First results of Solar Imaging

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LAND BRANDENBURG
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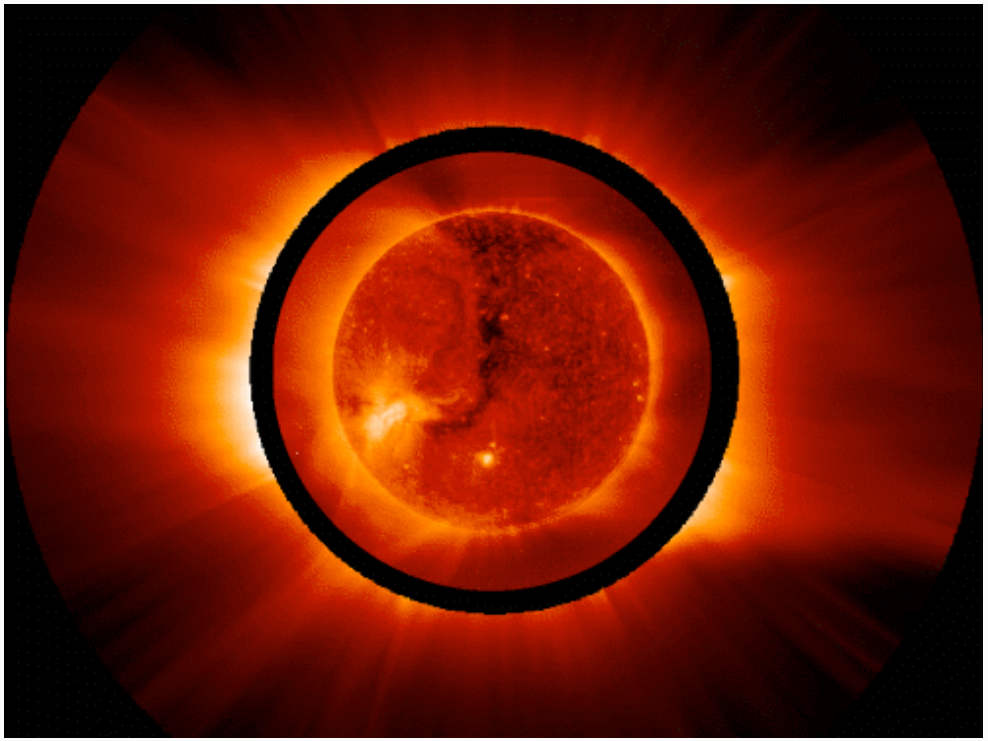
Solar radio radiation

The Sun is a strong radio source:

- Thermal: 10^6 K corona
- Nonthermal: Flares, CMEs



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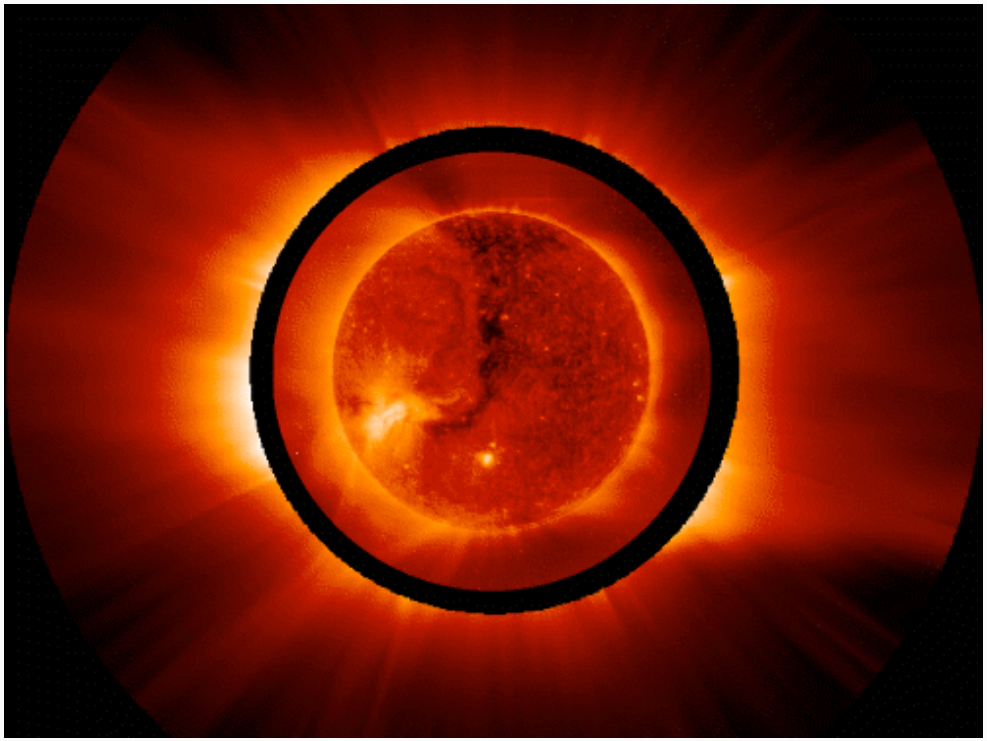

Itensities:

- Thermal: some 10^4 Jy
- Nonthermal: up to 10^7 Jy

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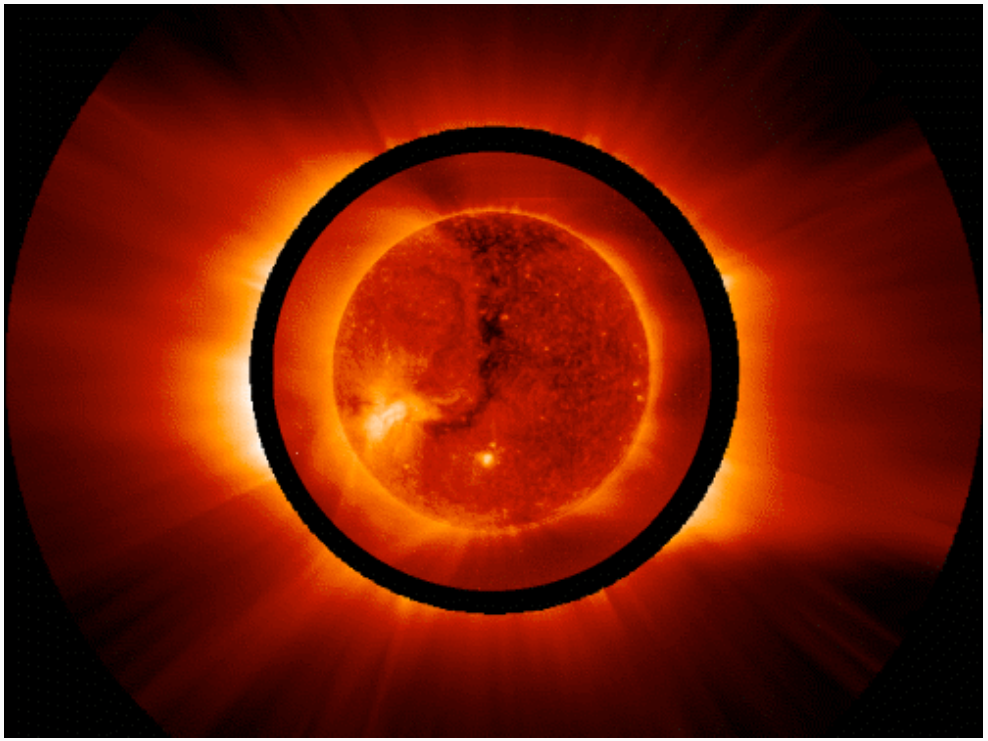

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Radio wave emission:

- Plasma emission

$$f = \sqrt{Ne^2/(m_e \epsilon_0)}/(2\pi)$$

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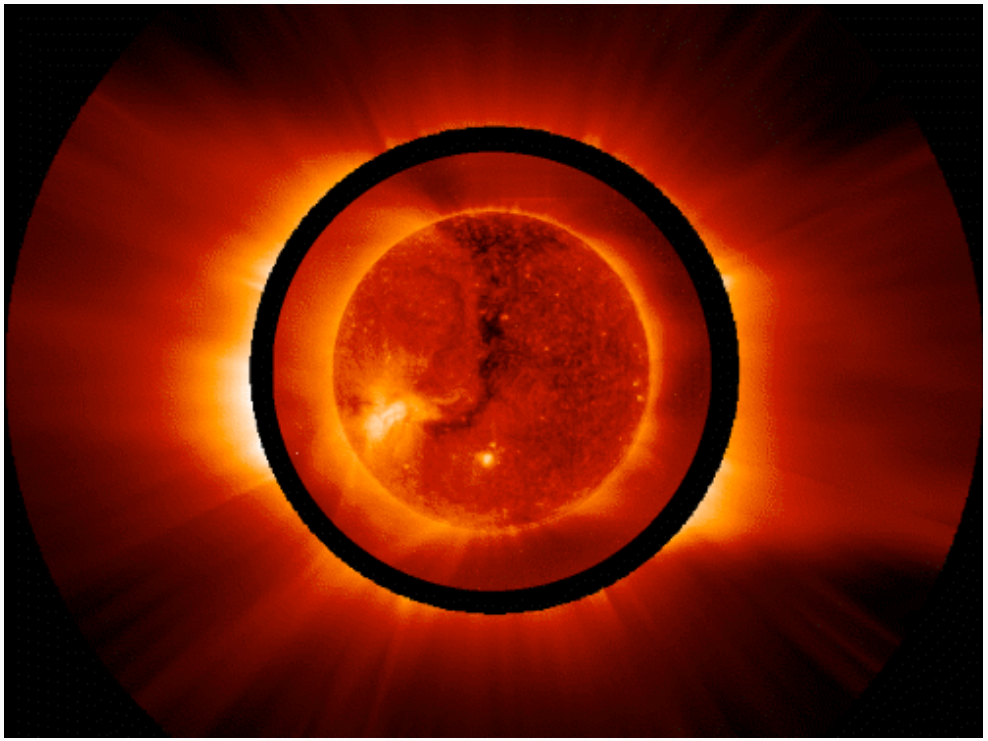

