Leibniz-Institut für
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Radio Emission from the Sun Observed by LOFAR and SKA

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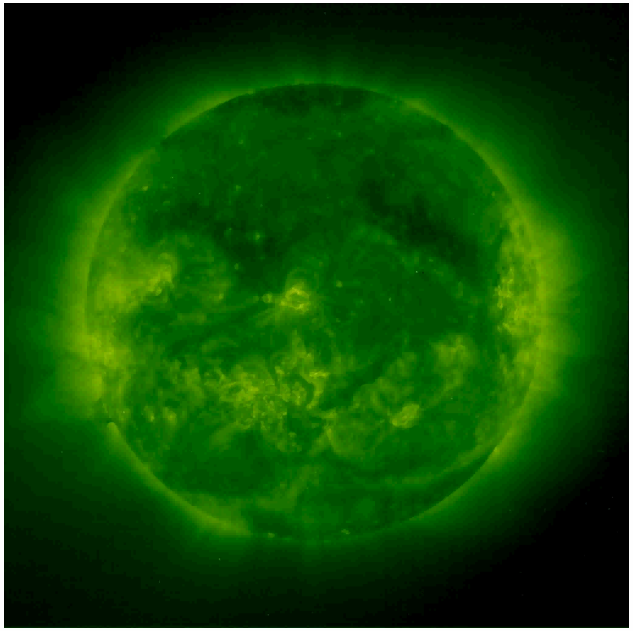
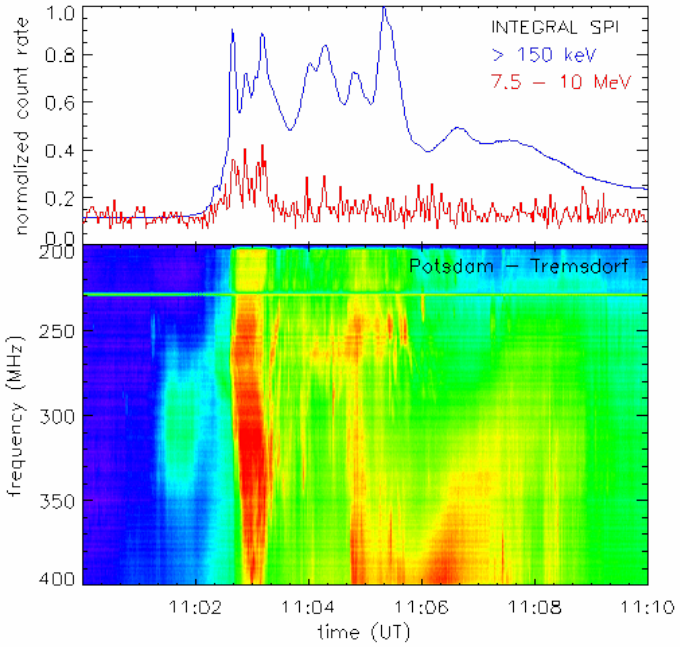
EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds
für regionale Entwicklung

The Flare on October 28, 2003





There is a strong correlation between radio-, hard X-ray and γ-ray emission at large flares, electrons with energies (> 10 MeV) are produced.

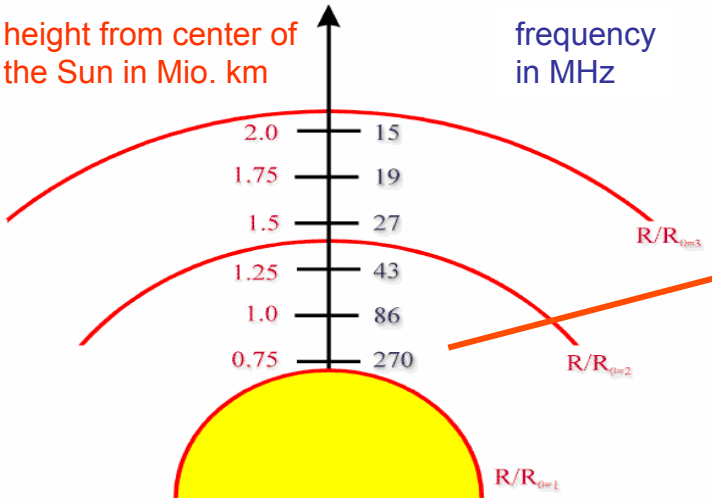
open question: **How are 10^{36} electrons accelerated up to energies > 20 keV within a second?**

