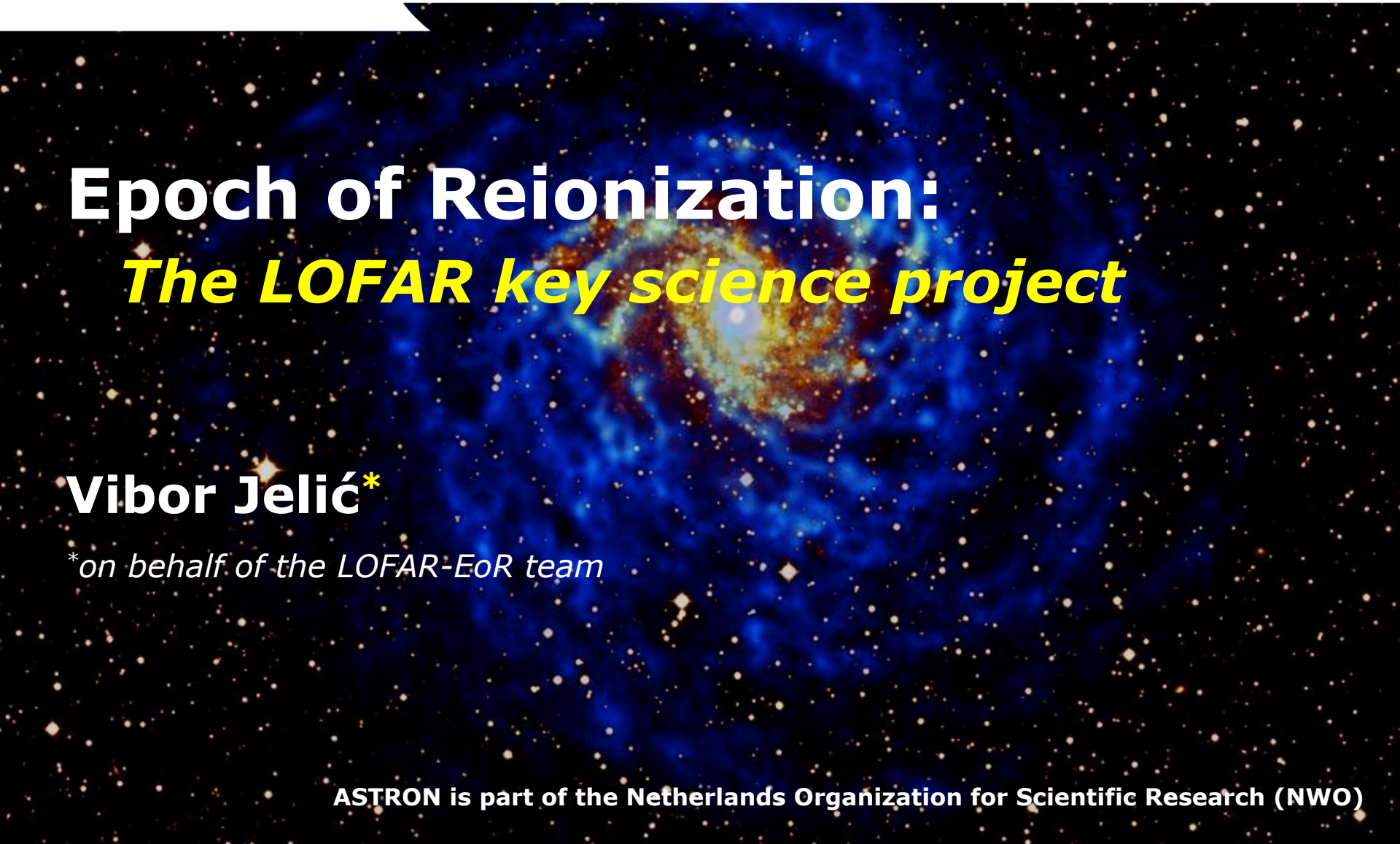
ASTRON

Netherlands Institute for Radio Astronomy

LOFAR NWO



Epoch of Reionization:

The LOFAR key science project

Vibor Jelić*

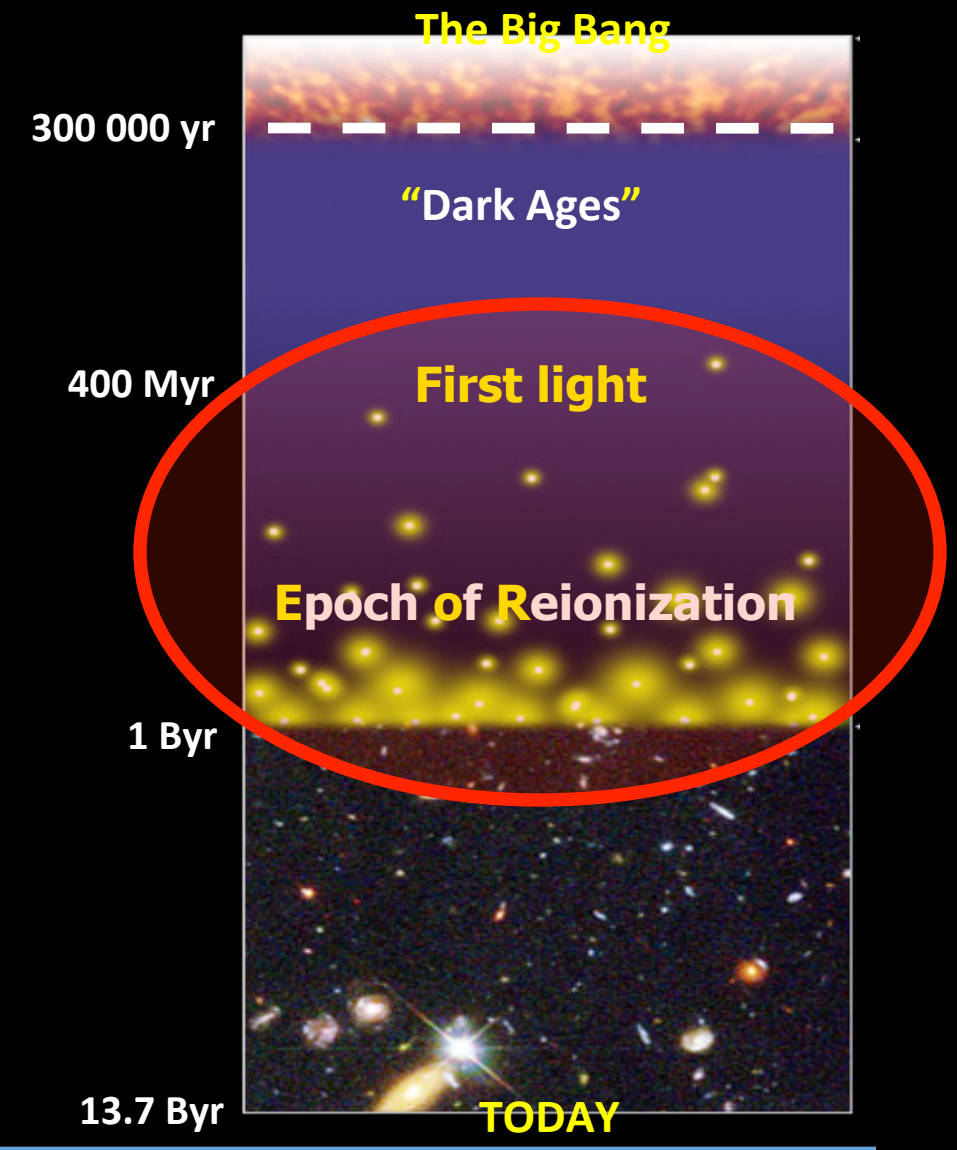
**on behalf of the LOFAR-EoR team*

ASTRON is part of the Netherlands Organization for Scientific Research (NWO)

Outline

- **Introduction**
  - Epoch of Reionization
- **LOFAR-EoR experiment**
  - Challenges
  - Simulations and the LOFAR-EoR pipeline
  - Observations and Commissioning results
- **Summary and Future**

Epoch of Reionization



SHORT HISTORY OF THE UNIVERSE

Epoch of Reionization

Observational constrains – limited information:

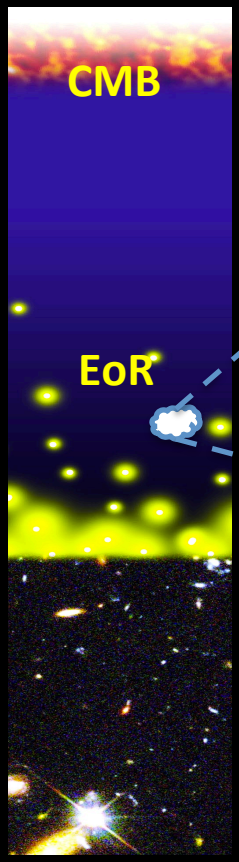
- CMB data
- QSOs spectra

- **WHEN** exactly the reionization had happened ?
- **WHAT** were the first sources that reionized the Universe ?
- **HOW** reionization had happened ?