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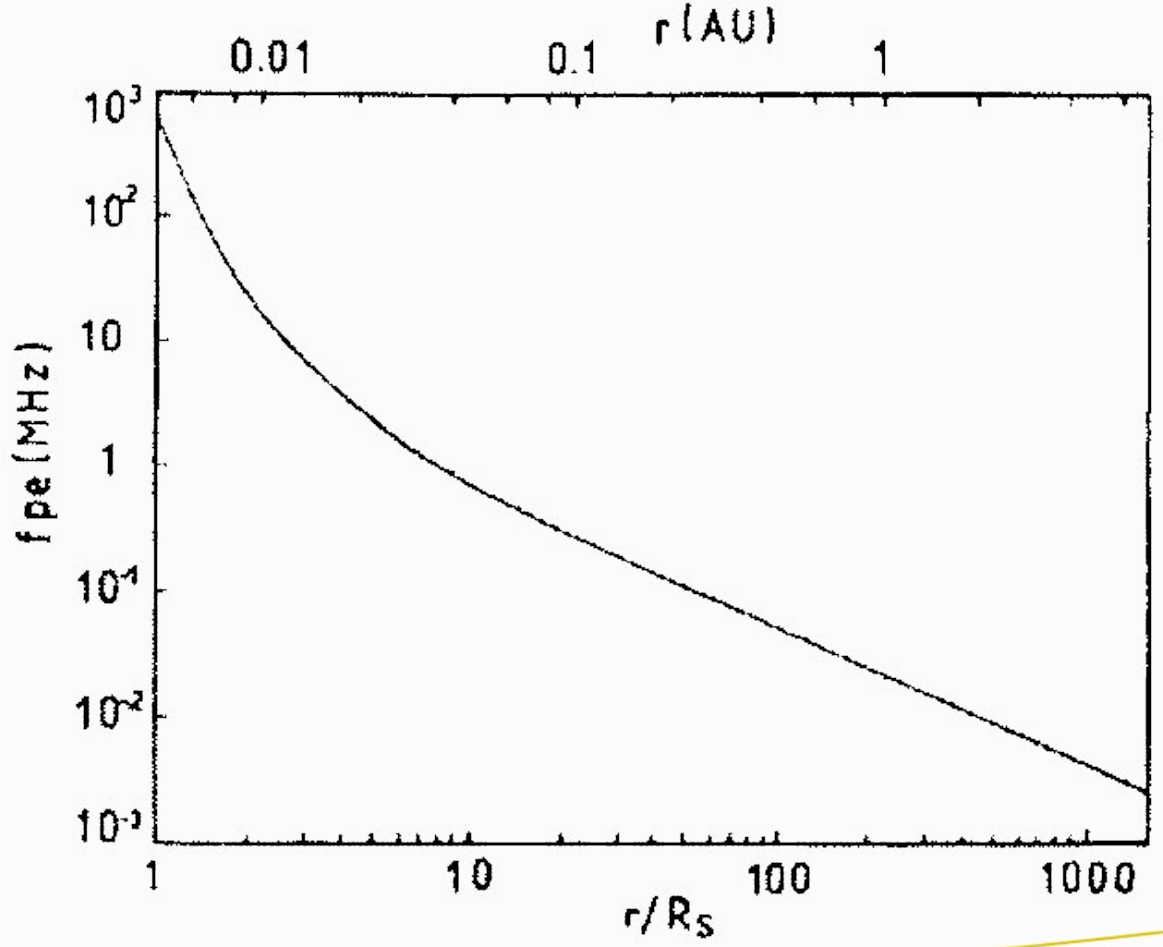
Frequency f depends only on density N

Heliospheric density model

Based on coronal observations and solar wind model

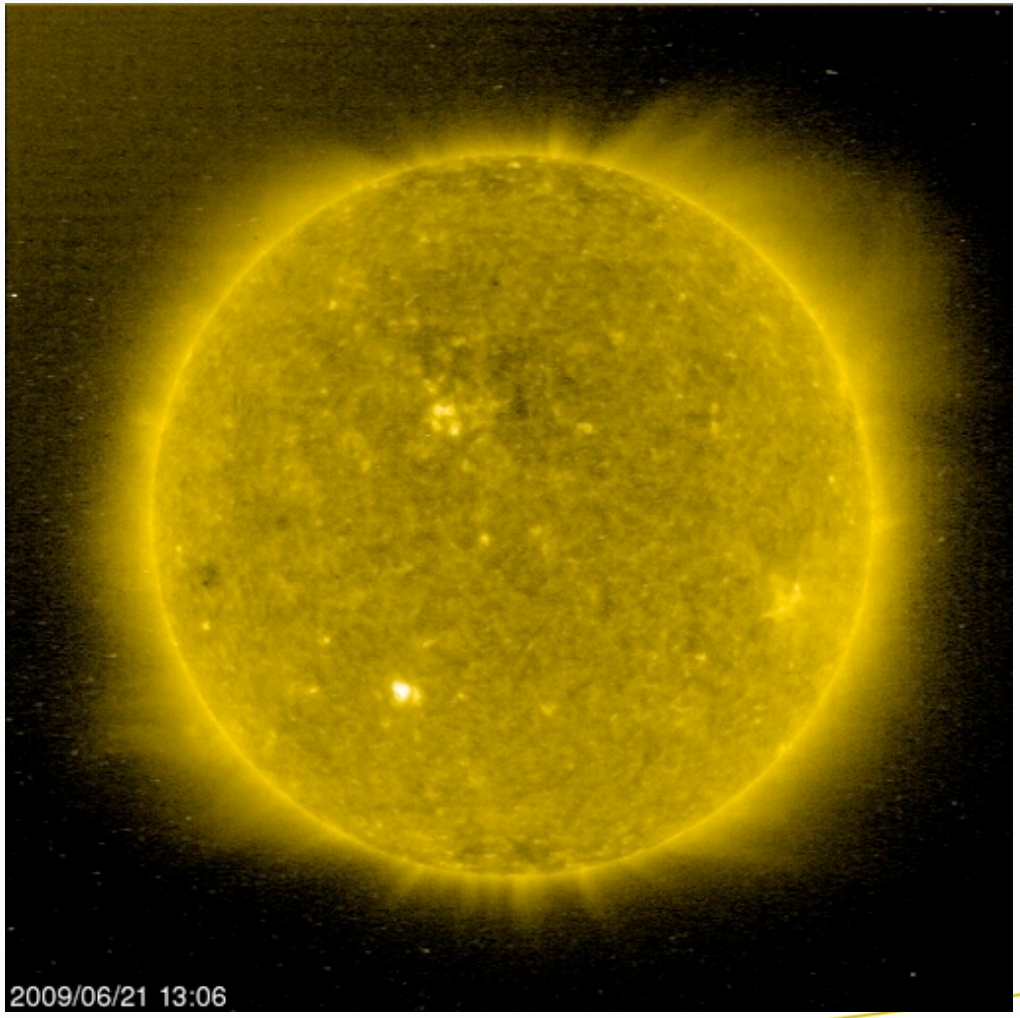


LOFAR frequencies in the corona

f/MHz	r/R_S
240	1.17
170	1.24
100	1.37
70	1.48
40	1.68
30	1.80
20	2.01
10	2.52

LOFAR Frequencies:

Middle and upper corona



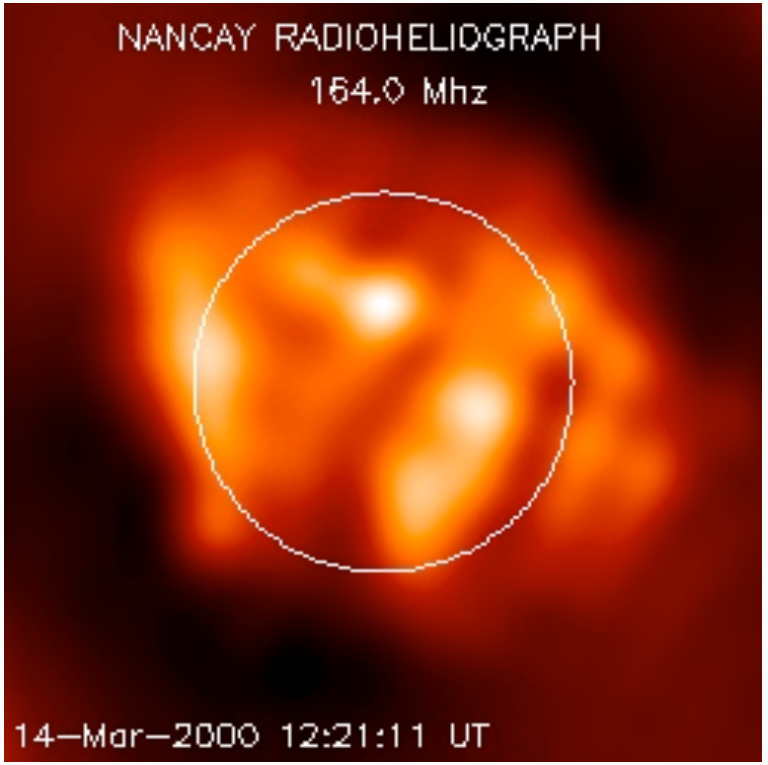
Solar imaging

Solar corona:

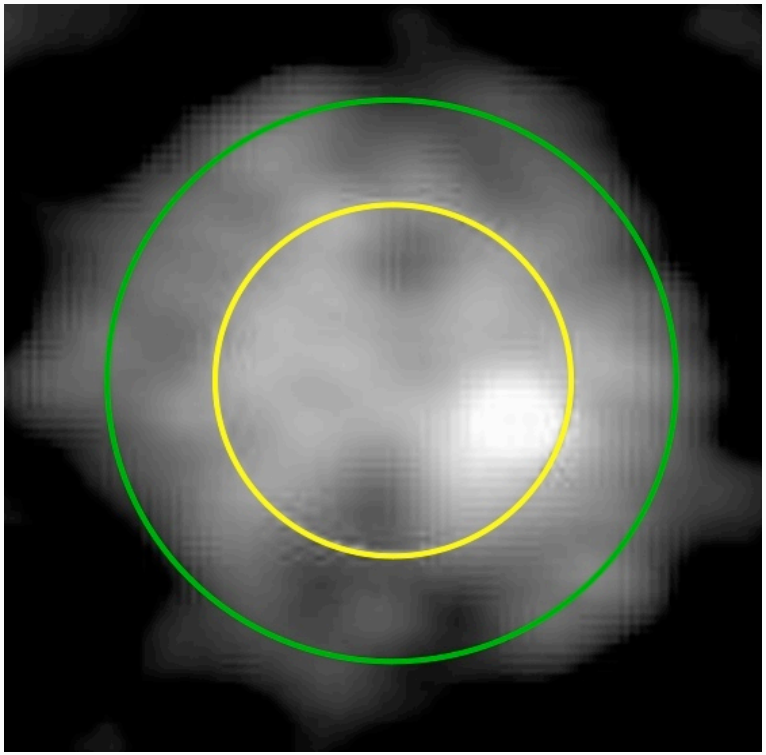
- Scattering of radio waves
- Resolution limited, few 10”

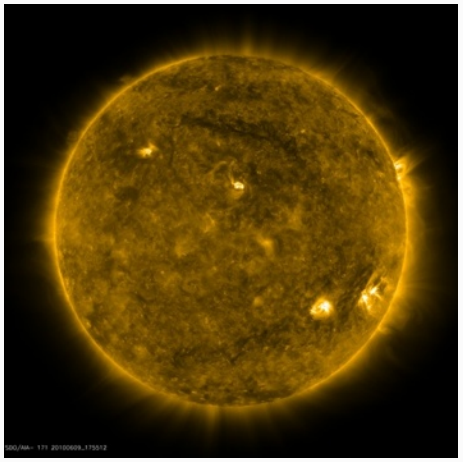
Solar imaging:

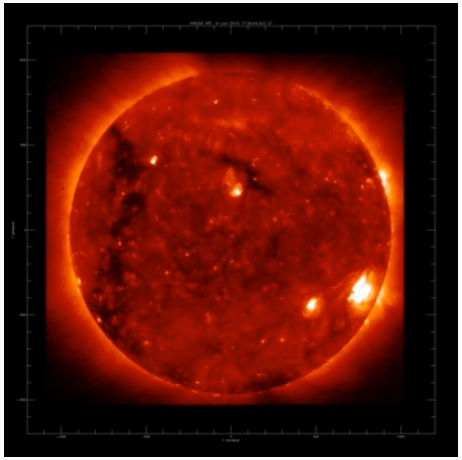
- Based on standard imaging
- Sun outshines calibration sources
- Sun is bright, extended source
- Snapshot imaging



First LOFAR image of the Sun

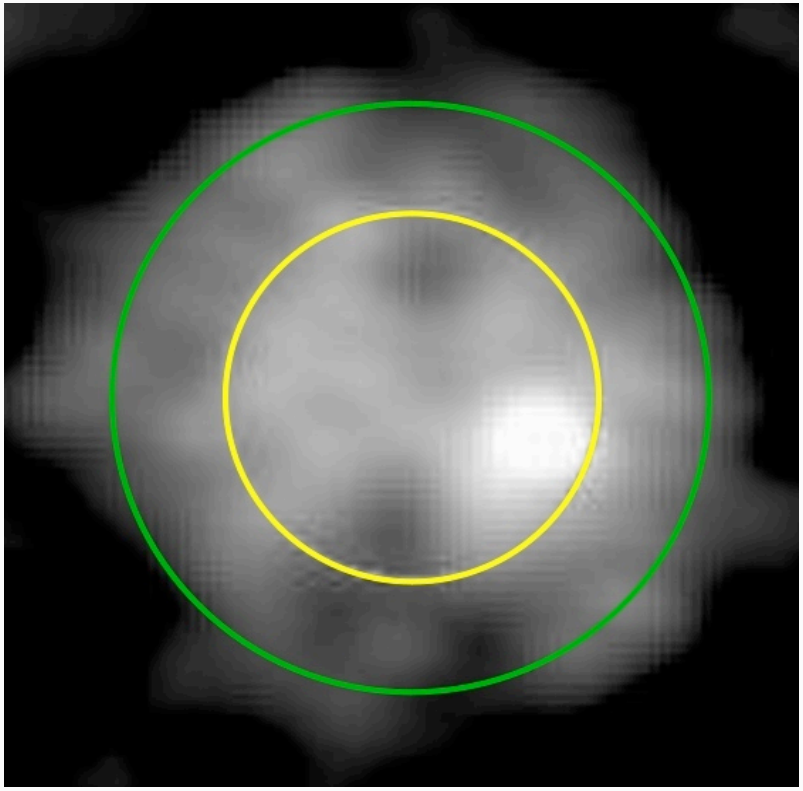




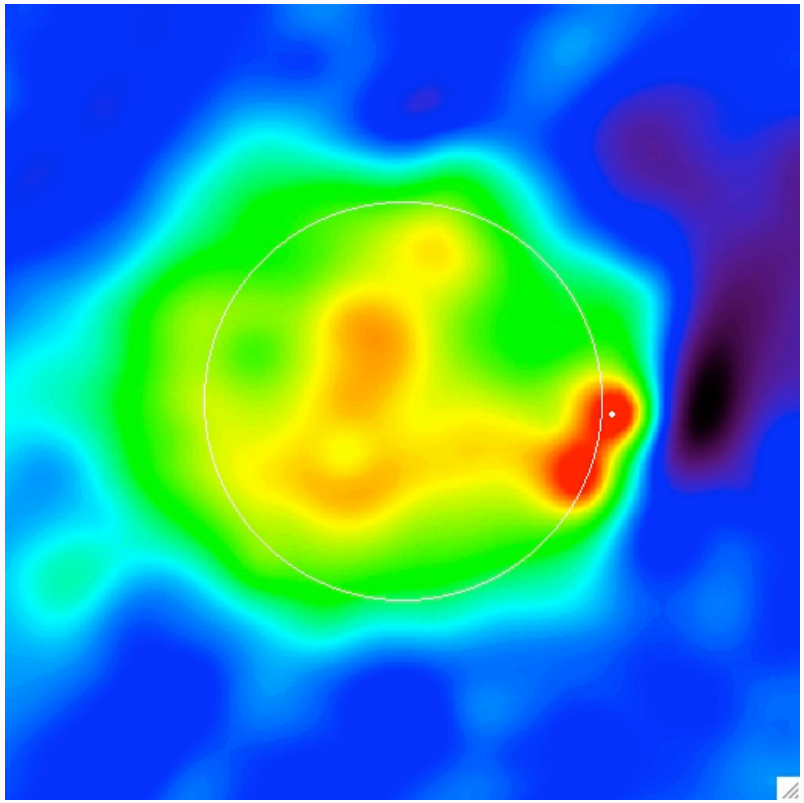


Radio image of the Sun (left) at 135 MHz as obtained by LOFAR on June 9, 2010. An EUV (middle) and soft X-ray image (right) of the Sun as simultaneously provided by the Solar Dynamics Observatory (AIA at 17,1 nm) and Hinode (XRT) is presented for comparison.

