Study of sunspot group evolution on a large statistical sample

Judit Muraközy

Heliophysical Observatory of Research Centre for Astronomy and Earth Sciences
HAS
Debrecen

March 09, 2015

Abstract

There are different mechanisms affecting the formation of sunspot groups e.g. buoyancy on the emerging flux ropes, drag force, tension, etc. To check the roles of these theoretical mechanisms one needs to study the evolutionary phases of sunspots and sunspot groups on a large statistical sample. Our study is based on the SOHO/MDI – Debrecen Data (SDD). Its high-temporal resolution allows to study the emergence and decay of the sunspot groups in detail. We investigate the distance and the growth/decay rates as well as the asymmetry between the compactness of the different polarity parts of active regions in time.

Outlook

Database - High temporal resolution
Sunspot group development
Sunspot group decay - preliminary results
References
Summary, conclusions

Outlook

Database - High temporal resolution

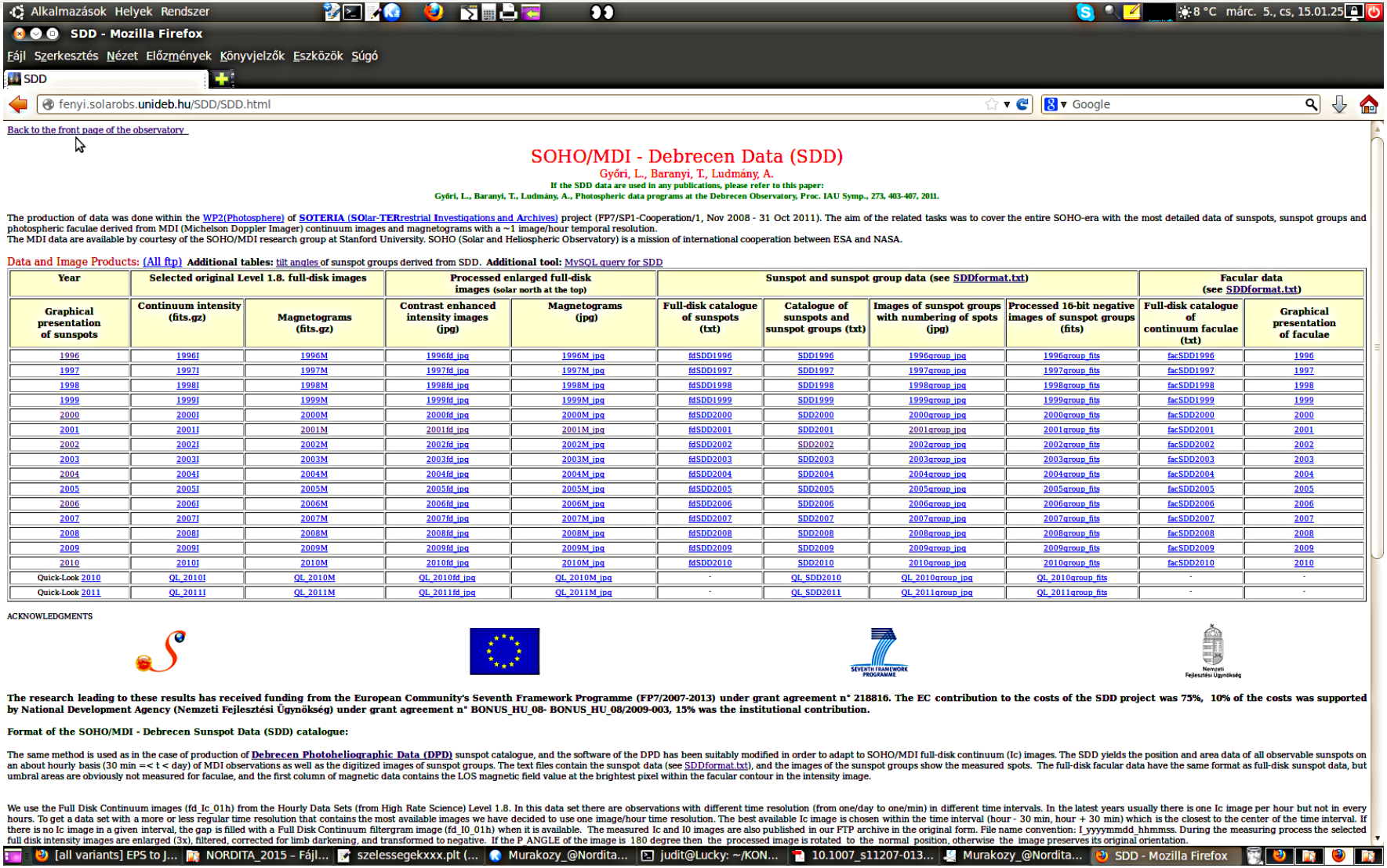
Sunspot group development

Sunspot group decay - preliminary results

References

Summary, conclusions

SOHO/MDI - Debrecen Data (SDD) - Győri, L., Baranyi T., Ludmány, A.



Alkalmazások Helyek Rendszer — 8 °C márc. 5., cs, 15.01.25

SDD - Mozilla Firefox

Fájl Szerkesztés Nézet Előzmények Könyvjelzők Eszközök Súgó

SDD

fenyi.solarobs.unideb.hu/SDD/SDD.html

Google

Back to the front page of the observatory

SOHO/MDI - Debrecen Data (SDD)

Győri, L., Baranyi, T., Ludmány, A.

If the SDD data are used in any publications, please refer to this paper:

Győri, L., Baranyi, T., Ludmány, A., Photospheric data programs at the Debrecen Observatory, Proc. IAU Symp., 273, 403-407, 2011.

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

Year	Selected original Level 1.8. full-disk images		Processed enlarged full-disk images (solar north at the top)		Sunspot and sunspot group data (see SDDformat.txt)				Facular data (see SDDformat.txt)	
Graphical presentation of sunspots	Continuum intensity (fits.gz)	Magnetograms (fits.gz)	Contrast enhanced intensity images (jpg)	Magnetograms (jpg)	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)	Full-disk catalogue of continuum faculae (txt)	Graphical presentation of faculae
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
2004	2004I	2004M	2004fd_jpg	2004M_jpg	fdSDD2004	SDD2004	2004group_jpg	2004group_fits	facSDD2004	2004
2005	2005I	2005M	2005fd_jpg	2005M_jpg	fdSDD2005	SDD2005	2005group_jpg	2005group_fits	facSDD2005	2005
2006	2006I	2006M	2006fd_jpg	2006M_jpg	fdSDD2006	SDD2006	2006group_jpg	2006group_fits	facSDD2006	2006
2007	2007I	2007M	2007fd_jpg	2007M_jpg	fdSDD2007	SDD2007	2007group_jpg	2007group_fits	facSDD2007	2007
2008	2008I	2008M	2008fd_jpg	2008M_jpg	fdSDD2008	SDD2008	2008group_jpg	2008group_fits	facSDD2008	2008
2009	2009I	2009M	2009fd_jpg	2009M_jpg	fdSDD2009	SDD2009	2009group_jpg	2009group_fits	facSDD2009	2009
2010	2010I	2010M	2010fd_jpg	2010M_jpg	fdSDD2010	SDD2010	2010group_jpg	2010group_fits	facSDD2010	2010
Quick-Look 2010	QL_2010I	QL_2010M	QL_2010fd_jpg	QL_2010M_jpg	-	QL_SDD2010	QL_2010group_jpg	QL_2010group_fits	-	-
Quick-Look 2011	QL_2011I	QL_2011M	QL_2011fd_jpg	QL_2011M_jpg	-	QL_SDD2011	QL_2011group_jpg	QL_2011group_fits	-	-

ACKNOWLEDGMENTS

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 218816. The EC contribution to the costs of the SDD project was 75%, 10% of the costs was supported by National Development Agency (Nemzeti Fejlesztési Ügynökség) under grant agreement n° BONUS_HU_08- BONUS_HU_08/2009-003, 15% was the institutional contribution.

