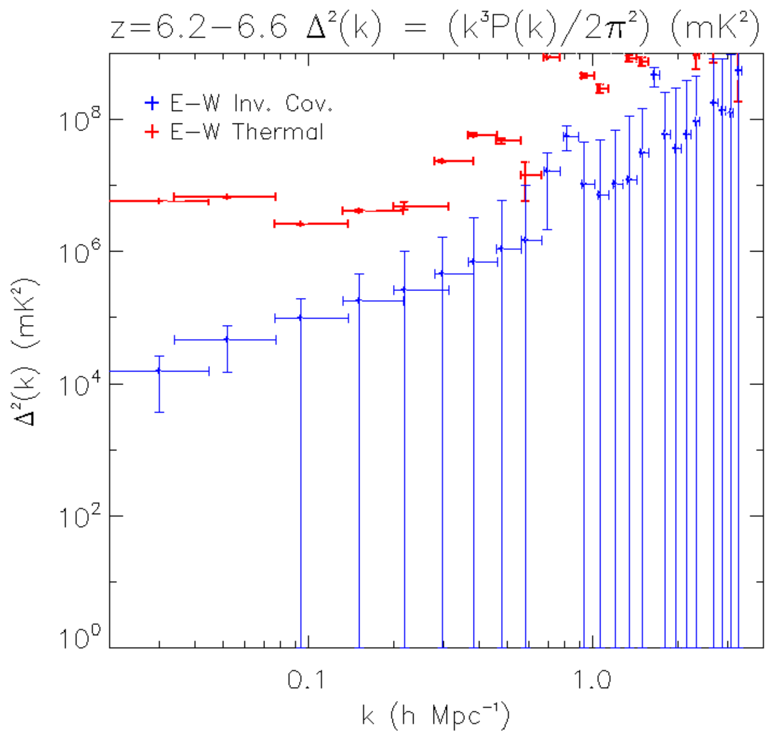
Trott+ (2015)

- Two calibration pipelines + two power spectrum pipelines
- 1000 hours of data observed on three fields

