The Decameter sky at sub-arcminute resolution

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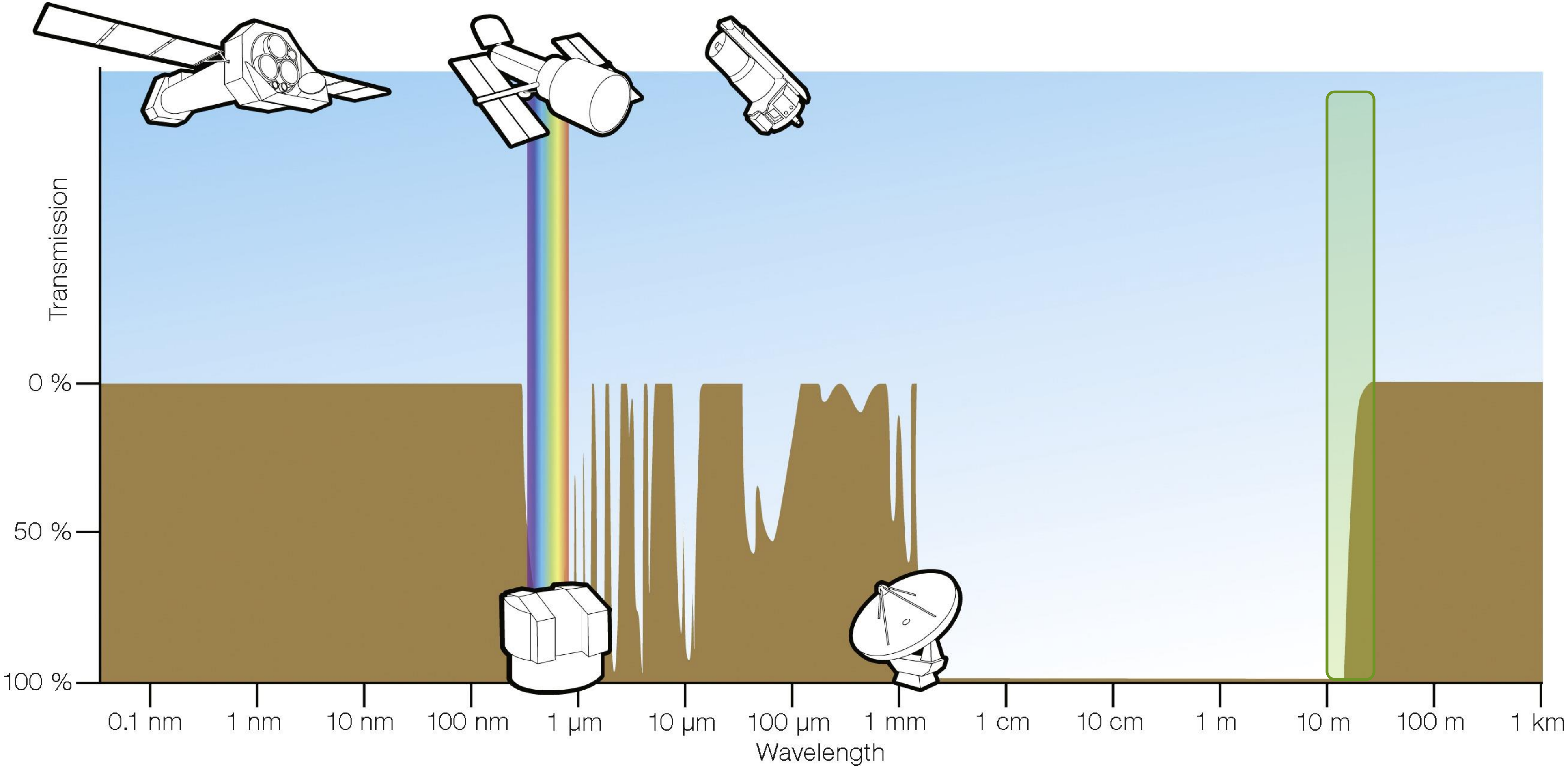
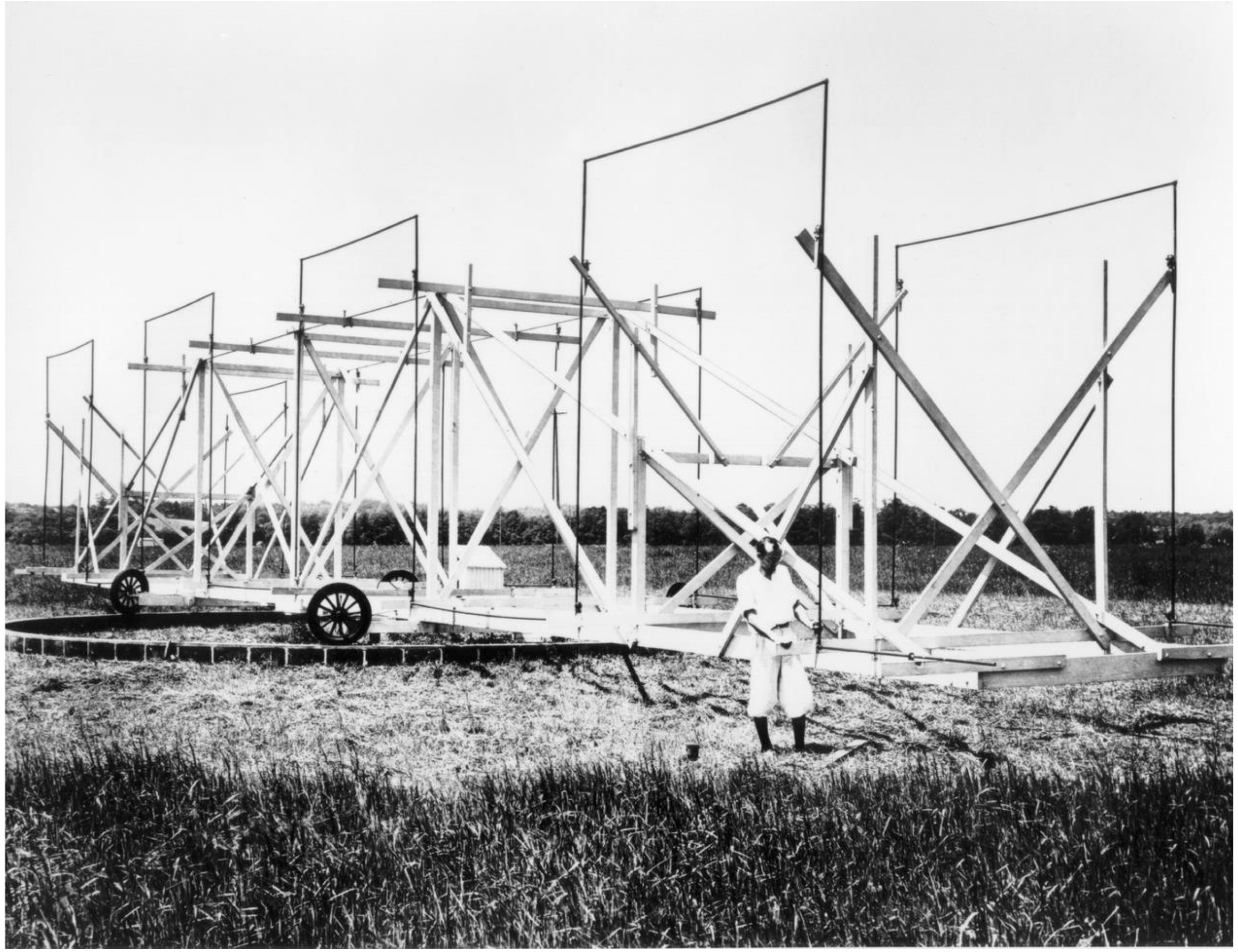
Decameter wavelength band

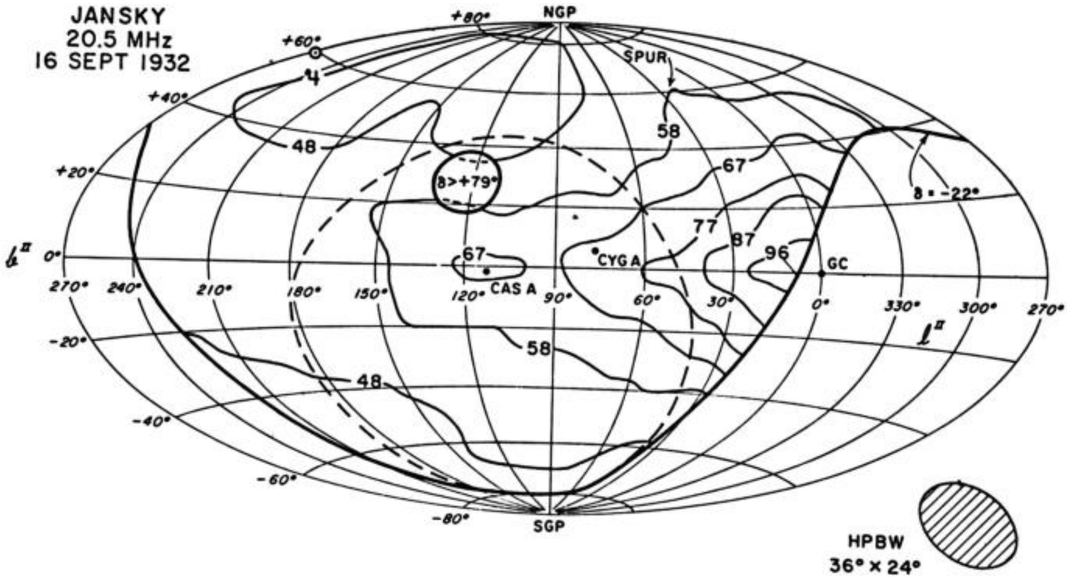


Source: F. Granato
(ESA/Hubble)

