

The **LOFAR-EoR** experiment: *Foregrounds and Elais N1 field*

Vibor Jelić*

**on behalf of the LOFAR-EoR group*

LOFAR-EoR experiment

PRIMARY SCIENTIFIC GOAL

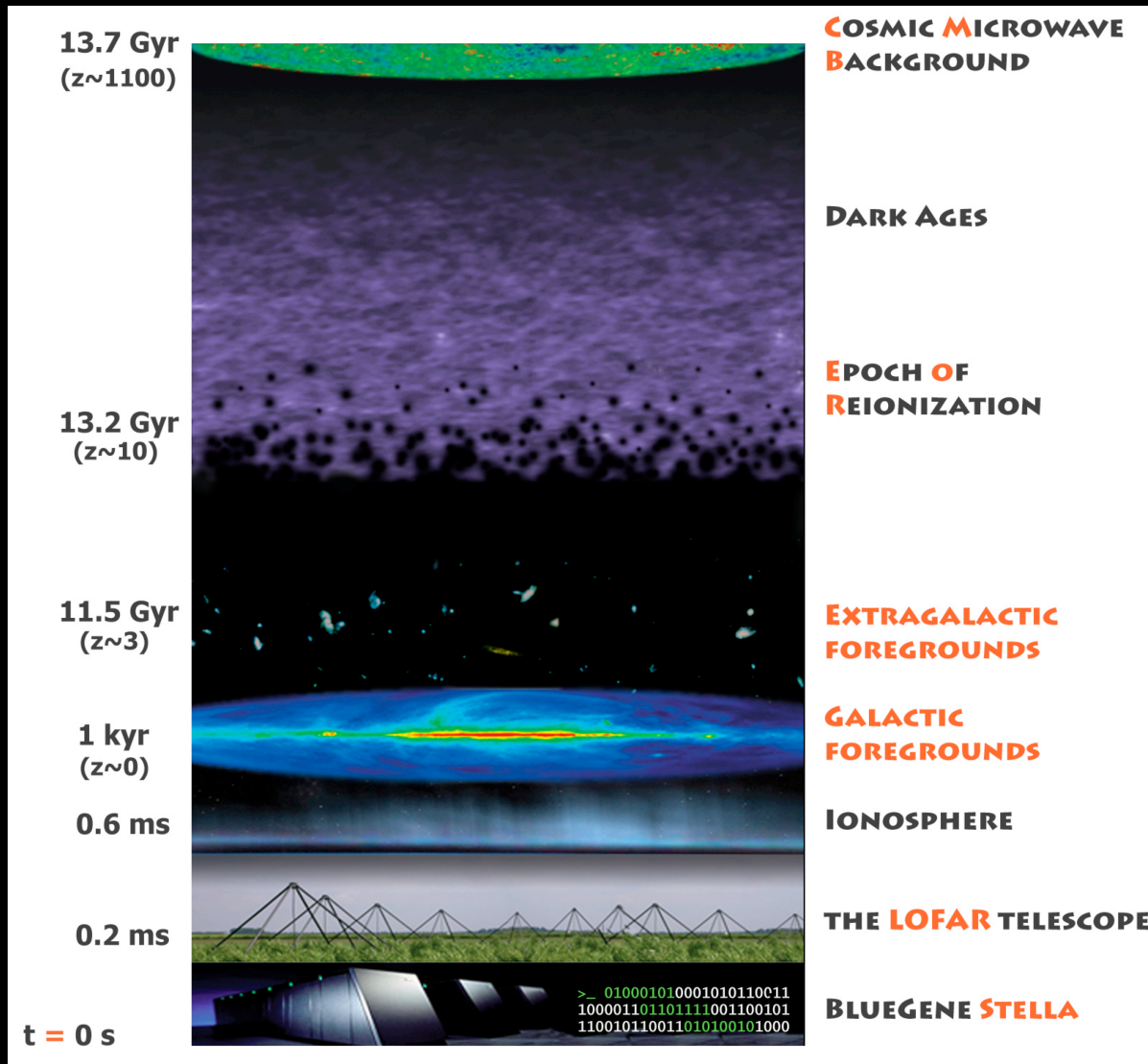
- detect cosmological 21cm signal from the Epoch of Reionization

LOFAR-EoR EXPERIMENT

- LOFAR – HBAs (112 – 190 MHz → $z \sim 11-6$)
- short baselines (core stations) for cosmological observations
- long baselines (NL + EU stations) to resolve foreground sources
- 5 observing windows (multi-beam observations)
- time resolution: 1 s (raw) / 5-10 s (avg)
- frequency resolution: 763 Hz (raw) / 9-10 kHz (avg)



LOFAR-EoR experiment: challenges

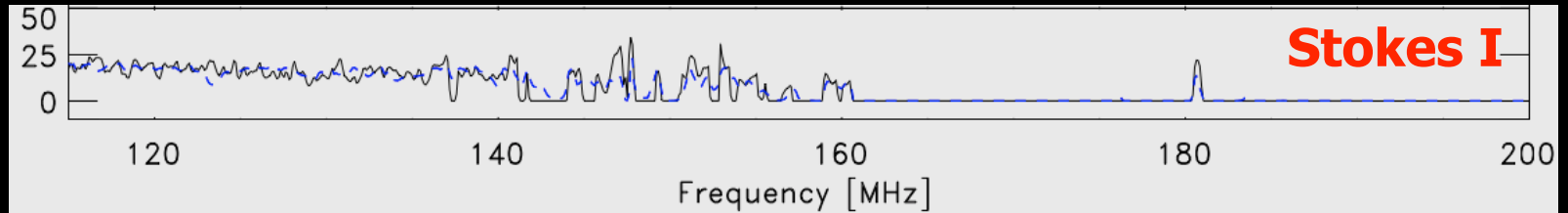


1. LOFAR-EoR end-to-end simulation pipeline
2. dedicated observations with the WSRT telescope
3. dedicated observations with the LOFAR telescope

Extraction of the 21cm signal

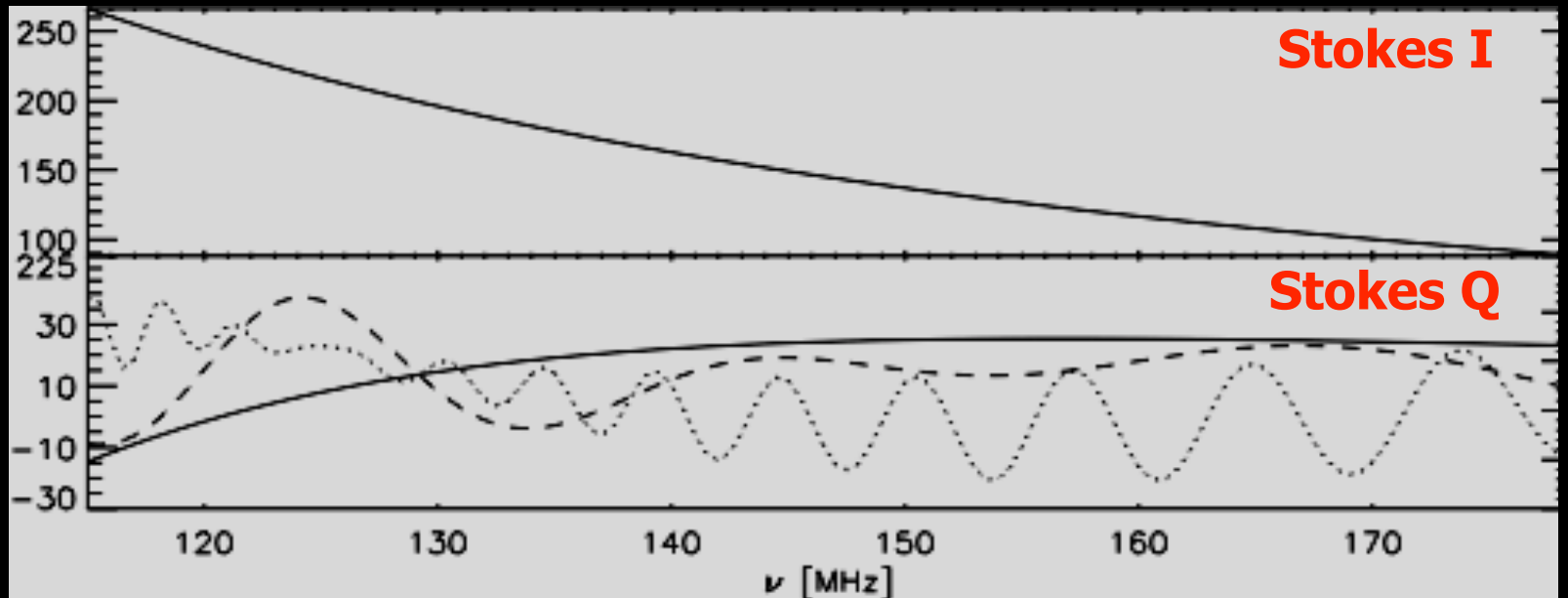
EoR

δT_b [mK]



foregrounds

δT_b [K]



- extraction is based on **smoothness of the foregrounds in total intensity**
(polynomial or non-parametric fitting; *Jelic et al. 2008*; *Harker et al. 2009*)

