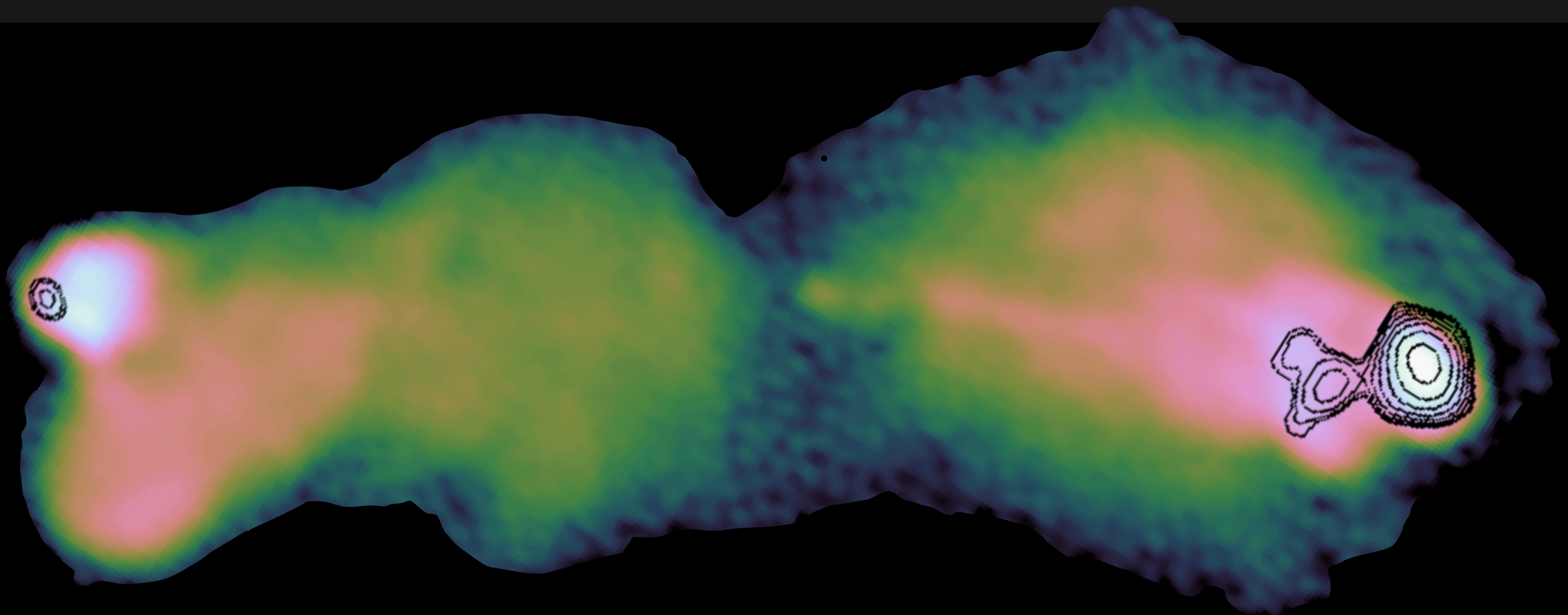


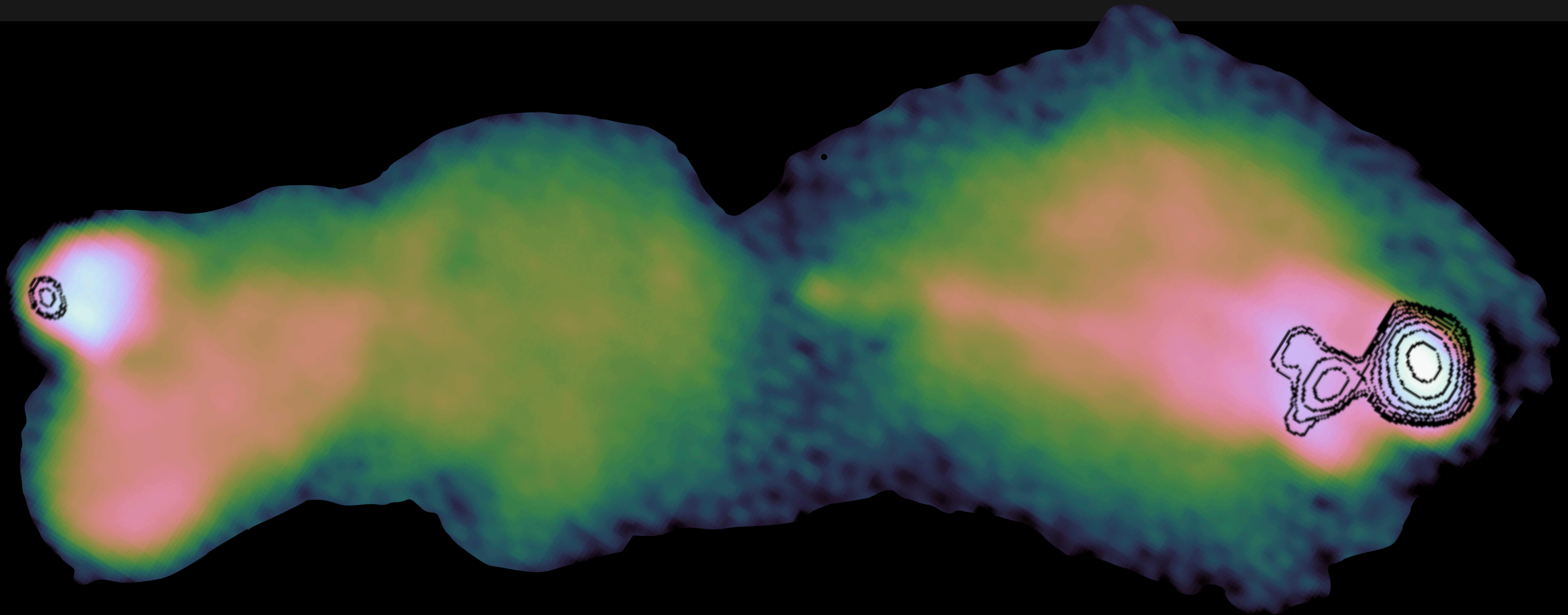
LOFAR polarisation imaging at subarcsecond resolution



Reinout van Weeren
Jurjen de Jong et al.

Leiden Observatory, Leiden University

LOFAR polarisation imaging at subarcsecond resolution

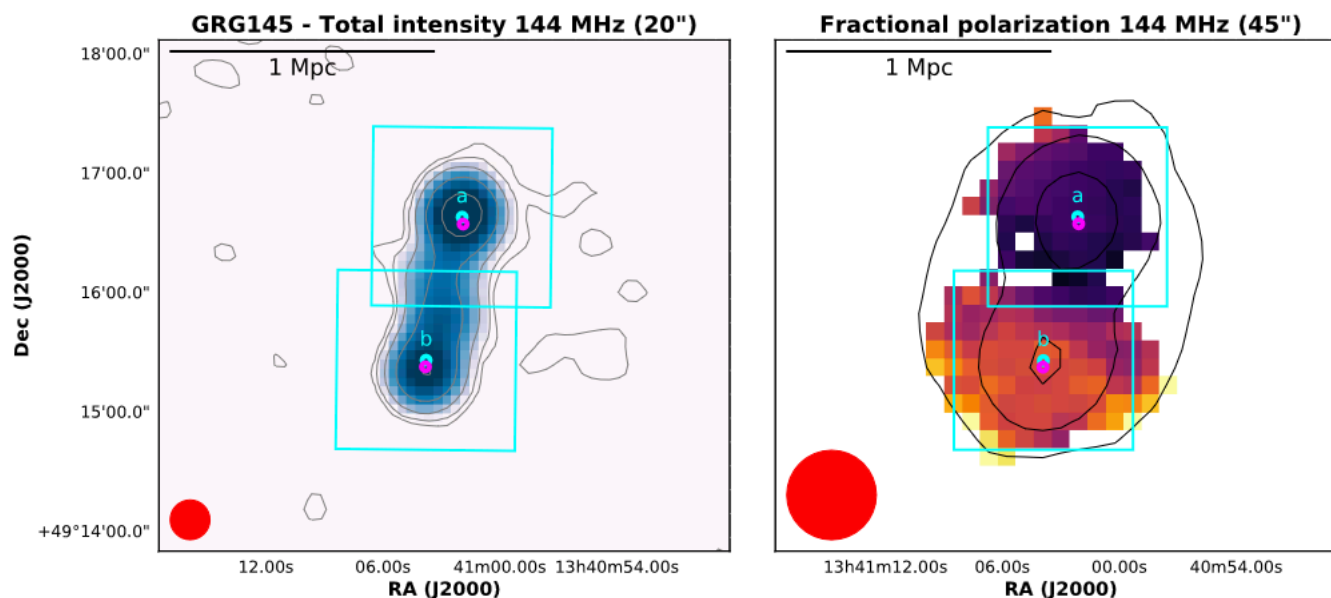


Polarisation and Faraday rotation measure imaging at metre wavelengths with sub-arcsecond resolution: a foundational calibration strategy

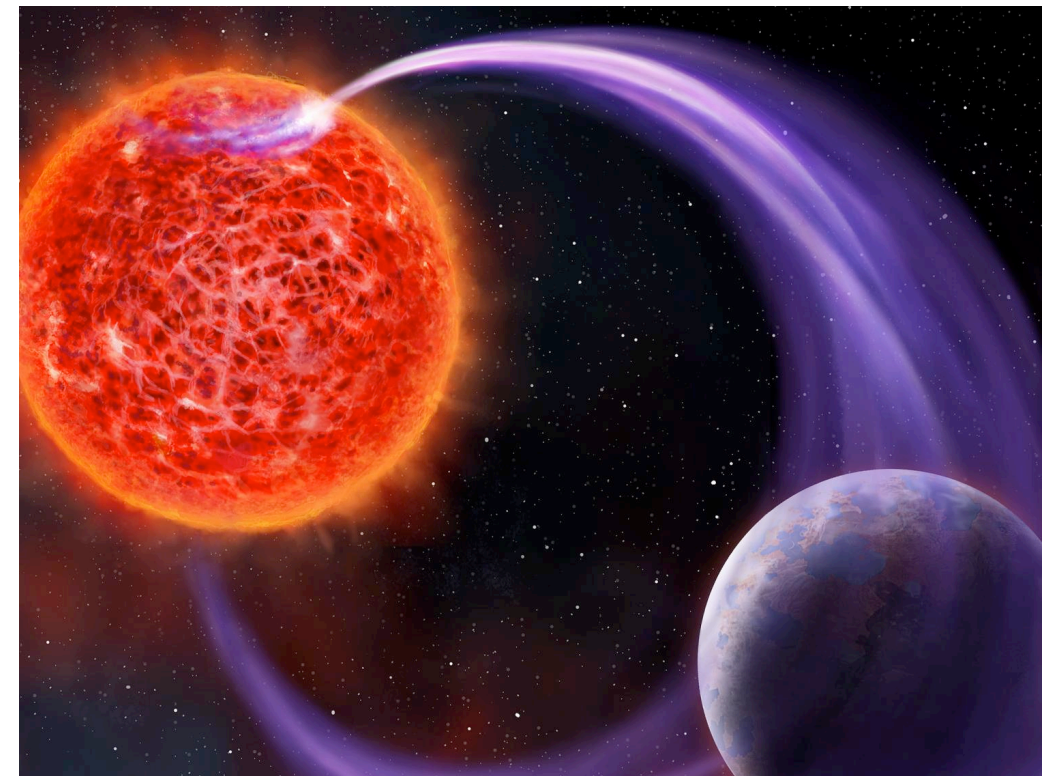
R. J. van Weeren^{1*}, J. M. G. H. J. de Jong^{1,2}, X. K Le Saux¹, V. A. Chakawri¹, Q. W. E. van Zegveld¹, D. de Jong¹, S. P. O'Sullivan³, F. Sweijen⁴, V. H. Mahatma^{5,6}, E. De Rubeis^{7,8}, L.K. Morabito^{4,9}, D. Alonso-López³, A. Bonafede^{10,8}, C. Horellou¹¹, M. van der Wild⁴

Motivation

- Low-frequency observations:
 - sensitive probe of magnetic fields in astrophysical sources and the intervening medium
 - magnetospheric emission from compact objects (e.g., pulsars, magnetically active stars, brown dwarfs, planetary aurorae)



Stuardi+ (2022)



Callingham+ (2021)

Danielle Futselaar (artsource.nl)

Motivation

- Low-frequency observations:
 - sensitive probe of magnetic fields in astrophysical sources and the intervening medium
 - magnetospheric emission from compact objects (e.g., pulsars, magnetically active stars, brown dwarfs, planetary aurorae)
- Sub-arcsecond resolution with the ILT:
 - studies of magnetic fields at high-spatial resolution and accurate localisation
 - reduced beam depolarisation: potential to uncover emission that is depolarised at Dutch-baseline resolution