Format of the SOHO/MDI - Debrecen Sunspot Data (SDD) catalogue:

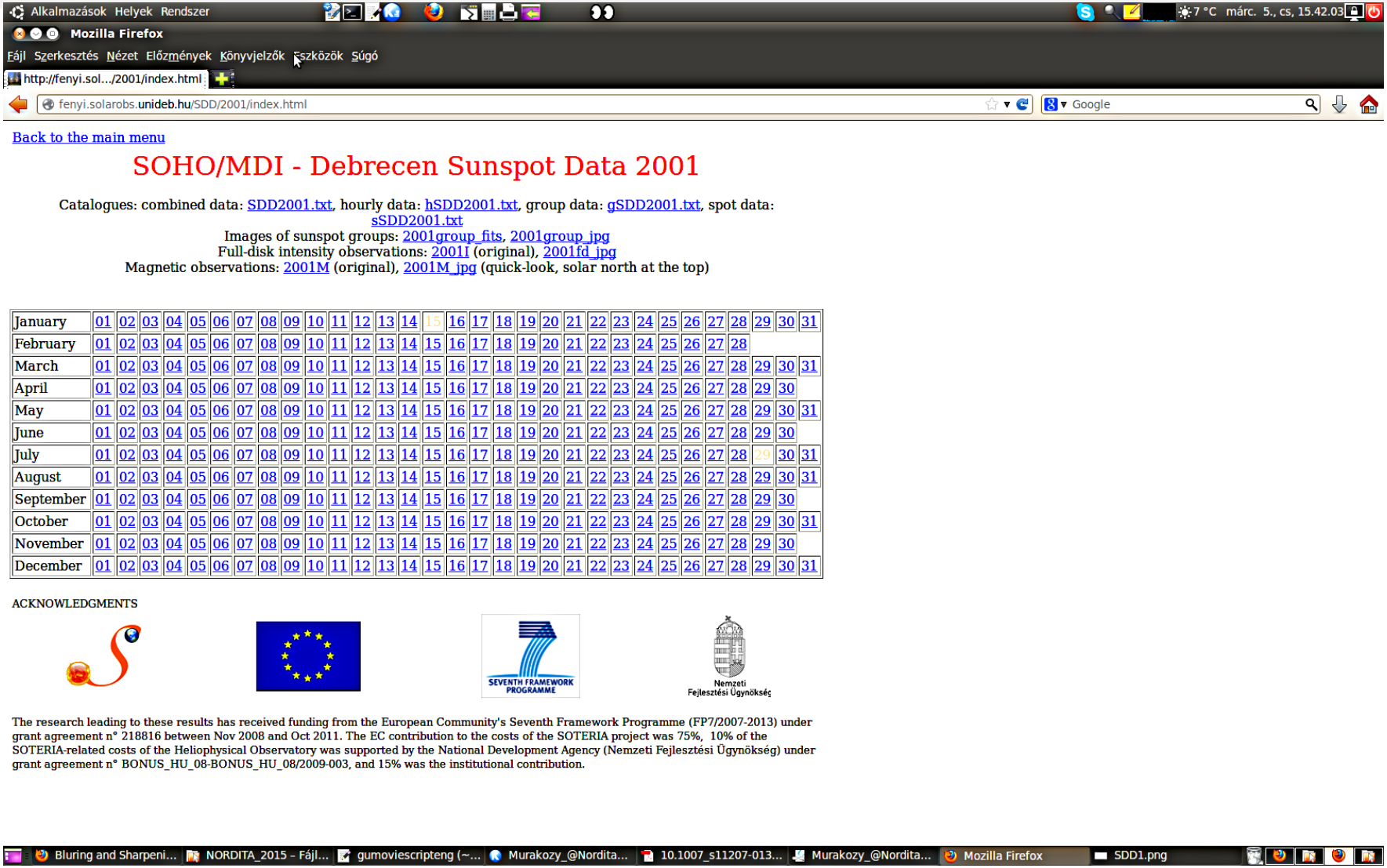
The same method is used as in the case of production of **Debrecen Photoheliographic Data (DPD)** sunspot catalogue, and the software of the DPD has been suitably modified in order to adapt to SOHO/MDI full-disk continuum (Ic) images. The SDD yields the position and area data of all observable sunspots on an about hourly basis (30 min =< t < day) of MDI observations as well as the digitized images of sunspot groups. The text files contain the sunspot data (see SDDformat.txt), and the images of the sunspot groups show the measured spots. The full-disk facular data have the same format as full-disk sunspot data, but umbral areas are obviously not measured for faculae, and the first column of magnetic data contains the LOS magnetic field value at the brightest pixel within the facular contour in the intensity image.

We use the Full Disk Continuum images (fd_Ic_01h) from the Hourly Data Sets (from High Rate Science) Level 1.8. In this data set there are observations with different time resolution (from one/day to one/min) in different time intervals. In the latest years usually there is one Ic image per hour but not in every hours. To get a data set with a more or less regular time resolution that contains the most available images we have decided to use one image/hour time resolution. The best available Ic image is chosen within the time interval (hour - 30 min, hour + 30 min) which is the closest to the center of the time interval. If there is no Ic image in a given interval, the gap is filled with a Full Disk Continuum filtergram image (fd_I0_01h) when it is available. The measured Ic and I0 images are also published in our FTP archive in the original form. File name convention: I yyyymmdd_hhmmss. During the measuring process the selected full disk intensity images are enlarged (3x), filtered, corrected for limb darkening, and transformed to negative. If the P_ANGLE of the image is 180 degree then the processed image is rotated to the normal position, otherwise the image preserves its original orientation.

[all variants] EPS to J... | NORDITA_2015 – Fájl... | szelessegekxxx.plt (... | Murakozy_@Nordita... | judit@Lucky: ~/KON... | 10.1007_s11207-013... | Murakozy_@Nordita... | SDD - Mozilla Firefox

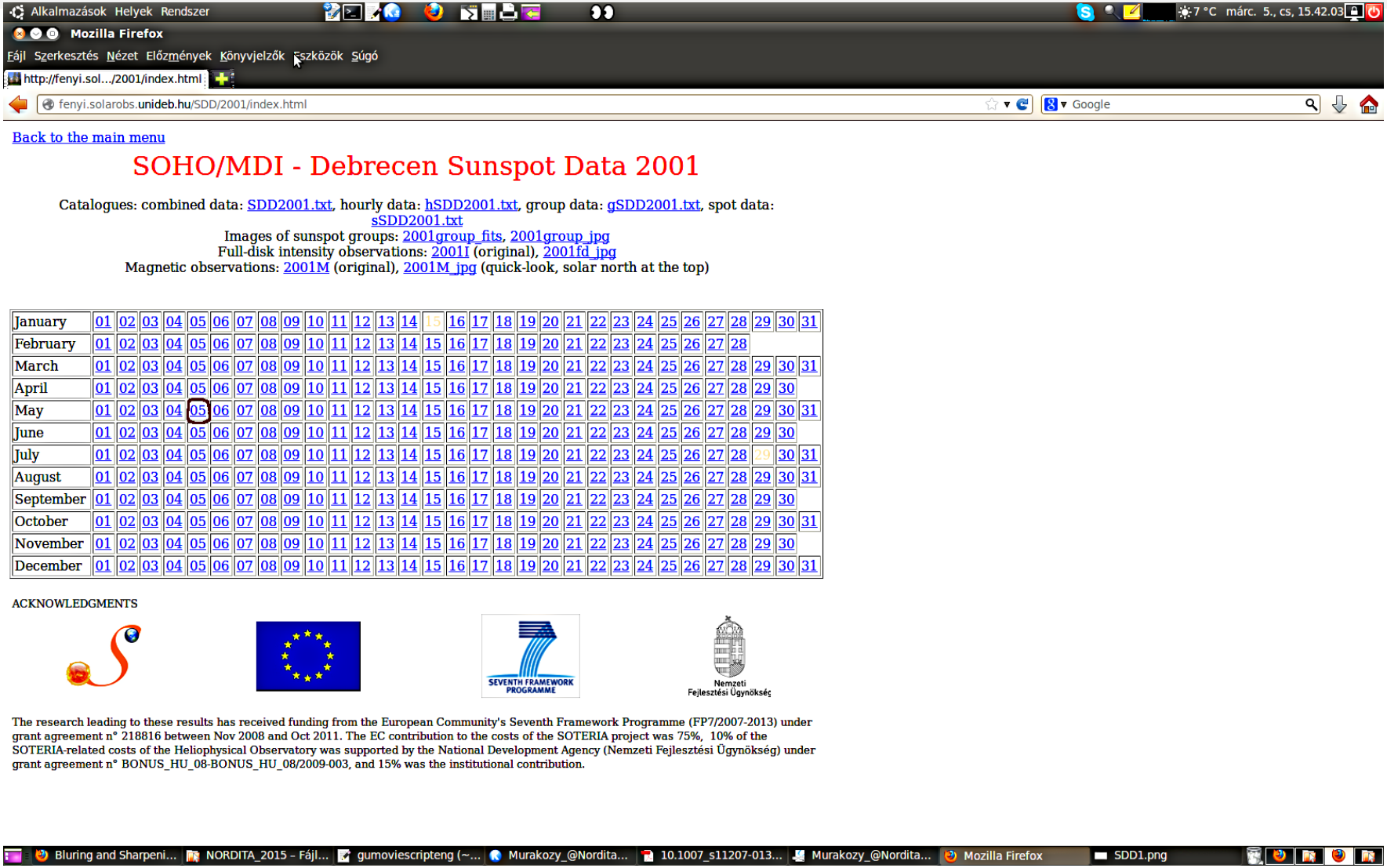
It can be found here: http://fenyi.solarobs.unideb.hu/SDD/SDD.html

