Australia's National Science Agency

LAMBDA: Low-frequency Australian Megametre Baseline Demonstrator Array

George Heald (CSIRO Astronomy and Space Science)

uGMRT VLBI workshop

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Overview

- Motivation
- Science case for low-frequency VLBI leading into SKA1-LOW era
- Concept for new low frequency stations
- Defining the LAMBDA project
- Challenges and opportunities

Motivation

- Low frequency ($\nu < 350$ MHz) interferometers are almost all limited to $\gtrsim$5” resolution (41 km at typical frequency 300 MHz)
  - SKA1-LOW (Bmax=65 km) will be limited to this typical resolution

- Low-frequency VLBI is feasible (e.g. LOFAR): typical isoplanatic patch ~ 1° and coherence timescale ~ 1-2 min (at 140 MHz; LBCS)
  - Sub-arcsecond capability at low frequency is crucial for certain targets

- Australia is well situated to develop this capability for the Southern hemisphere (~ 4000 km E-W extent, existing VLBI network, home of MWA and SKA1-LOW)
  - Potential to link to uGMRT, FAST, South Africa, ...

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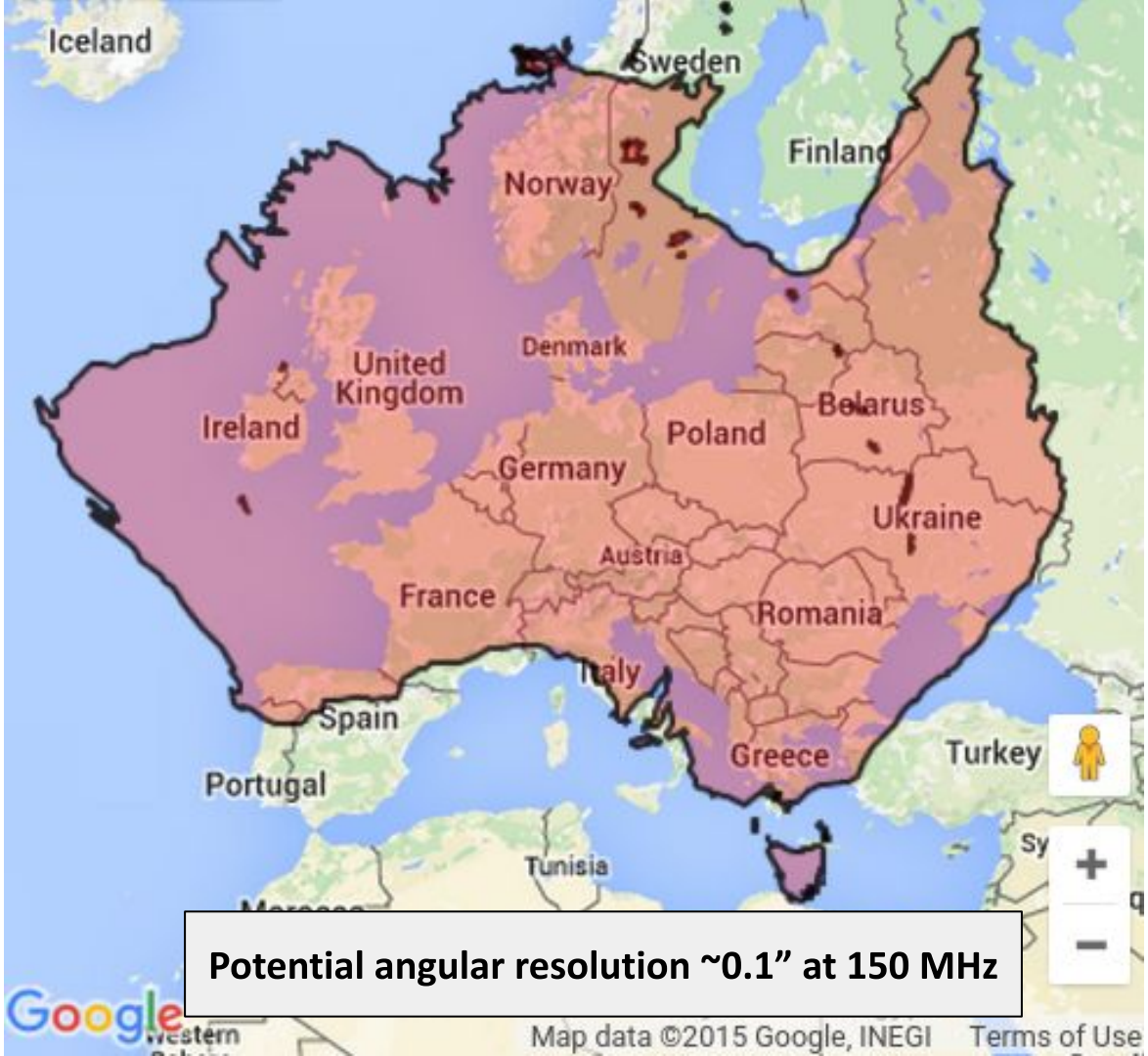
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Potential angular resolution ~0.1” at 150 MHz
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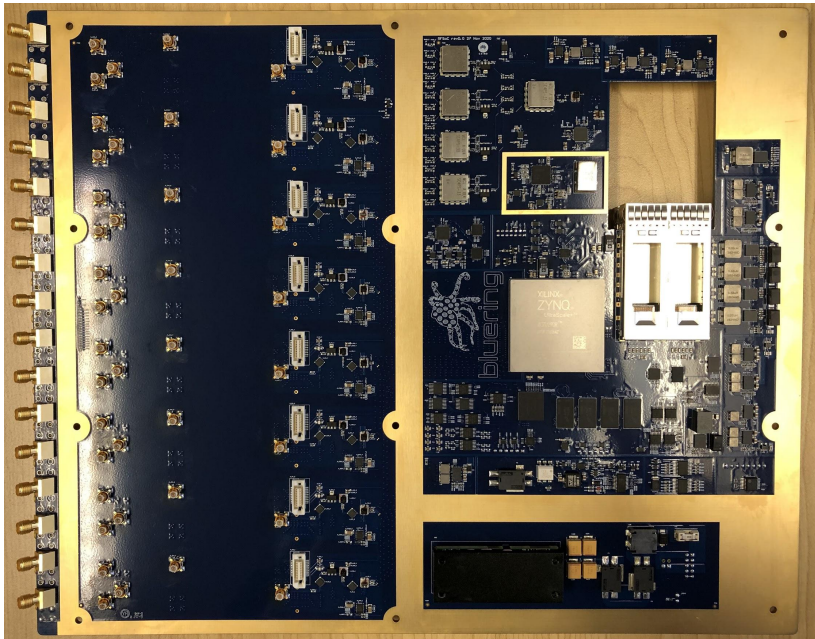
Science case

