Faraday Tomography with LOFAR

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Background: IC342 as seen by LOFAR (Stokes I)

Faraday Tomography with LOFAR

- Faraday tomography
- First results: the IC342 field

Faraday rotation

- Faraday rotation causes polarization to rotate, with a wavelength dependence:

$$\Delta\psi = \lambda^2 \left(0.81 \int_0^d n_e \vec{B} \cdot d\vec{l} \right) = \lambda^2 \phi$$

- Multiple polarized sources at different distances rotate at different rates, and superimpose, producing non-linear behaviour.

Faraday rotation

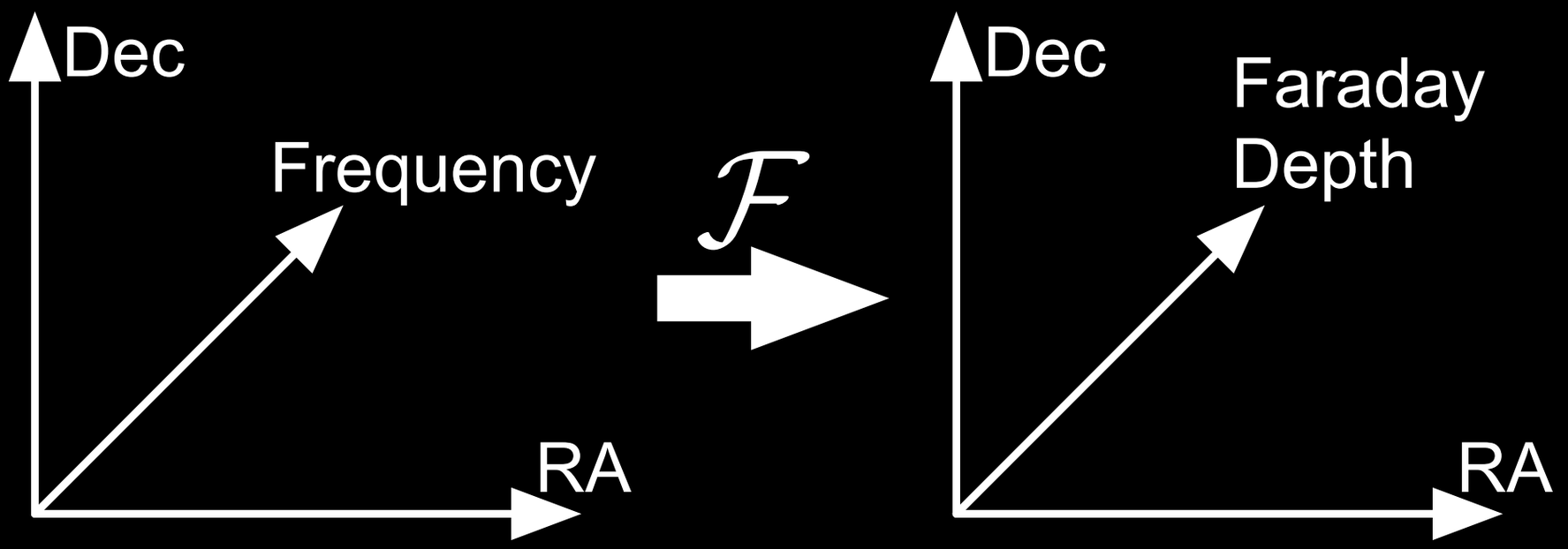
- Rotation is periodic, amenable to Fourier transform analysis:

$$P(\lambda^2) \xrightarrow{\mathcal{F}} P(\phi)$$

- Different polarized sources show up at different Faraday depths, can be identified and characterized.

Faraday Tomography

- Broad-band radio polarization cubes can be transformed into Faraday depth cubes:



- Weak polarized emission at all frequencies is concentrated into only a few frames in the Faraday cube.