Comparison with NRH



135 MHz



151 MHz

17 March 2011: Radio burst

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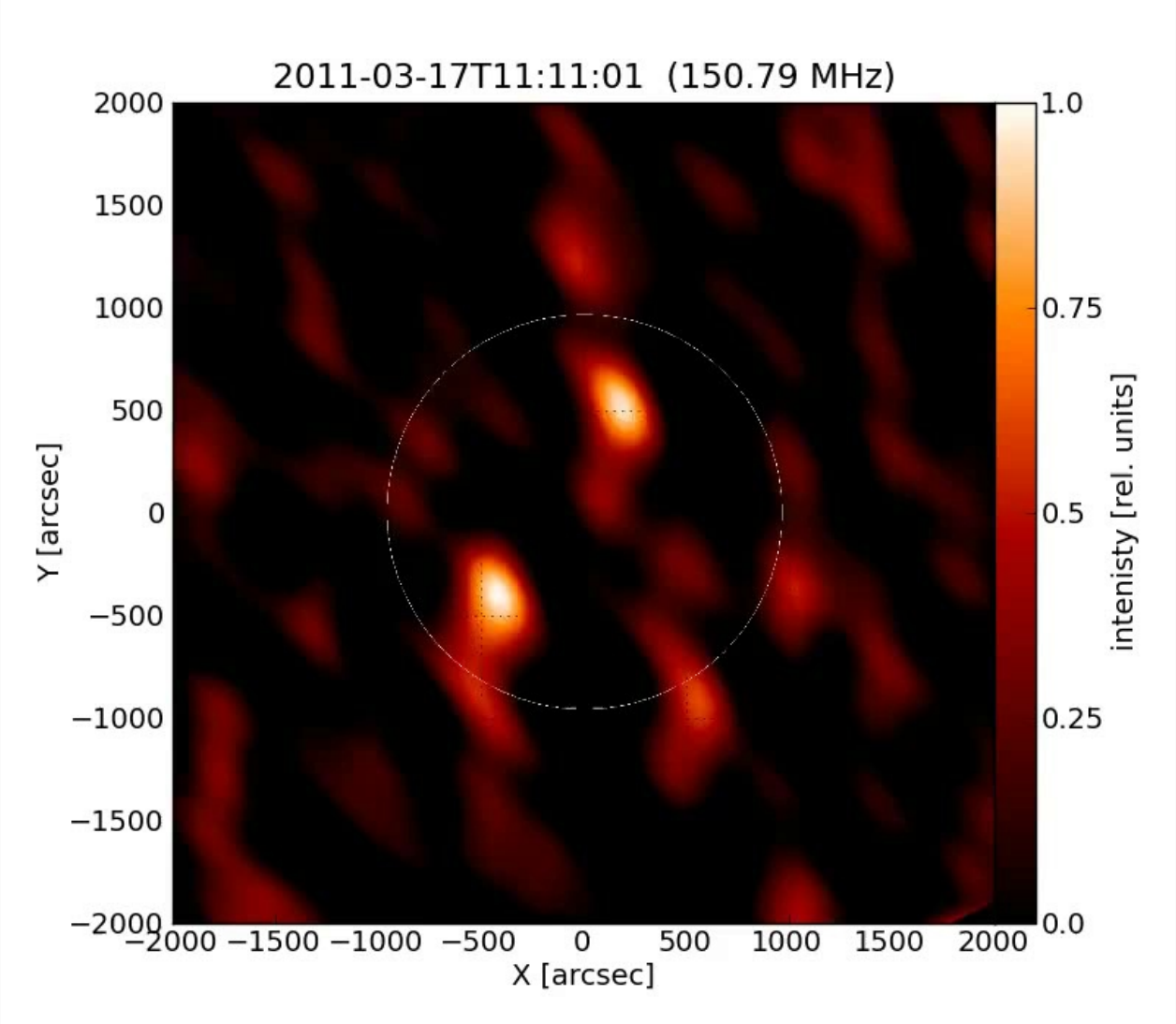
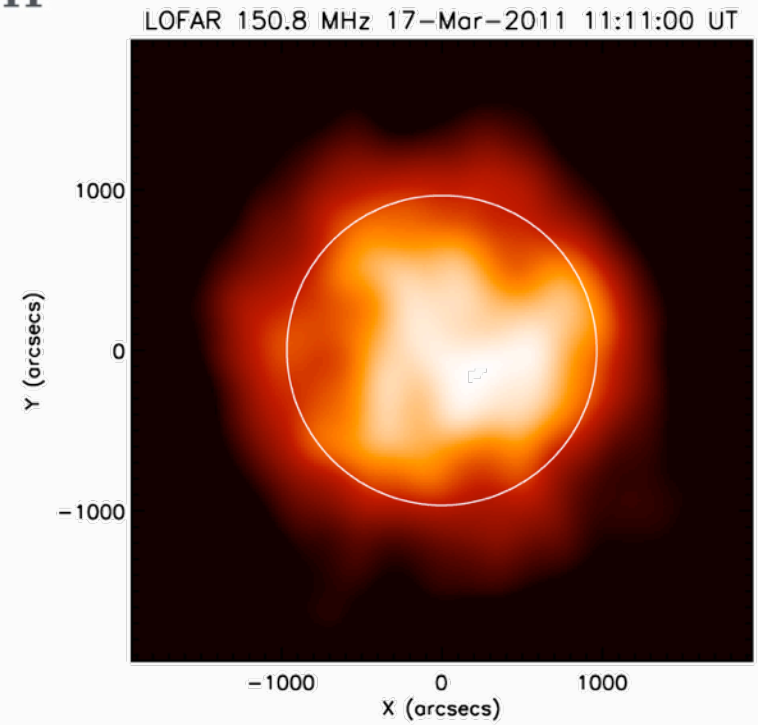
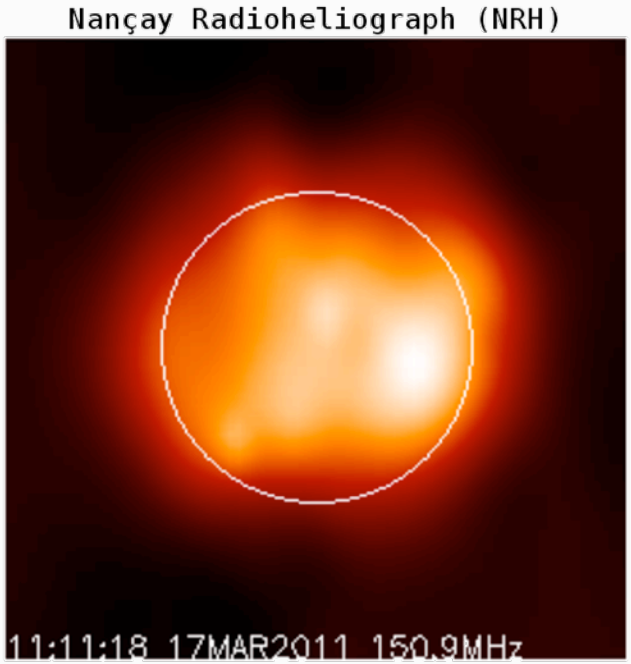


Early stage of solar imaging





Observation time start:	2011-03-17T11:11:00
Frequency range (MHz):	150.708 - 150.879
Wavelength range (m):	1.988 - 1.986
Subband width (KHz):	170.9
Integration time (s):	1.0
Subband no.:	183
Duration (min):	3.0
No. of antennas:	31
Max baseline (km):	25

Need for improvement

Shortcomings:

- The Sun is a structured, extended source
- Highly dynamic
- Sky-model features (Gaussian or disk) in results
- Risk of creating artifacts
- Convergence of iterative procedure not guaranteed

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Better calibrators: Point sources

- Mathematically simpler (Dirac delta)
- Easier phase and amplitude calibration

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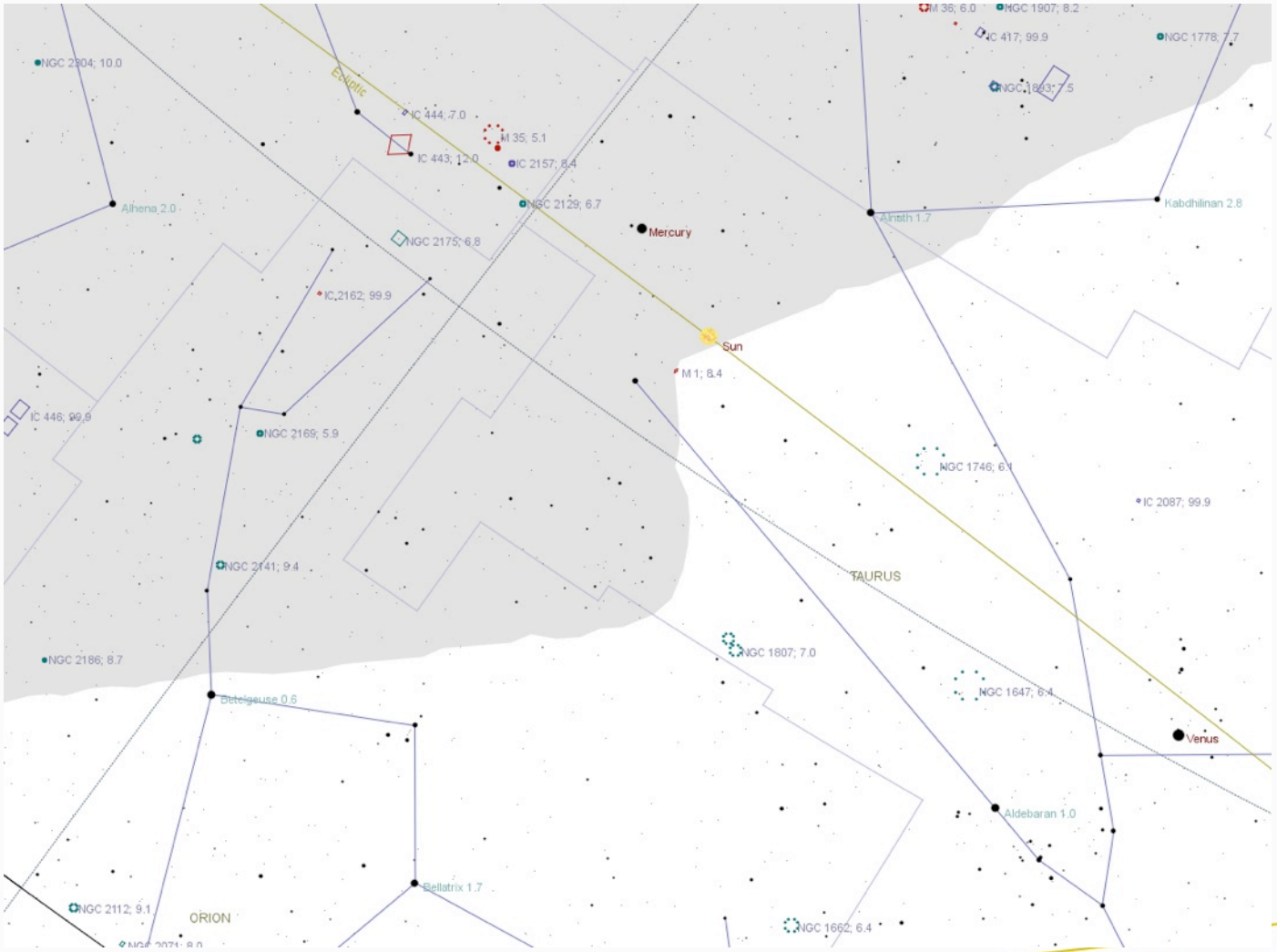
But the Sun outshines most (internal) calibrators…