Interpretation of Solar Radio Spectra?

radio wave emission → plasma emission $f \approx \sqrt{e^2 N_e / \pi m_e}$

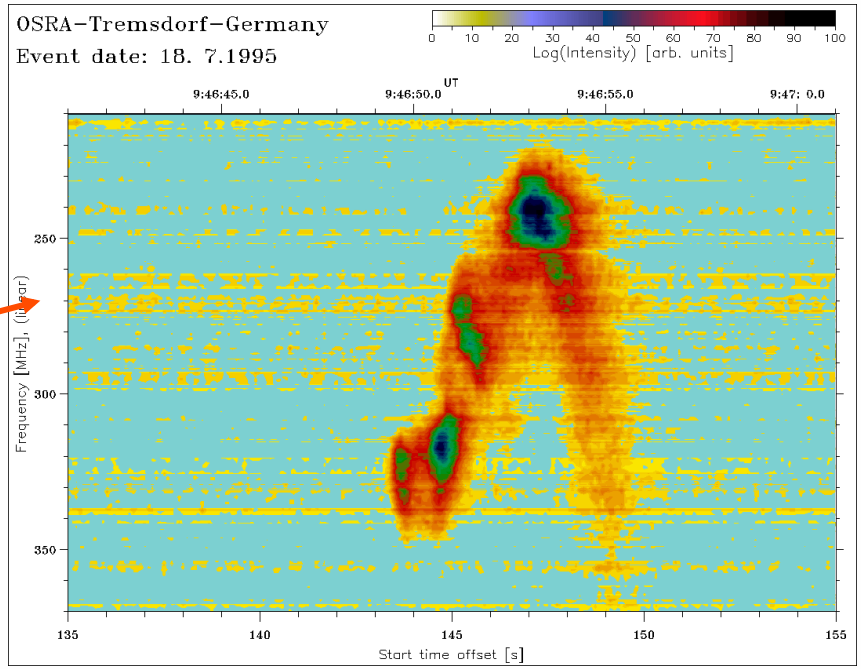
30 MHz	1.80 R_s
70 MHz	1.48 R_s
240 MHz	1.17 R_s

heliospheric density model (*Mann et al., A&A, 1999*)



height ≙ frequency

velocity ≙ drift rate



dynamic radio spectrogram ↔ height-time diagram

Solar Radio Emission I

radio emission from the solar corona – plasma emission

- fundamental rad.:Langmuir w. + low freq. plasma w. → radio wave

$$\omega_R = \omega_{pe} + \omega_{LF} \qquad \omega_{LF} \le \omega_{Whistler} \le 0.1\,\omega_{ce}$$

$$\omega_R \le \omega_{pe}\left[1 + 0.1\,\frac{\omega_{ce}}{\omega_{pe}}\right] \le 1.01\,\omega_{pe} \quad \text{because of } \omega_{pe}/\omega_{ce} > 10 \text{ in the corona}$$

- harmonic emission: Langmuir w. + Langmuir w. → radio wave

$$\omega_R = 2\,\omega_{pe}$$

index of refraction at the emission site

$$n = \sqrt{1 - \frac{\omega_{pe}^2}{\omega^2}} \le 0.14 \qquad \text{for fundamental emission}$$

$$n = 0.87 \qquad \text{for harmonic emission}$$

Solar Radio Emission II

law of refraction

$$\frac{\sin \vartheta_i}{\sin \vartheta_r} = n \quad \rightarrow \quad \vartheta_r = \arcsin\left(\frac{\sin \vartheta_i}{n}\right)$$

→ because of total reflection:

$\vartheta_i \leq 8°$ for fundamental emission

$\vartheta_i \leq 60°$ for fundamental emission

influence at local density fluctuations (turbulence)

$$n^2 = 1 - \frac{\omega_{p0}^2 (1 + \delta N / N_0)}{\omega_F^2}$$

$$\rightarrow \quad n = \sqrt{0.02 - 0.98 \frac{\delta N}{N_0}} \qquad \text{damping if :} \quad 0.02 \leq \delta N / N_0$$

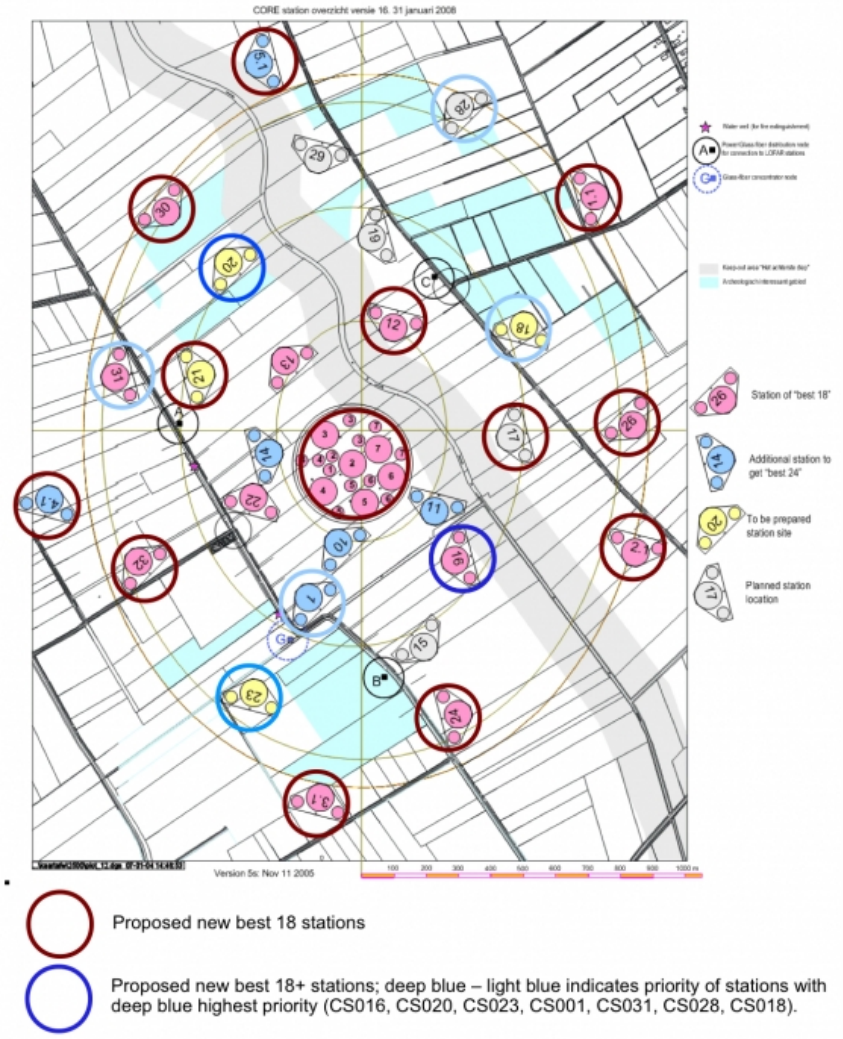
For the fundamental radiation, it is very difficult to leave the emission region in contrast to the harmonic one.

Solar Radio Emission

In the solar corona radio waves are emitted by plasma emission.

Due to density fluctuations in the corona, the spatial resolution is reduced to few 10".

LOFAR's core stations and first ring of remote stations are sufficient for solar observations.

