Key Science Projekt

Solar Physics and Space Weather with LOFAR

Gottfried Mann
Astrophysikalisches Institut Potsdam,
An der Sternwarte 16, D-14482 Potsdam, Germany
GMann@aip.de

AIP

LOFAR (30 – 240 MHz)

18 core stations
18 remote stations (in NL)
8 internat. remote stations (5 in D)

Leibniz Gemeinschaft

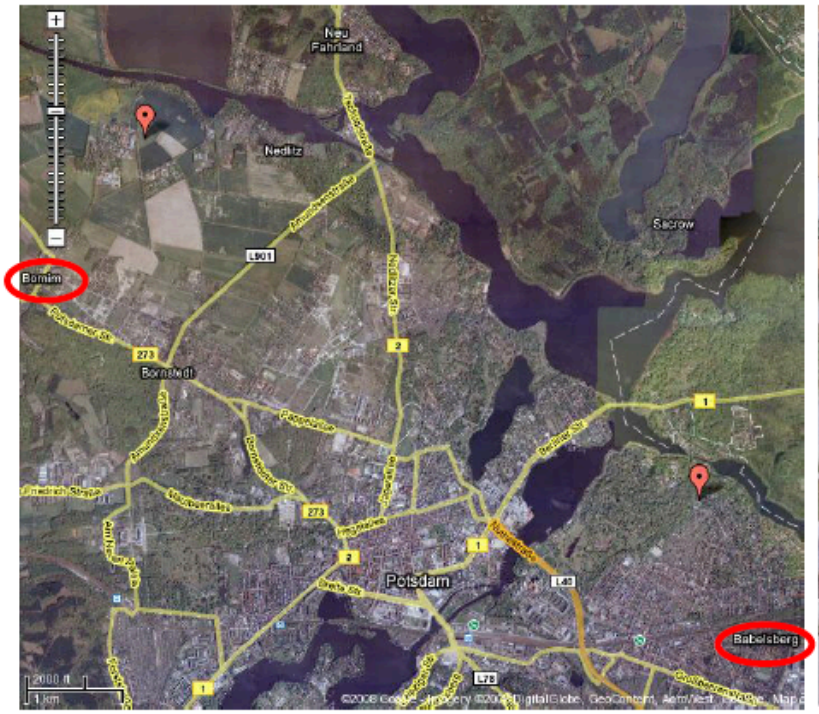
Bundesministerium für Bildung und Forschung

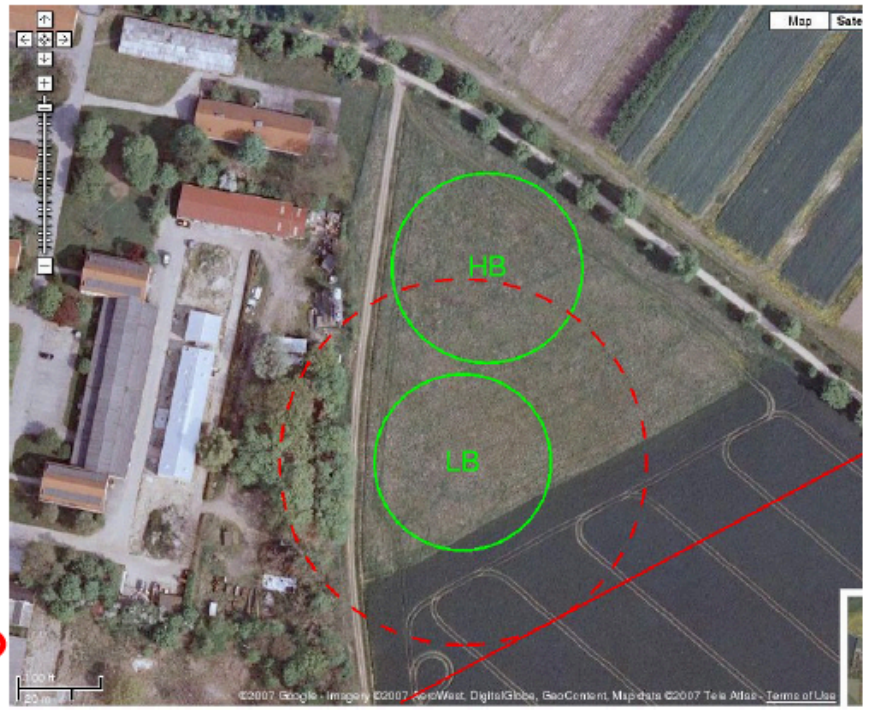
LOFAR Remote Stations in Germany

All stations are already funded.