First observations

Karl G. Jansky, 1932





Subsequent work

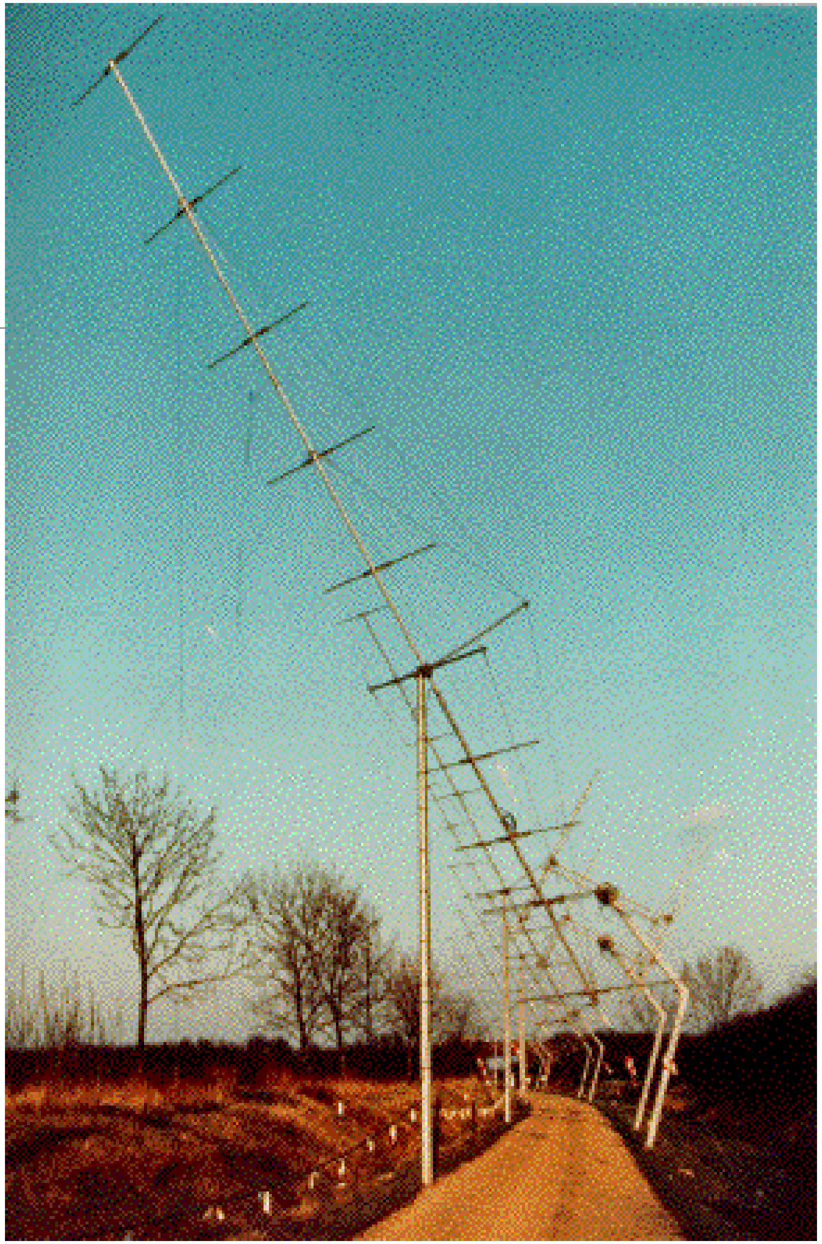
- UTR (Ukrainian T-shaped Radio Array)

Source: *ukrinform.com*

Subsequent work

- UTR (Ukrainian T-shaped Radio Array)
- 8C (Eighth Cambridge Catalogue)

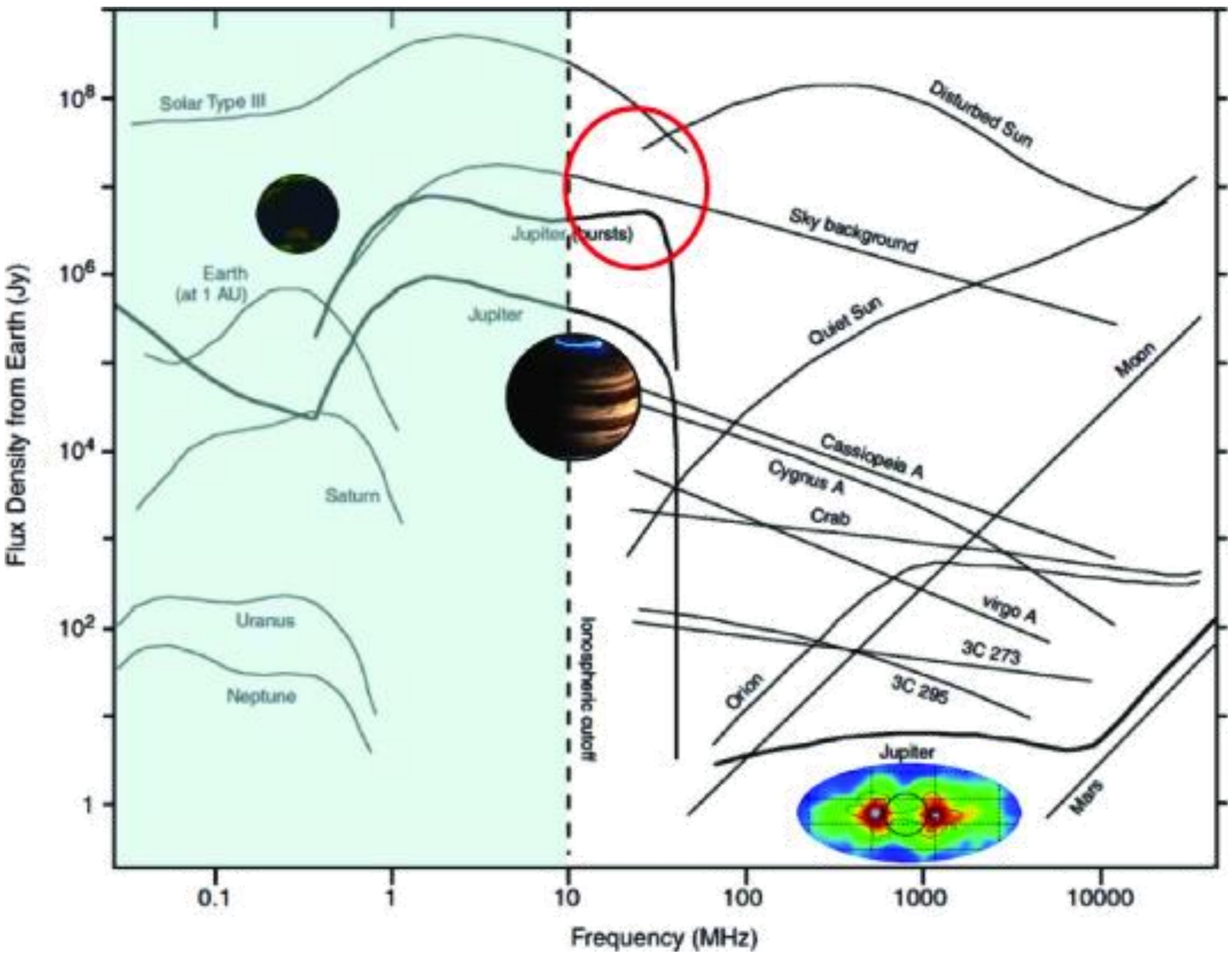
Source: *Mullard Radio Astronomy Observatory, 1995*



What do we see?

- **ECMI from Jupiter**

Jupiter becomes dominates in the decameter band – overtaking even the sun. Similar emission is expected from brown dwarf-exoplanet pairs.

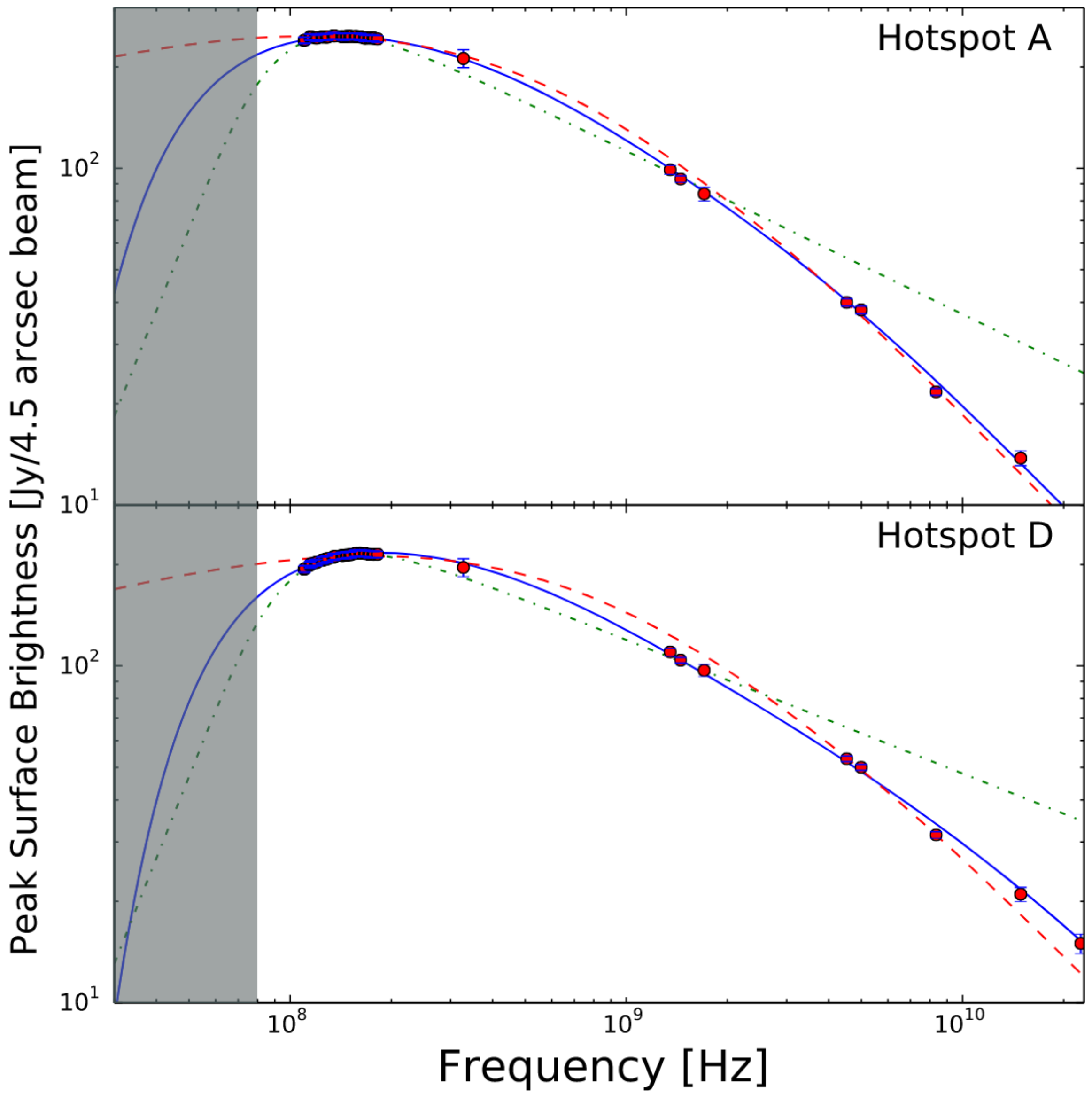


Source: Philippe Zarka

What do we see?