SOHO/MDI - Debrecen Data (SDD) - Győri, L., Baranyi T., Ludmány, A.



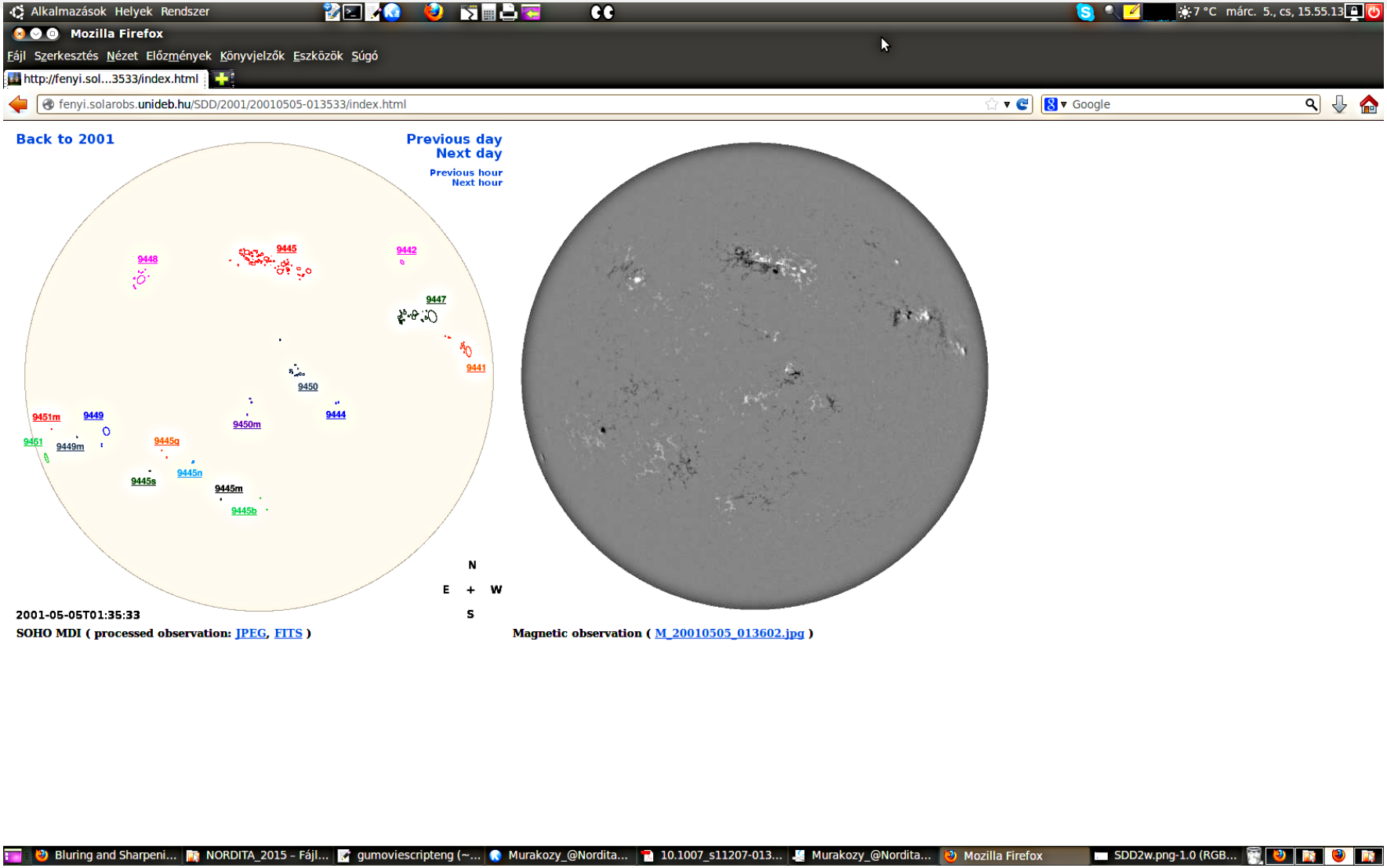
It can be found here: http://fenyi.solarobs.unideb.hu/SDD/SDD.html

SOHO/MDI - Debrecen Data (SDD) - Győri, L., Baranyi T., Ludmány, A.



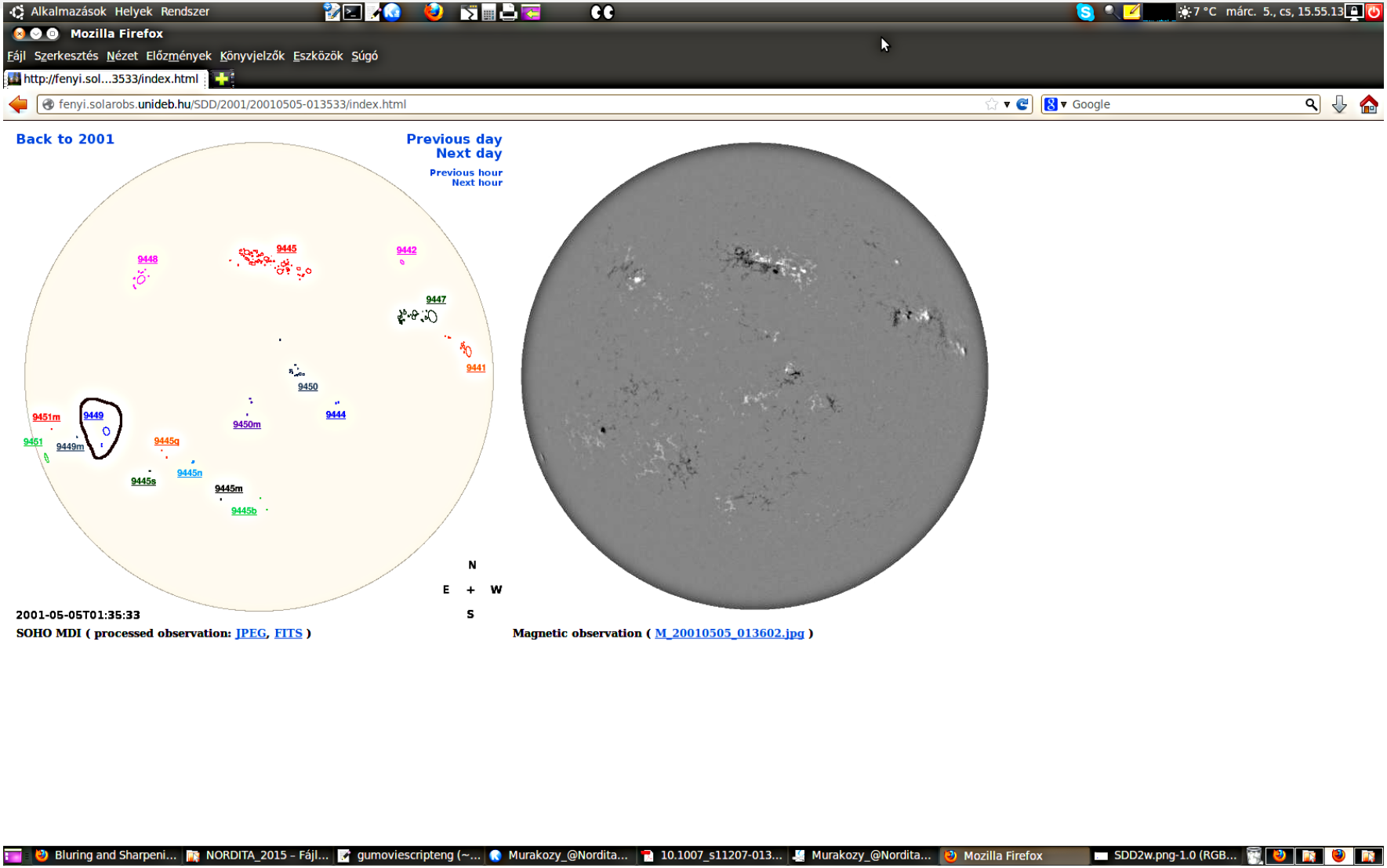
It can be found here: http://fenyi.solarobs.unideb.hu/SDD/SDD.html