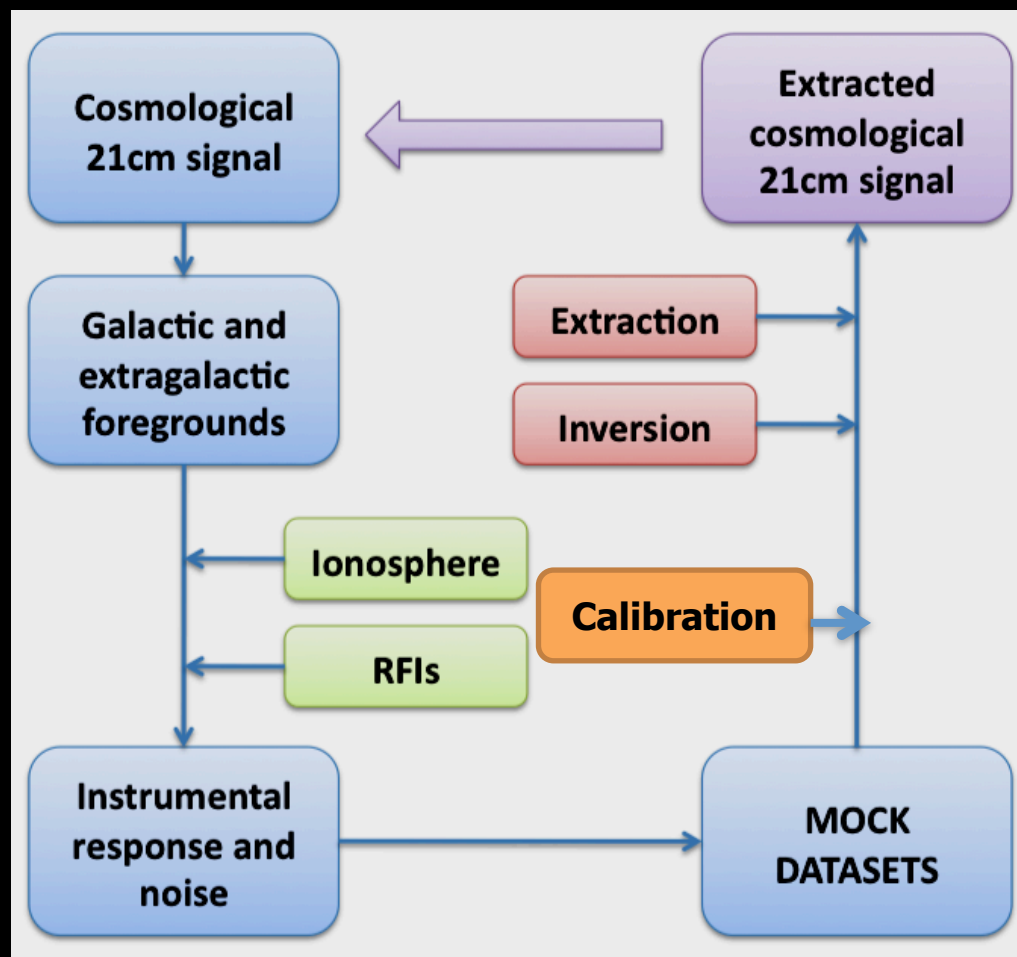
LOFAR-EoR experiment: end-to-end pipeline

R. Thomas
PhD thesis

V. Jelić
PhD thesis

A. Offringa
PhD thesis

P. Lambropoulos
PhD thesis

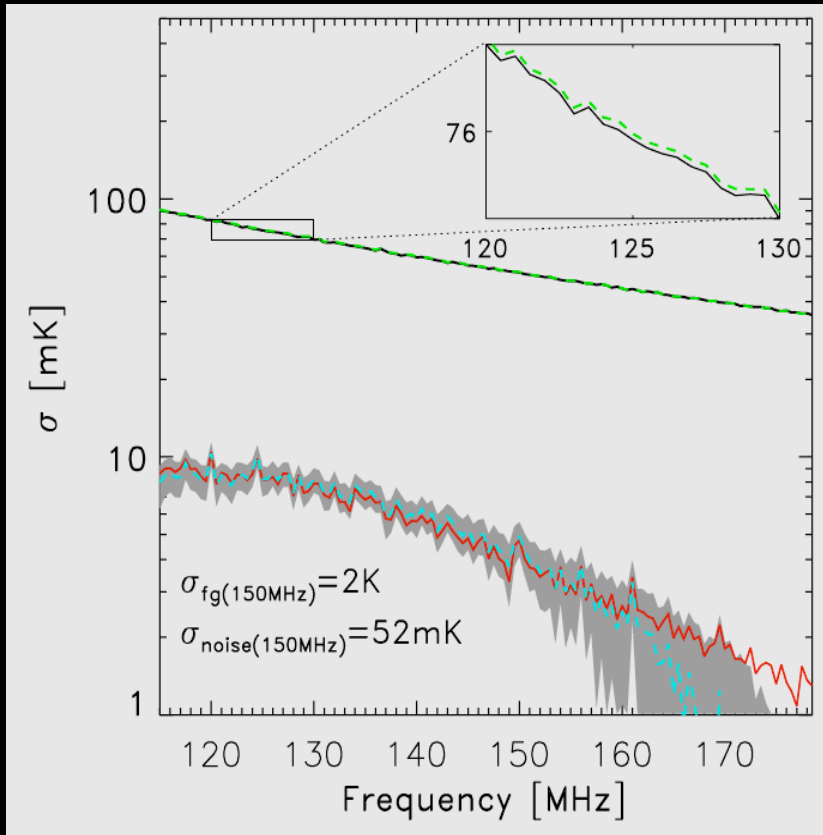


Jelic et al 2008
Harker et al 2009a
Harker et al 2009b
Harker et al 2010

Yatawatta et al 2009
Kazemi et al 2011

Extraction of the 21cm signal: **simulations**

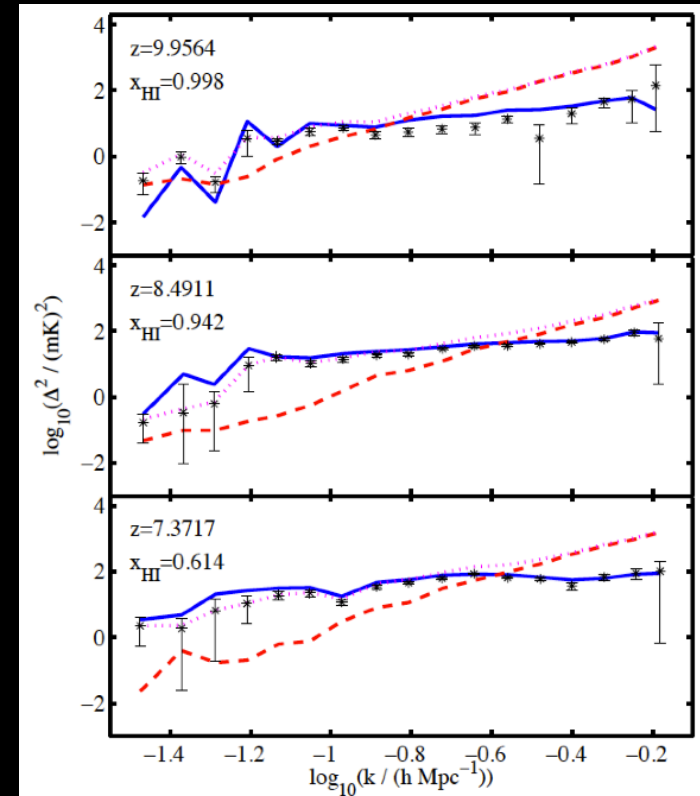
- Statistical detection of the EoR signal**



