



# Low-frequency VLBI

## Low-frequency Australian Megametre-Baseline Demonstrator Array (LAMBDA)

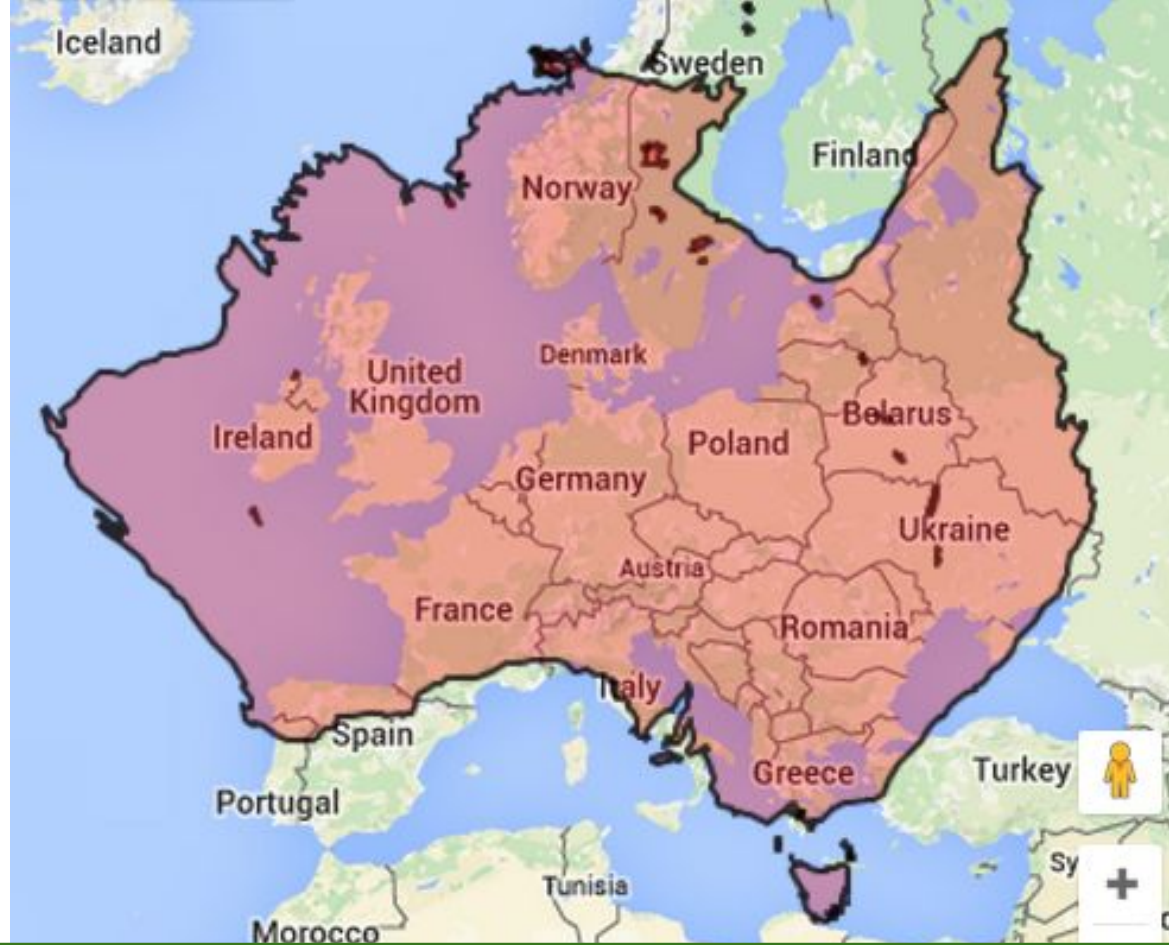
George Heald

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# Motivation

- Low frequency ( $\nu < 350$  MHz) interferometers are almost all limited to  $\gtrsim 5''$  resolution (41 km at typical frequency 300 MHz)
  - SKA1-LOW ( $B_{\max}=65$  km) will be limited to this typical resolution
- Low-frequency VLBI is feasible (e.g. LOFAR): typical isoplanatic patch  $\sim 1^\circ$  and coherence timescale  $\sim 1$ -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 ( $\sim 4000$  km E-W extent, existing VLBI network, home of MWA and SKA1-LOW)
  - Potential to link to uGMRT, FAST, Japan, South Africa, ...



