Solar Physics and Space weather

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Sun and Heliosphere: Why ?

- It is a very close star:
  - Detailed studies on magnetic field generation, convection, coronal heating….
  - Its a natural lab for collisionless plasmas physics
  - Magnetic field instabilities: flares, CMEs etc.
  - The sun is driving the interplanetary medium (solar wind)
  - The sun magnetic activity, through particles, MHD disturbances, solar wind, and more, has a strong impact on the IM and planets (leading to a « space weather » research activity)

Observations with LOFAR

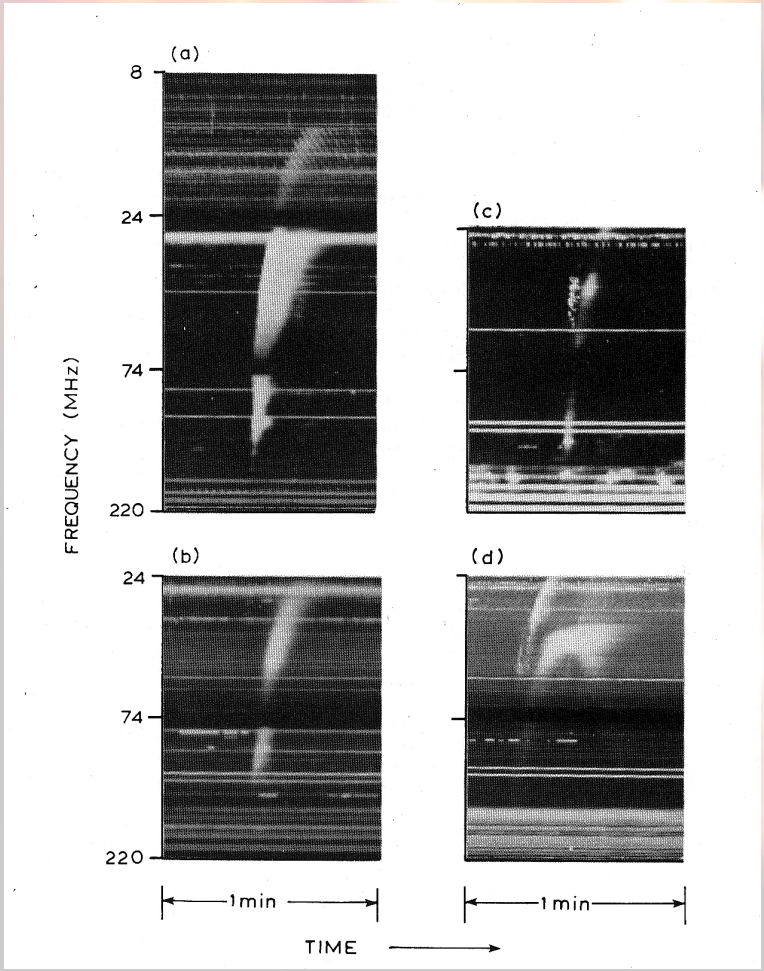
- Radio waves are emitted
  - - by accelerated electrons
    - Various waves-particles instabilities
    - Gyromagnetic emission
  - Brehmstrahlung thermal emission of the hot corona

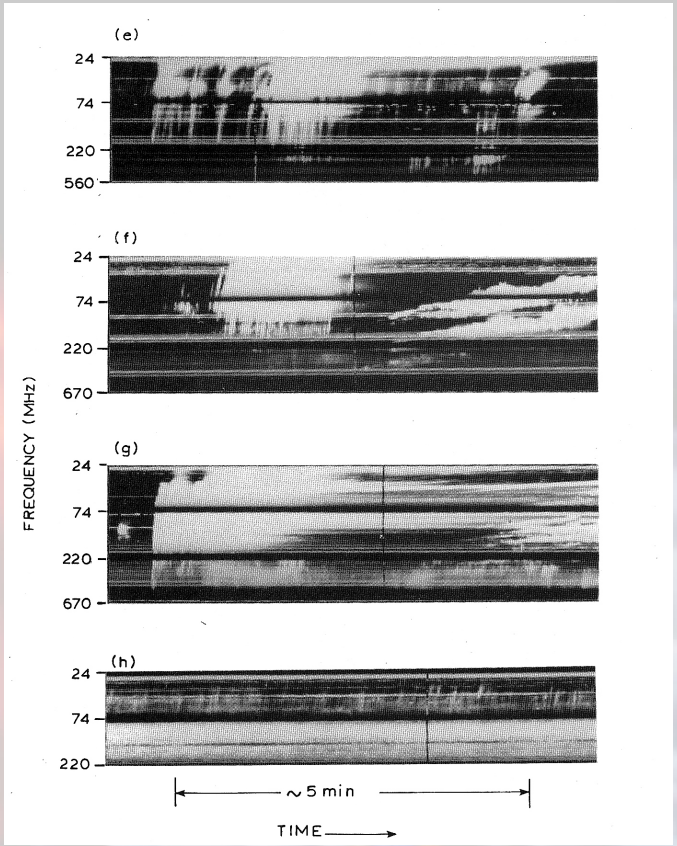
- The frequency is generally decreasing when the altitude increases
  - Lofar range correspond to 0.1 to 3 solar radii above the photosphere. This region makes the connexion between the magnetic activity (low corona, chromosphere) and the solar wind.

- What can we expect: better understanding of
  - Electrons acceleration in flares (together with higher frequencies) and propagation
  - MHD disturbances(Coronal mass ejections): generation and propagation
  - Shocks generation and propagation.
  - Large scale magnetic fields structuring the corona and the solar wind.