- ECMI from Jupiter
- **Spectral turnovers**

Many sources are expected to turn over at low frequencies – decameter observations can help find and characterize them.

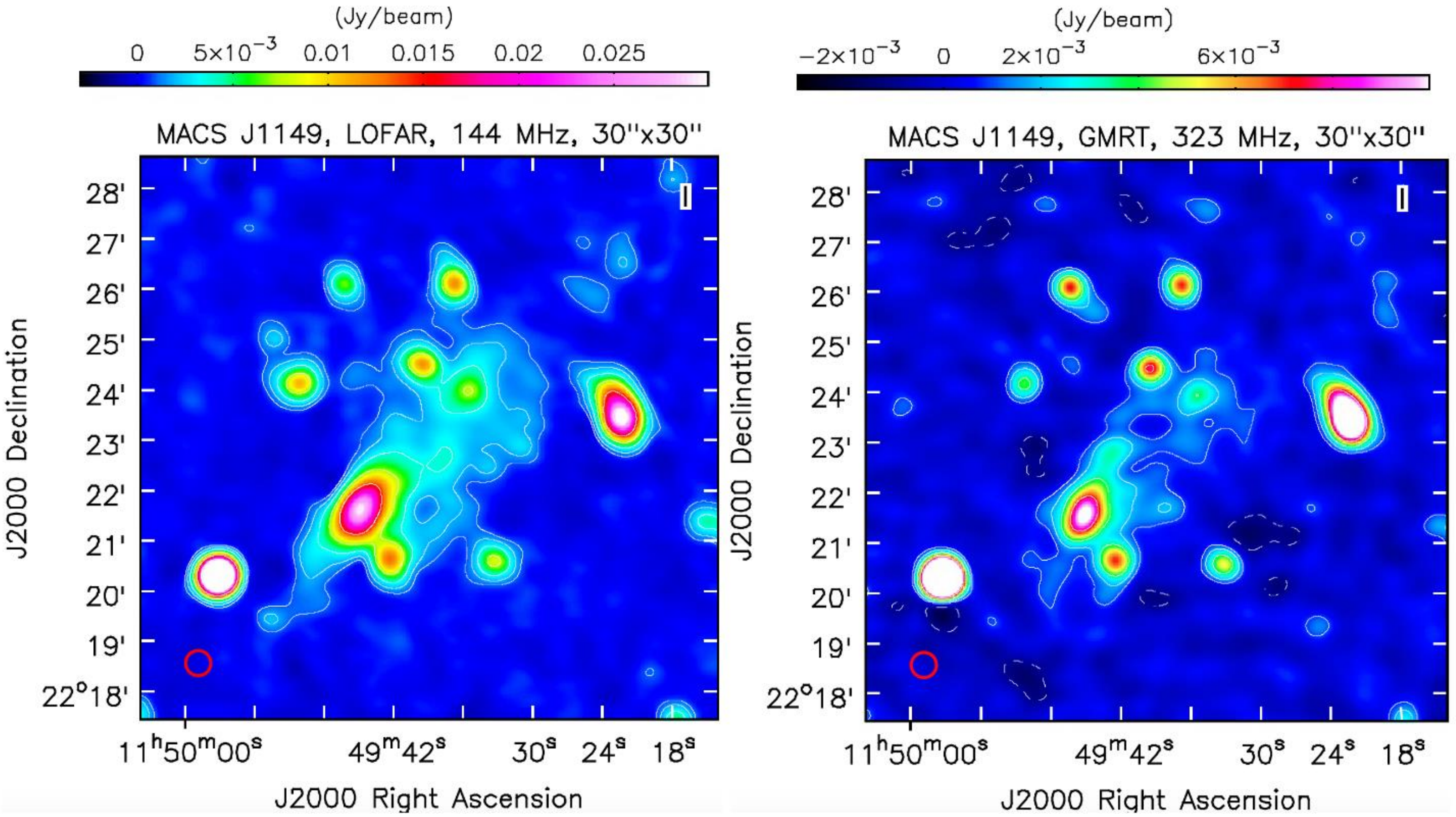


Source: John McKean (2016)

What do we see?

- ECMI from Jupiter
- Spectral turnovers
- **Steep spectra in galaxy clusters**

Galaxy clusters can host Mpc scale radio halos filled with electron plasma. Decameter astronomy gives us clues on how the electrons got accelerated to these energies.

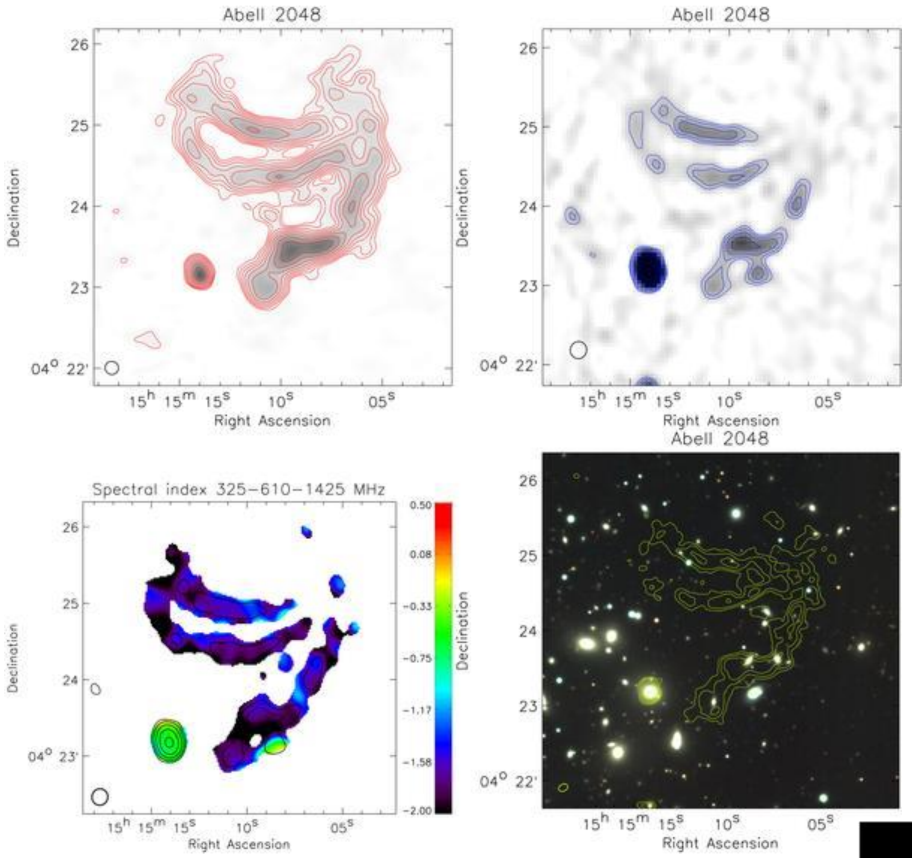


Source: Luca Bruno (2021)

What do we see?

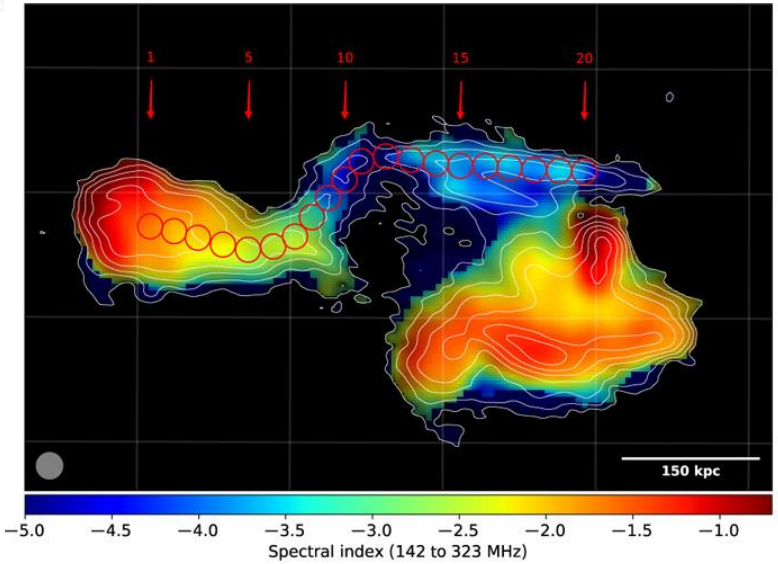
- ECMI from Jupiter
- Spectral turnovers
- Steep spectra in galaxy clusters
- **Re-energised fossil plasma**

Old AGN emission has been re-energised, e.g. via adiabatic compression to form diffuse, complex structures, with very steep spectra.



