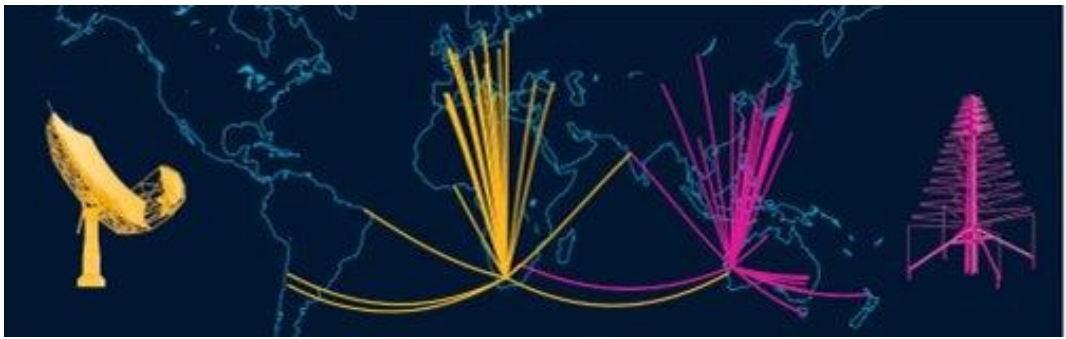
Australia's National Science Agency

LAMBDA

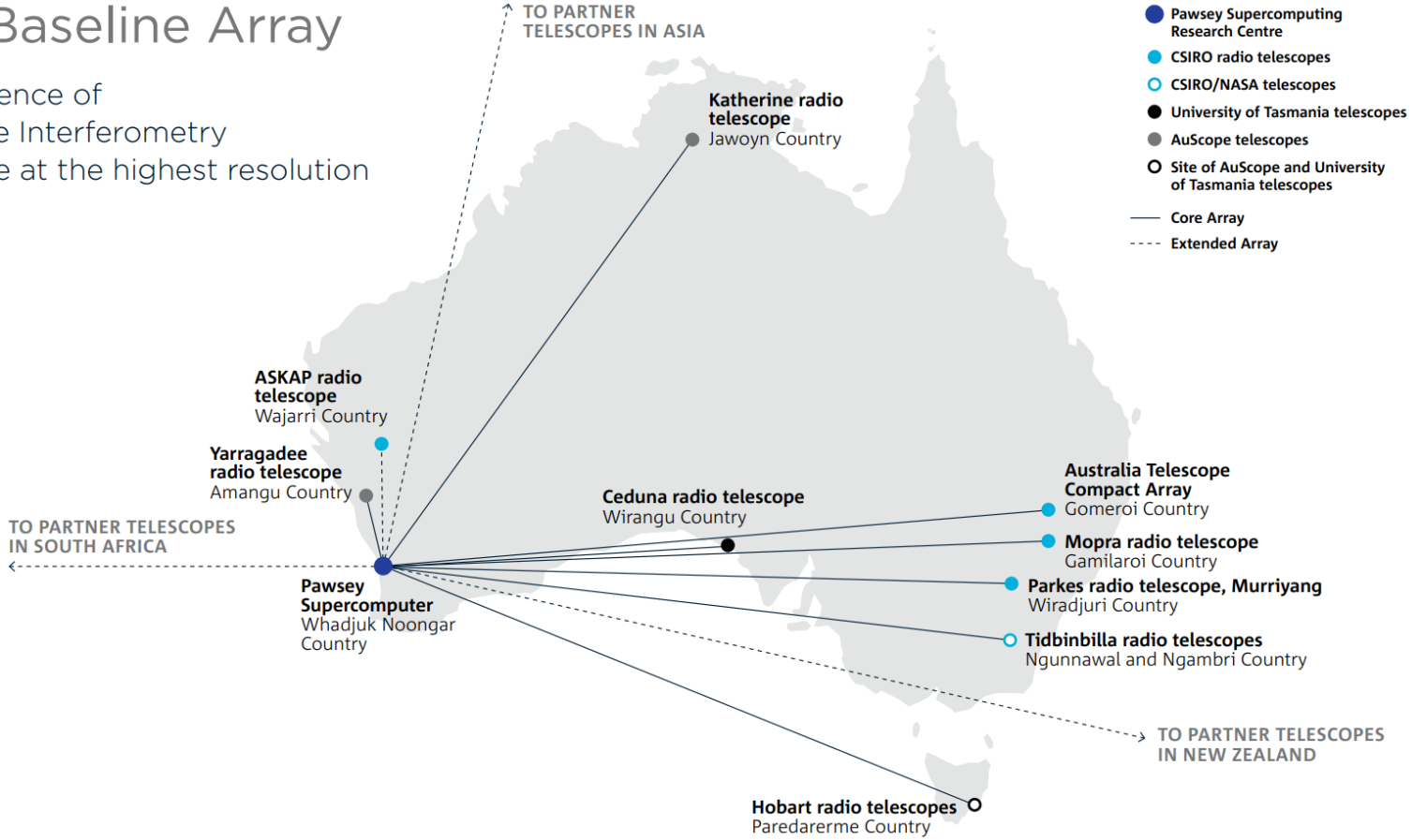
A low frequency VLBI demonstrator

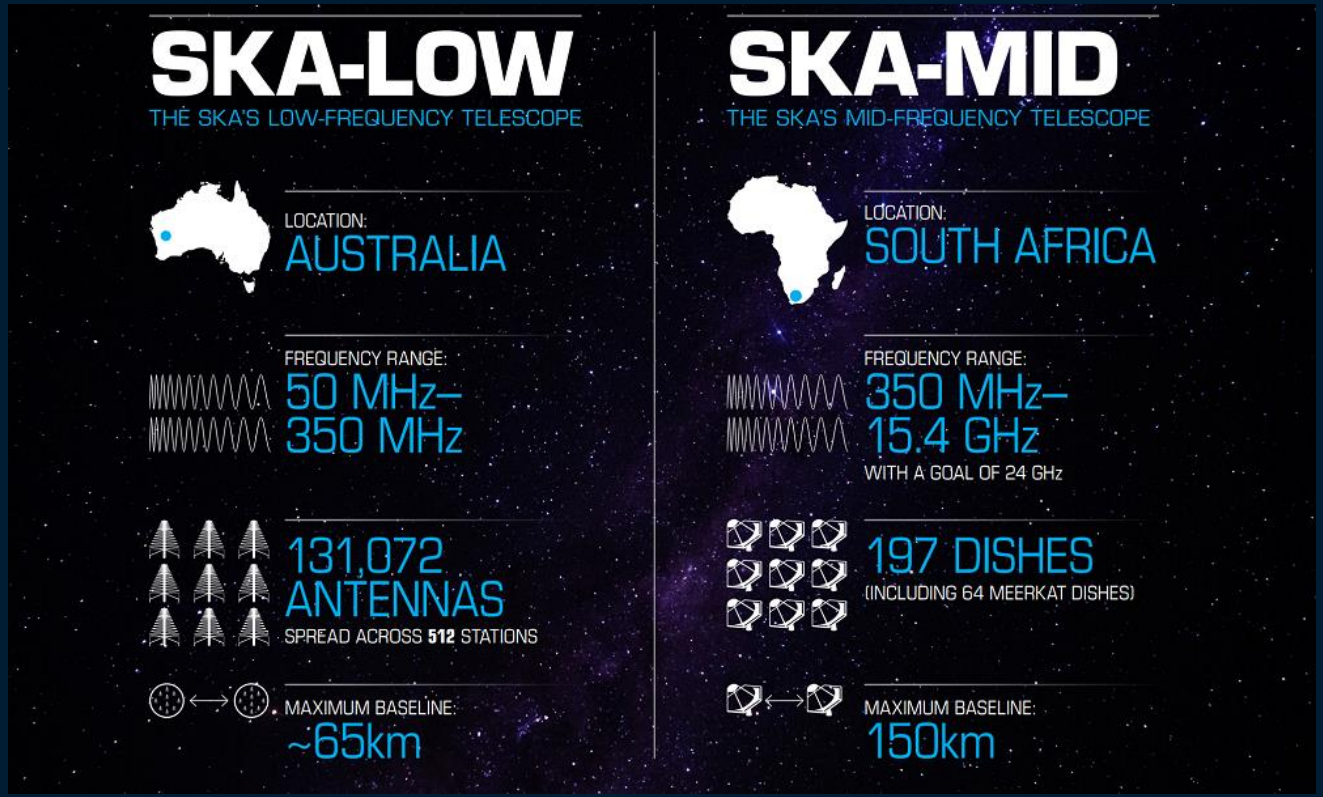