Station of the AIP in Potsdam-Bornim

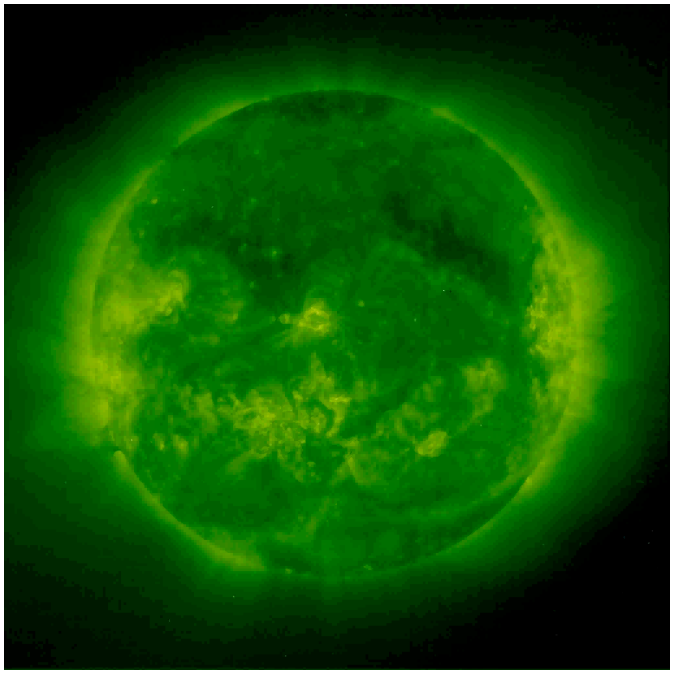
Site at the Leibniz-Institut für Agrartechnik Potsdam-Bornim (ATB)