Faraday Tomography

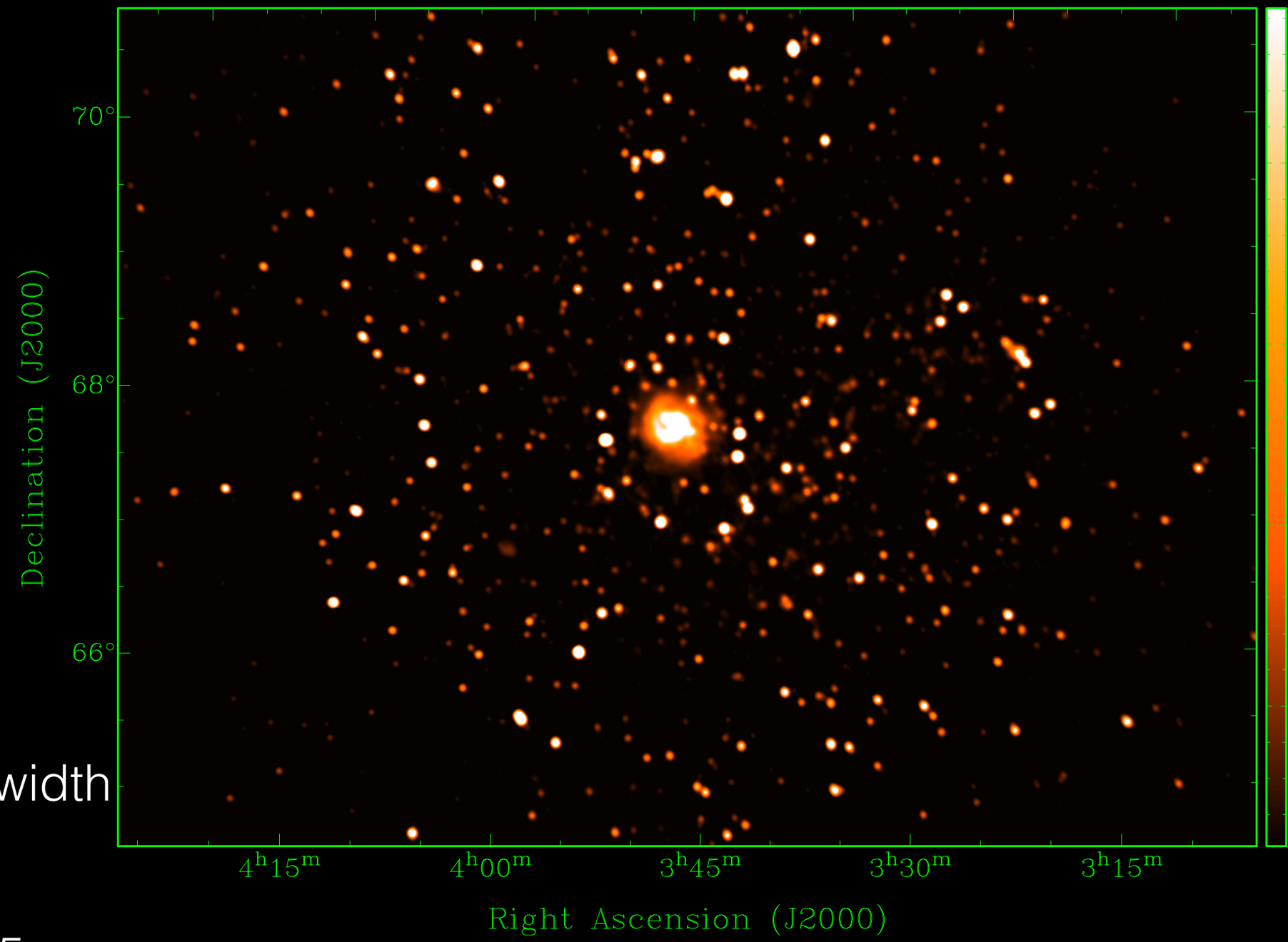
- Resolution in Faraday depth space depends on the wavelength coverage: broader coverage gives better resolution.

- LOFAR has extremely good Faraday depth resolution, around 1 rad/m^2, due to its large fractional bandwidth and long wavelengths.

IC342: Data and Science

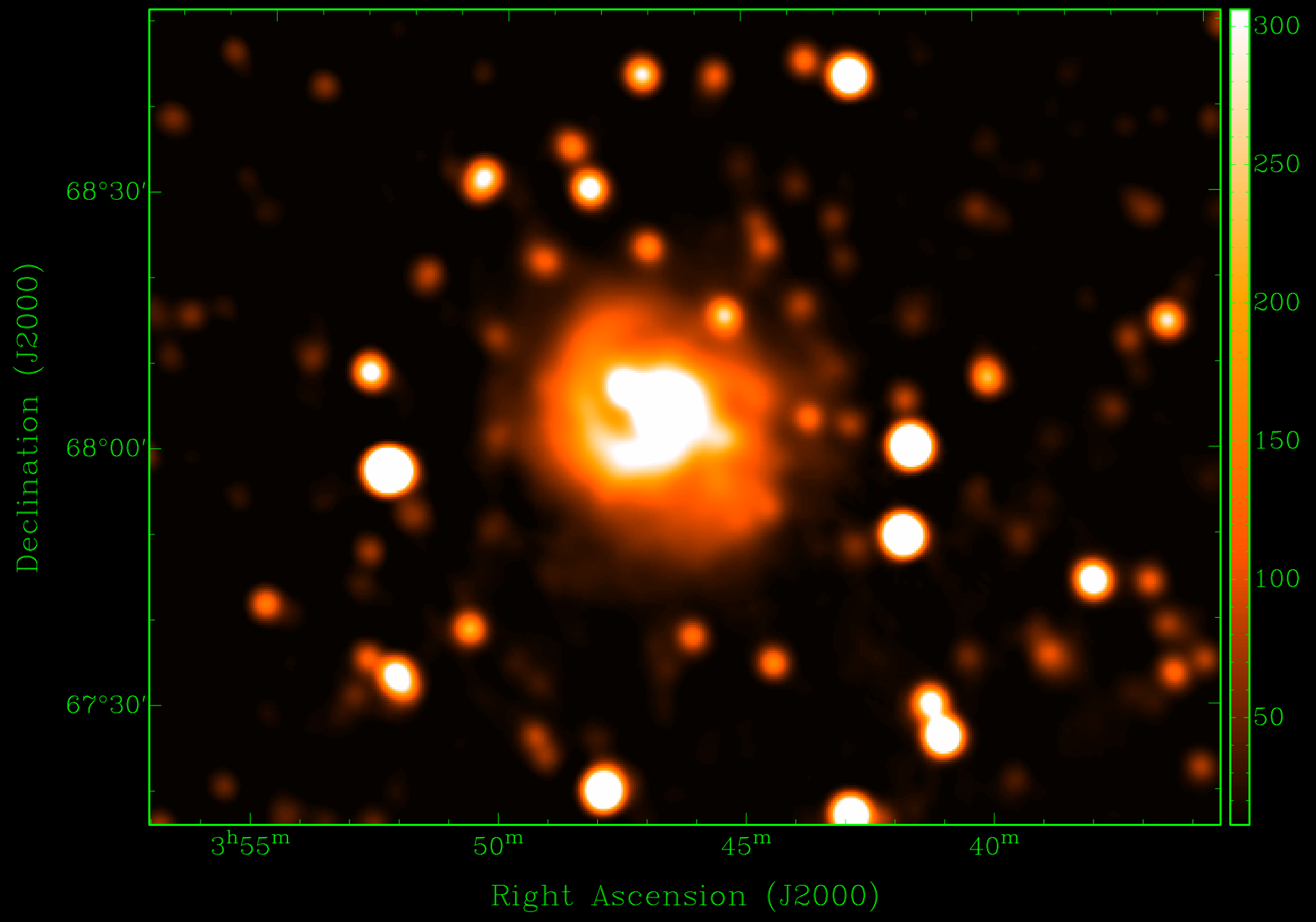
- Data: 2x 5 hour HBA (115-178 MHz) observations
- Science:
  - IC342: magnetic field, Far infrared-radio correlation, cosmic ray diffusion
  - Milky Way: polarized foregrounds
  - Transients: search for radio transients