Polarisation calibration

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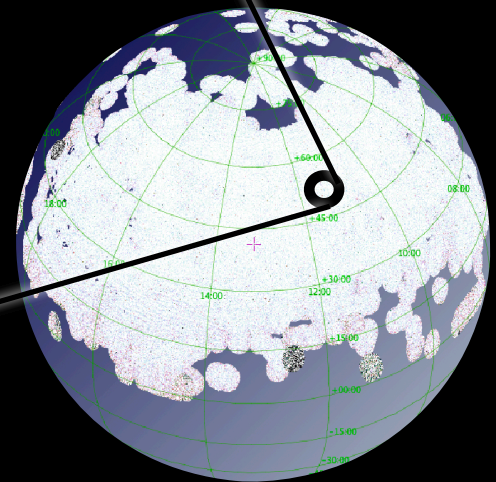
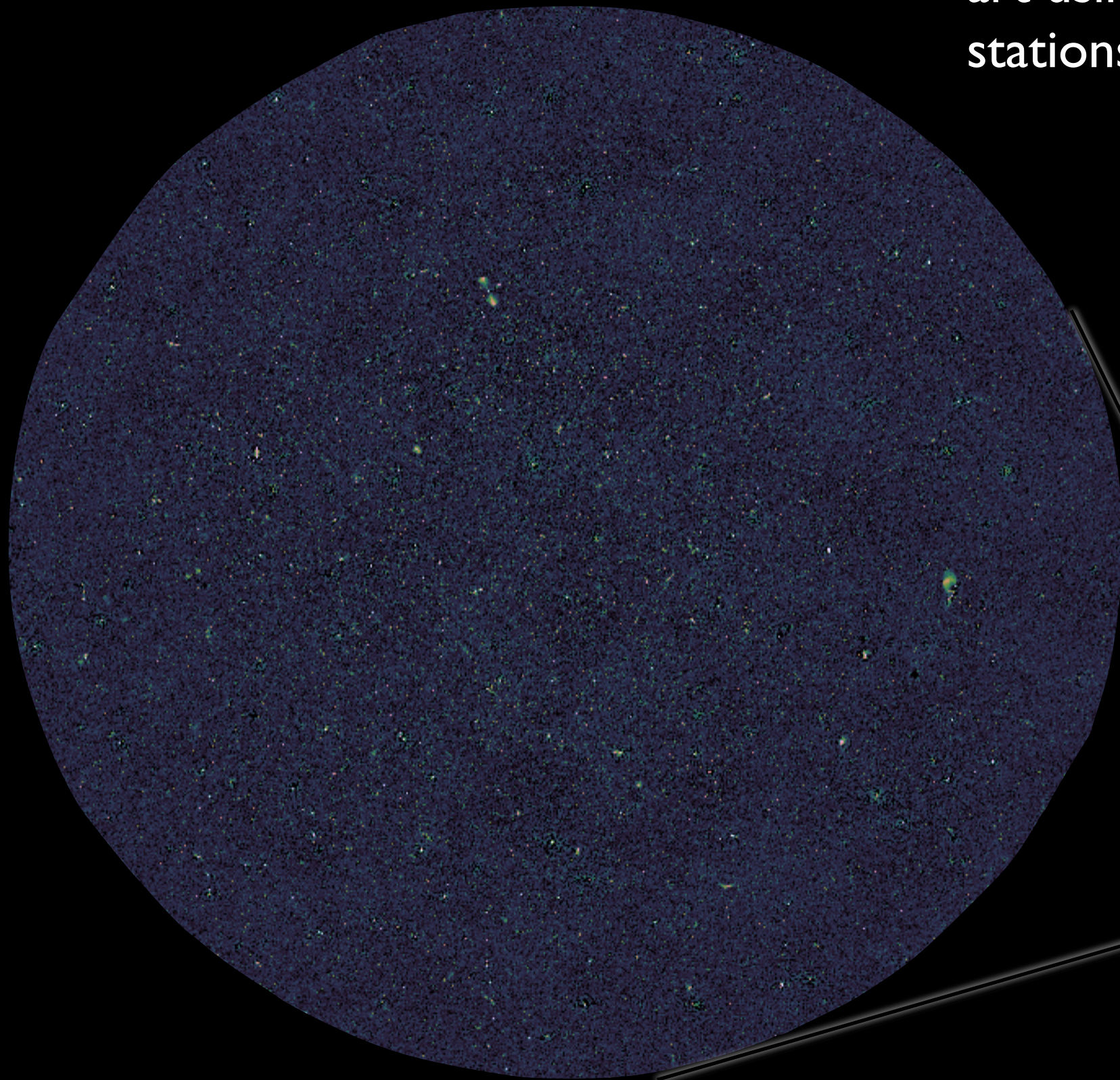
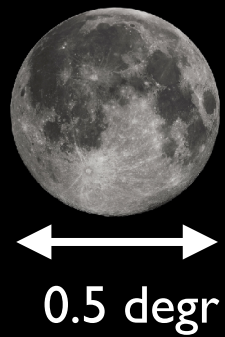
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 - International stations ✗ → **Use compact unpolarised source**
 - Alignment of polarization angles ✗ → **Use compact polarised source**

ELAIS-N1 single deep LOFAR image at 150 MHz

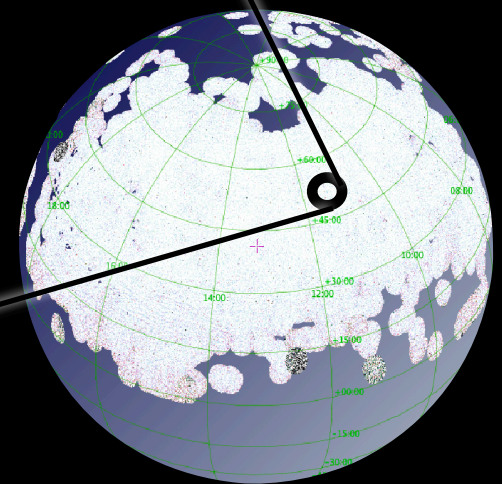
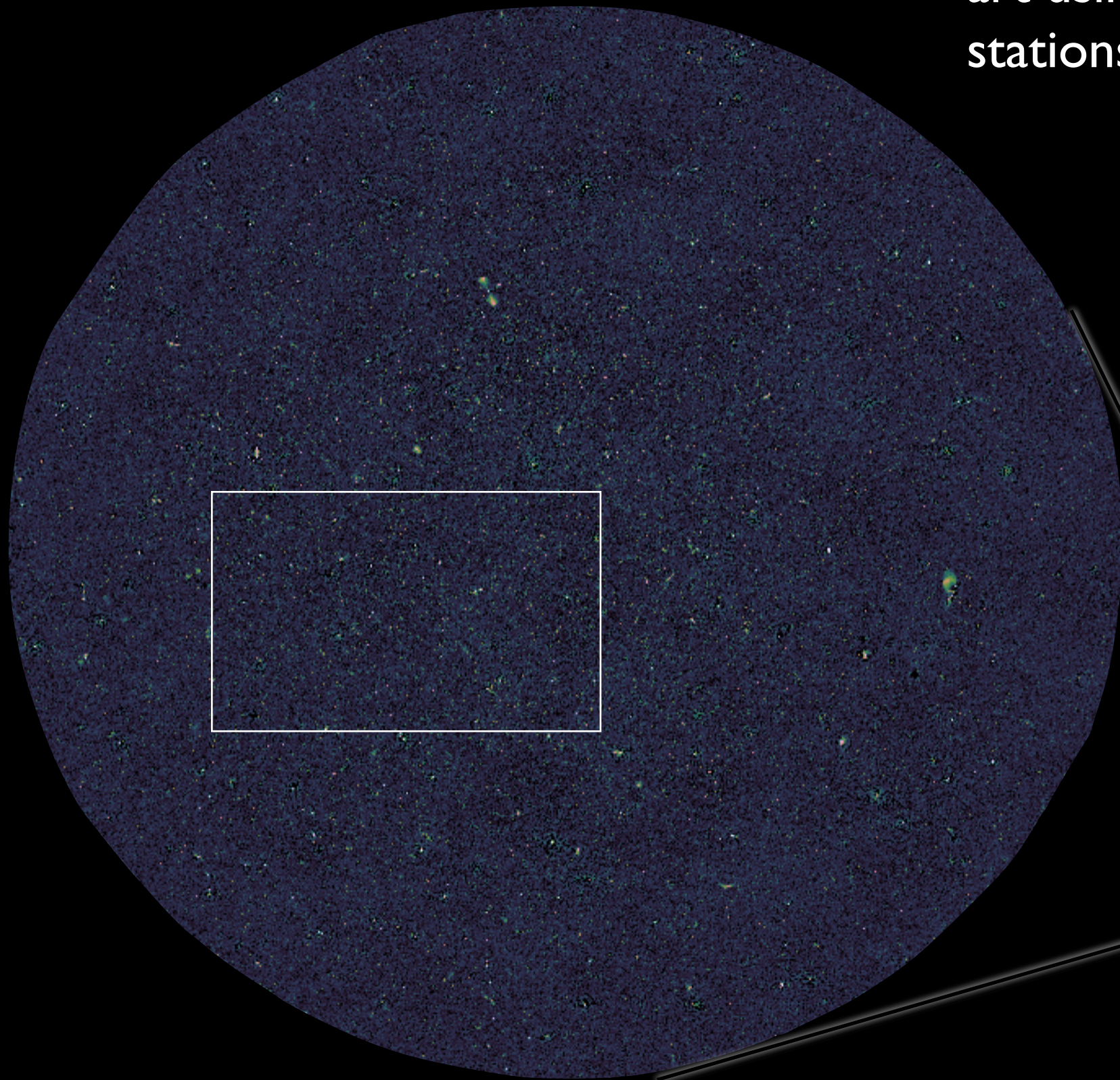
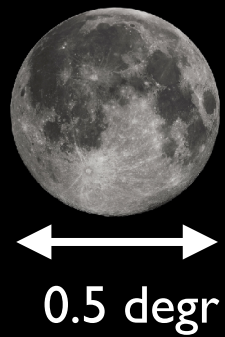
Current state-of-the-art using Dutch stations: $11 \mu\text{Jy beam}^{-1}$



Shimwell+ (2024)

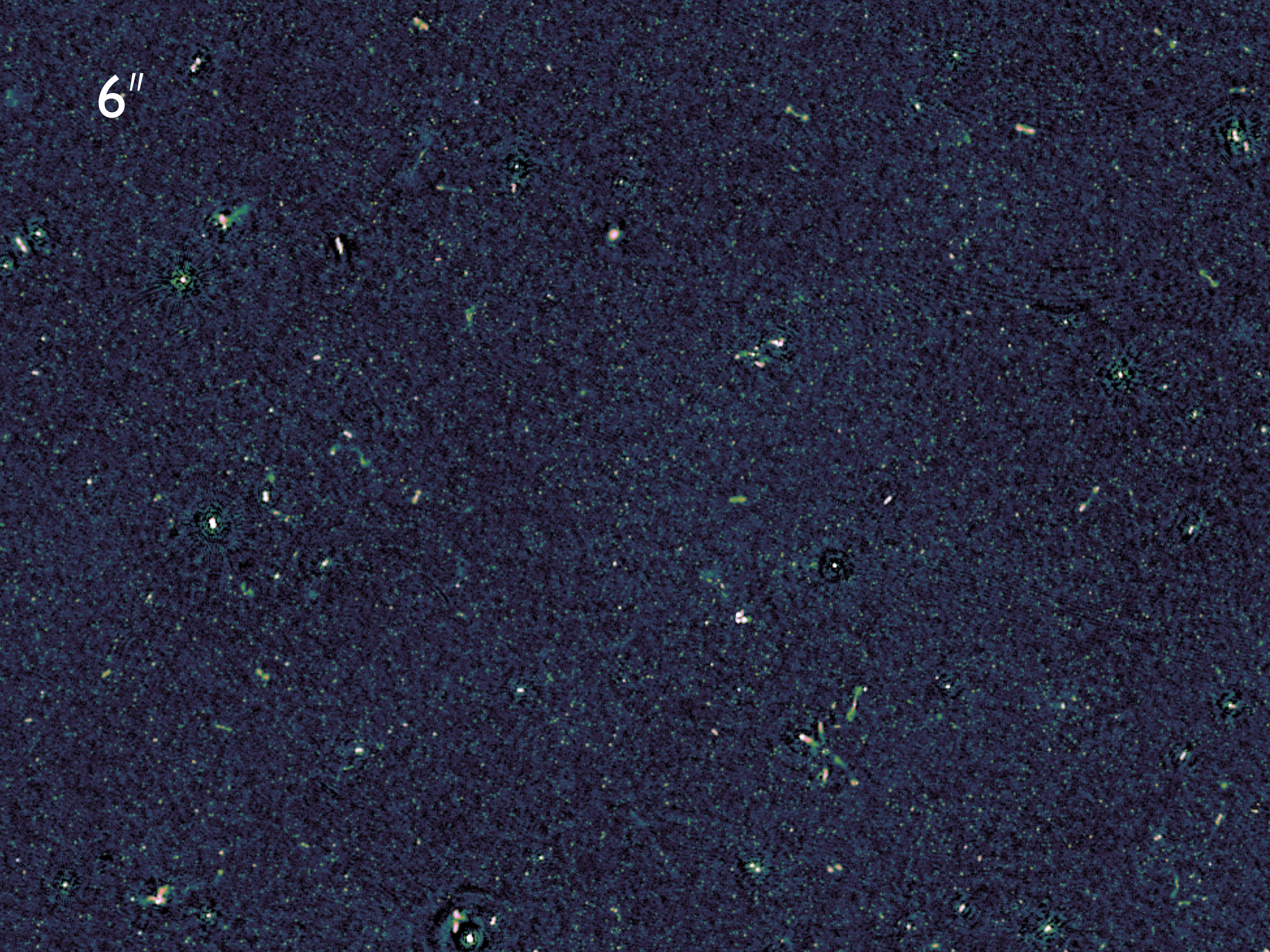
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6"