2D power spectra from 3 hours of data



1D power spectra from 3 hours of data



Native power

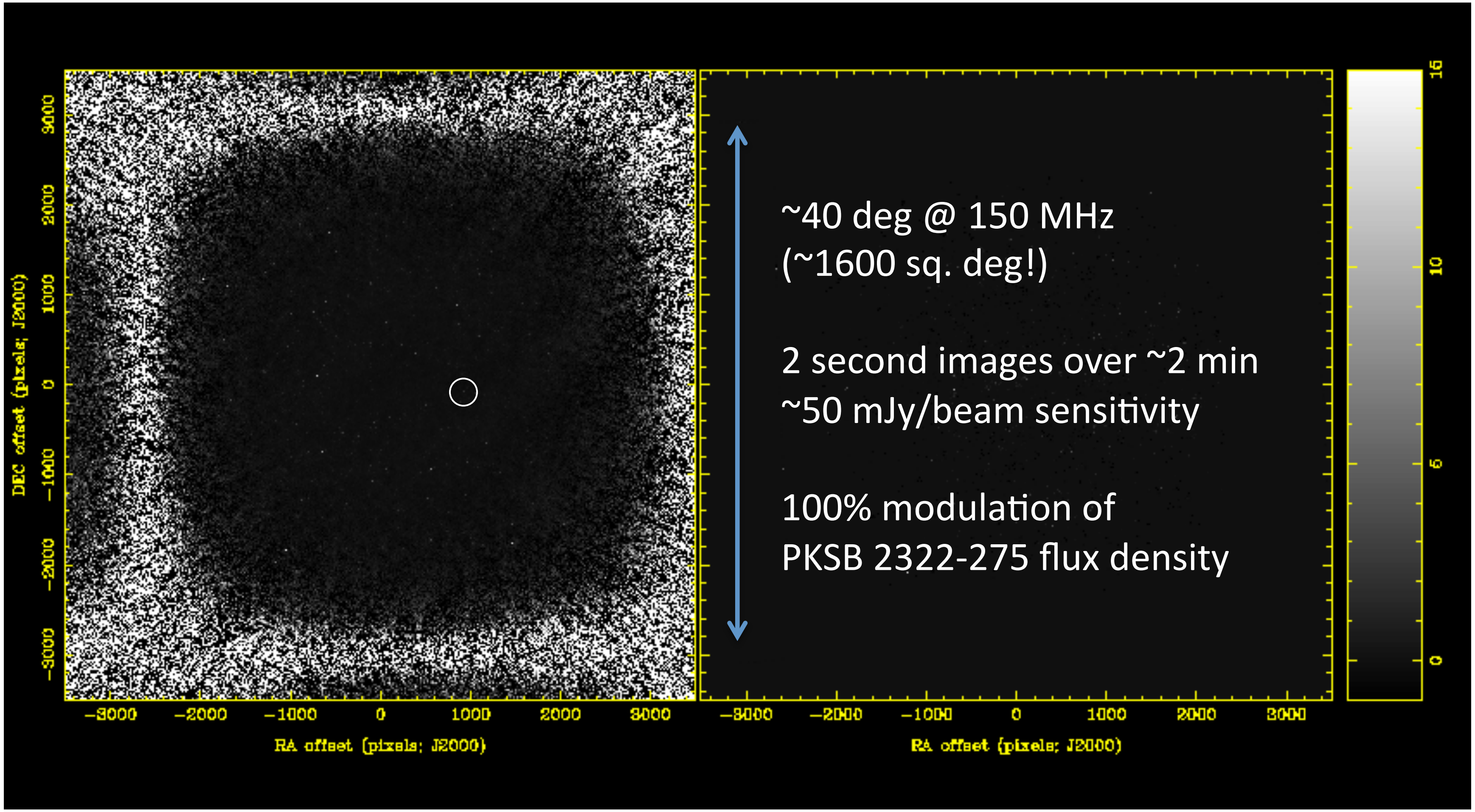
Foreground and instrument cleaned power

Upper limit on EoR power at $k=0.05$ Mpc^{-1}: $(275\ \mathrm{mK})^2$

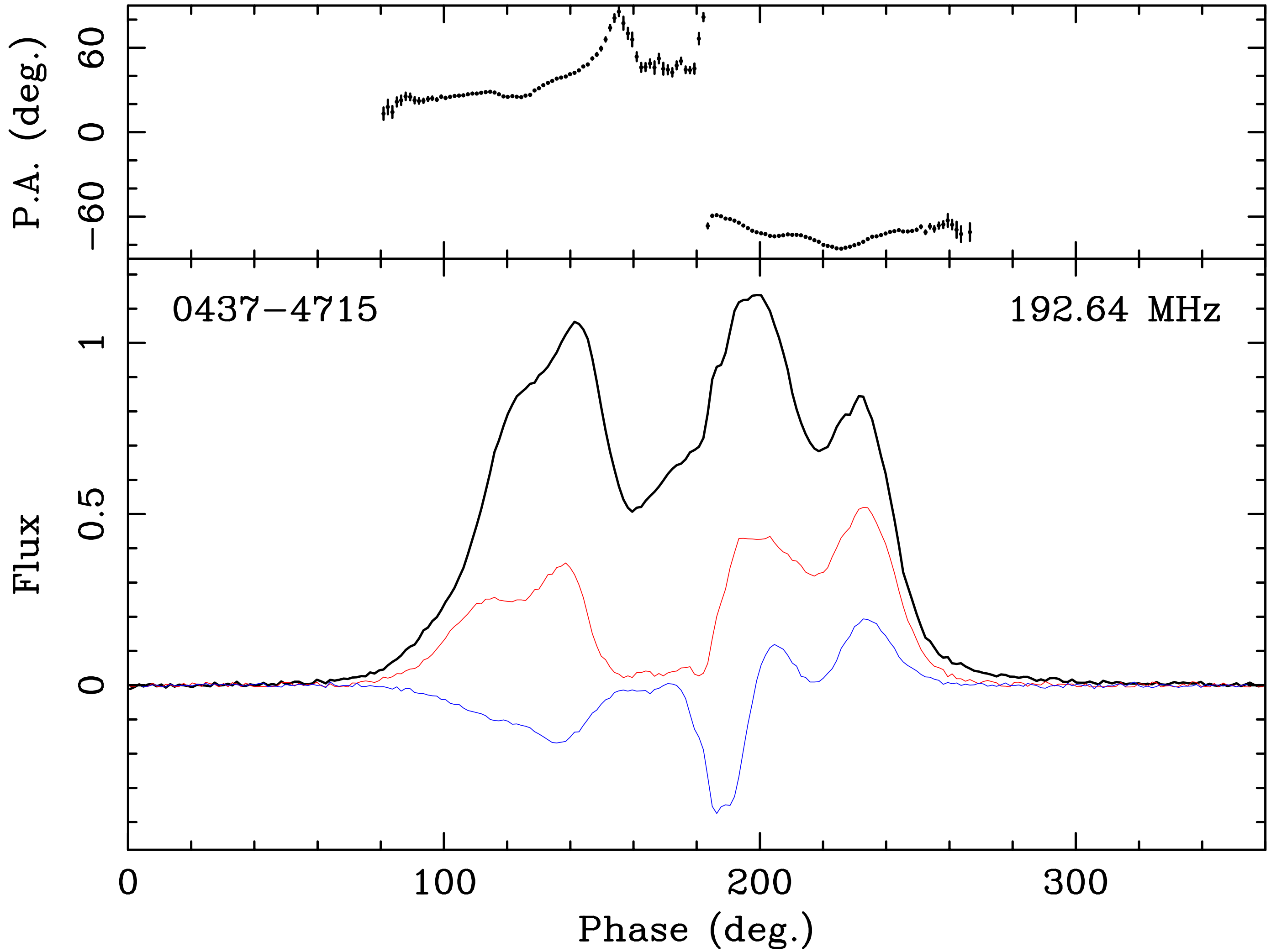
Consistent with expectations

MWA
MURCHISON
WIDEFIELD
ARRAY

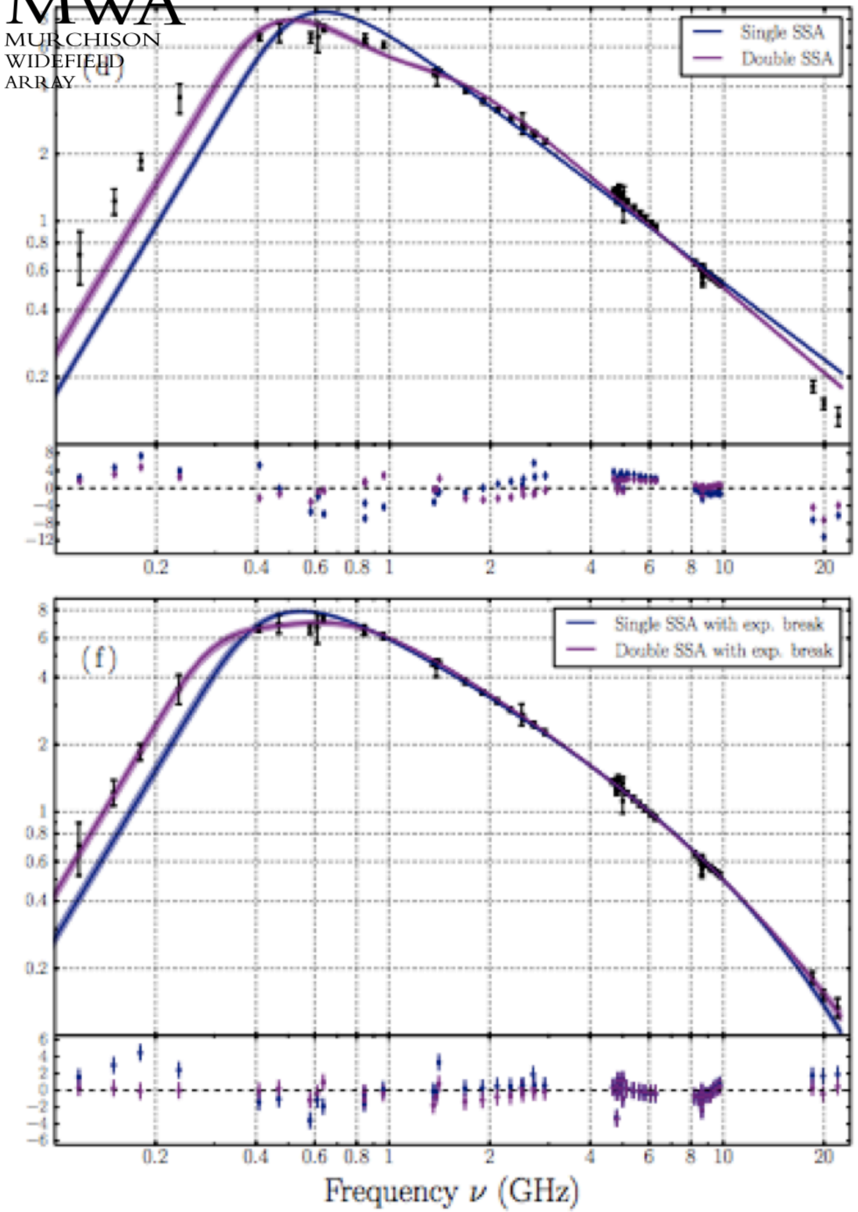
Interplanetary scintillation (Kaplan et al. 2015 ApJ 809)