- Solar physics uses all EM spectrum from gamma rays to km wavelengths, and particles

Typical m – deca radio emission: non thermal electrons



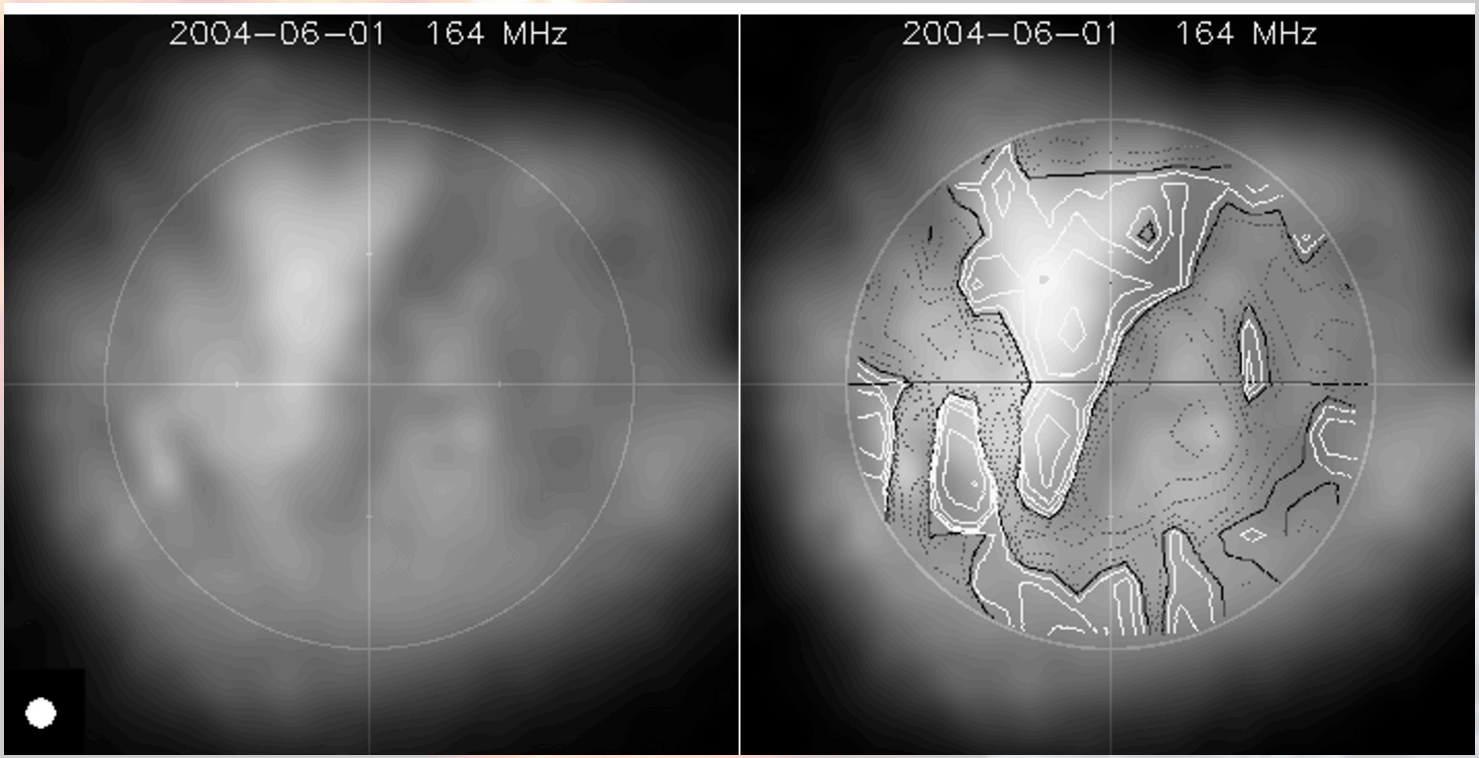


Electrons beams type III bursts
In the LOFAR frequency band

Type III, Type 2 (shocks) , continuas during a flare
Lofar frequency band, and above

Flux: 10^4 to 10^8 jansky

Typical m – deca radio emission: thermal corona emission



164 MHz image
6h synthesis

Nançay RH
164 MHz

Large scale photospheric B
overlay

Bright regions are located between photospheric inversion lines. Could be a support to recent Antochios works on coronal / solar wind magnetic fields.