Cormac Reynolds
(ack: George Heald, Grant Hampson)
ATUC, April 2024

The Long Baseline Array

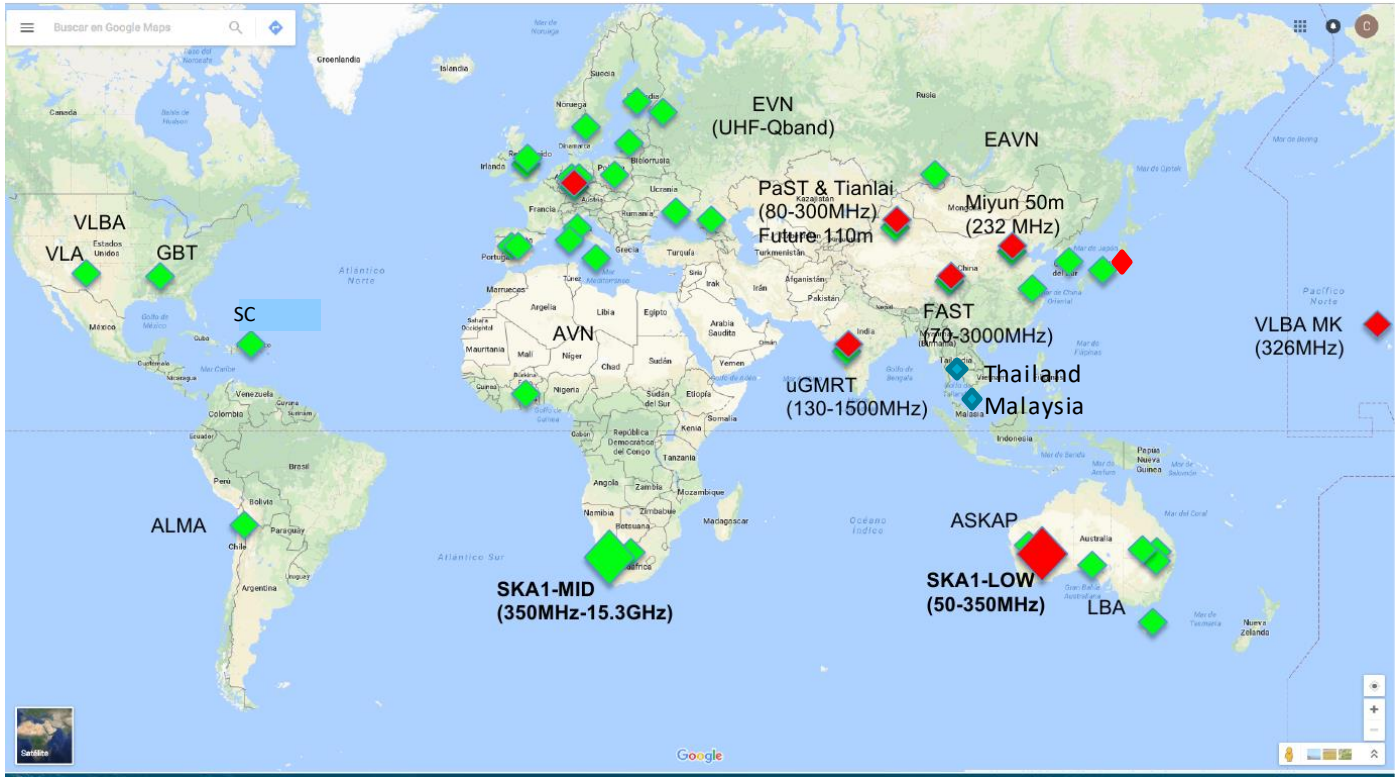
Harnessing the science of
Very Long Baseline Interferometry
to see our Universe at the highest resolution





The SKA telescopes are very sensitive, but their highest angular resolution images will come through co-observing with other telescopes -- VLBI