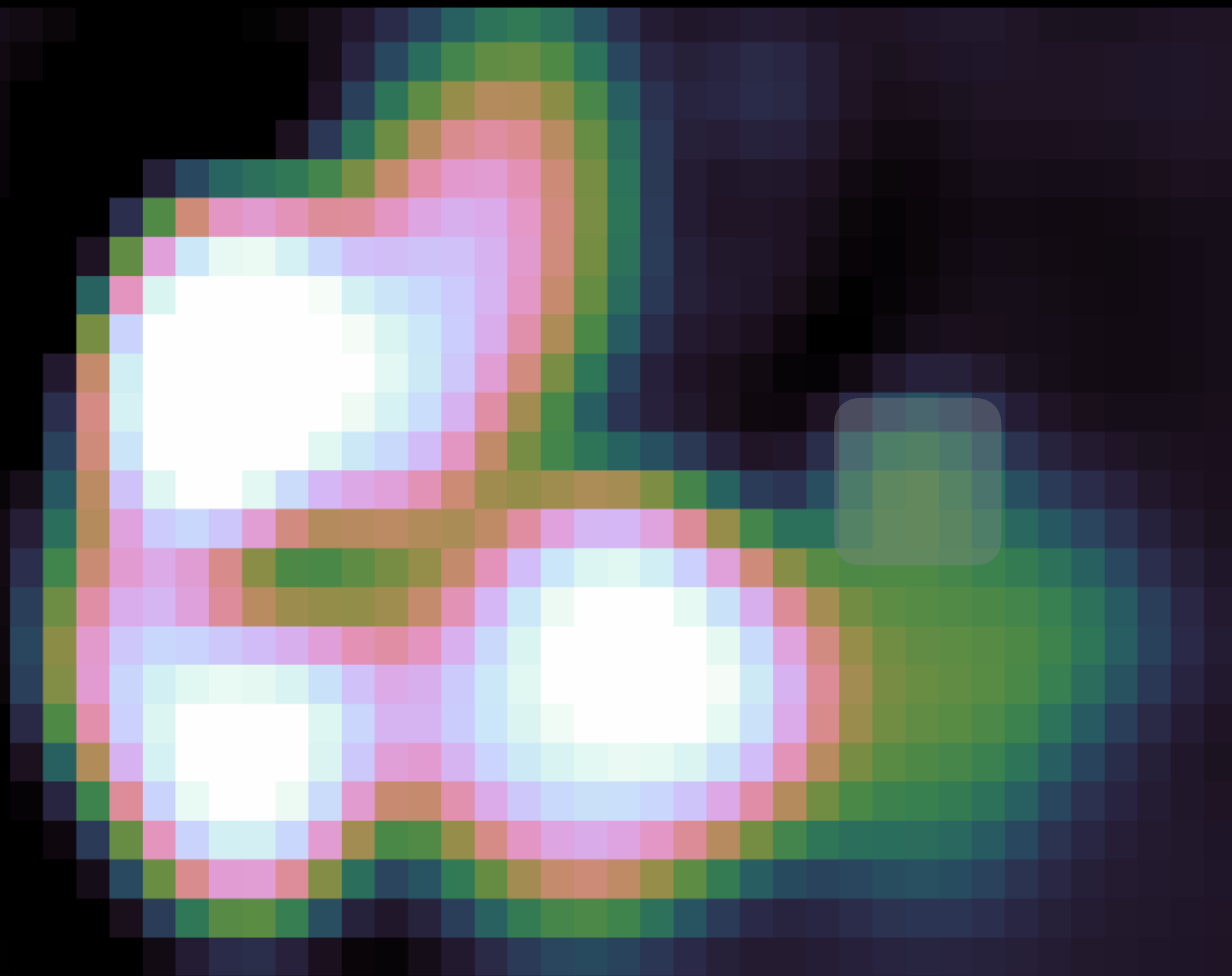


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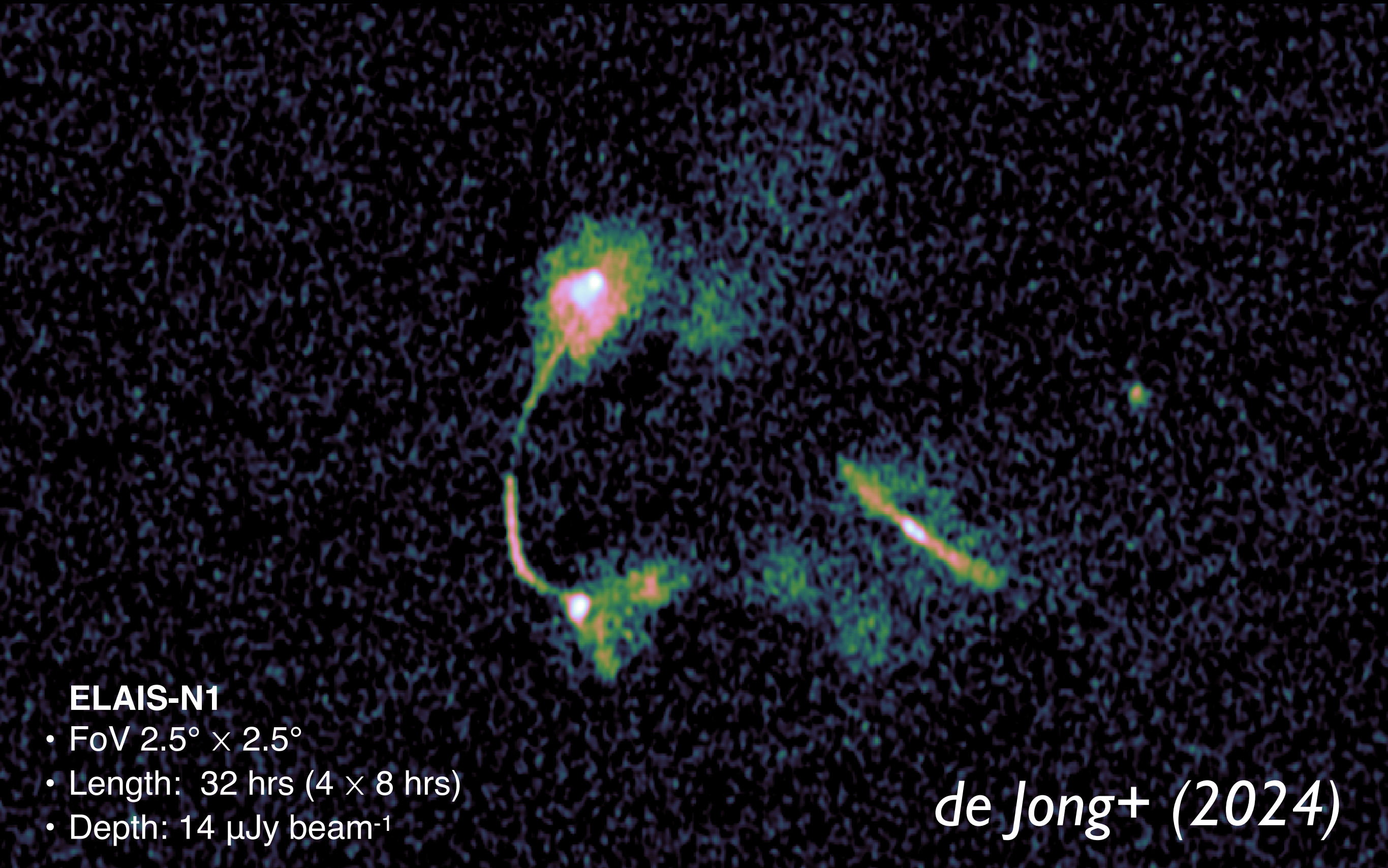


6"

Dutch LOFAR resolution

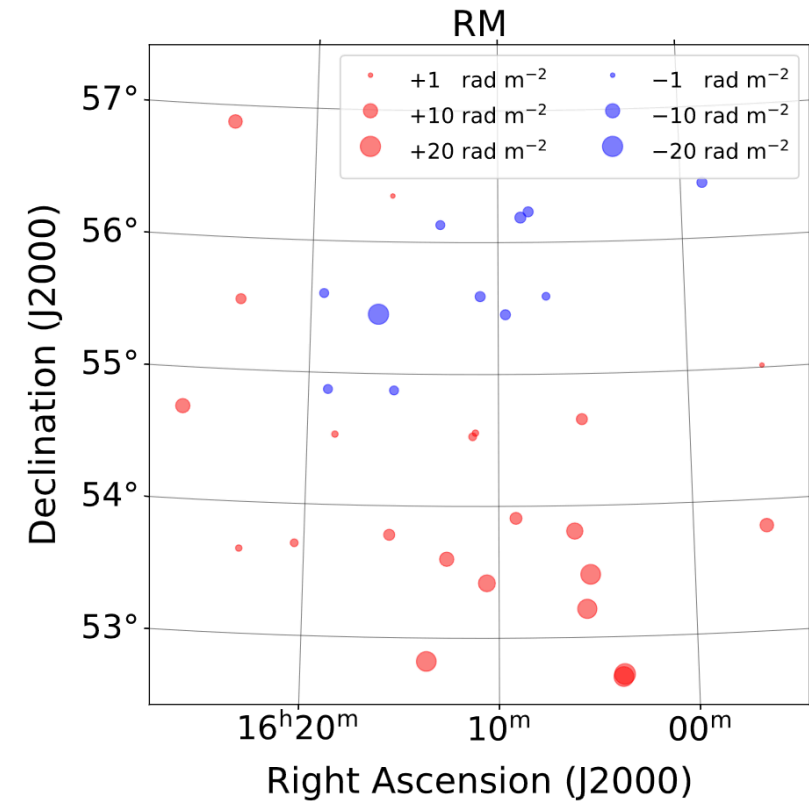
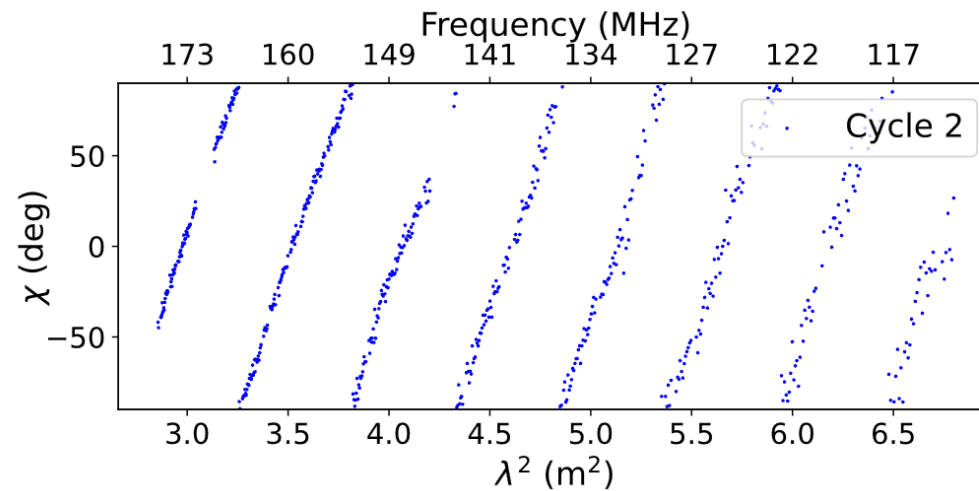
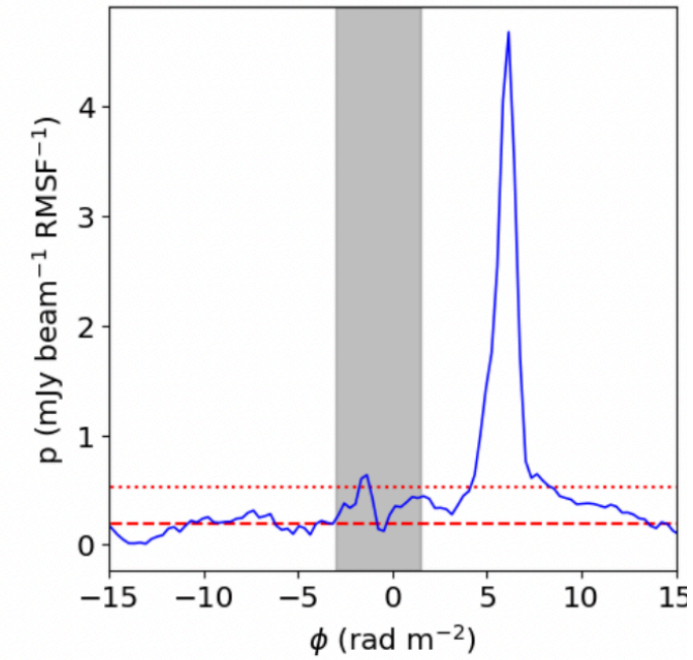
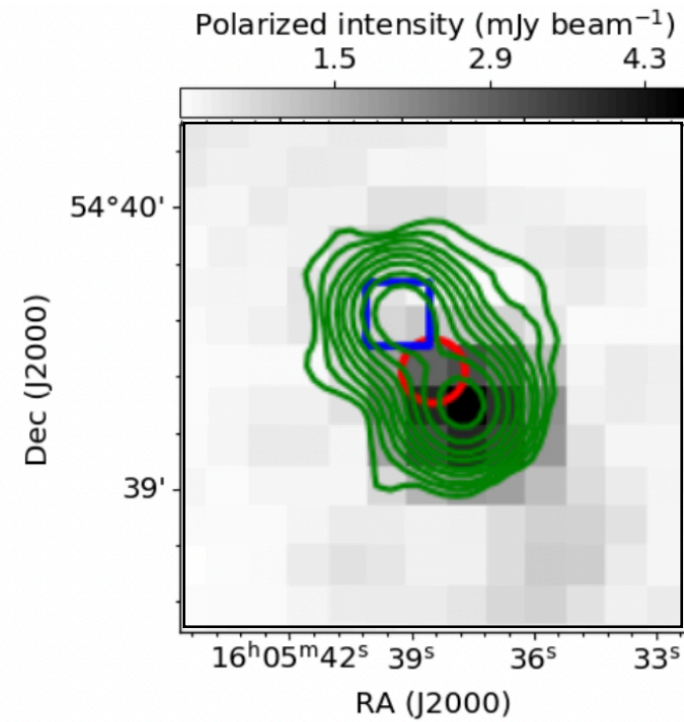
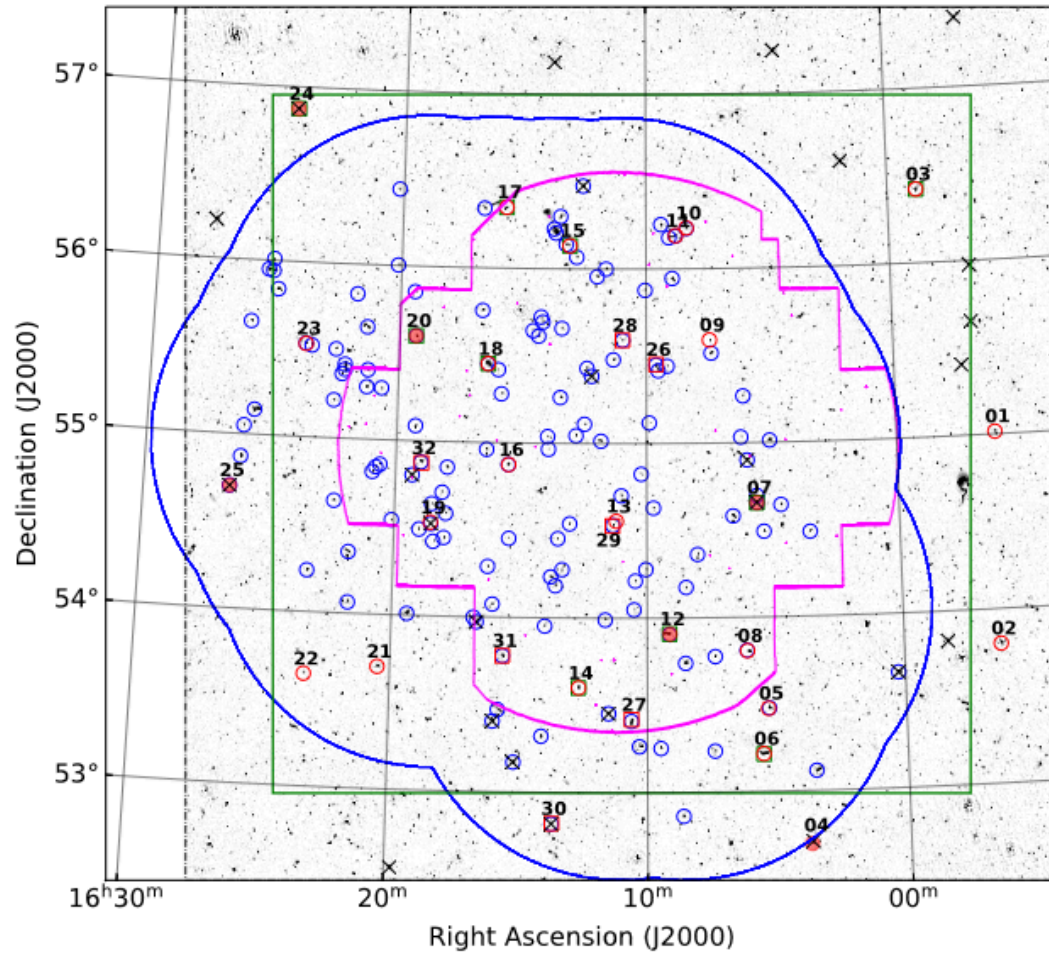


0.3'' International LOFAR resolution



ELIAS-N1 polarisation at 20 and 6''

Herrera Ruiz+ (2021); Piras+ (2024, 2025)