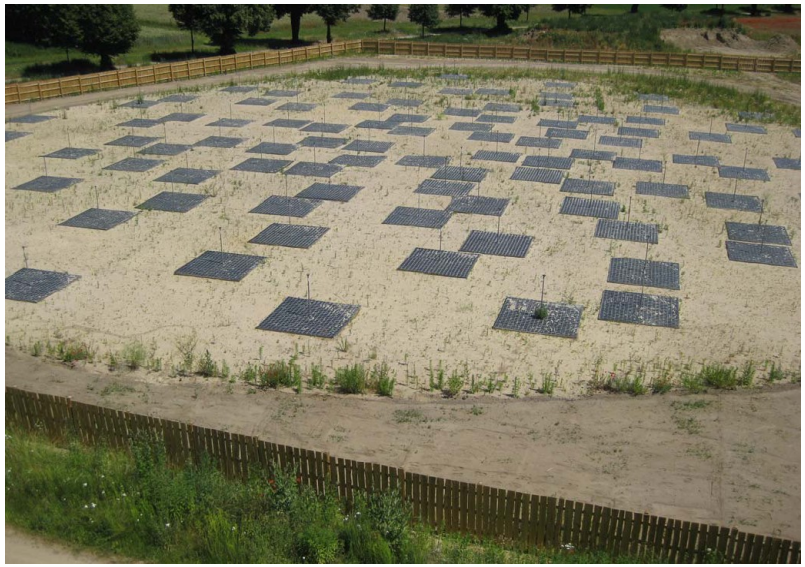


LOFAR as Pathfinder for SKA

LOFAR: LOw Frequency ARray

- 30 – 240 MHz
- LBA: 30 – 80 MHz
- HBA: 120 – 240 MHz

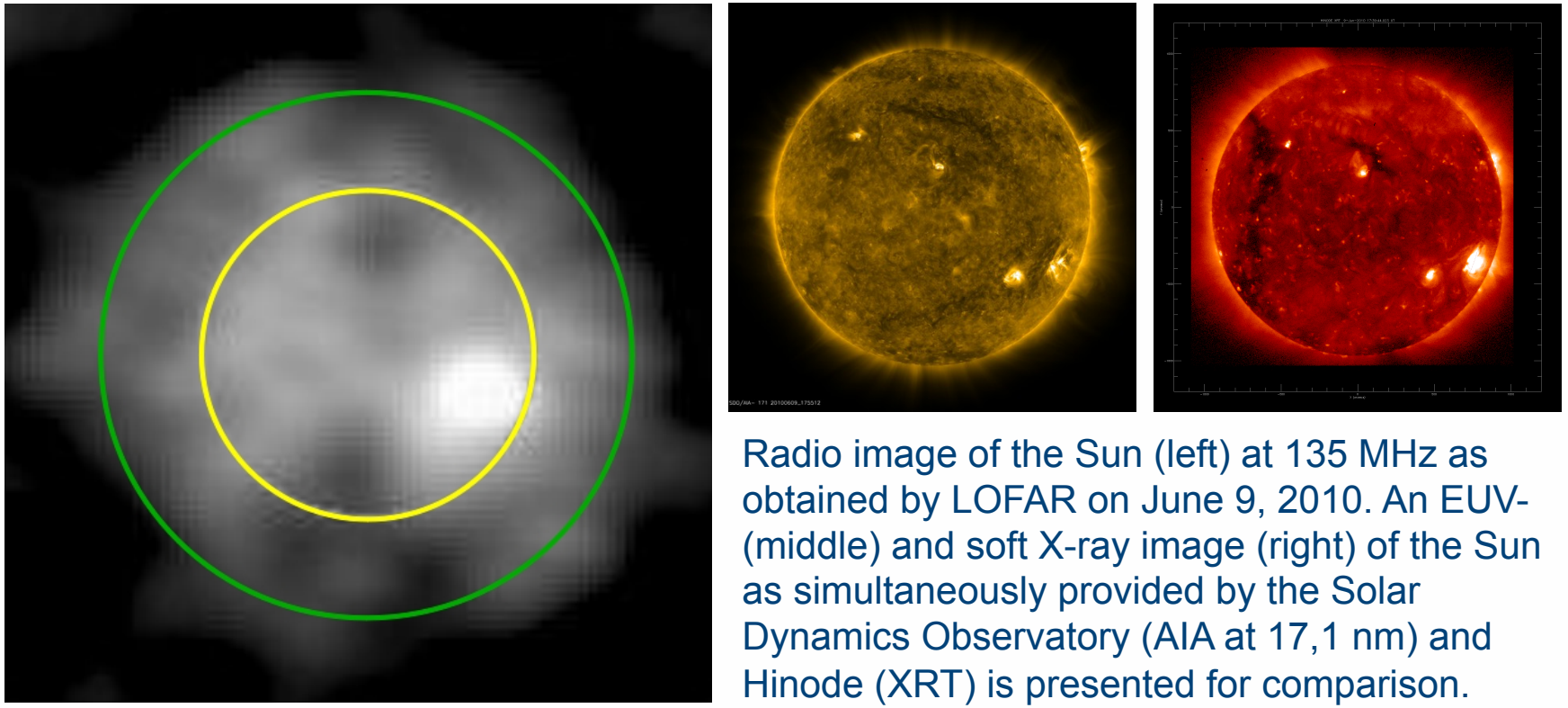
- 22 core stations in NL
- 18 remote stations in NL
- 8 international remote stations (one in Potsdam-Bornim/AIP)