Sun and Tau A on 15 June

Tau A =
Crab pulsar
and nebula

Closest:
1.3 degree
on 15 June



Interest in the conjunction

Solar imaging:

- Bright calibration source in the field of view
- Improved imaging for these observations
- Comparison with self-cal on the Sun
- Test of solution transfer from external calibrators

Long-baseline studies:

- Influence of solar corona and wind on pulsar observations
- Faraday-rotation by coronal magnetic fields

Observation program

June 13: Low Band, 30-80 MHz, 12 h time

- Alternating subbands pointing on Sun and Tau A
- Tau A in the field of view of solar beam

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June 15: High Band, 120-170 MHz, 12 h time

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June 17: High Band, 210-240 MHz, 12 h time

- Same subbands pointing on Sun and Tau A
- Tau A outside the field of view of solar beam

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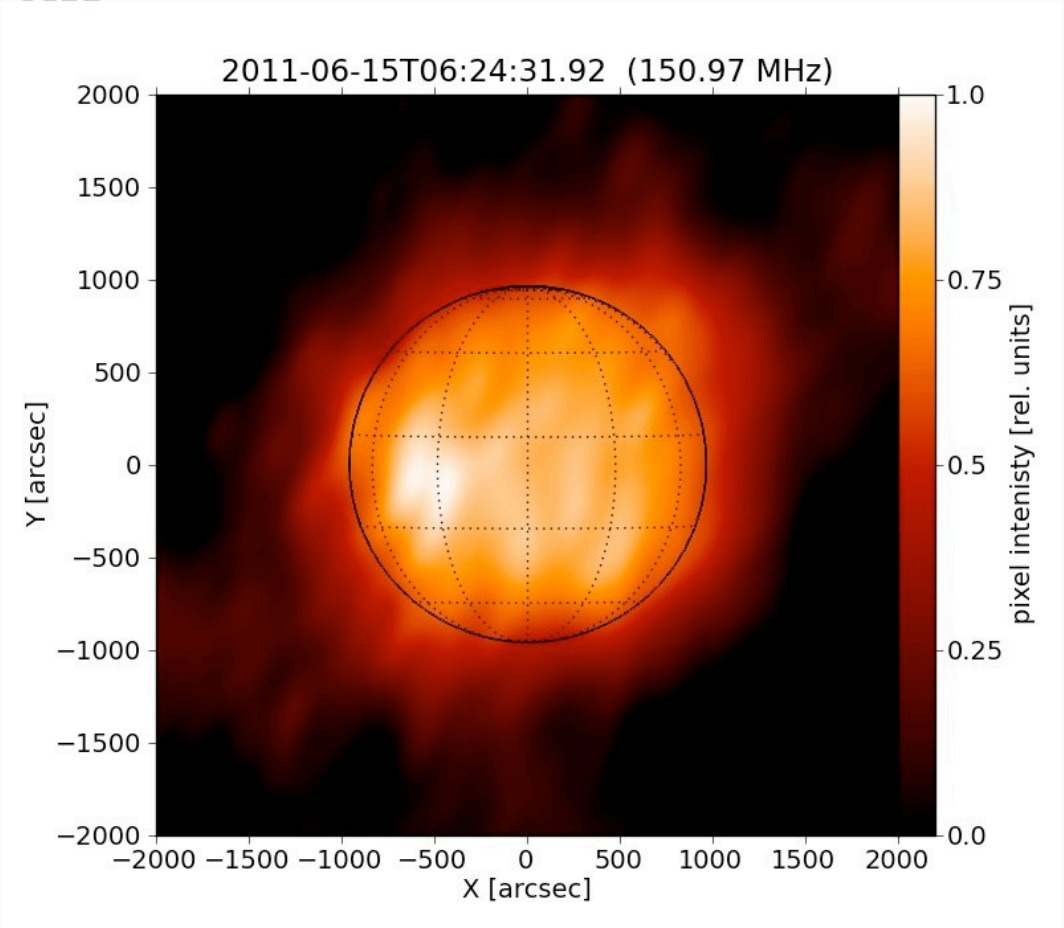
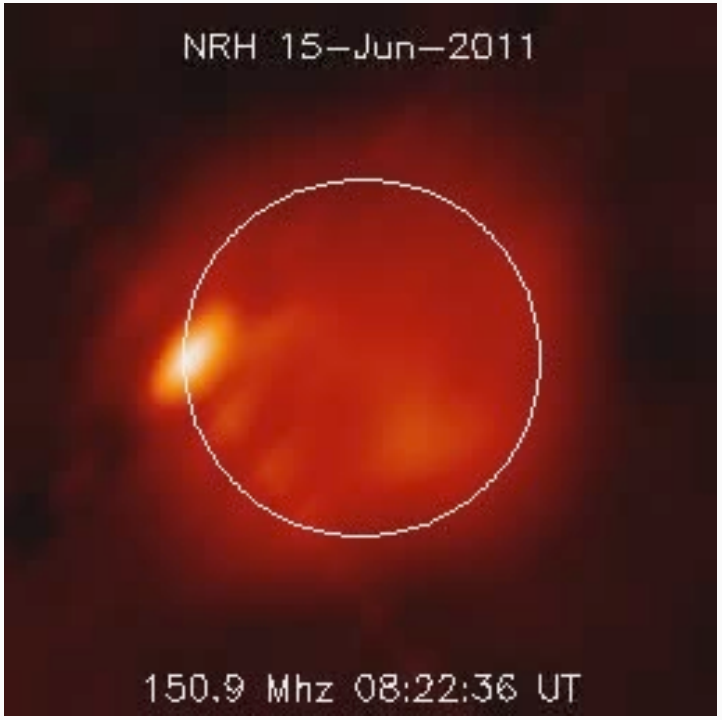
June 17: High Band, 210-240 MHz, 12 h time

- Same subbands pointing on Sun and Tau A
- Tau A outside the field of view of solar beam — failed, no data