standard deviation and higher order statistics

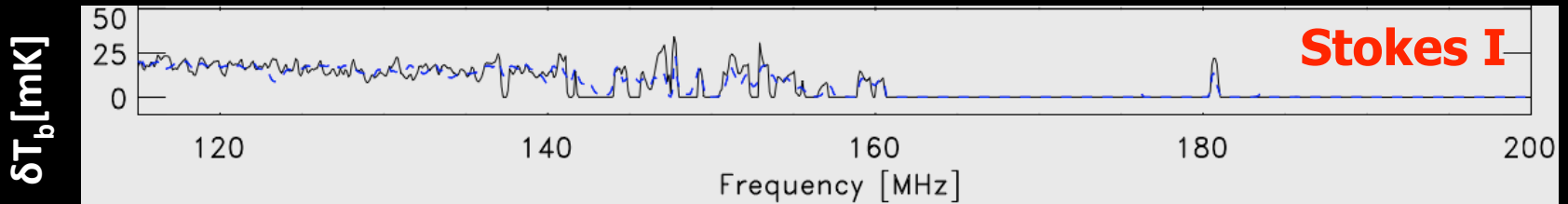
Jelic et al. 2008, Harker et al. 2009

**Power spectrum
Harker et al. 2010**

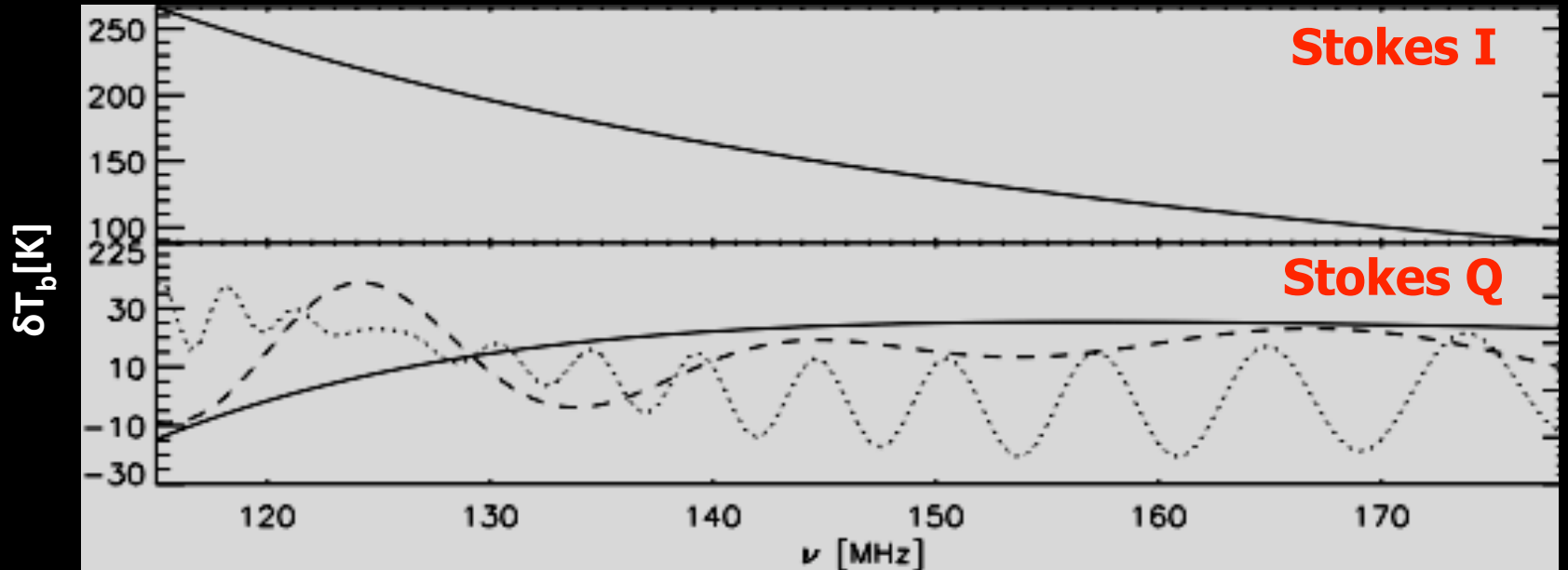


Extraction of the 21cm signal: **simulations**

EoR



foregrounds



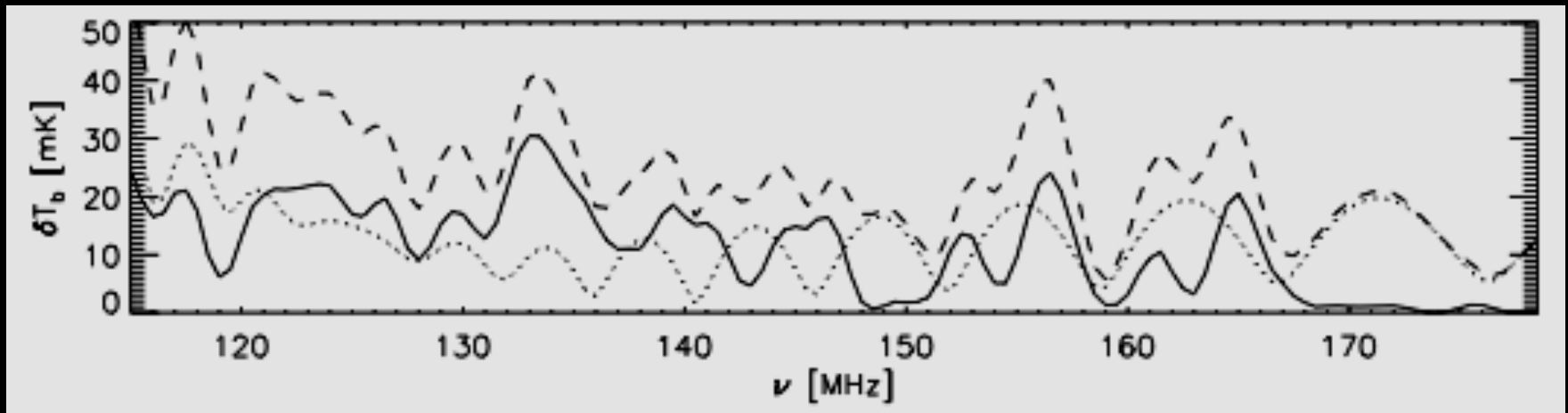
- extraction is based on **smoothness of the foregrounds in total intensity**

Importance for the EoR experiments

— EoR \sim 25 mK

⋯ FG \sim 2 K

residual leakage \sim 1.5 % (30mK)



➤ the leaked polarized emission can mimic the cosmological signal and make its extraction very difficult

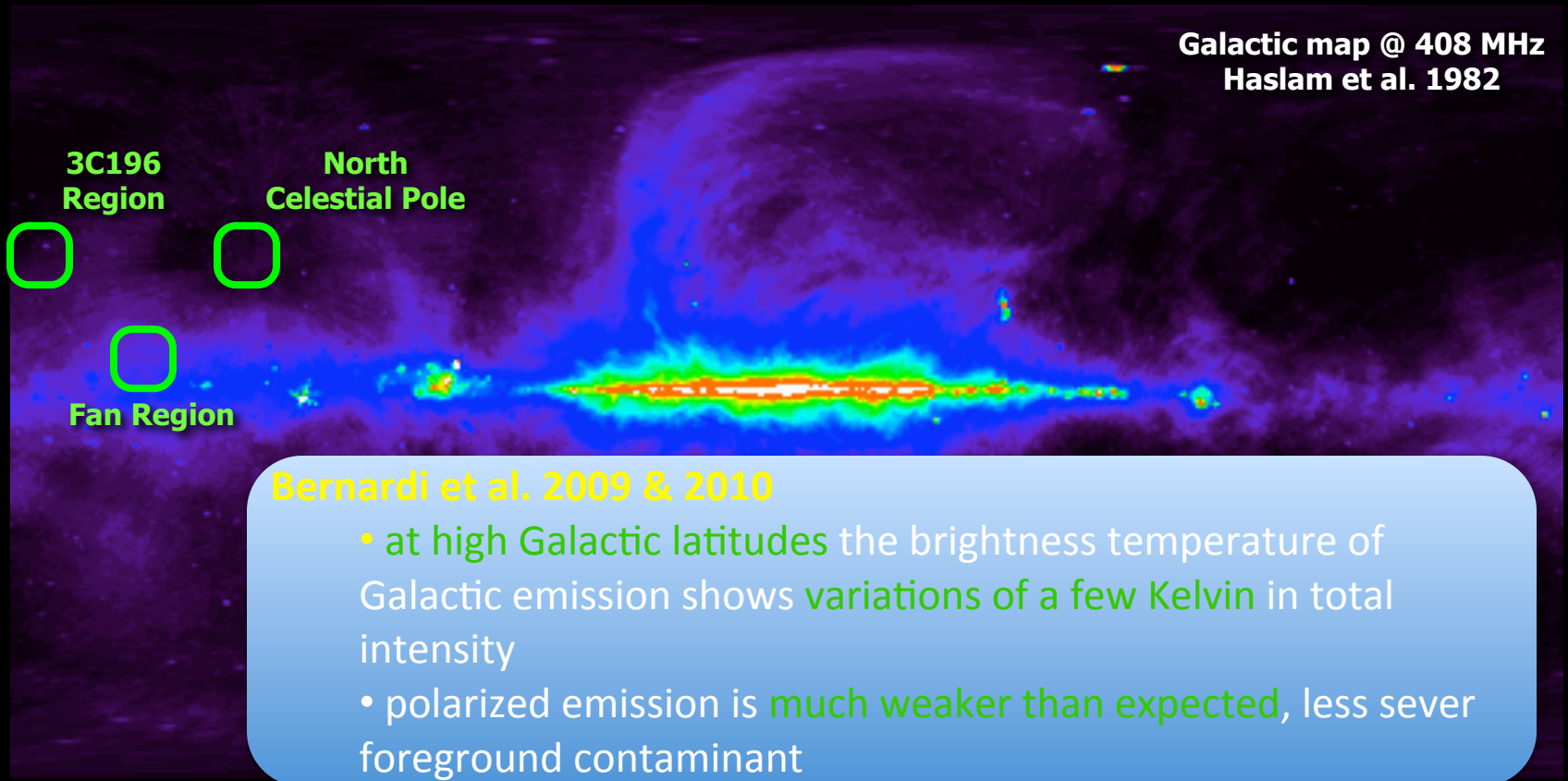
Jelic et al. 2010

LOFAR-EoR experiment: **observing windows**

- at high Galactic latitudes
- **low Galactic emission** (both in total and polarized intensity)
- “easy” sources for calibration
- deep field or available data at other frequencies

LOFAR-EoR experiment: **observations**

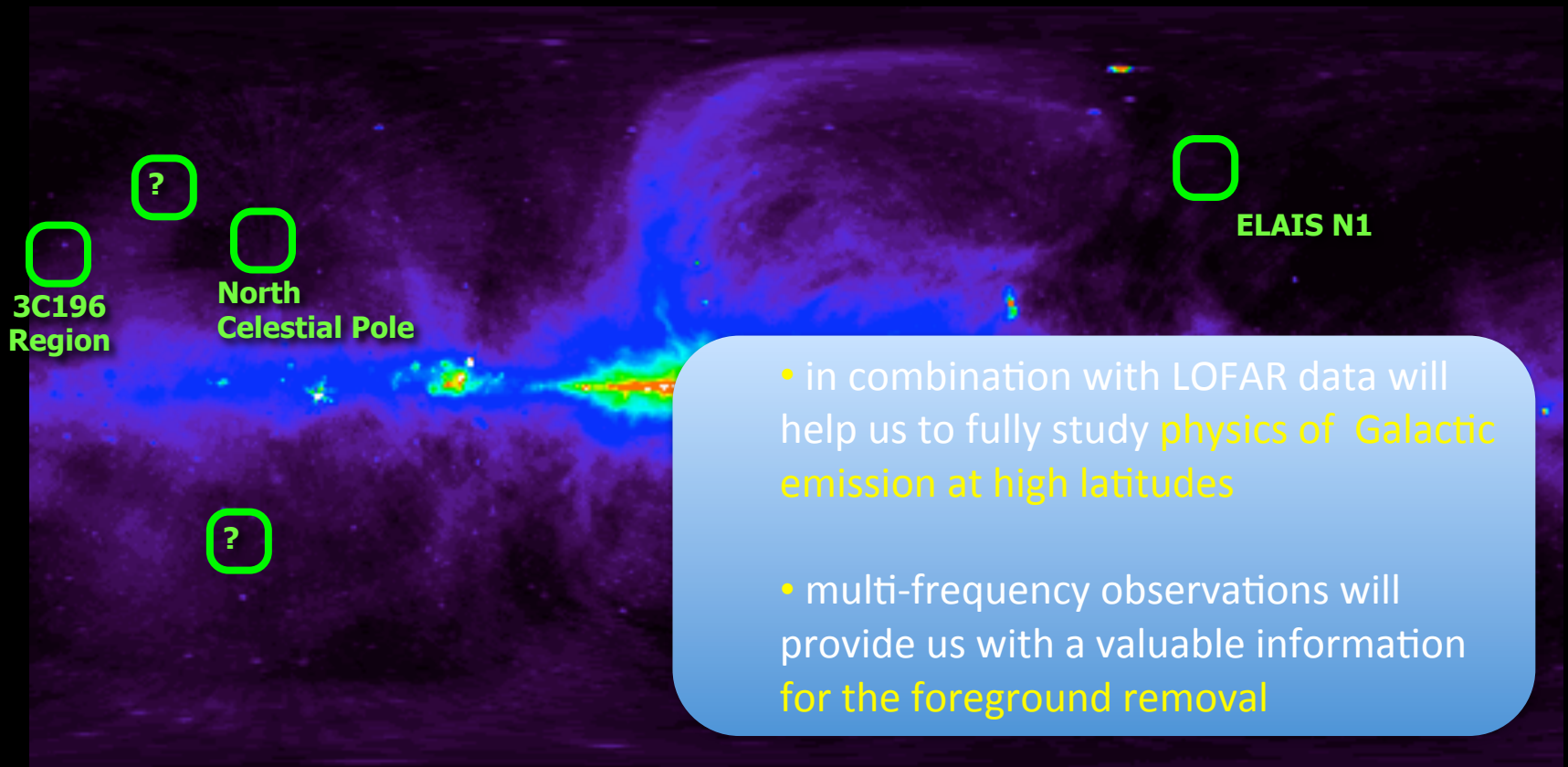
- with **LFFE@WSRT** telescope (115 – 170 MHz)