Source: Van Weeren et al. (2011)

Source: de Gasperin et al. (2017)



Why are there no deep surveys?

- Ionosphere changes heavily in time (~second)
- Ionosphere changes heavily in frequency (1/v)
- Faraday rotation (1/v^2)
- Corrections change severely throughout FoV
- Reflected RFI (during daytime)

… Decameter astronomy from space

Berkeley Physics

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LuSEE-Night will attempt first-of-its-kind measurements of the Dark Ages of the Universe.

Tricia Talbert, NASA *March 20, 2023*

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Bright gamma ray burst confounds models of black hole birth

News Archive

OLFAR - Orbiting Low Frequency Antenna for Radio Astronomy

Mark Bentum and Albert Jan Boonstra

***Abstract*—New interesting astronomical science drivers for very low frequency radio astronomy have emerged, ranging from studies of the astronomical dark ages, the epoch of reionization, exoplanets, to ultra-high energy cosmic rays. However, astronomical observations with Earth-bound radio telescopes at very low frequencies are hampered by the ionospheric plasma, which scatters impinging celestial radio waves. This effect is larger at lower frequencies. Below about 5 MHz at night or about 10 MHz during daytime, the ionosphere is even opaque for radio waves. That means that Earth-bound radio astronomy observations in those bands would be severely limited in sensitivity and spatial resolution, or would be entirely impossible. A radio telescope in space would not be hampered by the Earths ionosphere, but up to now such a telescope was technologically and financially not feasible. However, extrapolation of current technological advancements in signal processing and small satellite systems**

was technologically and financially not feasible. With todays technological advancements in signal processing and small satellite systems we can design a distributed low frequency radio telescopes in space which could be launched within 10

Original Article | Published: 30 August 2018

A space-based decametric wavelength radio telescope concept

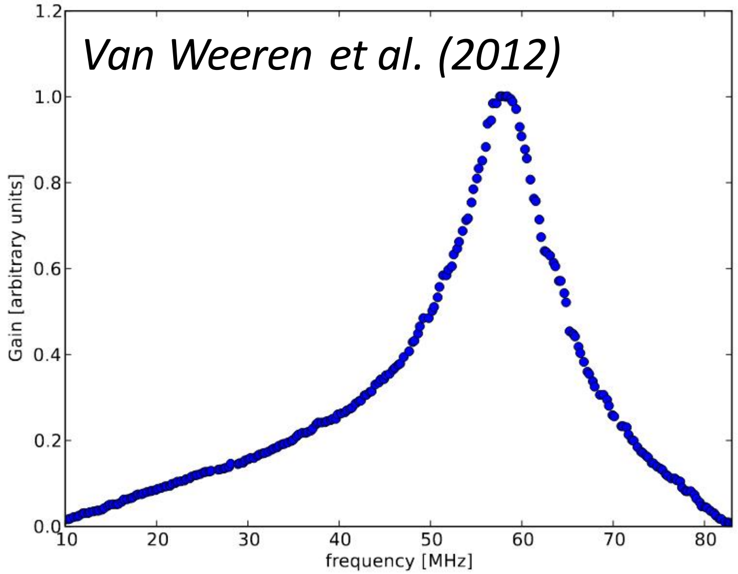
K. Belov, A. Branch, S. Broschart, J. Castillo-Rogez, S. Chien, L. Clare, R. Dengler, J. Gao, D. Garza, A. Hegedus, S. Hernandez, S. Herzig, T. Imken, H. Kim, S. Mandutianu, A. Romero-Wolf, S. Schaffer, M. Troesch, E. J. Wyatt & J. Lazio

Experimental Astronomy **46**, 241–284 (2018) | Cite this article

Abstract

This paper reports a design study for a space-based decametric wavelength telescope. While

Lowest frequencies with LOFAR



In principle 10-80 MHz

LoLSS: 42-66 MHz

Decameter band: 16-30 MHz

Test observation in 3C196 field

Ionosphere

F. de Gasperin et al.: LOFAR calibration strategy

Systematic effect	Type of Jones matrix[a]	Ph/Amp/Both[b]	Frequency dependency	Direction dependent?	Time dependent?
Clock drift	Scalar	Ph	$\propto \nu$	No	Yes (many seconds)
Polarisation alignment	Diagonal	Ph	$\propto \nu$	No	No
Ionosphere - 1st ord. (dispersive delay)	Scalar	Ph	$\propto \nu^{-1}$	Yes	Yes (few seconds)
Ionosphere - 2sn ord. (Faraday rotation)	Rotation	Both	$\propto \nu^{-2}$	Yes	Yes (few seconds)
Ionosphere - 3rd ord.	Scalar	Ph	$\propto \nu^{-3}$	Yes	Yes (few seconds)
Ionosphere - scintillations	Diagonal	Amp	–	Yes	Yes (few seconds)
Dipole beam	Full-Jones	Both	–	Yes	Yes (minutes)
Bandpass	Diagonal	Amp	–	No	No

[a] In linear polarisation basis.
[b] The matrix affects phases, amplitude or both.

Table 1: Type of systematic effects we isolated in LOFAR data. For each effect we describe the associated Jones matrix, the frequency dependency and if it is time or direction dependent.

Bandpass response → Clock drift → Direction independent calibration (full FoV) → Split up field in small regions → Direction dependent calibration + imaging

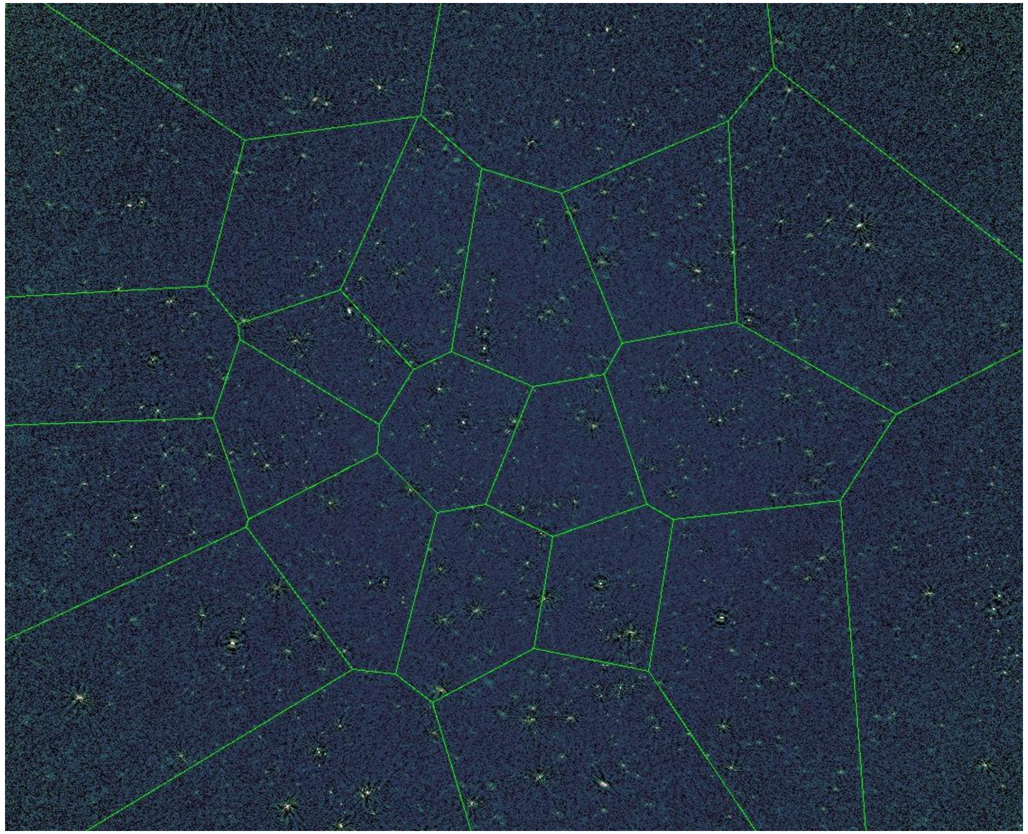
Direction dependent calibration

Previous work: calibrate whole image in one go

Direction dependent calibration:

- Calibrate whole image
- Chop up the image in small regions
- For each region:
  - Subtract rest of the field
  - **Facetselfcal.py**

- Need good model of the sky to subtract...