LOFAR


Onsala
Exloo
Potsdam
Jülich
Chilbolton
Tautenburg
Effelsberg
Garching
Nancay
Scale 1: 19,500,000
Lambert Conformal Conic Projection, standard parallels 40°N and 56°N
300 Kilometers
300 Miles
Boundary representation is not necessarily authoritative.
803304AI (R01083) 5-07

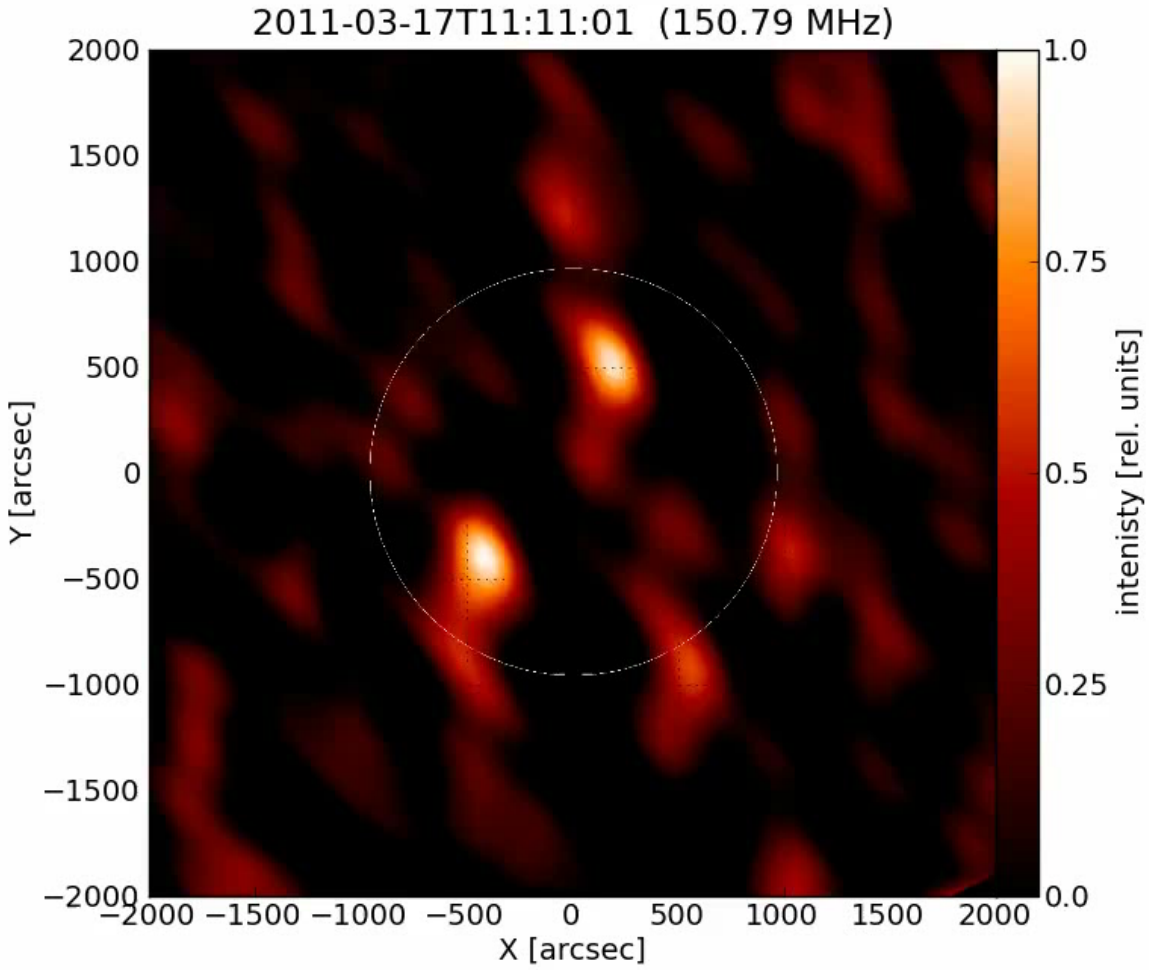