- High resolution (hundreds of mas) mapping of AGN and other radio sources detected with MWA, ASKAP
  - NB: EMU, POSSUM, FLASH, VAST all getting rolling now! 2/3 of the ASKAP sky cannot be imaged at low frequency with long baselines.
- Mapping exoplanetary emission, distinguishing radiation from planet vs host star
- Pulsar astrometry, distances, proper motions, scintillometry
- Gravitational lens discovery / imaging
- FRB followup and host imaging
- Single station mode: pulsar monitoring/timing, determination of high-precision ISM properties

Concept for new low frequency stations

- Layout: SKA1-LOW station
- Antenna: MWA dipoles or SKA1-LOW antenna
- Front-end signal processing and beamformer: CSIRO “BlueRing” *(Xilinx RFSoC based system)* Antenna coax in, beamformed optical signal out to correlator
- Local diskpacks and/or eVLBI
- Local timing
- Proof of concept station coming at Narrabri (primarily to test the BlueRing technology)



BlueRing Razorback module; courtesy Grant Hampson

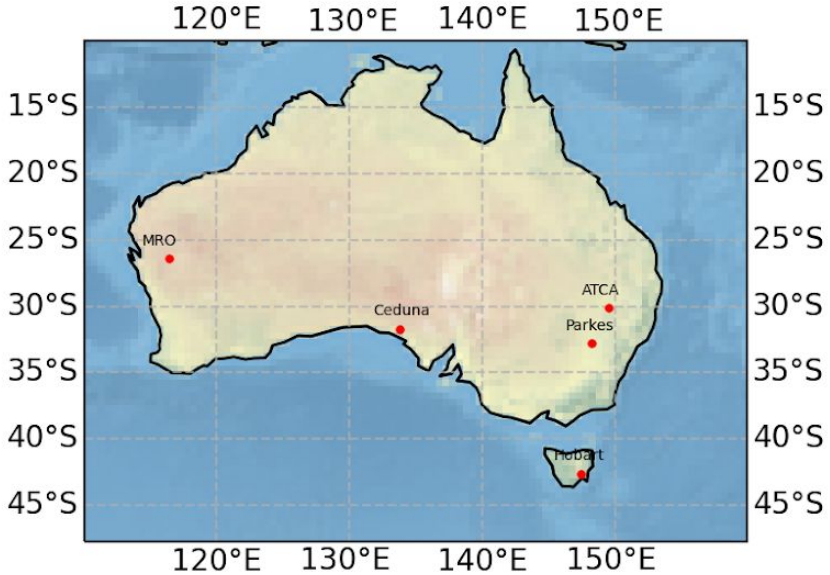
LAMBDA project - sensitivity

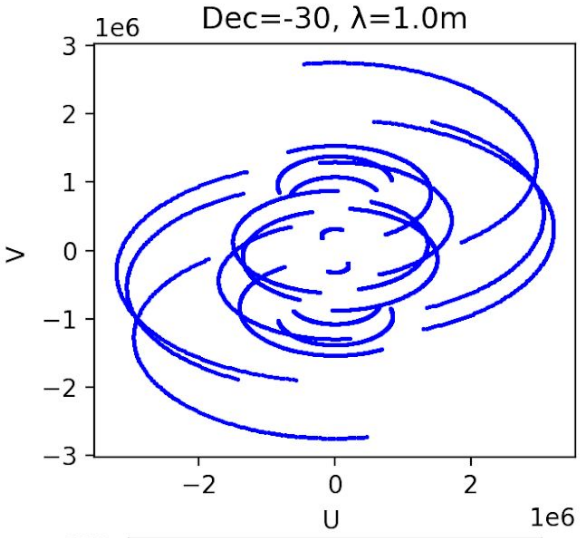
Indicative sensitivities for various LAMBDA scales and partnerships

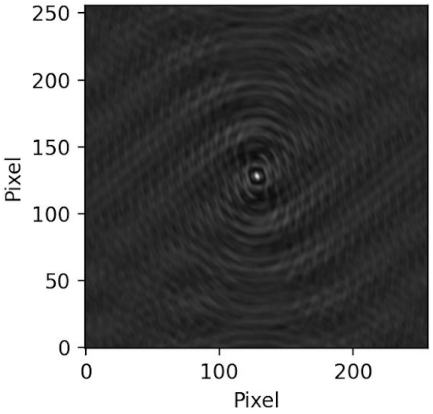
	BL rms (60s, 48 MHz)	rms (1h, 48 MHz)	rms (8h, 48 MHz)
6x 256 dipoles	26 mJy	870 µJy	310 µJy
6x 256 + MWA-III	6 mJy	460 µJy	160 µJy
16x 256 dipoles	26 mJy	310 µJy	110 µJy
16x 256 + MWA-III	6 mJy	180 µJy	64 µJy
32x 256 + SKA1 core	2 mJy	77 µJy	27 µJy

LAMBDA project - indicative uv coverage

Initial locations selected to coincide with existing LBA sites for power, network







Plots courtesy of Cormac Reynolds (CSIRO) and Yun Yu (SHAO)

LAMBDA project - future expandability

Future locations: follow fiber backbone in WA / across Australia?