Ionosphere

F. de Gasperin et al.: LOFAR calibration strategy

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Bandpass response

Clock drift

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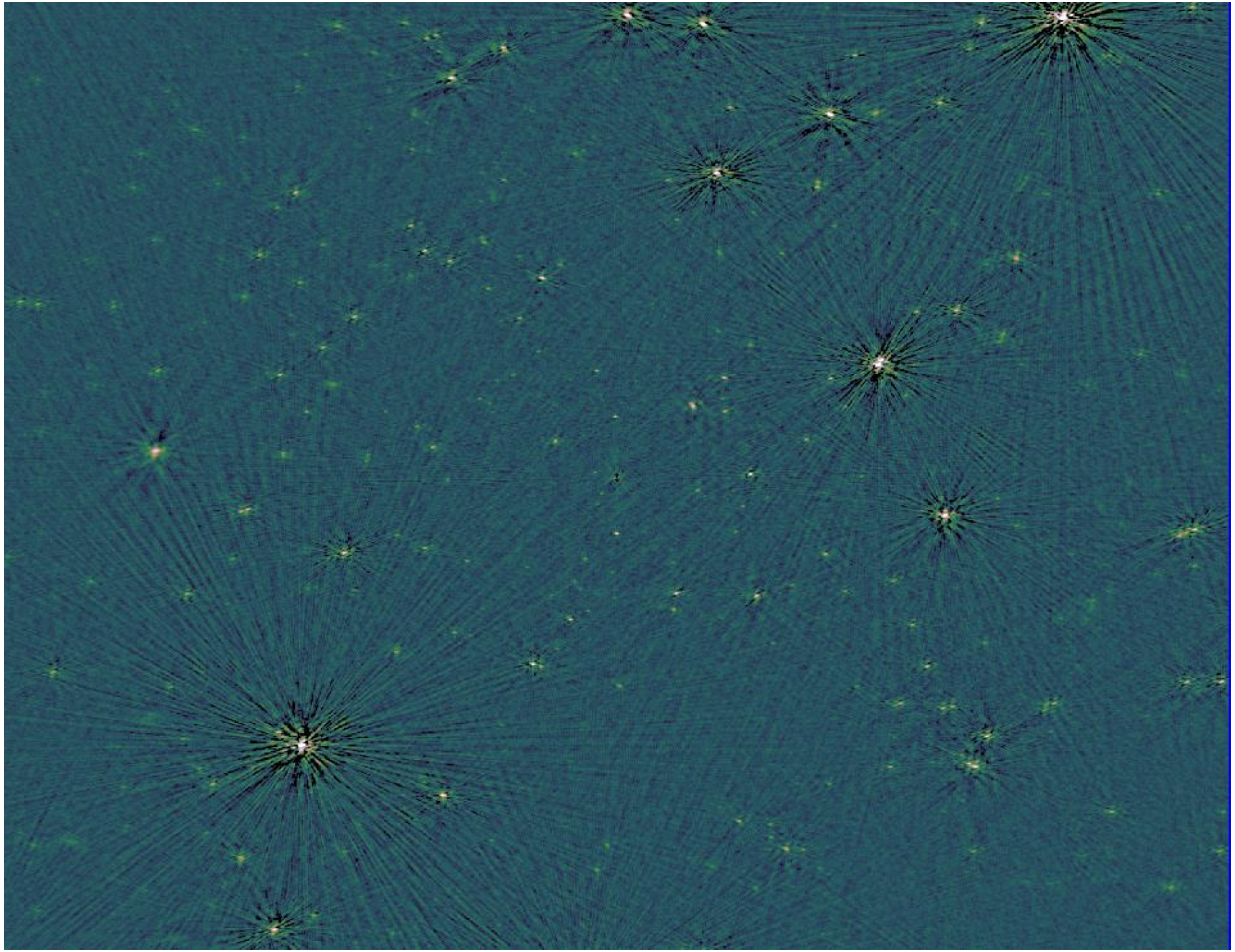
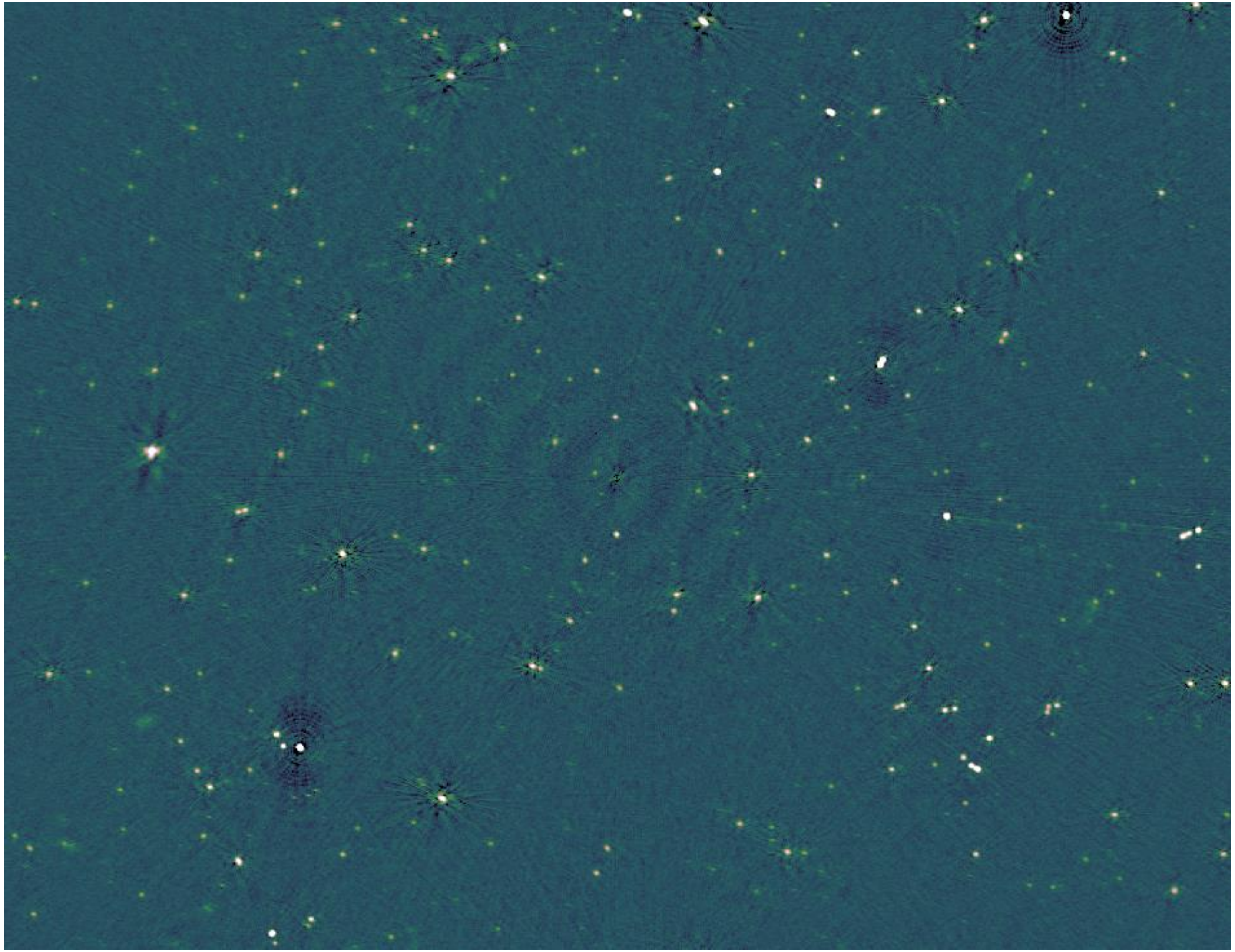
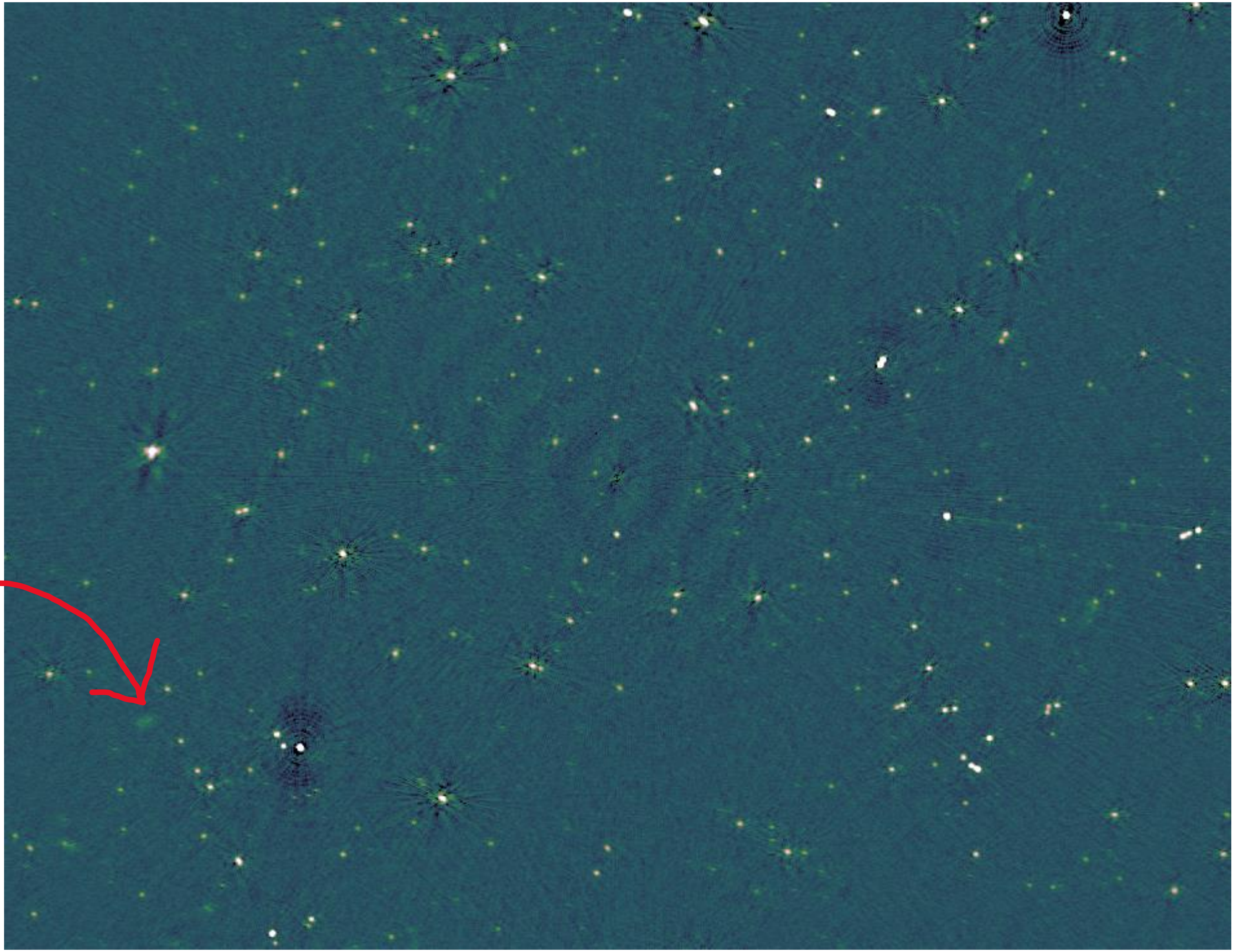
Direction dependent calibration + imaging

