- Overview and Capabilities
- Science drivers
- Science highlights

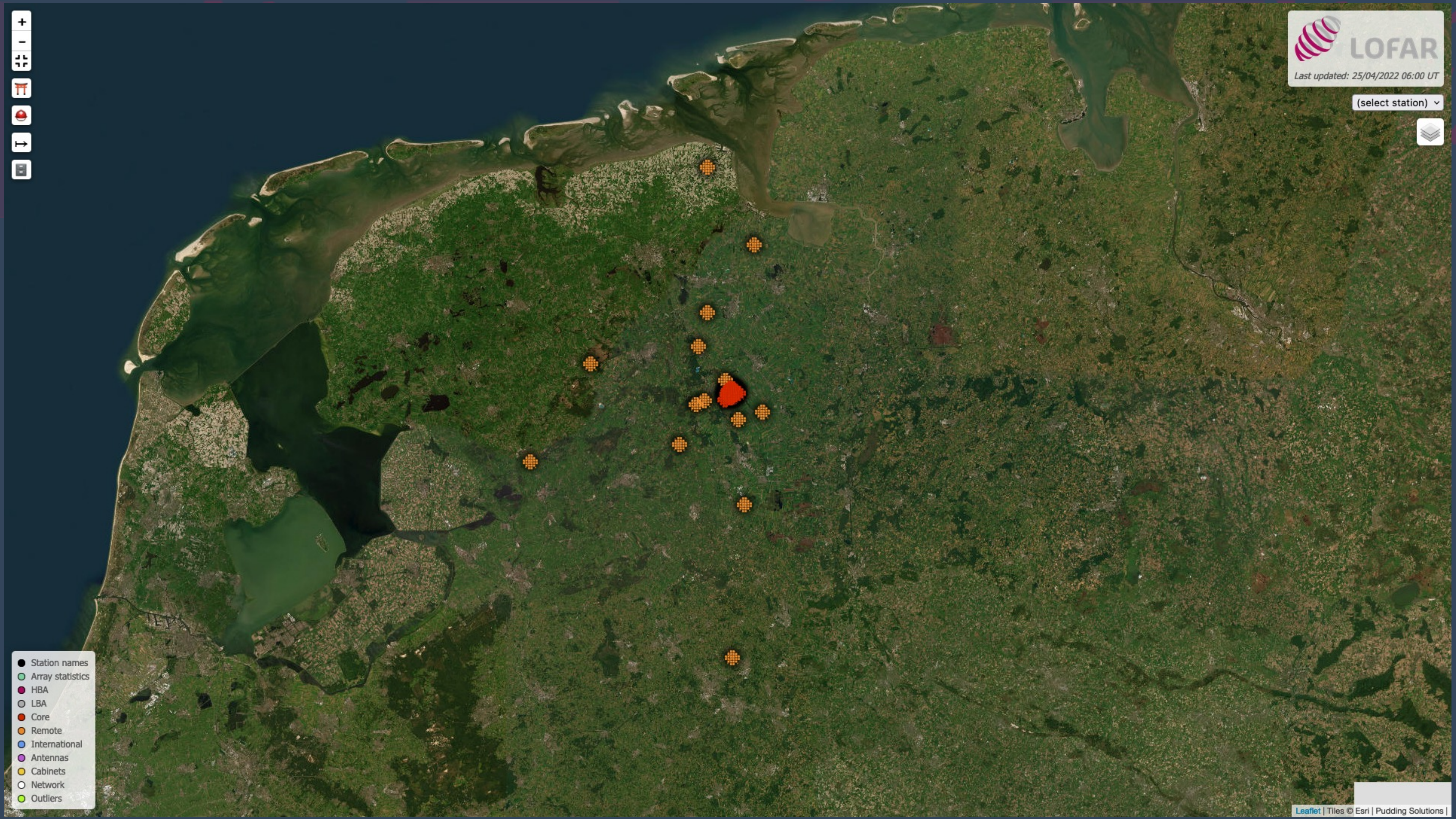
LOFAR OVERVIEW

Emanuela Orru'