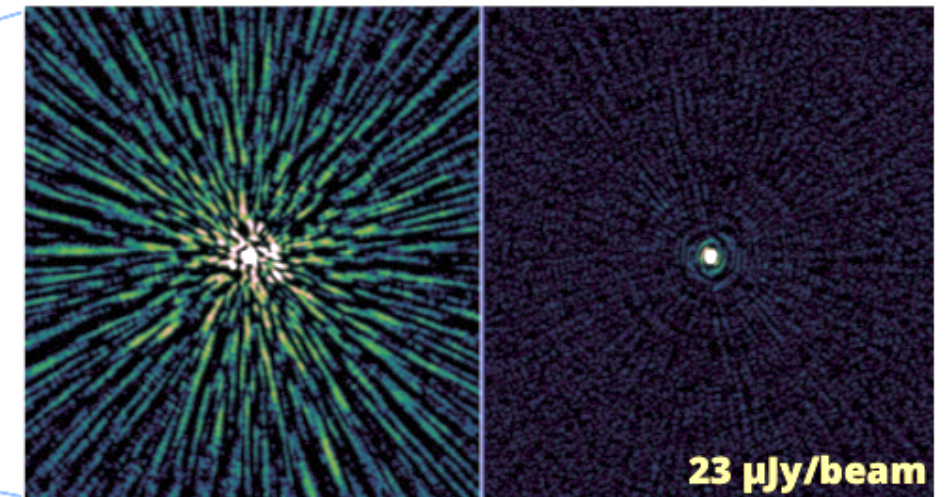
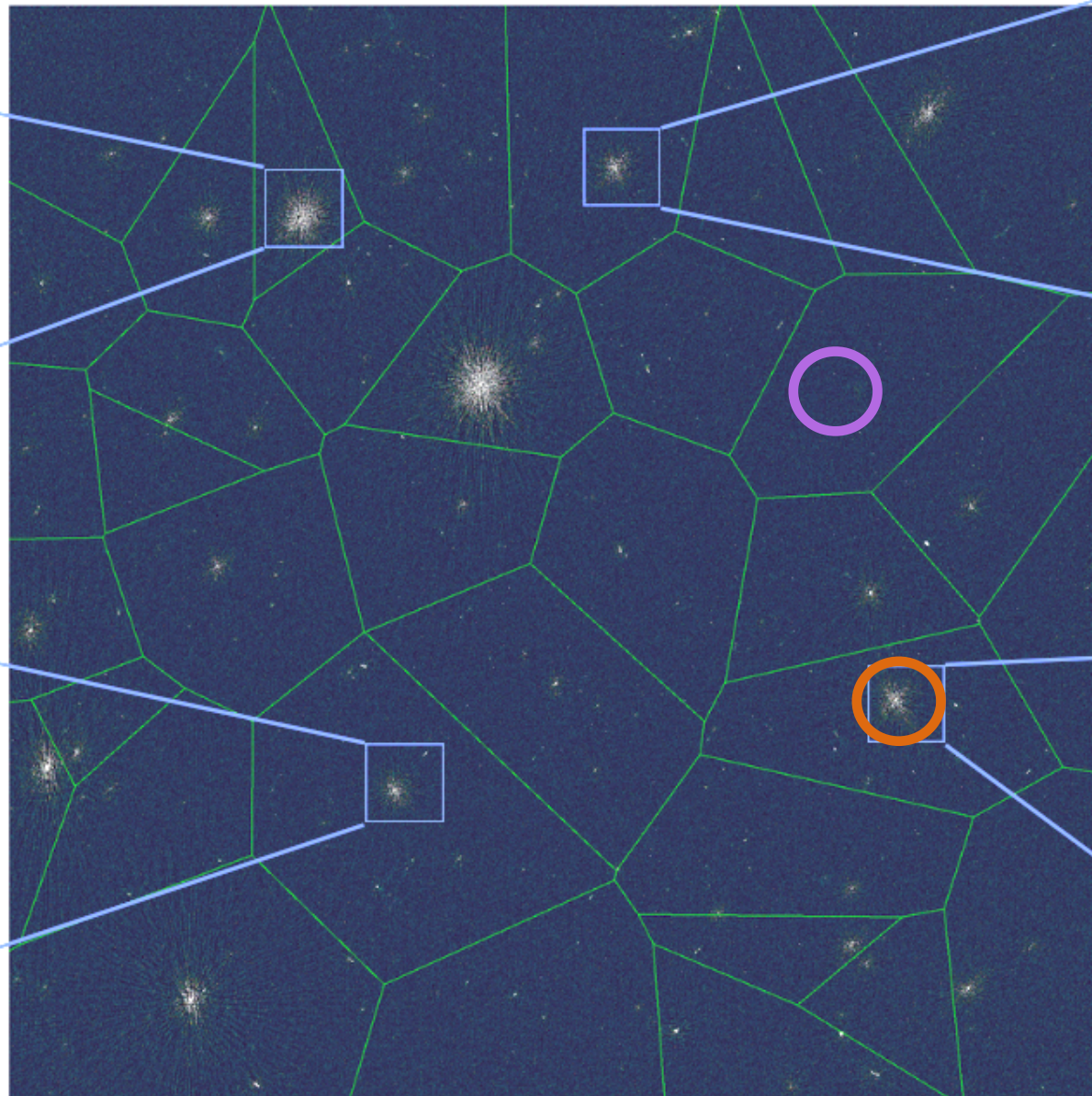


ILT: ELAIS-N1 calibration

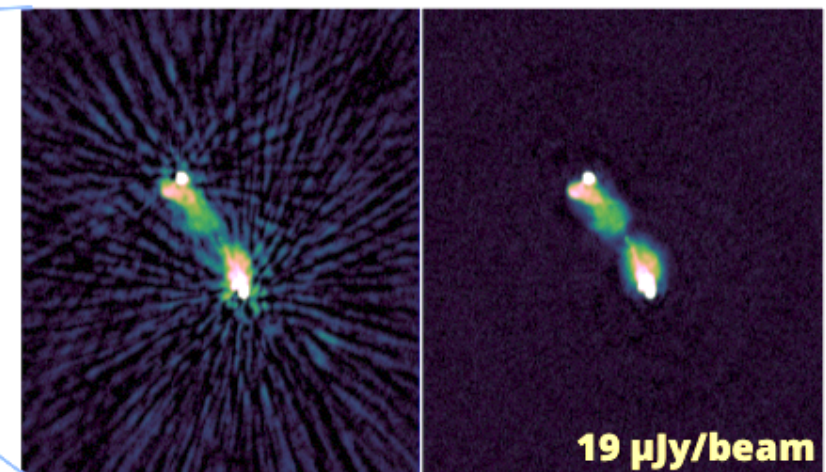
ILT calibration approach

Morabito+ (2022), Sweijen+ (2022), van der Wild+ (2026)

1. *facetselfcal*: in-field calibrator (corrects bulk of the ionosphere and clock)
2. *facetselfcal*: calibrate leakage terms on unpolarised in-field calibrator
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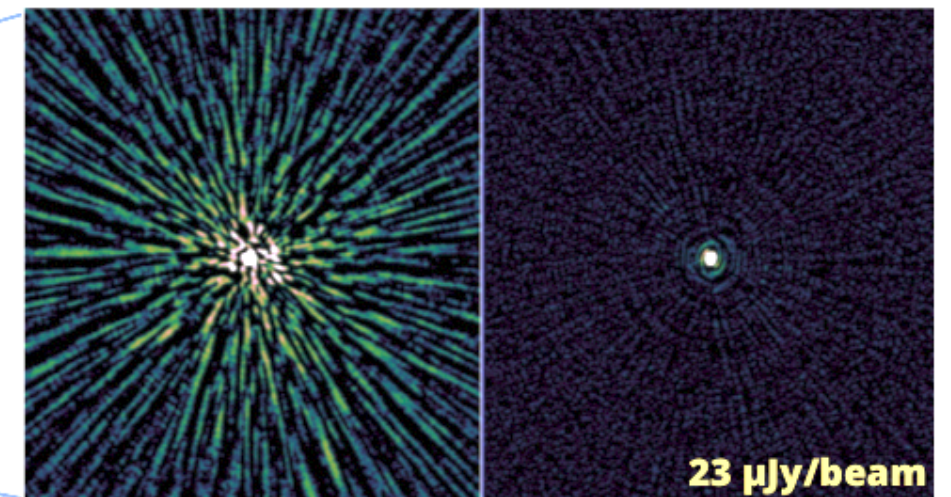
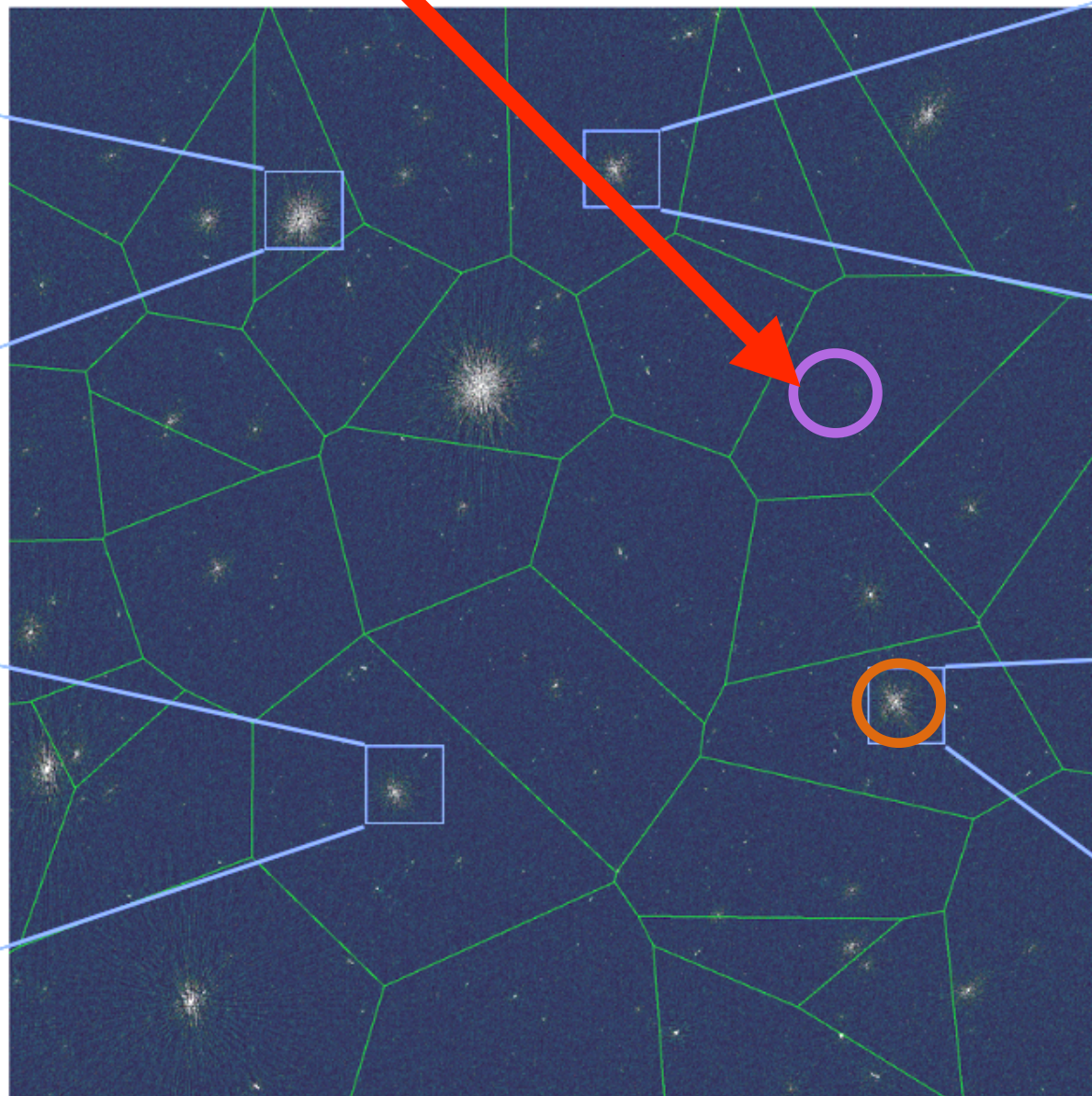


