Solar activity from detailed sunspot database
An alternative measure

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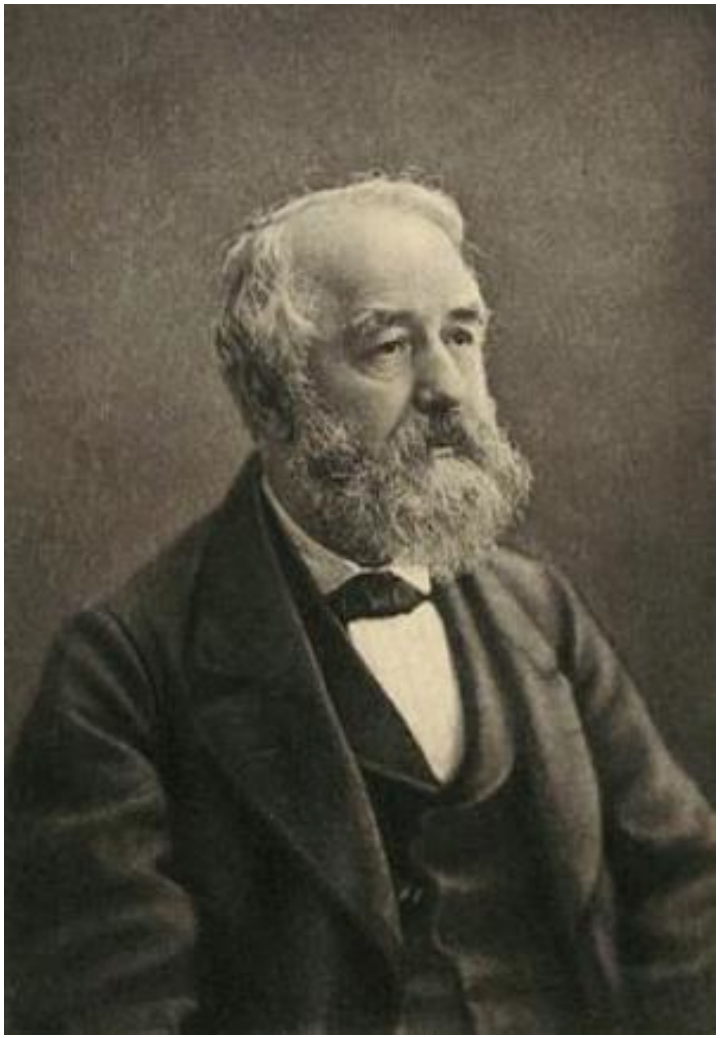
Abstract

To reconsider the physical meaning of the sunspot number we have to remember that there are different physical mechanisms which govern its two components: the number of observed sunspot groups (denoted by g) and the number of all observed spots (denoted by s). These are one of the reasons of the ambiguity of the sunspot number. To eliminate this ambiguity we need to take into account not only the sunspot sizes but the aspects of observability as well.
This talk will suggest a new activity index which can be given by using detailed sunspot data. The mentioned index is the amount of emerged magnetic flux which can be calculated by using the sunspot area dataset, the only long-term proxy measure. It can be calibrated to the magnetic flux.
The detailed Debrecen databases provide the opportunity to calculate the suggested sunspot index.

Outlook

- Measure of the solar activity
  - Past
  - Recent
- Its weaknesses
- Proposed alternative measure
  - Detailed sunspot database
  - Method
- Summary

Wolf number – Relative sunspot number



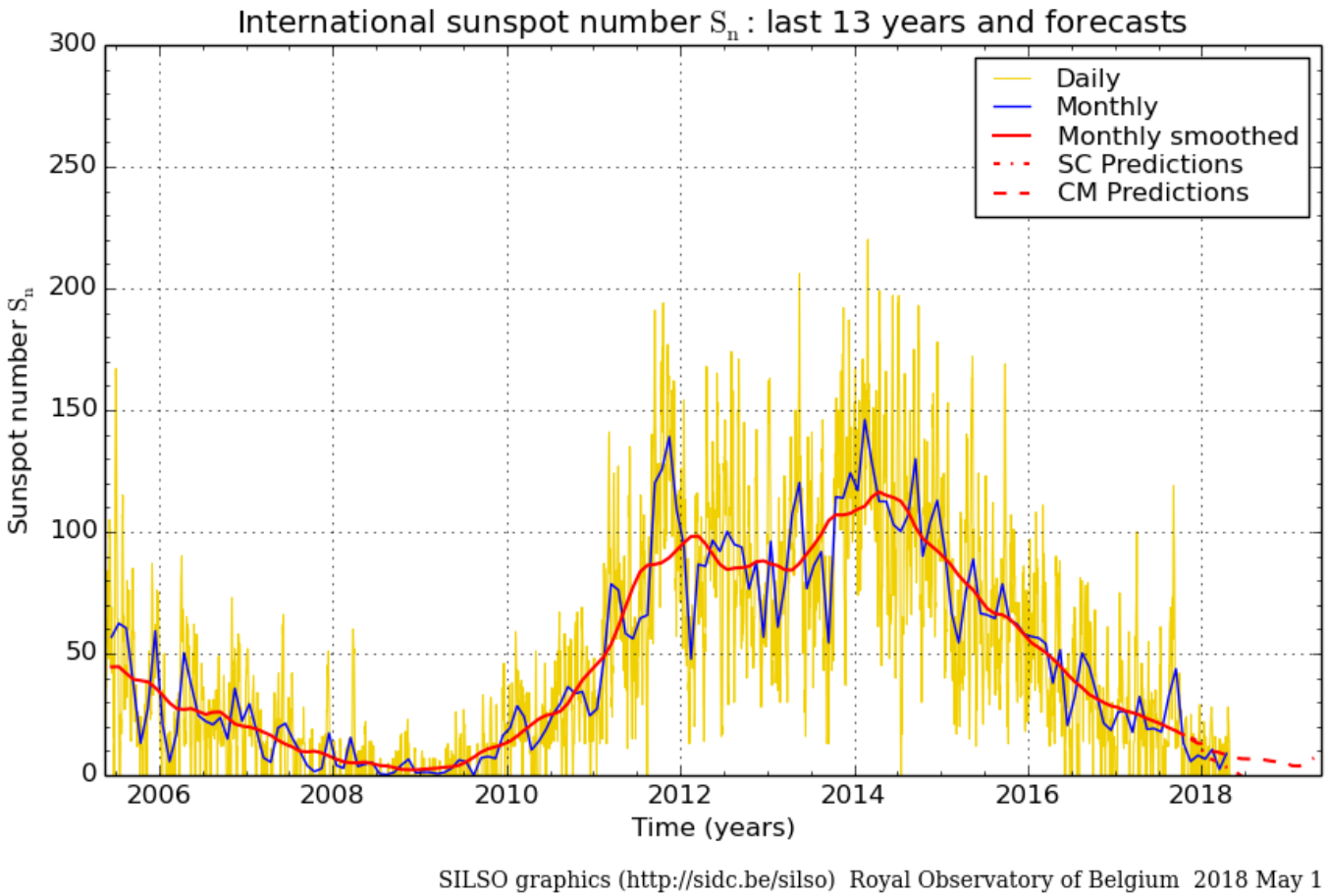
Introduced by R. Wolf 1848 at the Zurich Observatory

$$R_Z = k \cdot (10g + s) \qquad (1)$$

where k: constans for each observatory
g: number of sunspot groups
s: number of sunspots

International Sunspot Number

Now International Sunspot Number by Sunspot Index and Long-term Solar Observations (SILSO) team at the Royal Observatory, Brussels