➔ need for a direct probe
of the Epoch of Reionization

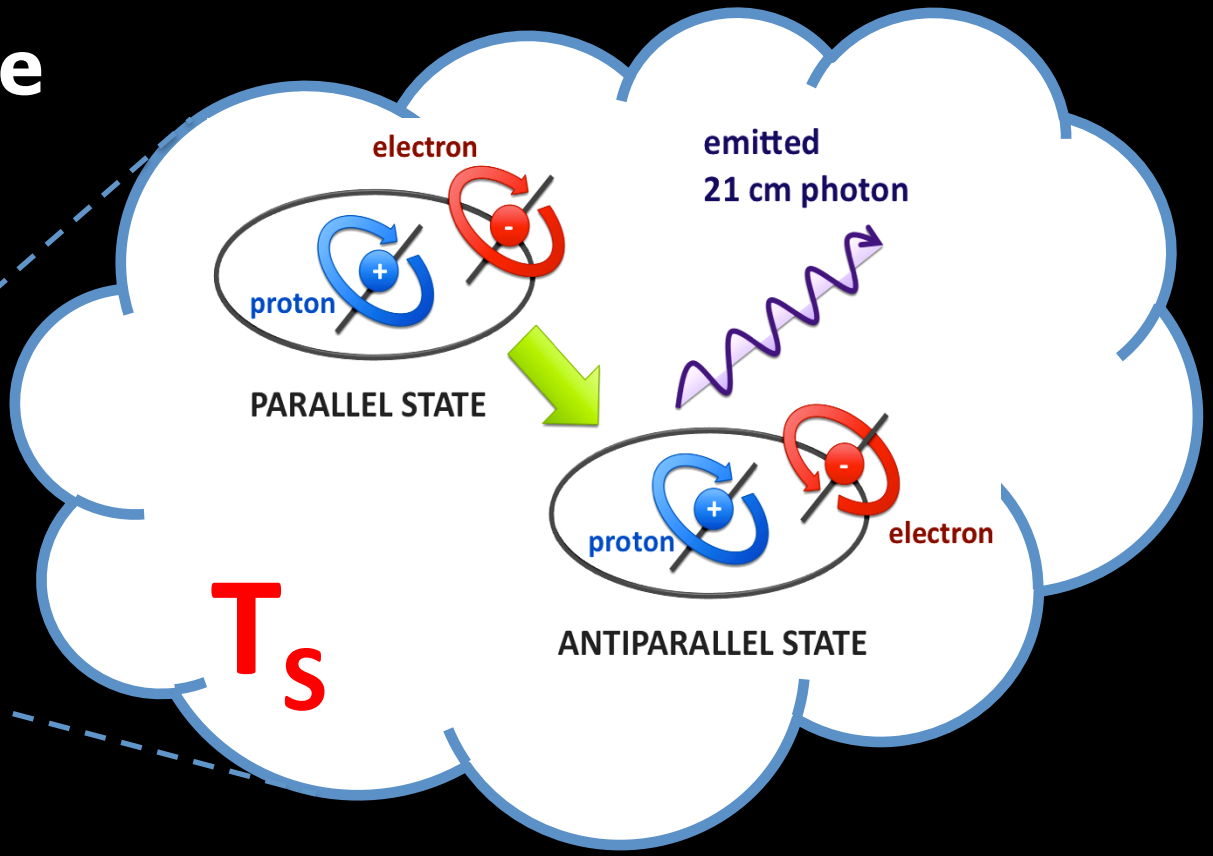
Epoch of Reionization

- H **21cm** line



21 cm

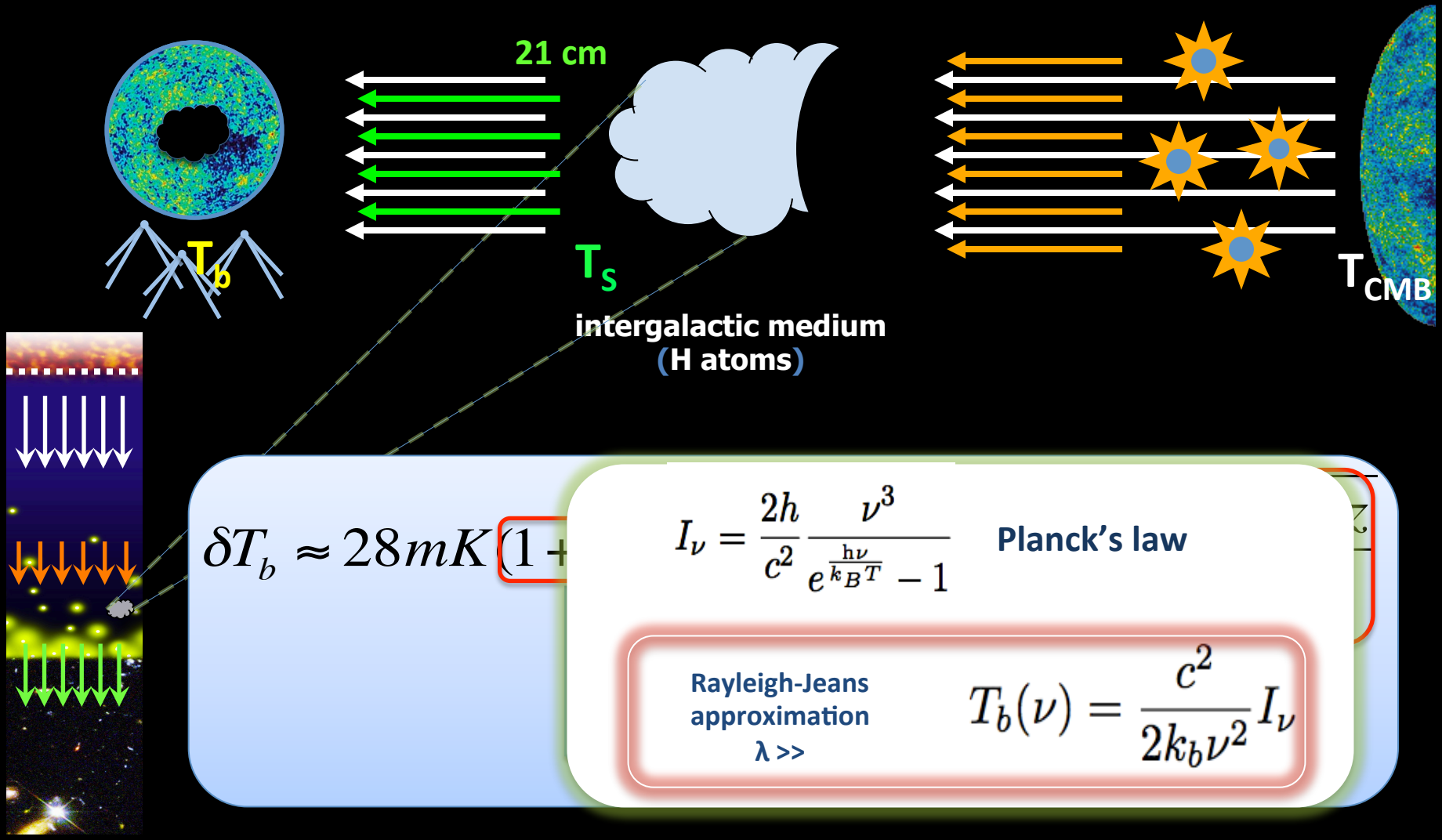
1.5-2.5 m



$$\frac{n_1}{n_0} \propto \exp(-E_{21cm}/k_b T_S)$$

Boltzmann distribution

Epoch of Reionization



$$\delta T_b \approx 28mK(1+$$

$$I_\nu = \frac{2h}{c^2}\frac{\nu^3}{e^{\frac{h\nu}{k_B T}} - 1}$$ Planck's law

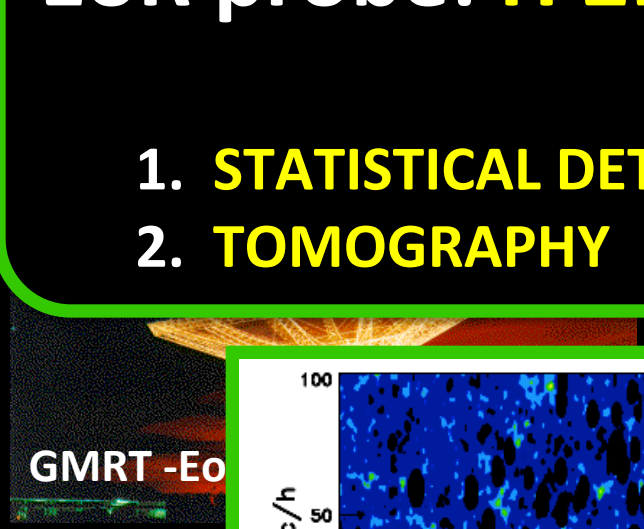
Rayleigh-Jeans approximation
λ >>

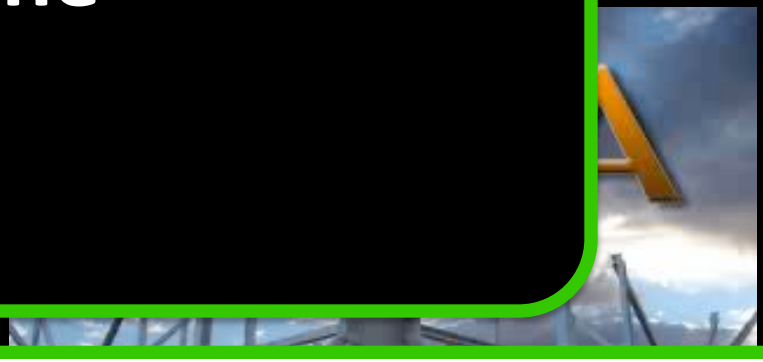
$$T_b(\nu) = \frac{c^2}{2k_b\nu^2} I_\nu$$