LOFAR-EoR experiment: **observations**

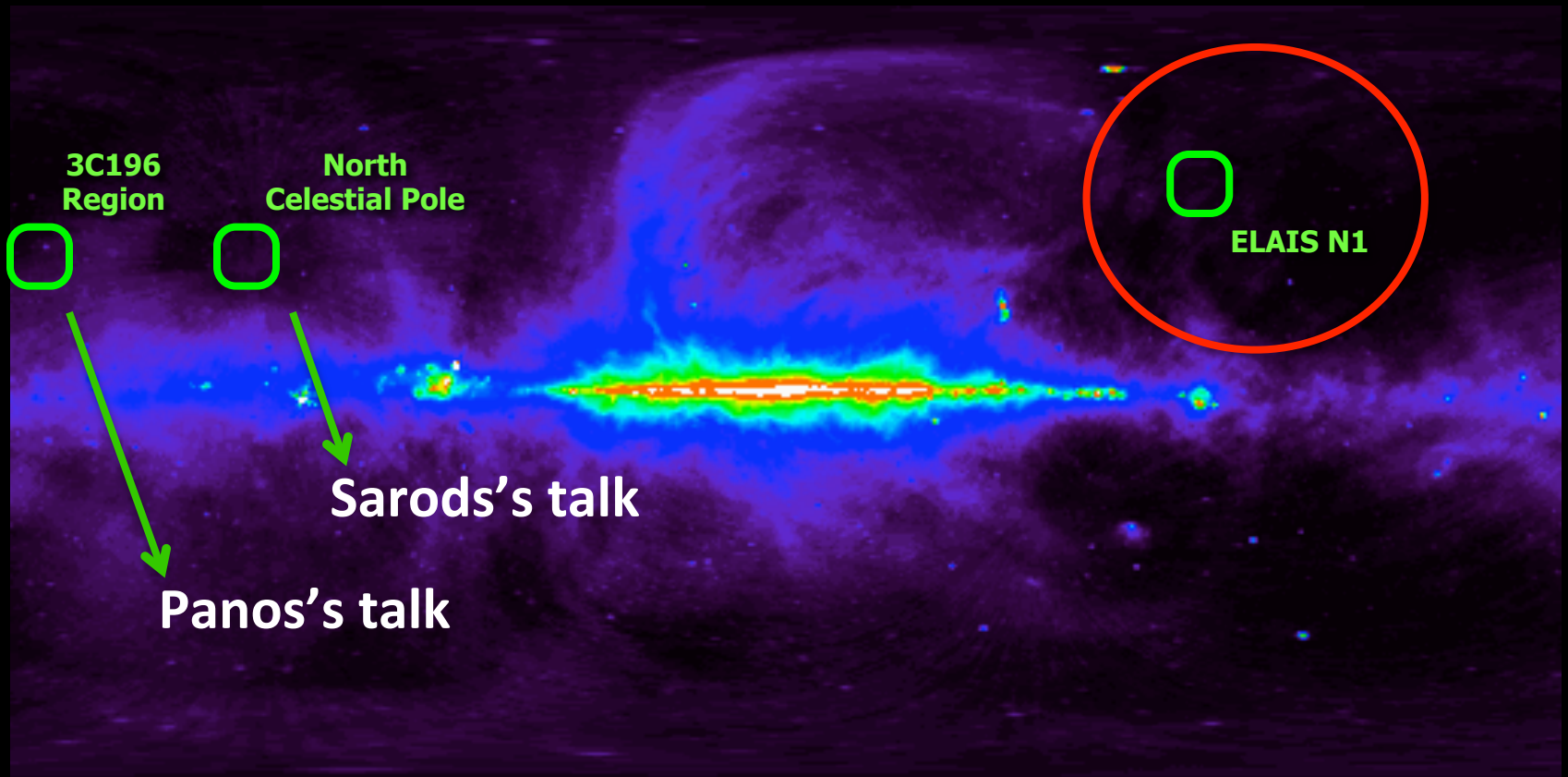
- with **WSRT 350 MHz** system (195h)

PI: Ger de Bruyn



LOFAR-EoR experiment: observations

- with LOFAR telescope: commissioning data

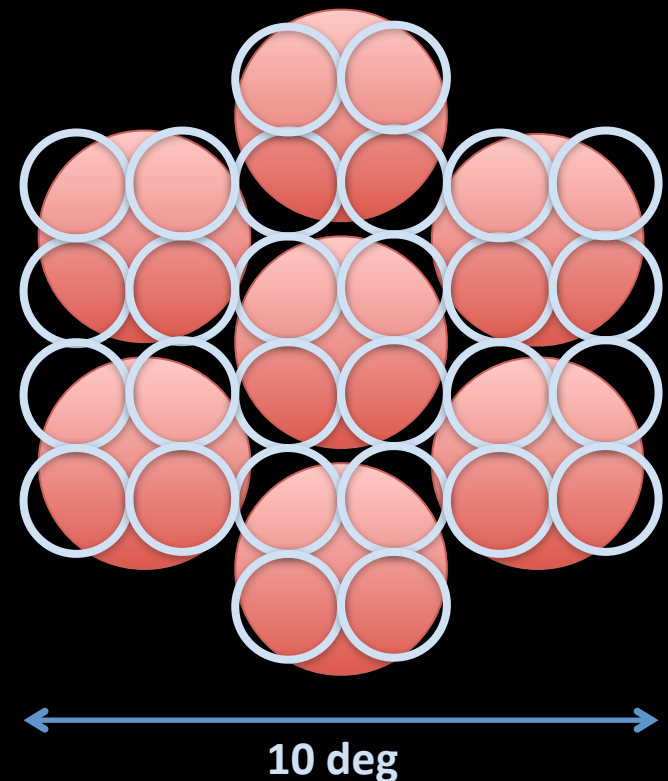


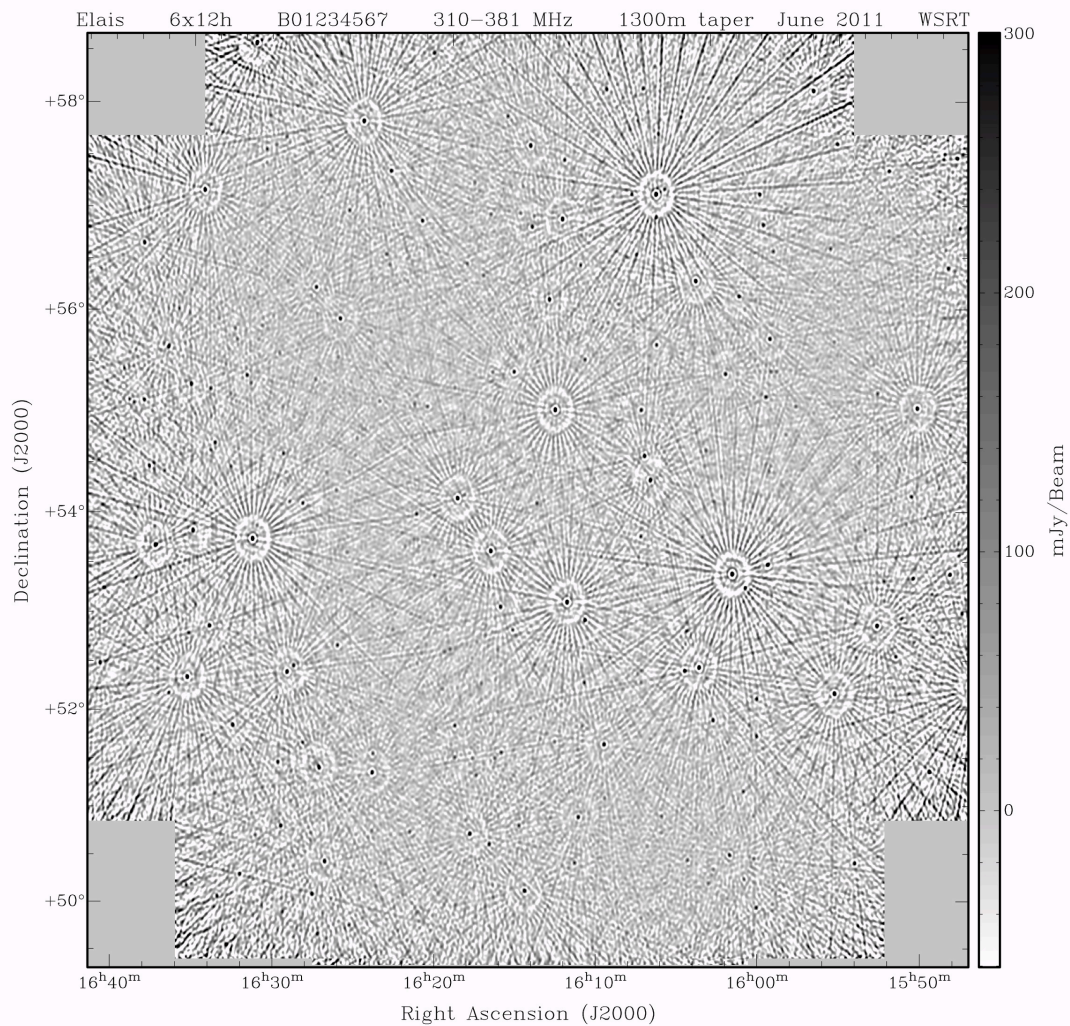
LOFAR-EoR experiment: Elais N1 field

- European Large Area ISO Survey – North 1 field
- RA 16h14m00s Dec +54:30:00
- motivation: one of Subaru fields and observed at many other wavelengths
- no bright sources (< 2 Jy)