(Note importance of intermediate-scale baselines for good imaging quality)

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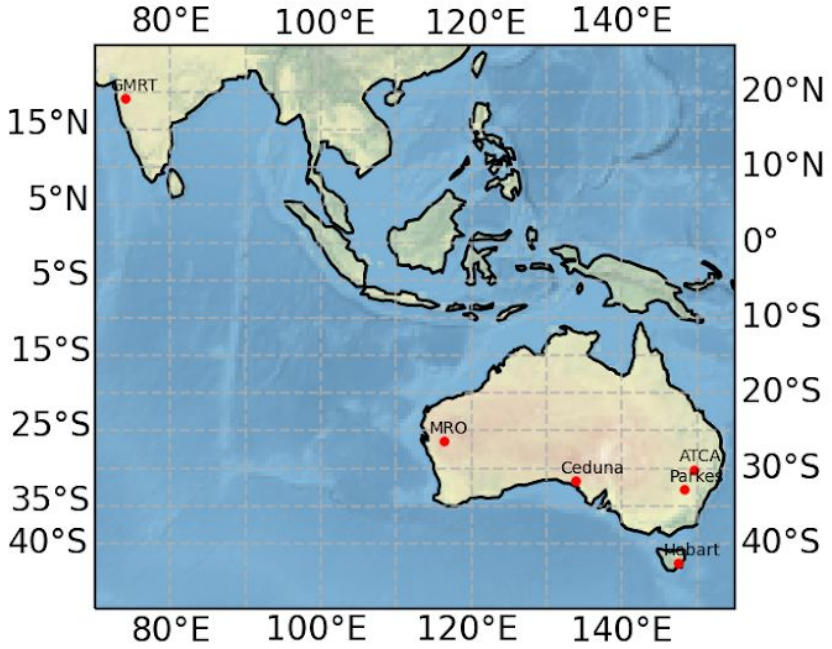
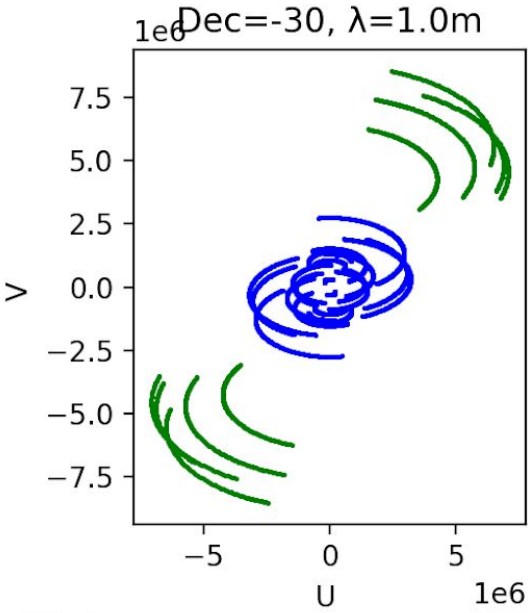
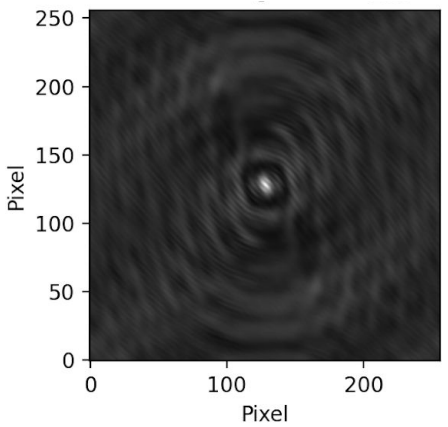
LAMBDA project - as part of global VLBI

Potential to link with uGMRT (150-250 MHz, maybe 250-350 MHz)