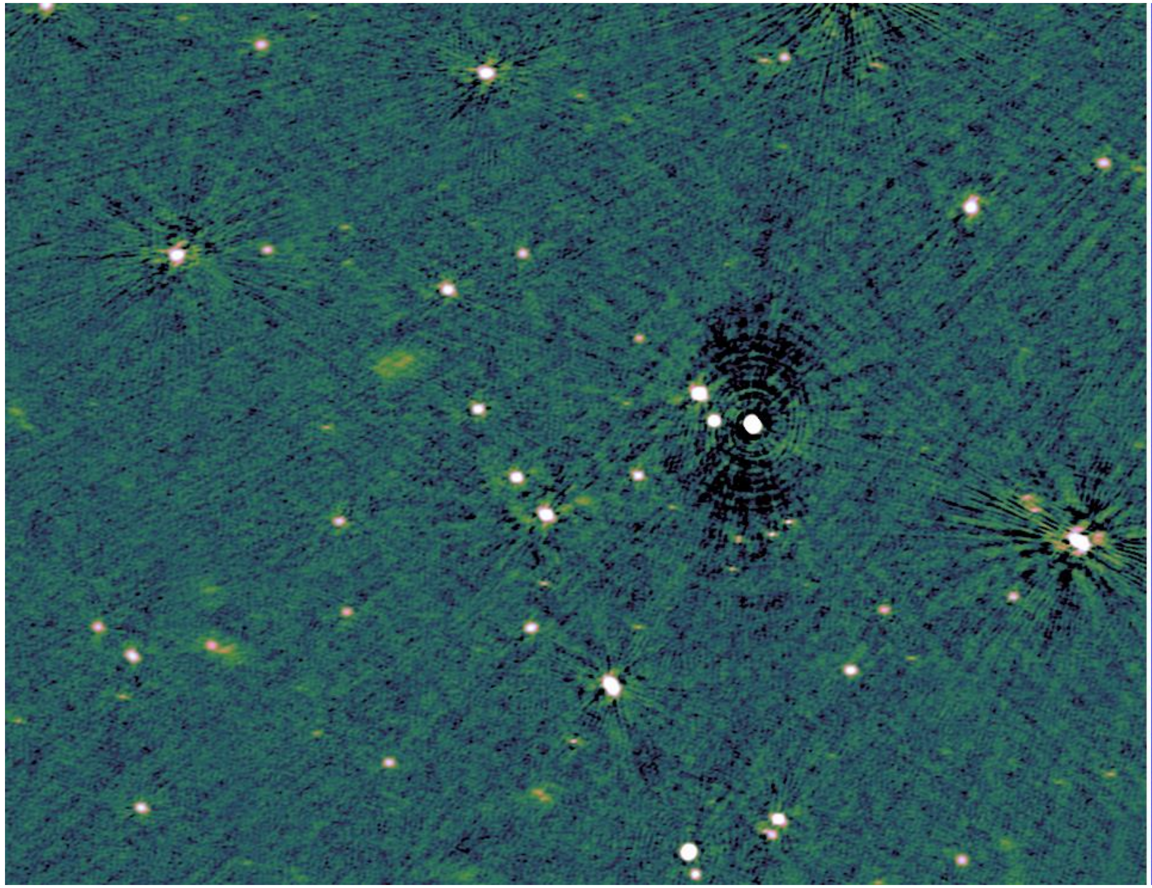
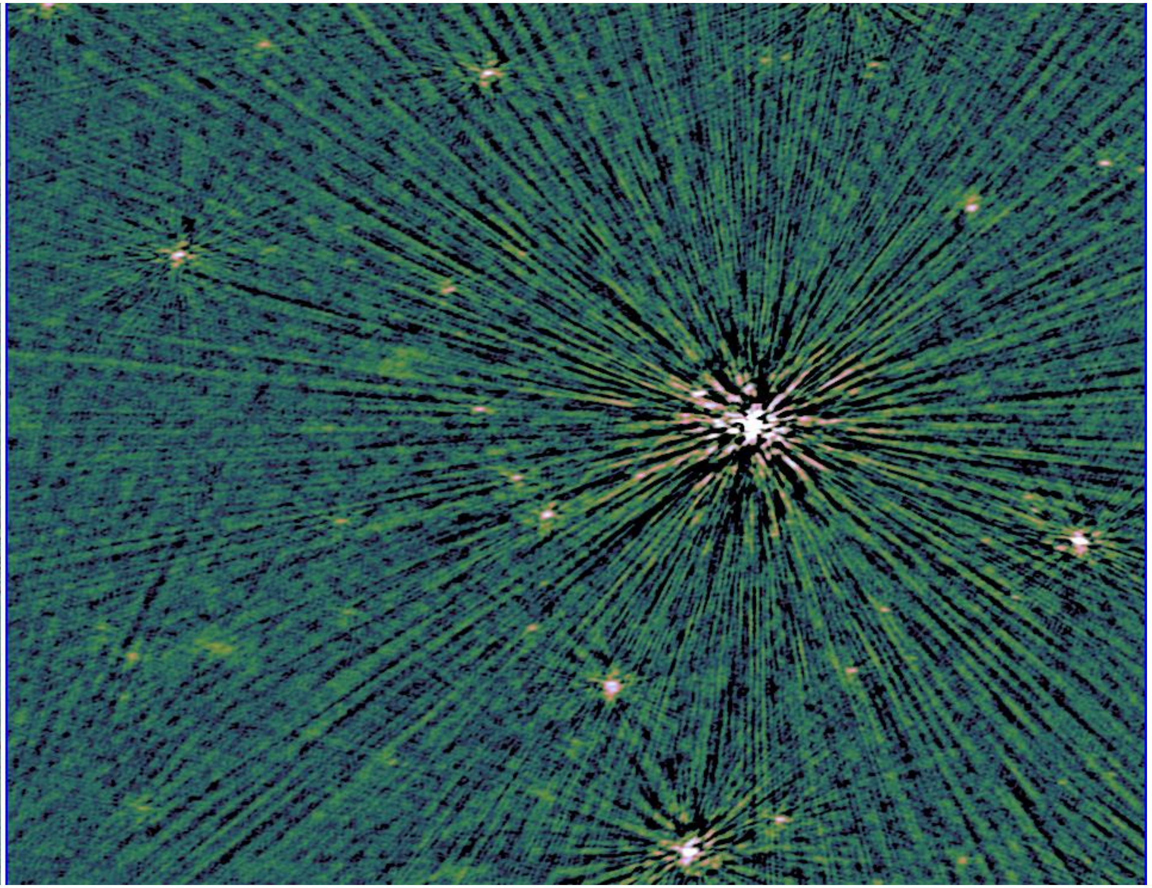