WSRT 28-pointings observation
6 x 12h, 310-380 MHz

LOFAR HBA 7-beams observation
6h, 110 – 190 MHz

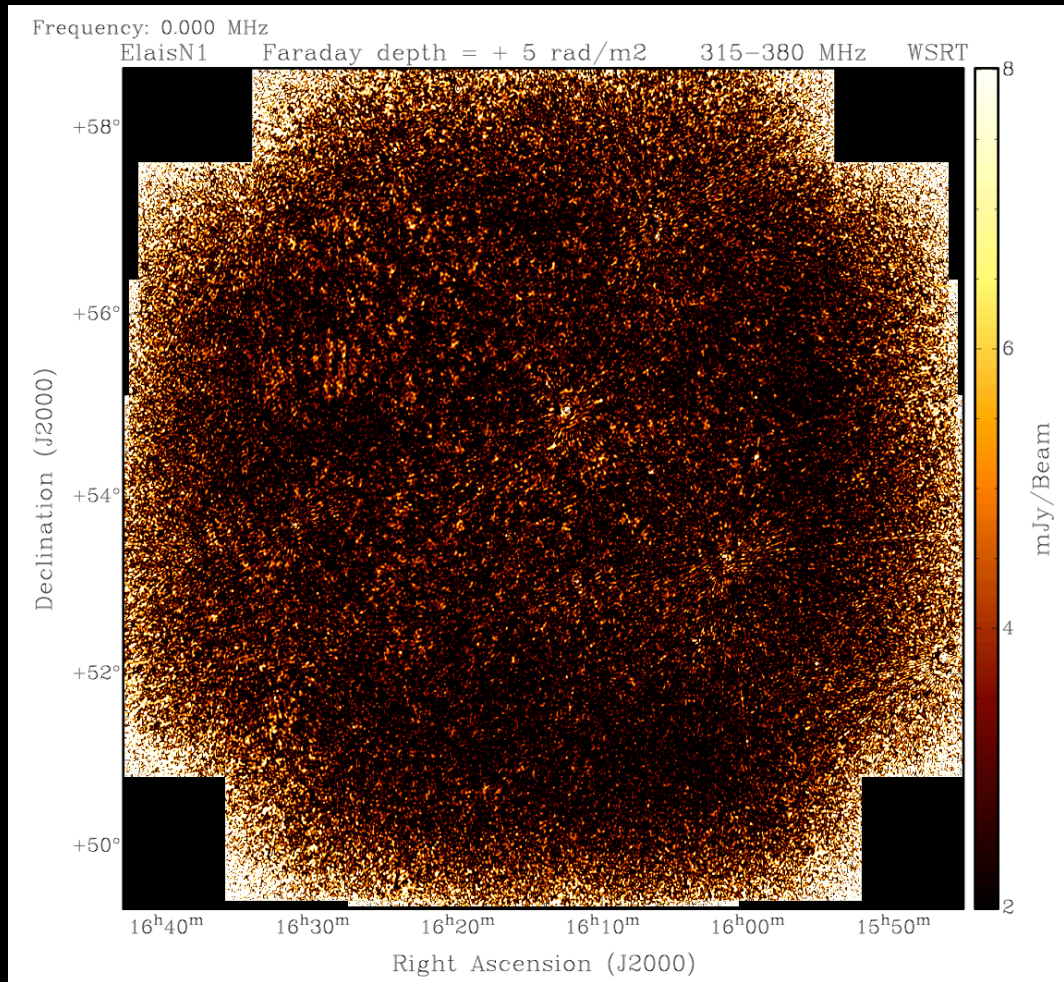




Ger de Bruyn (2011)

WSRT 28-pointings observation

LOFAR-EoR experiment: Elais N1 field



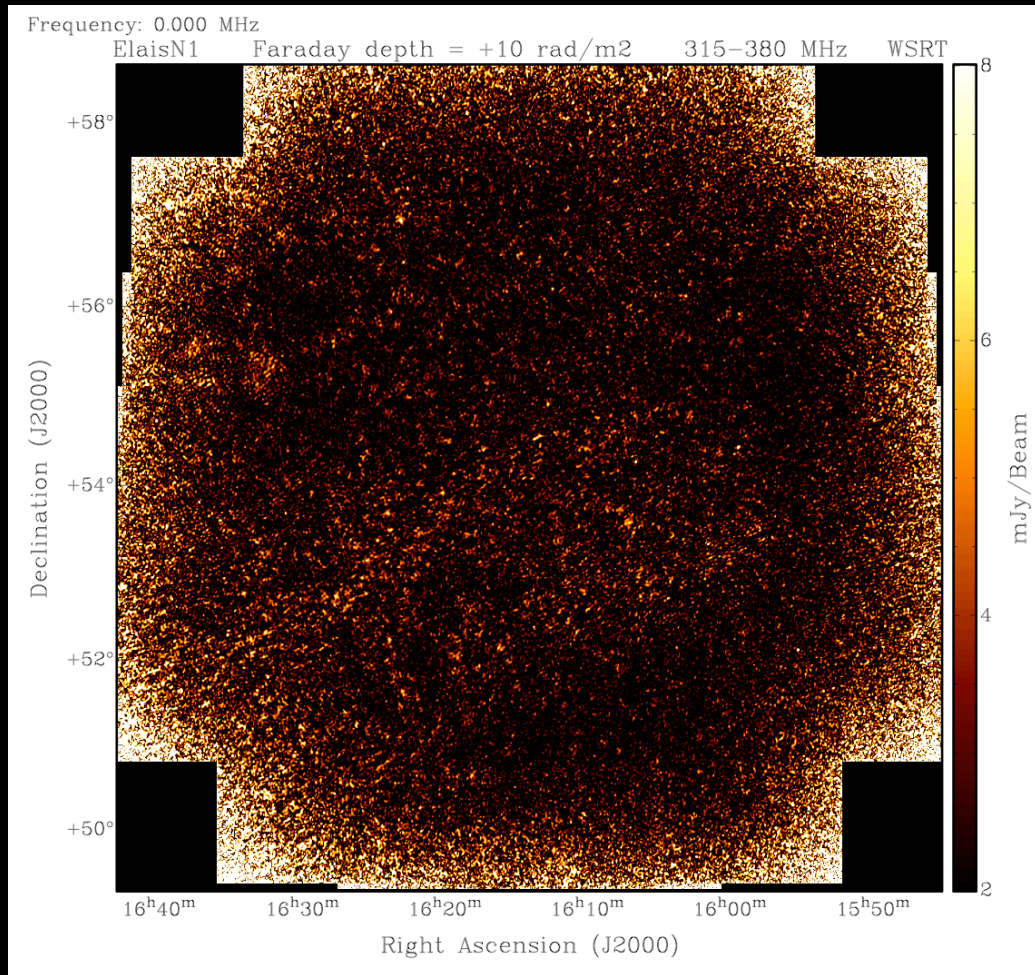
RM + 5 rad/m²

→ visible Galactic
polarized emission

Ger de Bruyn (2011)

WSRT 28-pointings observation

LOFAR-EoR experiment: Elais N1 field



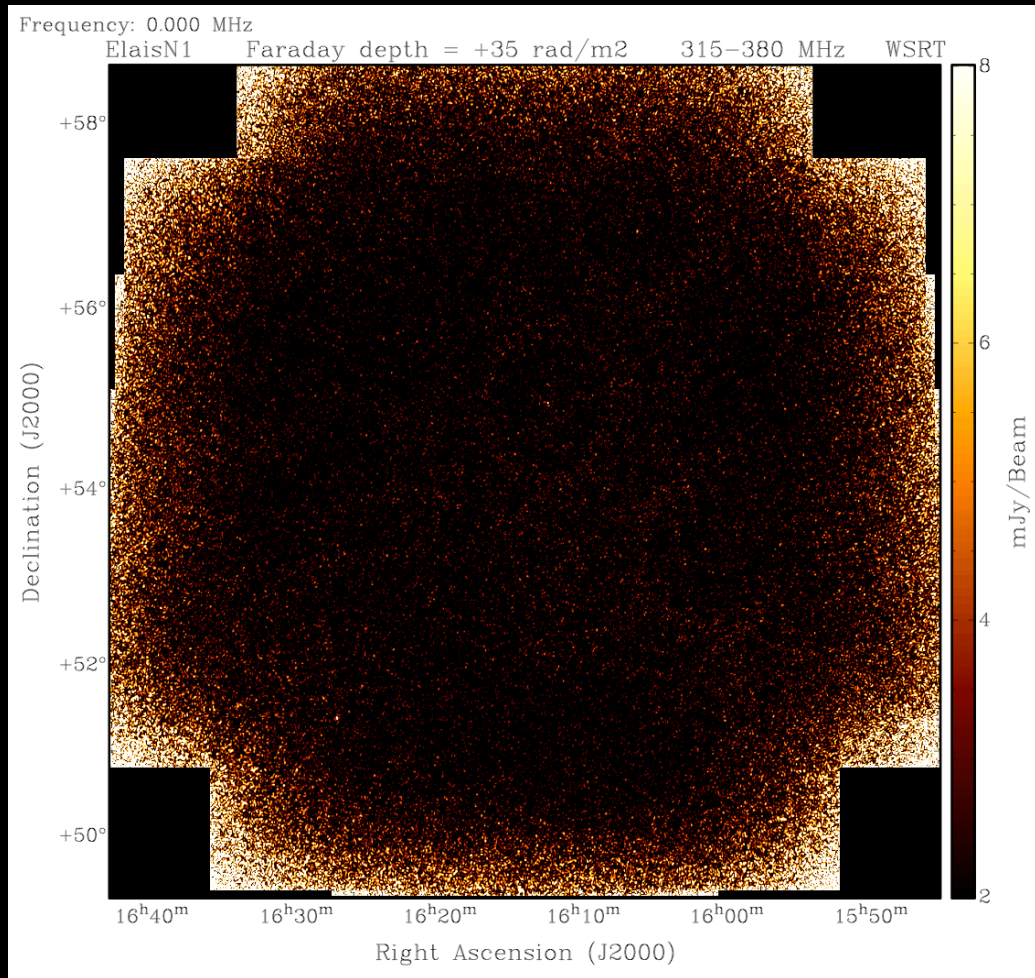
RM + 10 rad/m²

→ visible Galactic polarized emission

Ger de Bruyn (2011)