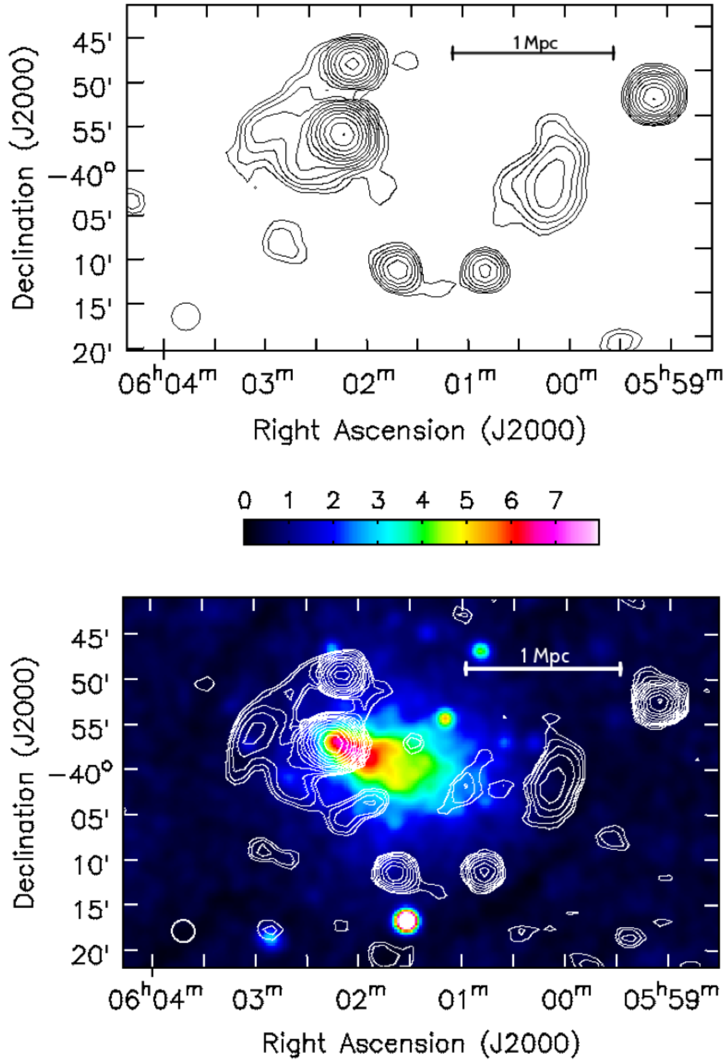
Coherently dedispersed polarimetric tied array beam on 0437-4715 (Ord et al.)



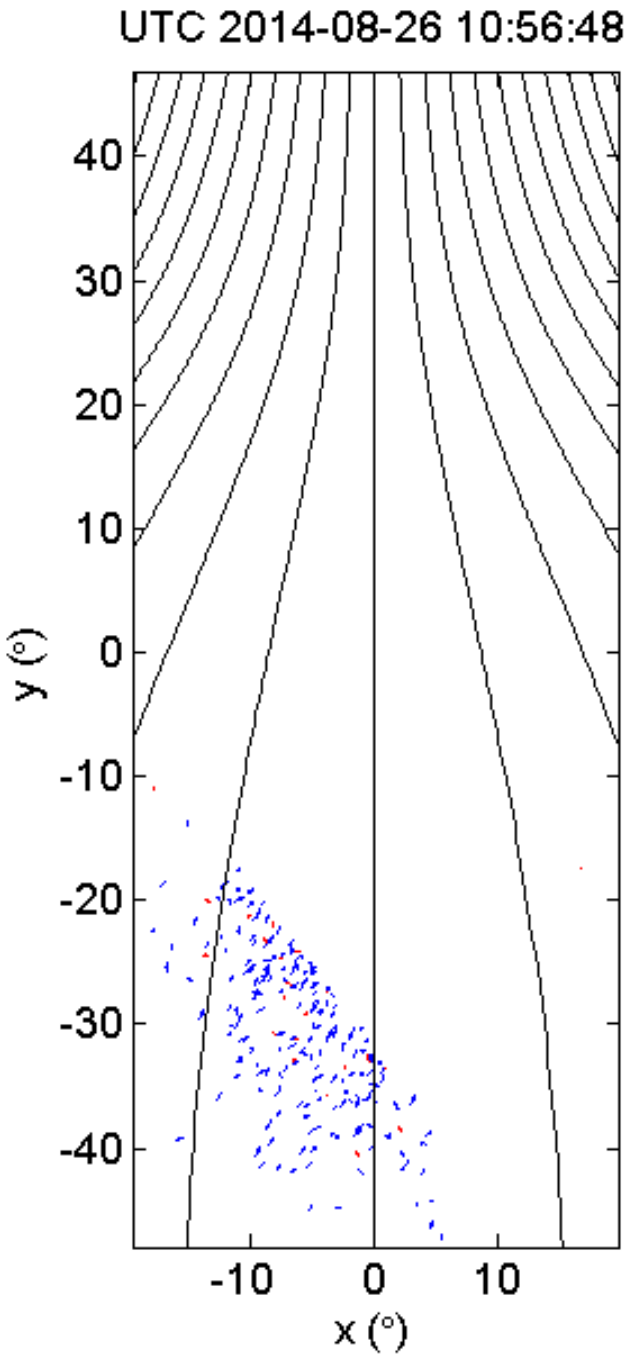
MWA MURCHISON WIDEFIELD ARRAY



THE EXTREME GIGAHERTZ-PEAKED SPECTRUM RADIO SOURCE PKS B0008-421: Callingham et al. 2015 ApJ 809 168C