HBA images



LOFAR



Nançay

Image stability

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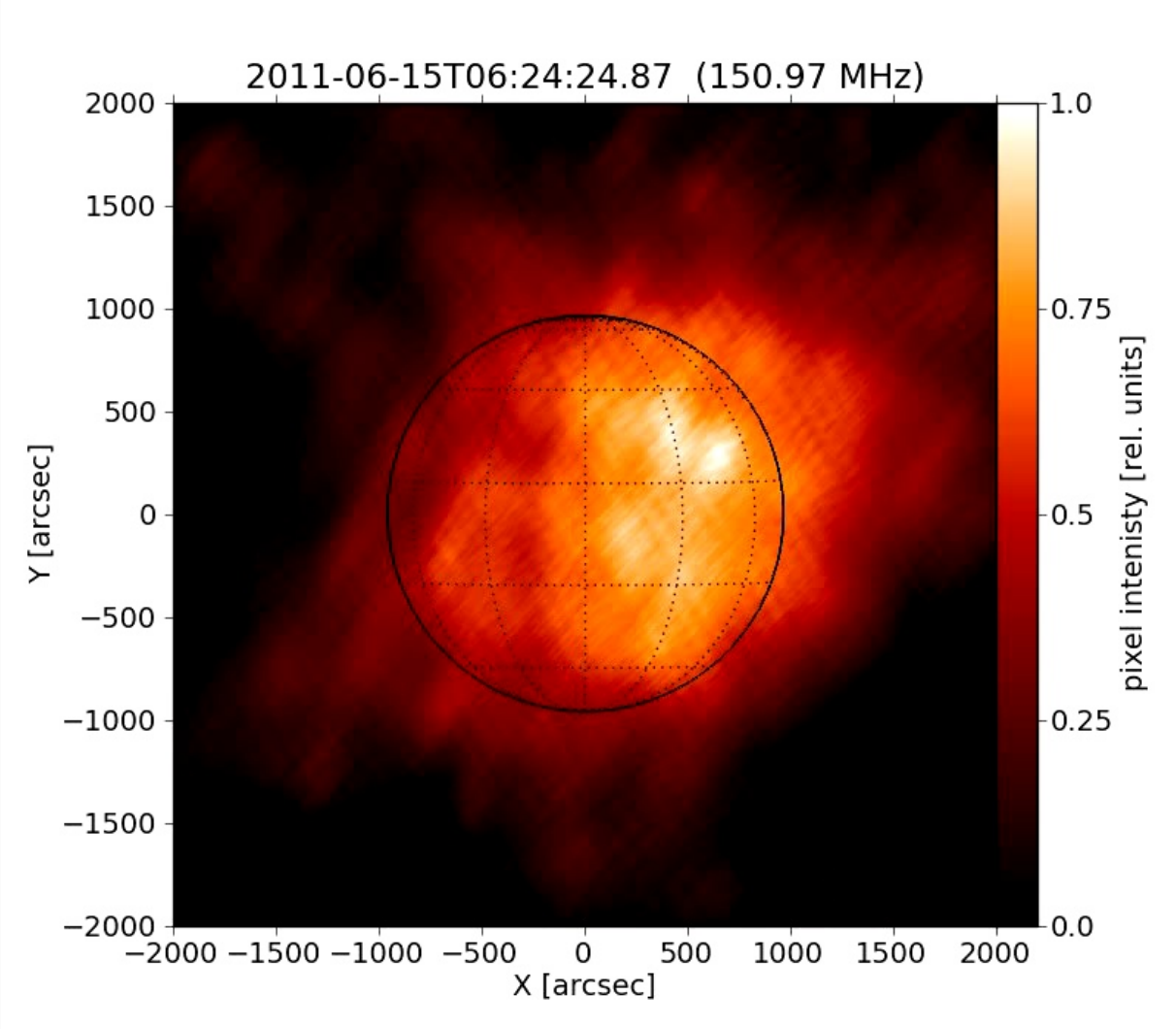
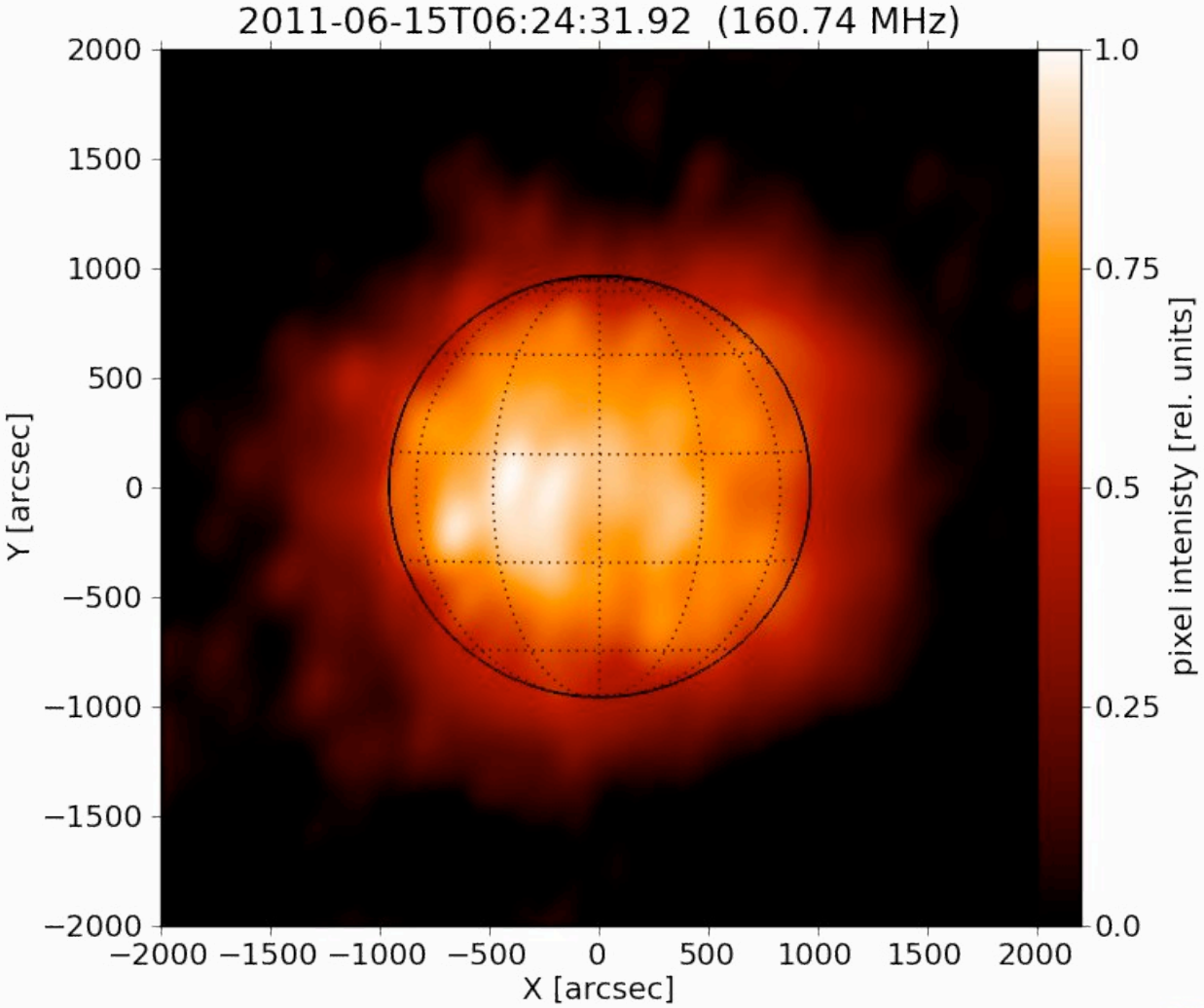


Change with frequency (i.e. height)



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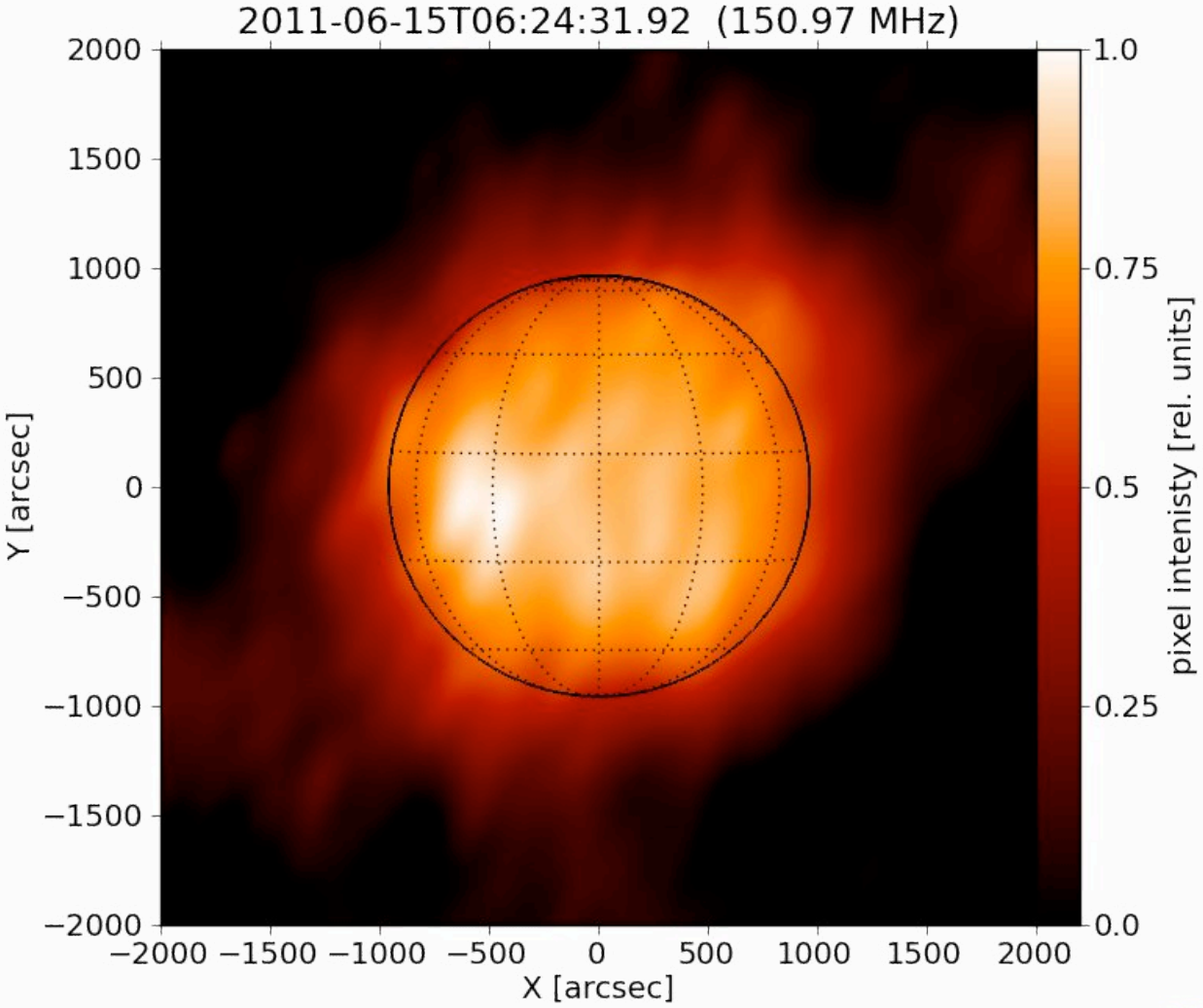