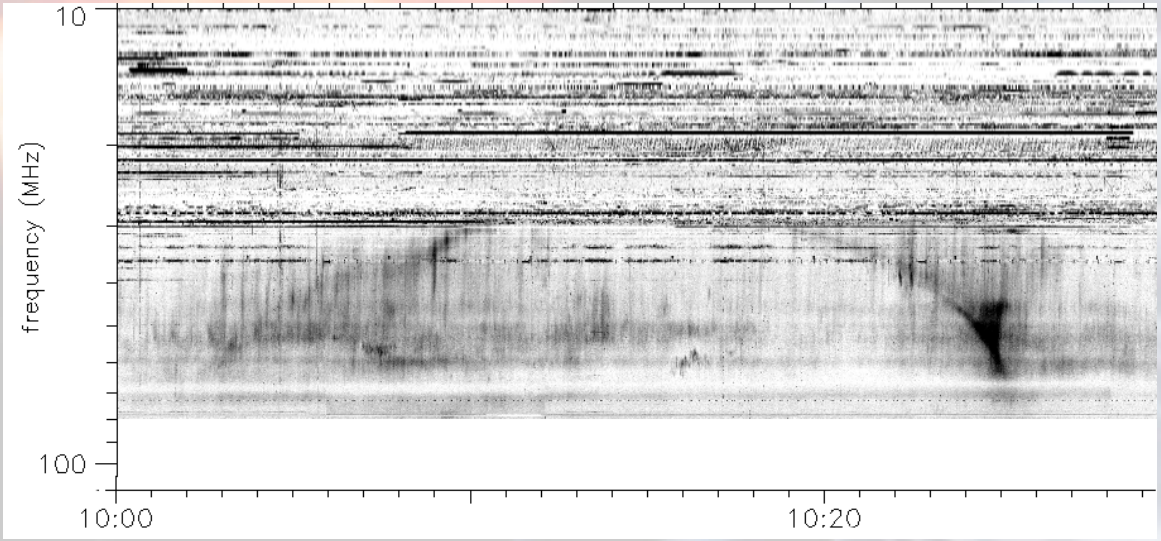
Specific solar problems

- General: Solar activity forecast is difficult
- Imaging:
  - Snapshots:
    - The object is extended, multiscale, and variable.
      - Bursts are very different at different frequencies. Measure the accurate position at each frequency is a main goal.
      - Even the corona thermal emission changes a lot with the frequency
    - Self calibration cannot be used because it looses the absolute position: we try to calibrate on known radio sources, not to close, not to far from the sun.
    - The accuracy and the stability of this calibration has to be known (the calibrator may be unavailable during strong solar emissions)
    - The basic strategy is to compare with the Nançay radioheliograph (NRH) in the High frequency band of LOFAR, then to apply to the low frequency band.
    - Ionosphere corrections ??
  - Rotationnal synthesis: should not be a problem if we can make snapshots.

Spectroscopy

- Easier than imaging
  - Can have high spectral and time resolution
    - LOFAR limitation to one frequency band is severe.
- Again: ionosphere

Expect position shift
> 1R @200 MHz



Nançay decametric array: 10-80 MHz spectrum of a flat continuum (January 5,2014)

Organisation:

Key Science Project
Solar Physics and Space Weather with LOFAR
PI Gottfried Mann, AIP, Potsdam

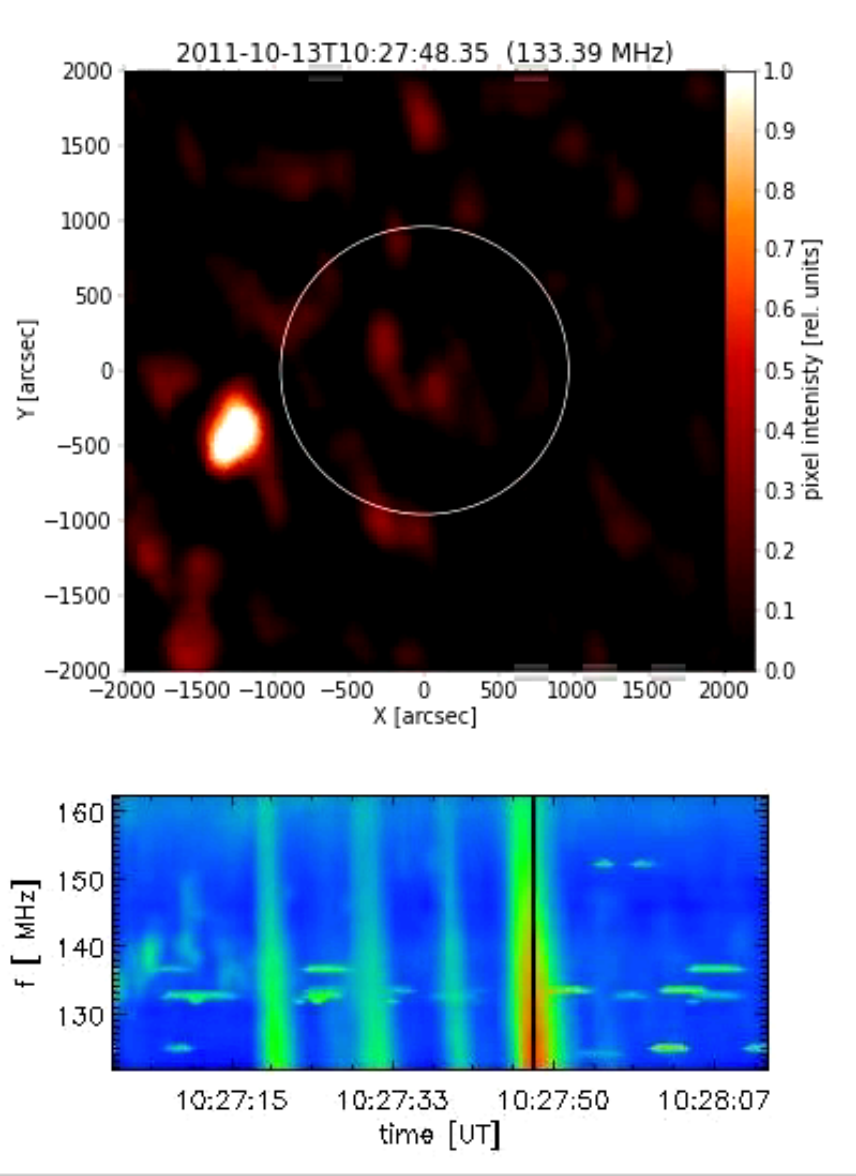
- ≈ 30 participants, 11 countries
- Annual workshops
- AIP makes:
  - A data center lsdc.aip.de
  - The image processing pipe line.