SOHO/MDI - Debrecen Data (SDD) - Győri, L., Baranyi T., Ludmány, A.



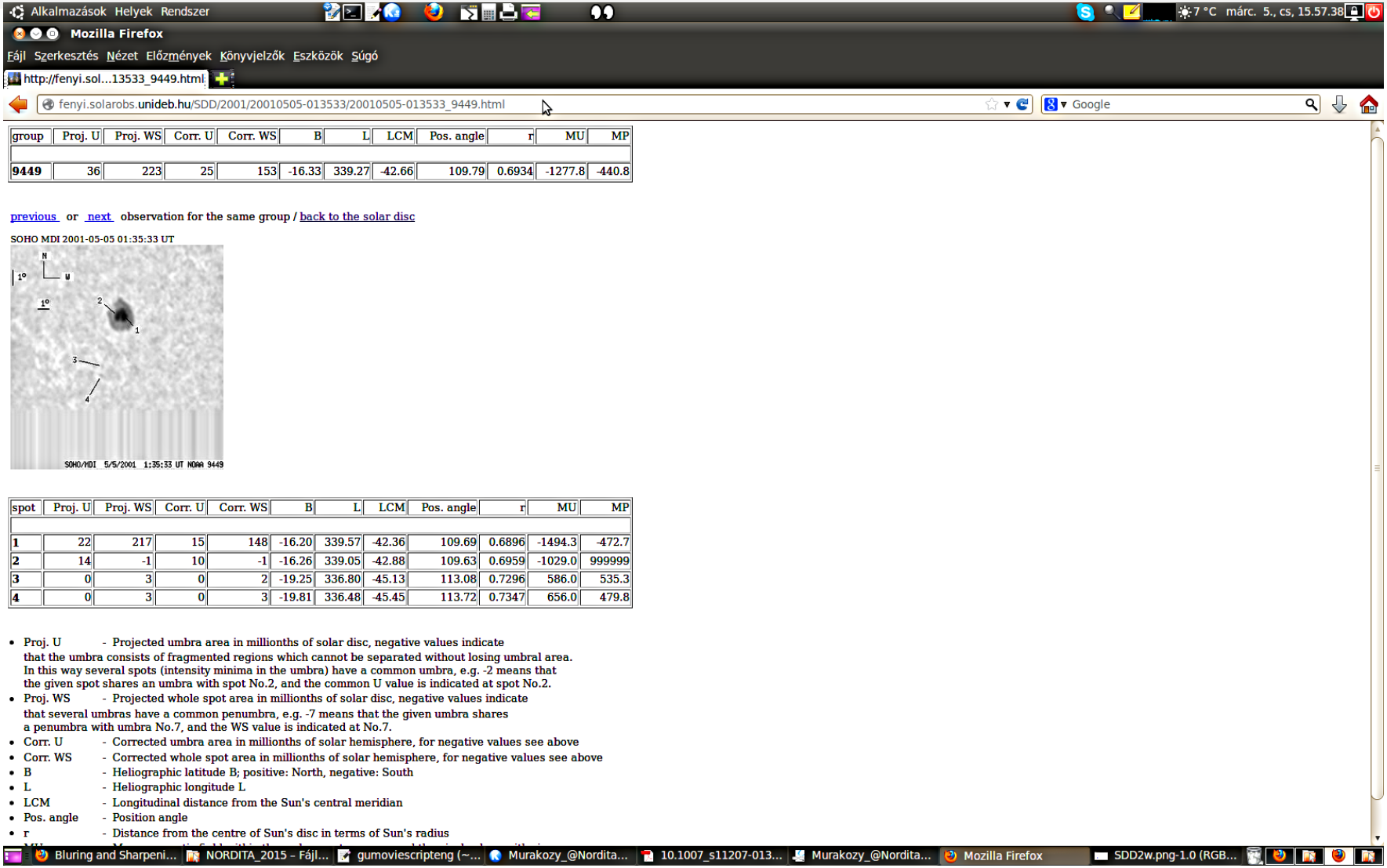
It can be found here: http://fenyi.solarobs.unideb.hu/SDD/SDD.html

SOHO/MDI - Debrecen Data (SDD) - Győri, L., Baranyi T., Ludmány, A.



It can be found here: http://fenyi.solarobs.unideb.hu/SDD/SDD.html

SOHO/MDI - Debrecen Data (SDD) - Győri, L., Baranyi T., Ludmány, A.



group	Proj. U	Proj. WS	Corr. U	Corr. WS	B	L	LCM	Pos. angle	r	MU	MP
9449	36	223	25	153	-16.33	339.27	-42.66	109.79	0.6934	-1277.8	-440.8

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

SOHO MDI 2001-05-05 01:35:33 UT

spot	Proj. U	Proj. WS	Corr. U	Corr. WS	B	L	LCM	Pos. angle	r	MU	MP
1	22	217	15	148	-16.20	339.57	-42.36	109.69	0.6896	-1494.3	-472.7
2	14	-1	10	-1	-16.26	339.05	-42.88	109.63	0.6959	-1029.0	999999
3	0	3	0	2	-19.25	336.80	-45.13	113.08	0.7296	586.0	535.3
4	0	3	0	3	-19.81	336.48	-45.45	113.72	0.7347	656.0	479.8

- Proj. U - Projected umbra area in millionths of solar disc, negative values indicate that the umbra consists of fragmented regions which cannot be separated without losing umbral area. In this way several spots (intensity minima in the umbra) have a common umbra, e.g. -2 means that the given spot shares an umbra with spot No.2, and the common U value is indicated at spot No.2.
- Proj. WS - Projected whole spot area in millionths of solar disc, negative values indicate that several umbras have a common penumbra, e.g. -7 means that the given umbra shares a penumbra with umbra No.7, and the WS value is indicated at No.7.
- Corr. U - Corrected umbra area in millionths of solar hemisphere, for negative values see above
- Corr. WS - Corrected whole spot area in millionths of solar hemisphere, for negative values see above
- B - Heliographic latitude B; positive: North, negative: South
- L - Heliographic longitude L
- LCM - Longitudinal distance from the Sun's central meridian
- Pos. angle - Position angle
- r - Distance from the centre of Sun's disc in terms of Sun's radius