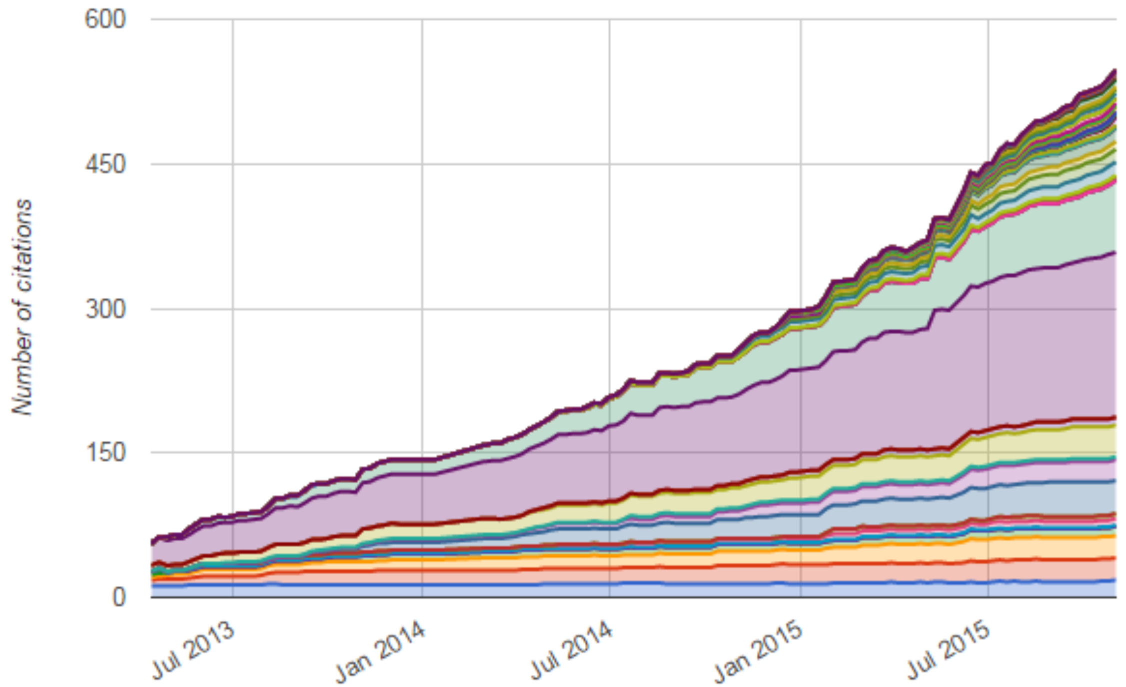
Halo and relic radio emission from Abell 3376: George et al. 2015



- MWA confirms existence of ionsopheric plasma ducts
  Loi et al 2015.
- Movie shows formation of ducts aligned with B fields (lines) after passage of travelling ionospheric disturbance.

MWA papers/citations

Nov 2015	July 2015	July 2014	July 2013	July 2012	Stage
39 (7)	33 (7)	16 (7)	11 (3)	2 (1)	Accepted/published by journals (conferences)
8	7	7	2	2	Submitted to journals
9	3	3	3	6	Drafts posted for collaboration review
28	23	18	5	3	Proposals posted for collaboration review
84 (7)	**66 (7)**	**44 (7)**	**21 (3)**	**13 (1)**	**TOTAL** (@20151104)