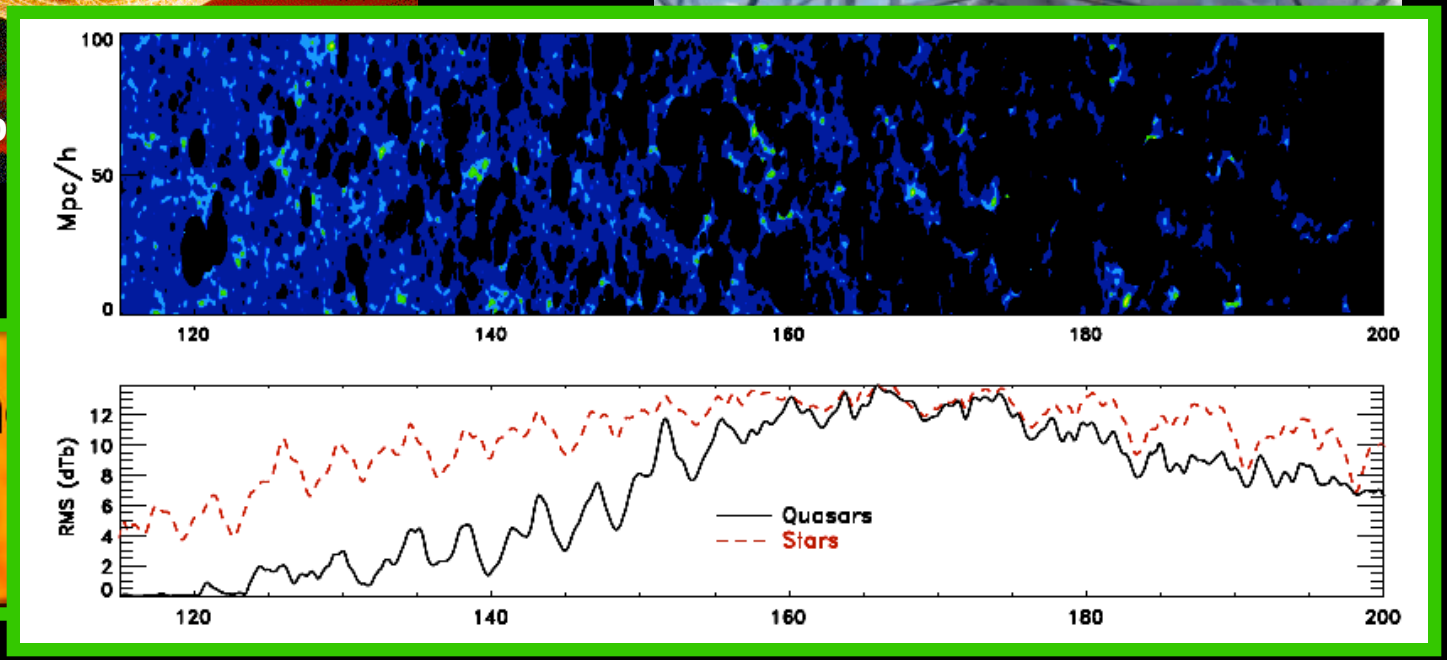
Epoch of Reionization

EoR probe: H 21cm line

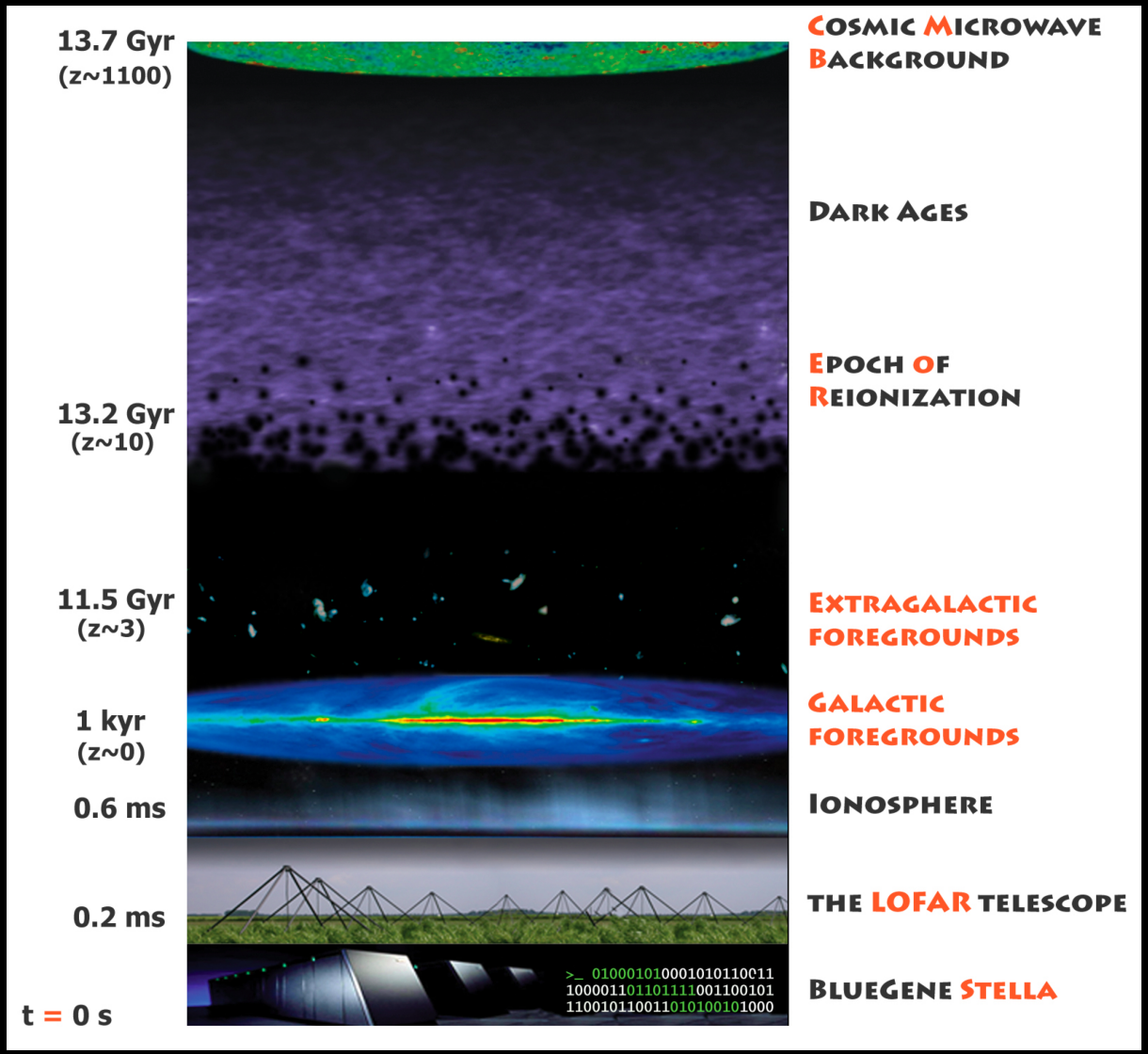
1. STATISTICAL DETECTION
2. TOMOGRAPHY







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

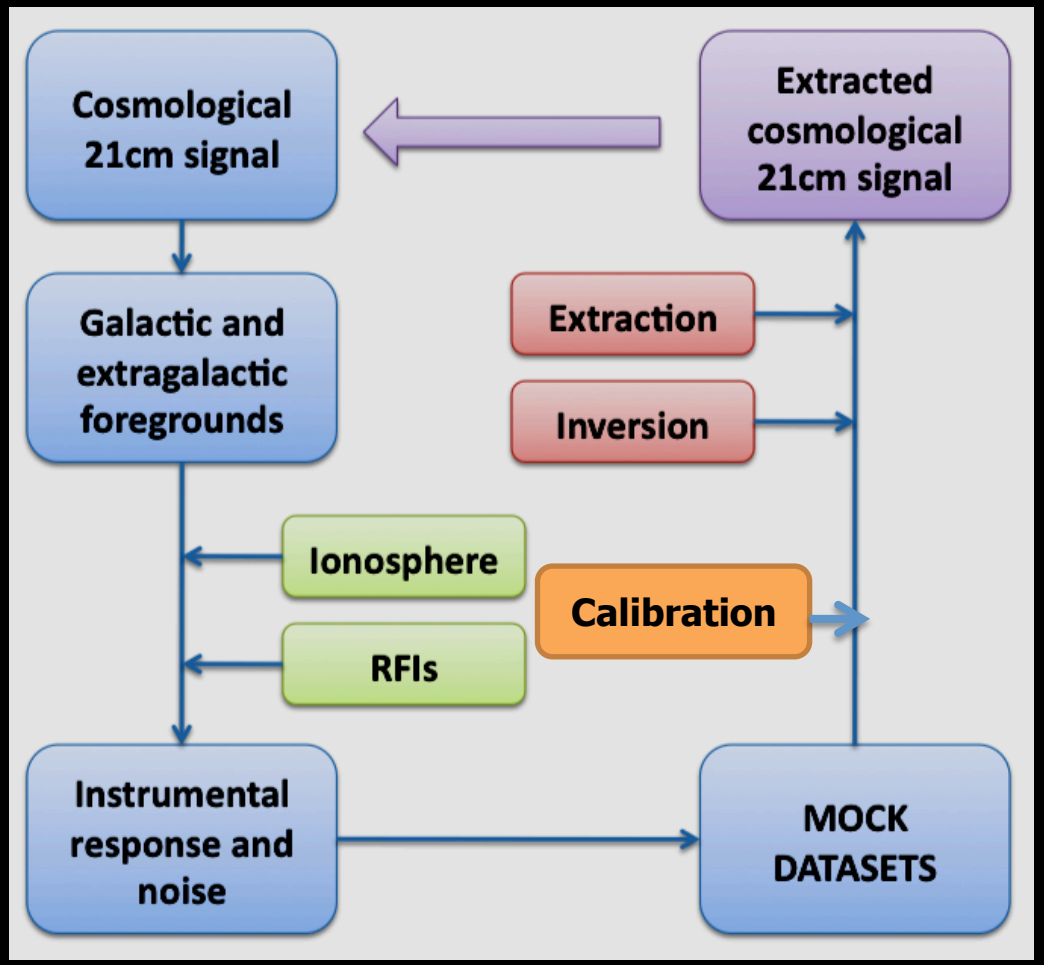