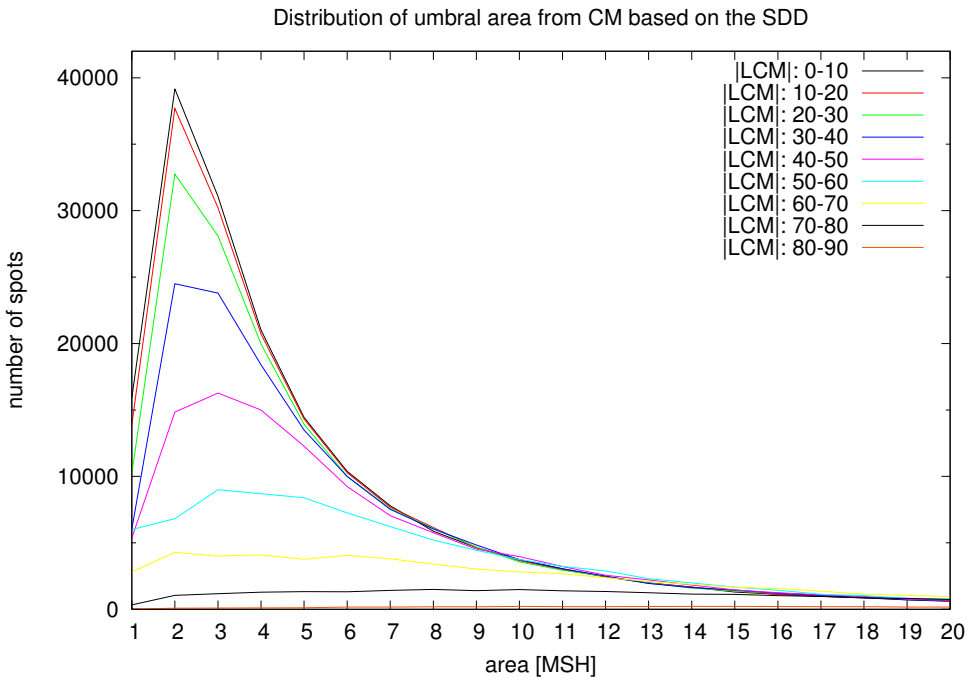
Problems with the Sunspot number

The number of observed groups depend on

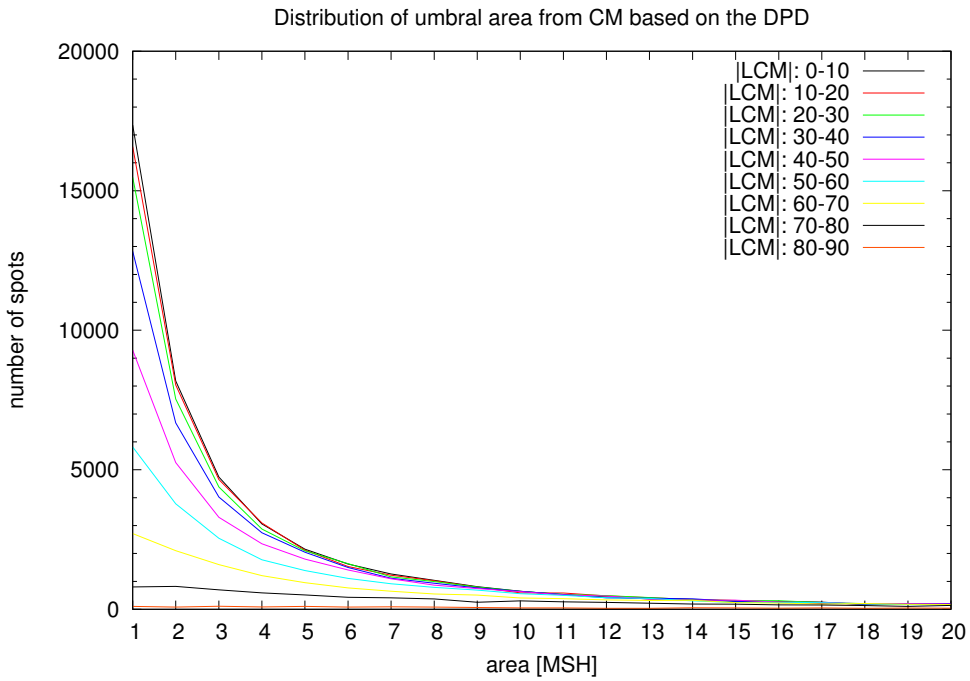
- Observational problem
  - the observability of sunpots (technical, seeing, center–limb variation of observability)
  - the sizes and distances from the central region
- Methodological problem
- Problem of the physical meaning of the Wolf definition