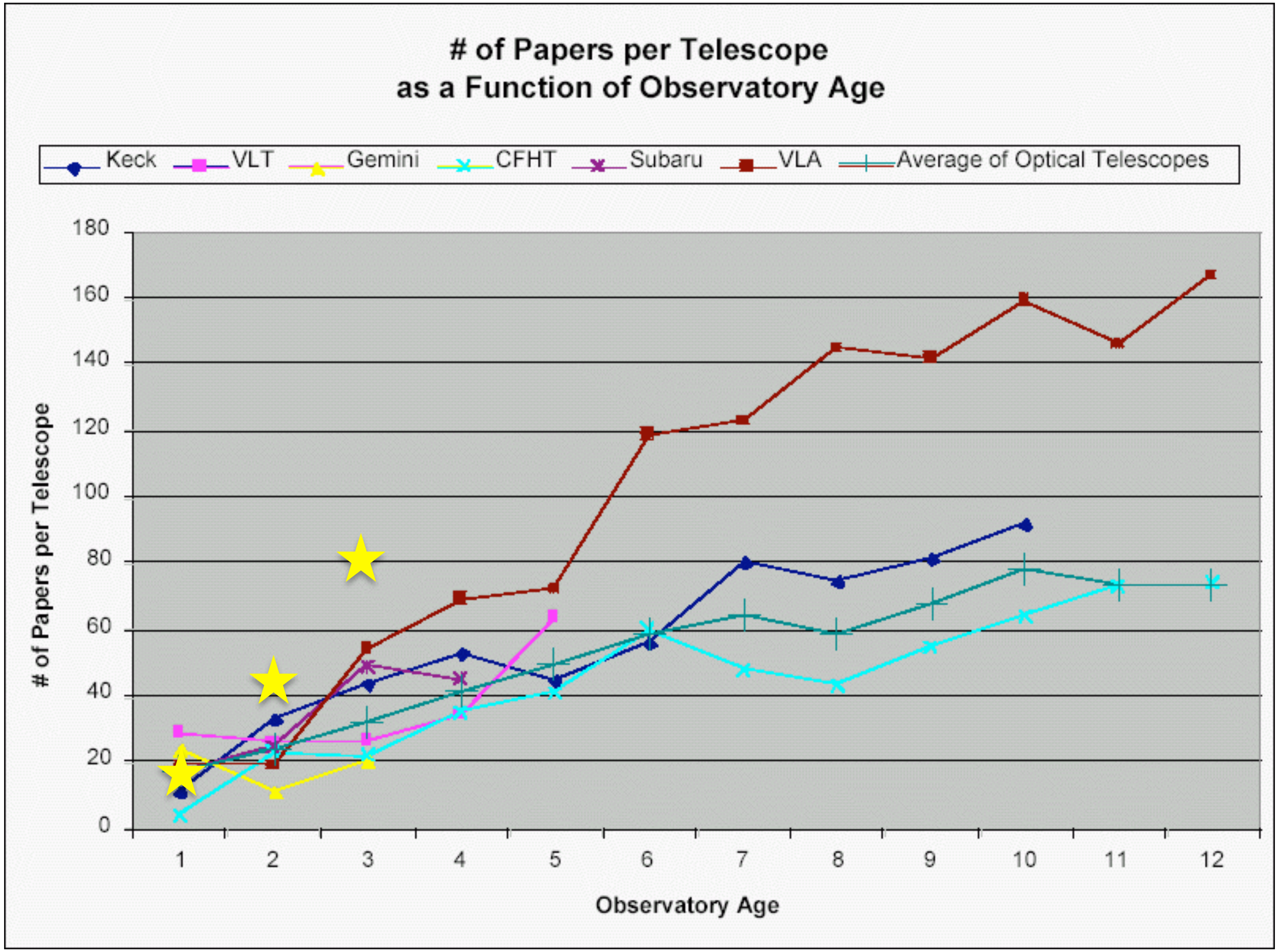
Scientific productivity

Professor Frank Briggs,
Dr Randall Wayth,
Professor Steven Tingay,
Professor Rachel Webster,
and Ms Kate Gunn

MWA instrument and scientists were recently recognised in the 2015 Thompson Reuters Citation and Innovation awards

MWA
MURCHISON
WIDEFIELD
ARRAY

Scientific productivity



From Prof. Ron Ekers, based on analysis in "The scientific productivity of the Gemini Telescopes", Jean-René Roy, Phil Puxley & Dennis Crabtree GSC/AOC-G Meetings, 12-14 Oct. 2004 -- Waikoloa, Hawaii

What are we doing?

- TAC currently reviewing 13 observing proposals for our 16A observing campaign

- Collaborating

What are we going to do?

- Phase 1: 2013-2016
  - 128 antennas, 2.5 km max baseline
- Phase 2: 2016-2018
  - Expand with additional 128 antennas, comprised of
    - 72 closely spaced in 2x hexagonal grids approx 100m size
    - 56 new long baseline antennas to double max baseline to 5km
  - Only 128 antennas used at any time: reconfigure for
    - 'EoR array' (existing core tiles plus new hexes)
    - 'Long baseline array' (existing non-core tiles + new long baseline tiles)
  - Same correlator, receivers: reconfigure by manual re-plugging of tiles into receivers
- Phase 3: 2018+(?)
  - All 256 tiles correlated
  - Increased frequency range and instantaneous bandwidth
  - Requires replacement of post-beamformer analogue and digital hardware

MWA Phase 2

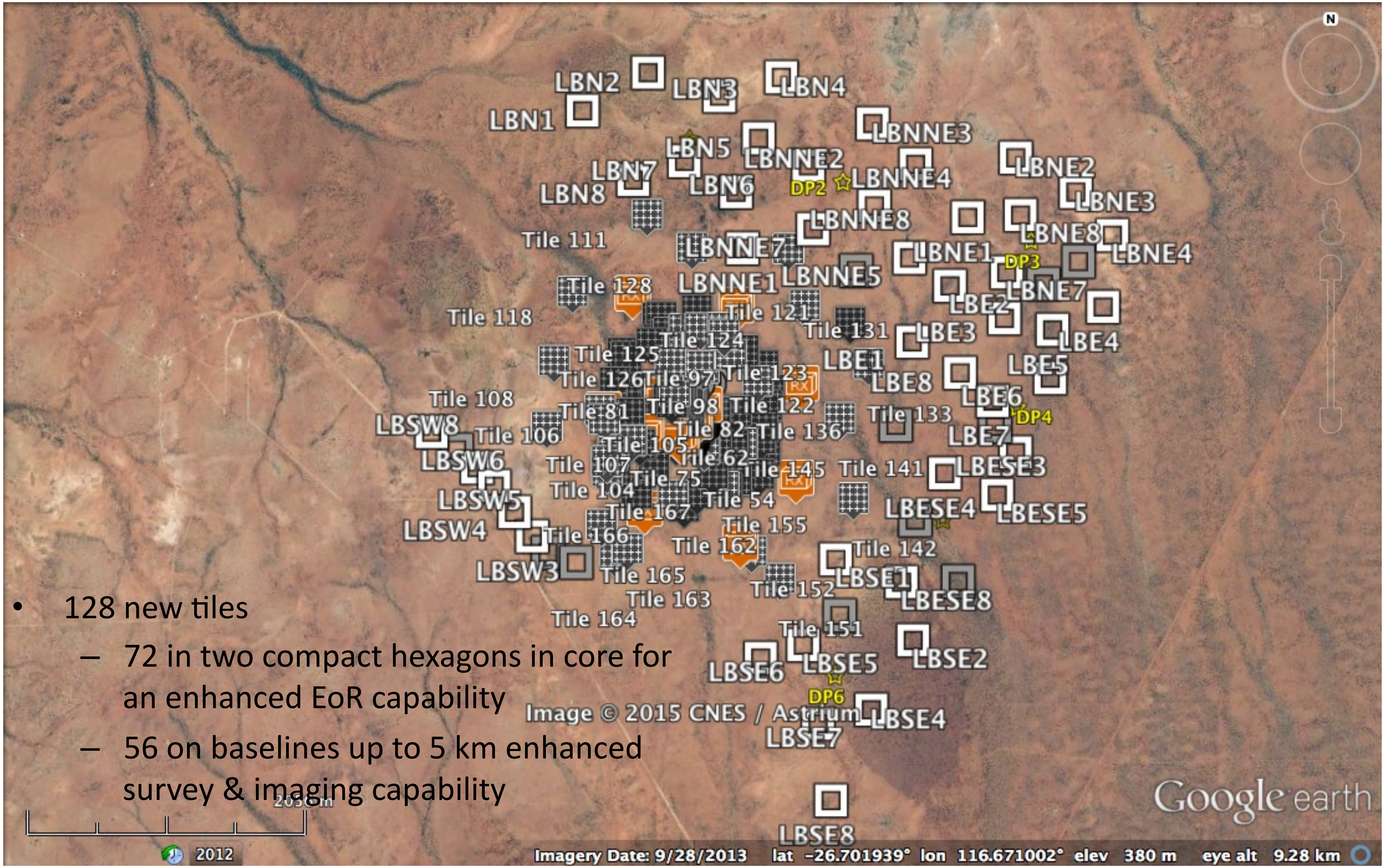
- Project costed at $2.8m
  - ARC LIEF scheme proposal for $1.2m, $1.6m from proposal partners
  - ARC awarded the proposal $1.0m on 30 October 2015