LOFAR-EoR experiment: end-to-end pipeline

R. Thomas
PhD thesis

V. Jelić
PhD thesis

A. Offringa
PhD thesis

P. Lambropuolos
PhD thesis



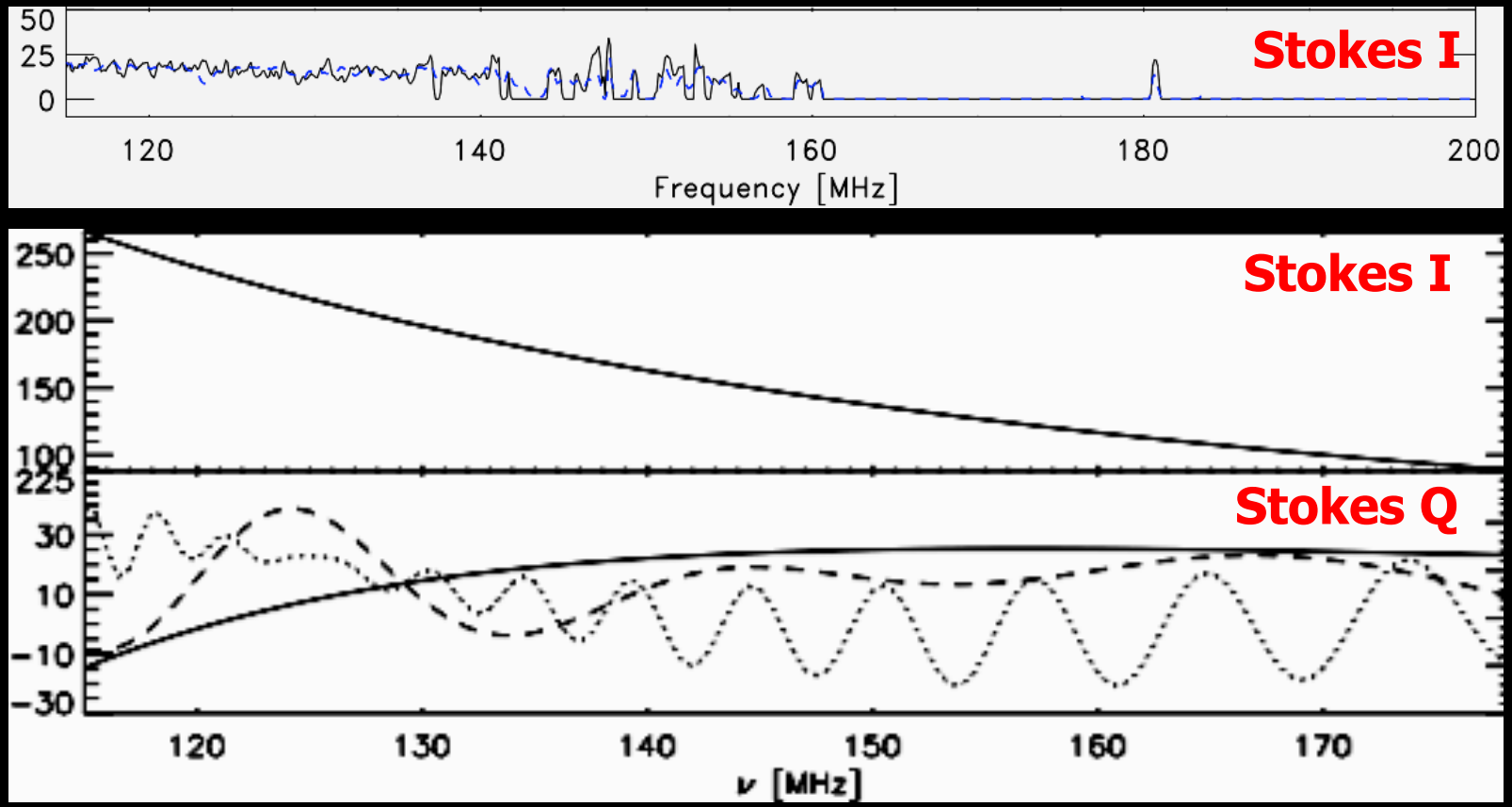
Jelic et al 2008
Harker at al 2009a
Harker et al 2009b
Harker et al 2010