IC342 field

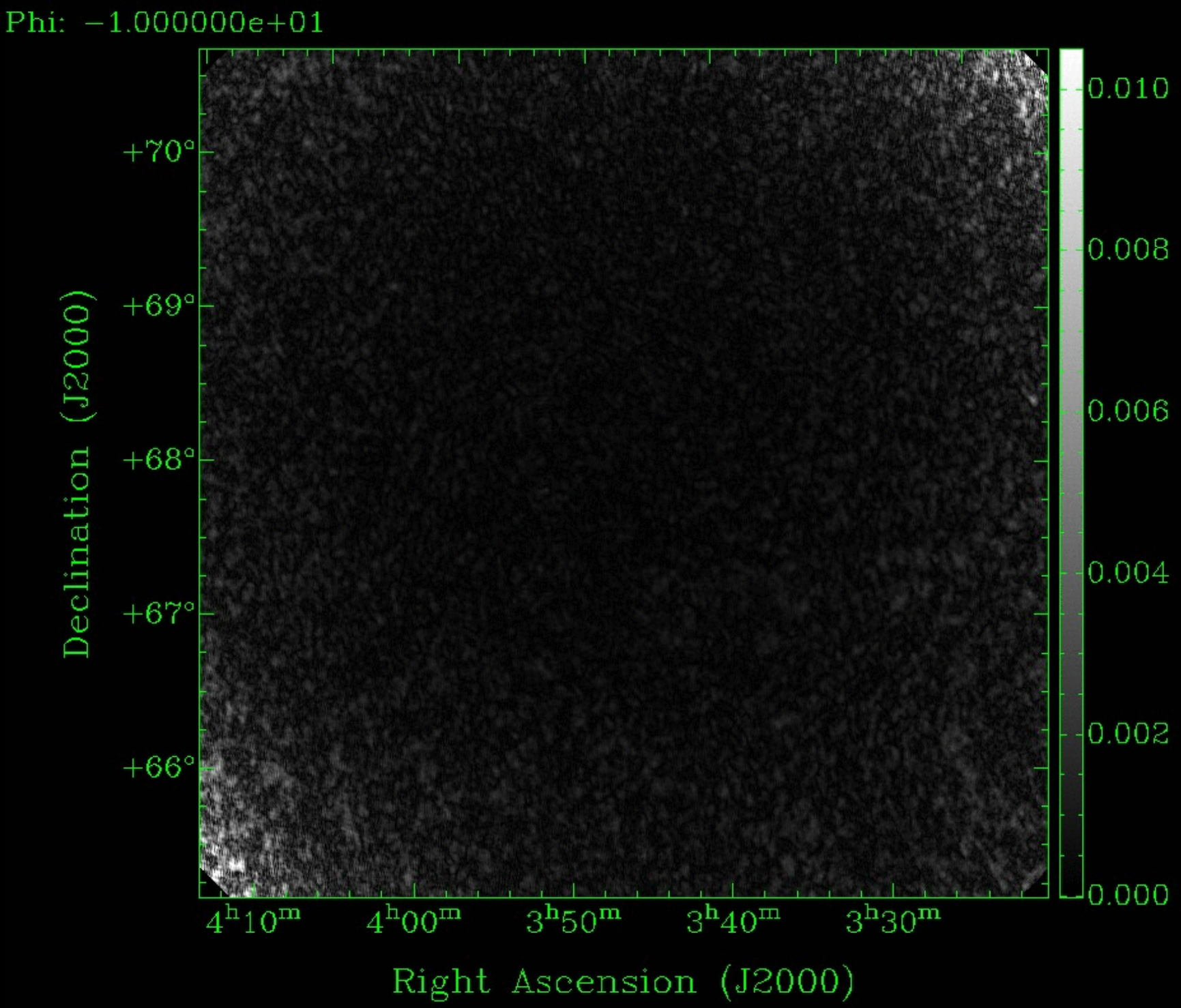


- 7.6hr x 61MHz bandwidth
- 2.4’ resolution
- Confusion limited: ~ 5 mJy noise level