It can be found here: http://fenyi.solarobs.unideb.hu/SDD/SDD.html

Outlook

Database - High temporal resolution

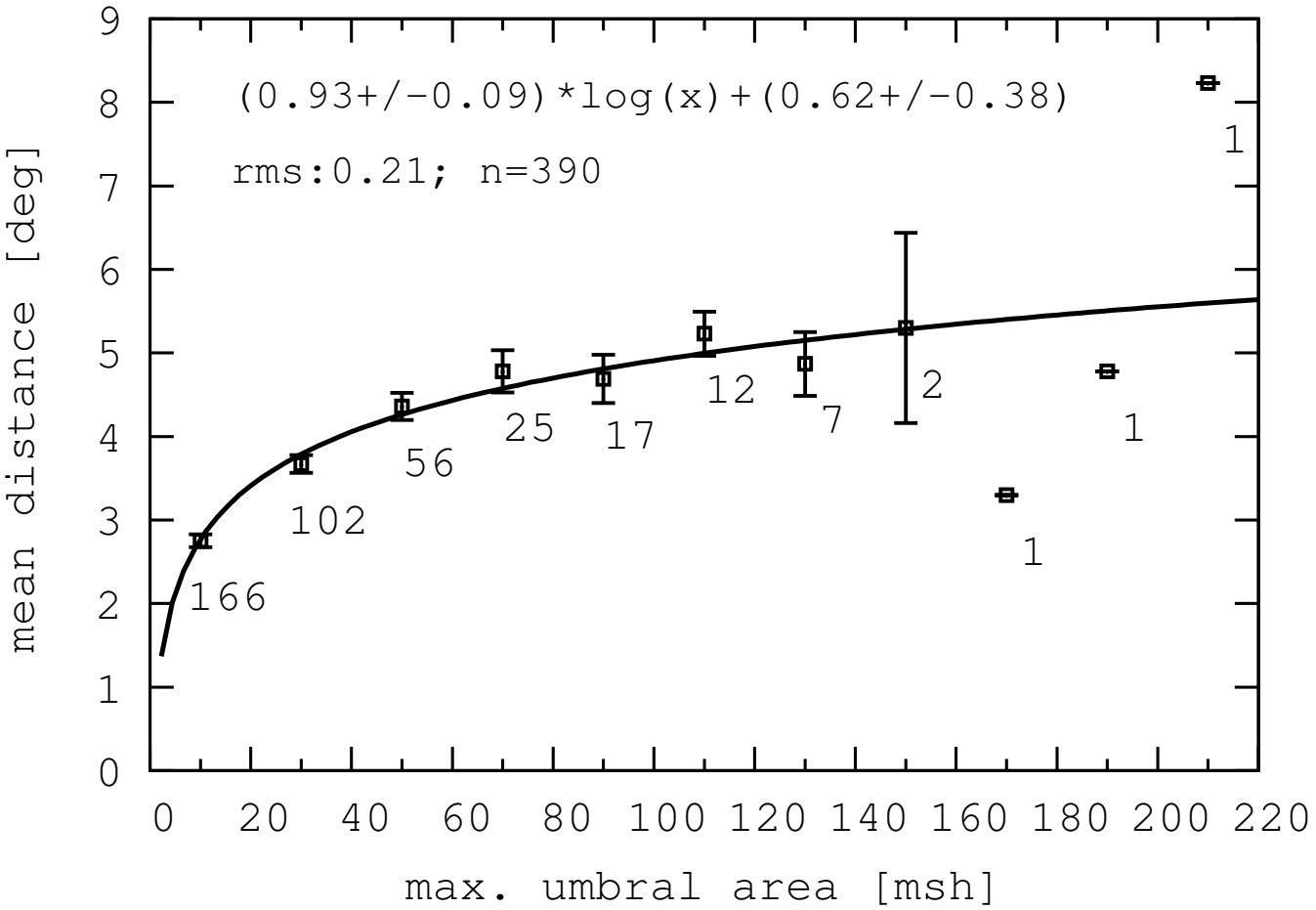
Sunspot group development

Sunspot group decay - preliminary results

References

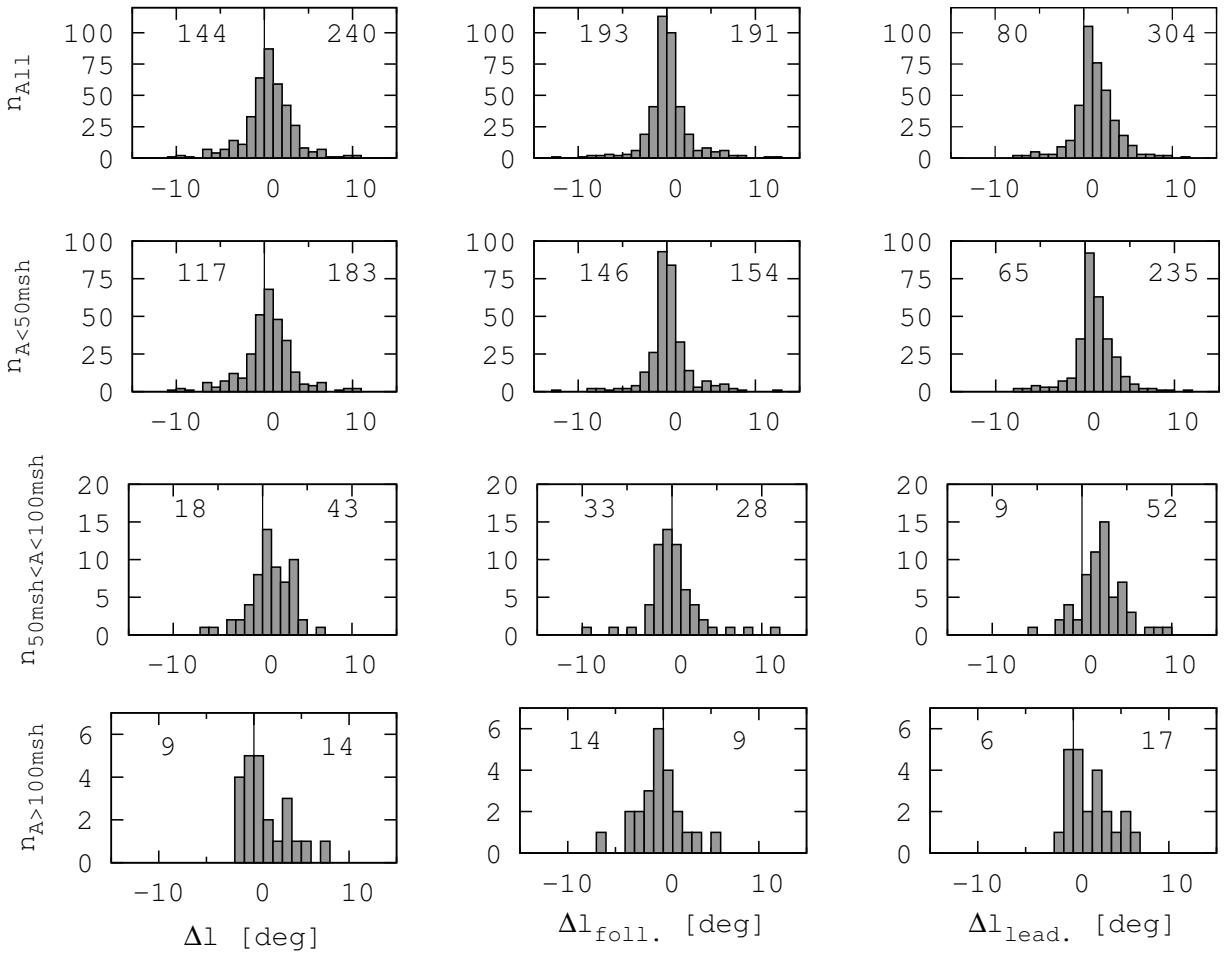
Summary, conclusions

Distance of the leading-following parts



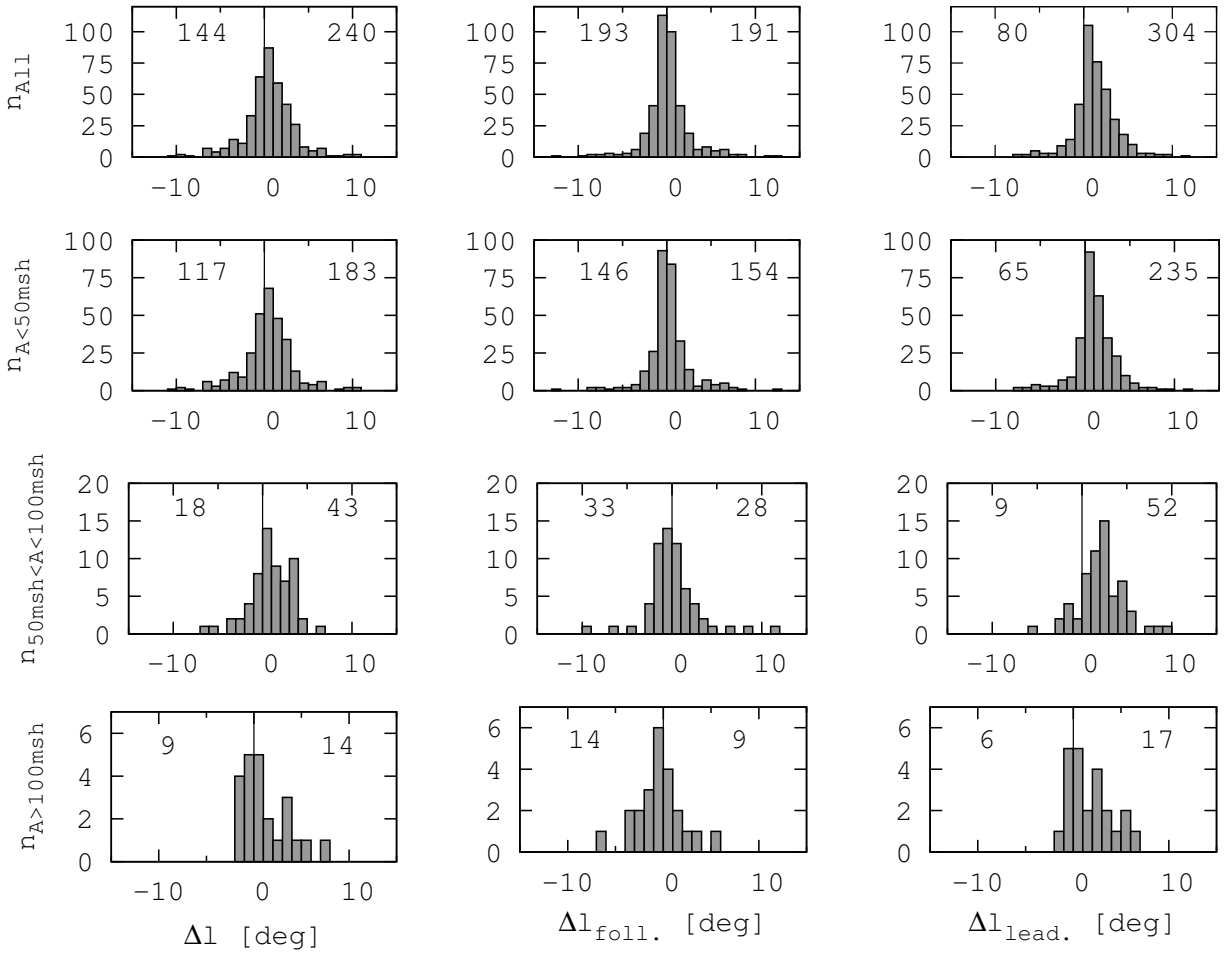
(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