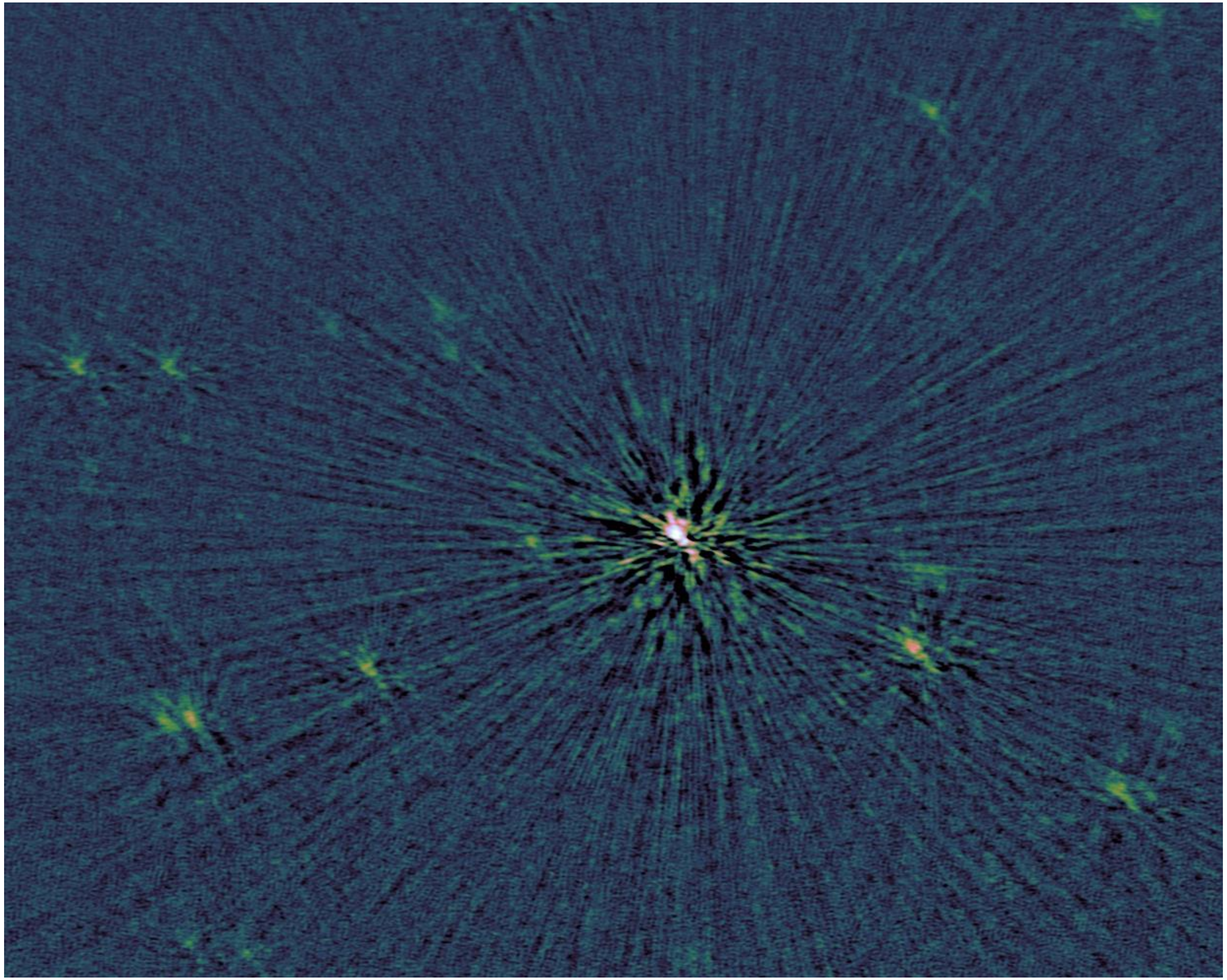
12-36 MHz image



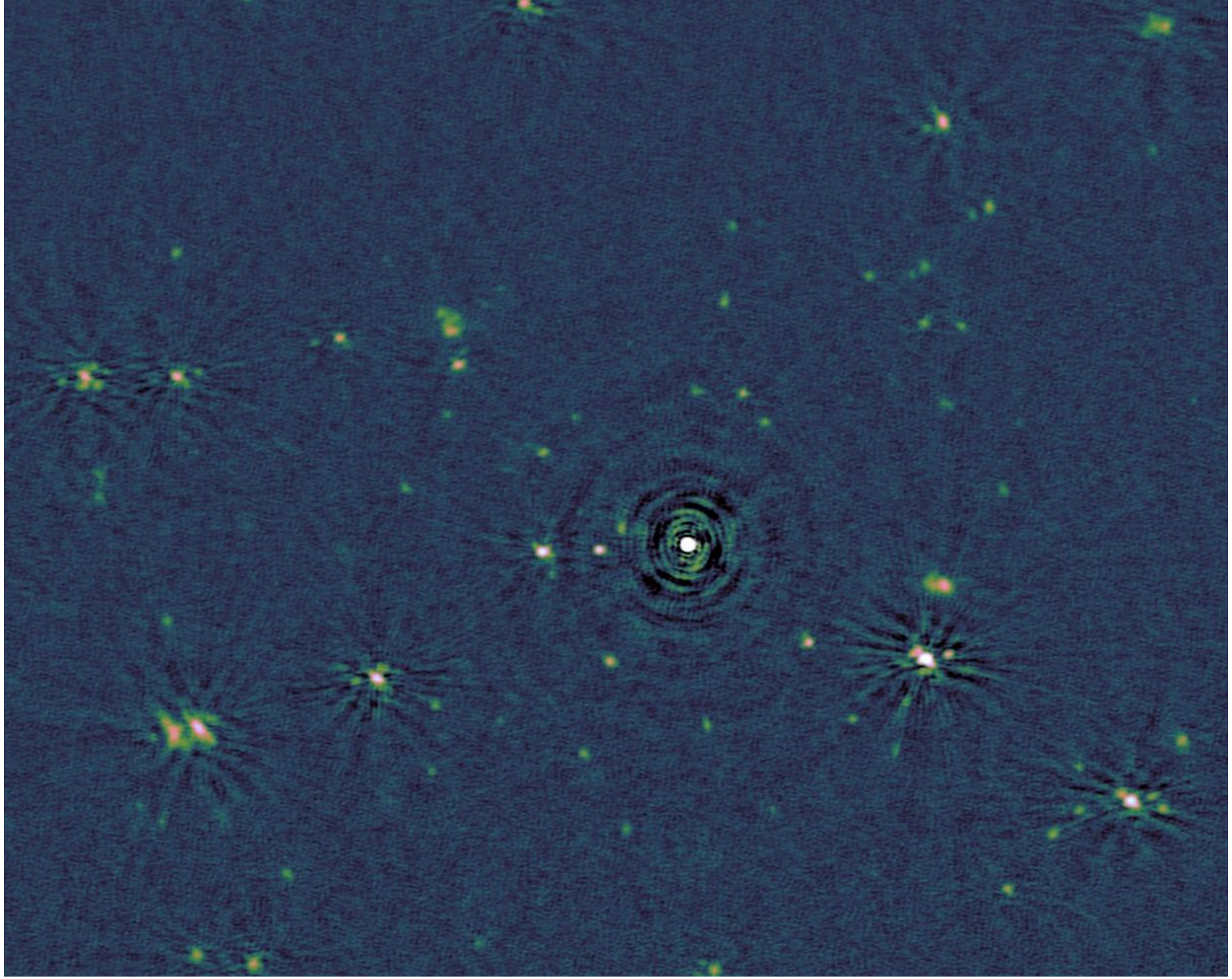


Abell 655!