IC342 field

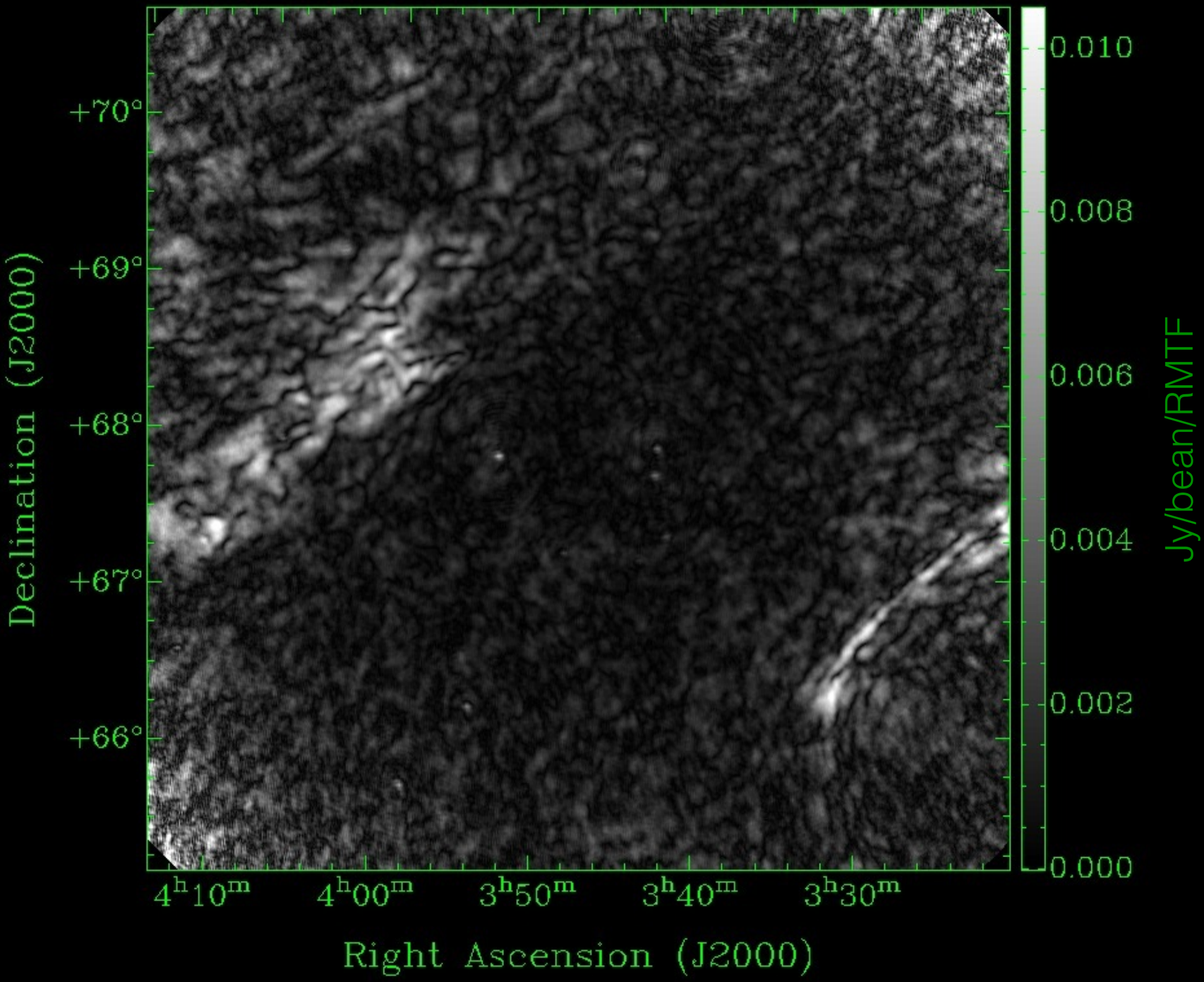

68°30′
68°00′
67°30′
Declination (J2000)
3h55m
50m
45m
40m
Right Ascension (J2000)
300
250
200
150
100
50
mJy/Beam