Area distribution

SDD

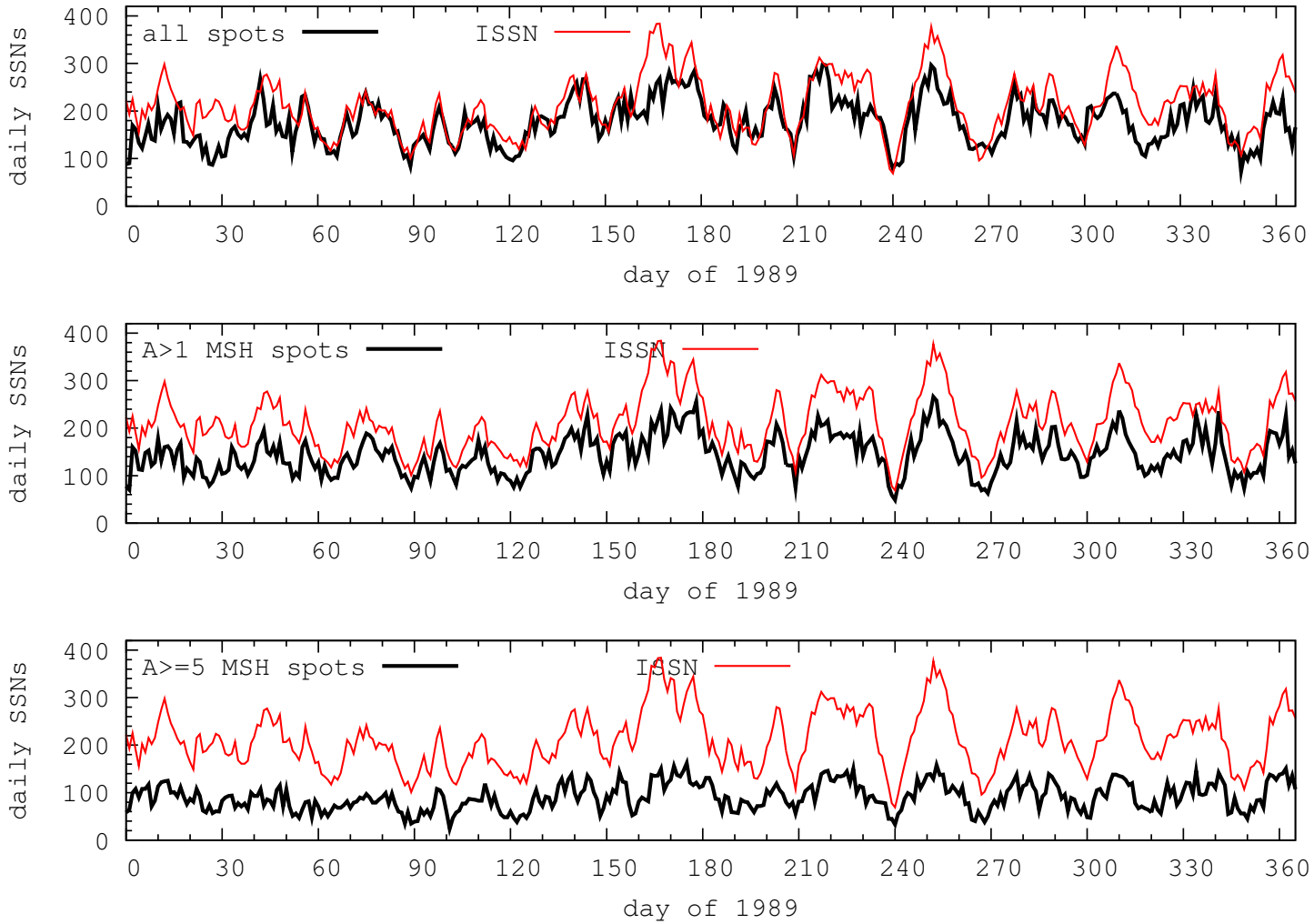


DPD



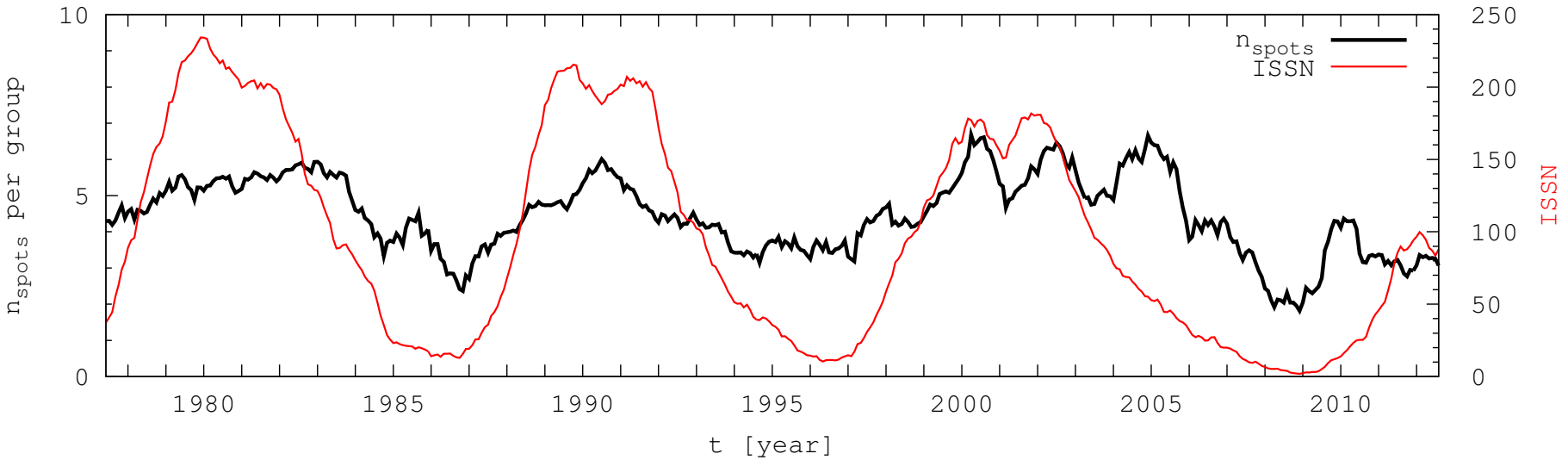
(Muraközy, J., Baranyi, T., Ludmány, A. 2016, *Sol.Phys.*, **291**, 2941-2950)

ISSN – Wolf number (DPD; k=1)



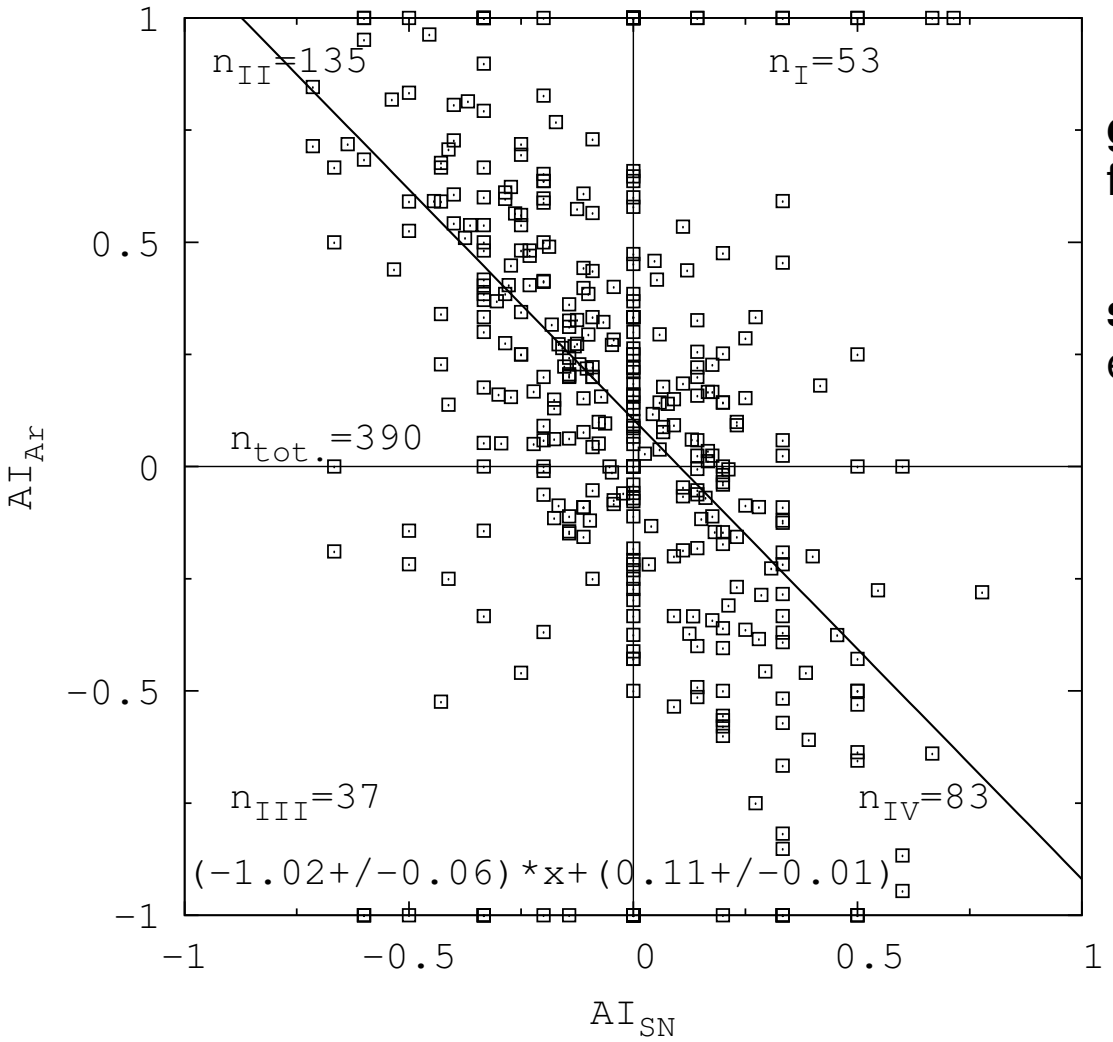
(Muraközy, J., Baranyi, T., Ludmány, A. 2016, *Sol.Phys.*, **291**, 2941-2950)

The real weight of a sunspot group



(Muraközy, J., Baranyi, T., Ludmány, A. 2016, *Sol.Phys.*, **291**, 2941-2950)