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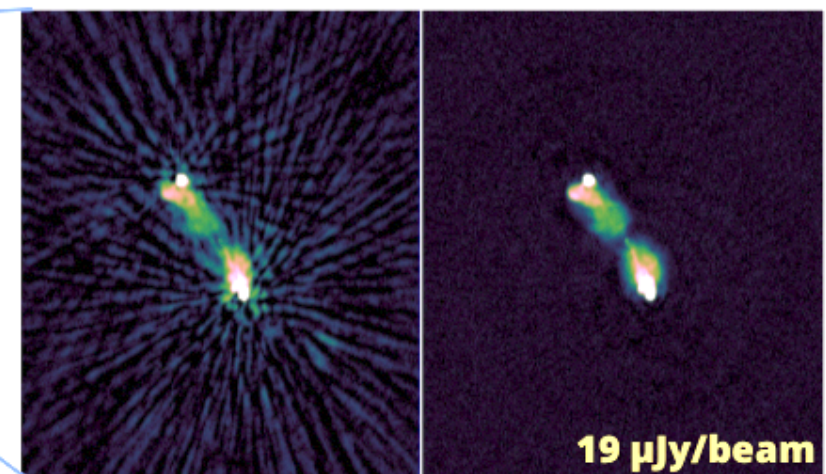
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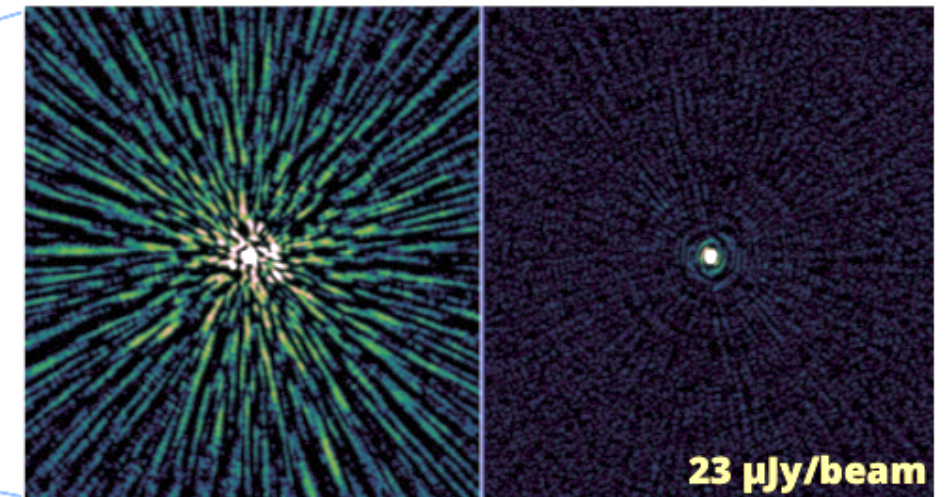
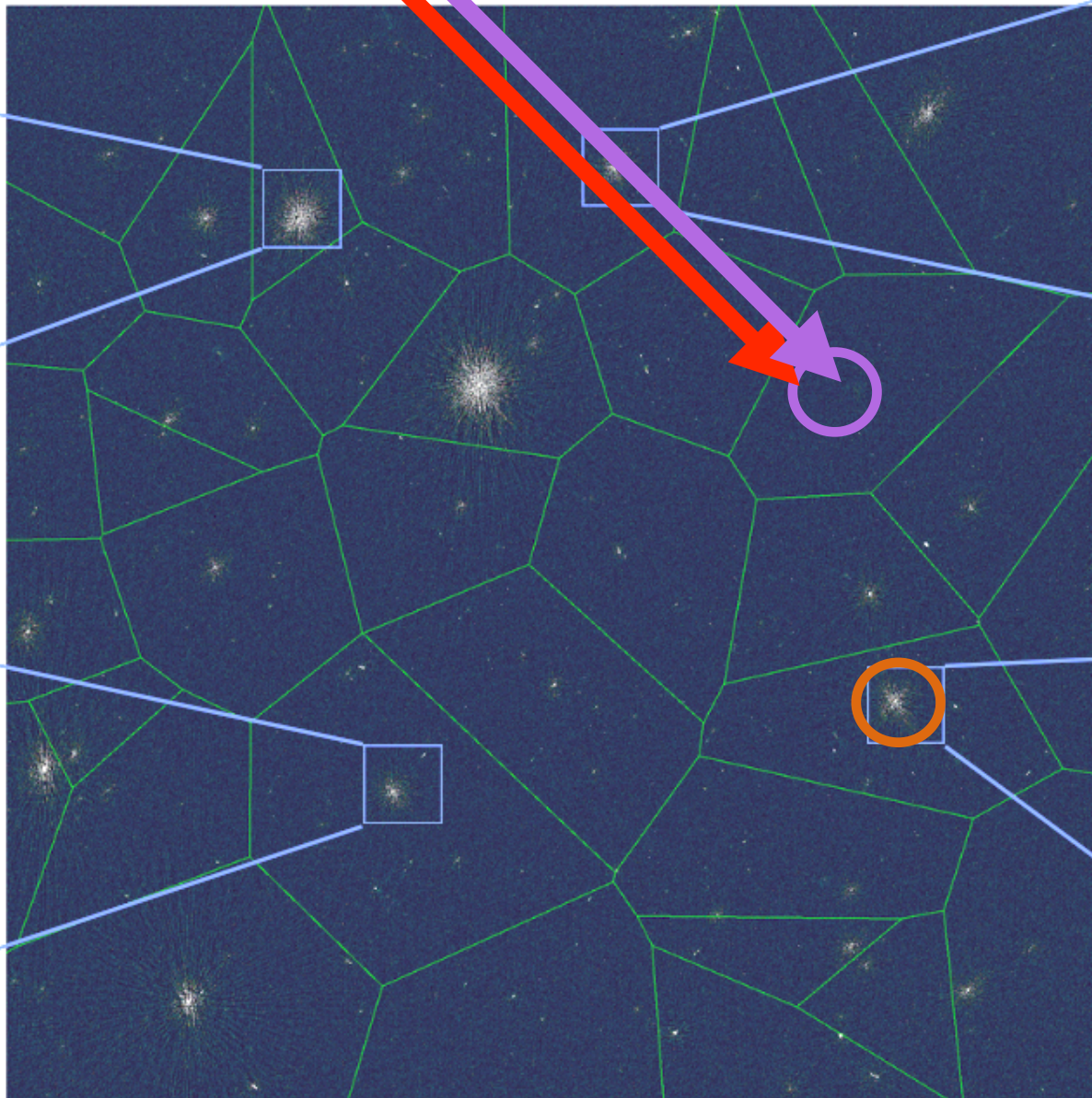


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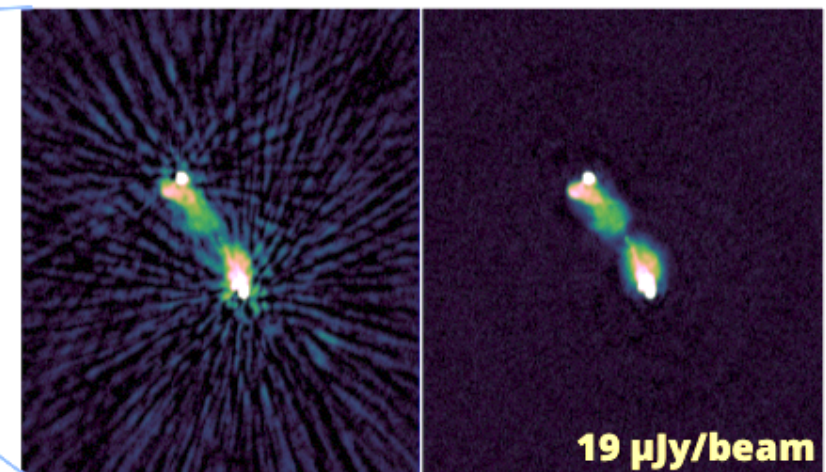
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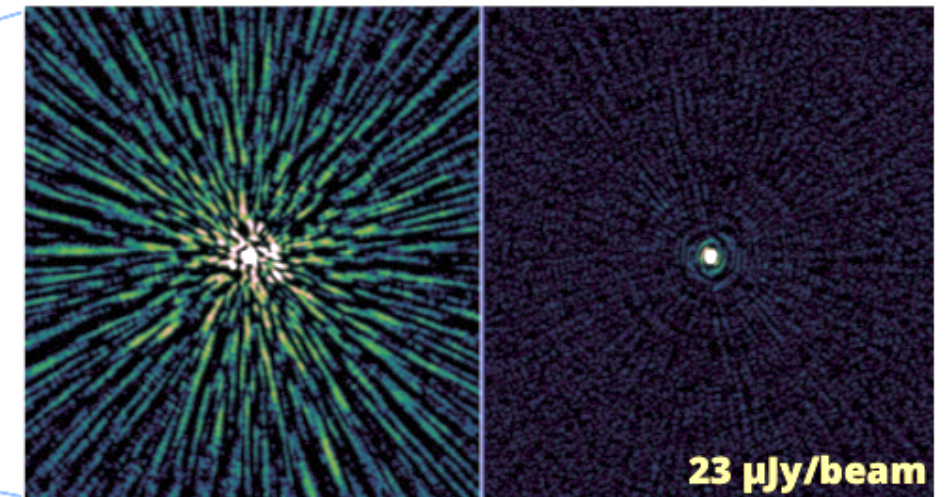
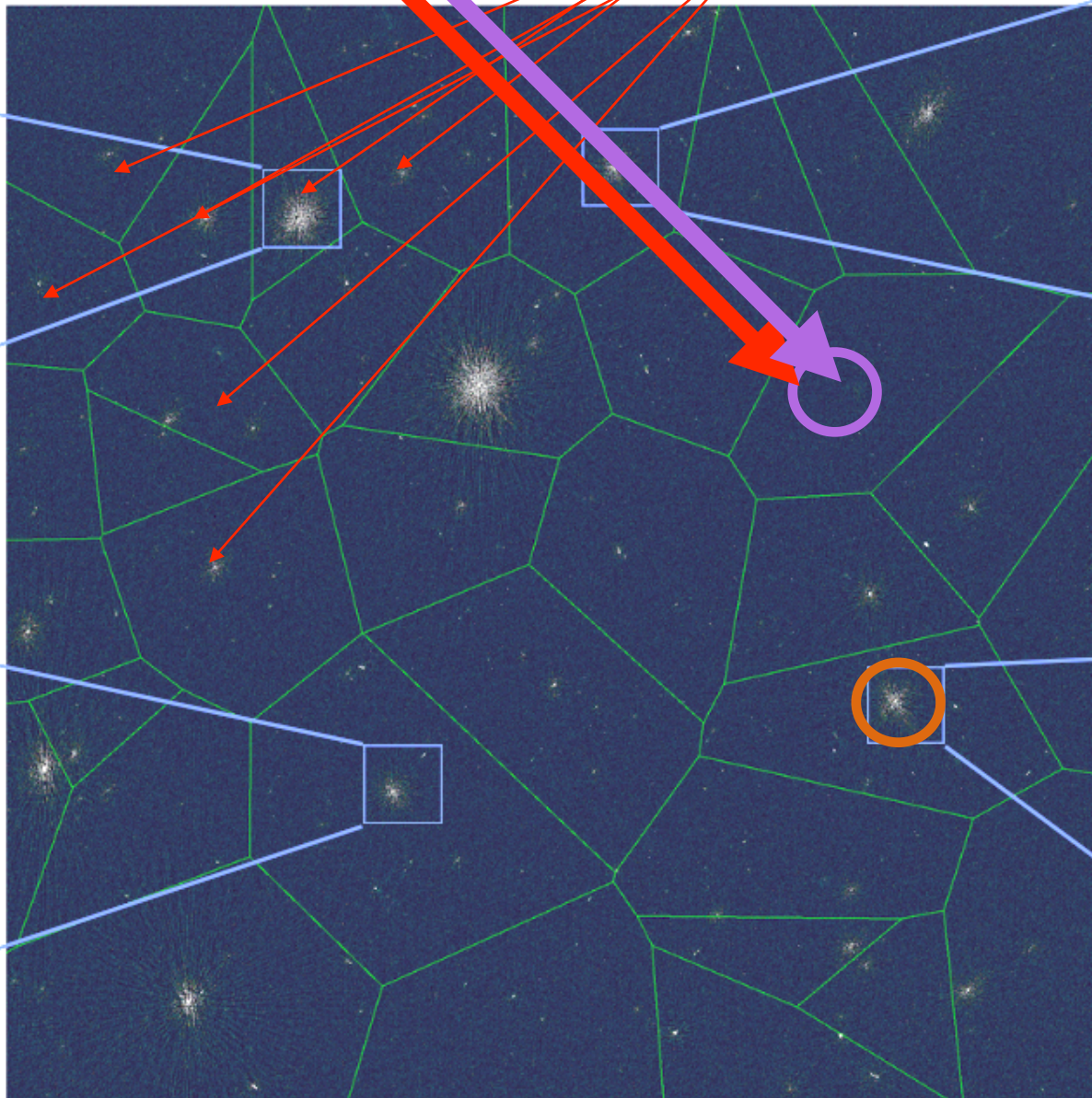


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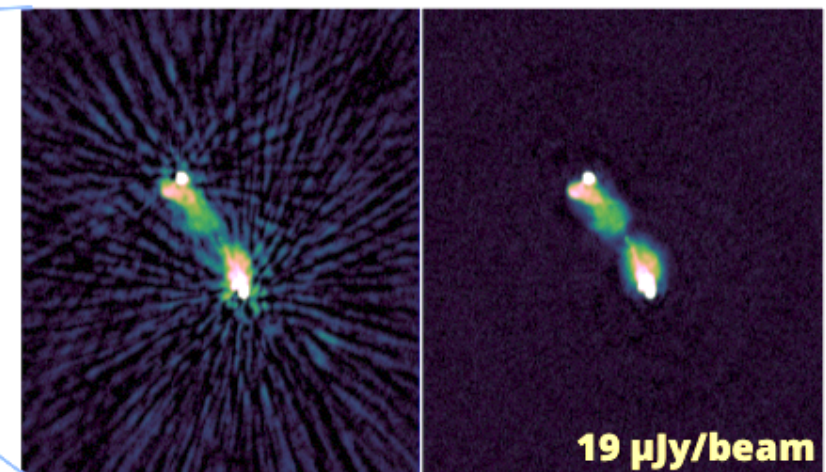
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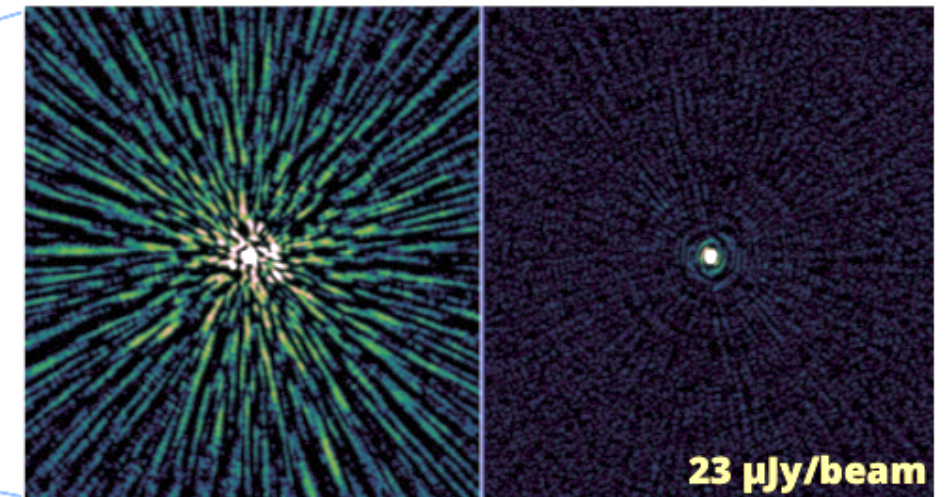
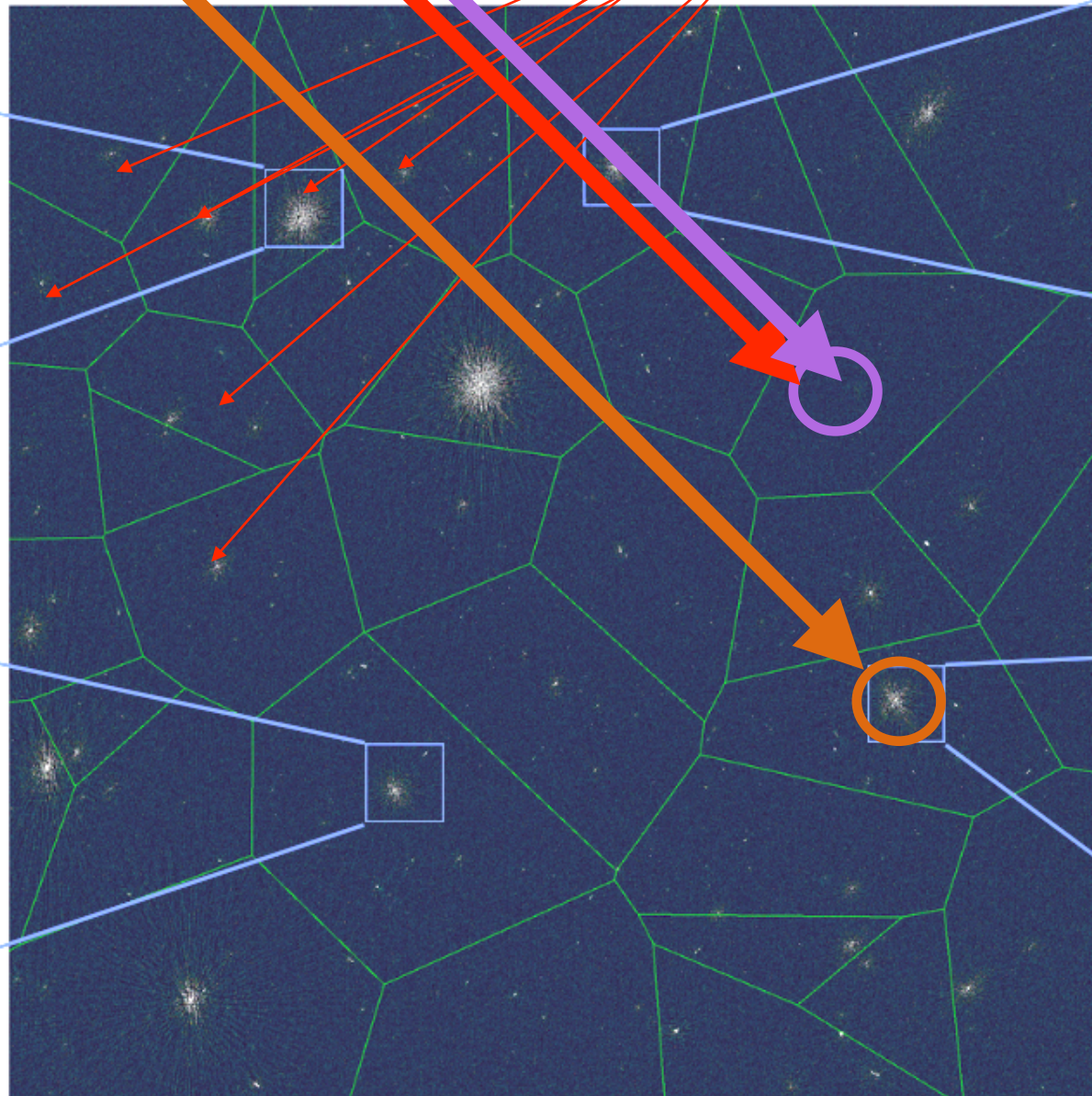