IC342 field: Faraday tomography

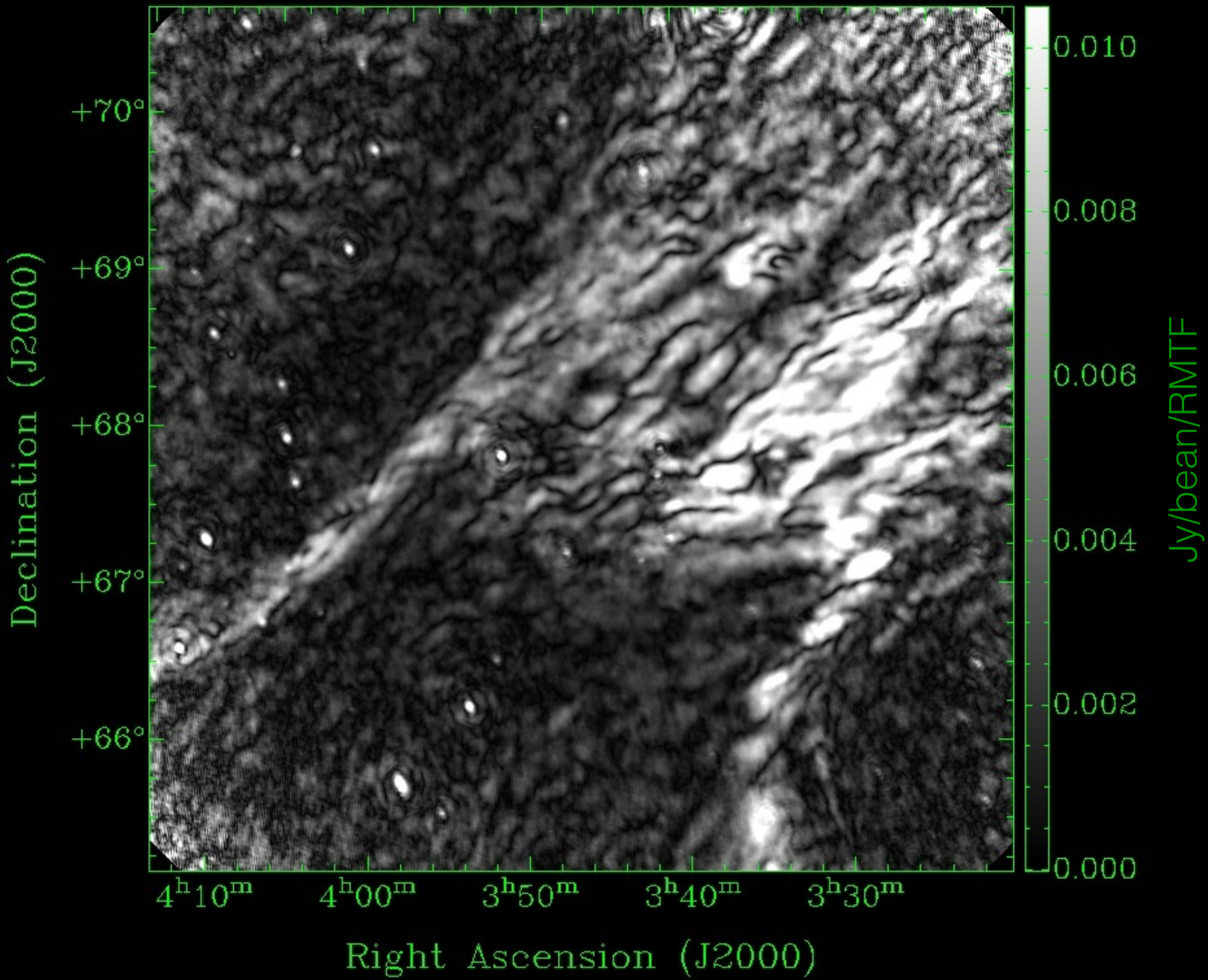


- Noise level: 0.1 mJy/beam/ RMTF (~0.25 K)
- Angular Resolution: 2.4’
- Faraday depth resolution: 1 rad/m^2
- Field of view: 5°x5°