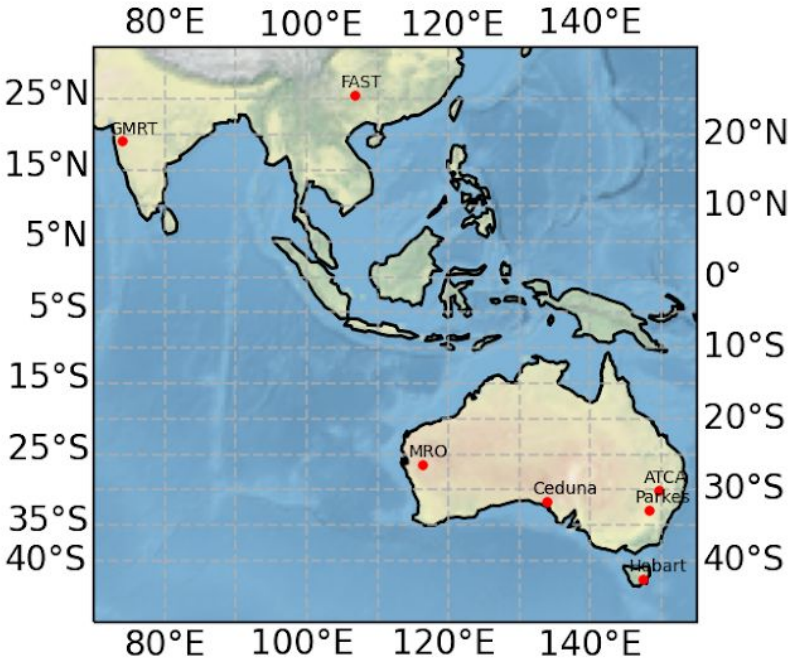


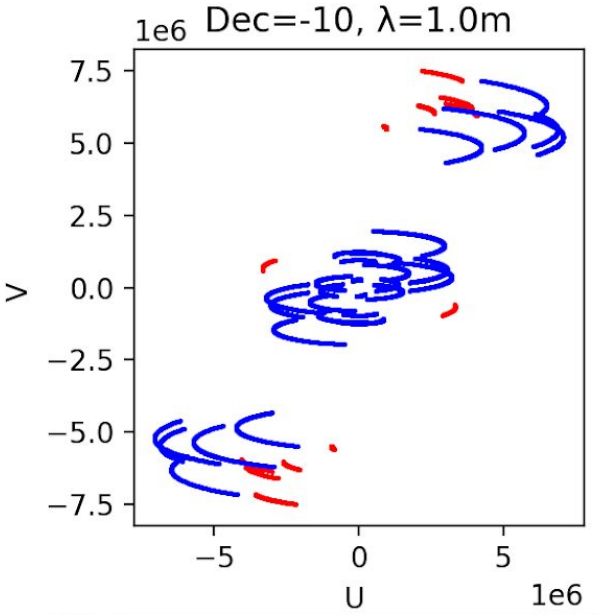


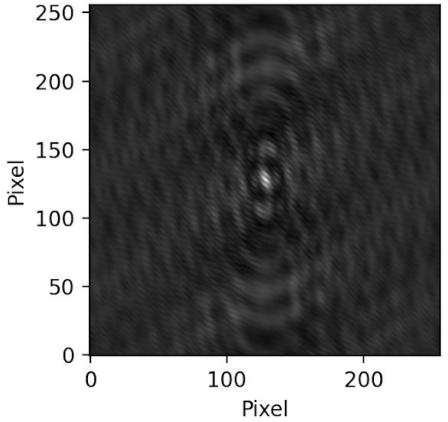
Plots courtesy of Cormac Reynolds (CSIRO) and Yun Yu (SHAO)

LAMBDA project - as part of global VLBI

Potential to link with uGMRT and FAST







Plots courtesy of Cormac Reynolds (CSIRO) and Yun Yu (SHAO)

LAMBDA project

Operational concept

- Stations can operate standalone (pulsar monitoring, FRB/transient search) or as an array possibly including other elements (phased uGMRT, phased MWA, or in future phased SKA1-LOW)
- Multibeam & rapid repointing for surveys and FRB/transient followup
- VLBI correlation and data production/delivery via same resources as Australian Long Baseline Array (LBA)
- Operate as a National Facility (akin to ATCA, Parkes, LBA)

Challenges

- Feasibility amongst other ATNF priorities
  - Cost to establish and operate
  - Operational support
  - Maintenance
- RFI at “easy” sites, accessibility at radio-quiet sites
- Training and support for user base
- Sensitivity limitations with an early rollout
  (ramp up with early calibrator survey project?)

Opportunities

- Set the stage for a robust and capable low-frequency VLBI network in the South incorporating and supplementing SKA1-LOW
- Leverage Australian VLBI capability and international resources (uGMRT and others) to add further science value to the SKA
- Use existing cal/imaging experience (fringe fitting, LOFAR-VLBI)
- Unique VLBI capability exceeding mid-frequency LBA:
  - Potential for far higher availability
  - Larger field of view (sky survey concept)
  - Rapid re-pointing and flexibility
  - Highly extensible with global partnerships
- High-availability, flexible followup resource for MWA detections (including through IPS) and ASKAP survey discoveries

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Thank you

Questions or comments:

George Heald
george.heald@csiro.au