Longitudinal shifts of sunspot groups



(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

Longitudinal shifts of sunspot groups



All groups - forward motion (leading part)

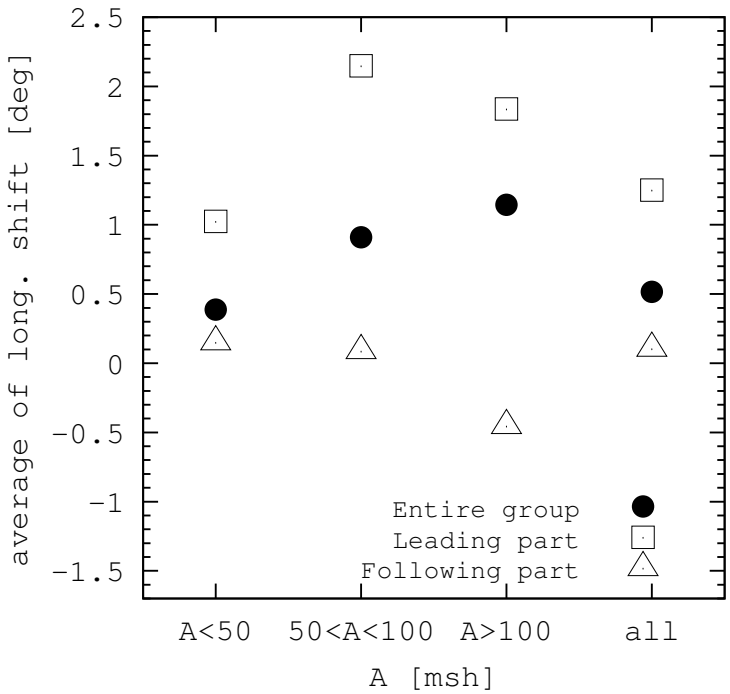
Smaller groups - remain very close to their first positions

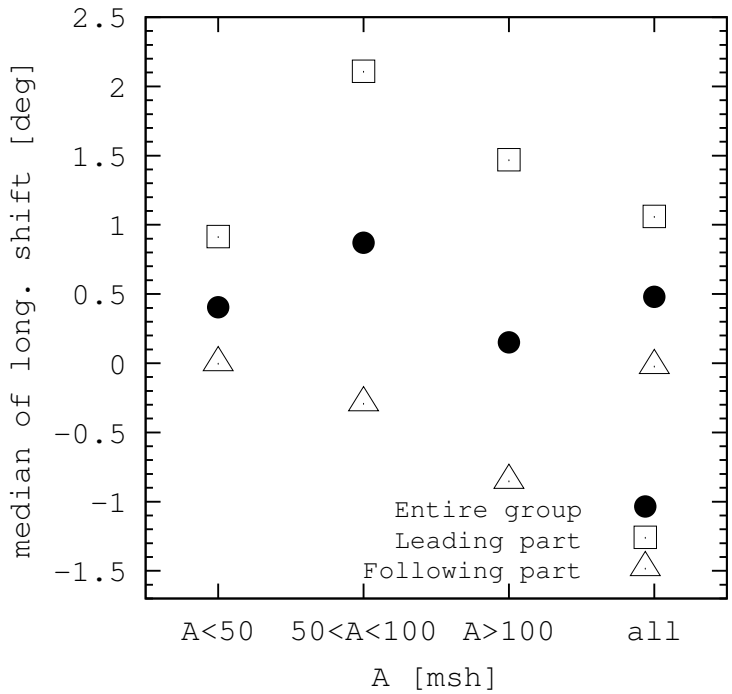
Medium sized groups - mainly forward motion, foll. parts move backward