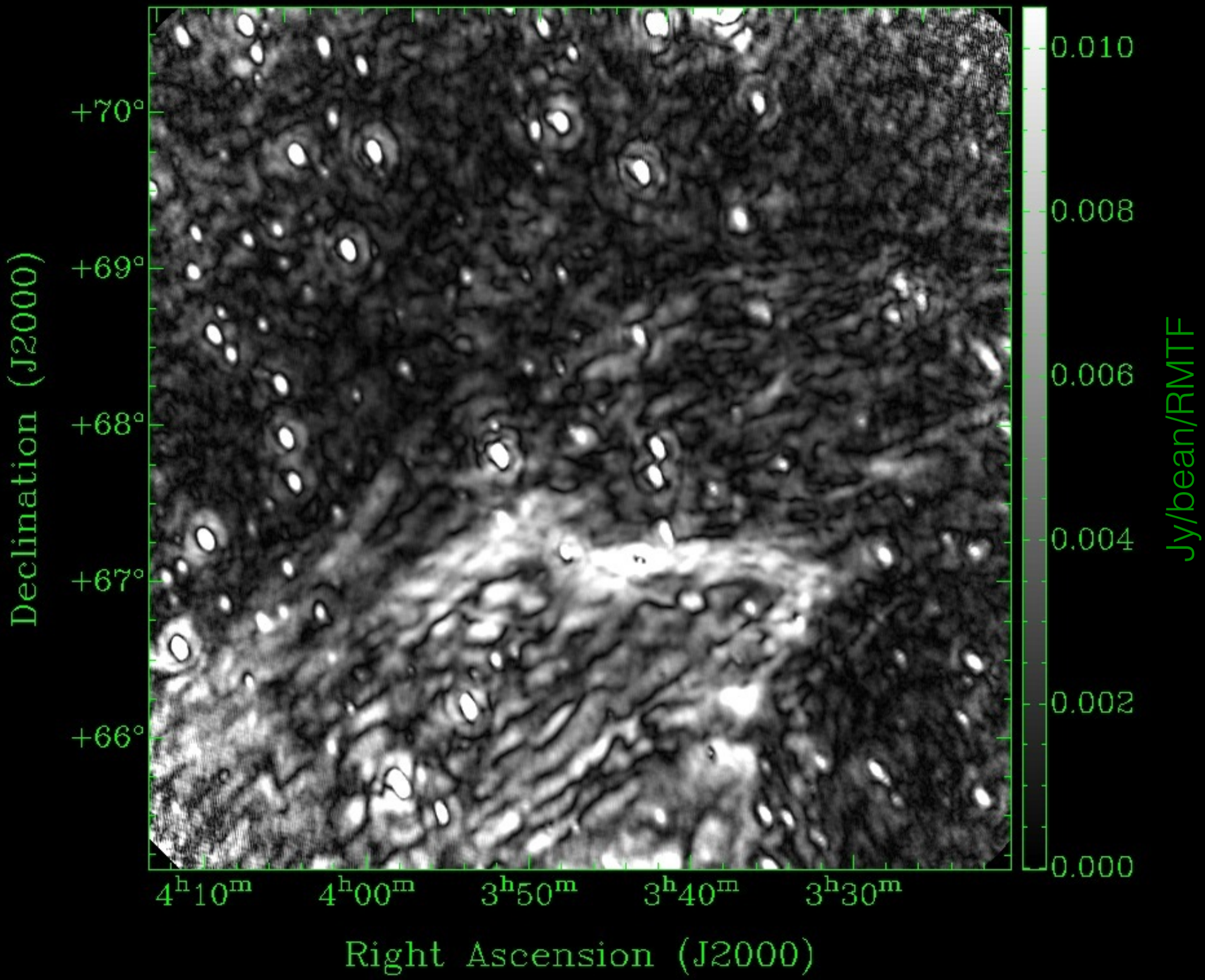
Phi: −3.500000e+00



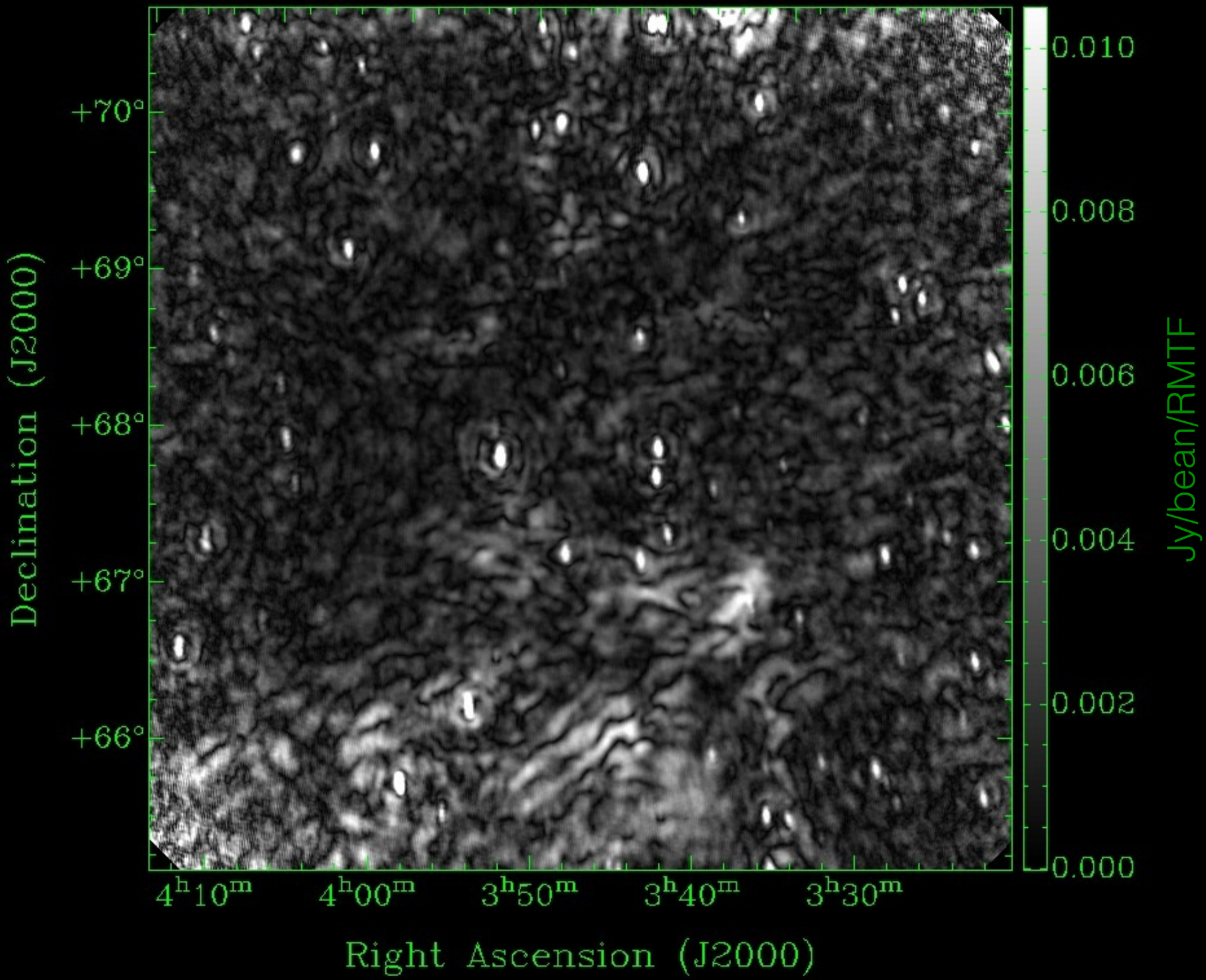
Phi: −1.500000e+00



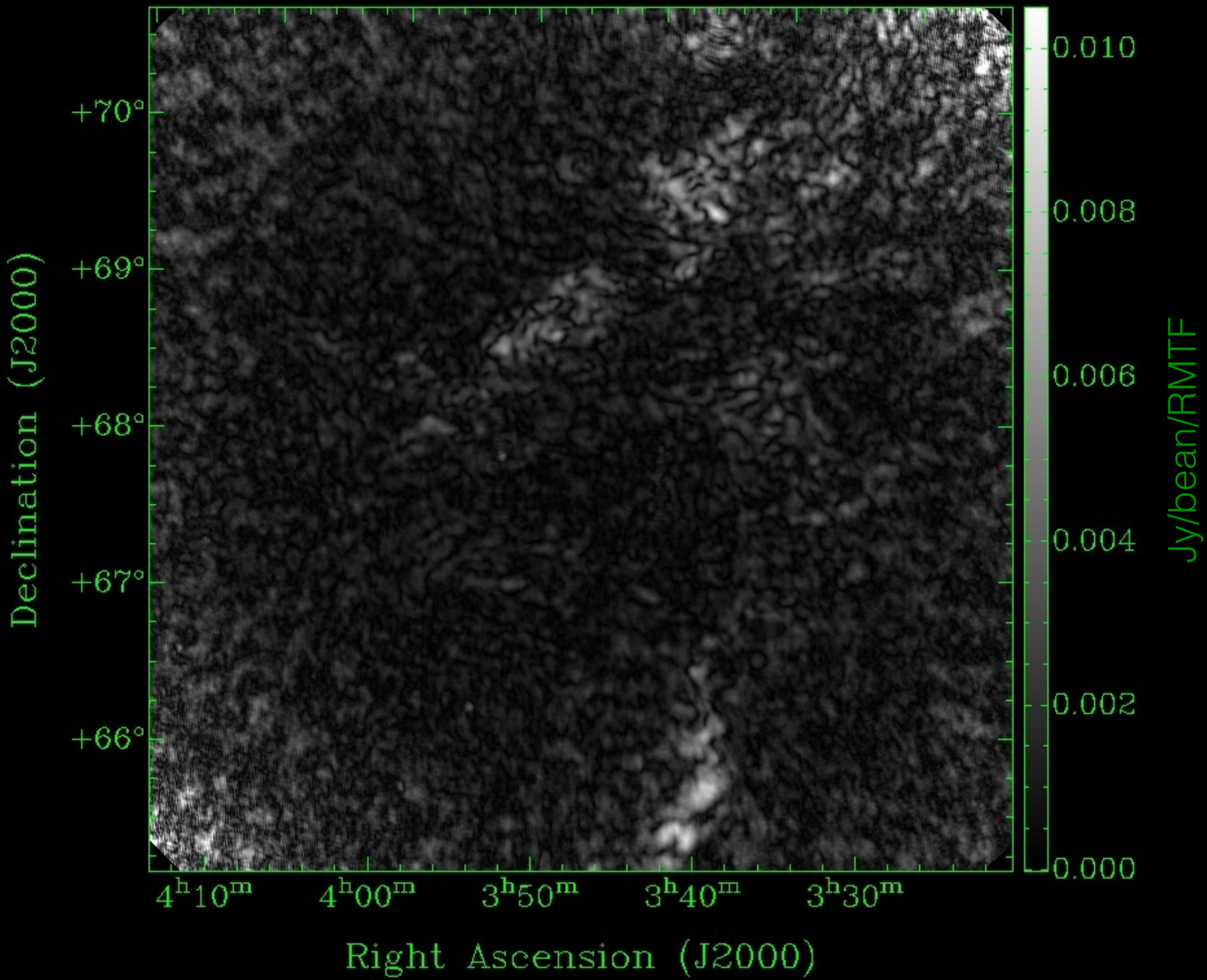
Phi: −5.000000e−01



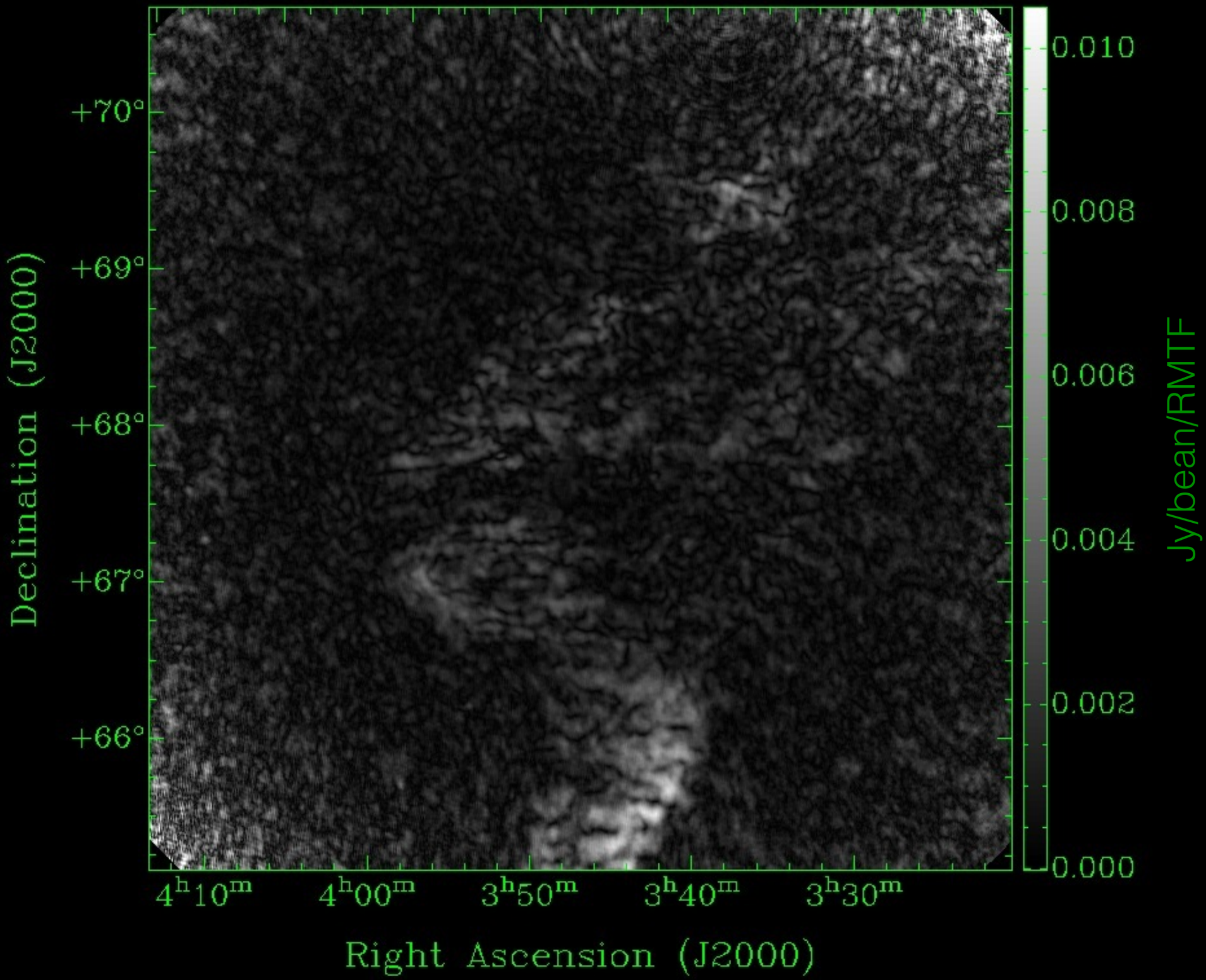
Phi: 5.000000e−01



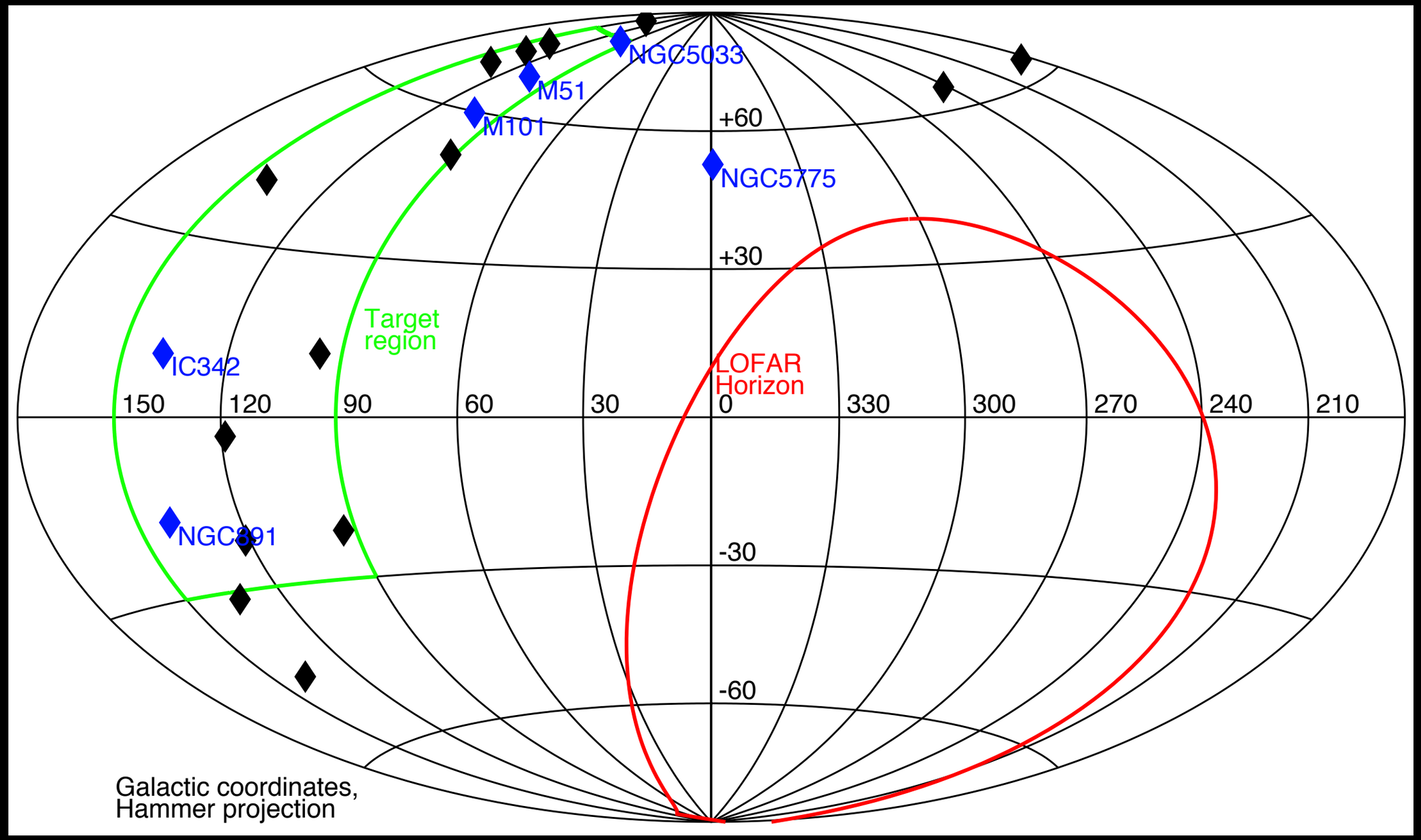
Phi: 3.000000e+00



Phi: 4.000000e+00



Long term goal



Data requirements

- HBA / HBA-high
- Broad, preferably continuous, frequency coverage
- 2+ channels/SB
- Well calibrated at ~2’ resolution (core stations)
- Noise ~ 1 mJy/beam in Stokes Q/U

Summary

- LOFAR gives us unprecedented sensitivity and resolution at these very low frequencies. Low frequencies, or very long wavelengths, give better Faraday depth resolution.

- Faraday tomography gives us a means to probe complex structures in diffuse polarization.

- There are probably many LOFAR data sets that are suitable for this type of analysis.