Different mechanisms for g and s



g: amount of the emerging magnetic flux

s: fragmentation process during the flux emergence

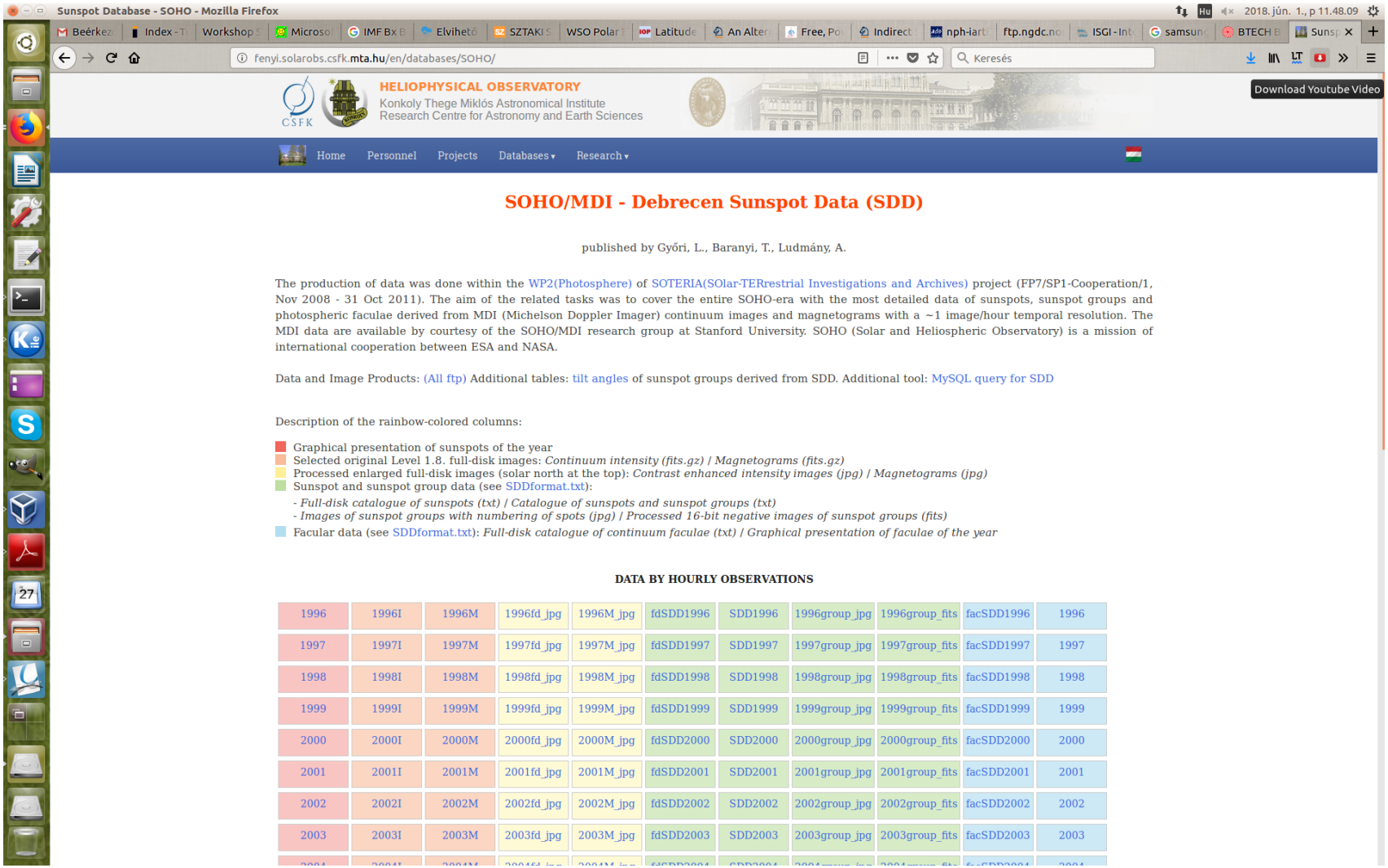
(Muraközy, J., Baranyi, T., Ludmány, A. 2014, *Sol.Phys.*, **289**, 563-577)

SOHO/MDI - Debrecen Sunspot Data – SDD

http://fenyi.solarobs.csfk.mta.hu/en/databases/SOHO/

- Published by Győri, L., Baranyi, T., Ludmány, A.
- Unique detailed sunspot catalogue
- Data for 1996–2010
- Contains area, location and magnetic polarity data for all individual sunspots
- Hourly resolution
- Freely available but the data policy: refer two publications

SOHO/MDI - Debrecen Sunspot Data – SDD



SOHO/MDI - Debrecen Sunspot Data (SDD)

published by Győri, L., Baranyi, T., Ludmány, A.

The production of data was done within the WP2(Photosphere) of SOTERIA(SOlar-TERrestrial Investigations and Archives) project (FP7/SP1-Cooperation/1, Nov 2008 - 31 Oct 2011). The aim of the related tasks was to cover the entire SOHO-era with the most detailed data of sunspots, sunspot groups and photospheric faculae derived from MDI (Michelson Doppler Imager) continuum images and magnetograms with a ~1 image/hour temporal resolution. The MDI data are available by courtesy of the SOHO/MDI research group at Stanford University. SOHO (Solar and Heliospheric Observatory) is a mission of international cooperation between ESA and NASA.

Data and Image Products: (All ftp) Additional tables: tilt angles of sunspot groups derived from SDD. Additional tool: MySQL query for SDD

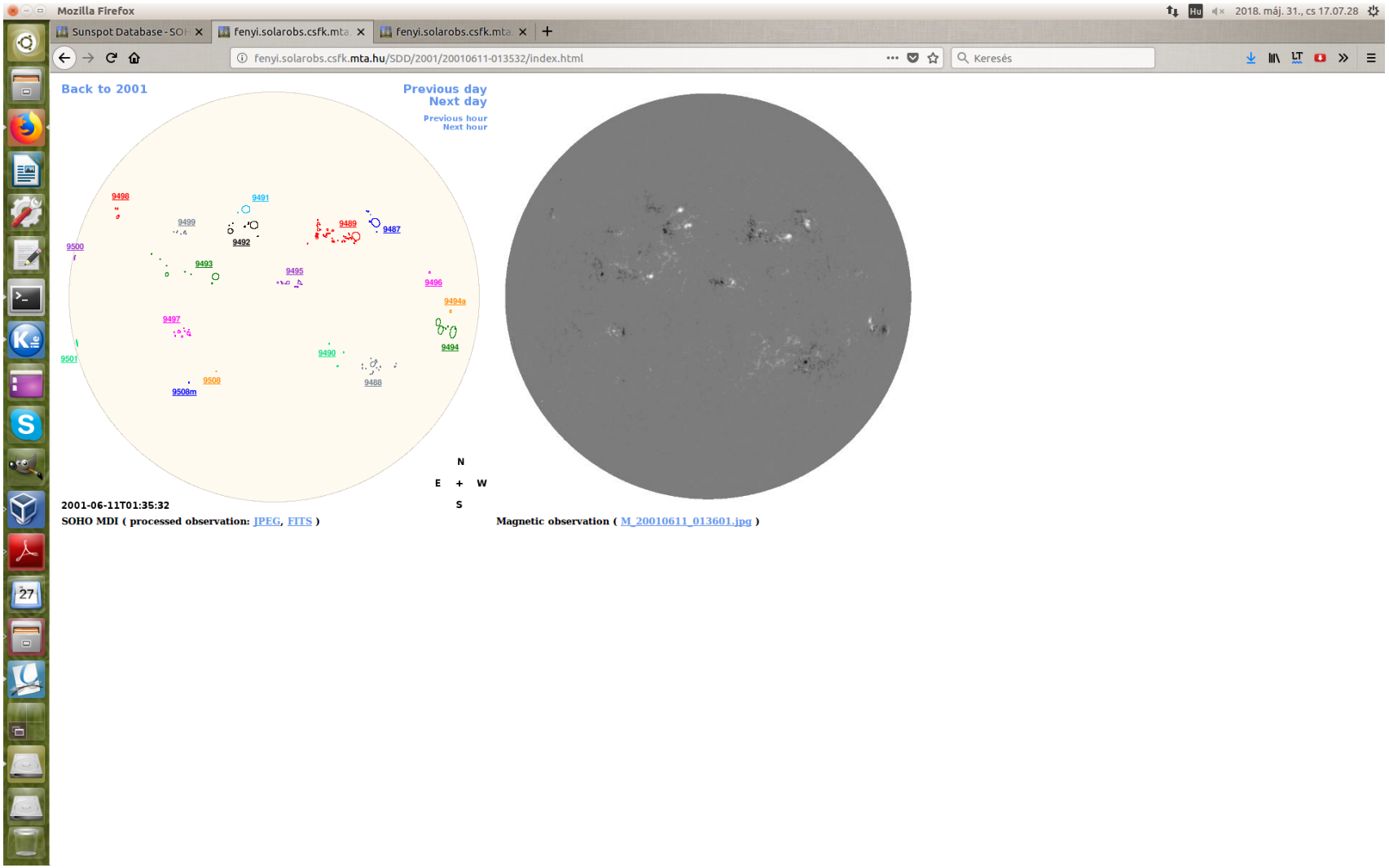
Description of the rainbow-colored columns:

- Graphical presentation of sunspots of the year
- Selected original Level 1.8. full-disk images: *Continuum intensity (fits.gz) / Magnetograms (fits.gz)*
- Processed enlarged full-disk images (solar north at the top): *Contrast enhanced intensity images (jpg) / Magnetograms (jpg)*
- Sunspot and sunspot group data (see SDDformat.txt):
  - *Full-disk catalogue of sunspots (txt) / Catalogue of sunspots and sunspot groups (txt)*
  - *Images of sunspot groups with numbering of spots (jpg) / Processed 16-bit negative images of sunspot groups (fits)*
- Facular data (see SDDformat.txt): *Full-disk catalogue of continuum faculae (txt) / Graphical presentation of faculae of the year*

DATA BY HOURLY OBSERVATIONS

1996	1996I	1996M	1996fd_jpg	1996M_jpg	fdSDD1996	SDD1996	1996group_jpg	1996group_fits	facSDD1996	1996
1997	1997I	1997M	1997fd_jpg	1997M_jpg	fdSDD1997	SDD1997	1997group_jpg	1997group_fits	facSDD1997	1997
1998	1998I	1998M	1998fd_jpg	1998M_jpg	fdSDD1998	SDD1998	1998group_jpg	1998group_fits	facSDD1998	1998
1999	1999I	1999M	1999fd_jpg	1999M_jpg	fdSDD1999	SDD1999	1999group_jpg	1999group_fits	facSDD1999	1999
2000	2000I	2000M	2000fd_jpg	2000M_jpg	fdSDD2000	SDD2000	2000group_jpg	2000group_fits	facSDD2000	2000
2001	2001I	2001M	2001fd_jpg	2001M_jpg	fdSDD2001	SDD2001	2001group_jpg	2001group_fits	facSDD2001	2001
2002	2002I	2002M	2002fd_jpg	2002M_jpg	fdSDD2002	SDD2002	2002group_jpg	2002group_fits	facSDD2002	2002
2003	2003I	2003M	2003fd_jpg	2003M_jpg	fdSDD2003	SDD2003	2003group_jpg	2003group_fits	facSDD2003	2003

SOHO/MDI - Debrecen Sunspot Data – HTML presentation



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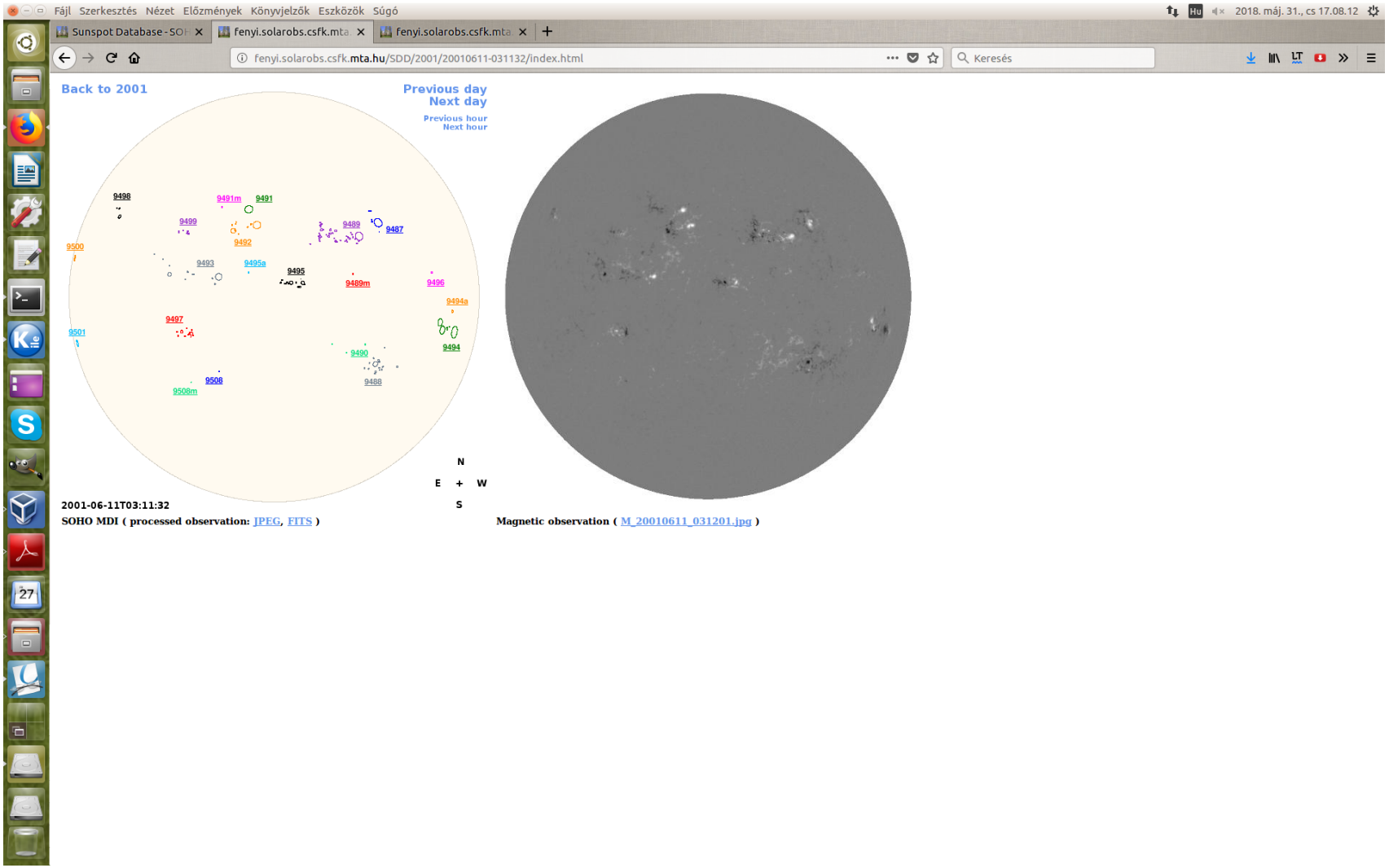

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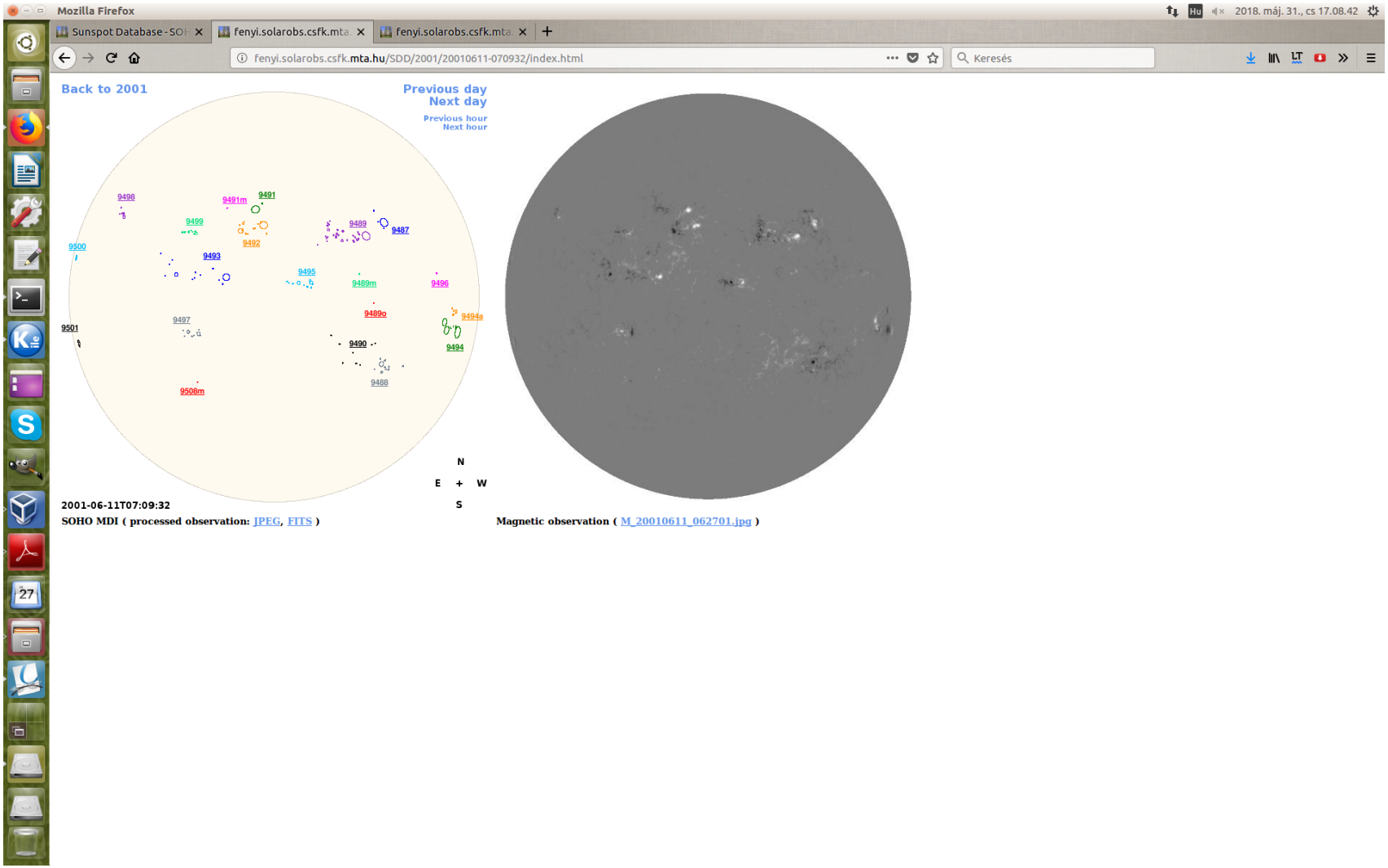
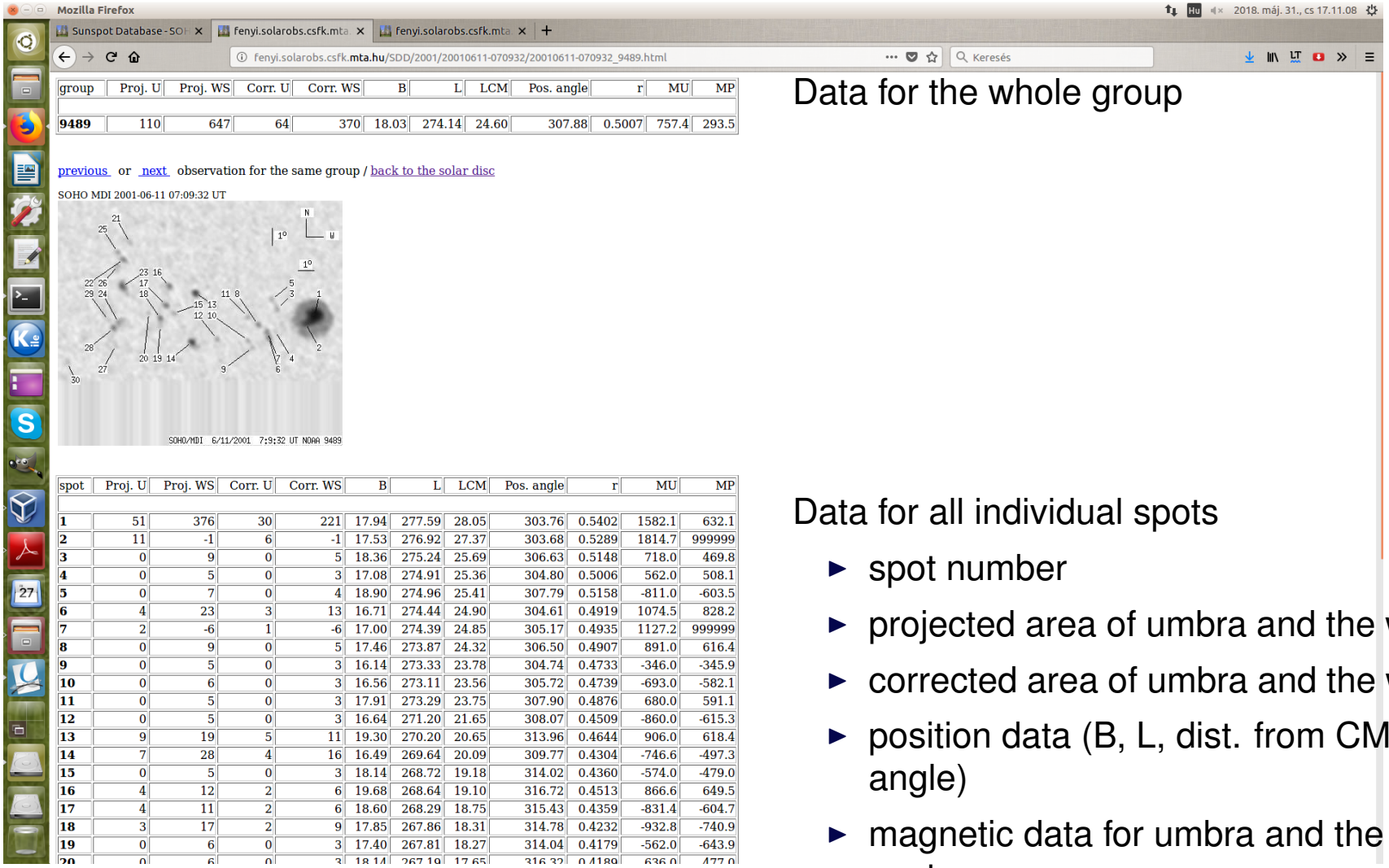


SOHO/MDI - Debrecen Sunspot Data – Data groups & spots



group	Proj. U	Proj. WS	Corr. U	Corr. WS	B	L	LCM	Pos. angle	r	MU	MP
9489	110	647	64	370	18.03	274.14	24.60	307.88	0.5007	757.4	293.5

previous or next observation for the same group / back to the solar disc

SOHO MDI 2001-06-11 07:09:32 UT

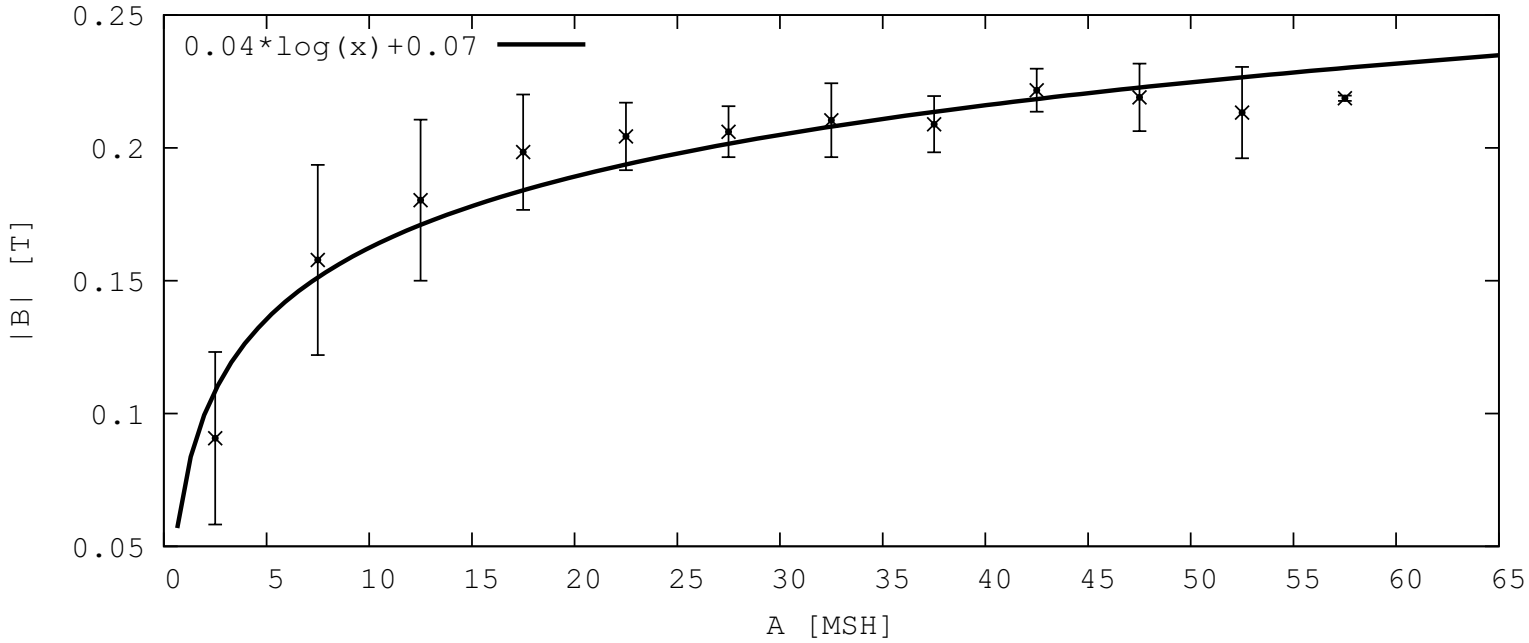
spot	Proj. U	Proj. WS	Corr. U	Corr. WS	B	L	LCM	Pos. angle	r	MU	MP
1	51	376	30	221	17.94	277.59	28.05	303.76	0.5402	1582.1	632.1
2	11	-1	6	-1	17.53	276.92	27.37	303.68	0.5289	1814.7	999999
3	0	9	0	5	18.36	275.24	25.69	306.63	0.5148	718.0	469.8
4	0	5	0	3	17.08	274.91	25.36	304.80	0.5006	562.0	508.1
5	0	7	0	4	18.90	274.96	25.41	307.79	0.5158	-811.0	-603.5
6	4	23	3	13	16.71	274.44	24.90	304.61	0.4919	1074.5	828.2
7	2	-6	1	-6	17.00	274.39	24.85	305.17	0.4935	1127.2	999999
8	0	9	0	5	17.46	273.87	24.32	306.50	0.4907	891.0	616.4
9	0	5	0	3	16.14	273.33	23.78	304.74	0.4733	-346.0	-345.9
10	0	6	0	3	16.56	273.11	23.56	305.72	0.4739	-693.0	-582.1
11	0	5	0	3	17.91	273.29	23.75	307.90	0.4876	680.0	591.1
12	0	5	0	3	16.64	271.20	21.65	308.07	0.4509	-860.0	-615.3
13	9	19	5	11	19.30	270.20	20.65	313.96	0.4644	906.0	618.4
14	7	28	4	16	16.49	269.64	20.09	309.77	0.4304	-746.6	-497.3
15	0	5	0	3	18.14	268.72	19.18	314.02	0.4360	-574.0	-479.0
16	4	12	2	6	19.68	268.64	19.10	316.72	0.4513	866.6	649.5
17	4	11	2	6	18.60	268.29	18.75	315.43	0.4359	-831.4	-604.7
18	3	17	2	9	17.85	267.86	18.31	314.78	0.4232	-932.8	-740.9
19	0	6	0	3	17.40	267.81	18.27	314.04	0.4179	-562.0	-643.9
20	0	6	0	3	18.14	267.19	17.65	316.32	0.4189	636.0	477.0

Data for the whole group

Data for all individual spots

- spot number
- projected area of umbra and the whole spot
- corrected area of umbra and the whole spot
- position data (B, L, dist. from CM, pos. angle)
- magnetic data for umbra and the whole spot

Total amount of emerged magnetic flux



(Muraközy, J., Baranyi, T., Ludmány, A. 2016, *Sol.Phys.*, **291**, 2941-2950)

Area – magnetic field relationship:

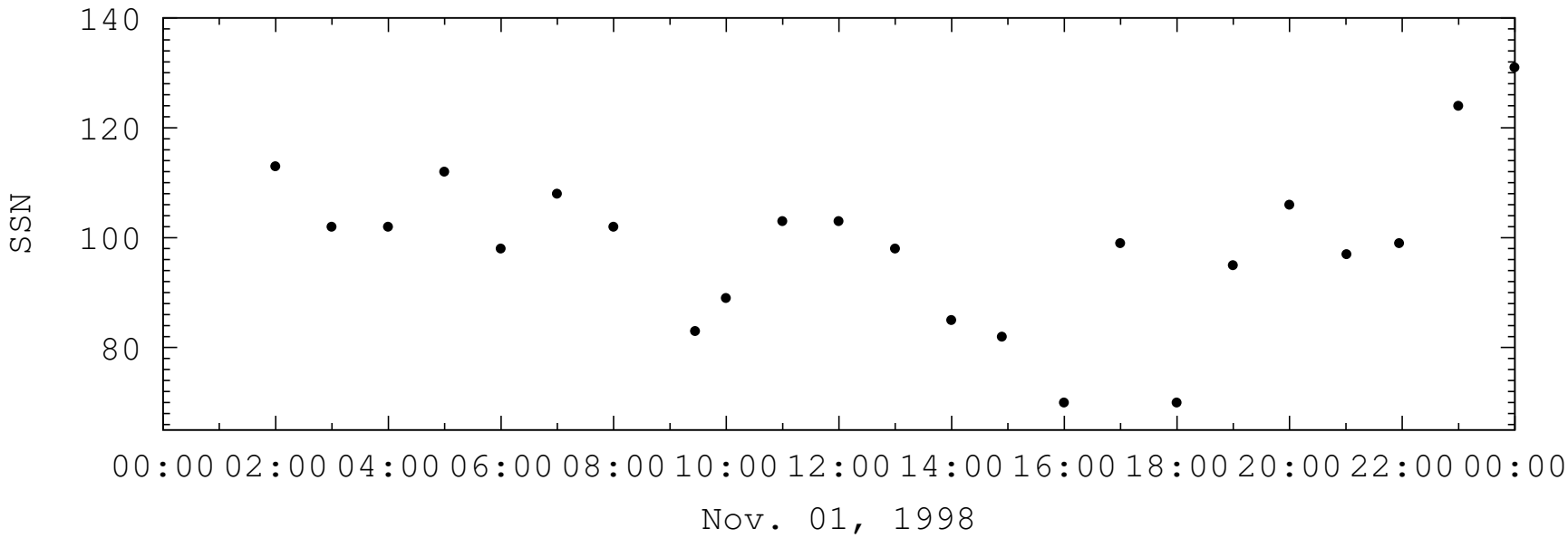
$$B = 0.04 \cdot logA + 0.07$$

The total magnetic flux:

$$TMF = K \left[\sum f(A_i) A_i \right]_{LP}$$

Dependence on the time of observations

Daily variation of the SSN



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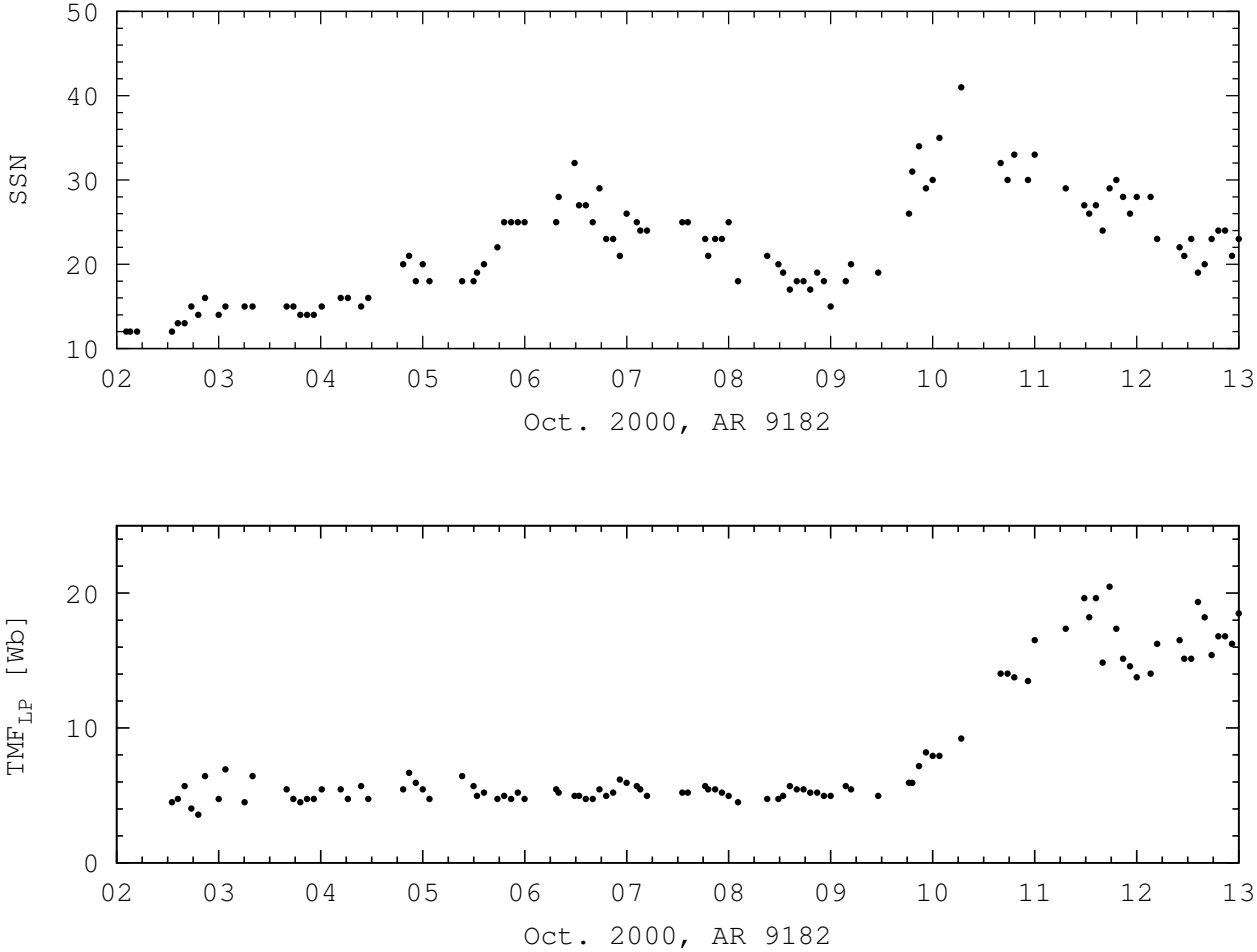
Dependence on the time of observations

Variations during the passage across the dics the SSN



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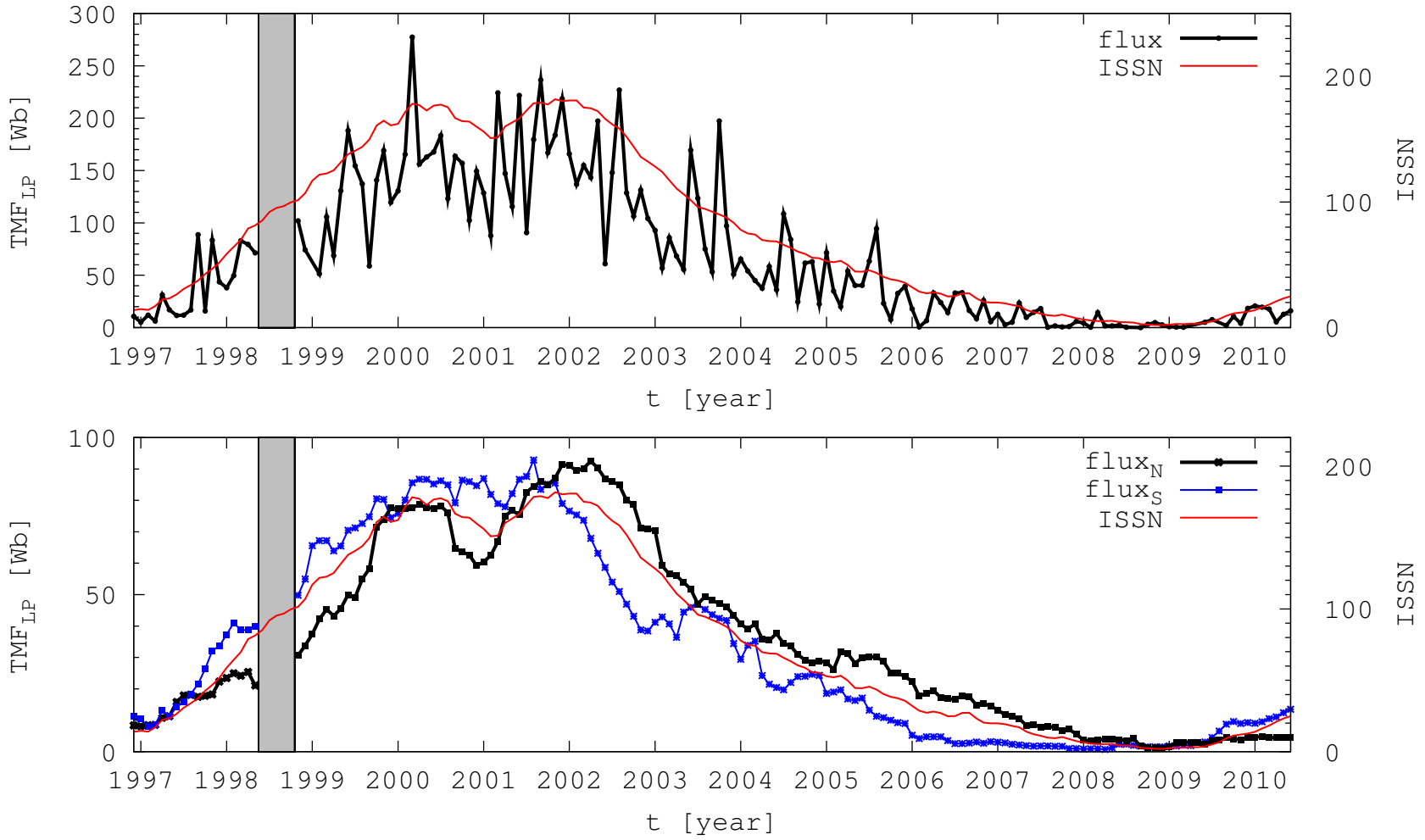
Monthly variation of the TMF



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Sum up

- Wolf introduced the sunspot number in 1848
- The Wolf number has some weaknesses (observability, methodologicaly, meaning)
- The more reliable parameter to measure the solar activity is the TMF, which is not contaminated with non-activity measures
- The smaller sunspots have less impact on the TMF than on the Wolf number because of the quickly decreasing flux amount

Thank you for your attention!