Potential angular resolution  $\sim 0.1''$  at 150 MHz

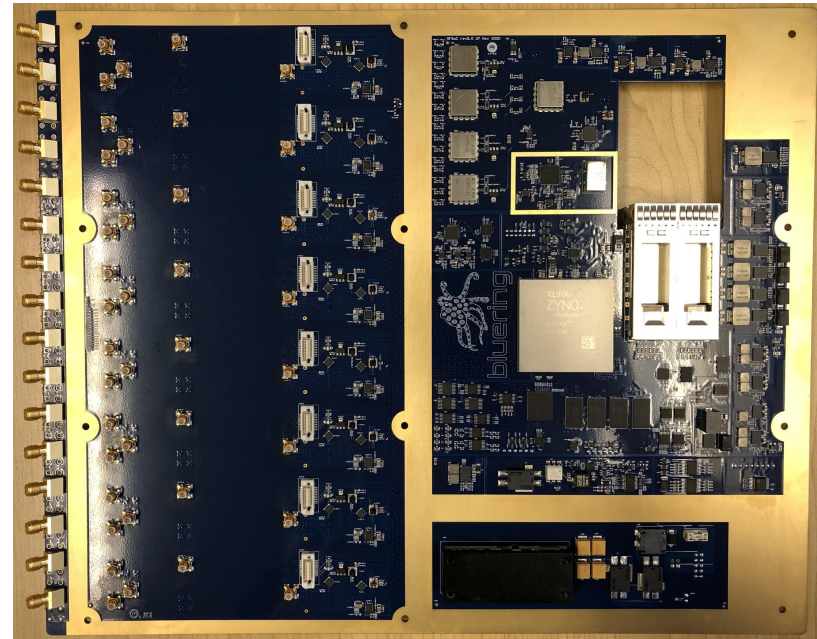
# Science case

- 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.*
  - MWA-motivated LBA proposals have started to be submitted
- 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*



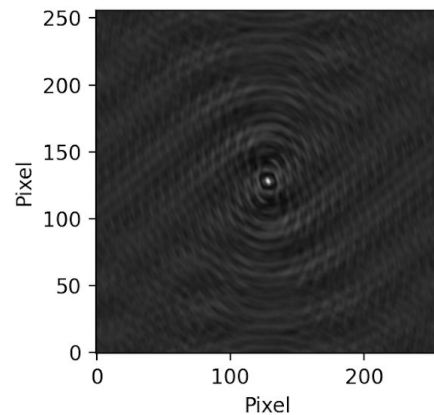
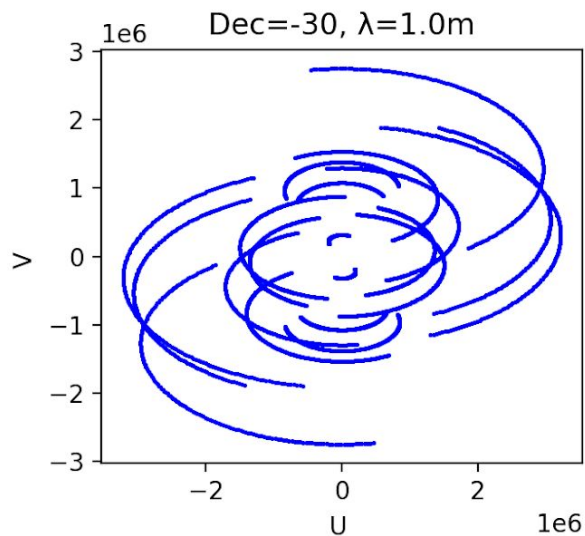
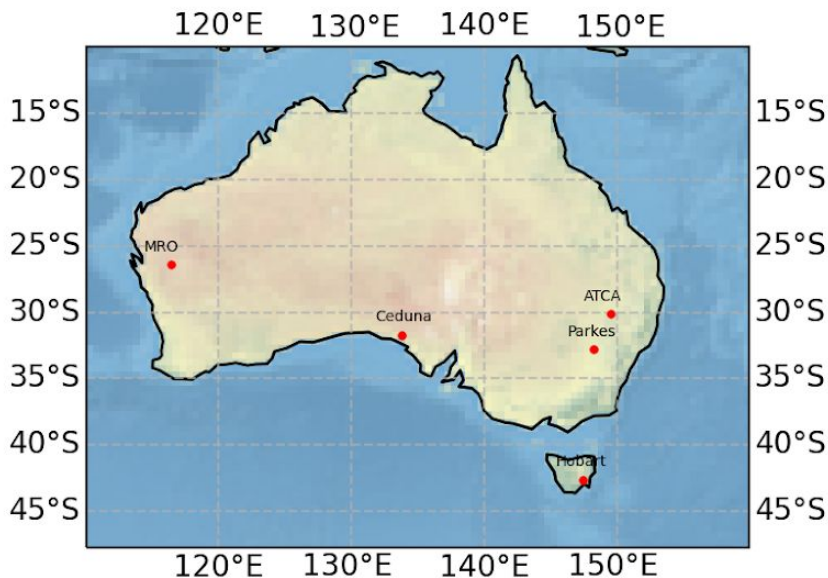
# LAMBDA project - sensitivity