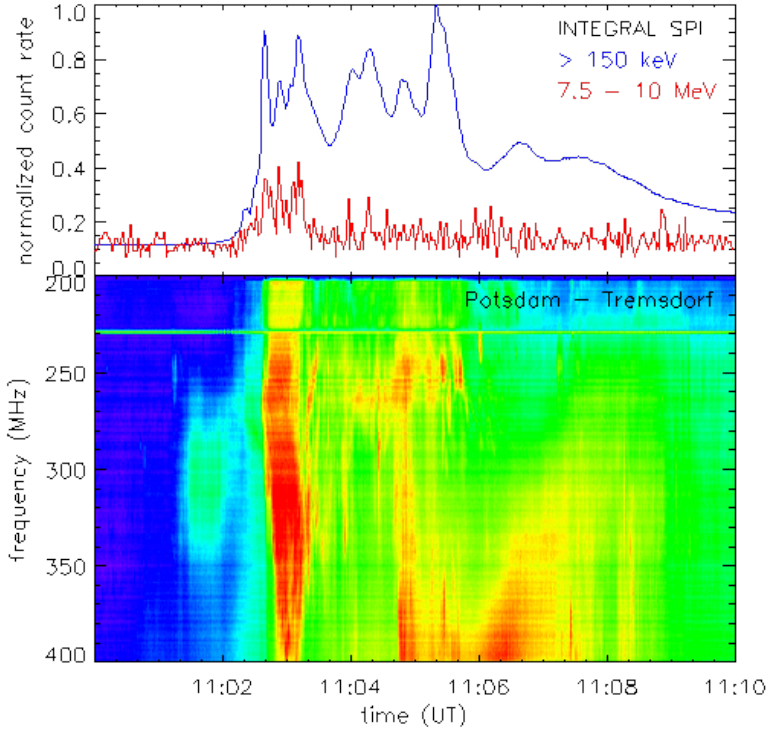


The Sun is a Radio Emitter

nonthermal solar radio radiation – sensitive indicator of ***solar activity***



solar event on Oct. 28, 2003



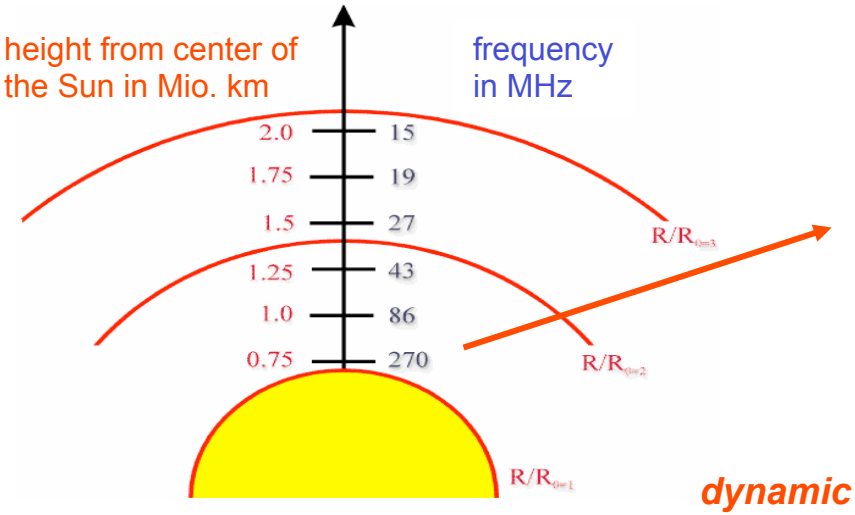
Coronal Radio Emission

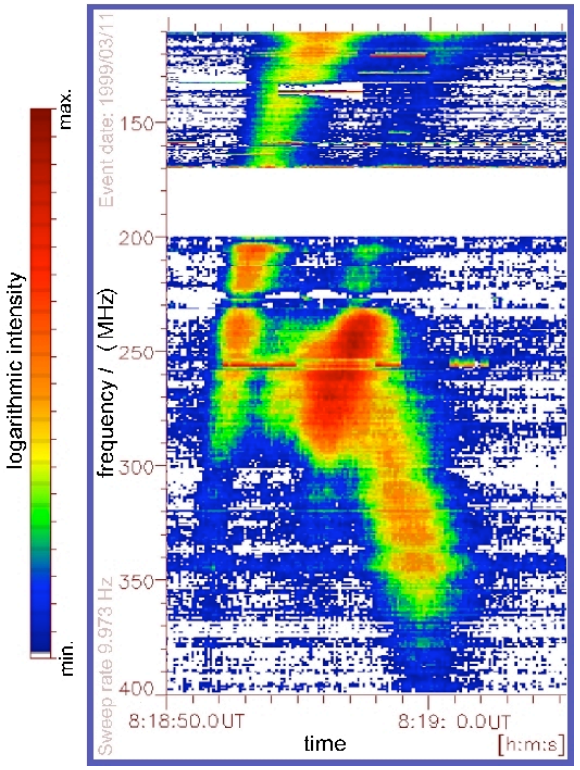
f_{NRH} (MHz)	r/R_S	f_{NRH} (MHz)	t (ms)
432	1.06		
411	1.07		
327	1.11		
	1.17	240	0
237	1.17		
	1.21	200	9
164	1.25		
151	1.27		
	1.32	120	35
	1.44	80	63
	1.80	30	1470