- 128 new tiles
  - 72 in two compact hexagons in core for an enhanced EoR capability
  - 56 on baselines up to 6 km for enhanced survey imaging capability

- 128 of 256 tiles correlated: reconfigure for
  - 'EoR array' (existing core tiles plus new hexes)
  - 'Long baseline array' (existing non-core tiles + new long baseline tiles)
  - Same correlator, receivers: reconfigure by manual re-plugging of tiles into receivers

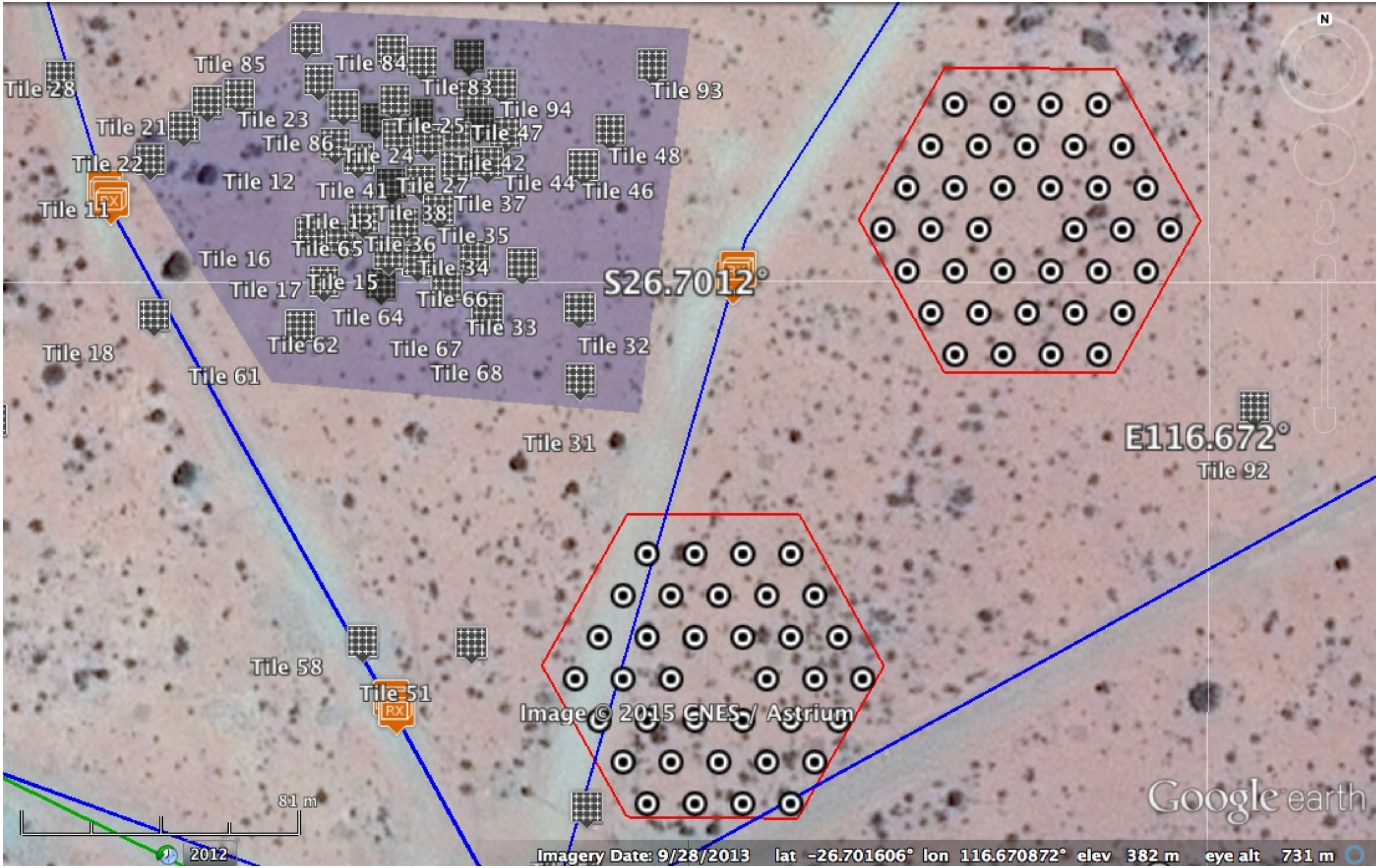
- Phase 2 will see new partners join the MWA Collaboration
  - University of Toronto, Canada
  - University of Western Sydney, Australia