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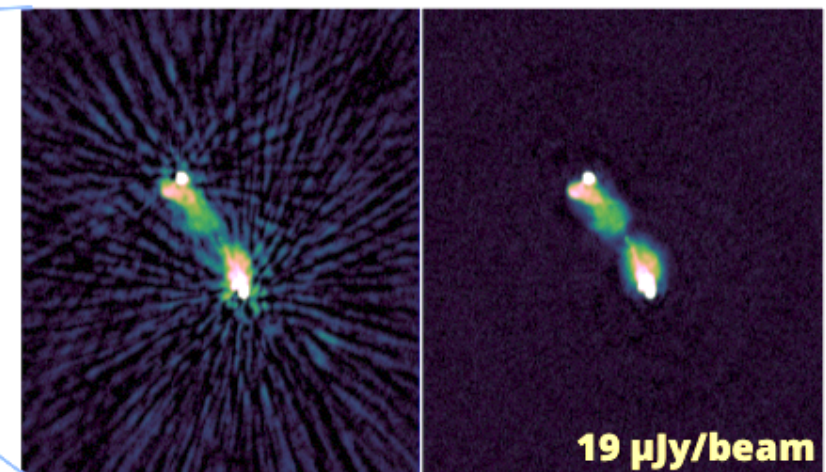
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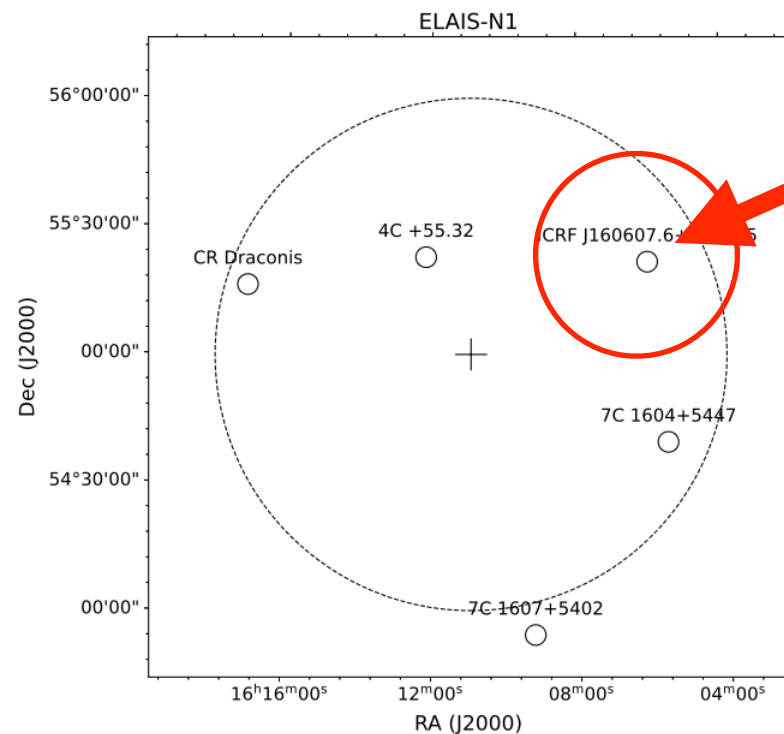


Jurjen de Jong+ (2024)



Leakage calibration

- Considerations:
 - unpolarised source with enough compact flux ($\gtrsim 0.2$ Jy peak)
 - check against the LoTSS RM Grid (O'Sullivan+ 2023, 2026)
- ELAIS-N1:
 - use infield calibrator



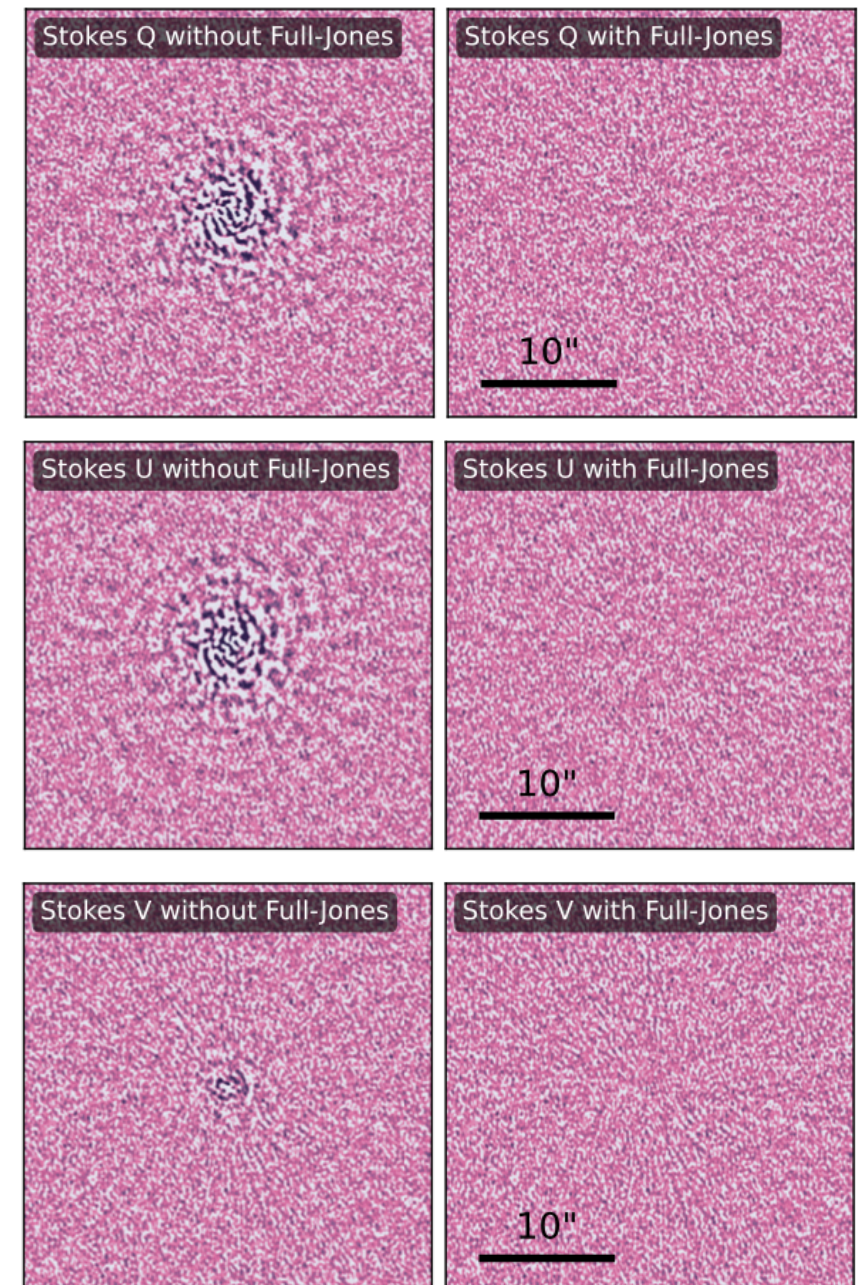
Q

U

V

without
leakage
calibration

including
leakage
calibration



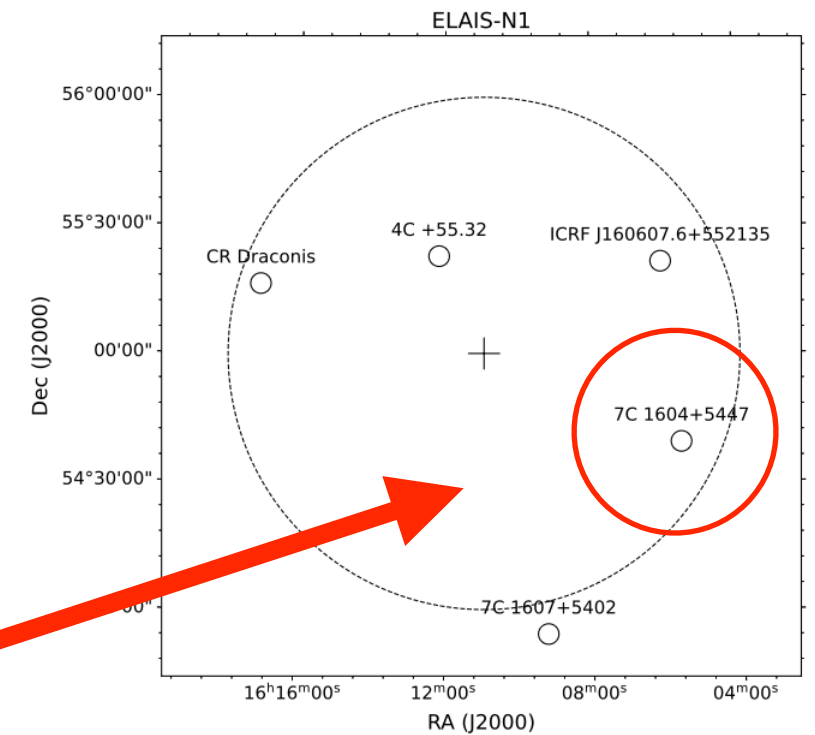
Polarisation angle calibrator

- Considerations:

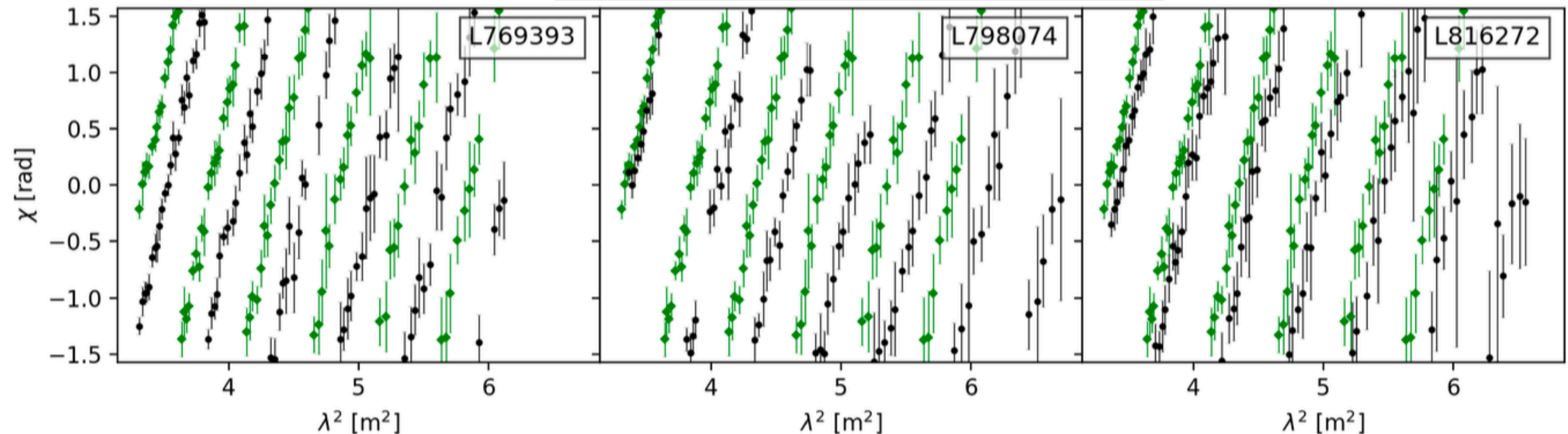
- polarised source with enough compact flux (few mJy)
- check against the LoTSS RM Grid (O'Sullivan+ 2023, 2026)

- ELAIS-N1:

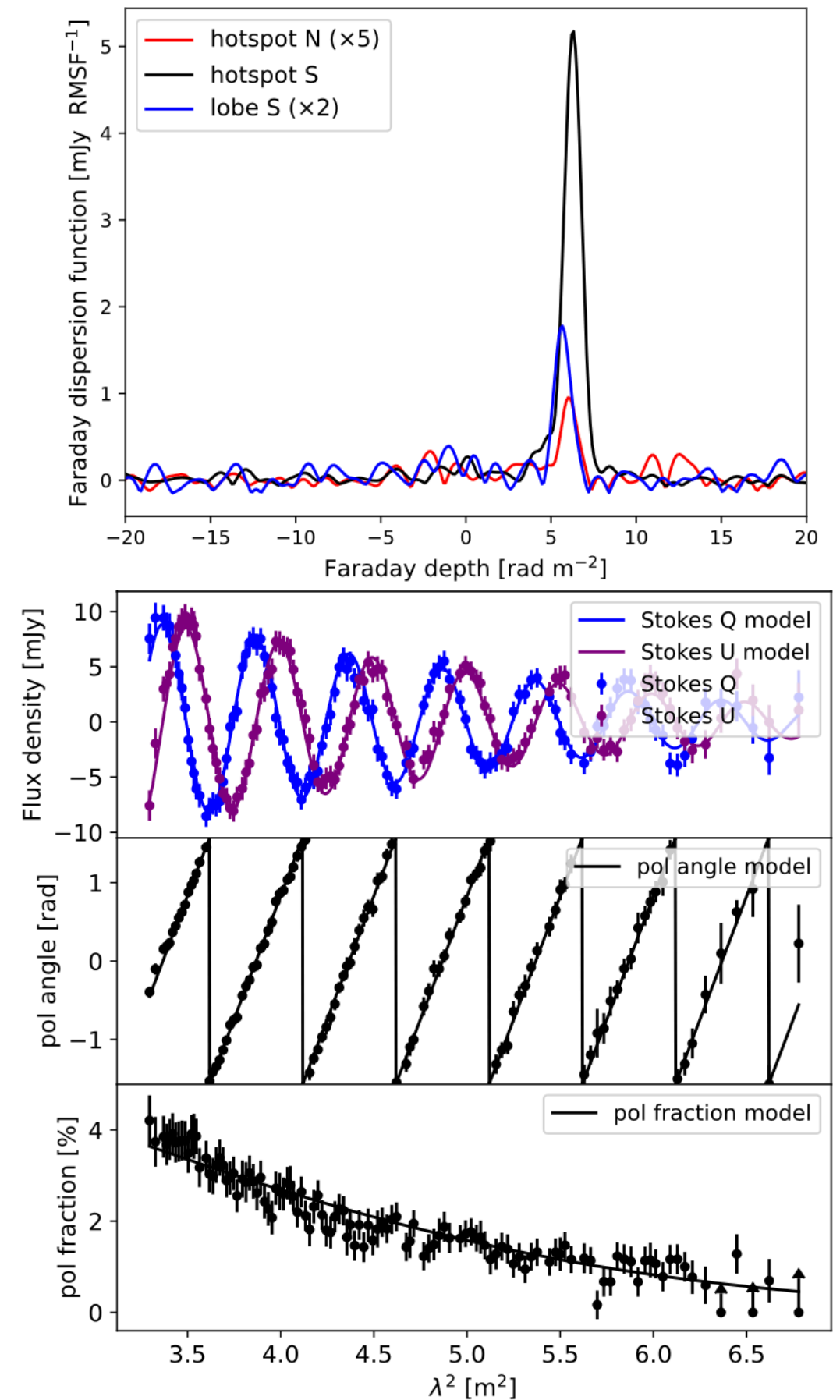
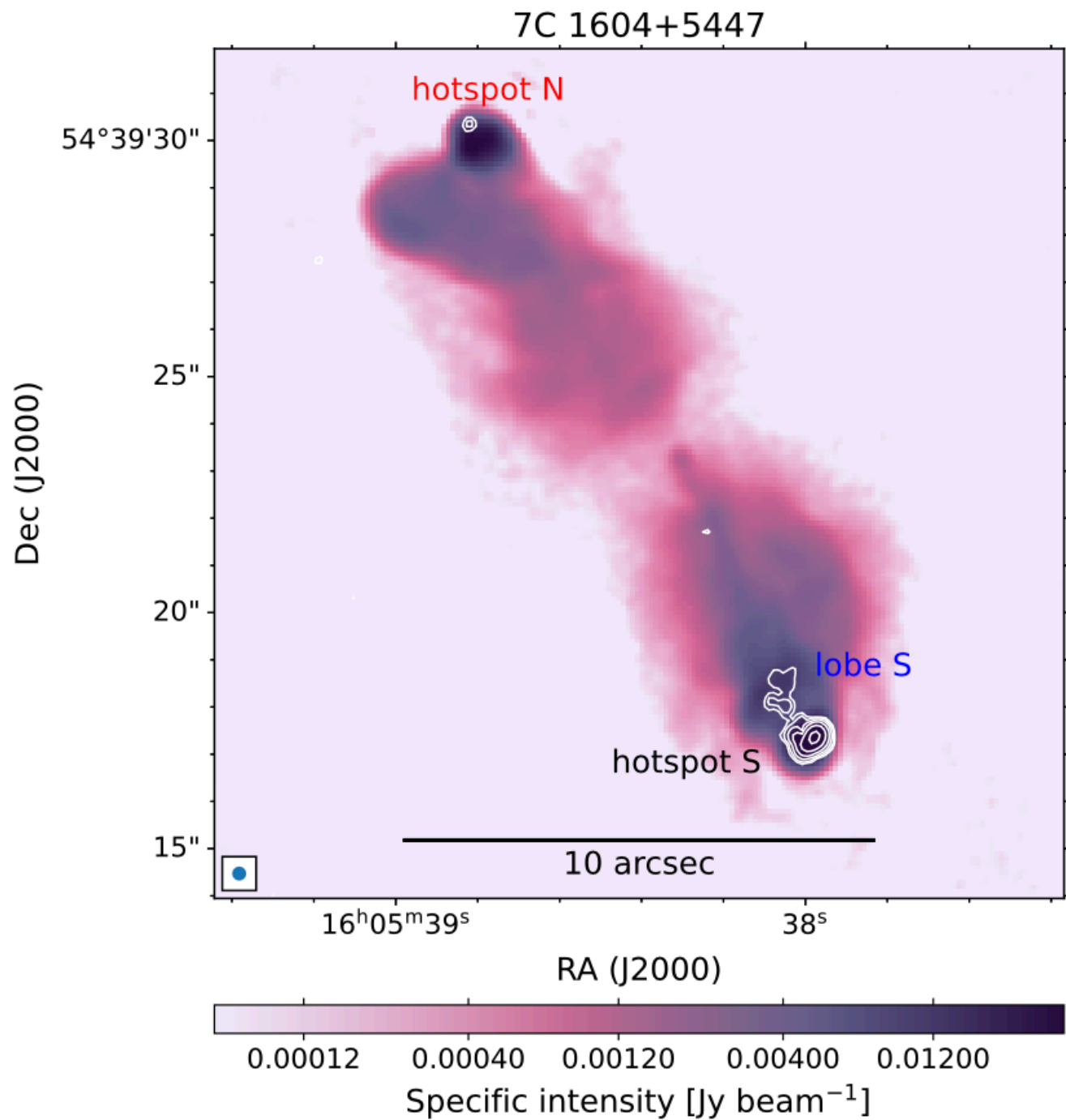
- use 7C1604+5447 (RM=6.3 rad m⁻²)



green = reference epoch



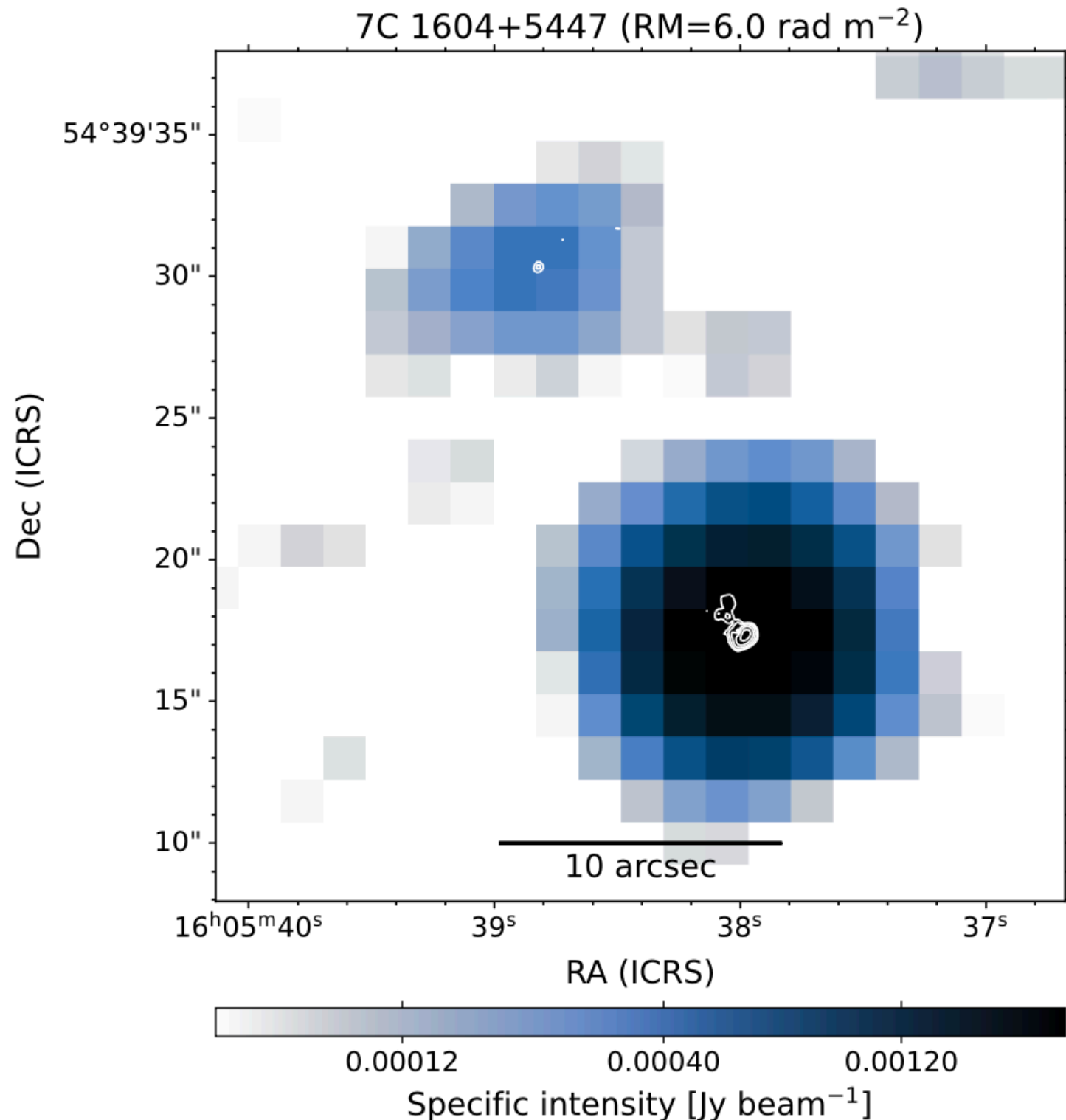
ELAIS-N1 results: 7C1604+5447 (polarisation calibrator)



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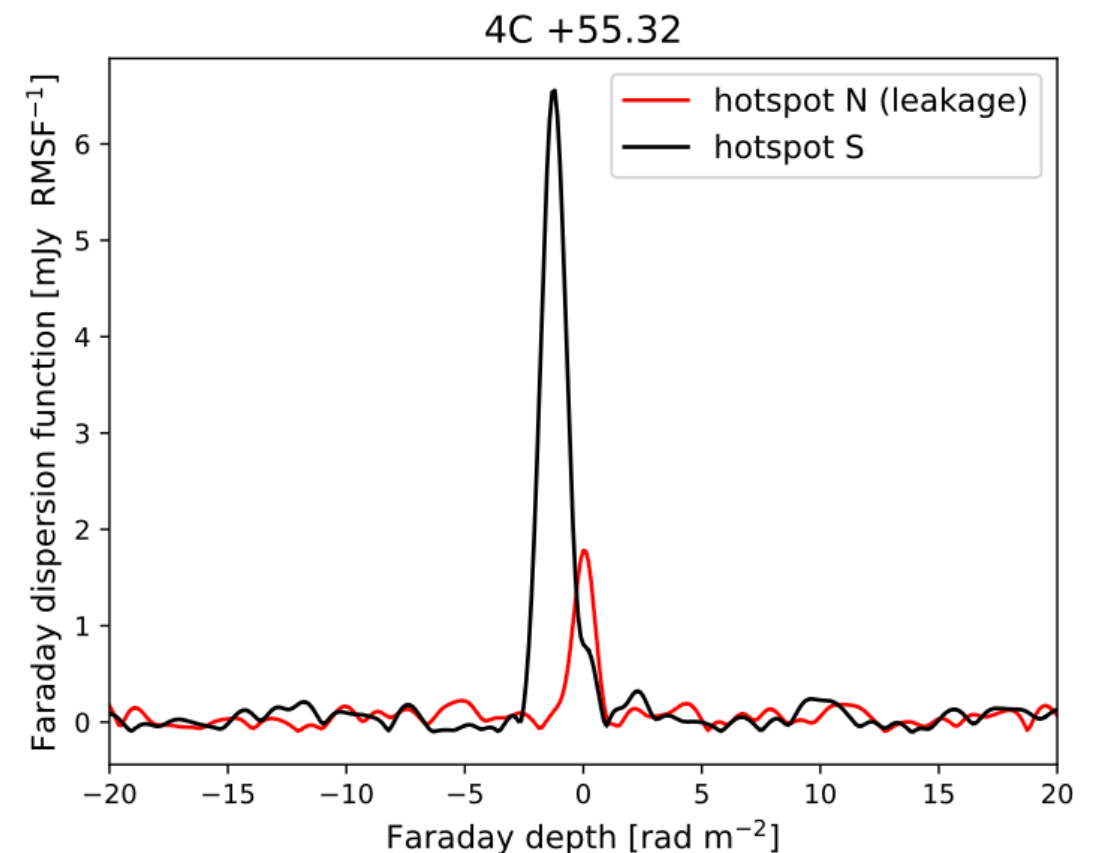
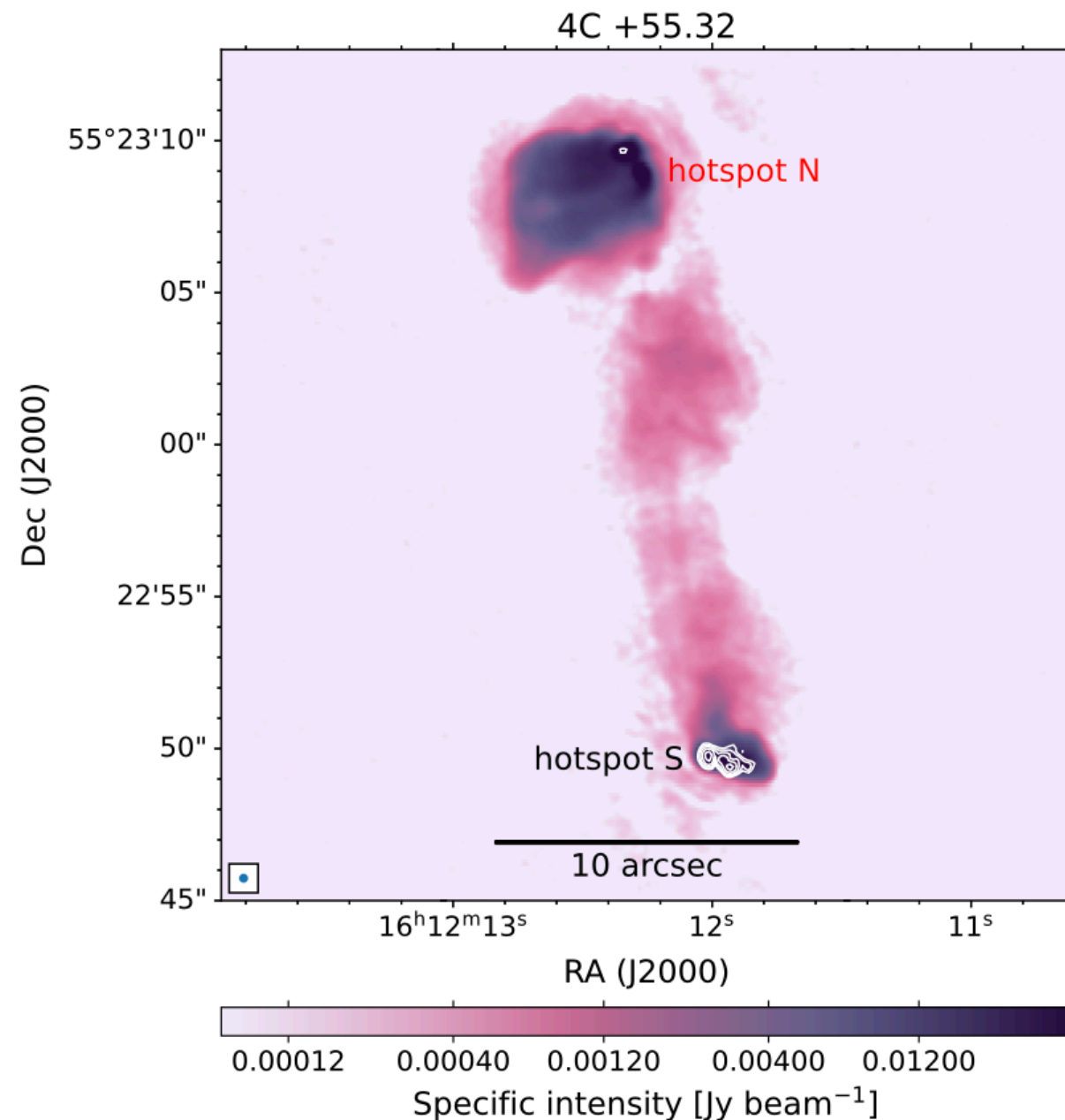
Polarized
intensity
image