First LOFAR Image of the Sun



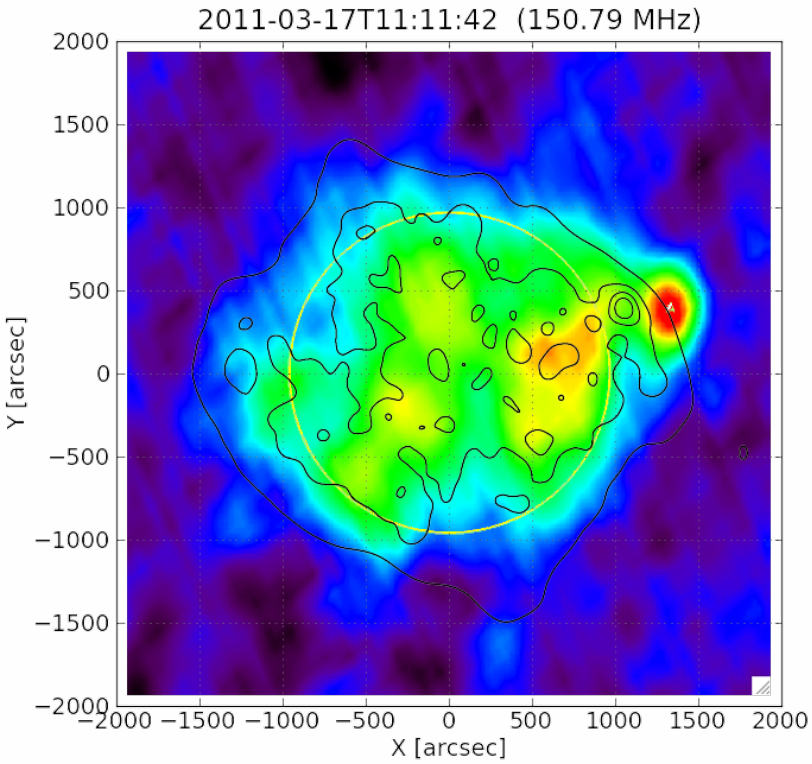
Radio image of the Sun (left) at 135 MHz as obtained by LOFAR on June 9, 2010. An EUV- (middle) and soft X-ray image (right) of the Sun as simultaneously provided by the Solar Dynamics Observatory (AIA at 17,1 nm) and Hinode (XRT) is presented for comparison.