Status of imaging the pipe line

- Using external calibrators has been tested
  - Imaging a radio source calibrated by a second one.
  - Verifying that positions of radio burst at different frequencies are plausible (AIP, work in progress)
  - The instrument is unstable, calibration are valid for a few minutes only.

- The main problem is the scheduling process, its timescale is in weeks. Solar activity prevision is <1 day.

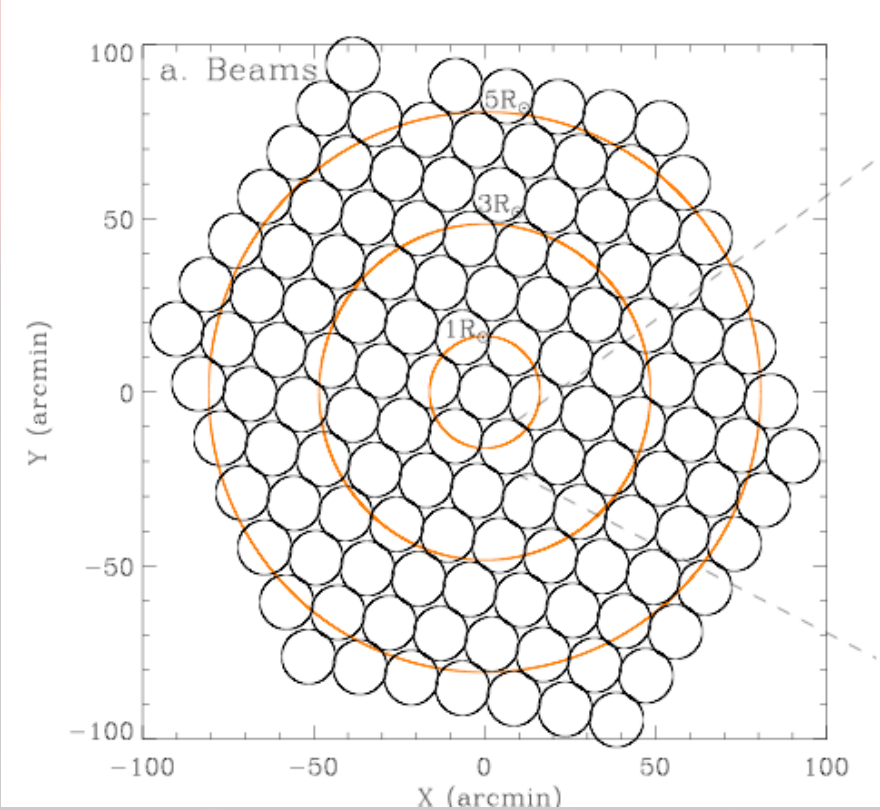
Imaging with a calibrator



LOFAR – NRH images of a T III burst 134 and 151 MHz.

Positions ?