Larger groups - forward motion, foll. parts move backward

(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

Longitudinal shifts of sunspot groups

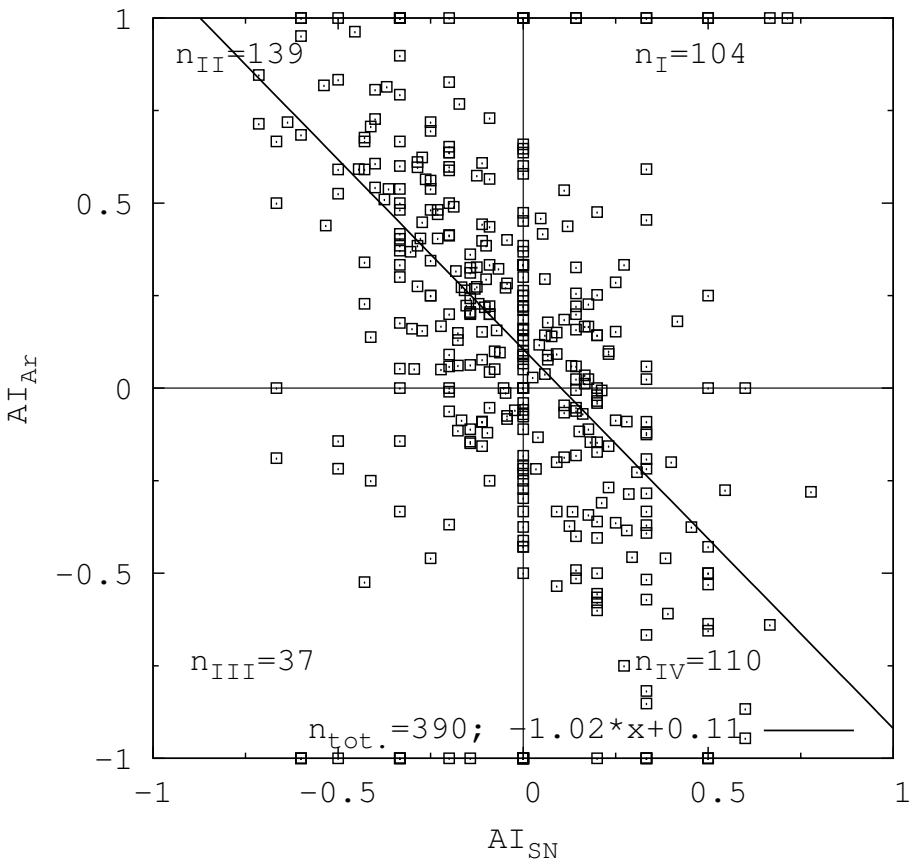




(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

The forward motion of the leading parts is relatively high.
The following parts remain in their first appearance or shift backward.
The forward motion caused by the high forward shift of the leading part.

Asymmetric compactness - sunspot number and area



$$AI_{SN} = \frac{SN_L - SN_F}{SN_L + SN_F}$$

higher leading area

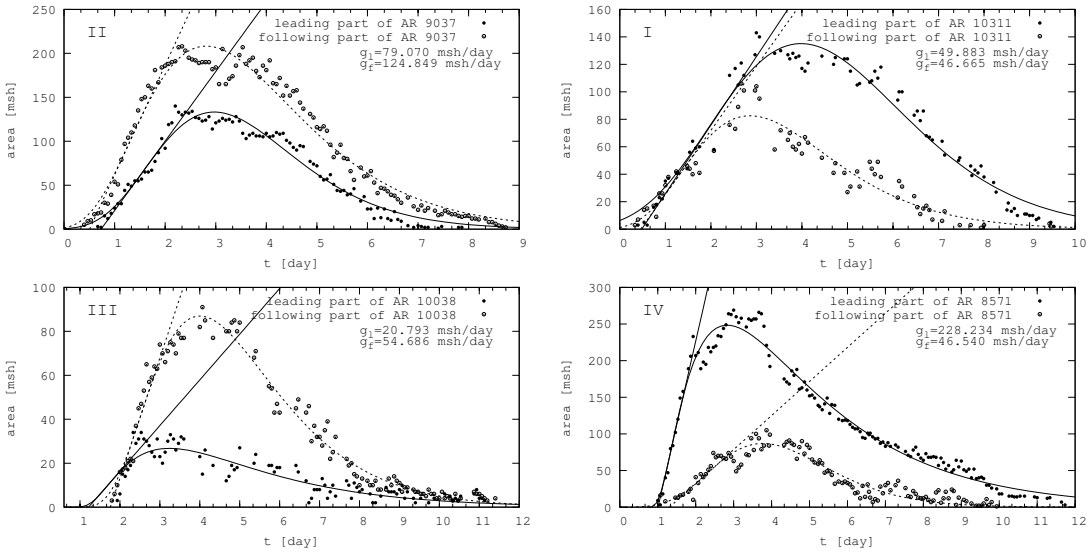
higher following area

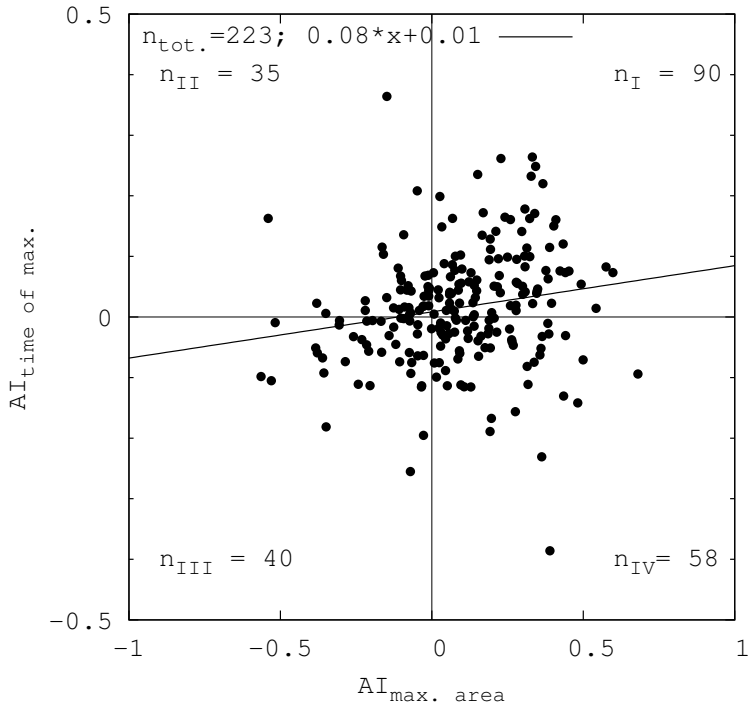
more following spots - more leading spots

The most crowded panel: less leading spots with higher area and more following ones with smaller area.

(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

Time profiles of sunspot group development



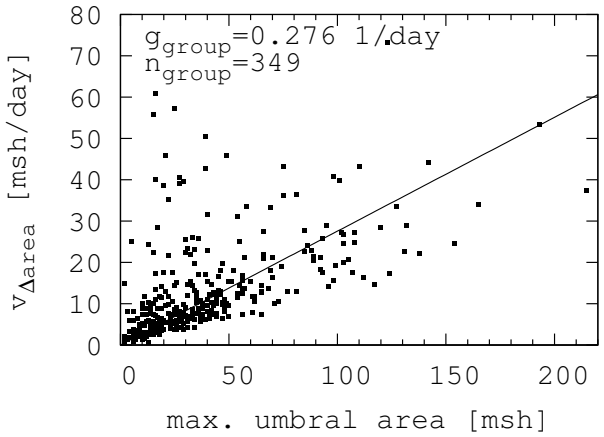


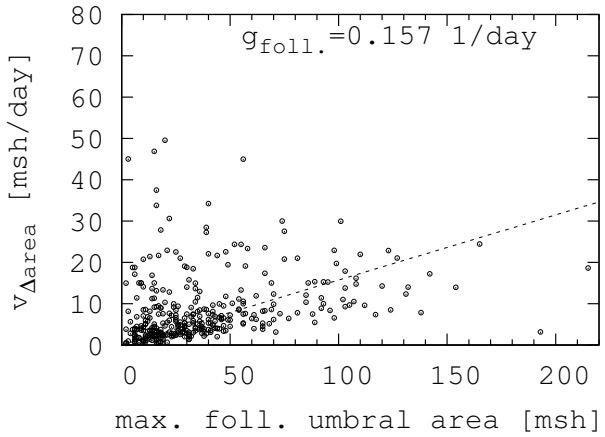
asymmetric Gaussian-function: $$f(t) = H \cdot exp(-\frac{(t - t_M)^2}{D(1 + A(t - t_M))})$$

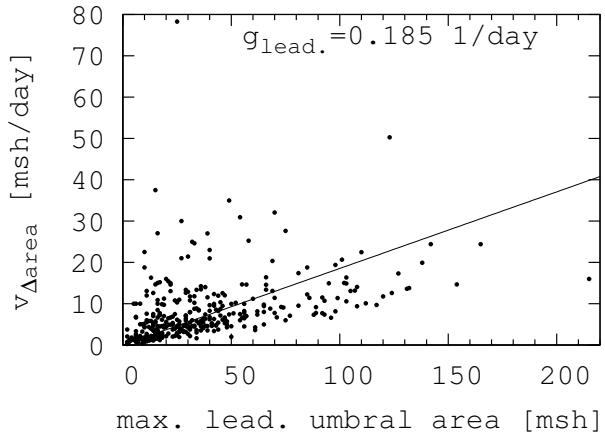
The slopes of the fitted lines mean the growth rate of the different parts.