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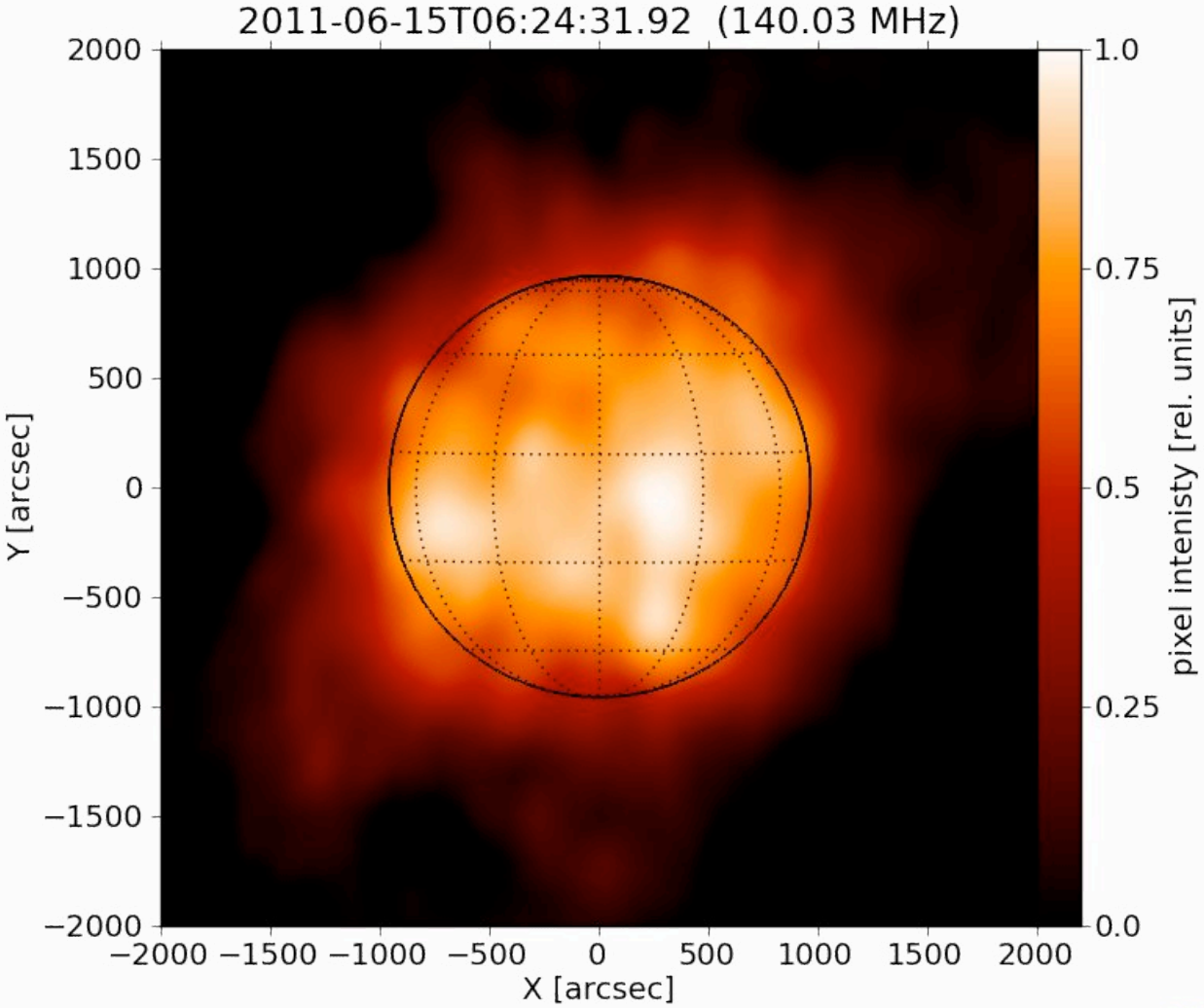

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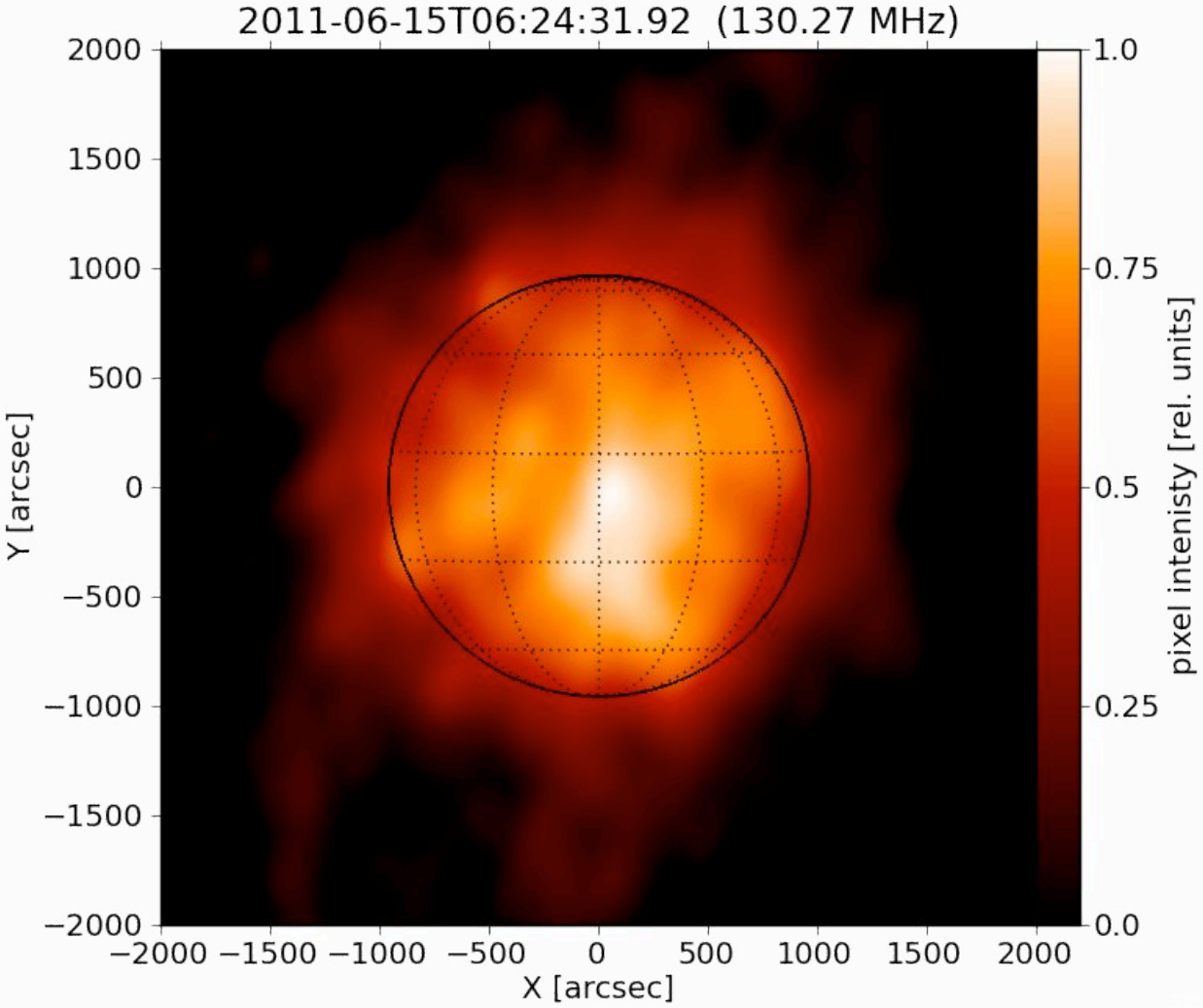

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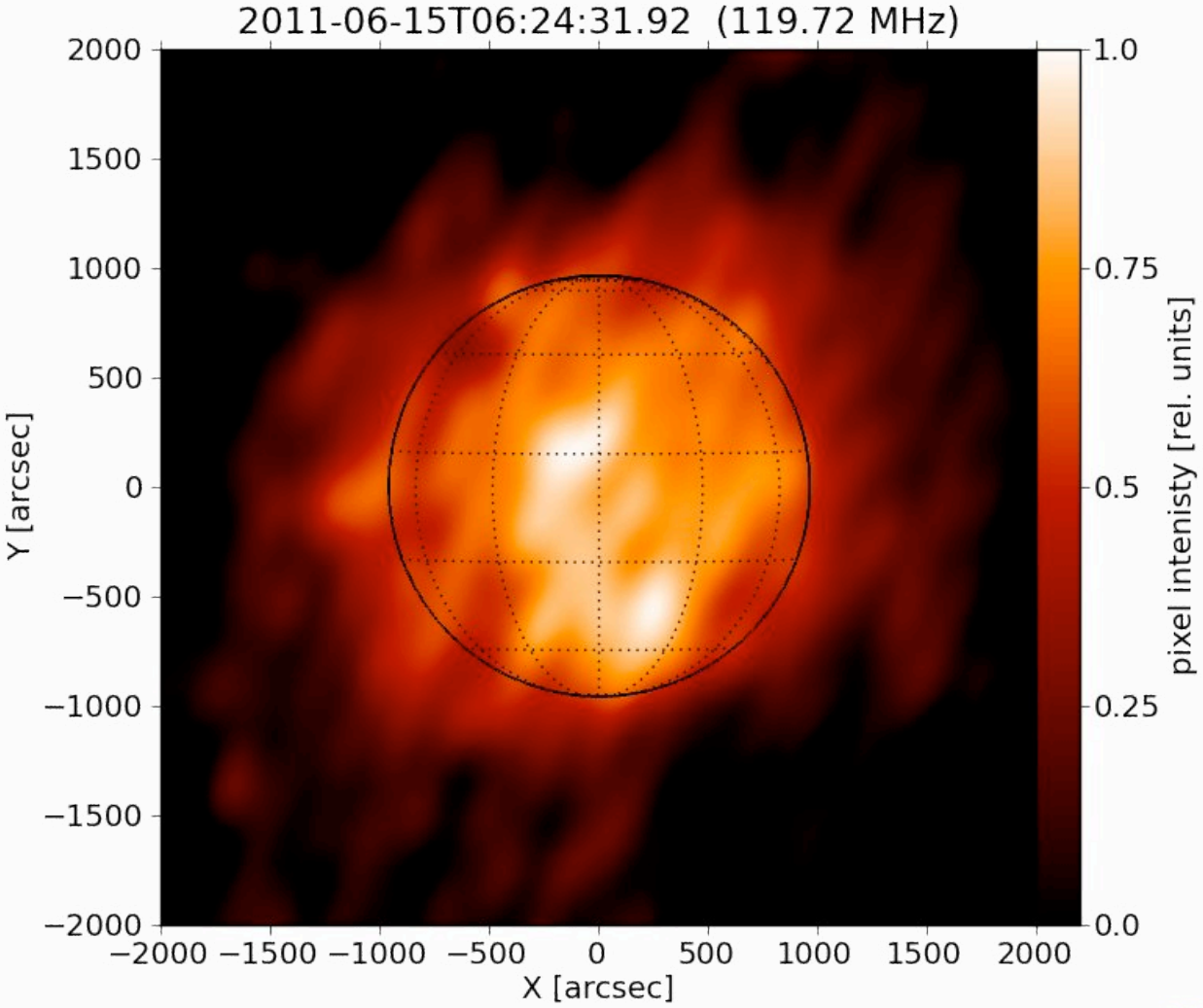

Low band observations

Shown here:

- Uncalibrated data
- Tau A at
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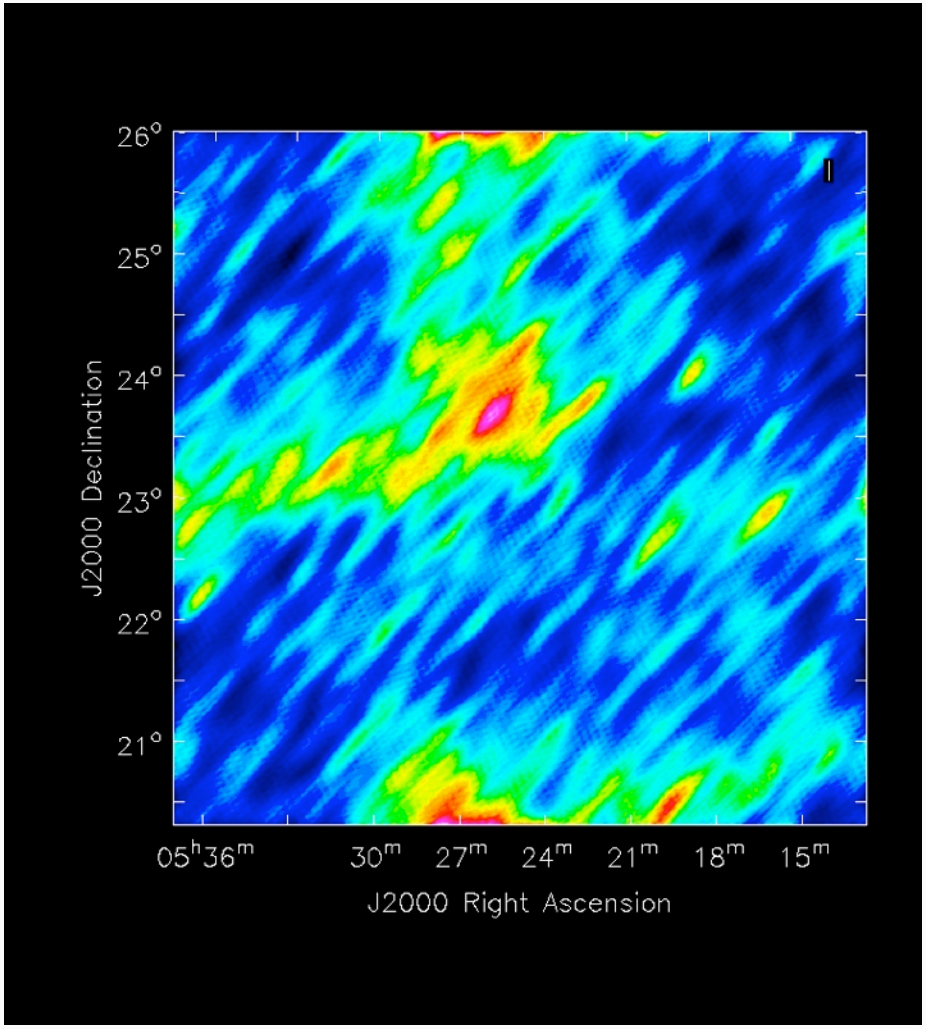

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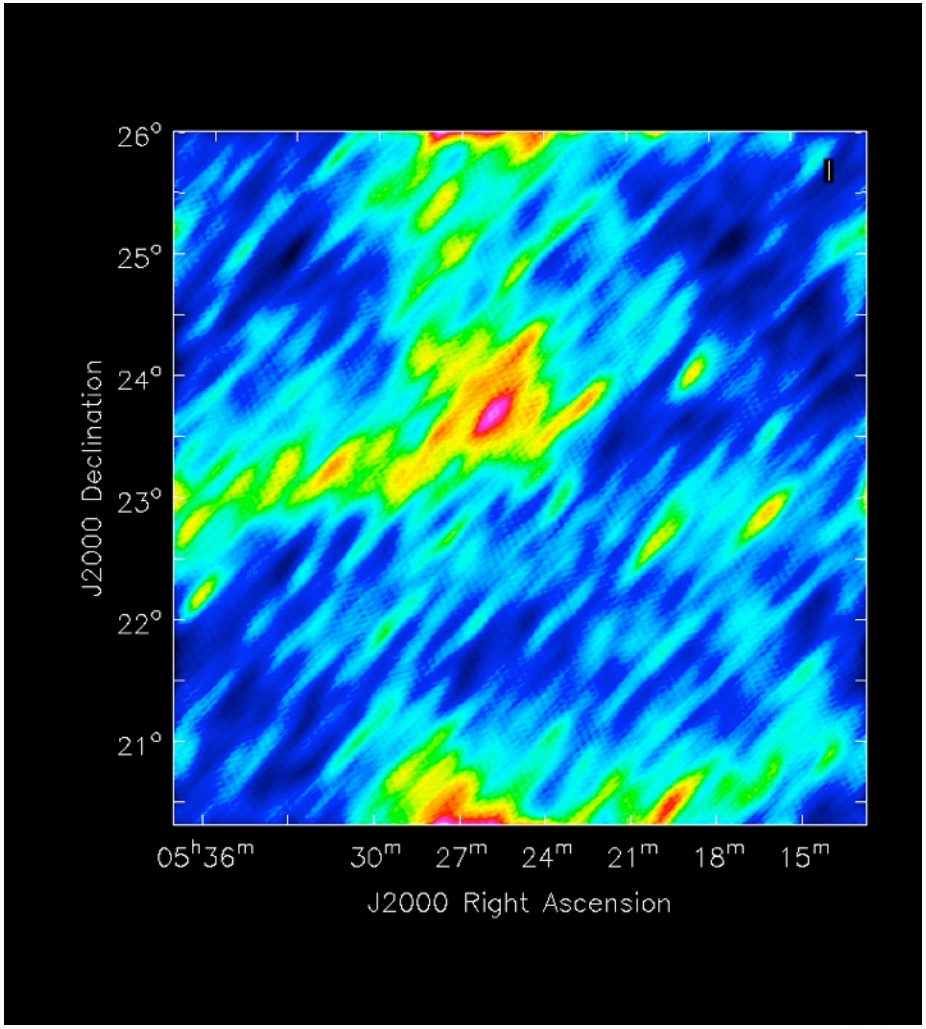

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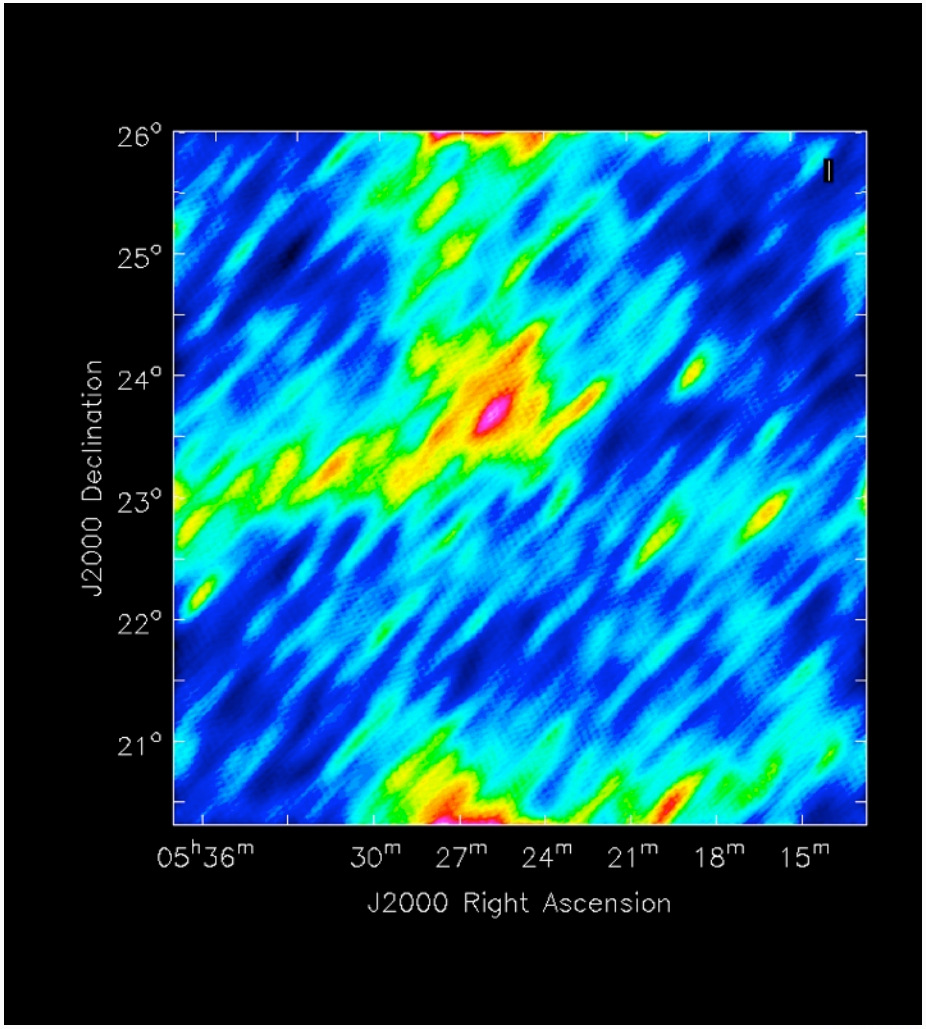
Calibration with BBS does not work yet



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- Use it for calibration
- Reduce influence of initial sky model for the Sun
- Low-band imaging

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Solar imaging pipeline development:

- Try solution transfer from external calibrators
- Improved image quality

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Solar imaging:

- Based on standard imaging
- The Sun poses special calibration challenges

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Solar imaging pipeline development:

- Implement new insights into pipeline
- Use of “solution transfer” from external calibrators