MWA phase2

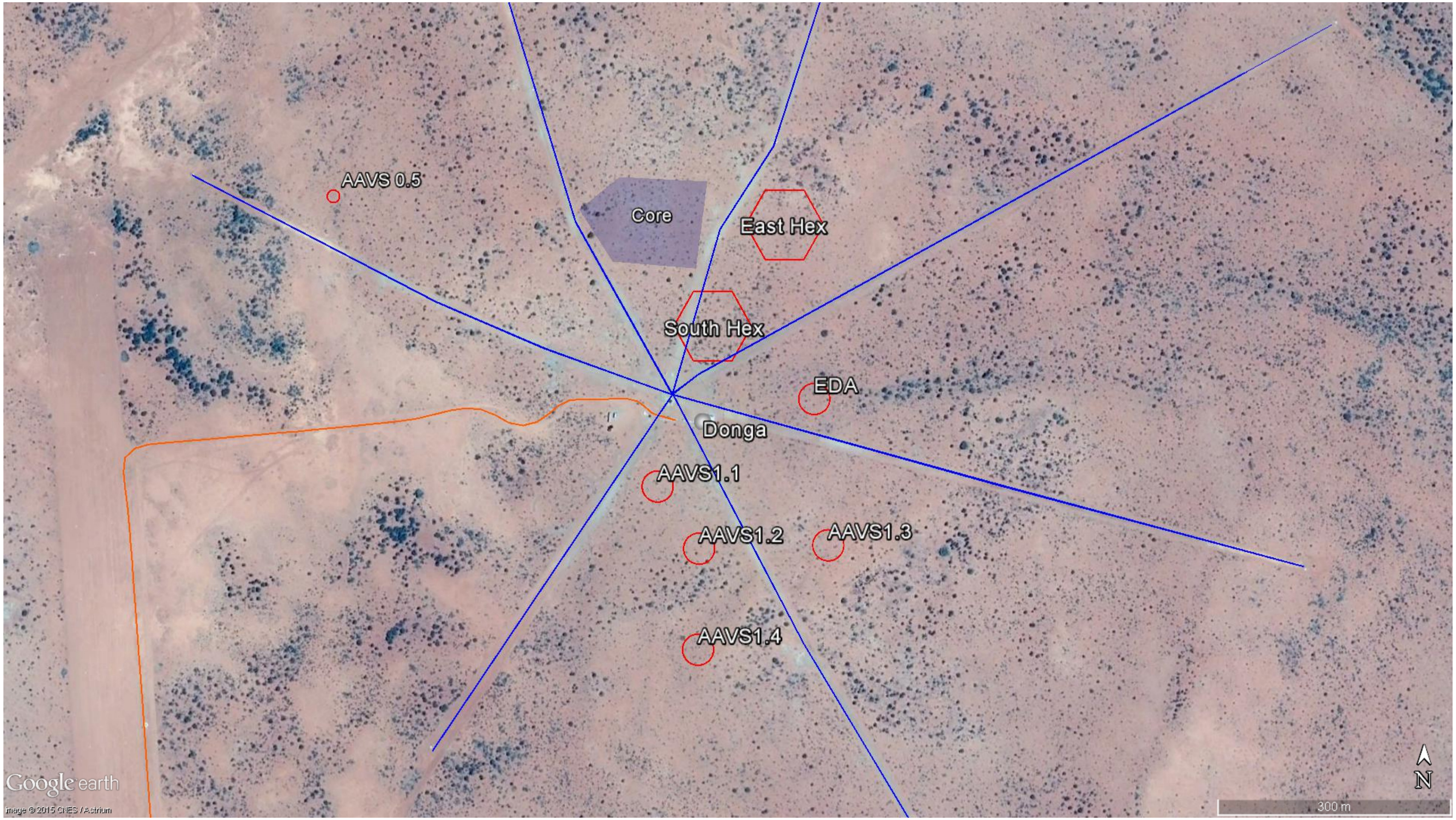


- 128 new tiles
  - 72 in two compact hexagons in core for an enhanced EoR capability
  - 56 on baselines up to 5 km enhanced survey & imaging capability

MWA phase 2: core region



What do we enable and support?



Engineering Development Array (EDA)

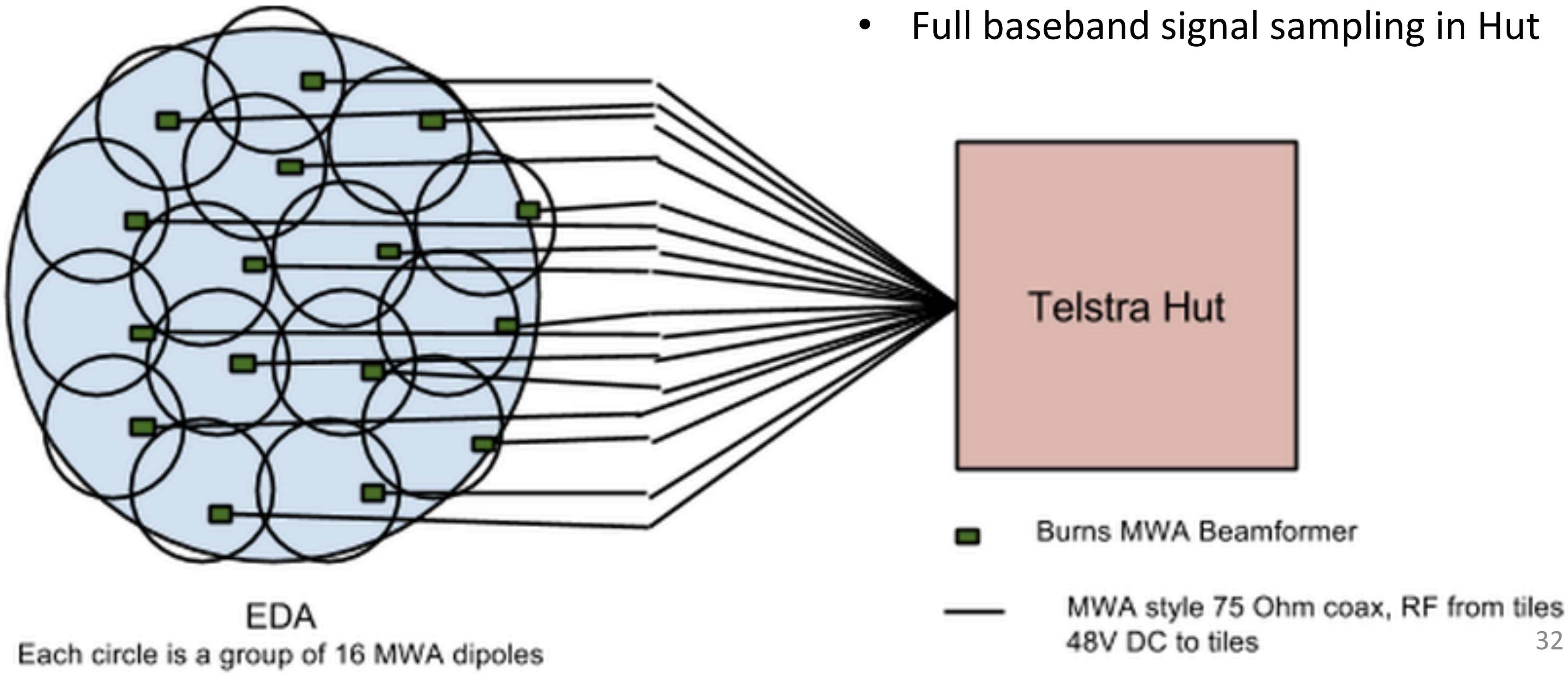
- Purpose:
  - Prototype and test technology required for expanded MWA phases 2 and 3
    - Remote (long baseline tiles with RFoF)
    - Network/comms to remote tiles
    - Provide signal and control path for potential MWA phase 3 without current MWA receivers
  - Enable testing of MWA correlator expansion project
    - External data into MWA correlator → full cross correlation with entire MWA (mutually beneficial)
    - Hybrid array calibration schemes
  - AAVS1 reference/comparison system
    - Aids AAVS1 characterization, regardless of any comparison role
    - Beamforming and beam metrology on same sized station
    - Comparison of station performance over SKA_Low frequency range
  - Provide ICRAR/Curtin University with a “sandpit” for array radio science and engineering developments