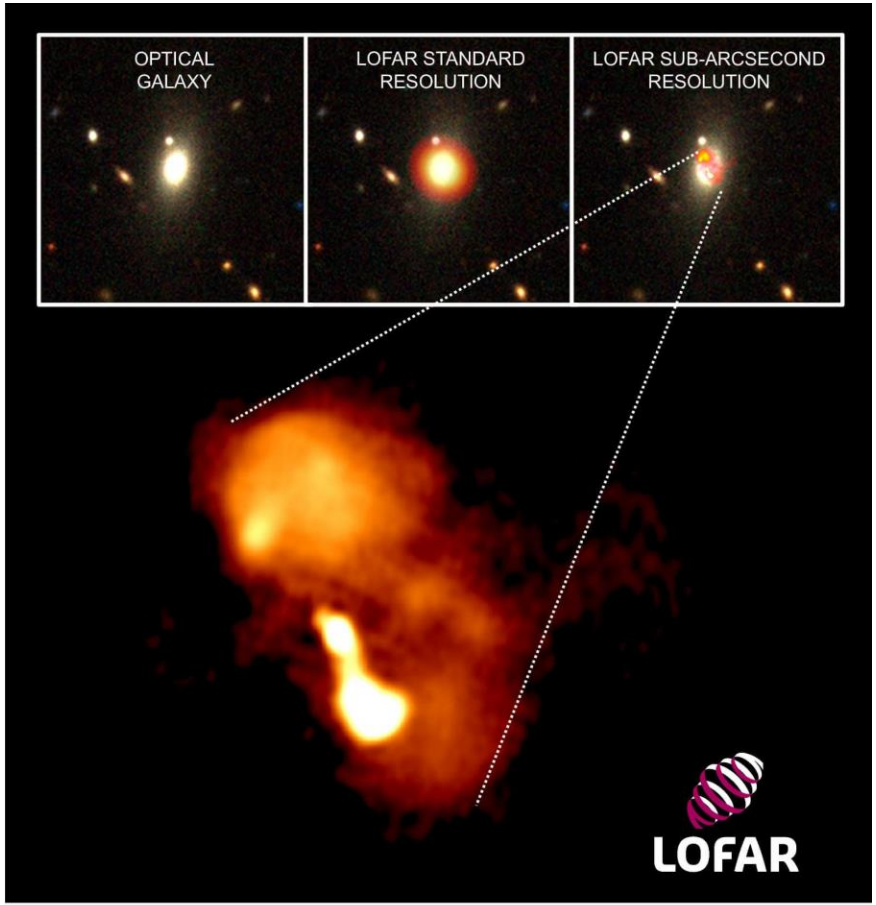
SKA-VLBI Potential Elements



Green = SKA-Mid. Red = SKA-Low. Too few and not enough short baselines!

Low frequency VLBI

- Turbulence in the Earth's ionosphere has traditionally made VLBI challenging at frequencies below ~500 MHz
- The International LOFAR Telescope has demonstrated that this problem is now tractable on baselines up to (at least) ~2000km



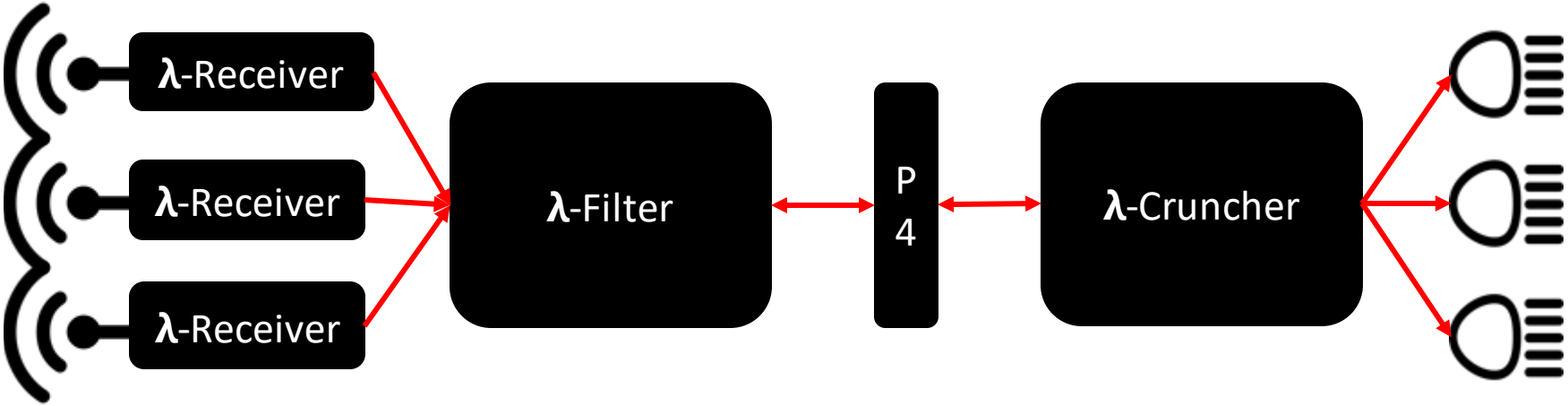
Galaxy-scale jets revealed by new calibration techniques
("Sub-arcsecond imaging with the International LOFAR Telescope"
Special issue, 2022, A&A, 658)