ASTRON, Dwingeloo 5 June 2023

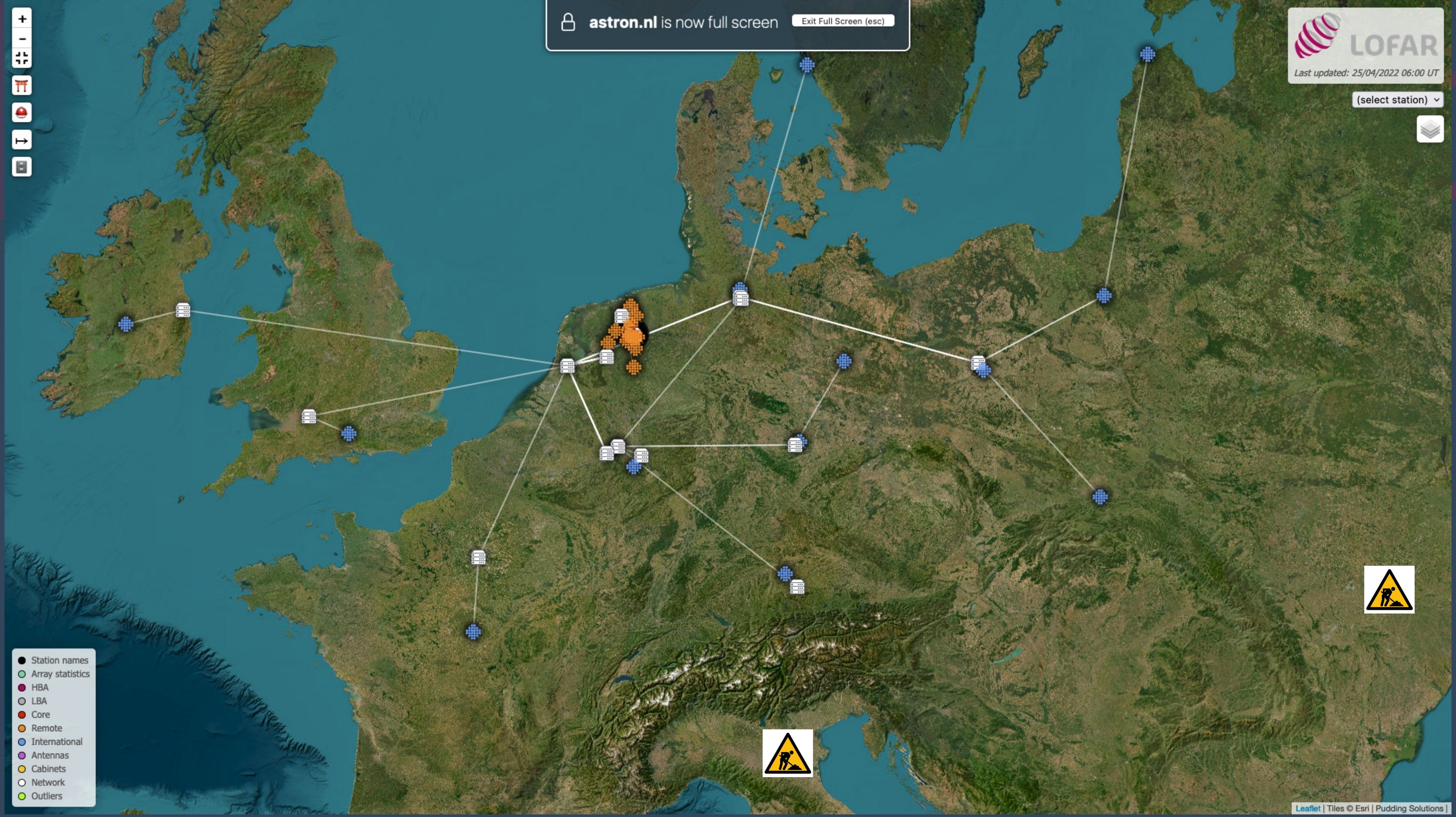
Core: 150 m – 3 km

https://www.astron.nl/lofartools/lofarmap.html



Remote Stations: 5 km – 90 km

https://www.astron.nl/lofartools/lofarmap.html



Remote Stations: > 1000 km

https://www.astron.nl/lofartools/lofarmap.html

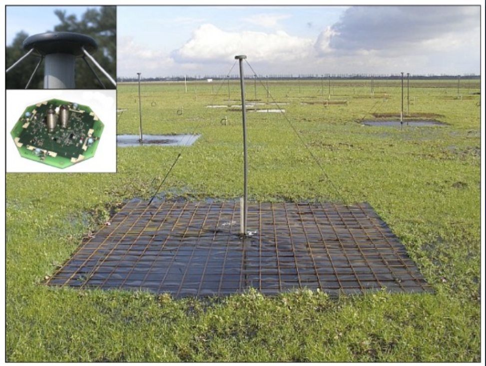
THE LOW FREQUENCY ARRAY – KEY FACTS

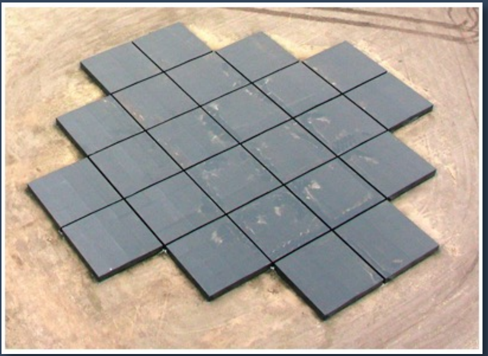
LOFAR

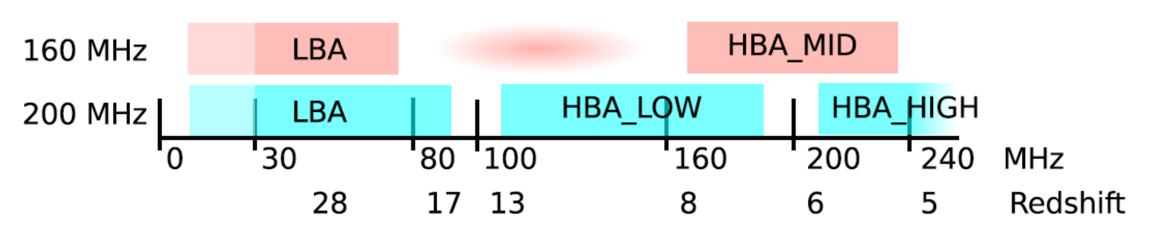
ASTRON

Operating frequency is 10-250 MHz

- 1 beam, up to 96 MHz total bandwidth, split into 488 sub bands with 64 frequency channels (8-bit mode)
- < 488 beams on the sky with ~ 0,2 MHz bandwidth
- Low band antenna (LBA; Area ~ 75200 m^2; 10-90 MHz)
- High Band Antenna (HBA; Area ~ 57000 m^2; 110-240 MHz)



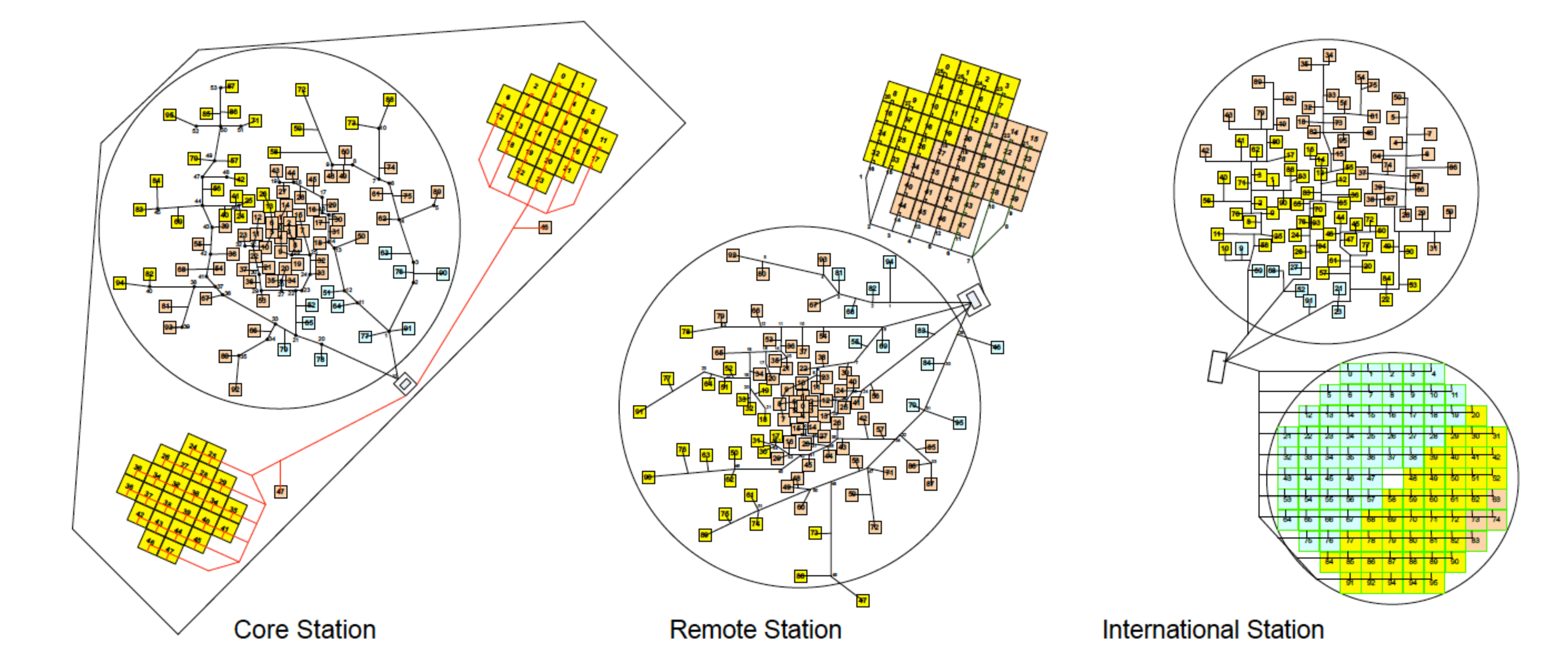




LOFAR STATIONS: CONFIGURATION

LOFAR

ASTRON

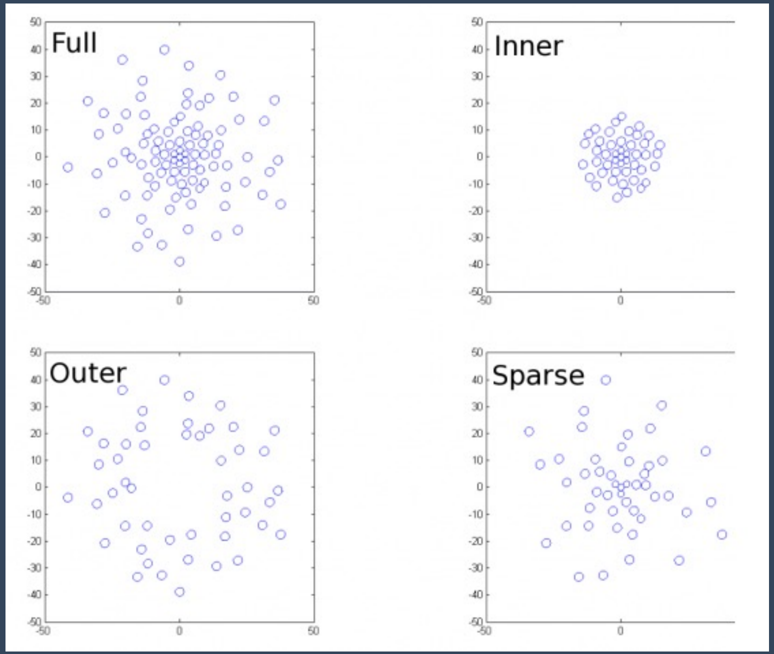


- Three types: Core (24), Remote (14) and International (12, but more to come!)
- Different beam shapes
- Different sensitivities

48 HBA tiles/96 LBA dipoles

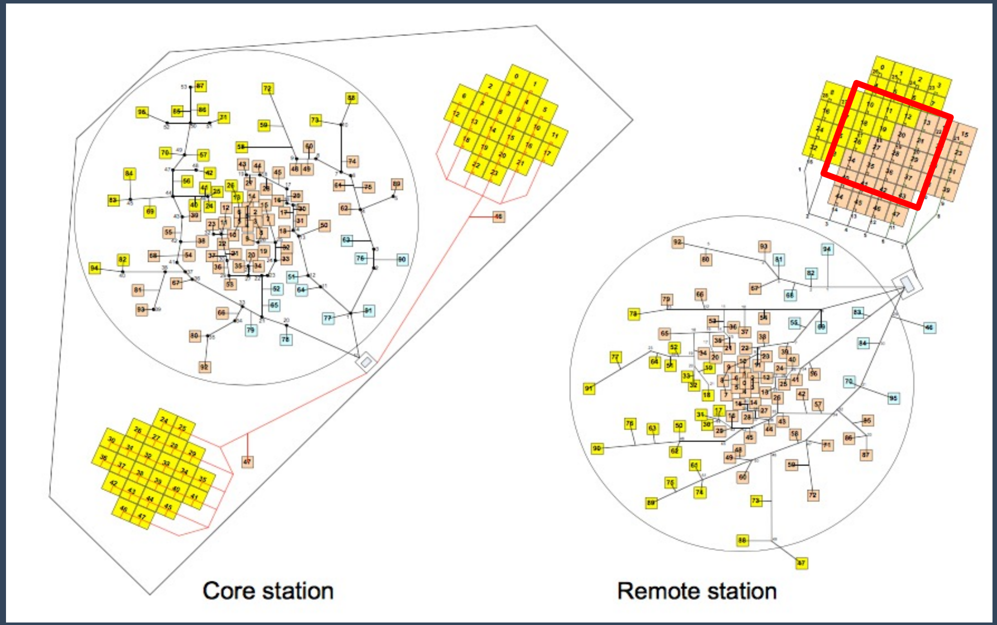
LBA

- 96 dipoles BUT 48 signal paths dual polarization
- Half of dipoles for NL stations can be used
- Inner – Outer - Sparse



HBA

- All for NL stations can be used
- Core stations: joined or dual
- Remote stations Inner or Outer



THE LOFAR SYSTEM: DATA FLOW

Station signals collected in the station cabinets

Signal sent to COBALT2 for correlation

CENTRAL PROCESSING

Data inititially edited (flag,A-team removal, avg)

LTA

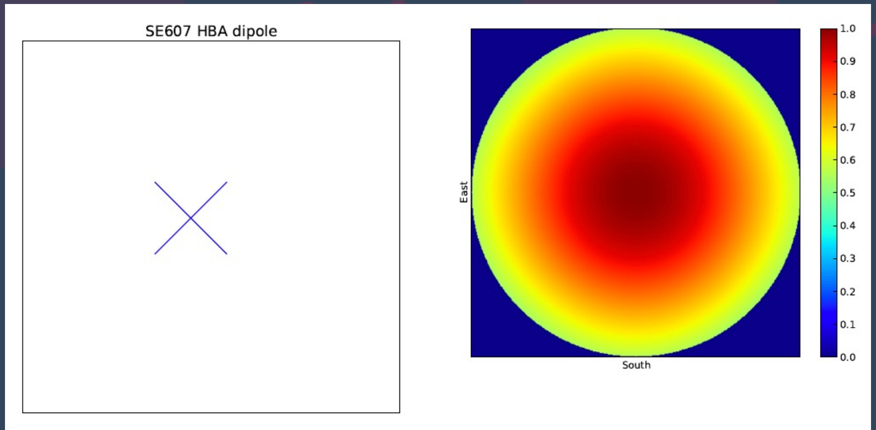
Products sent to the long-term archive

- Large data transport rates ➔ data storage challenges (35 TB /h)
- LOFAR is the first of a number of new astronomical facilities dealing with the transport, processing and storage of these large amounts of data and therefore ***represents an important technological pathfinder for the SKA***

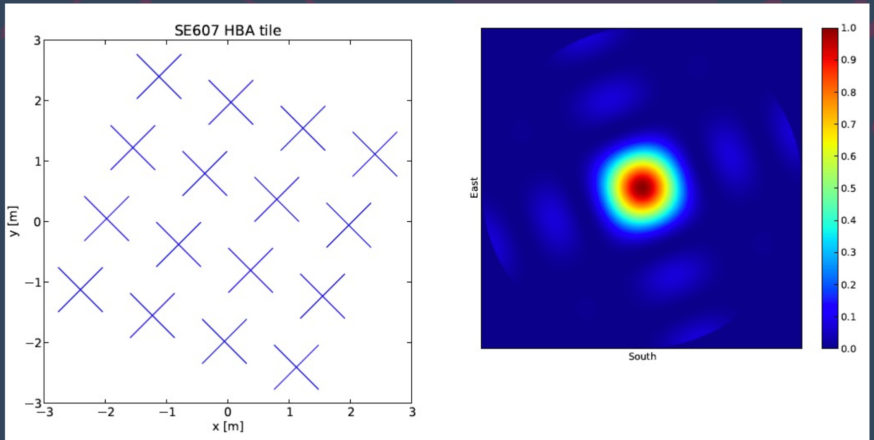
BEAM-FORMING – PARALLEL OBSERVATIONS

- Unlike standard telescopes, LOFAR has no moving parts
- Pointing is achieved by combining the beams from each individual element (antenna or tile), at the station level, using different complex weights
- <488 beams can be formed, increasing survey speed, efficiency, calibration

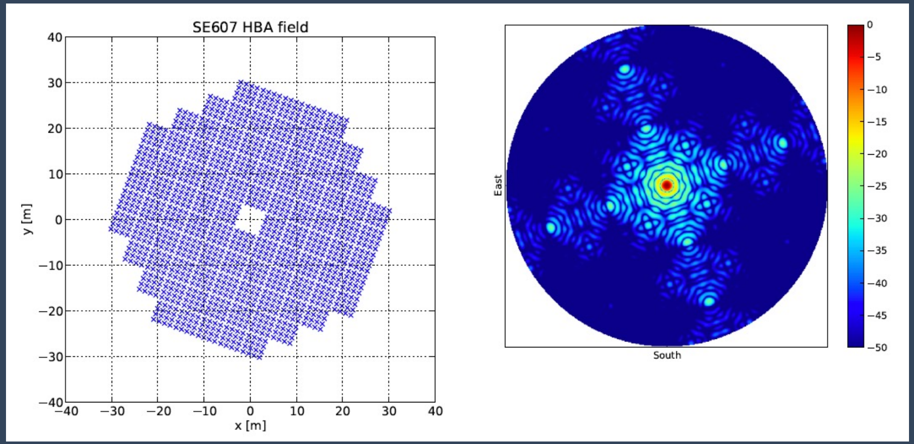
Beam patterns



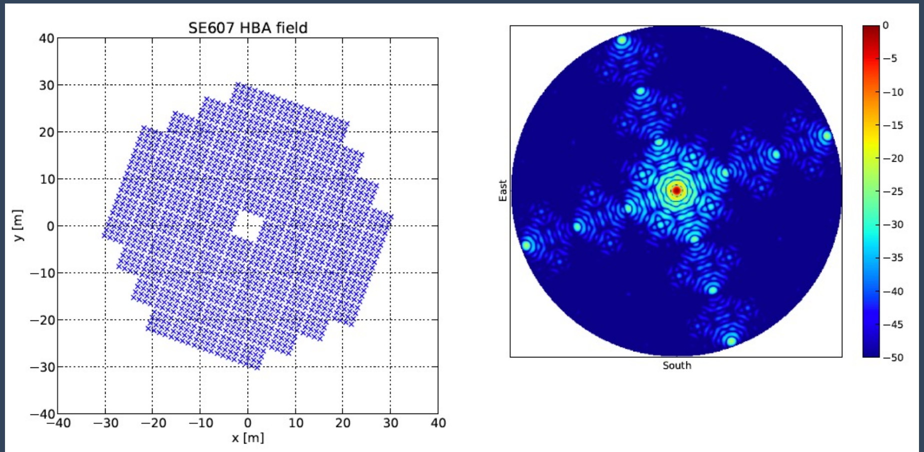
Element beam 150 MHz



Analogue tile beam 150 MHz

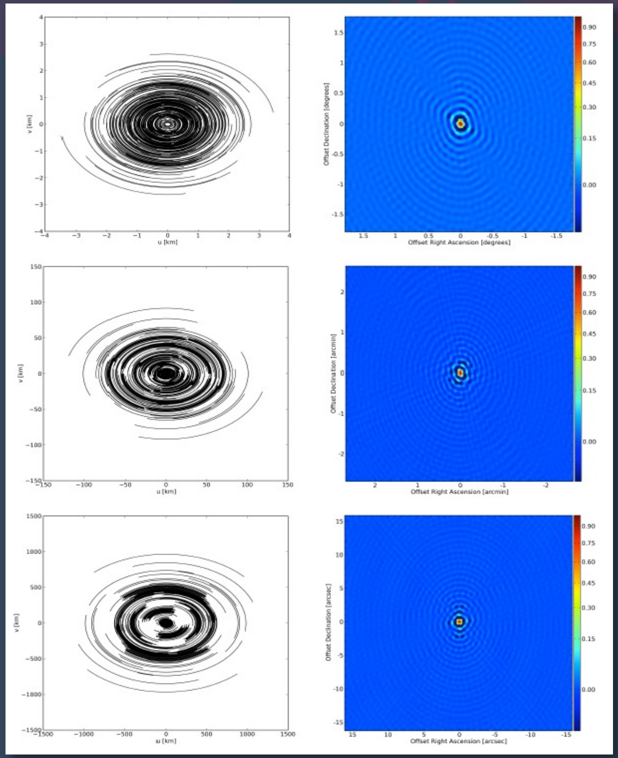


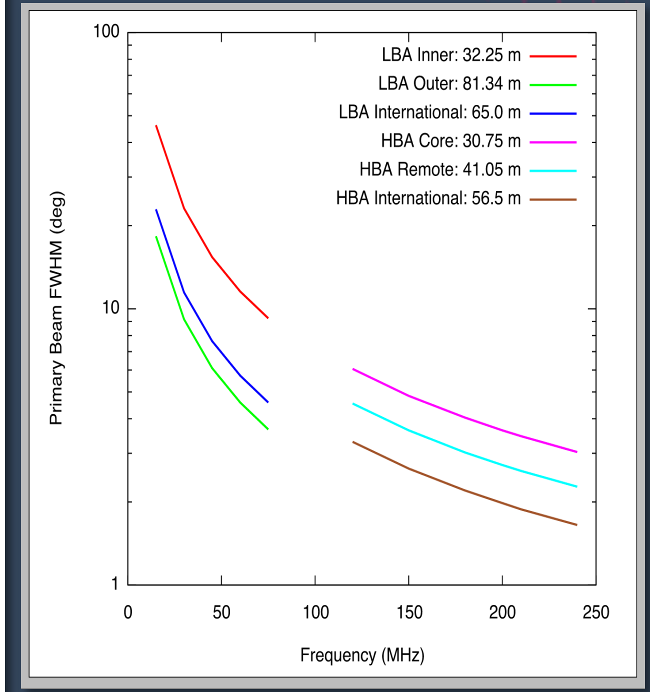
Station beam 150 MHz

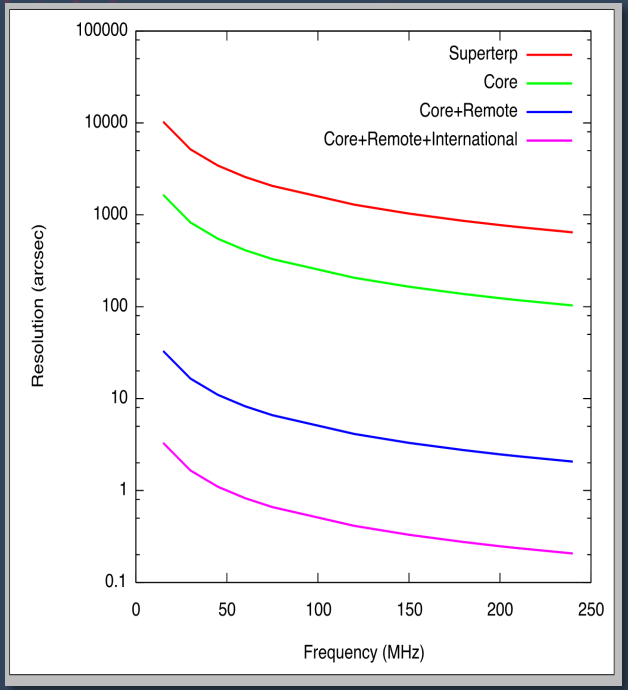


Station beam 180 MHz

UV COVERAGE, ANGULAR RESOLUTION AND FOV



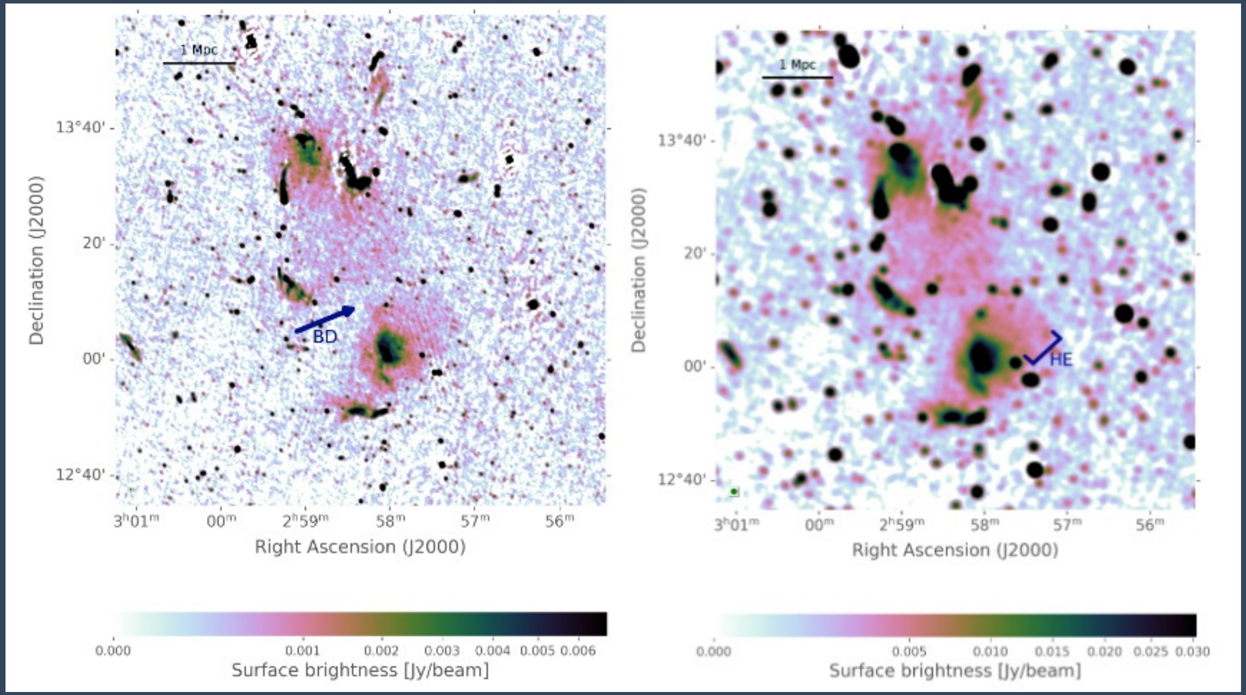




- One of the transformational aspects of LOFAR is the unprecedented range of angular scales that are achievable at low observing frequencies.

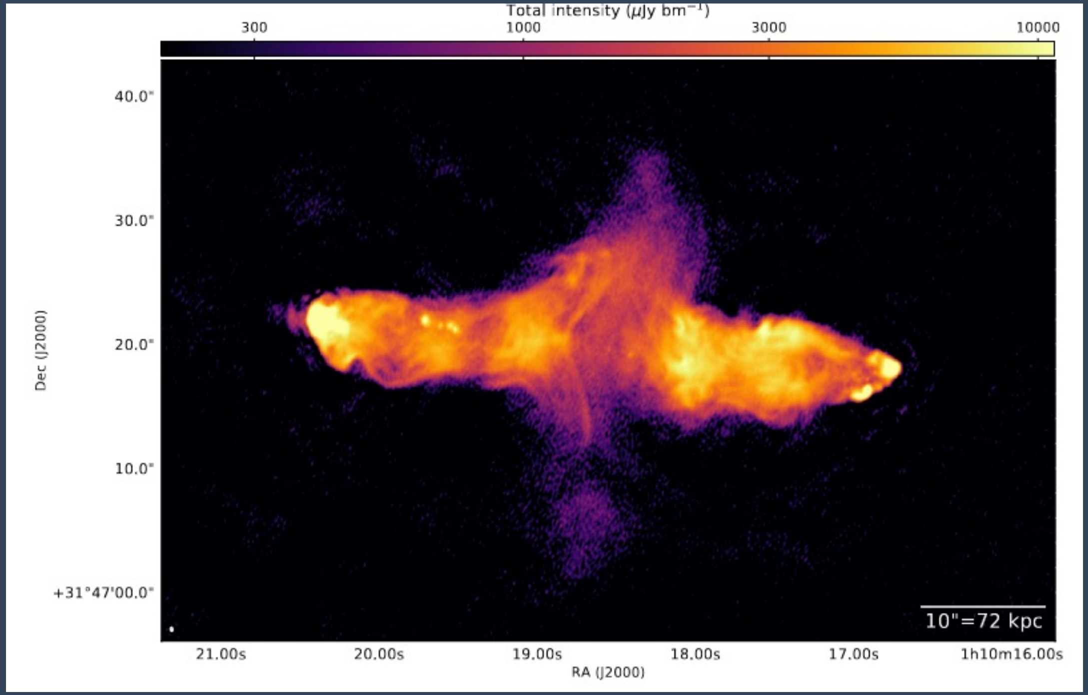
LARGE & SMALL SCALES in one instrument

degrees



J. de Jong 2022

Sub-arcsec



V. Mahatma2023

Observing modes

- Interferometric
- Tide array mode (Core coherent)
- Transient buffer board
- Commensal (AARTFAAC, TBB cosmic rays)

https://science.astron.nl/telescopes/lofar/lofar-system-overview/observing-modes/

LOFAR Science Drivers

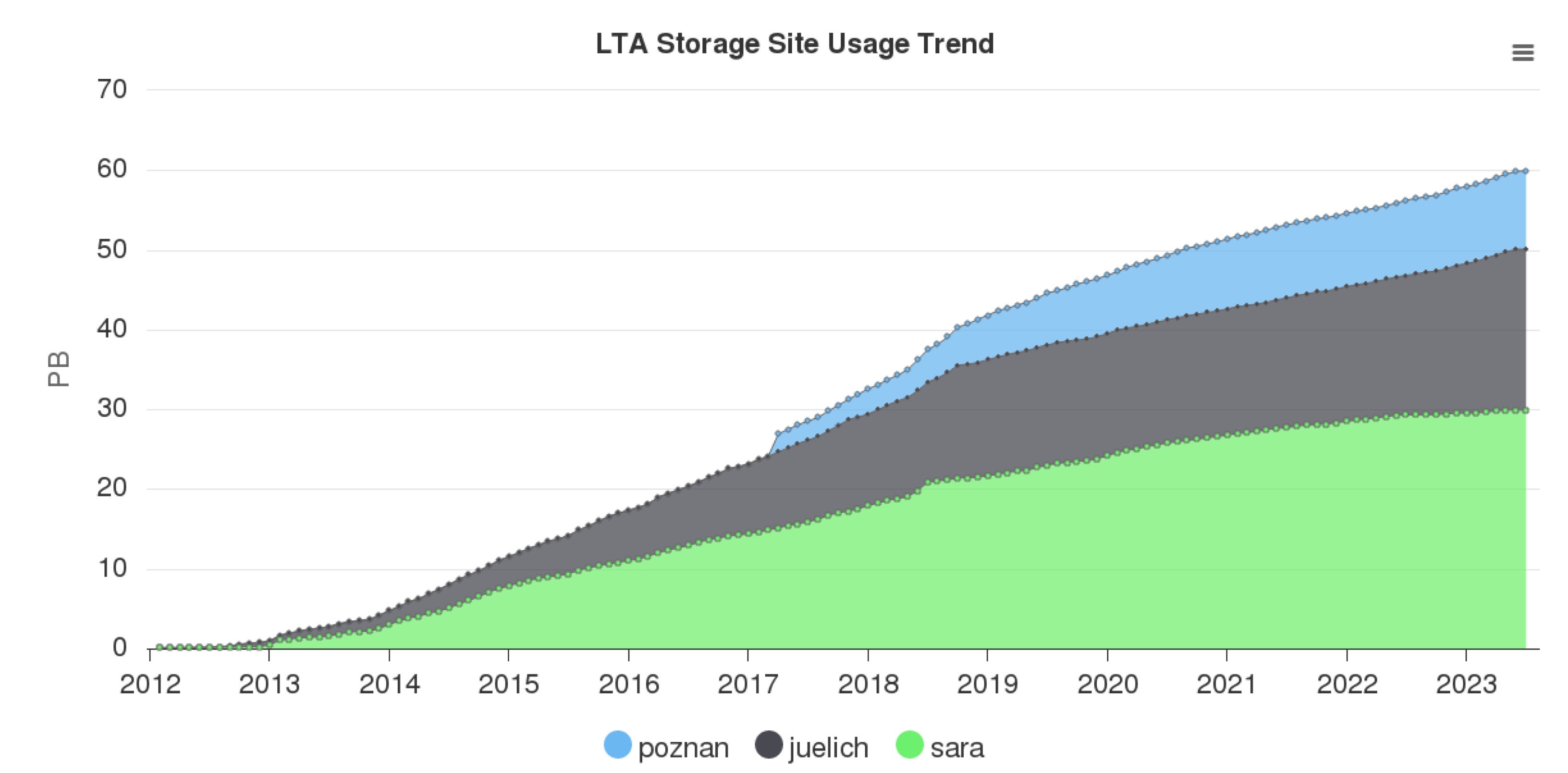
Key Science Projects

- ***Epoch of Reionization***
- ***Surveys and Distant Universe***
- ***Transients and Pulsars***
- ***High Energy Cosmic Rays***
- ***Cosmic Magnetism***
- ***Solar Physics and Space Weather***

International membership from countries all over the World

Constribute development and commissioning resources

Long Term Archive



MS uncalibrated visibilities
PSR hf5
Solar data
Images

More to come with the LDV project
Processing the LTA content to provide science ready data product

https://science.astron.nl/sdc/astron-data-explorer/

Special content for VLBI lovers

Sub-arcsecond imaging with the International LOFAR Telescope - I. Foundational calibration strategy and pipeline
L. K. Morabito et al.
A&A, 658 (2022) A1 DOI: https://doi.org/10.1051/0004-6361/202140649

Sub-arcsecond imaging with the International LOFAR Telescope - II. Completion of the LOFAR Long-Baseline Calibrator Survey
N. Jackson et al.
A&A, 658 (2022) A2 DOI: https://doi.org/10.1051/0004-6361/202140756

High-resolution international LOFAR observations of 4C 43.15 - Spectral ages and injection indices in a high-z radio galaxy
F. Sweijen, L. K. Morabito, J. Harwood, R. J. van Weeren, H. J. A. Röttgering, J. R. Callingham, N. Jackson, G. Miley and J. Moldon
A&A, 658 (2022) A3 DOI: https://doi.org/10.1051/0004-6361/202039871

Sub-arcsecond LOFAR imaging of Arp 299 at 150 MHz - Tracing the nuclear and diffuse extended emission of a bright LIRG
N. Ramírez-Olivencia, E. Varenius, M. Pérez-Torres, A. Alberdi, J. E. Conway, A. Alonso-Herrero, M. Pereira-Santaella and R. Herrero-Illana
A&A, 658 (2022) A4 DOI: https://doi.org/10.1051/0004-6361/202140822

Origin of the ring structures in Hercules A - Sub-arcsecond 144 MHz to 7 GHz observations
R. Timmerman, et al.
A&A, 658 (2022) A5 DOI: https://doi.org/10.1051/0004-6361/202140880

Unmasking the history of 3C 293 with LOFAR sub-arcsecond imaging
Pranav Kukreti, Raffaella Morganti, Timothy W. Shimwell, Leah K. Morabito, Robert J. Beswick, Marisa Brienza, Martin J. Hardcastle, Frits Sweijen, Neal Jackson, George K. Miley, Javier Moldon, Tom Oosterloo and Francesco de Gasperin
A&A, 658 (2022) A6 DOI: https://doi.org/10.1051/0004-6361/202140814

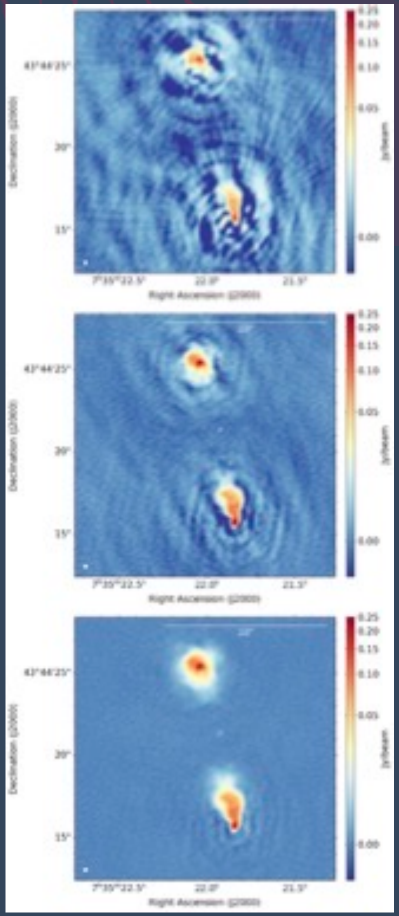
High-resolution imaging with the International LOFAR Telescope: Observations of the gravitational lenses MG 0751+2716 and CLASS B1600+434
S. Badole, D. Venkattu, N. Jackson, S. Wallace, J. Dhandha, P. Hartley, C. Riddell-Rovira, A. Townsend, L. K. Morabito and J. P. McKean
A&A, 658 (2022) A7 DOI: https://doi.org/10.1051/0004-6361/202141227

The resolved jet of 3C 273 at 150 MHz - Sub-arcsecond imaging with the LOFAR international baselines
J. J. Harwood, S. Mooney, L. K. Morabito, J. Quinn, F. Sweijen, C. Groeneveld, E. Bonnassieux, A. Kappes and J. Moldon
A&A, 658 (2022) A8 DOI: https://doi.org/10.1051/0004-6361/202141579

Pushing sub-arcsecond resolution imaging down to 30 MHz with the trans-European International LOFAR Telescope
C. Groeneveld et al.
A&A, 658 (2022) A9 DOI: https://doi.org/10.1051/0004-6361/202141352

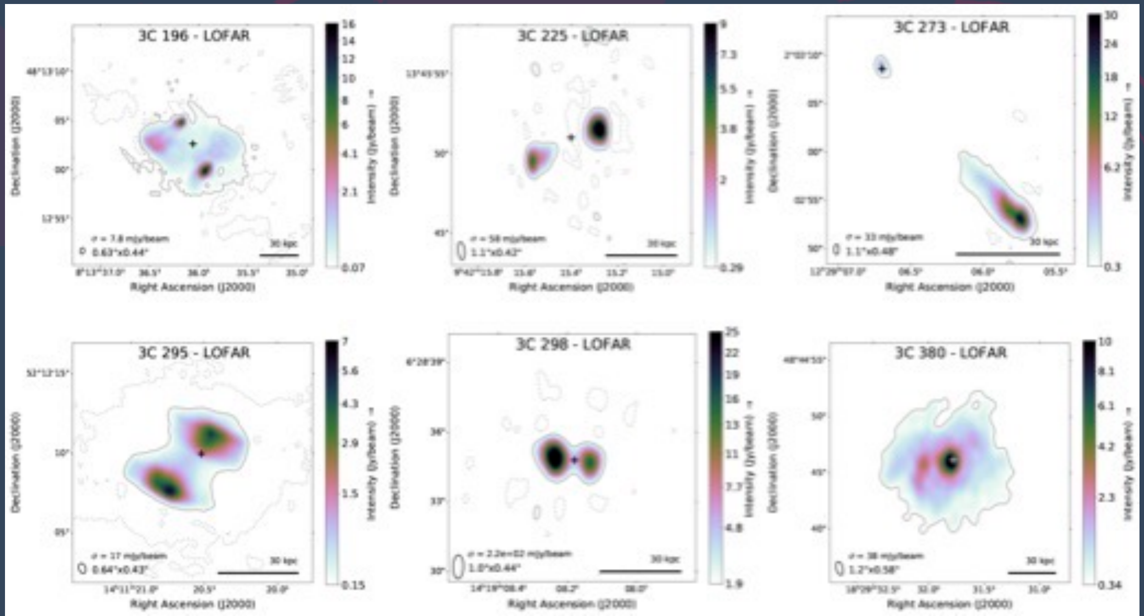
Spectral analysis of spatially resolved 3C295 (sub-arcsecond resolution) with the International LOFAR Telescope
Etienne Bonnassieux et al.
A&A, 658 (2022) A10 DOI: https://doi.org/10.1051/0004-6361/202141731

Subarcsecond view on the high-redshift blazar GB 1508+5714 by the International LOFAR Telescope
A. Kappes, et al. A&A, 663 (2022) A44 DOI: https://doi.org/10.1051/0004-6361/202141720

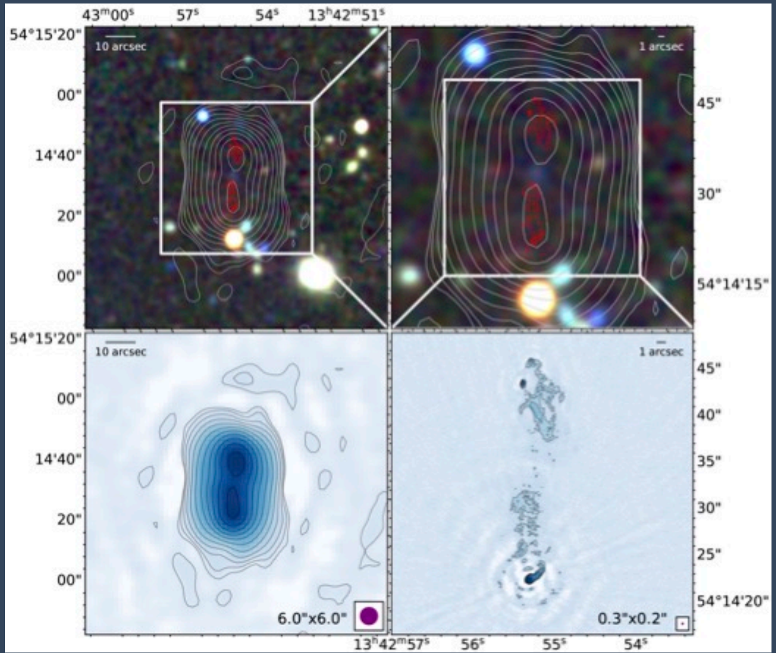


F. Sweijen et al. 2022

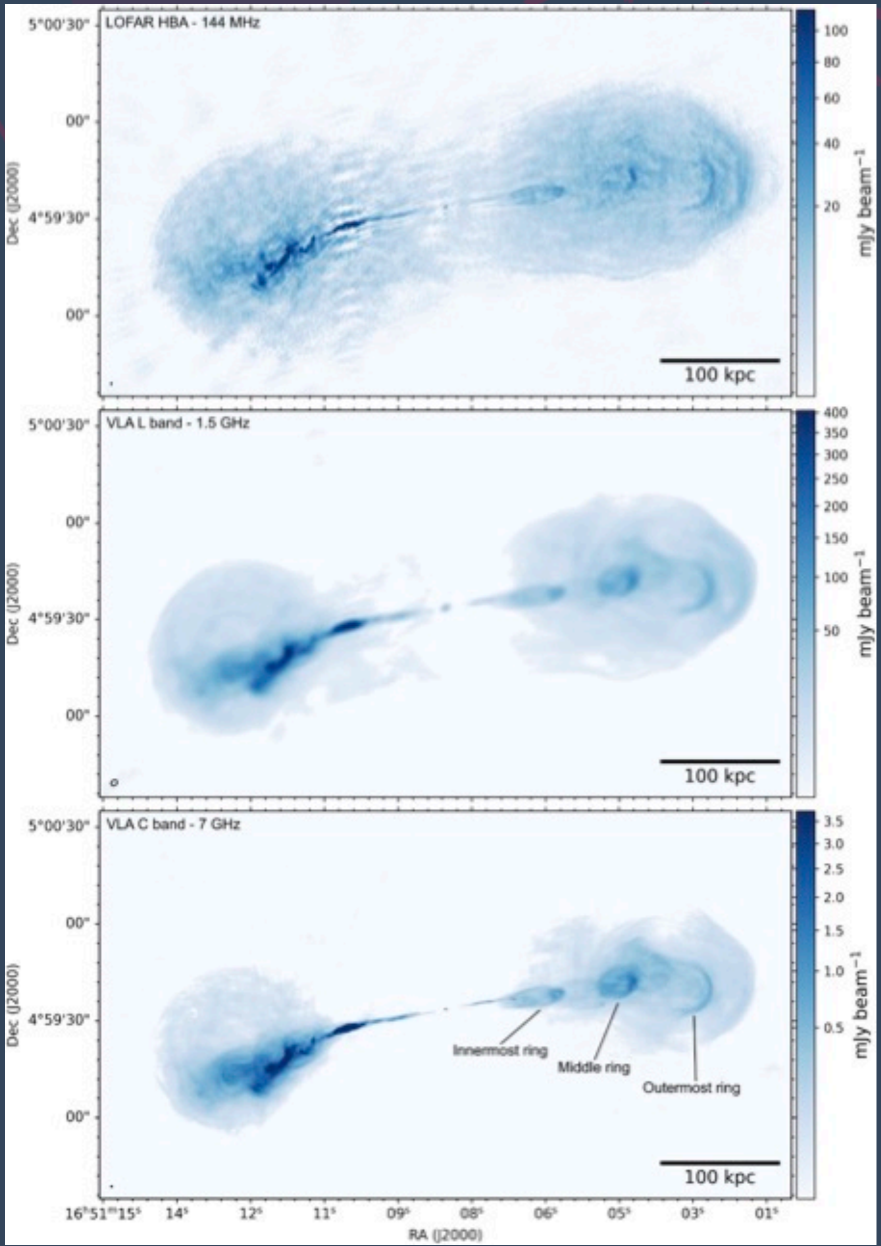
Comparison between the pipeline-calibrated (top), phase-only self-calibrated (middle), and amplitude-and-phase self-calibrated (bottom) images of the 143 MHz data.



C. Groeneveldt al. 2022



Morabito et. al 2022



R. Timmerman et al. 2022

Take away message

- LOFAR is a complex and data intensive telescope
- Can sample very large and very small scales at the same time
- Can be used in various observing modes for a variety of scientific cases
- LOFAR is a VLBI instrument by all means

DO YOU WANT TO LEARN MORE ABOUT LOFAR?
Join us at the 7th LOFAR Data School 15-19 April 2024 @Astron
First Announcement is coming soon! Ask me if interested

OPTICON RadioNet Pilot

This event has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004719