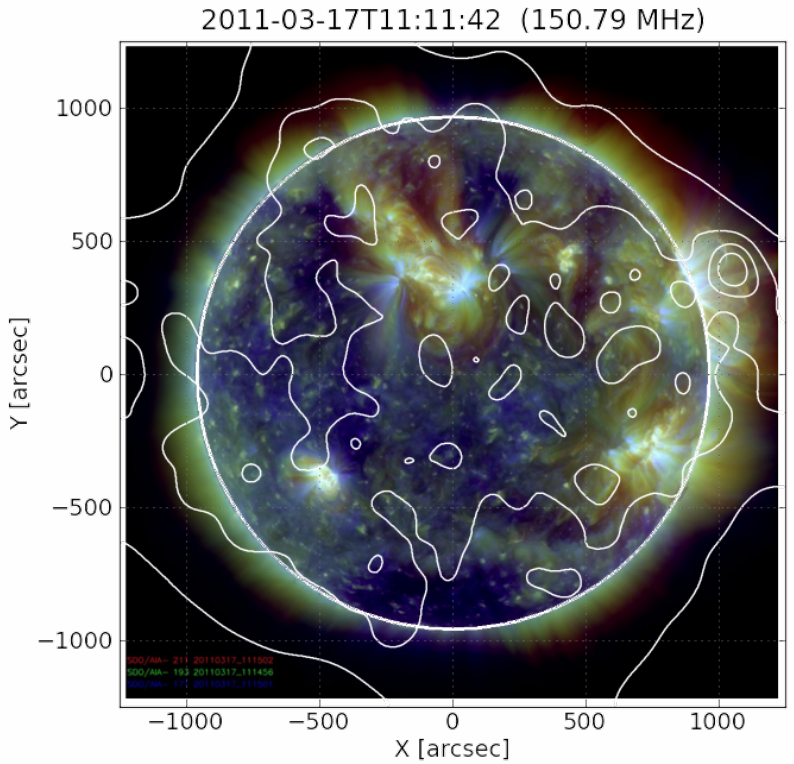
Active region (enhanced radio emission) and polar coronal wholes (reduced emission) are well seen.

First Radio Burst Observed by LOFAR I (March 17, 2011)

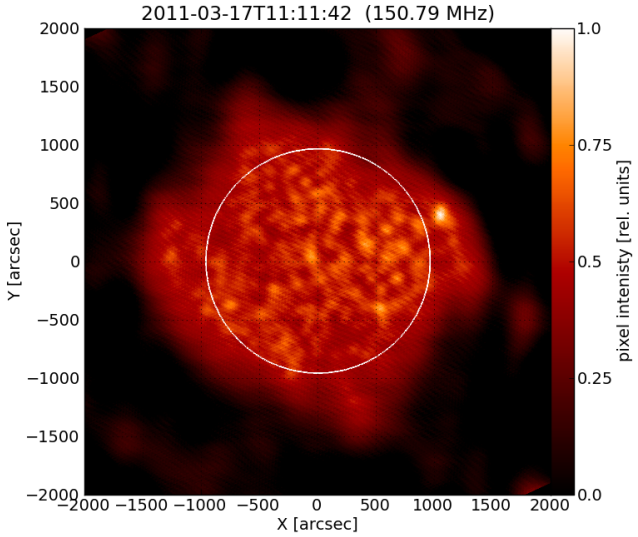


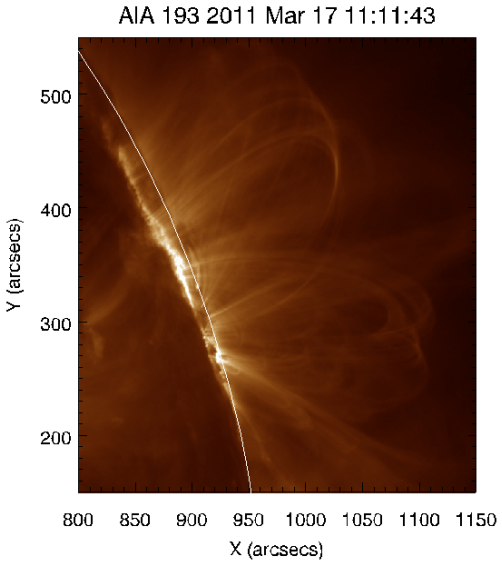
First Radio Burst Observed by LOFAR II (March 17, 2011)

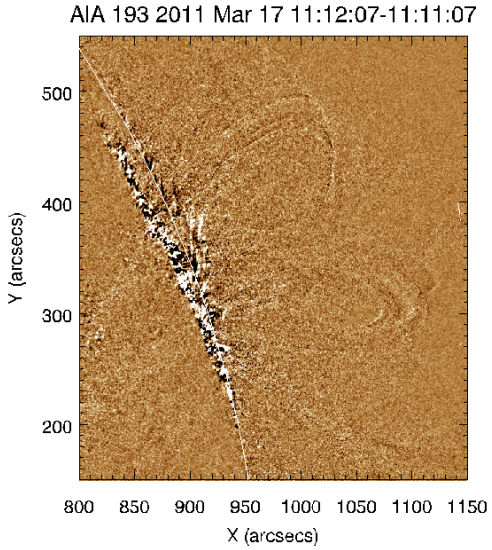




First Radio Burst Observed by LOFAR III (March 17, 2011)







Magnetic reconnection generates a hot plasma jet (→ radio burst)

(Miteva, Mann & Vocks, 2008)

Solar Physics with LOFAR and SKA

SKA and LOFAR as ist pathfinder allows a 3D tomography of the solar radio activity in the corona

scientific objectives:

- magnetic energy release
- electron acceleration
- plasma jets
- shock waves
- solar energetic particle events
- coronal mass ejections (CMEs)

Inst. CMEs influence our Earth ‘s environment and technical civilisation → *Space Weath*

refer to: LOFAR-KSP *Solar Physics and Space Weather with LOFAR*

http://www.aip.de/groups/osra/german/de_lofar.html

Summary

SKA and LOFAR as ist pathfinder are of great interest for solar physics, since these instruments allow a 3D tomography of the solar activity in the corona.

Solar radio astronomy can study plasma processes related energetic electrons. That can never be done by other instruments.

These processes are of special interest, since they are able to influence our Earth's environment and our technical civilization, which is usually called Space Weather.

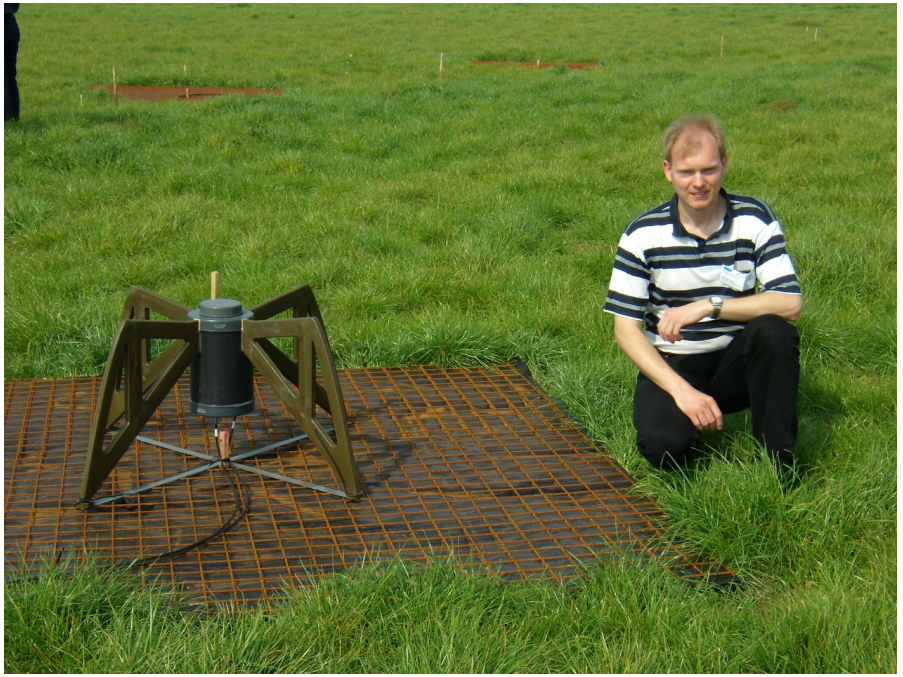
Thank you for your attention !

LOFAR

LBA: 30 – 80 MHz

96 antennas

HBA: 120 – 240 MHz



4 x 4 x 96 antennas

All stations are connected with high data trasfer (10 Gbit/s) link with Groningen, where the data are correlated.

Key Science Project
Solar Physics and Space Weather with LOFAR

31 participants from 11 countries

1st workshop	Oct. 5/6, 2006
2nd workshop	June 24/25, 2009
3rd workshop	July 5/6, 2010
4th workshop	Nov. 8/9, 2010
5th workshop	June 28-30, 2011