LAMBDA – Low-frequency Australian Megametre Baseline Demonstrator Array

- Goal: Demonstrate Feasibility of Long Baseline Science with SKA-Low
- Low frequency antennas, e.g. CRAB, SKALA
  - 256 dual polarization antennas
  - VLBI target frequency – 150-350 MHz
- Locate at existing LBA observatories (or CSIRO sites)
  - Saves on site costs (power, network etc)
- Extend with new stations near existing networks and internationally
- Leverage CryoPAF/SKA efforts

LAMBDA System

- Needs to
  - be modular/scalable
  - have costs suitable for large arrays
  - be flexible/adaptable
- Leverages CryoPAF/SKA developments



λ-Receiver, Filter, Cruncher

- Receiver - digitise at the antenna
  - LNA, ADC clock, ~14 bit ADC to cope with RFI, optical connection to Filter
- Filter - FPGA to support receivers, delay correction, filterbank, packetise, timestamp, beamform
- Cruncher – GPU/Alveo to receive data from switch, antenna calibration, VLBI band construction
  - Optional extras for station processing (pulsars, RFI, SETI, fancy stuff)

Narrabri Test Bed

- 16 dual-pol MWA antennas + ground-plane

- ATCA infrastructure including mains power, with expansion in mind

- Fiber to Control Building for timing, data, control

Opportunity to leverage SKA-Low

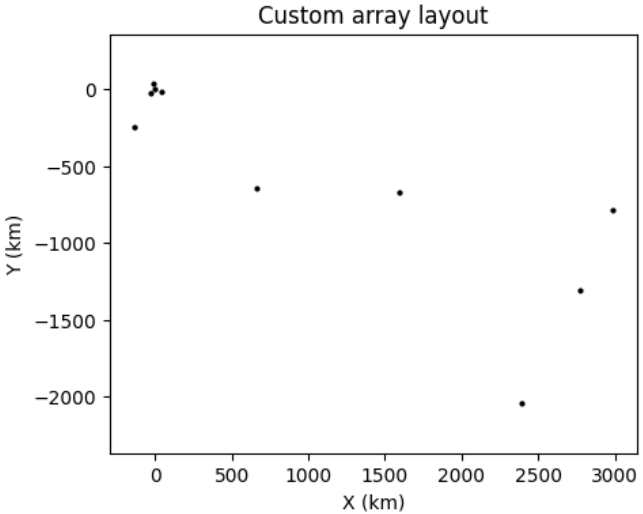
- Unique science capability that enhances SKA outcomes across the developing Key Science Project portfolio
  - Magnify impact potential of the SKA – *precursor for "SKA-Low 2"*
  - Ensure feasibility to connect SKA-Low into Global VLBI network

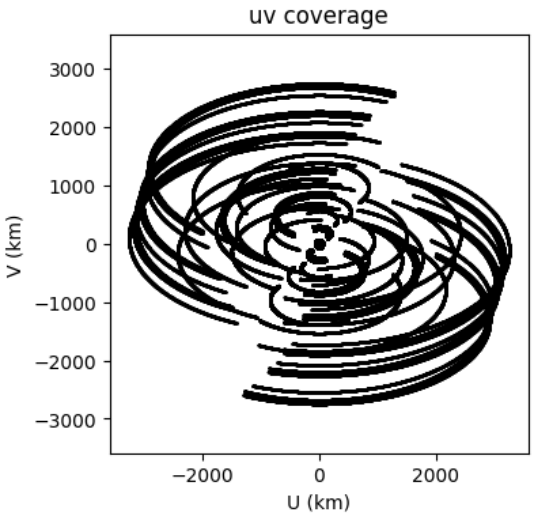
- Distinct area of technology development and science delivery for ATNF that leverages our existing strengths and LBA capability