radio wave emission → plasma emission

$$f \approx \sqrt{e^2 N_e / \pi m_e}$$

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





dynamic radio spectrogram ↔ height-time diagram

Coronal Density Model

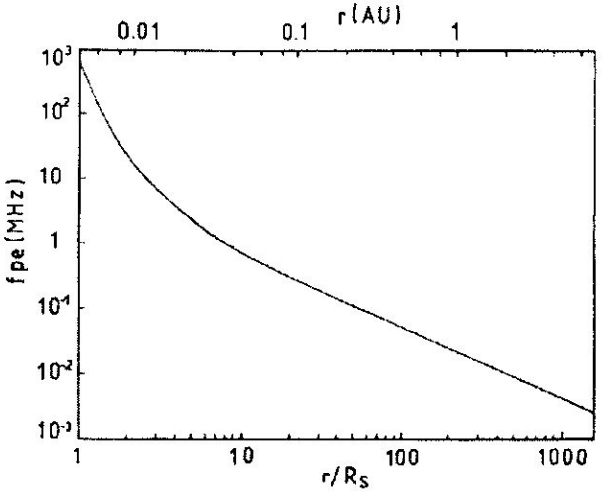
Parker's wind equation *(1958)*

$$\frac{v(r)^2}{v_c^2} - \ln\left(\frac{v(r)^2}{v_c^2}\right) = 4\ln\left(\frac{r}{r_c}\right) + 4\cdot\frac{r_c}{r} - 3$$

$$v_c = (k_B T / \tilde{\mu} m_p)^{1/2}$$

$$r_c = GM_S / 2v_c^2$$

$\tilde{\mu} = 0.6$ – mean molecular weight

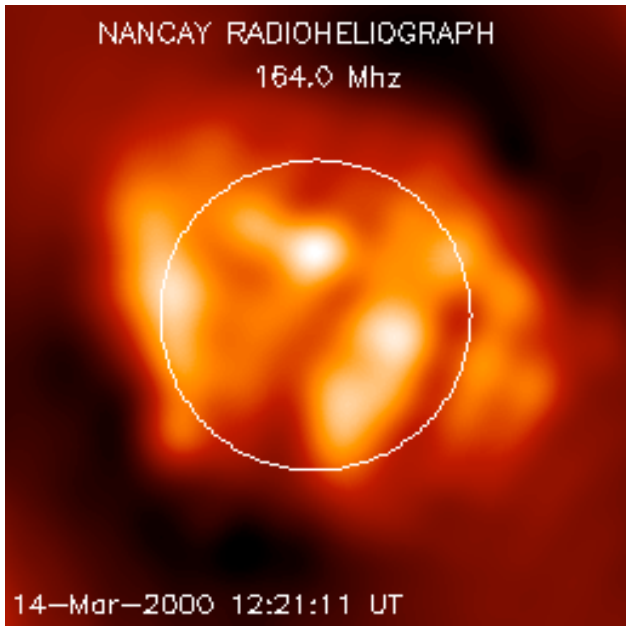


A ***special*** solution agrees well with density measurements up to 5 AU (*Mann et al., 1999*)

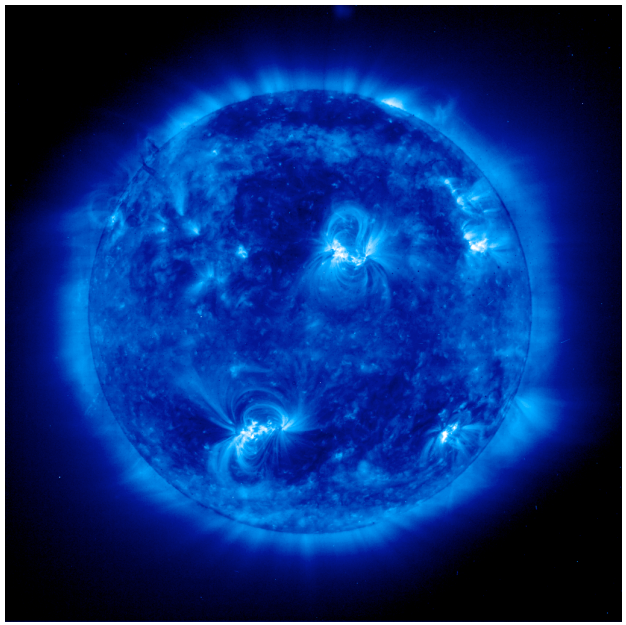
f	r/R_S
240	1.17
170	1.24
100	1.37
70	1.48
40	1.68
30	1.80

→ ***LOFAR is able to observe the high corona.***

Solar Observations with LOFAR



Nancay radio heliograph image
(resolution 60“ = 43000 km)



- theoretical resolution 2“
- due to scattering of radio waves
  in the corona → resolution 40 – 60“

$$n = \sqrt{1 - \frac{\omega_{pe}^2}{\omega^2}} \leq 0.1 \quad \text{with} \quad \omega \leq \omega_{pe} + 0.1\omega_{ce}$$

→ **LOFAR‘s core stations are sufficient enough for observing the corona.**

Observing Modes for the Solar KSP

The radio images at different frequencies, i.e. different height levels, allows a 3D tomography, of the flare related processes in the corona of the Sun.

3 observing modes:
- radio spectrometery (spectrometer mode)
- solar burst imaging (burst mode)
- monitoring the solar activity (monitoring mode)

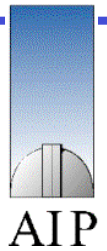
– ***Solar Science Data Center*** at the AIP

– complementary ground-based observations to space missions (e.g. RHESSI, STEREO, Hinode, SDO, and Solar Orbiter (EPT, STIX)) and to LOIS

The monitoring mode provides an important input for the forecast of solar activity.

– ***Space Weather*** is of social relevance → important for our funding agencies.

Data Volume I



spectrometer mode:

- temporal resolution 0.01 s
- spectral resolution 100 kHz

  30 – 80 MHz and 120 – 240 MHz (= 170 MHz total band with)
  → 170 MHz/100 kHz = 1700 channels

  each value = 2 bytes → data rate: 340 kB/s = 1.224 GB/h

- multiple stations (6) have to be combined.

monitoring mode:

- temporal resolution 1 minute
- frequencies: 40, 80, 120, 240 MHz → data rate: 26 kB/s = 93.6 MB/h

Data Volume II

burst mode:

- temporal resolution: 0.1 s
- measuring at 22 frequencies

low band:

frequency Nr.	1	2	3	4	5	6	7	8	9
frequency [MHz]	40	45	50	55	60	65	70	75	80

high band:

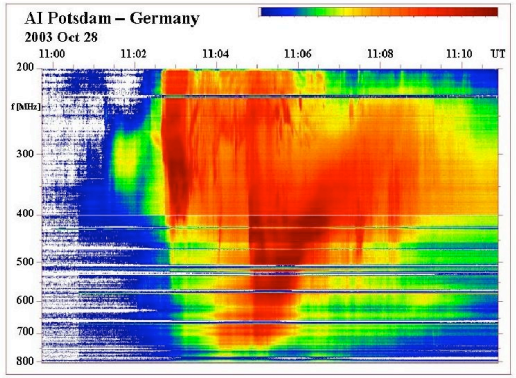
frequency Nr.	10	11	12	13	14	15	16	17	18	19	20	21	22
frequency [MHz]	120	130	140	150	160	170	180	190	200	210	220	230	240

→ data rate: 100 MB/s = 360 GB/s

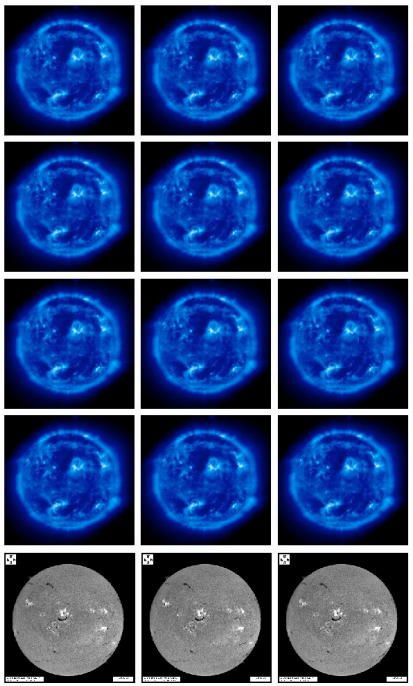
The switching between monitoring and burst mode can be triggered by an external instrument (egs. radiospectrometer 30 – 2000 MHz), which acts on a ***burst bell.***

Monitoring the Solar Activity

Radio Spectrum



time



link to the H_α-patrol mission

KSO (Kanzelhöhe, Austria)

Management Structure

	Name	Affiliation	Country
PI	Prof. Dr. Gottfried Mann	AIP	Germany
core members	Dr. Alain Kerdraon	Obs. de Paris-Meudon	France
	Dr. Alec McKinnon	Univ. Glasgow	UK
	Prof. Dr. Bo Thide	Univ. Uppsala	Sweden
(project manager)	Dr. Christian Vocks	AIP	Germany
ordinary members	Dr. Henry Aurass	AIP	Germany
	Dr. Andy Breen	Univ. Aberystwyth	UK
	Frank Breitling	AIP	Germany
	Dr. Harry Enke	AIP	Germany
	Dr. Richard Fallows	Univ. Aberystwyth	UK
	Dr. Peter Gallagher	Trinity College Dublin	Ireland
	Dr. Norbert Jakowski	DLR Neustrelitz	Germany
	Dr. Matthias Hoeft	Thür. LSW Tautenburg	Germany
	Dr. Alexander Konovalenko	Institute of Radio Astronomy	Ukraine
	Dr. Eduard Kontar	Univ. Glasgow	UK
	Dr. Christophe Marqué	Royal Obs. of Belgium	Belgium
	Dr. Jürgen Rendtel	AIP	Germany
	Prof. Dr. Helmut Rucker	IWF Graz	Austria
associated memb.	Prof. Dr. John Brown	Univ. Glasgow	UK
	Dr. Philippa Browning	Univ. Manchester	UK
	Dr. Bartosz Dabrowski	Royal Obs. of Belgium	Belgium
	Prof. Dr. Carsten Denker	AIP	Germany
	Dr. Lyndsay Fletcher	Univ. Glasgow	UK
	Prof. Dr. Arnold Hanslmeier	Univ. Graz	Austria
	Dr. Karl-Ludwig Klein	Obs. de Paris-Meudon	France
	Dr. Jasmina Magdalenic	Royal Obs. of Belgium	Belgium
	Mag- Wolfgang Otruba	Sonnenobs. Kanzelhöhe	Austria
	Prof. Dr. Joachim Vogt	Jacobs Univ. Bremen	Germany
	Dr. Alexander Warmuth	AIP	Germany

AIP

The combined observations of the solar radio radiation

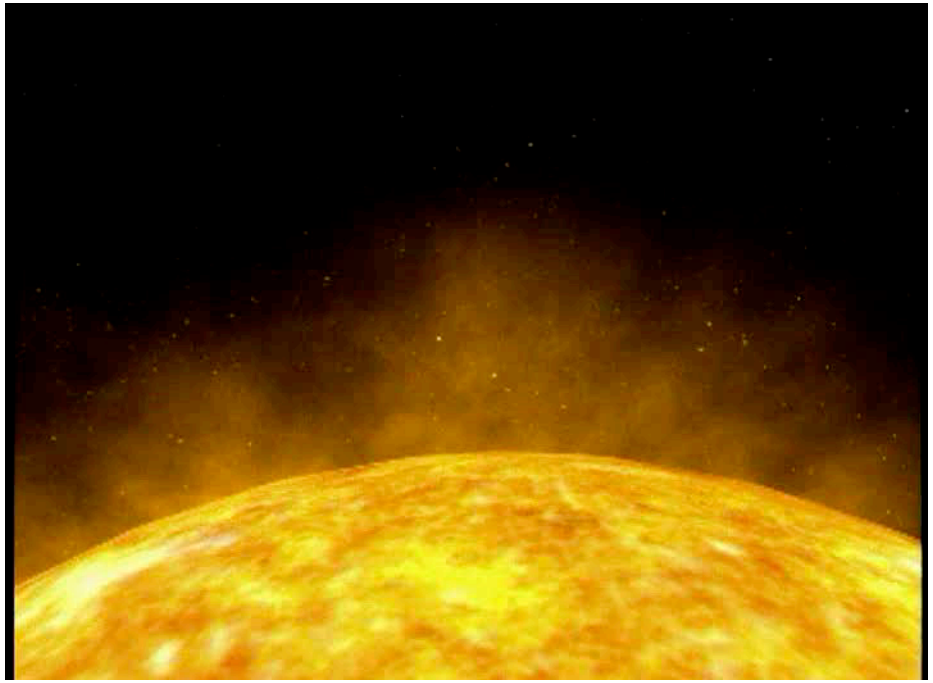
by NRH and LOFAR

would allow to study the solar activity in 3D in the whole corona.

Let‘s hope to realize our intentions concerning LOFAR

Space Weather

The ***Sun*** is influencing our ***Earth's environment***.



- ***solar flares – emission of electromagnetic radiation (radio – γ ray range)***

  → ionosphere
  → upper atmosphere

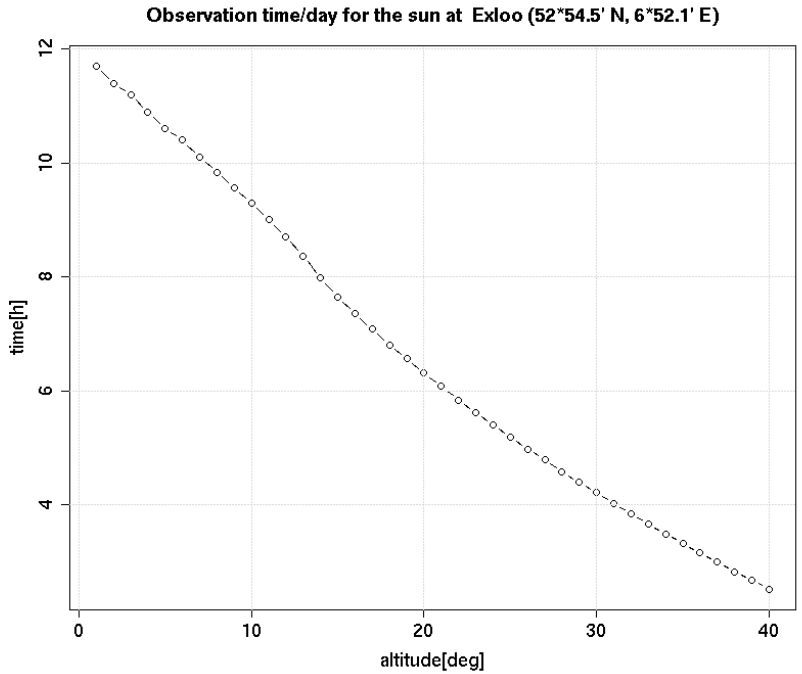
- ***energetic particles***
  (after 10 – 60 minutes)

  → northern lights
  → disturbances of electronic equipments

- ***Coronal Mass Ejections***
  (after 20 – 100 hours)

  → magnetic storms
  → disturbances of navigation
  → voltage flashes in pipelines

Observation Time



daily observation time for the Sun with an altitude > 10°.

in average: 8h

thermal flux of the Sun: ≈ 1 sfu = 10^{-22} W·m^{-2}·Hz^{-1}

non-thermal flux at flares: ≤ 10^4 sfu

Data Volume III

(Summary)

data type	data rate [MB/s]	data per year [TB]
burst mode	100	100
monitoring mode	0.026	0.27
spectrometer mode	0.34	3.57

Financial Support by Funding Agencies

- D-LOFAR, Bundesministerium für Bildung und Forschung, 2008 – 2011, 162 T€
  - Frank Breitling
  - software development for solar LOFAR observations
- Neue Perspektiven in der Astronomie mittels LOFAR, Leibniz Society, 2009 – 2011, 596 T€
  - Dr. Christian Vocks – project manager

possibly in future: FP7 space work programme

SPA 2010: 2.3-01 Security of space assets from space weather events

call: July 30, 2009

deadline: Nov. 12, 2009