Yatawatta et al 2009
Kazemi at al 2011

Extraction of the 21cm signal: simulations

EoR

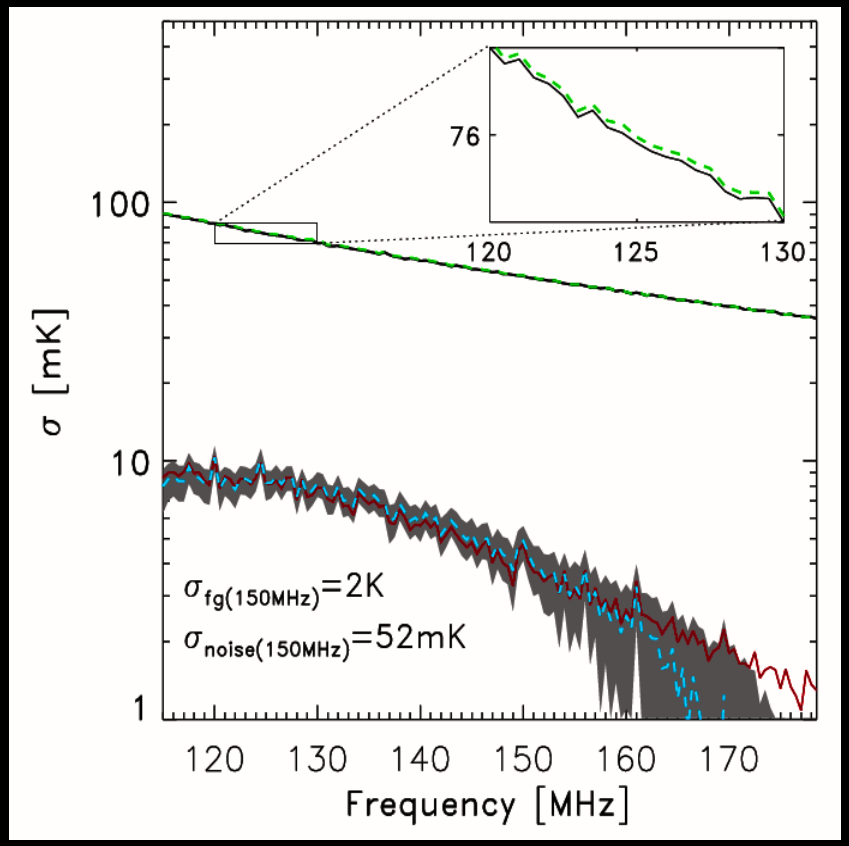
foregrounds



- extraction is based on smoothness of the foregrounds in total intensity
- the leaked polarized emission can mimic the cosmological signal: extraction much more difficult

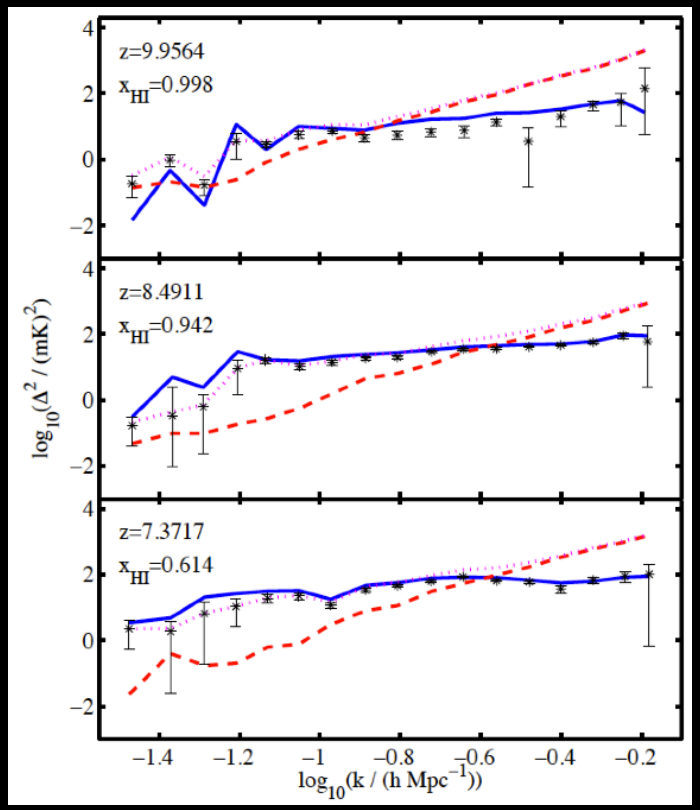
(*Jelic et al. 2008; Harker et al. 2009, Chapman et al., in prep.*)

Statistical detection of the 21cm signal: simulations



standard deviation and higher order statistics
Jelic et al. 2008, Harker et al. 2009