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 $\mu$ Jy	310 $\mu$ Jy
6x 256 + MWA-III	6 mJy	460 $\mu$ Jy	160 $\mu$ Jy
16x 256 dipoles	26 mJy	310 $\mu$ Jy	110 $\mu$ Jy
16x 256 + MWA-III	6 mJy	180 $\mu$ Jy	64 $\mu$ Jy
32x 256 + SKA1 core	2 mJy	77 $\mu$ Jy	27 $\mu$ Jy

# LAMBDA project - indicative uv coverage

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



# LAMBDA project - future expandability

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

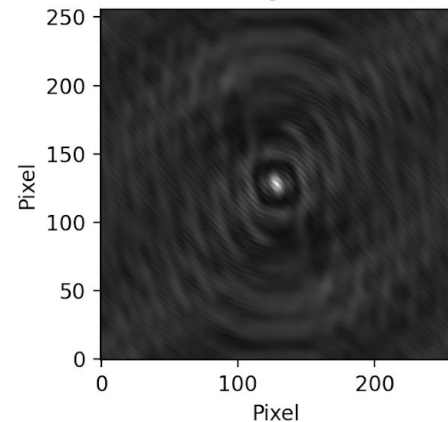
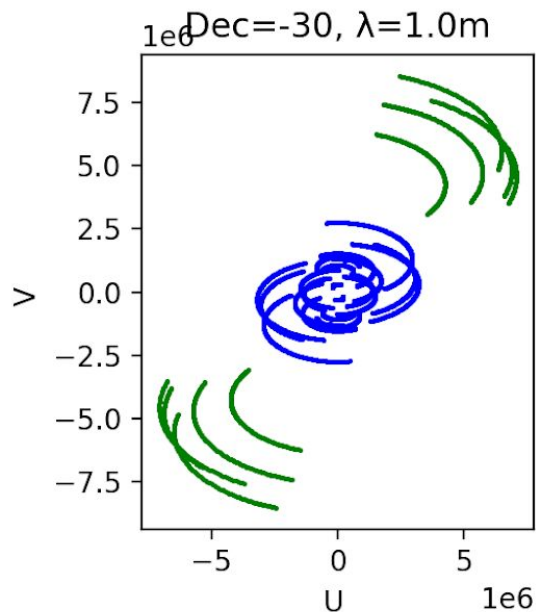
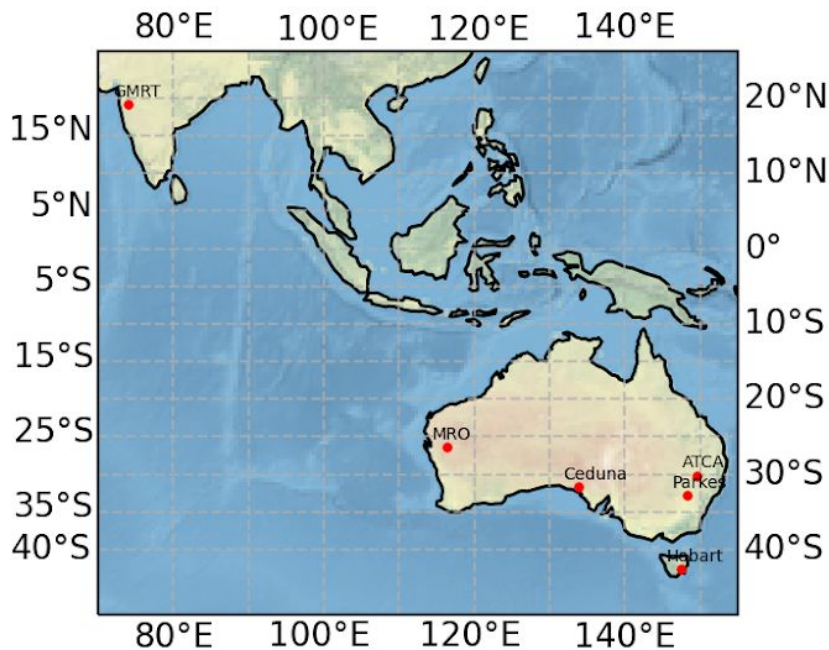
(Note importance of intermediate-scale baselines for good imaging quality)





# 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

## 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)
- Potential to operate as a National Facility (supplementing 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

# What are we doing?

- Developing **science case** (input welcome) and **system design** description
- Planning **technology test / demonstration** at Narrabri (preparations have started; on-sky tests beginning mid-year?)
- CSIRO-funded **virtual conference** “VLBI in the SKA era”  
Meeting dates: TBD, aiming for November 2021  
SOC now being formed, announcement coming soon
- Discussing role of VLBI in ATNF’s **strategy** for SKA era

# Thank you

**Questions or comments:**

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Australia's National Science Agency