Tied beam mode observation of solar bursts

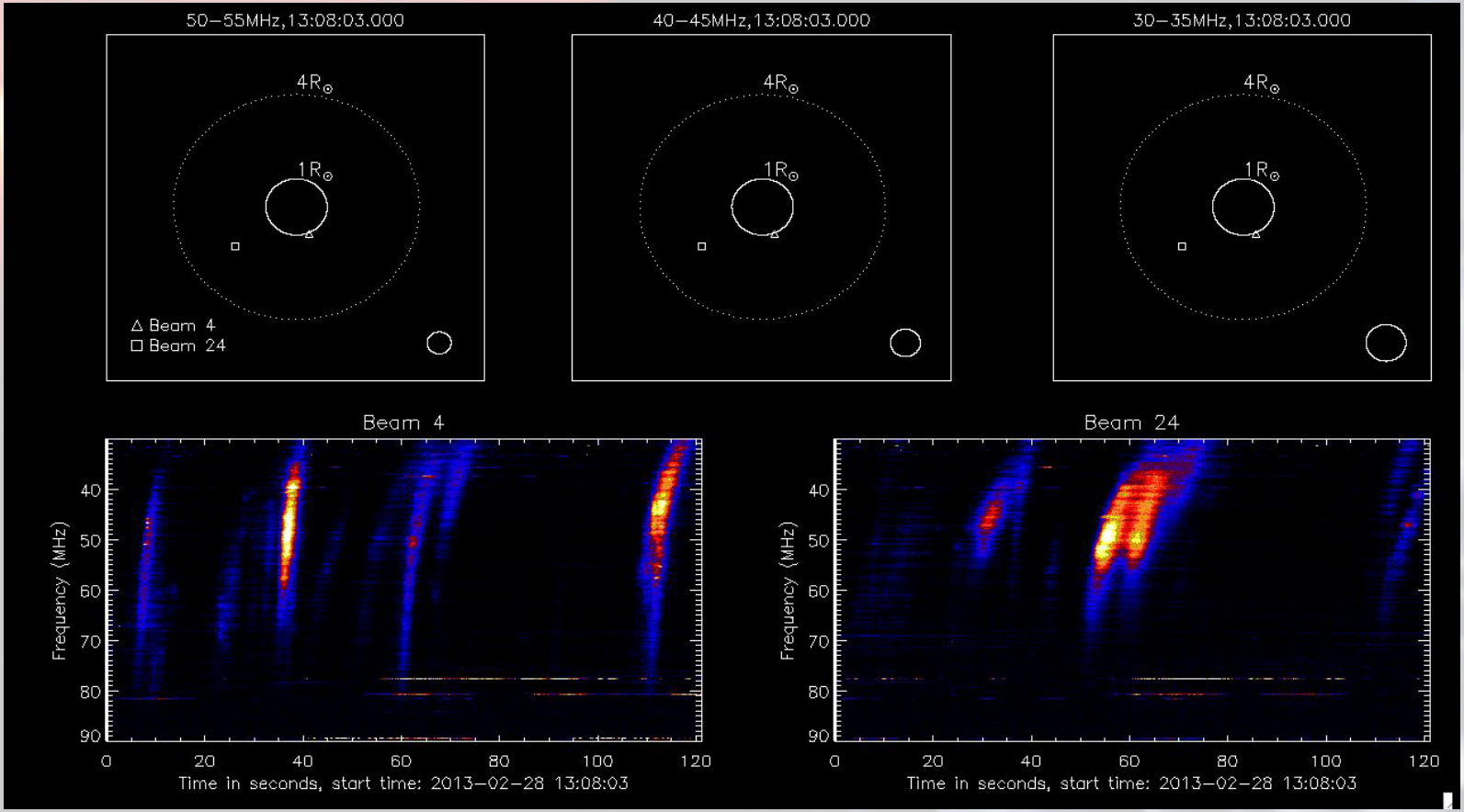


Field 200’ * 200’
126 beams, 15’ @ 40MHz

Gives high resolution spectras in each beam.

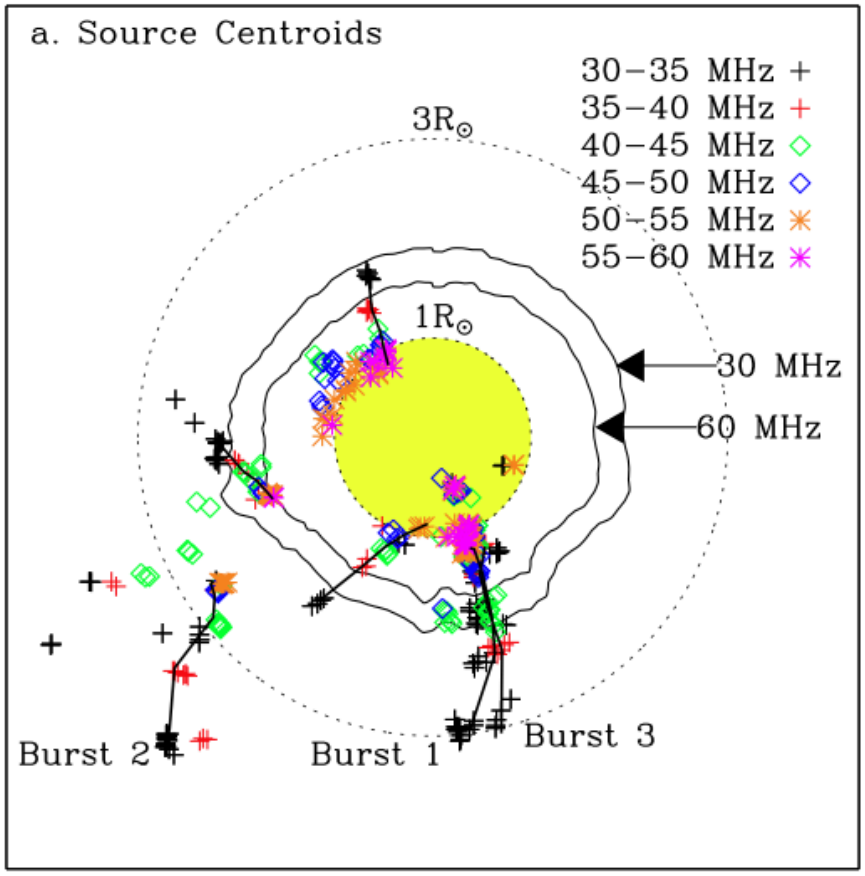
Good complement to FT imaging (if both modes are available together)

Tied beam mode “images”
30-90 MHz spectras in beams 4 and 24



Morosan D. et al, to be published in A & A

Tied beam mode “images”



Is it true, or ionosphere ?

This is a storm activity, which has a stable position at higher frequencies / lower altitudes.

Other observations with LOFAR

- IPS: Possible with LOFAR (Fallows R.A., Solar Phys. 2013)

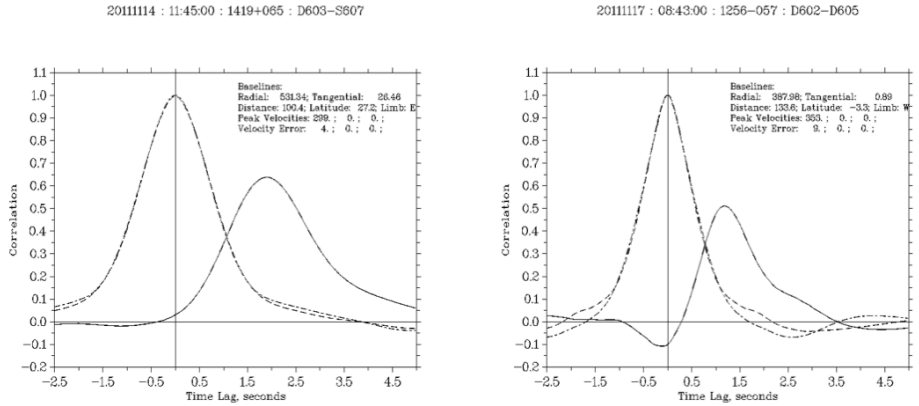


Figure 8. Left: Auto- and cross-correlation functions for an observation of 3C298 taken on 14 November 2011. Right: Same for an observation of 3C279 taken on 17 November 2011.