WSRT 28-pointings observation

LOFAR-EoR experiment: Elais N1 field



RM + 15 rad/m²

Ger de Bruyn (2011)

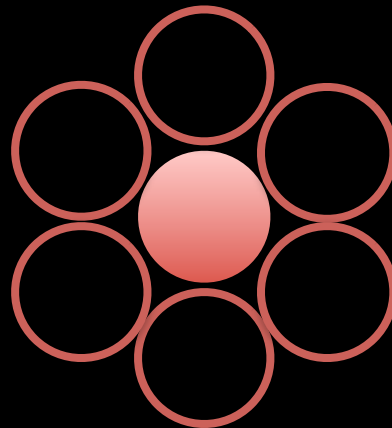
WSRT 28-pointings observation

LOFAR-EoR experiment: Elais N1 field

LOFAR 7-beams observation

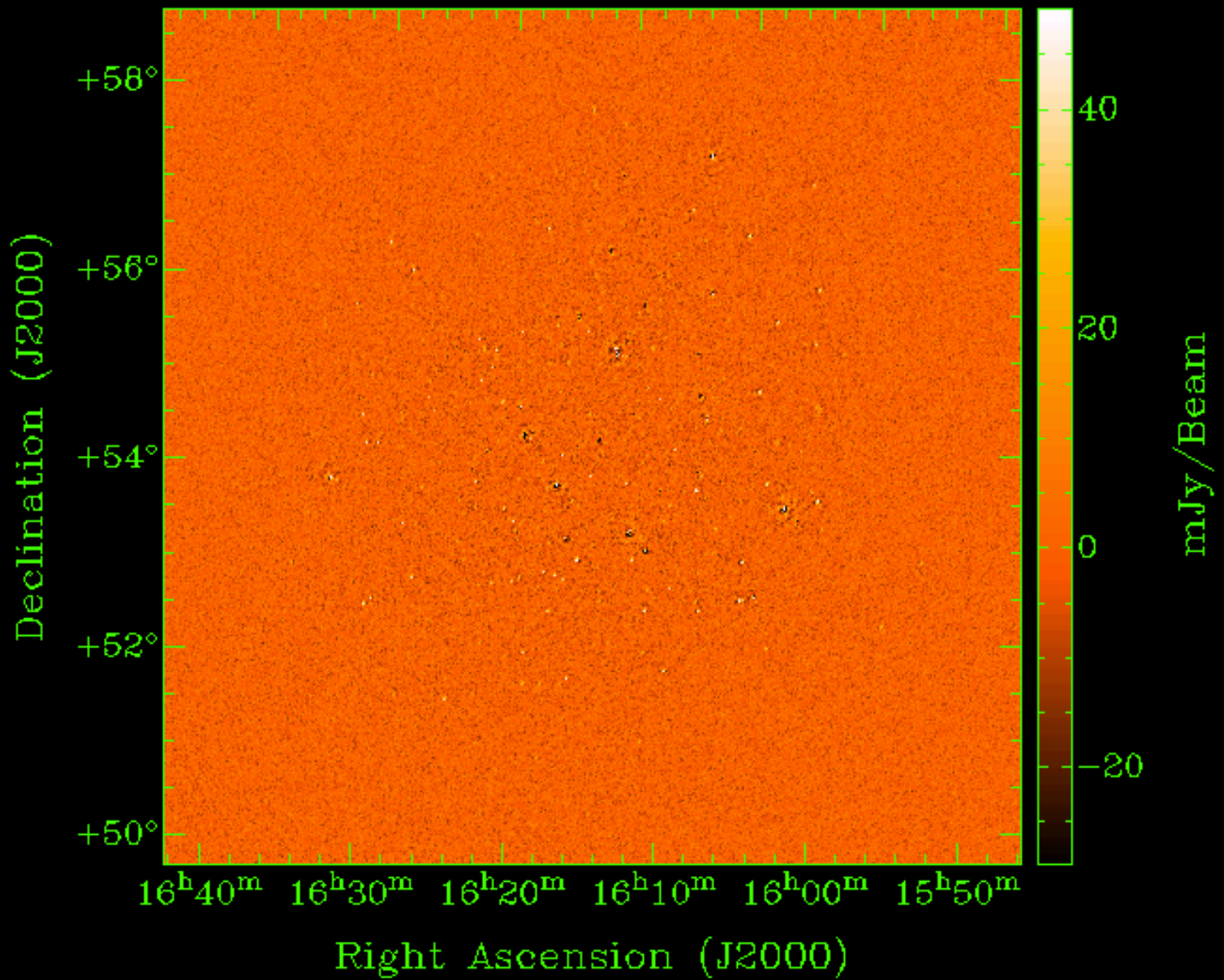
6h, 110 – 190 MHz, 238 (7x34) subbands

- preprocessed with NDPPP and *Andre Offringa flagger*
- calibration was done on the *EoR cluster* using BBS
- sky models were produced using *BuildSky* (*Sarod Yatawatta*) and WENSS data and were later updated using LOFAR data
 - poor signal-to-noise ratio makes calibration difficult

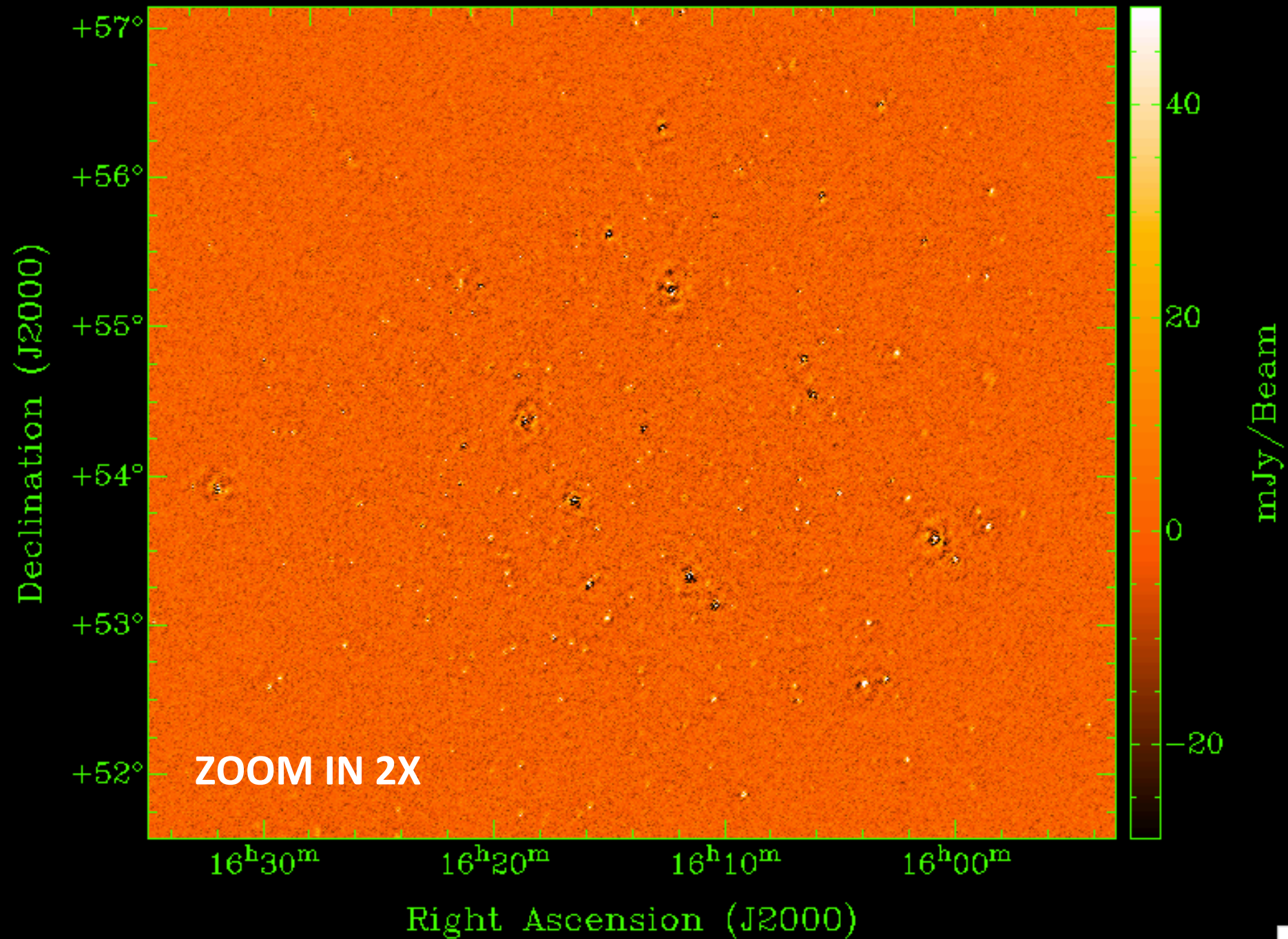


→ central field image avg.
over 34 subbands
(preliminary results)

BEAM→0



BEAM→0



BEAM \rightarrow 0

Declination (J2000)

+55°30'
+55°00'
+54°30'
+54°00'
+53°30'

ZOOM IN 4X

16^h20^m

15^m

10^m

Right Ascension (J2000)