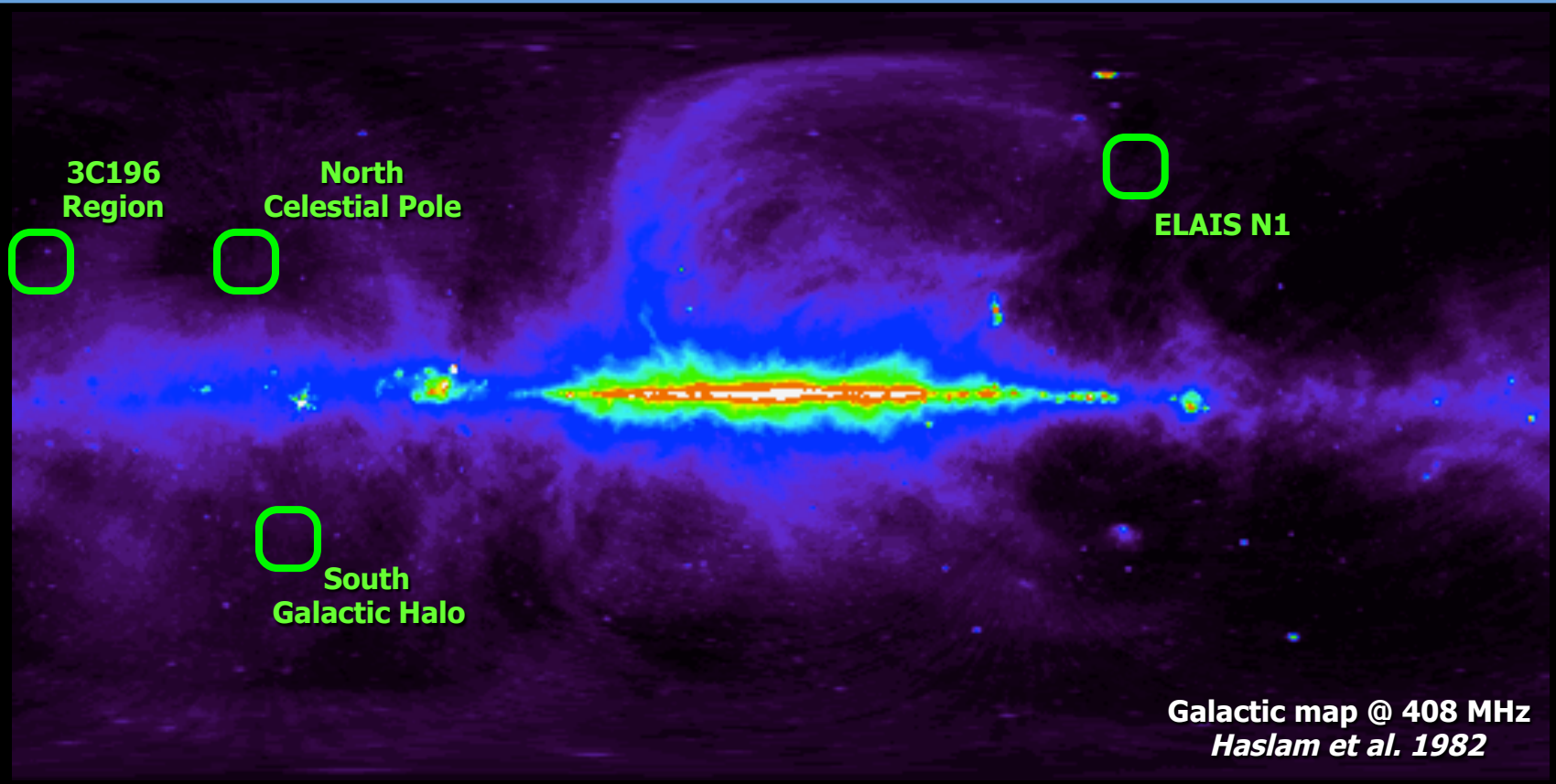
Power spectrum
Harker et al. 2010



LOFAR-EoR experiment: observing windows

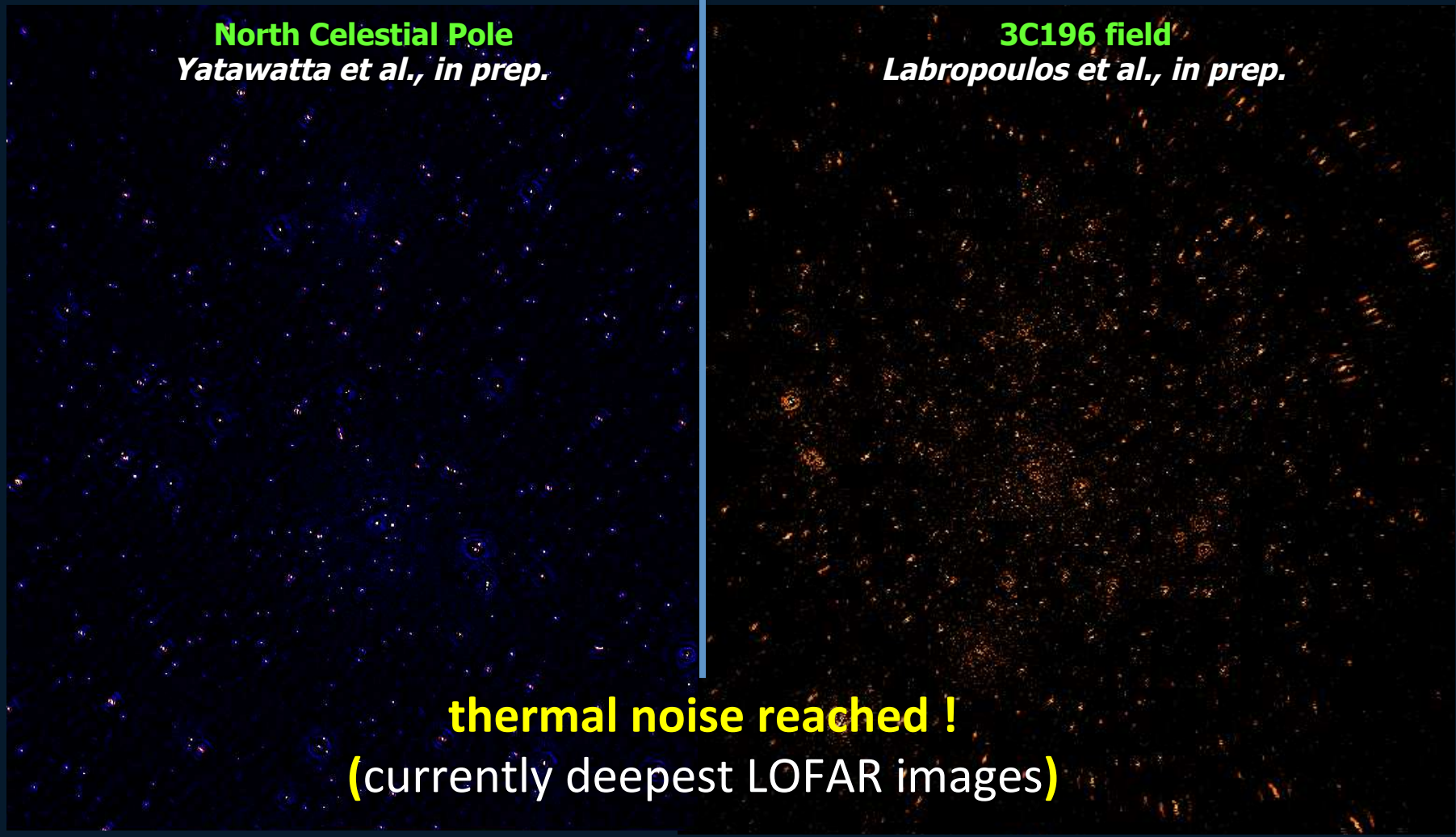
- ✓ **low Galactic emission**
  - both in total and polarized intensity
  - at high Galactic latitudes
- ✓ **“easy”sources for calibration**
- ✓ **available data at other frequencies**