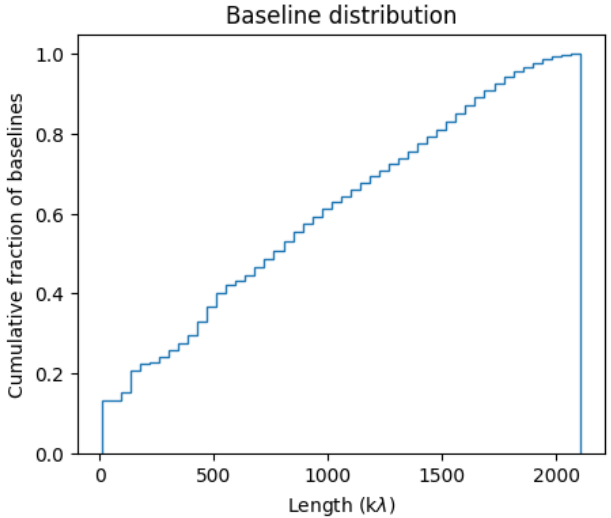
- Prospect to implement multi-disciplinary use for individual stations (space science, all-sky monitor, etc.)

LAMBDA in the SKA Era

Example uv coverage (dec -30, 12hr):
SKA core+clusters, Narrabri, Tid, Ceduna, Hobart, Yarragadee, Balladonia







Expansion Potential

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

GMRT+FAST+...

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

Correlation at Pawsey

- Existing e-transfer facility
- Throughput capable
  - Observing cadence TBD
- Offline/buffering
  - Probably can do real-time ops, but many disadvantages

Science cases

- High resolution (sub-kiloparsec scale at all redshifts) mapping of AGN
  - 2/3 of ASKAP sky inaccessible at low frequencies with long baselines
- Pulsar astrometry, distances, proper motions, scintillometry
- Young stellar objects and Supernova Remnants in our Galaxy
- Gravitational lens discovery / imaging
- Resolving stellar systems, distinguishing planet from host star
  - (e.g., Sun-Jupiter system to D ~ 50 parsecs)
- FRB follow-up and host imaging with optical resolution
- Determination of high-precision ISM properties
- Technosignature Searches
- Ionosphere and Space Weather

Initial Project Timescale

- CSIRO Science Leader position to be filled to lead development of low-frequency VLBI capability
- CSIRO capital funding (FY2024/25) to develop LAMBDA
  - *Science & Technology* demonstrator
  - Prototype and initial cluster at Narrabri
  - Second cluster at Parkes for interferometric tests
  - Longer term, expand to other LBA site(s) or even new sites
- Complementary work at MWA to provide a phased array output
- Build on recent successes in VLBI collaboration with GMRT, FAST, UTAS, Spaceops
- Potential for a future user facility

Thank you

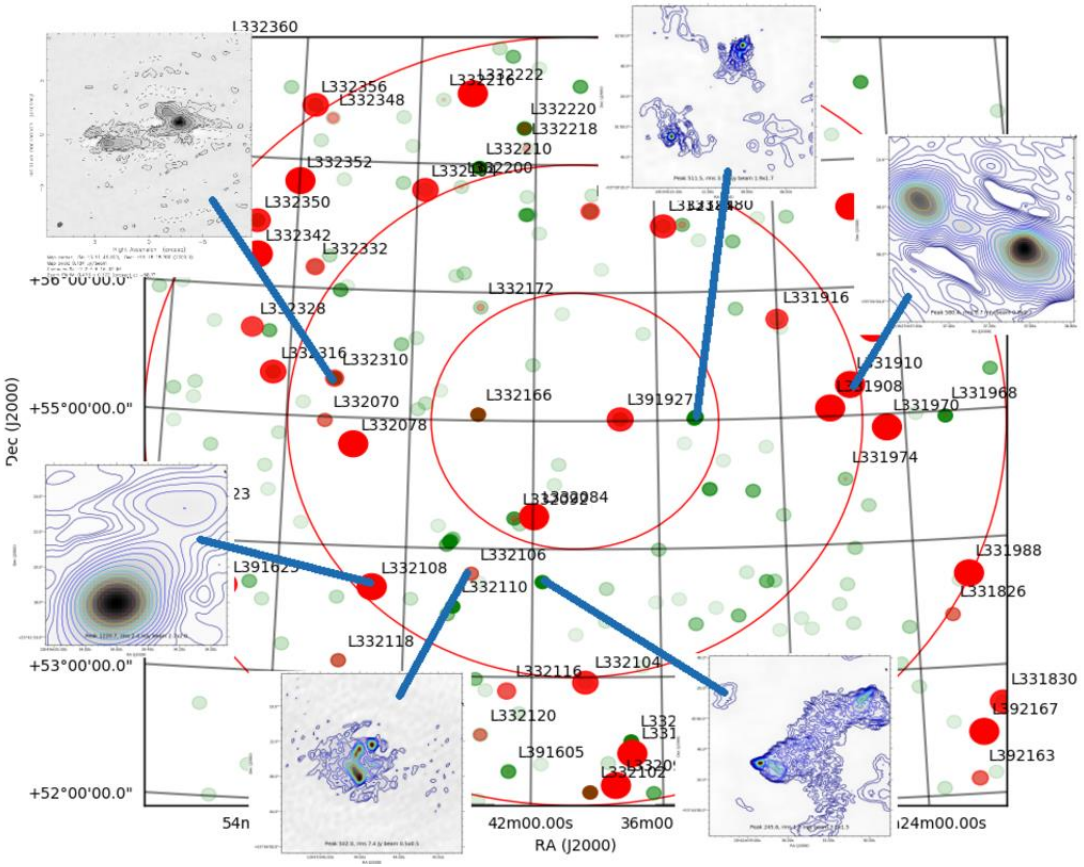
CSIRO Space and Astronomy
www.atnf.csiro.au