Auto and cross Correlations for 2 days

Possible CME detection (left)

Many baselines, but there are already 4 dedicated telescopes in the world (India, Japan, Mexico, Korea) which can provide daily maps of the solar wind.

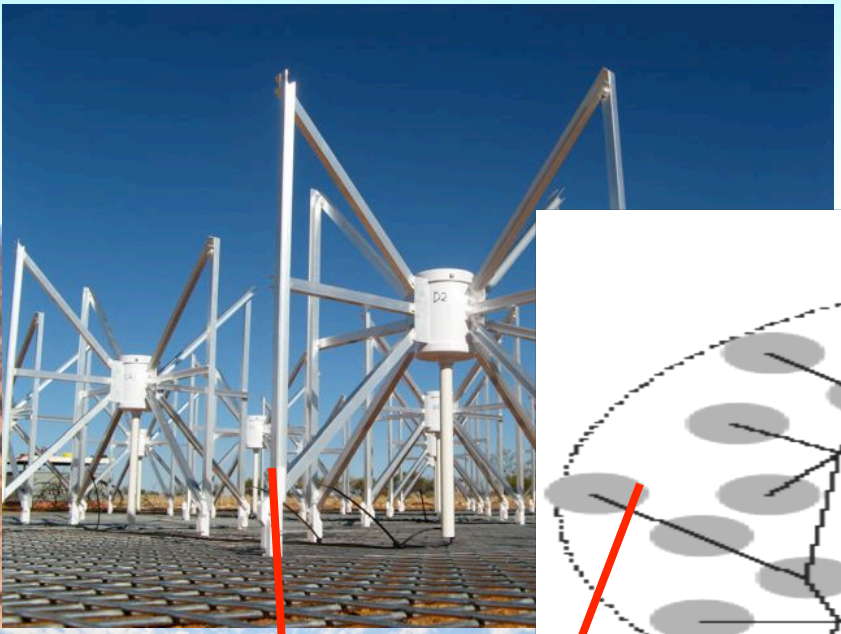
- Faraday rotation in the solar wind ?