LOFAR-EoR experiment: observations



- with WSRT telescope (*Bernardi et al 2009, 2010*)
  LFFE (115 – 170 MHz) and 350 MHz system
- with LOFAR telescope

LOFAR-EoR experiment: commissioning data

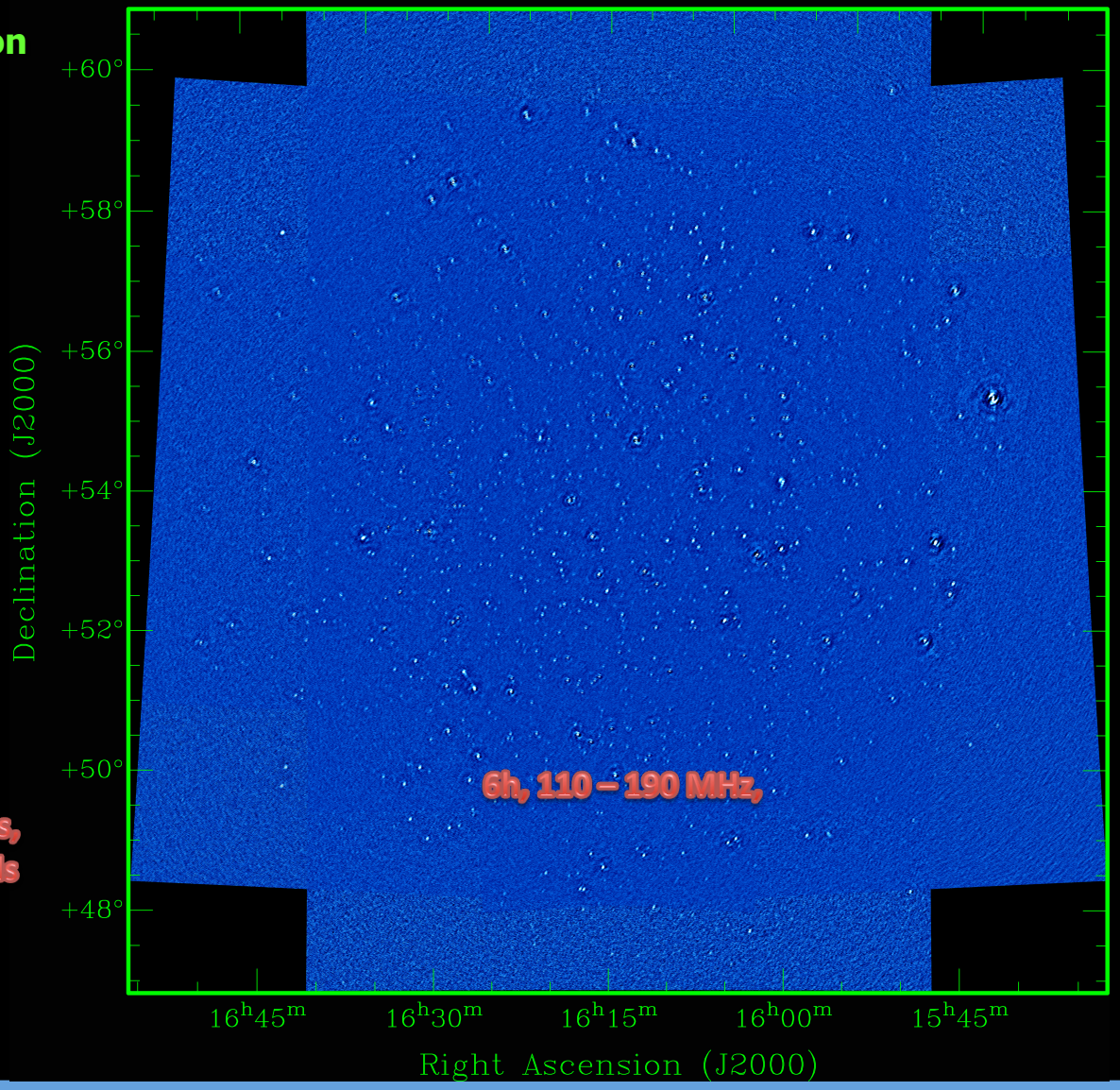


thermal noise reached !

(currently deepest LOFAR images)

LOFAR-EoR experiment: commissioning data

ELAIS 7 beams observation
Jelic et al., in prep.



238 (7x34) subbands,
images avg. over 34 subbands

Summary and Future

PRIMARY SCIENTIFIC GOAL

- detect cosmological 21cm signal from the Epoch of Reionization

SECONDARY SCIENTIFIC GOALS

- study the physics of the foregrounds
  (Galactic emission and magnetic fields, extragalactic sources)

LOFAR-EoR EXPERIMENT

- LOFAR – HBAs (112 – 190 MHz → z ~11-6)
- short baselines (core stations) for cosmological observations
- long baselines (NL + EU stations) to resolve foreground sources
- 5 observing windows (multi-beam observations)

Summary and Future

- the LOFAR telescope is ready and dedicated LOFAR-EoR observations should start in 2012
- by the end of 2012 we expect the first results !

The near future will be interesting and exciting !!!

ASTRON

Netherlands Institute for Radio Astronomy

LOFAR NWO

THANK YOU FOR YOUR ATTENTION !

www.lofar.org

www.astro.rug.nl/~LofarEoR