Vanessa Kelly, VLBI, 2019


CSIRO

International LOFAR Telescope

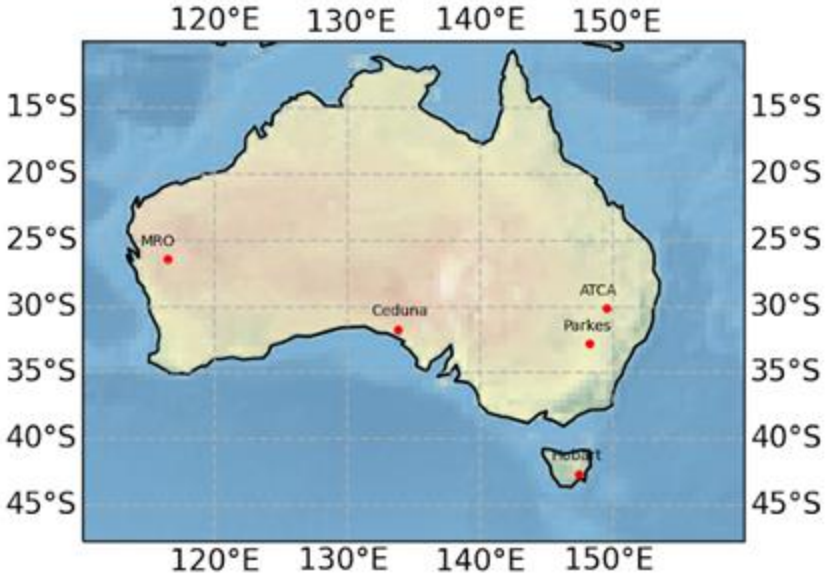
0.3 arcsec resolution
1 degree field of view