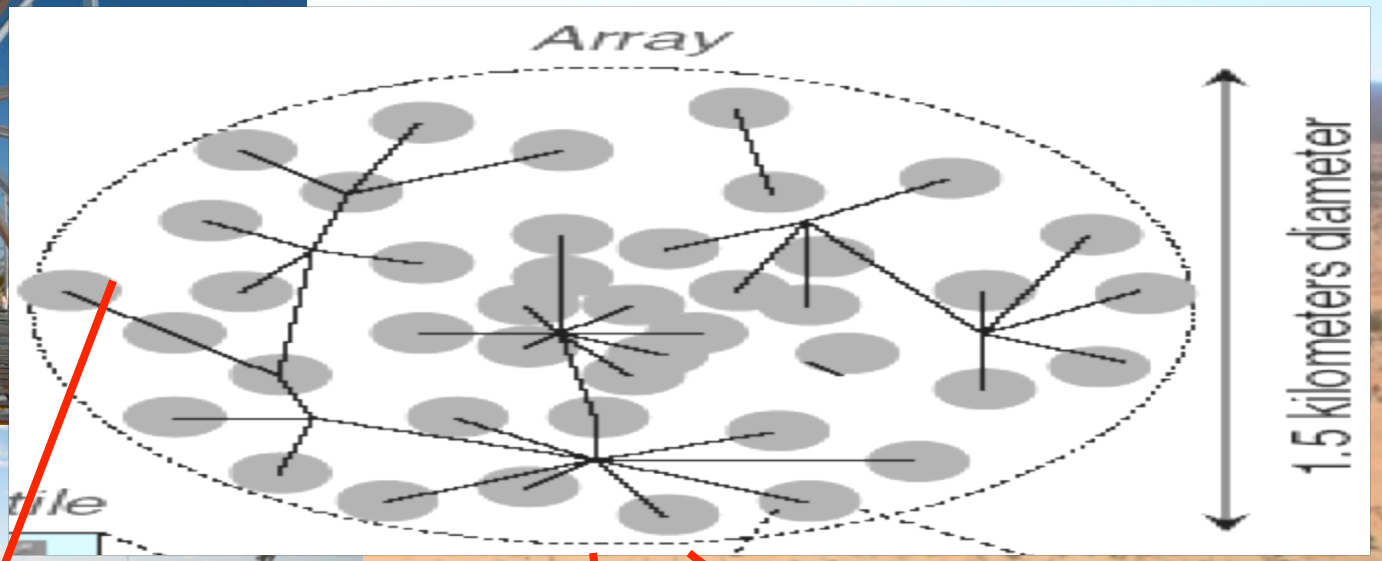
Cycle 1 projects

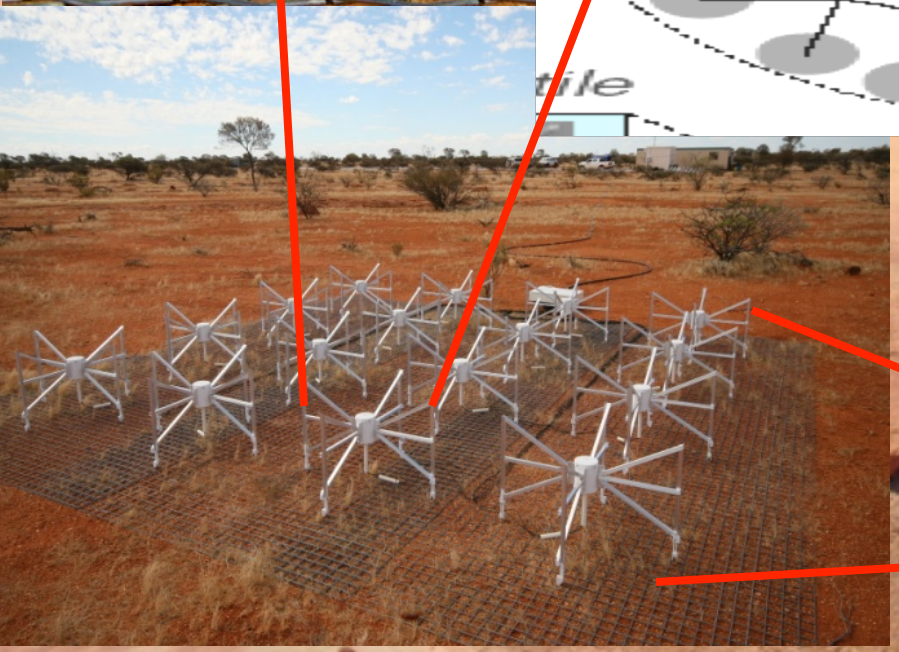
- 4 proposals
  - 1 rejected (tied mode), 3 (22,25,44) merged with a common allocation of 8*6 hours.
  - An alert mechanism is desireable
    - Otherwise, chances to get no interesting emissions are high.
    - Referees mentionned a 24h notice…
    - A quiet sun obervation has its own scientific rationale, despite there was no such proposal.
  - We may add single station spectroscopy
    - The proposal need only the core of Lofar: some international stations may be available during the solar observations.
  - Combine with UTR2 low frequency (10 – 38 MHZ) spectras .

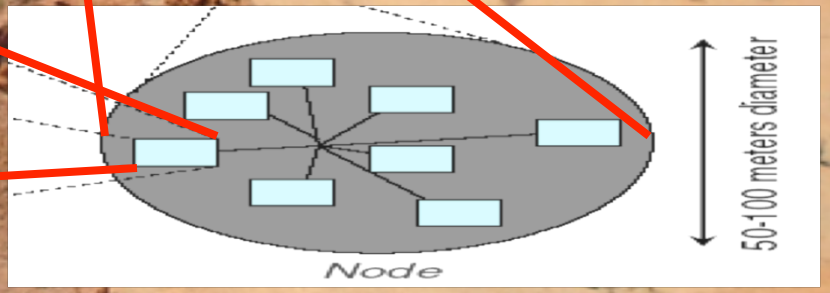
Other instruments: MWA

- Located in Australia
- Compact array
  - Many baselines: high dynamic imaging
  - 100 – 300 MHz
  - Possible drawbacks: speed, dynamic.
  - First call to proposals now.