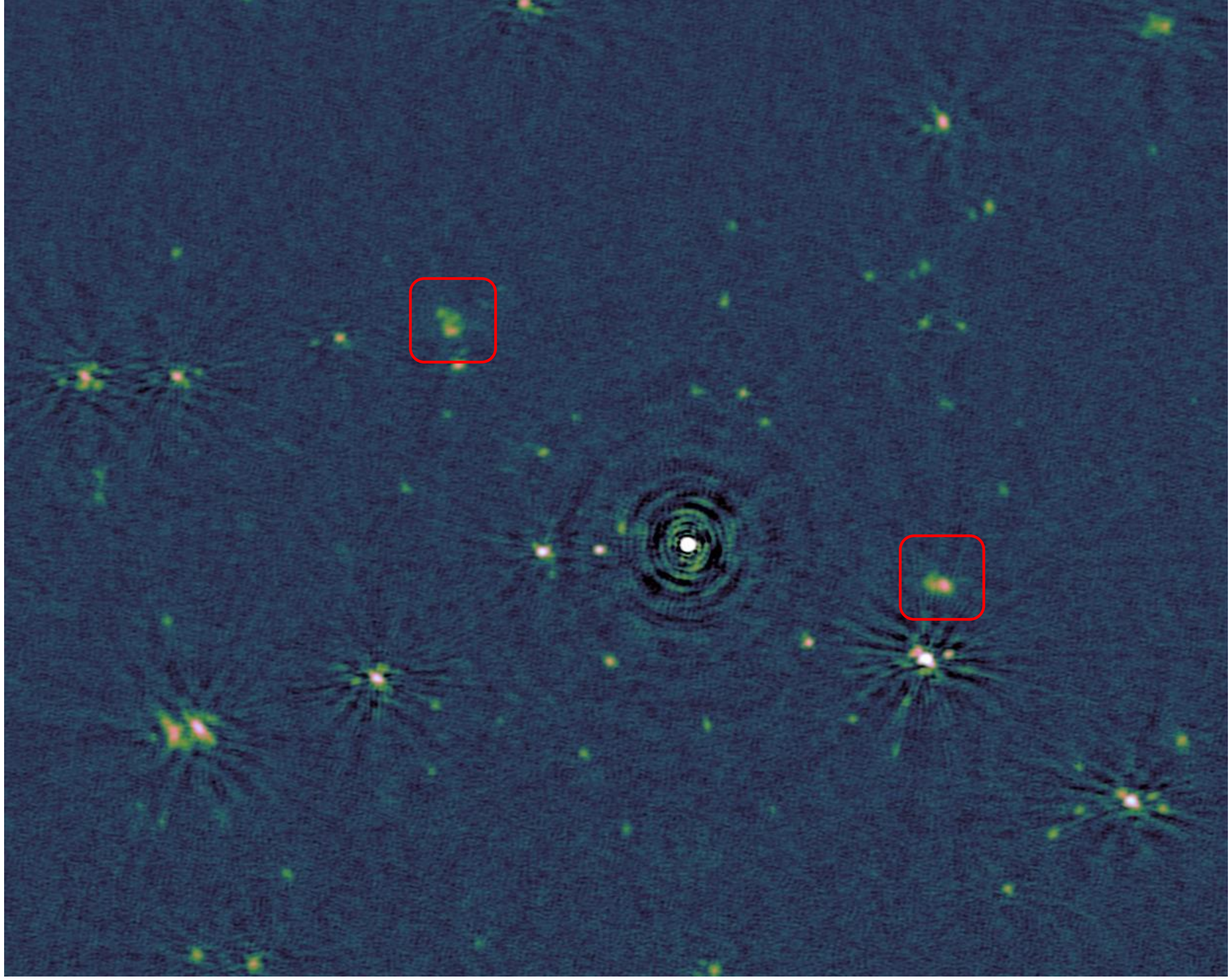





16-30 MHz image



16-30 MHz image



16-30 MHz image

LOFAR Decameter Sky Survey

- Full northern sky (Dec > 20°)
- 14-30 MHz

- Resolution: 45 arcsecond
- Depth: 15 mJy

- Progress:
  - 90% observed
  - 2 processed

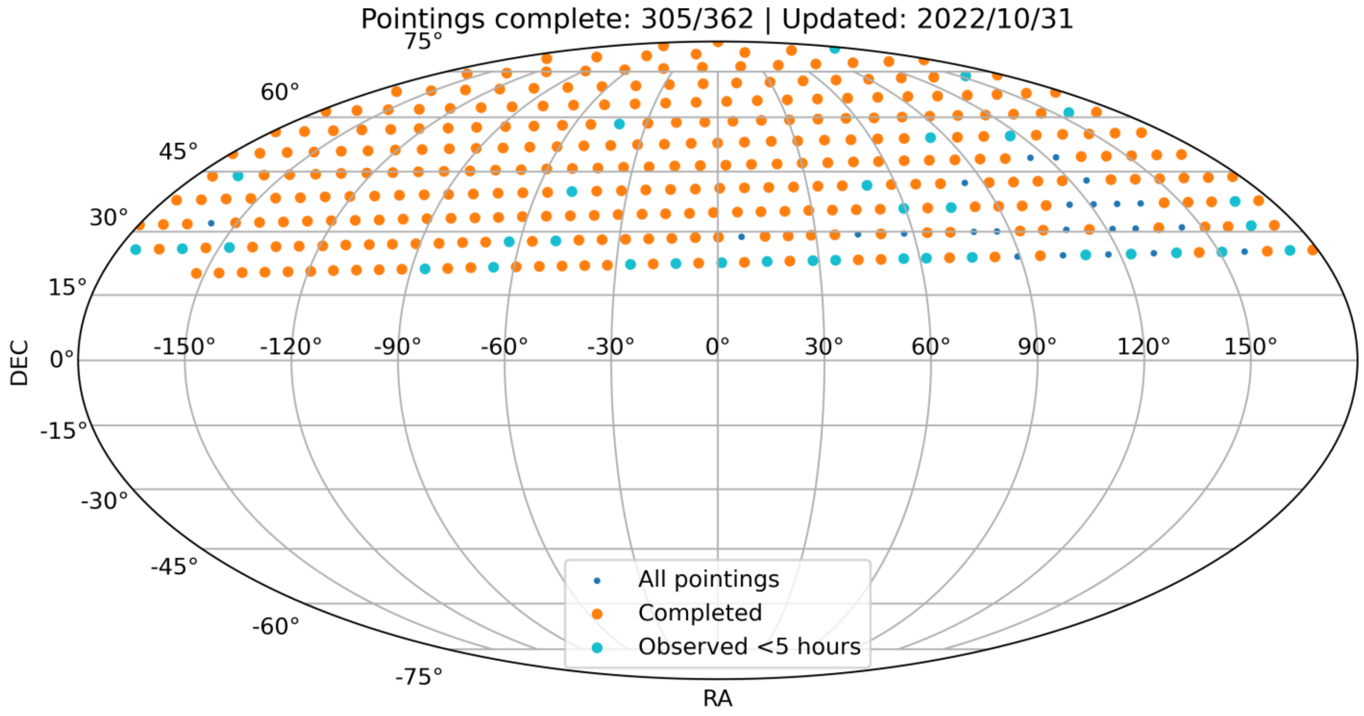
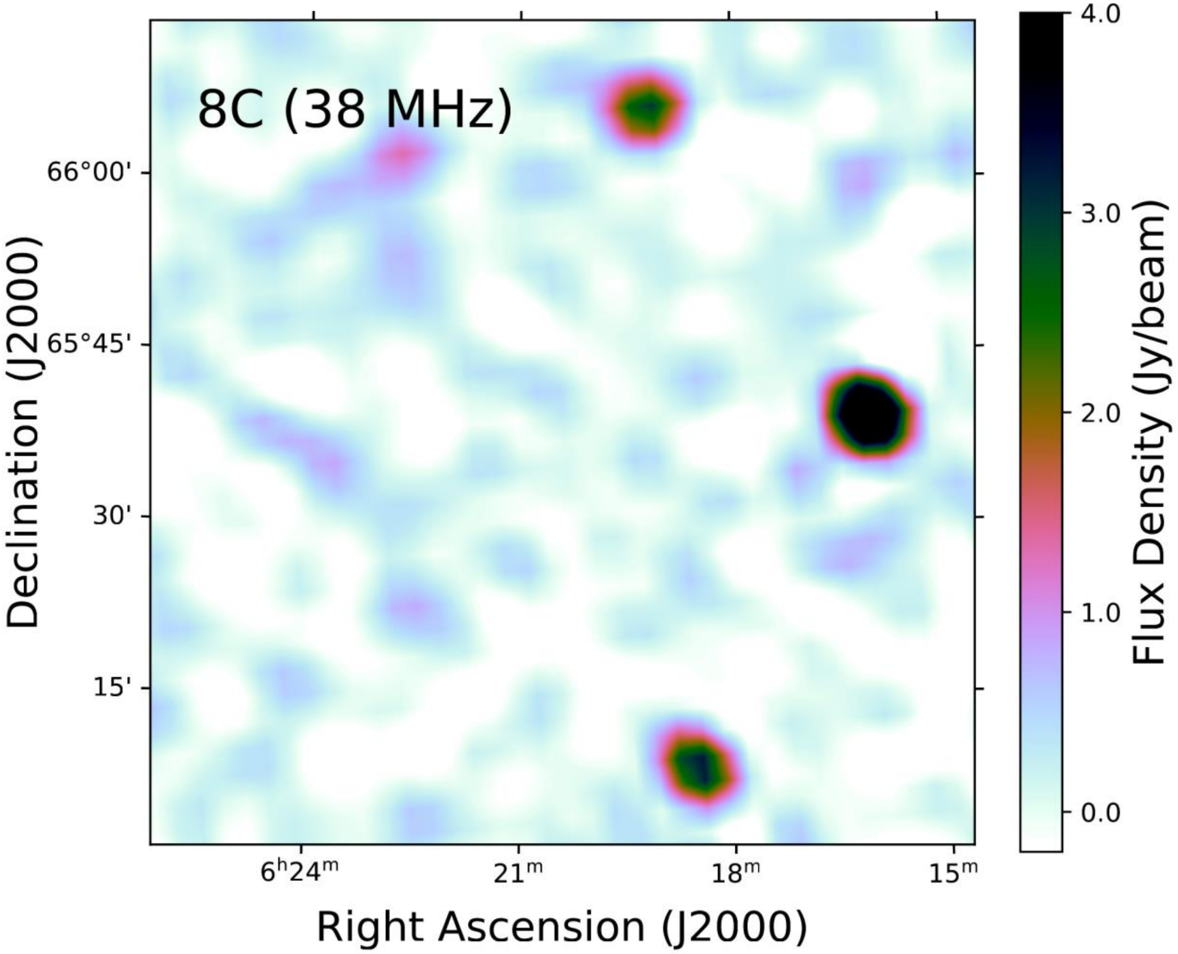
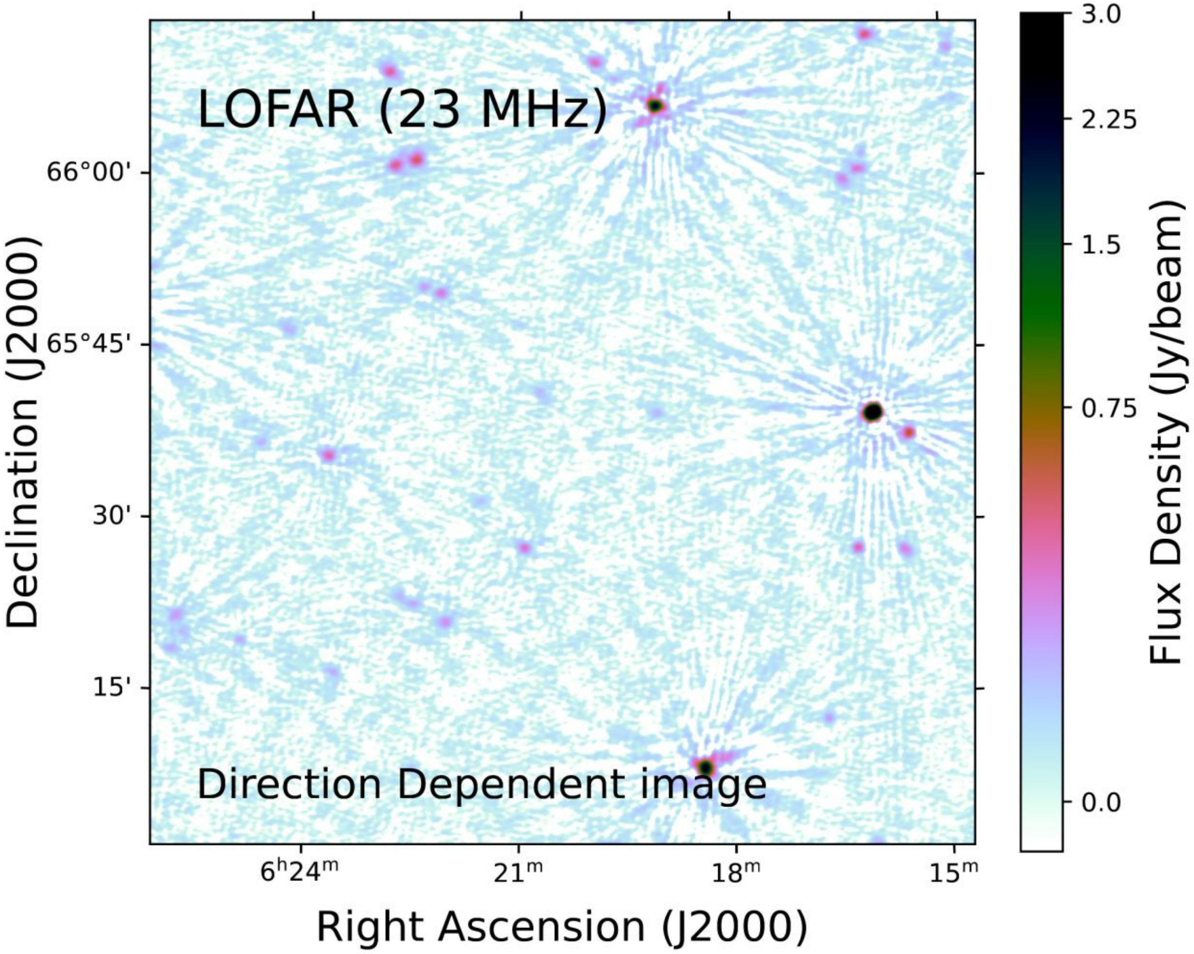


Image credit: Erik Osinga


8C (38 MHz)
Declination (J2000)
66°00'
65°45'
30'
15'
6h24m
21m
18m
15m
Right Ascension (J2000)
4.0
3.0
2.0
1.0
0.0
Flux Density (Jy/beam)


LOFAR (23 MHz)
Direction Dependent image
Declination (J2000)
66°00'
65°45'
30'
15'
6h24m
21m
18m
15m
Right Ascension (J2000)
3.0
2.25
1.5
0.75
0.0
Flux Density (Jy/beam)

Future potential

- LOFAR 2.0
- Additional stations in NL?
- Data processing:
  - Stokes V-maps for star-planet interaction
  - Transient sources in overlapping coverage

- Science:
  - Radio halos (galaxy clusters)
  - Peaked-spectrum sources
  - Re-energised fossil plasma
  - Exoplanets (?)
  - Ionosphere
  - Other sources... (any suggestions?)

Conclusion

- LOFAR is capable of observing below 30 MHz
- Survey under way
- Paper submitted