resolution:
 $0.3''$ vs $6''$

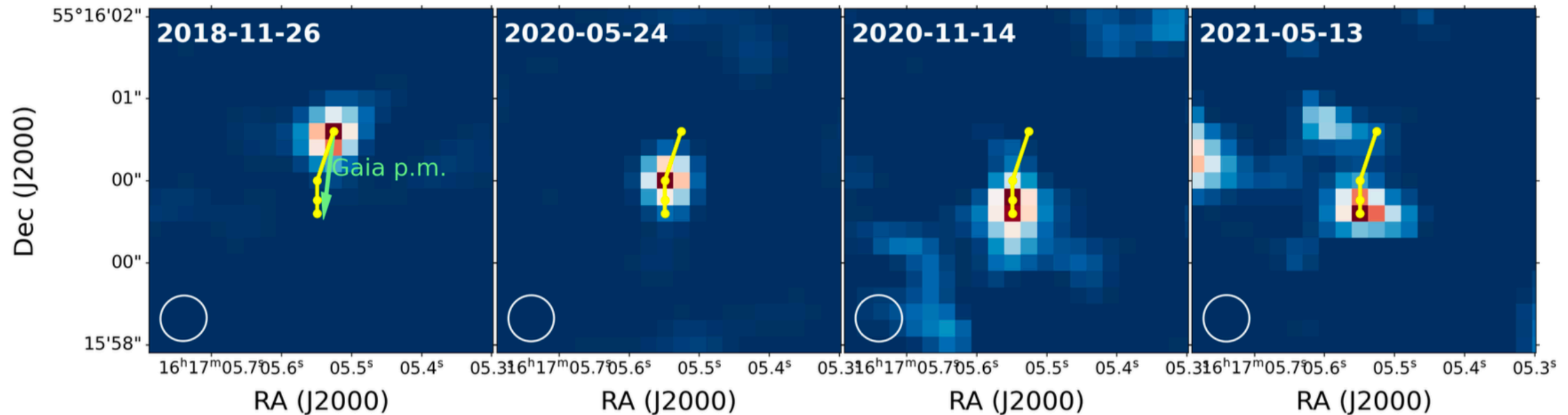


ELAIS-N1 results: new detection 4C +55.32

First detection at low frequencies (missed by earlier LOFAR studies)



ELAIS-N1 results: Stokes V detection of CR Draconis



- yellow lines: positions of the source from the four observations.
- green vector: Gaia proper motion

Proper motion of the
source detected!

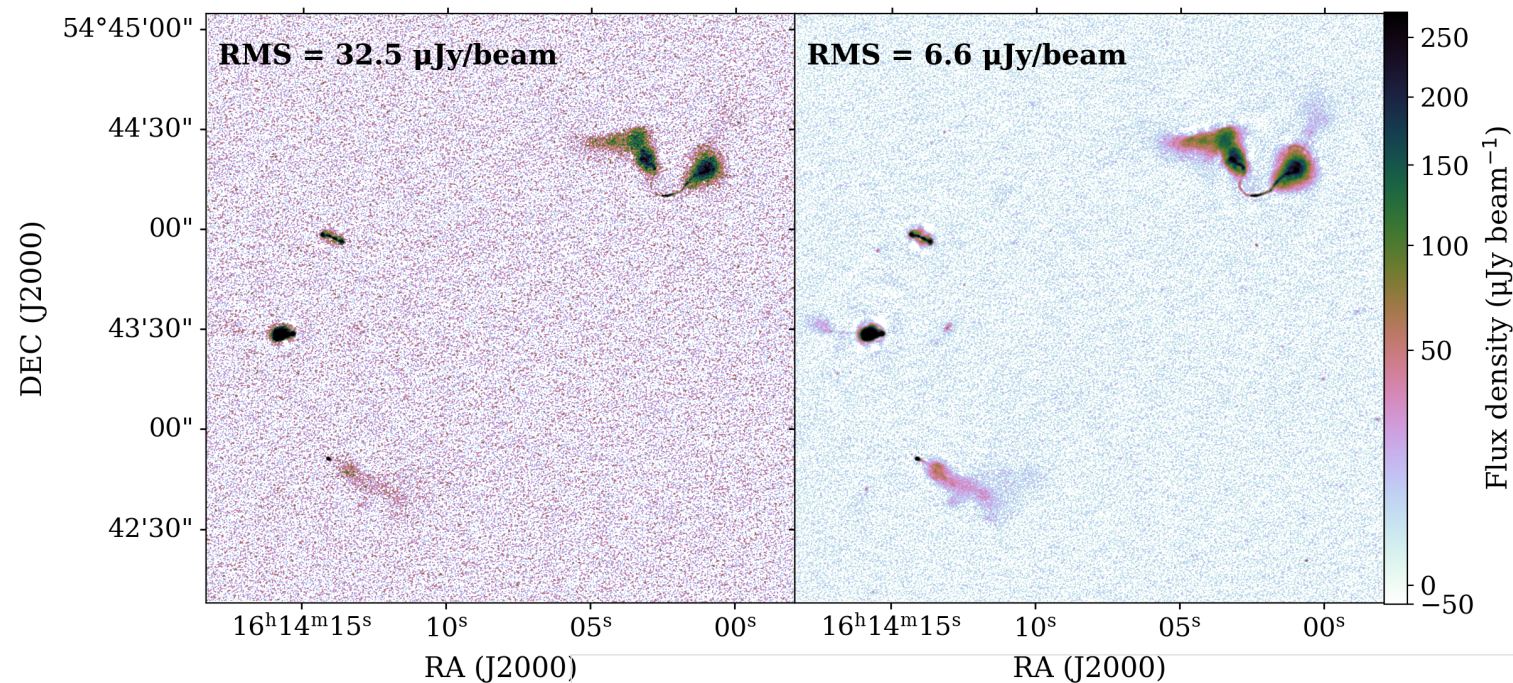
see Callingham+ (2021) for a
dynamic spectrum study with
LOFAR

Next steps

- Apply the method to other targets observed with the ILT
- Characterize the source population in the ELAIS-N1 200 hrs dataset:

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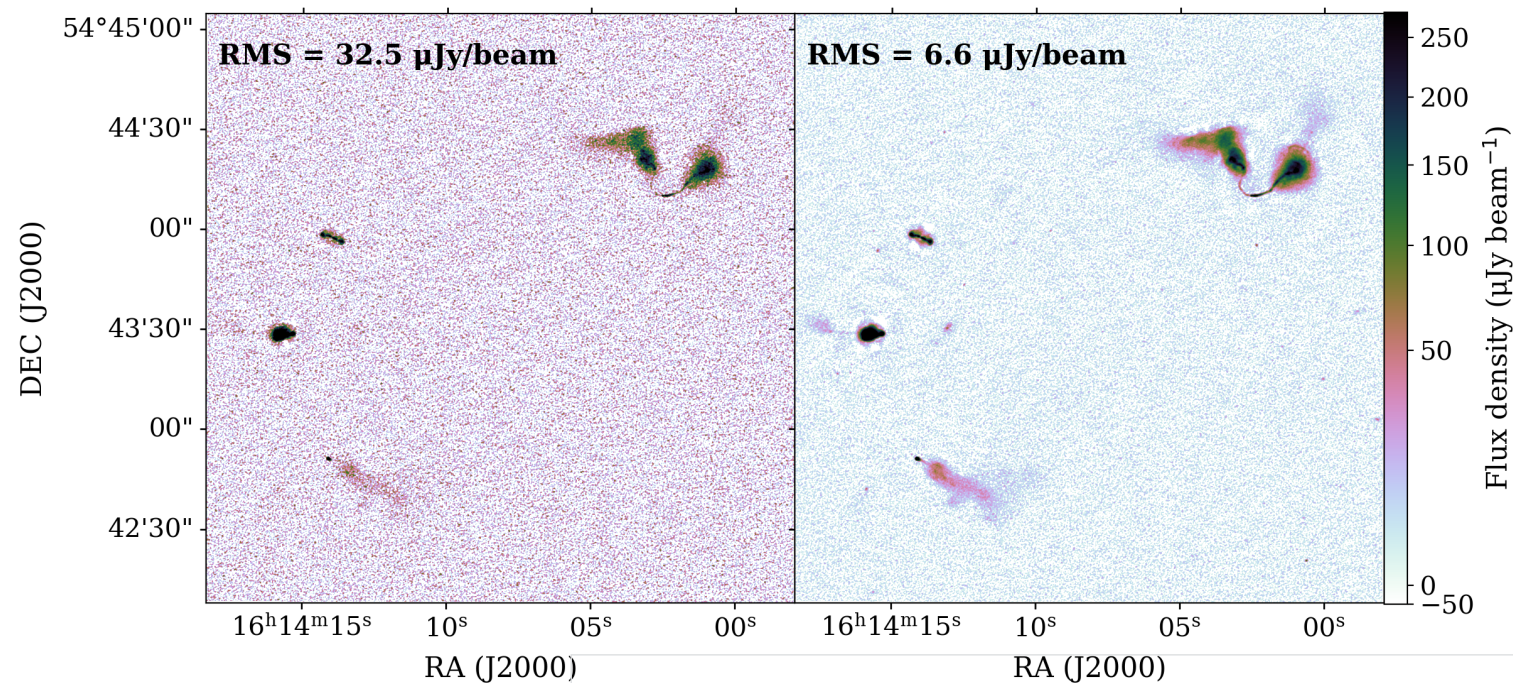
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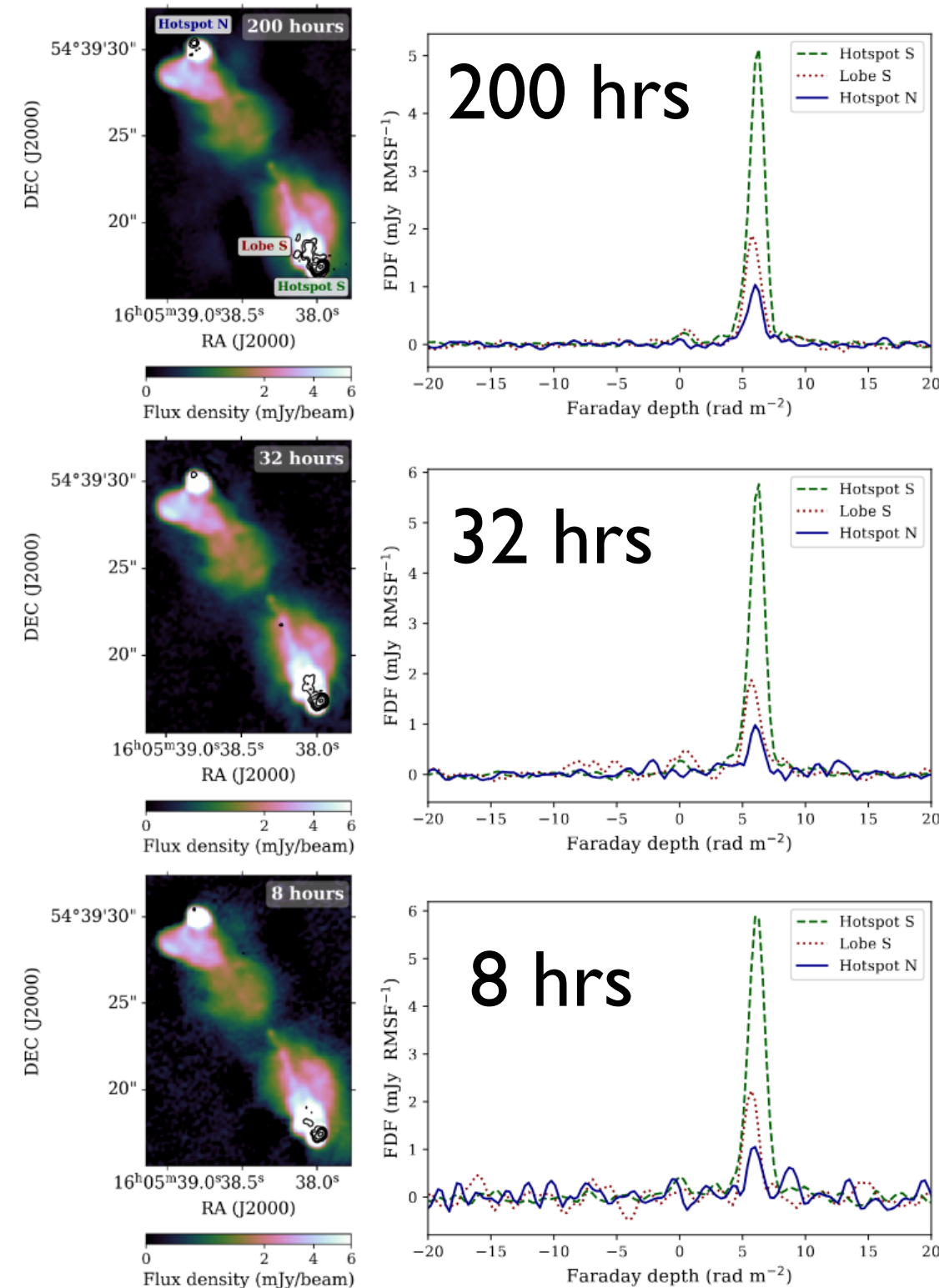
de Jong et al. (in prep)

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de Jong et al. (in prep)



Summary

- Subarcsecond resolution polarisation studies are possible with the ILT
- Requires: compact unpolarized calibrator
- Combining multi-epochs requires (relative) polarization angle calibration
- Successfully detected linear and circular polarised sources at $0.3''$ resolution in the ELAIS-N1 field
- Next step: Carry out scientific analysis of the polarised source population using 200 hrs of ELAIS-N1 data (de Jong et al. in prep)