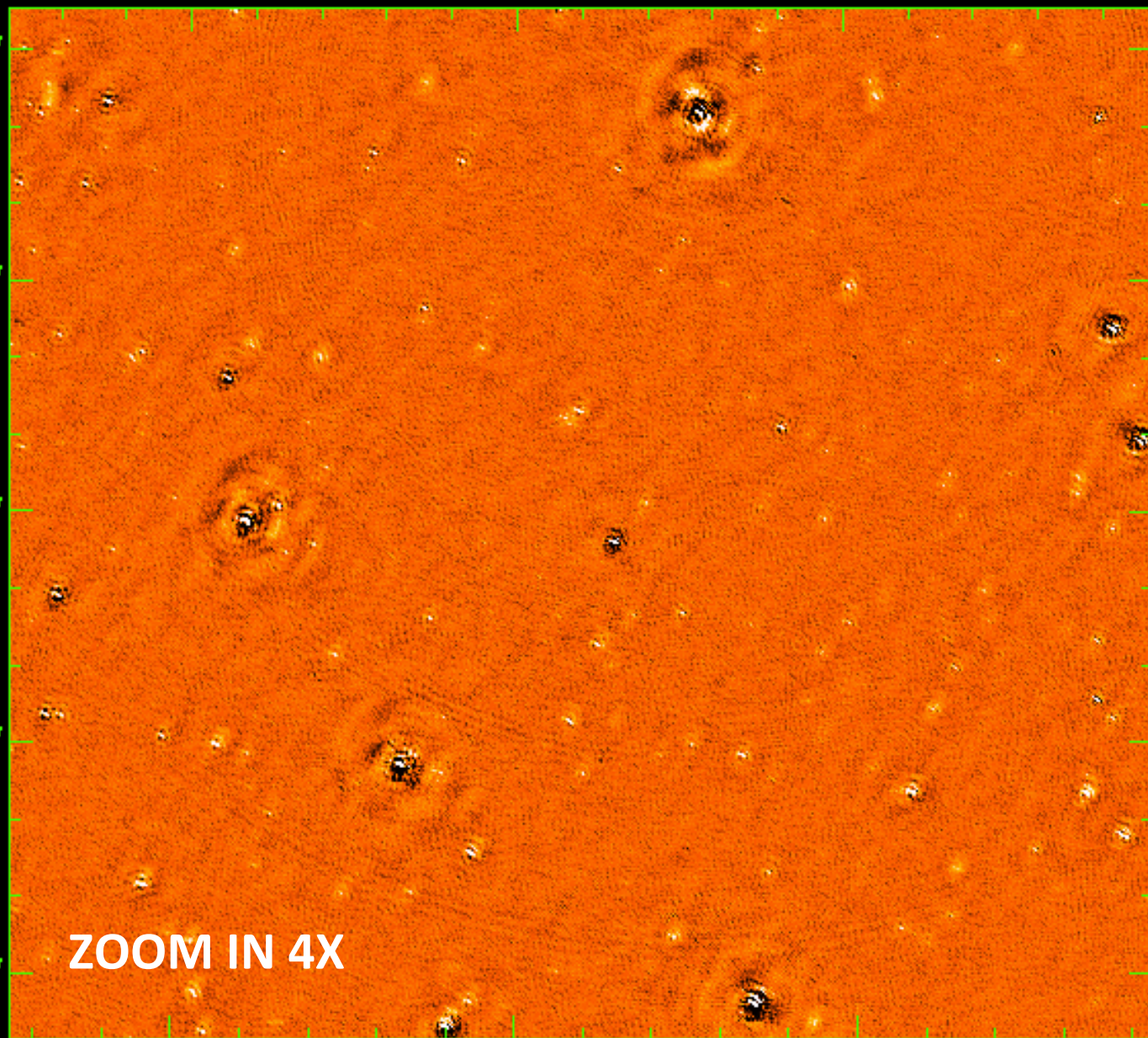
40

20

0

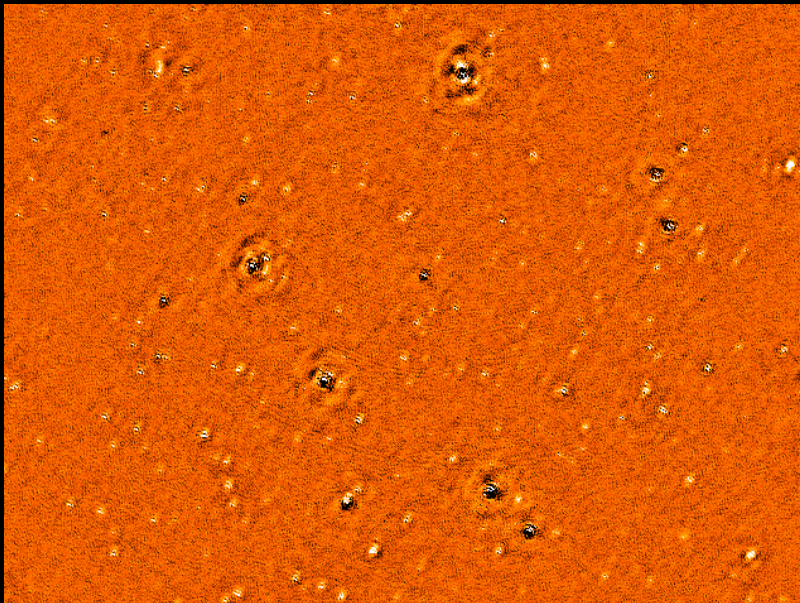
-20

mJy/Beam

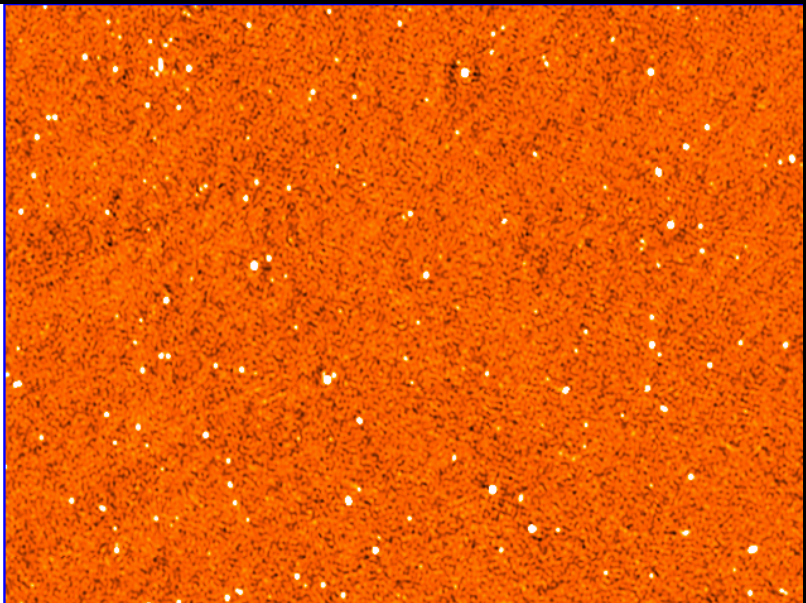


LOFAR-EoR experiment: Elais N1 field

LOFAR



WENSS

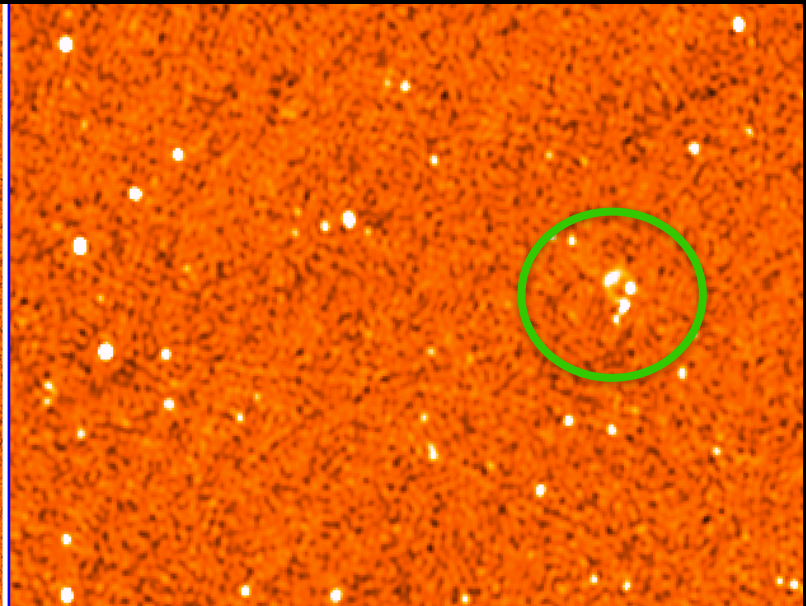


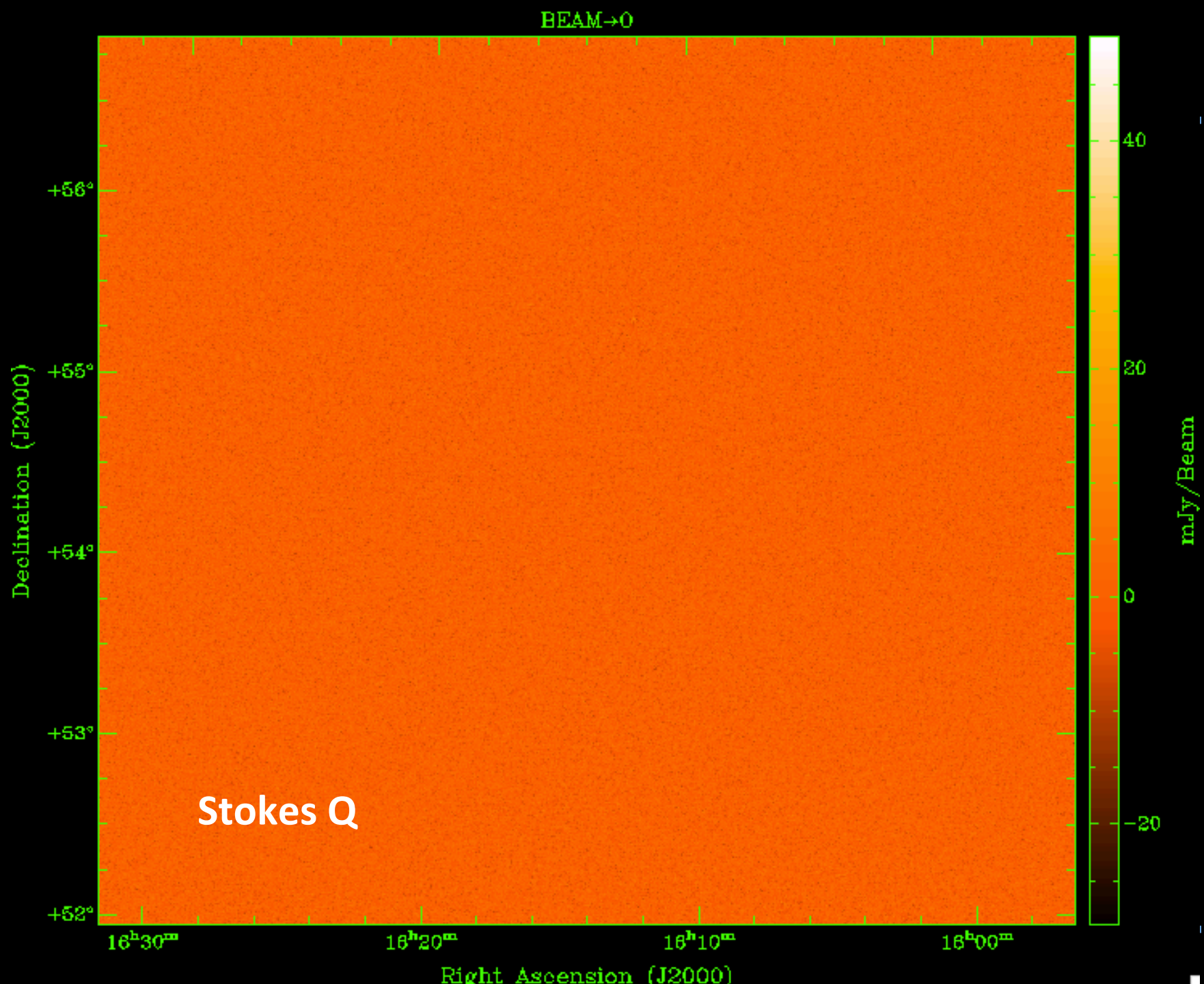
LOFAR-EoR experiment: Elais N1 field

LOFAR

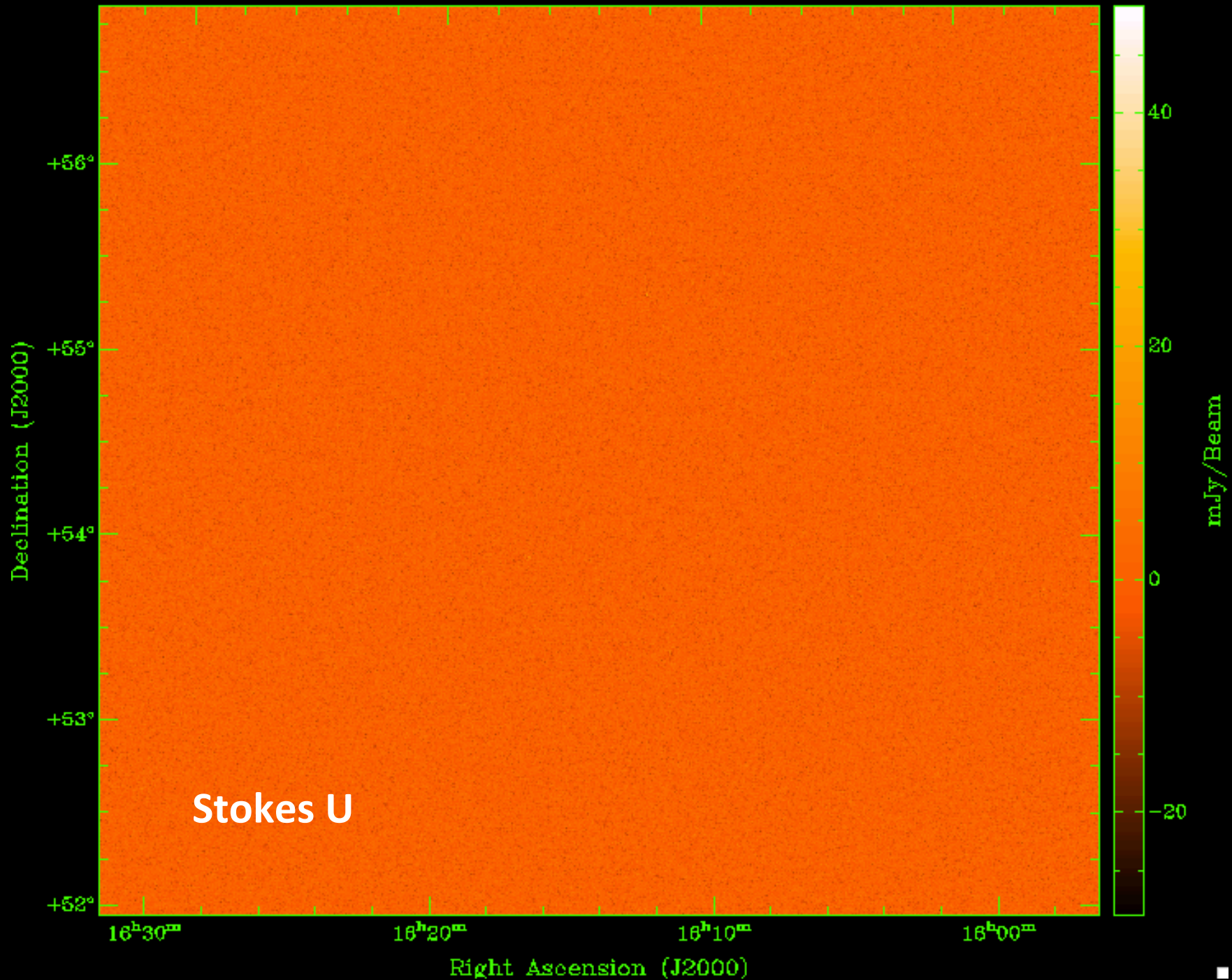


WENSS

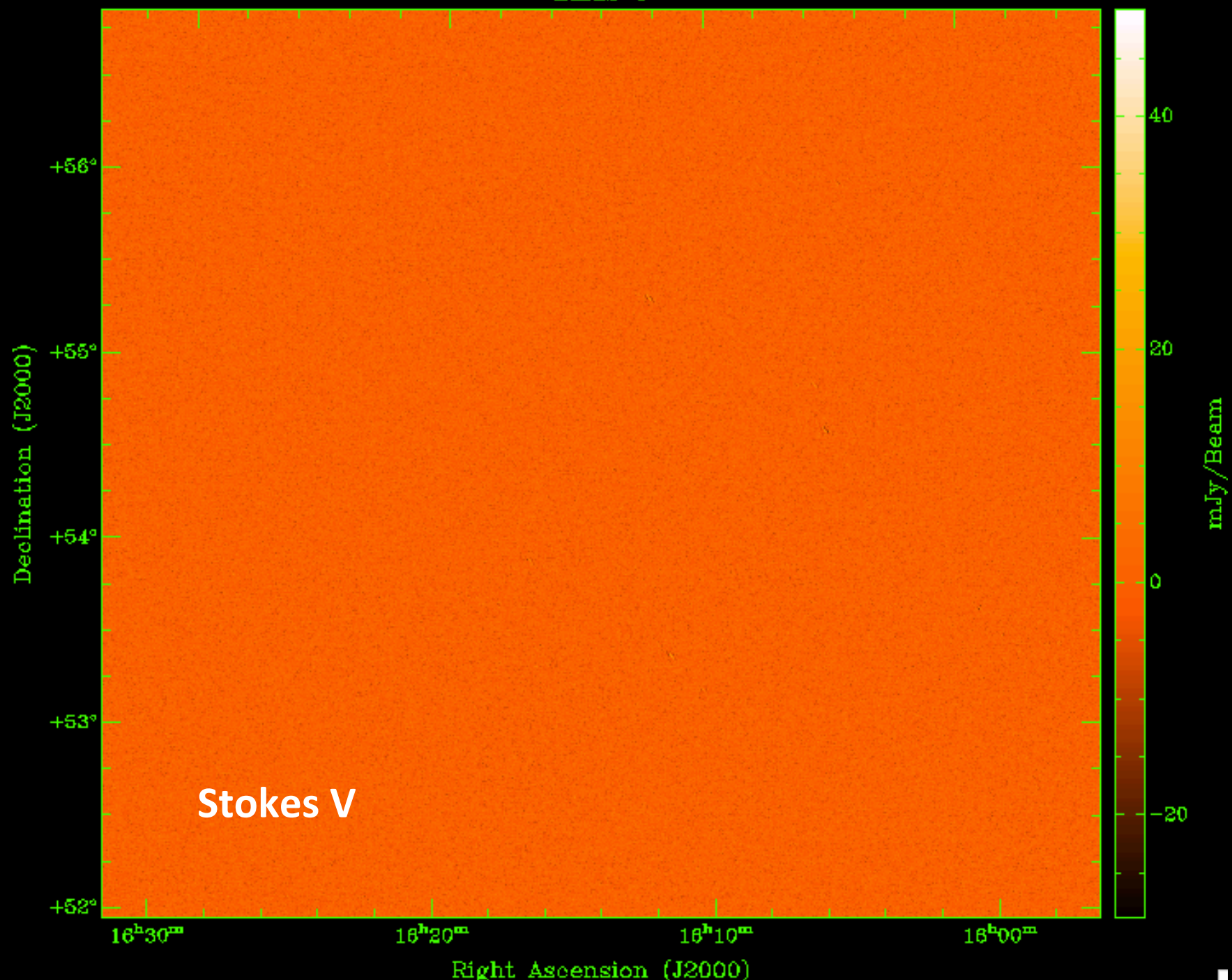




BEAM→0



BEAM→0



Conclusions & Future Plans

ELAIS N1 field

- reached noise level of 2 mJy in avg. 33 sb image
- better sky model and further analysis needed to reach thermal noise in the images (e.g. direction dependent calibration)
- no detection of Galactic polarized emission – need to be confirmed by further analysis

➤ **STILL POSSIBLE EoR FIELD**

Shallow EoR survey needed

- To find other possible EoR windows

THANK YOU FOR YOUR ATTENTION !

www.lofar.org
www.astro.rug.nl/~LofarEoR