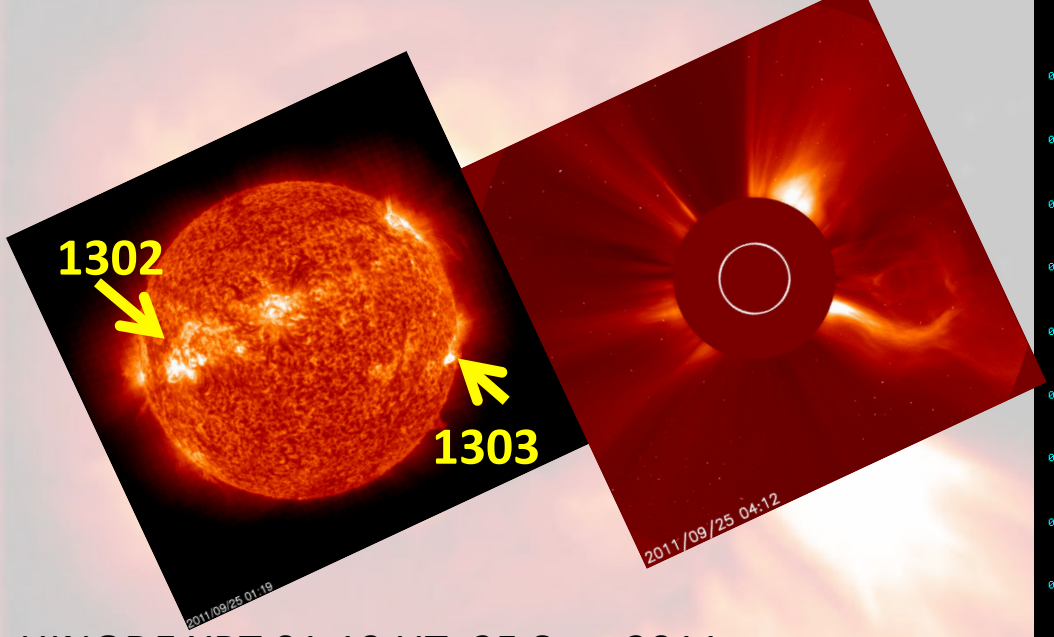

Array
1.5 kilometers diameter

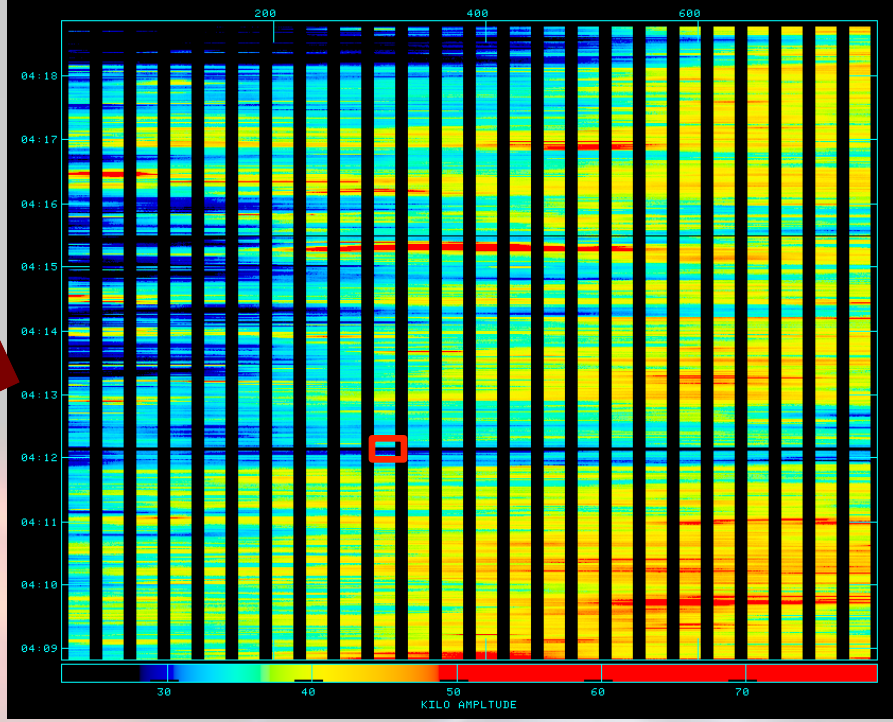



Node
50-100 meters diameter

MWA Performance Parameters

Frequency range	80-300 MHz
Number of receptors	2,048 dual polarization dipoles
Number of tiles	128
Collecting area	~2,000 m^2 (at 200 MHz)
Field of view	~15°-50° (1000 deg^2 at 200 MHz)
Configuration	Centrally condensed core array ~1.5 km dia. Outliers elements - out to a ~3 km dia.
Bandwidth	220 MHz (Sampled); 30.72 MHz (Processed)
# Spectral channels	768 (Processed)
Temporal resolution	0.5 s (Raw); 8 s (Processed)
Polarization	Full Stokes
Point source sensitivity	80mJy in 1 s (30.72 MHz, 200 MHz)
Number of baselines	8,128 (VLA: 351, GMRT: 435, ATA: 861)

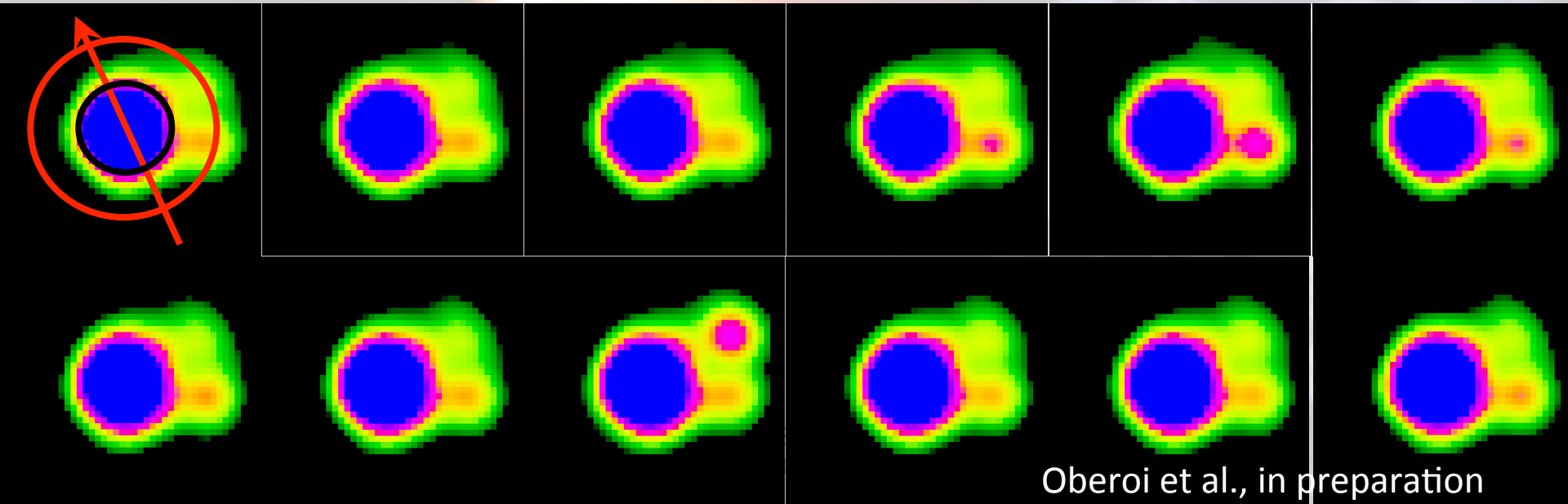




HINODE XRT 01:19 UT, 25 Sep. 2011

SOHO/LASCO C2 at 04:12 UT (19 s integration)

32T 152.3 MHz, 1s, 80 kHz, θ_0=13.3', log scale, DR ~1100, images are 1 s apart



Oberoi et al., in preparation

Merci