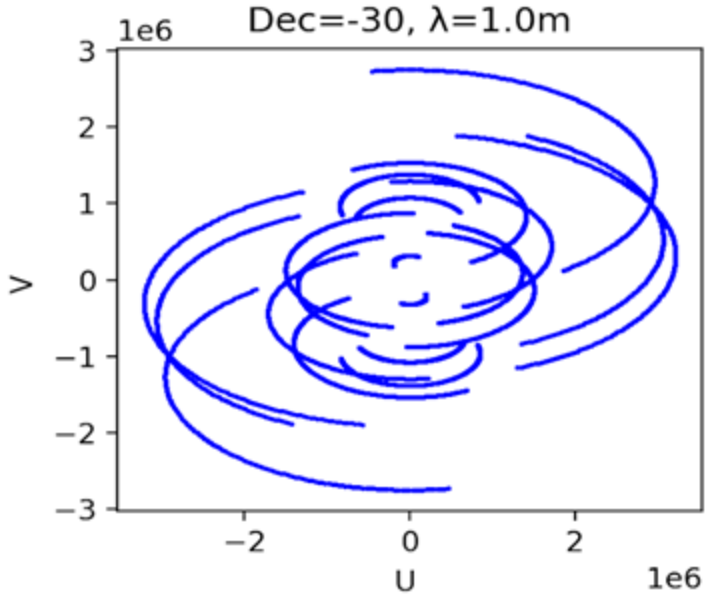


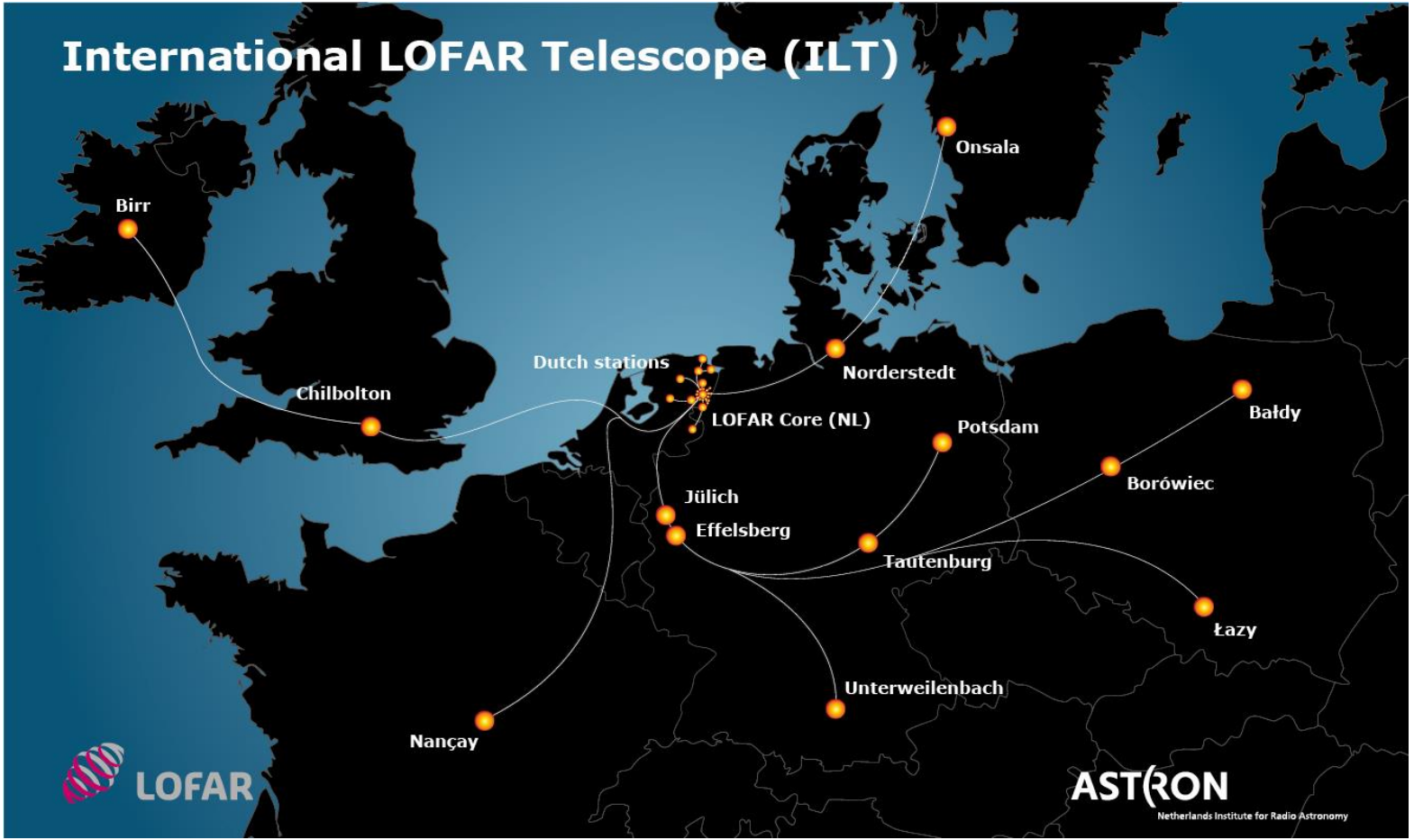
Morabito et al.

LAMBDA - indicative u,v coverage

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






International LOFAR Telescope (ILT)
Onsala
Birr
Dutch stations
Norderstedt
Chilbolton
LOFAR Core (NL)
Potsdam
Bałdy
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Unterweilenbach
Nançay
LOFAR
ASTRON
Netherlands Institute for Radio Astronomy