EDA - Initial implementation

- Made from off-the-shelf or existing MWA components
  - MWA active antenna dipoles with **expanded low freq range** LNA (50-330 MHz)
  - RF/data over 200m coax
- Analogue beam-formed sub-arrays
- 256 dipoles total

High-level design

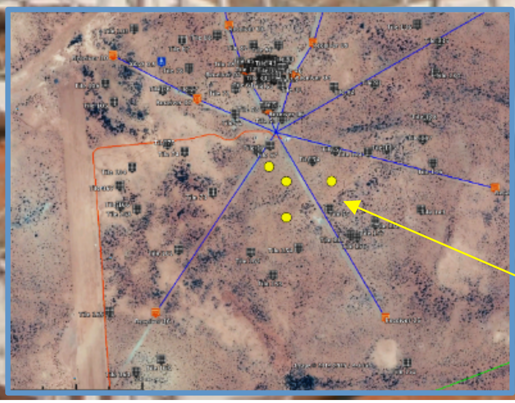
- 2nd stage beamforming (analogue or digital) in Hut
- Full baseband signal sampling in Hut



EDA
Each circle is a group of 16 MWA dipoles

Aperture Array Verification System 1 (AAVS1)

- Prototype of technology proposed for SKA-Low and MWA extension
- Owned by 6 international research partners, led in Australia by ICRAR/Curtin (not an SKAO instrument)
  - Low Frequency Aperture Array development consortium
- Operated stand-alone, and in conjunction with MWA
- Will trial economical, low-impact construction techniques which might be used for SKA-Low
- About 400 antennas, grouped in four 35m diameter ‘stations’
  - One full “SKA1-Low” station
- Aim to build in 2015-16 and operate in 2016-17
- Mainly an engineering development instrument, but will do science alongside MWA
- Site civil work largely complete; thanks to regional and indigenous contractors



AAVS1 stations
(approximately to scale)

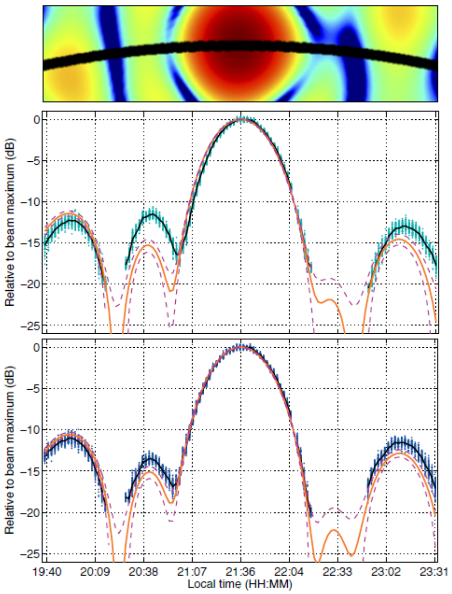
SKA SQUARE KILOMETRE ARRAY
LOW-FREQUENCY APERTURE ARRAY

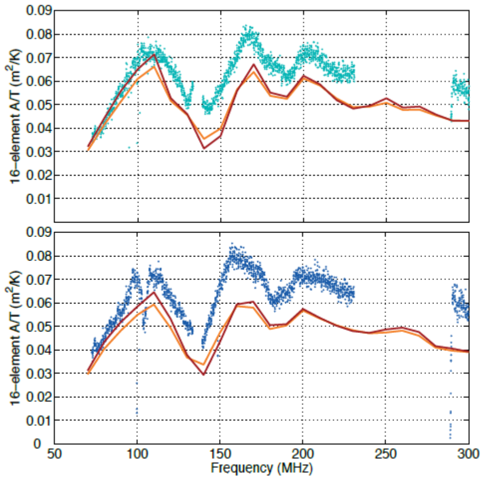
AAVS 0.5 – a taste of things to come

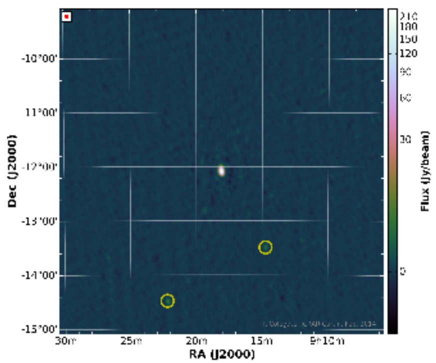
- **AAVS 0.5 (16 antennas)**
  - External instrument of MWA (returns to MWA, SKA)
  - Main job done, observations complete
  - New antenna/array metrology in "difficult" frequency range
  - Continued use as environment and technology test platform for AAVS1

Characterization of Aperture Array Verification System 0.5: Radio Astronomy Interferometry and Full-Wave Simulation

A. T. Sutinjo, T. M. Colegate, R. B. Wayth, P. J. Hall, E. de Lera Acedo, T. Booler, A. J. Faulkner, L. Feng, N. Hurley-Walker, B. Juswardy, S. K. Padhi, N. Razavi-Ghods, M. Sokolowski, S. J. Tingay, J. G. Bij de Vaate







Electromagnetic engineering + astronomy = verification of SKA1 design tools

MWA
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- For updates:
  - www.facebook.com/murchison.widefield.array
- For info:
  - www.mwatelescope.org
- For contact:
  - MWA-Director@curtin.edu.au

THANKS!!!

Wadjarri Yamatji people	Traditional Owners of the MRO site
CSIRO	Operates the MRO
Astronomy Australia Limited	Administers Federal funding
Australian Government	Provides Federal funding
Western Australian Government	Provides State funding
CAASTRO	Major science partner

Yamatji Marlpa ABORIGINAL CORPORATION

CSIRO

Astronomy Australia Ltd.

Australian Government

GOVERNMENT OF WESTERN AUSTRALIA

CAASTRO ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS