

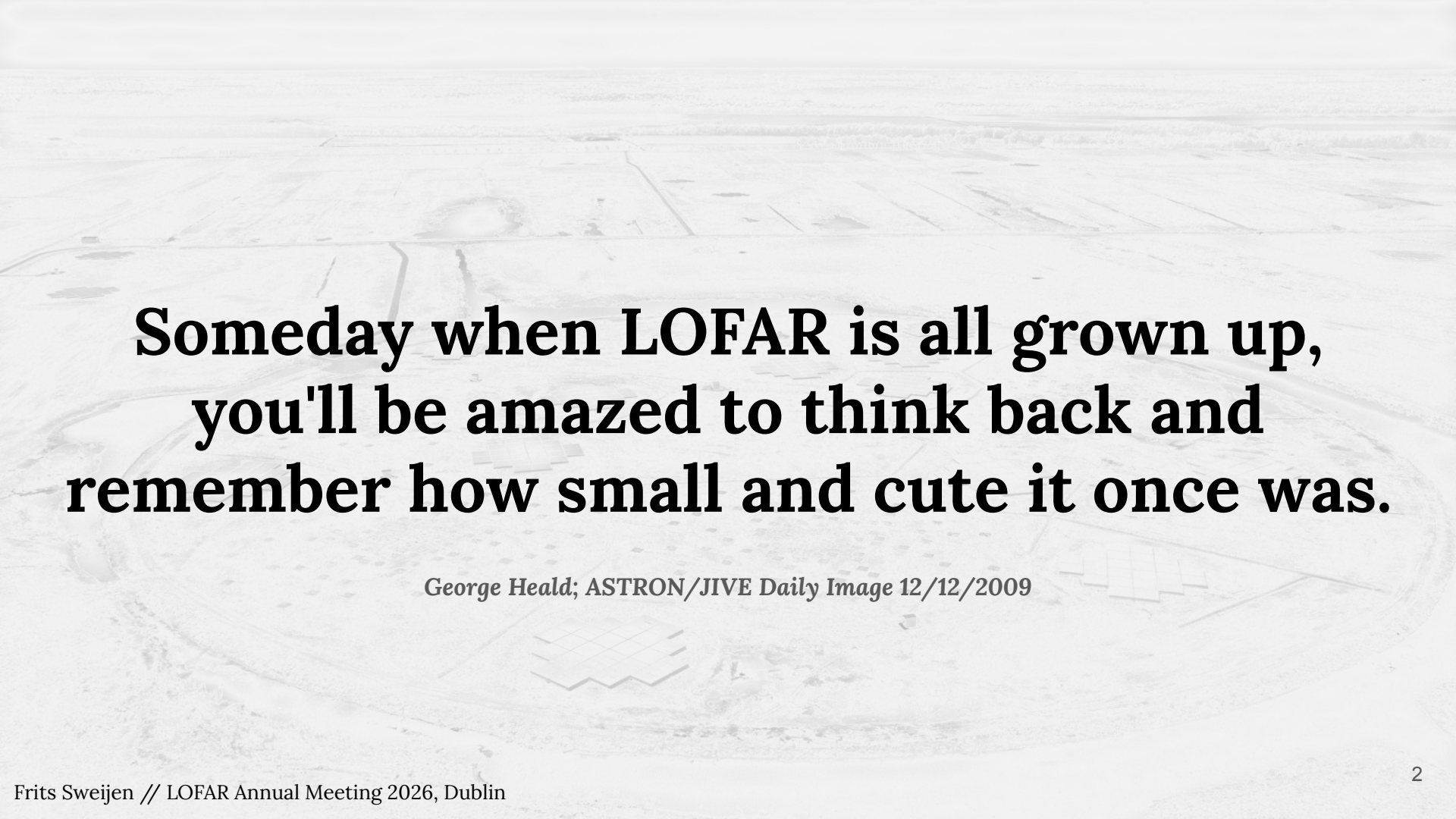


Durham
University

Pushing the fringe

Towards an all-sky 144 MHz survey with the ILT

Frits Sweijen
on behalf of the long-baseline working group

An aerial photograph of the LOFAR radio telescope array, showing a vast, flat landscape with numerous small, rectangular antenna structures arranged in a grid-like pattern. The text is overlaid on the image.

**Someday when LOFAR is all grown up,
you'll be amazed to think back and
remember how small and cute it once was.**

George Heald; ASTRON/JIVE Daily Image 12/12/2009

Outline

What sets the ILT apart from other VLBI instruments

Science with the ILT

LBWG & Pipeline for International LOFAR Telescope
(PILOT)

Future ILT prospects

More ILT this week

Session 1, Today

Roland Timmerman – LoTSS-HR: The high-resolution post-processing of the LOFAR Two-Metre Sky Survey

Session 7, Tue

Reinout van Weeren – Polarisation imaging at metre wavelengths with sub-arcsecond resolution

Session 9, Wed

Leah Morabito – The hidden AGN population: a novel LOFAR perspective

Giulia Lusetti – Galaxy-Scale Jets In the LOFAR-VLBI Deep Fields

Session 9, Wed

John McKean – Gravitational lensing with the ILT: A new probe of dark matter, cosmology and the high redshift Universe

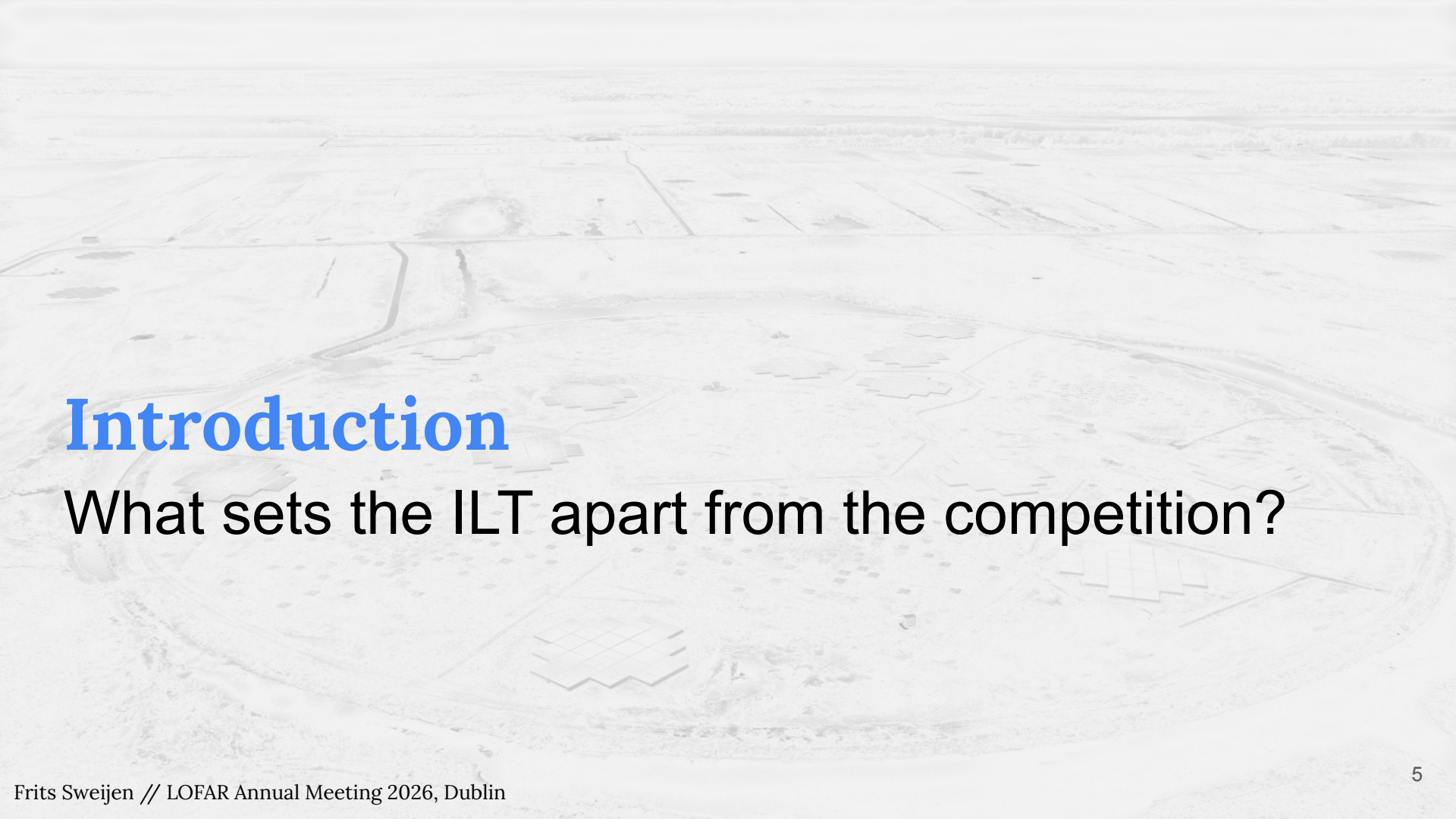
Sagar Sethi – Tracing a radio jet from sub-kiloparsec to hundreds of kiloparsecs in a giant radio galaxy using LOFAR and LOFAR-VLBI

Session 20, Fri

Nadia Biava – Investigating the filamentary emission of radio phoenixes and characterising their peculiarities

Poster

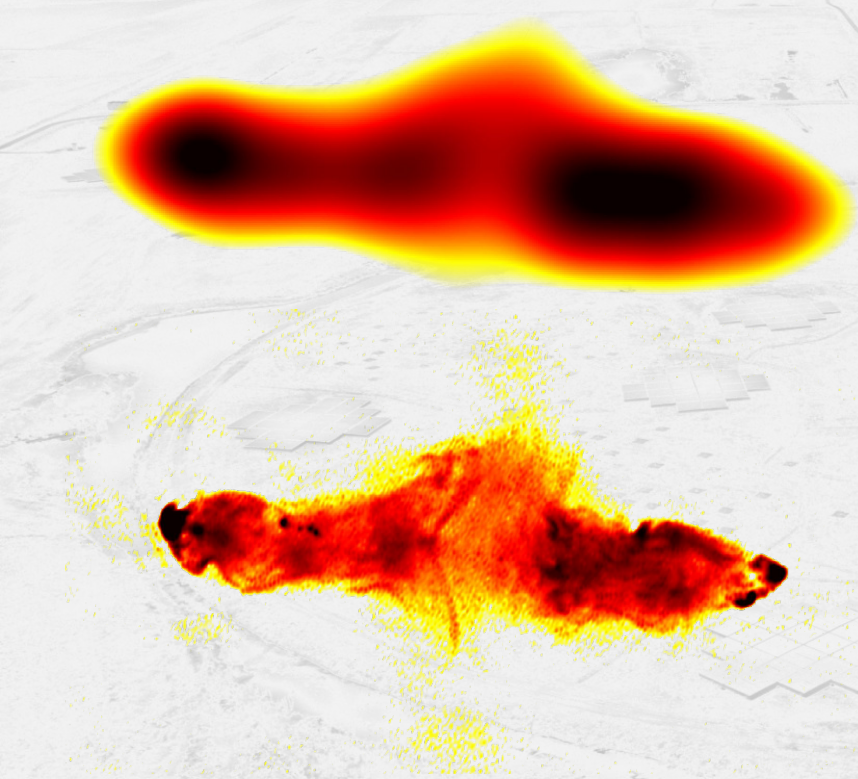
Aleksandra Wołowska – Exploring the Low-Frequency Radio Sky with LOFAR: Surveys of Compact and Faint Radio Sources



Introduction

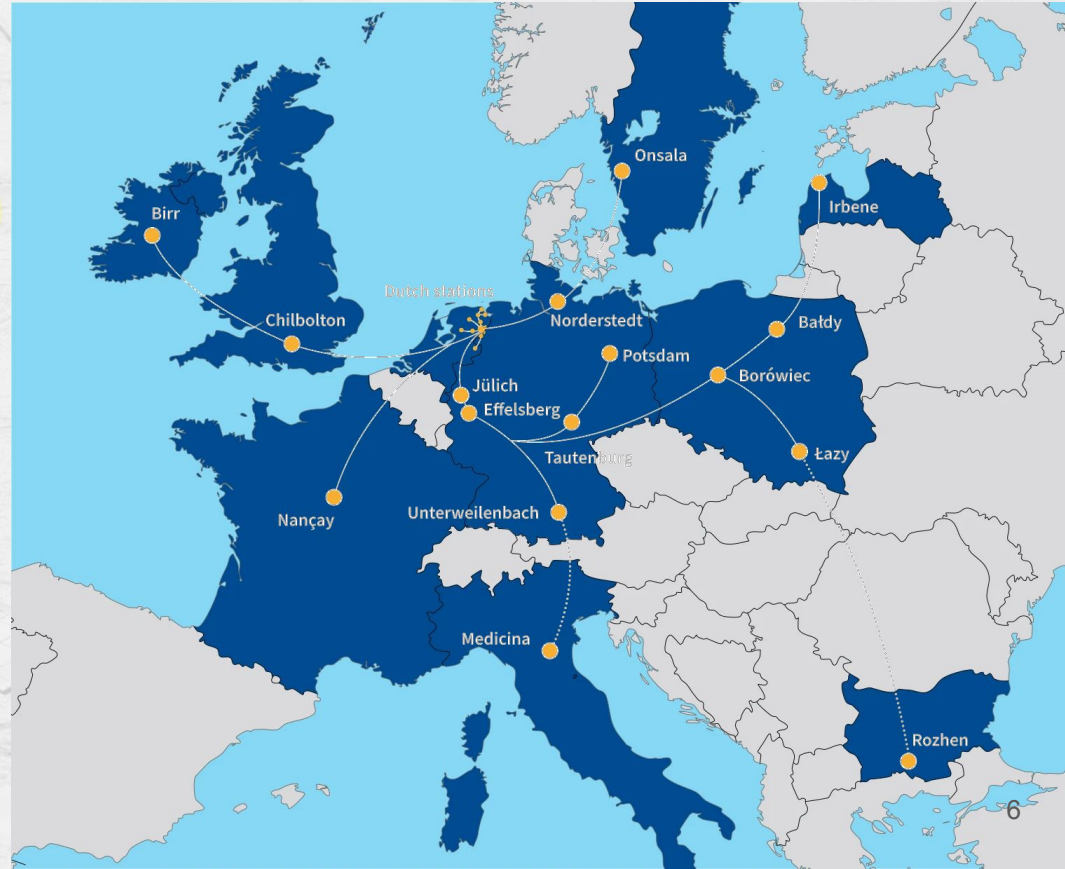
What sets the ILT apart from the competition?

International LOFAR Telescope



3C 34; Mahatma+2024

Frits Sweijen // LOFAR Annual Meeting 2026, Dublin



What sets the ILT apart – angular scales

8 hour synthesis + 48 MHz bandwidth

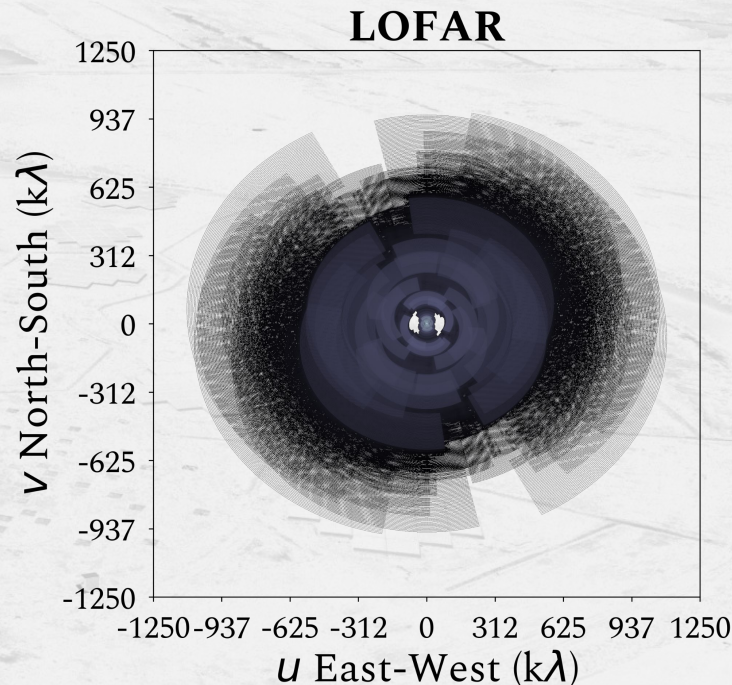
Nearly uniformly filled uv plane

Shortest baseline: ~ 100 m // ~ 1 deg

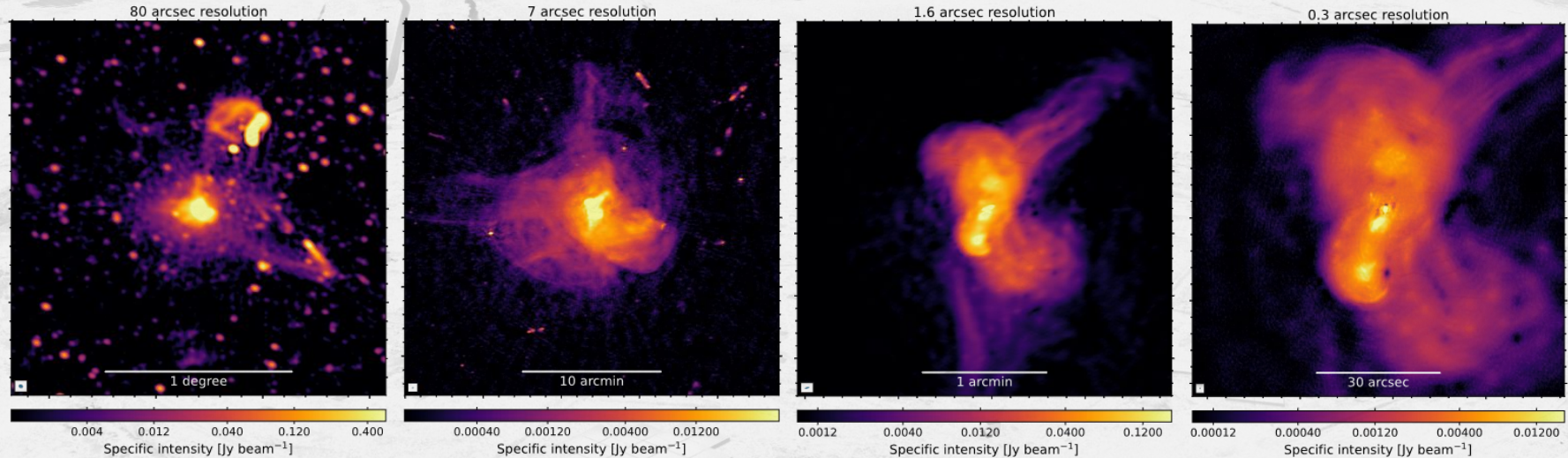
Longest baseline: ~ 1980 km // $0.2''$ @ 144 MHz

Missing baselines: 100–300 km east-west :)

See <https://tikk3r.github.io/wati/> for an interactive version



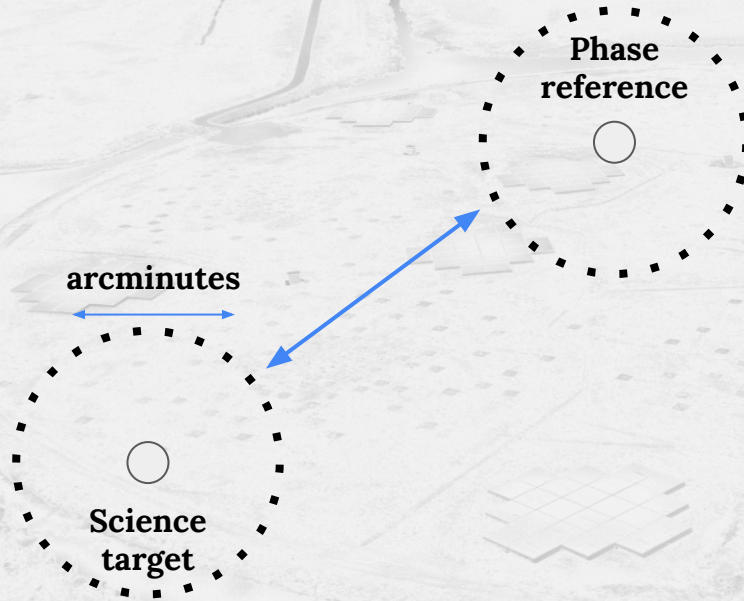
What sets the ILT apart – angular scales



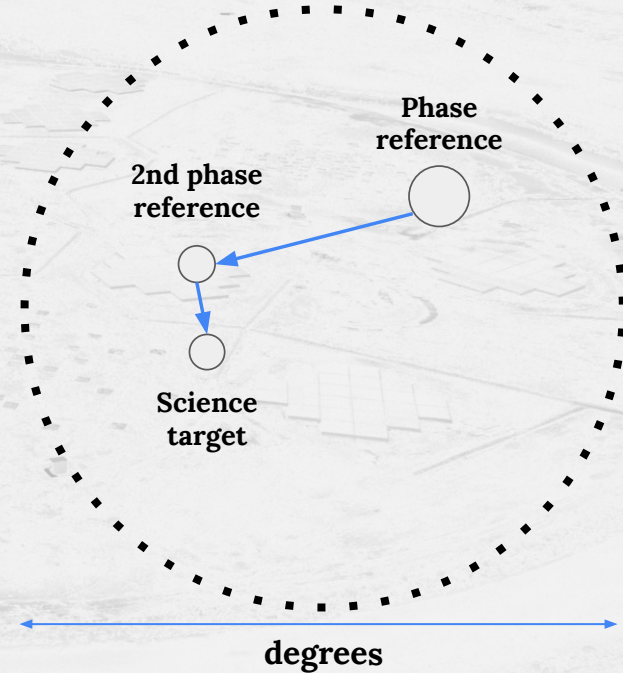
van Weeren+2024

What sets the ILT apart – efficiency

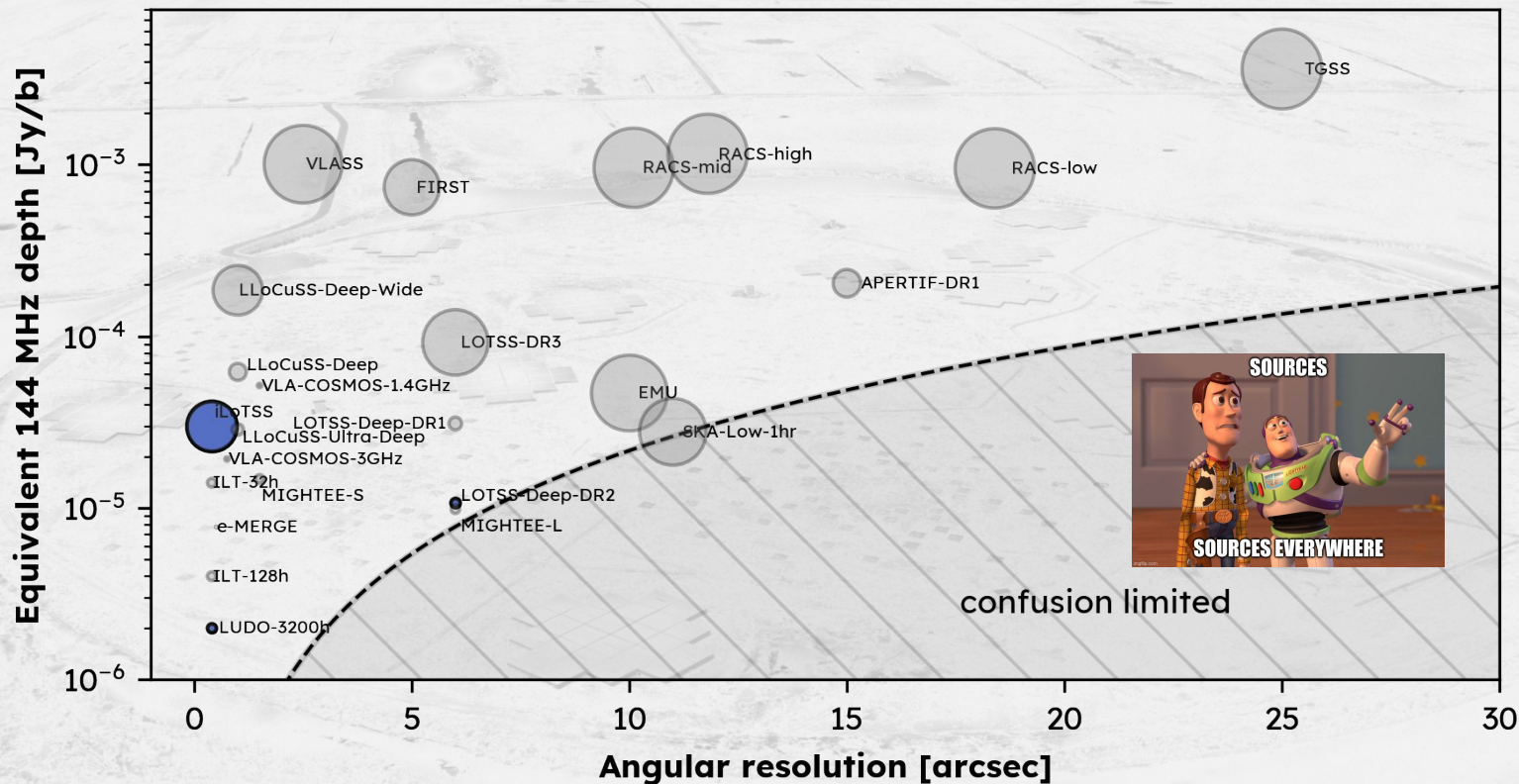
“Traditional” VLBI



ILT



What sets the ILT apart – confusion





Science with the ILT

Science with the ILT

Matched-resolution multi-wavelength

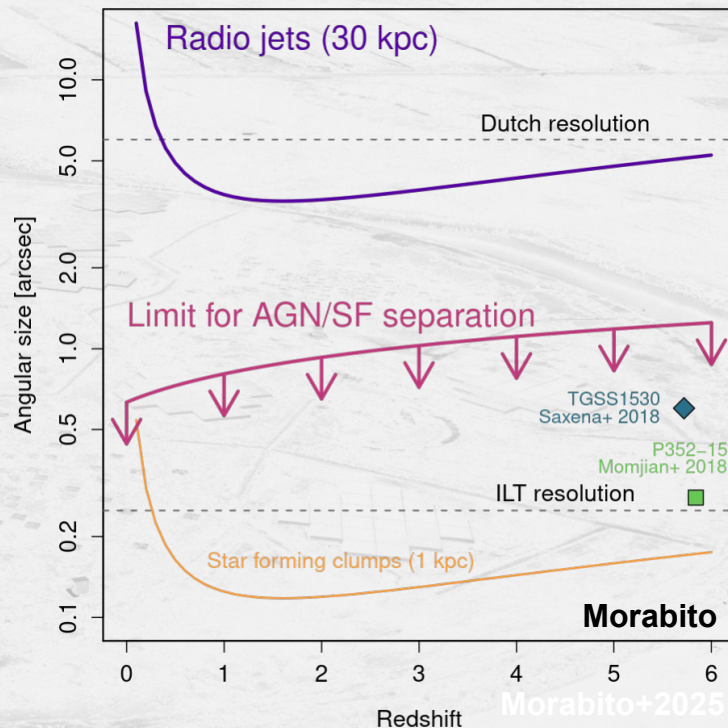
Same spatial scales between optical, x-ray, IR etc.

Statistical studies

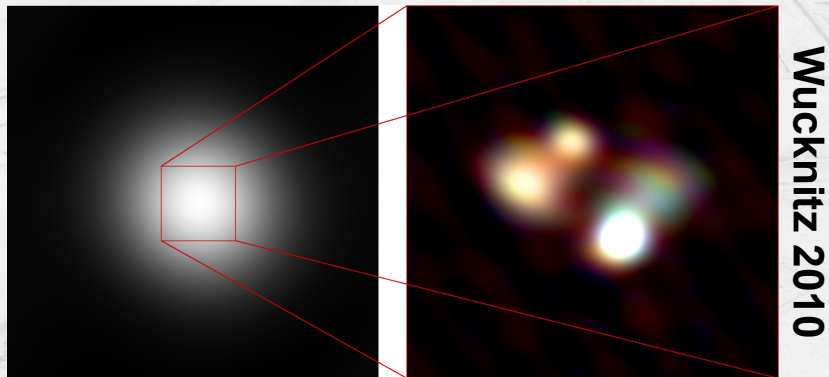
Blind sample follow-up, luminosity functions (see Leah's talk S9 Wed)

Rare/serendipitous object discovery space

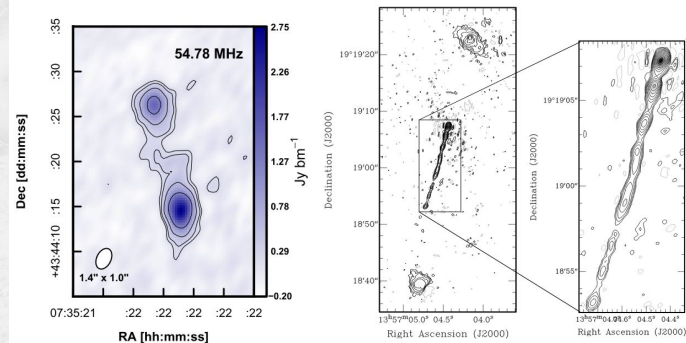
Lenses, high- z AGNs, strange objects



Science with the ILT

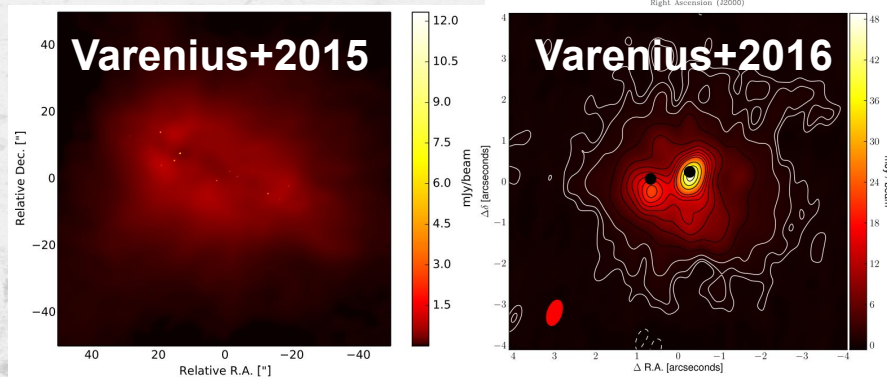
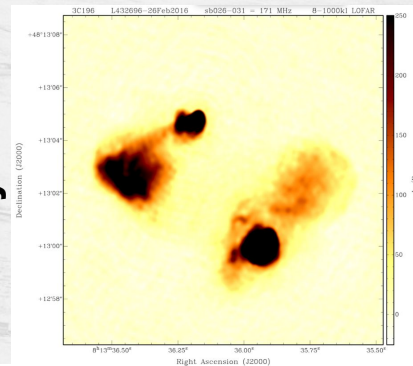


Morabito+2016

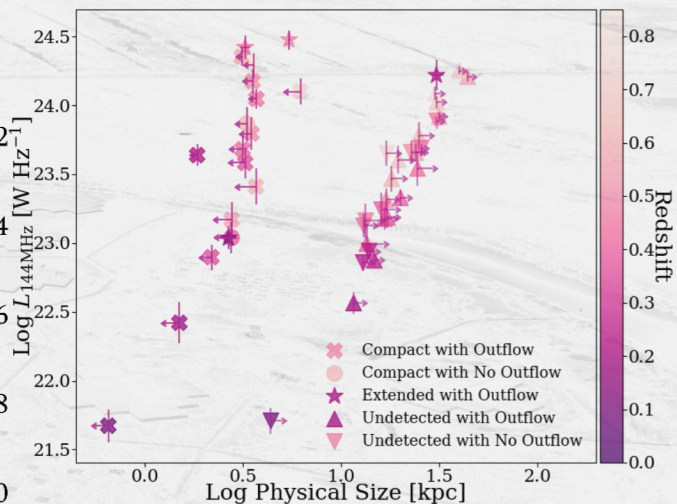
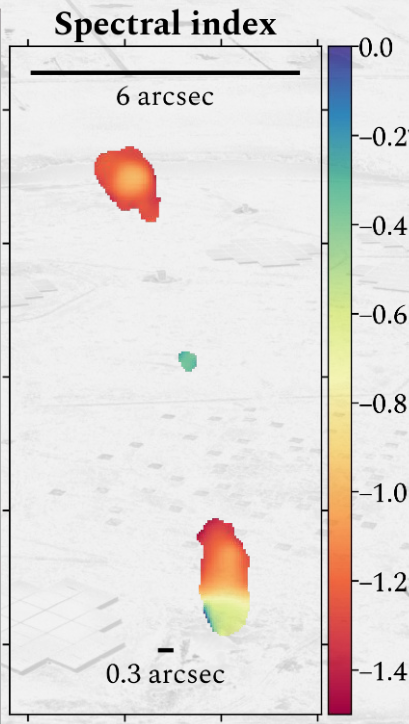
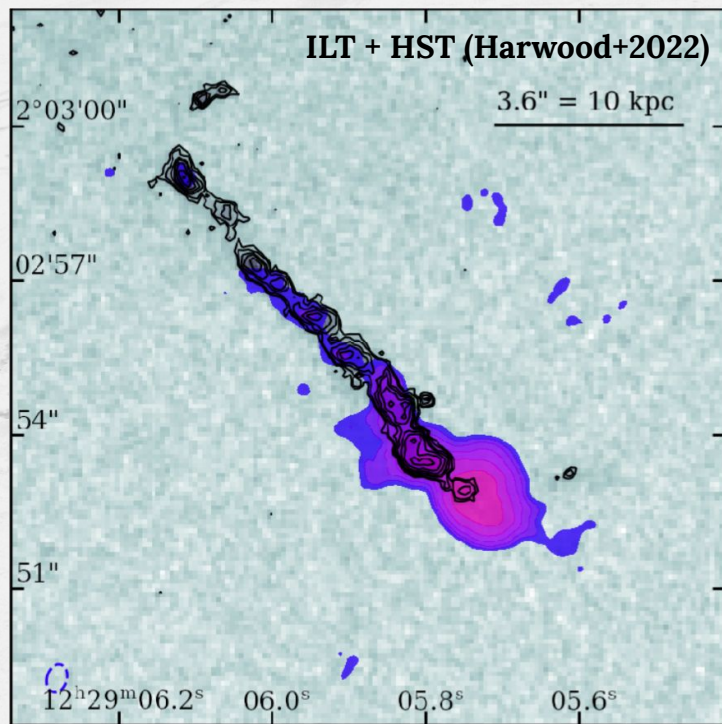


Harris+2019

De Bruyn 2016



Science with the ILT



ILT + OIII (Escott+2026)

ILT + VLA (Sweijen+2021)

Science with the ILT

2022: A&A special issue

11 diverse papers jointly published

Foundational strategies

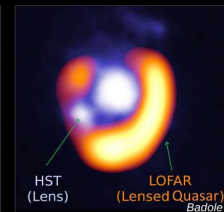
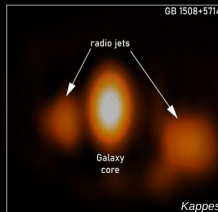
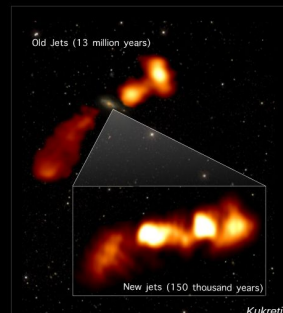
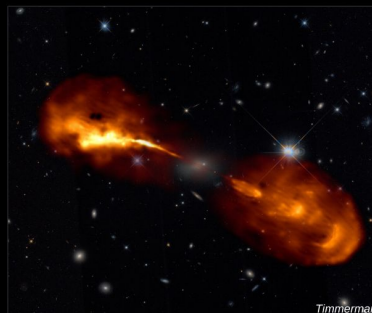
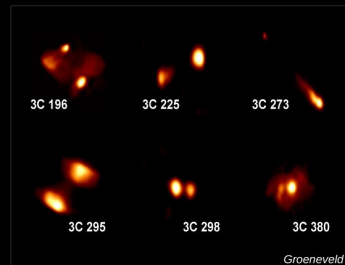
Nearby AGNs

High-z AGNs

Gravitational lens

LBA 50 MHz

Sub-arcsecond imaging with the International LOFAR Telescope



NEW TECHNIQUES DRIVE NEW SCIENCE

Using new data calibration techniques to make high-resolution images, astronomers are uncovering low frequency radio emission on never-before-seen scales. This is a gallery of new science results, revealing the shape of the radio emission in distant galaxies.

INTERNATIONAL LOFAR TELESCOPE

The LOw Frequency ARray (LOFAR) is a radio telescope with antennas spread across 8 European countries. It operates at frequencies around the FM radio band, where jets from black holes are particularly bright.

Science with the ILT

2022: A&A special issue

11 papers jointly published

2025: review of 10 years ILT

Reflection on past efforts, current science and future prospects

Astrophysics and Space Science (2025) 370:19
<https://doi.org/10.1007/s10509-025-04406-x>

REVIEW



A decade of sub-arcsecond imaging with the International LOFAR Telescope

Leah K. Morabito^{1,2} · Neal Jackson³ · Jurjen de Jong⁴ · Emmy Escott¹ · Christian Groeneveld^{4,5} · Vijay Mahatma^{6,7} · James Petley^{1,4} · Frits Sweijs¹ · Roland Timmerman^{1,2} · Reinout J. van Weeren⁴

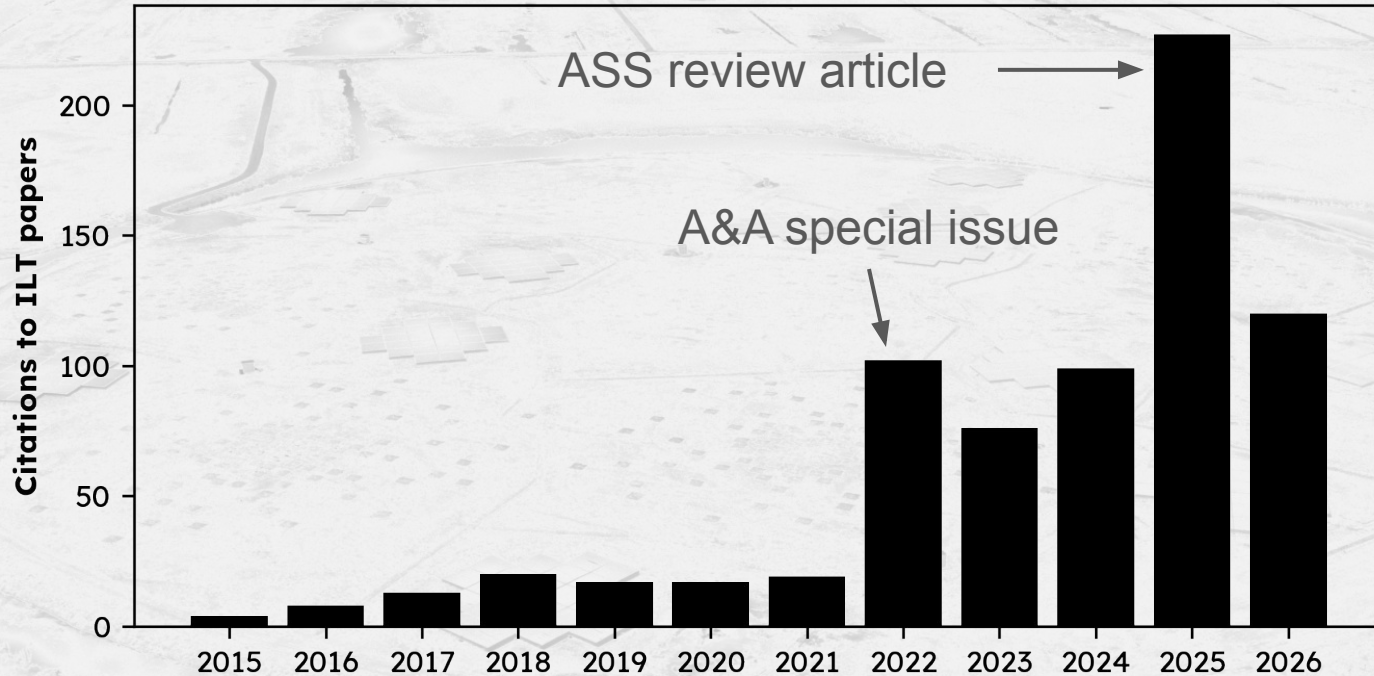
Received: 6 December 2024 / Accepted: 7 February 2025 / Published online: 24 February 2025
© The Author(s) 2025

Abstract

The International LOFAR Telescope (ILT) is a pan-European radio interferometer with baselines up to 2000 km. This provides sub-arcsecond resolution at frequencies of <200 MHz. Since starting science operations in 2012, the ILT has carried out observations for the state-of-the-art LOFAR Two-metre Sky Survey, which has 6 arcsec resolution at 144 MHz. Wide-area surveys at low frequencies, while scientifically productive, have to compromise on resolution. Sub-arcsecond imaging with the ILT has become more accessible over the last decade, thanks to efforts to build a publicly available pipeline using LOFAR-specific tools, which has resulted in a dramatic increase in the number of publications. The ILT's combination of resolution, field of view, and low observing frequency make it a unique instrument for a wide range of scientific applications, and it will remain unparalleled even in the era of the Square Kilometre Array Observatory. Here we provide an overview of the technical considerations and calibration methods sub-arcsecond imaging with the ILT. This is followed by a review of the unique capabilities unlocked by sub-arcsecond imaging with the ILT, using examples from the literature for demonstration. Finally we describe ongoing work including: surveying large areas of the sky at high resolution, going deeper in fields with excellent ancillary information, producing images of polarisation, and extending to lower frequencies (<100 MHz).

Keywords Radio astronomy · Extragalactic · High-resolution imaging · Radio surveys

Science with the ILT

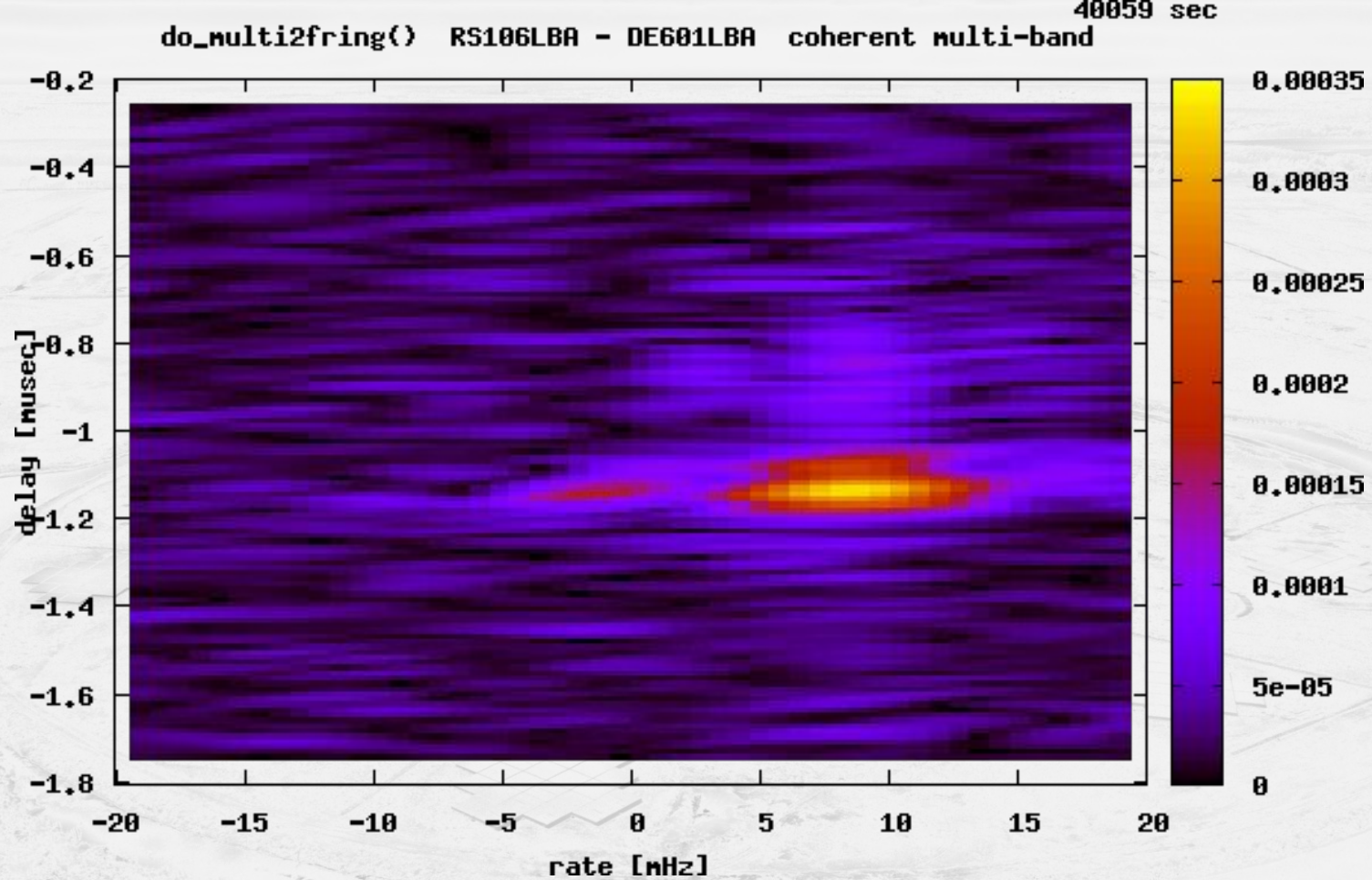


<https://ui.adsabs.harvard.edu/public-libraries/fy3hB2dNToiWGJSqMMcVg>

Science with the ILT



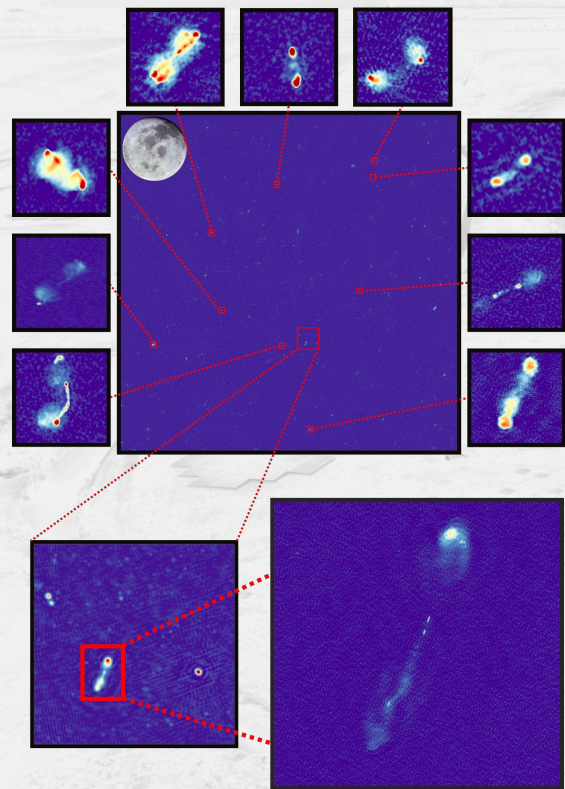
<https://ui.adsabs.harvard.edu/public-libraries/fy3hB2dNToiWGJSqMMcVg>



First international baseline fringes (O. Wucknitz, ASTRON/JIVE Daily Image 2/10/2009)

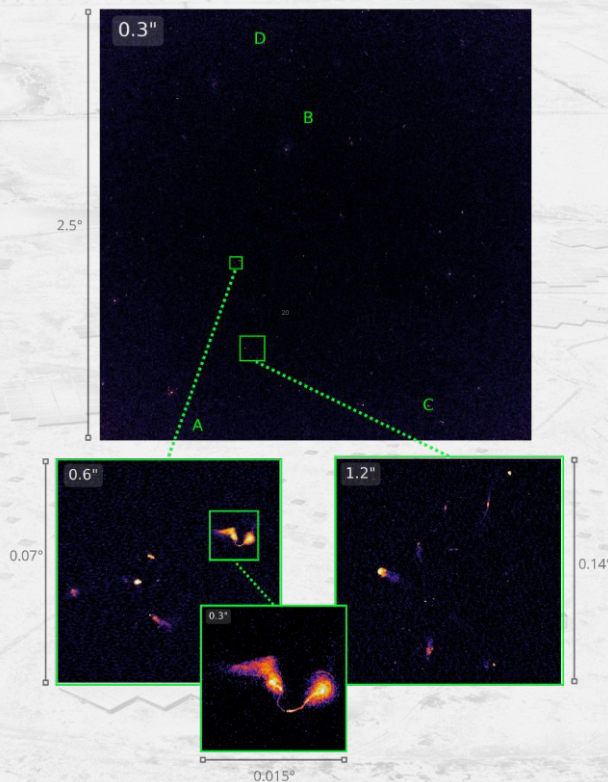
Some 24 deg² at 0.3'' resolution between Lockman Hole, ELAIS-N1, Boötes and EDF-N!

Lockman Hole



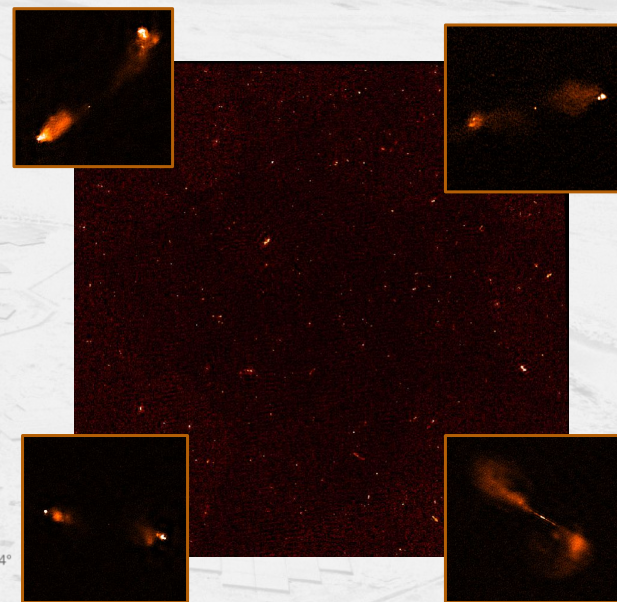
Sweijen et al. 2022

ELAIS-N1



de Jong et al. 2024

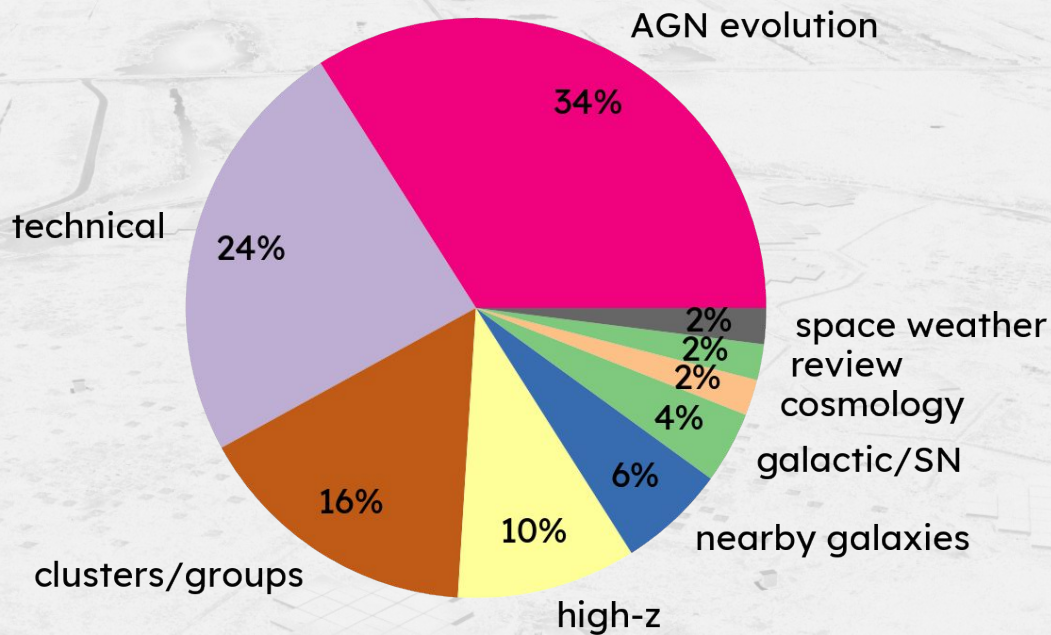
Boötes



Escott et al. 2026

Also EDF-N (de Jong+in prep.)

Science with the ILT



*Disclaimer: based on my totally unbiased classification of my ADS library that may or may not be complete



The Journal of
Open Source Software

An automated pipeline for LOFAR very-long baseline interferometry

Submitted 02 December 2025

van der Wild+subm.

PILOT

Pipeline for the International LOFAR Telescope

<https://github.com/LOFAR-VLBI/pilot>

PILOT

Active working group with a strong feedback loop

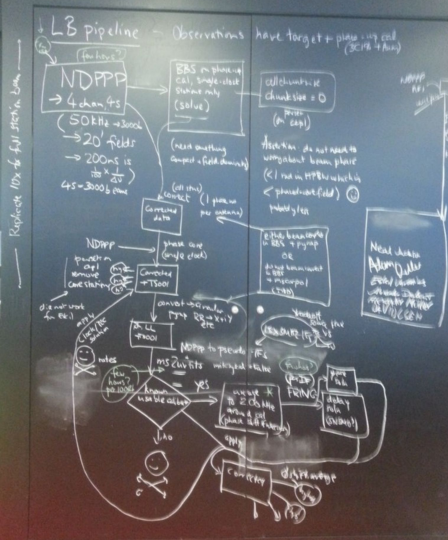
Biannual “busy weeks” to develop the pipeline, help with data reduction etc.

Fortnightly telecons

Active Slack workspace

GPT Image 2.0's idea of a busy week and the pipeline





PILOT

One stop shop end-to-end pipeline

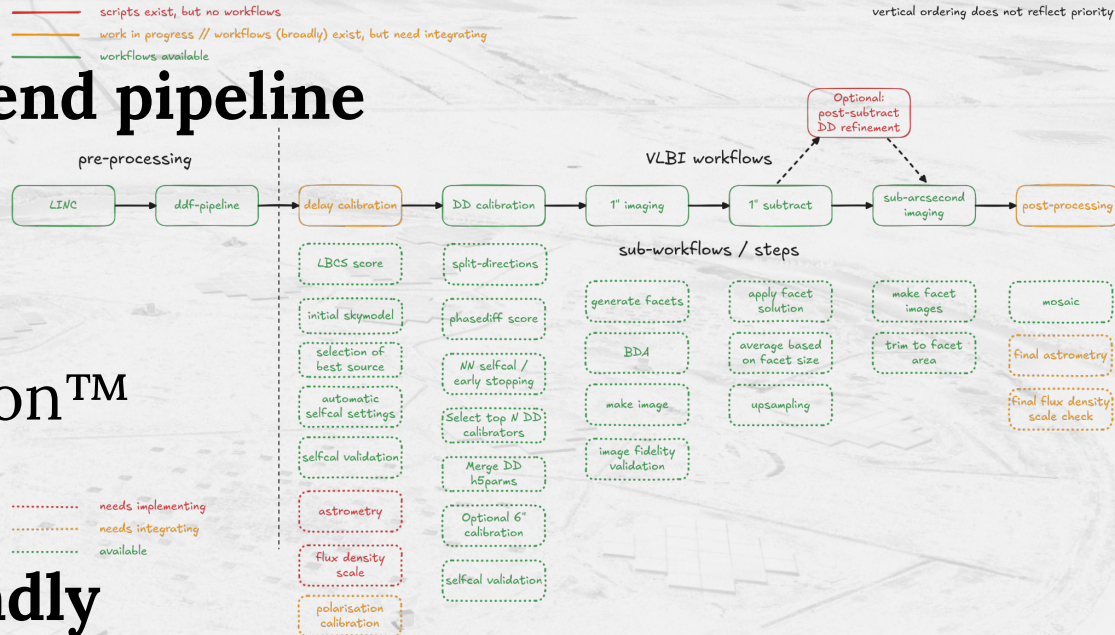
Single or multi-target

Full FoV imaging

Polarisation imaging soon™

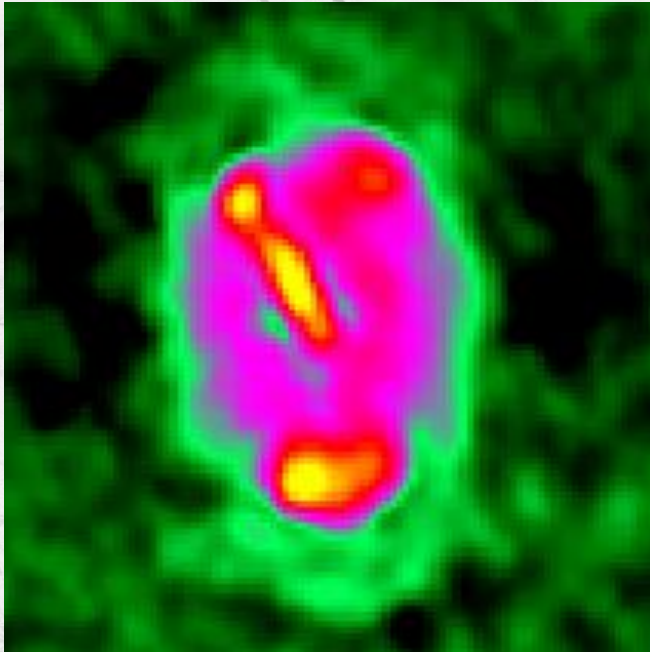
Scalable and user-friendly

Single machine or Slurm through CWL + flocs

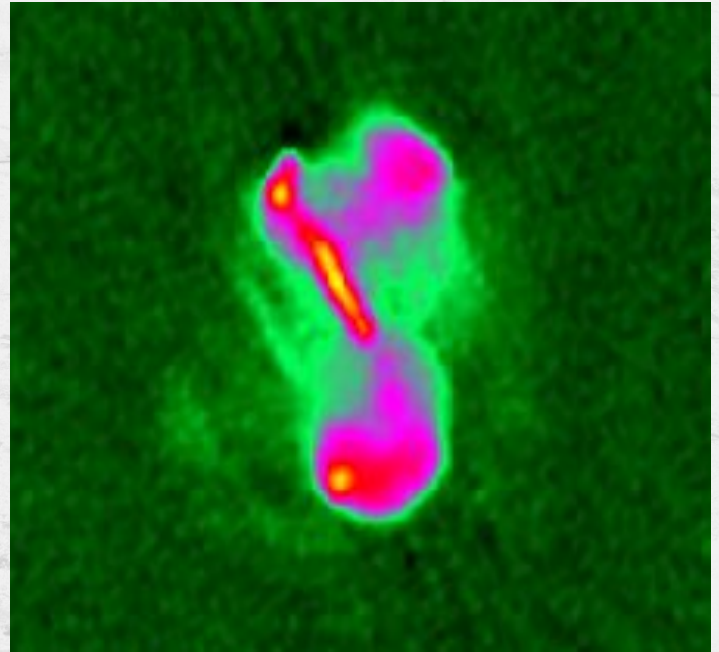


PILOT

Then (Sweijen+2022)



Now



PILOT

Affordable processing

~3,000 ch single target

~10,000 ch 100 targets

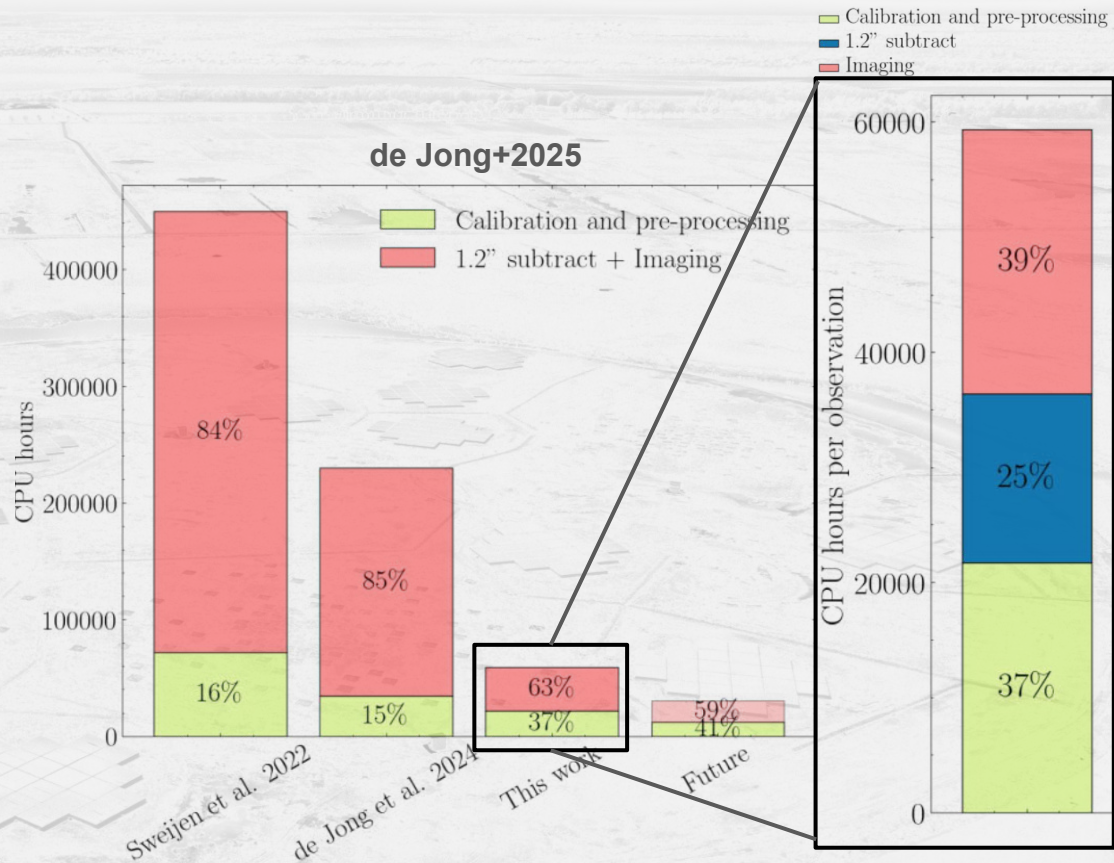
~60,000 ch full FoV

LoTSS DR2 $\approx$ 5M ch

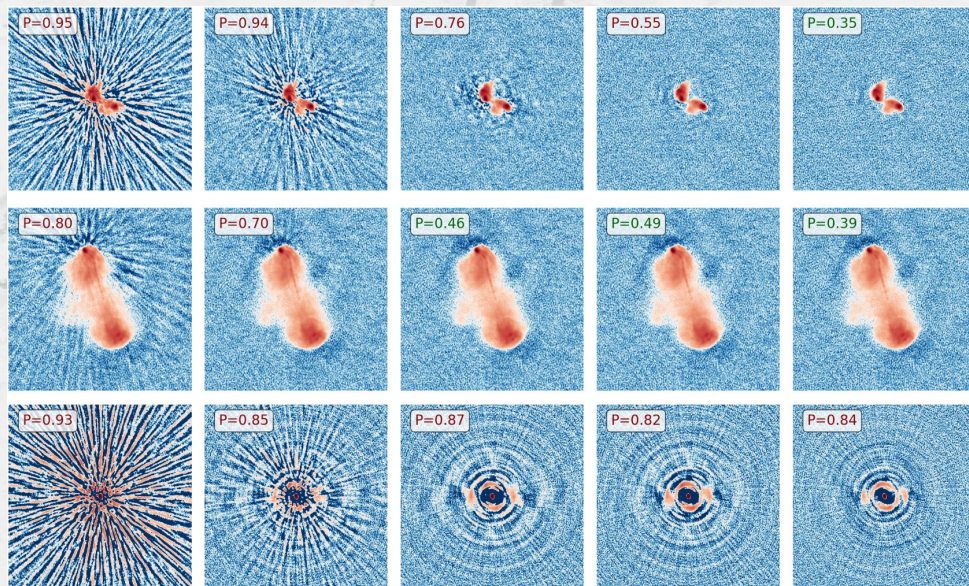
iLoTSS $\approx$ 273M ch

841 DR2 pointings

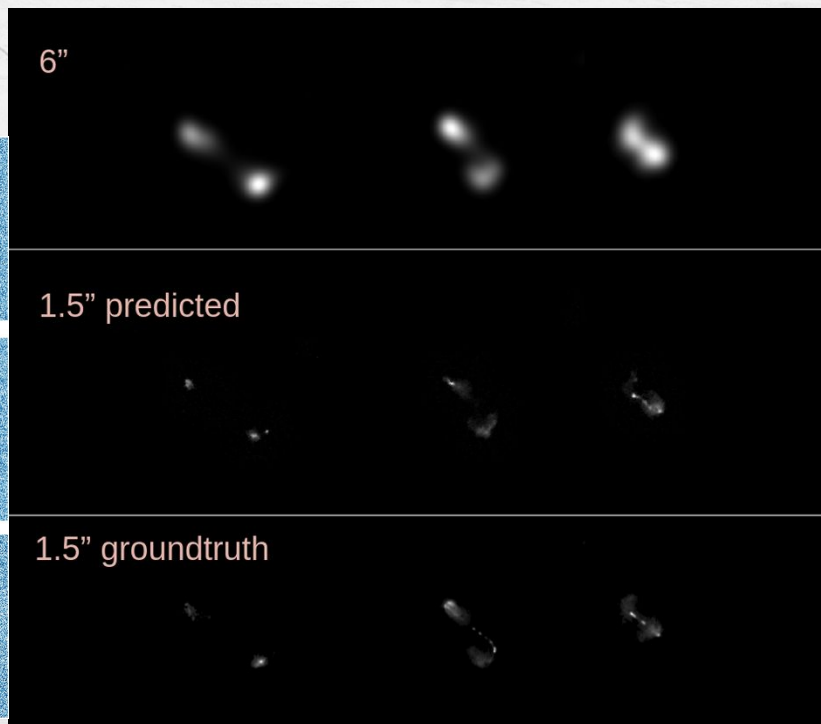
+ 3,714 new pointings



ML assisted calibration



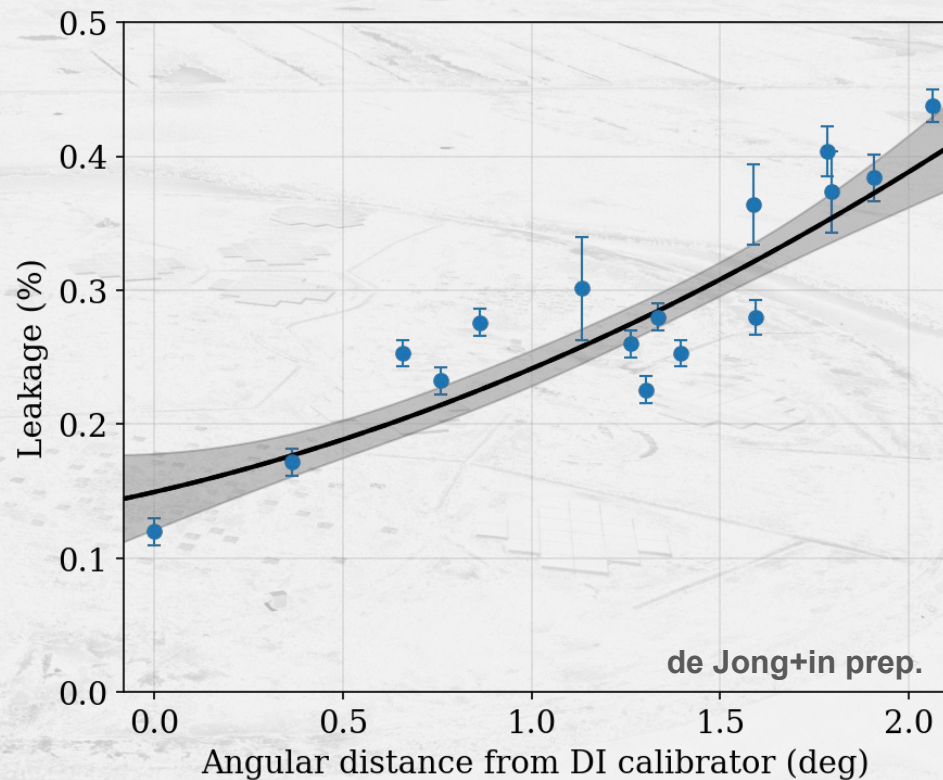
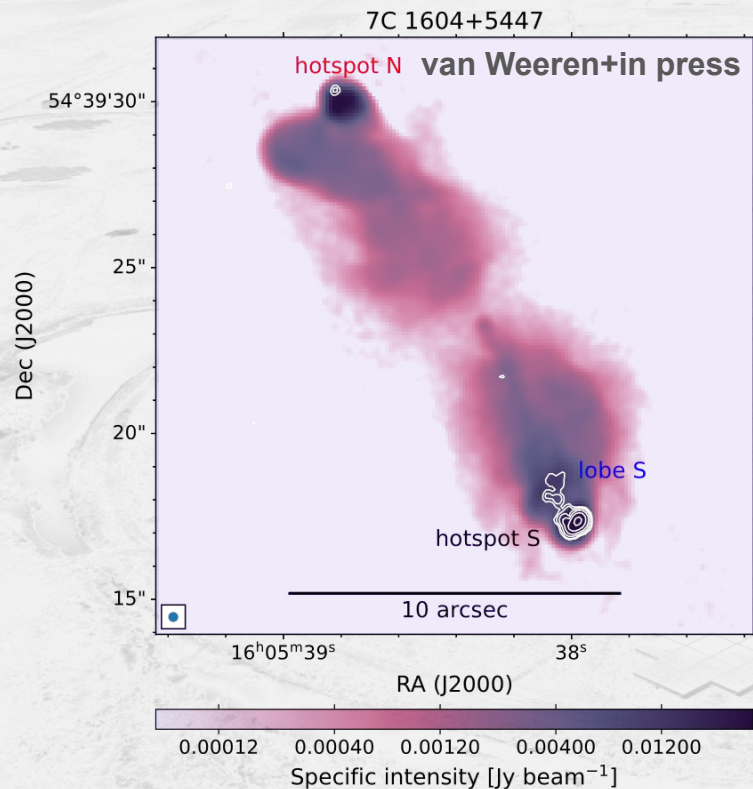
Detecting selfcal convergence (de Jong+2025)



Upscaling 6'' images to star (E. Woest)

Sub-arcsecond resolution polarisation

See Reinout's talk in
Session 7, Tue



Future prospects – LOFAR2 era

LoTSS-HR (see Roland's talk this session)

High-resolution follow-up of >10 mJy sources

iLoTSS (<https://lofar-surveys.org/ilotss.html>)

Archival reprocessing and new observations to fill gaps in the LoTSS grid
Full FoV imaging across $\sim 7,600$ deg² targeting ~ 30 μ Jy beam⁻¹

LUDO (<https://sites.google.com/view/lofarultradeep/eoi>)

Ultra deep observations of EDF-N – $\sim 3,200$ h targeting ~ 2 μ Jy beam⁻¹

Future prospects – technical frontiers

Quality assurance

Need robust quality control all the way back to LINC

Polarisation

Need to know (un)polarised calibrator sources

Galactic plane

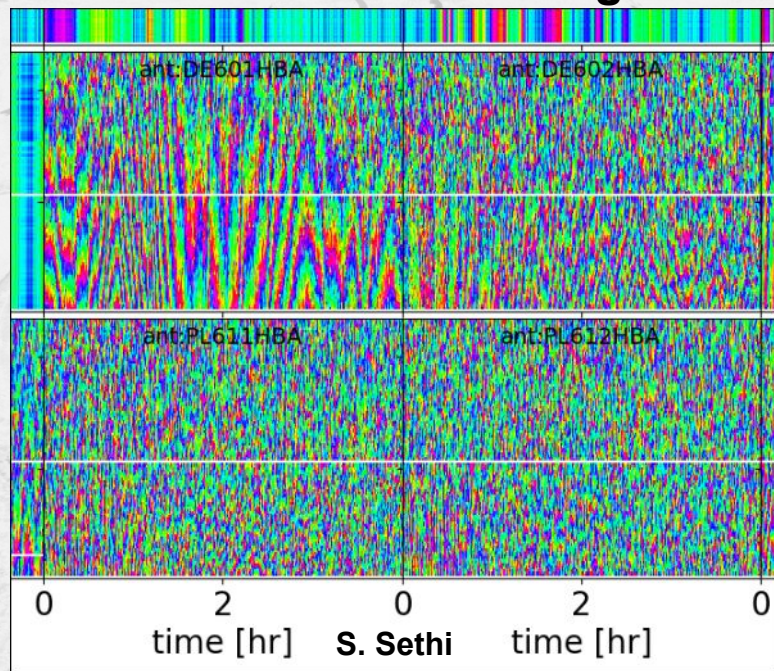
Interstellar scattering washes out usable signal; not properly characterised yet

LBA

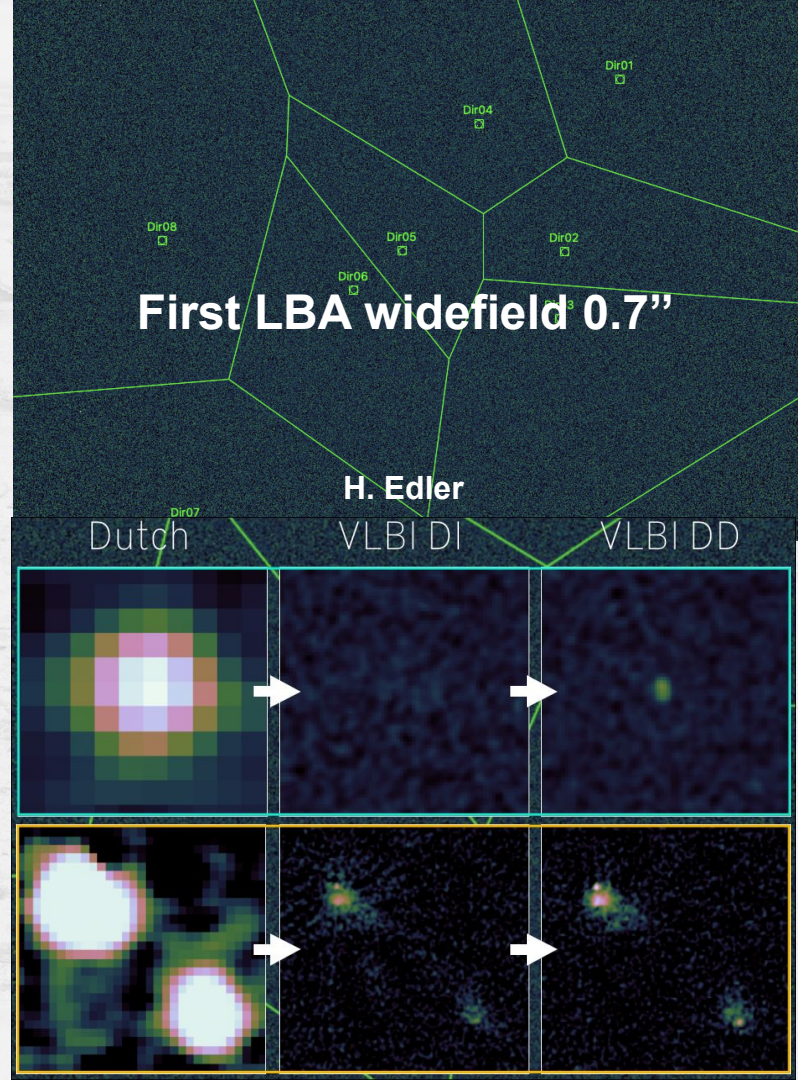
ionosphere $\propto \lambda$; FR $\propto \lambda^2$, so everything at least 3x worse $\backslash_(\ツ)_/_/$

Future prospects

Interstellar scattering?



First LBA widefield 0.7''



Conclusions

ILT facilitates a diverse palette of science

Statistical studies, matched-resolution multi-wavelength, serendipity

HBA long baseline processing is now accessible

PILOT provides end-to-end data reduction

Scalable from single machine to clusters

Active working group chipping away at the next challenges

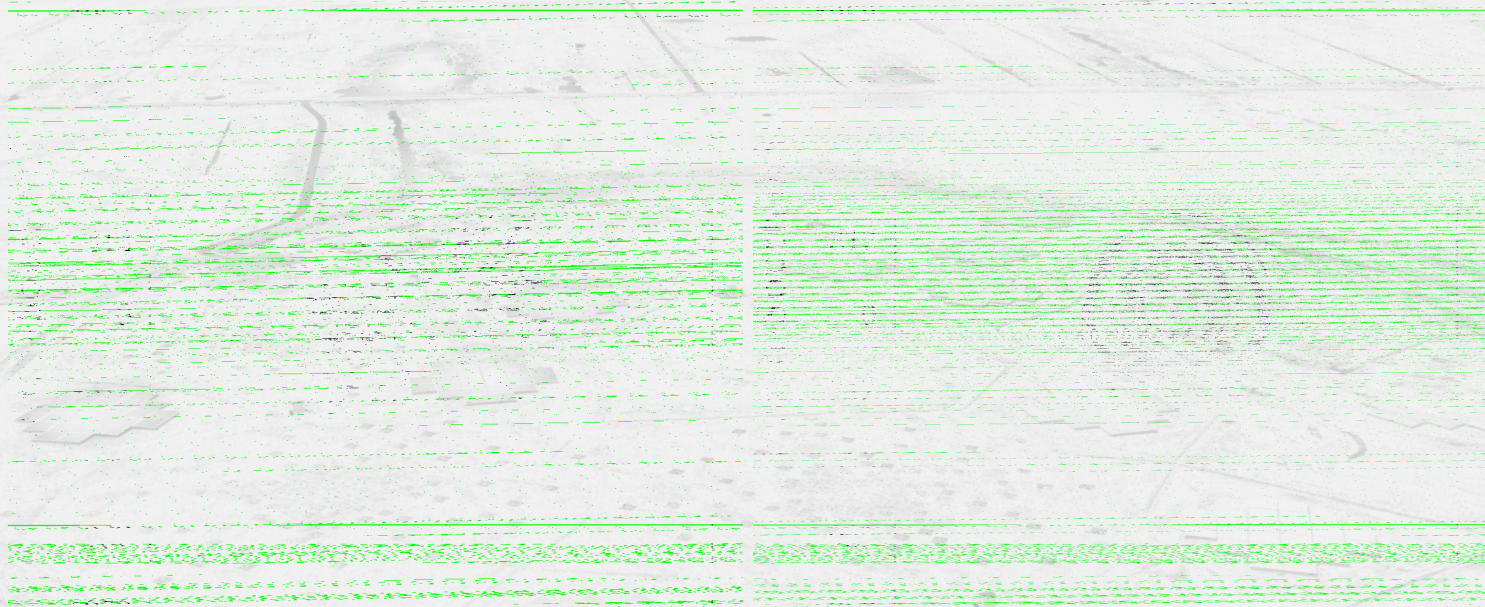
Regular “busy weeks”

Issues or pull requests welcome

But no, we are not planning to disconnect the German stations from the rest of the array to produce our own maps. An interferometer is more valuable than the sum of its parts, and the same is true for the combination of the Dutch and German subarrays.

Olaf Wucknitz; ASTRON/JIVE Daily Image 03/03/2010

What sets the ILT apart – angular scales



See <https://tikk3r.github.io/wati/> for an interactive version

What sets the ILT apart – angular scales