(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

Growth rate

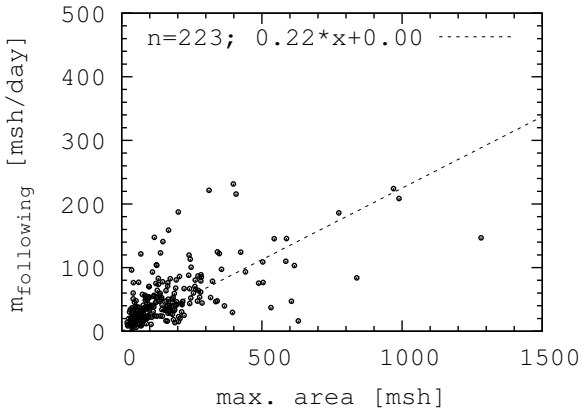


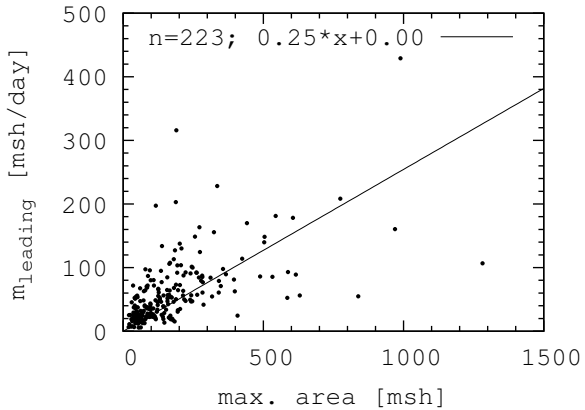




(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

The growth rate has a linear dependence on the area.
The leading parts grow faster than the following ones.





(Muraközy, Baranyi, Ludmány: 2014, *SolPhys.*, **289**, 563-577)

Outlook

Database - High temporal resolution

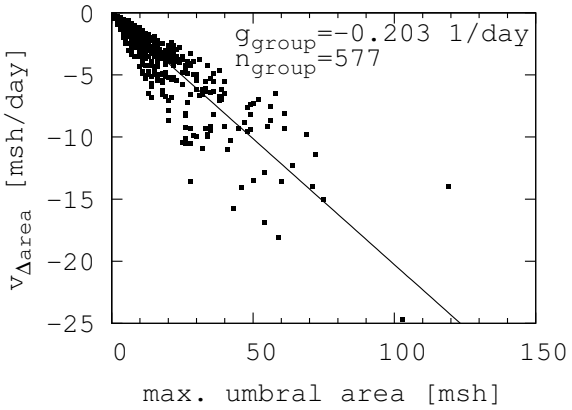
Sunspot group development

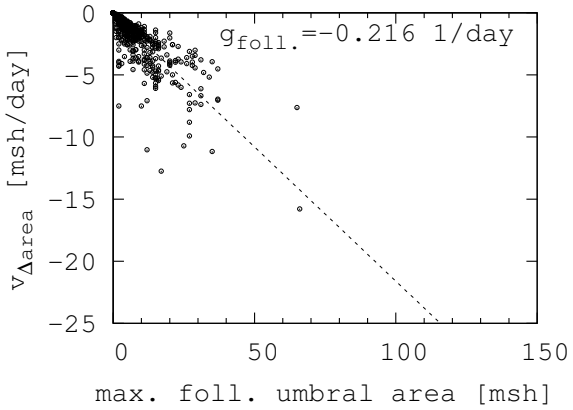
Sunspot group decay - preliminary results

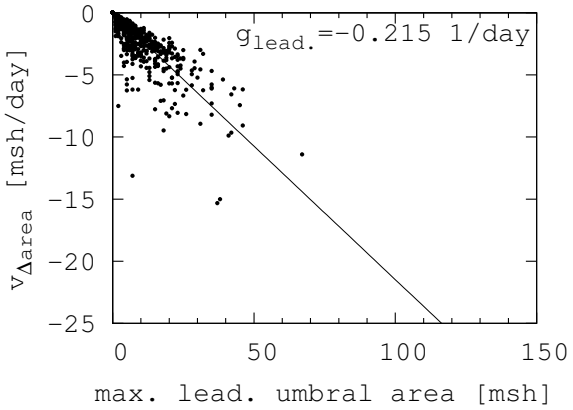
References

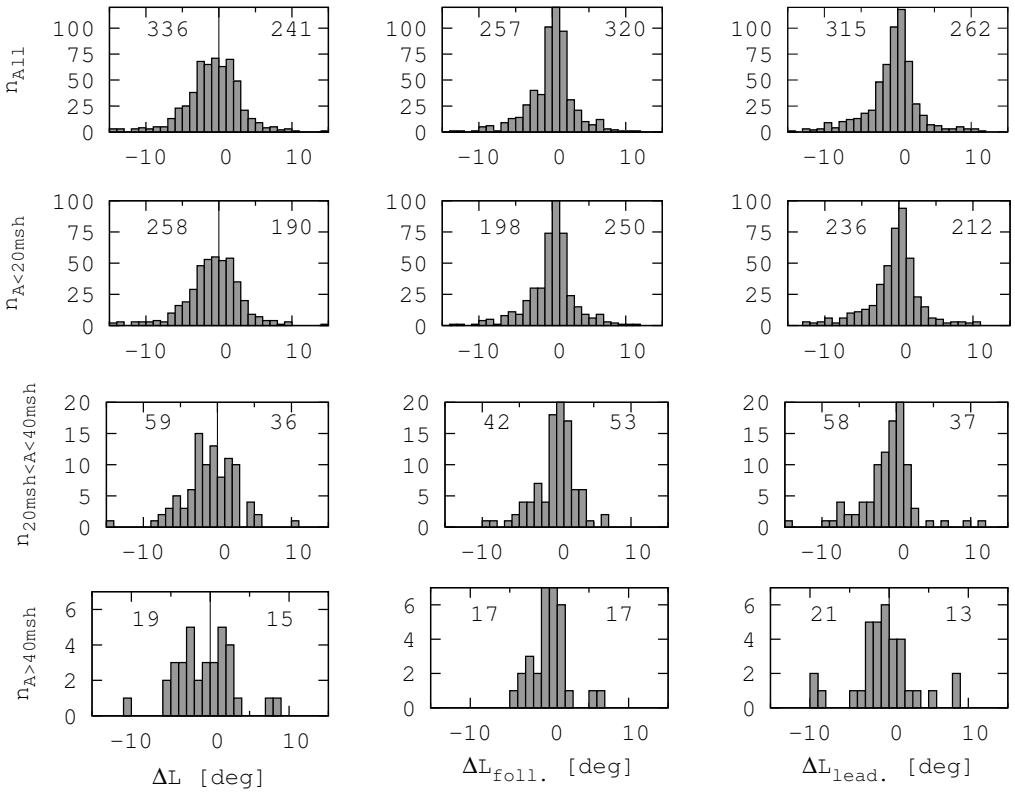
Summary, conclusions

Decay rates of sunspot groups and their shifts during the decay









Similar decay rates of the leading and following parts.
During the decay the leading parts move backward and the following parts shift forward more or less.

Outlook

Database - High temporal resolution

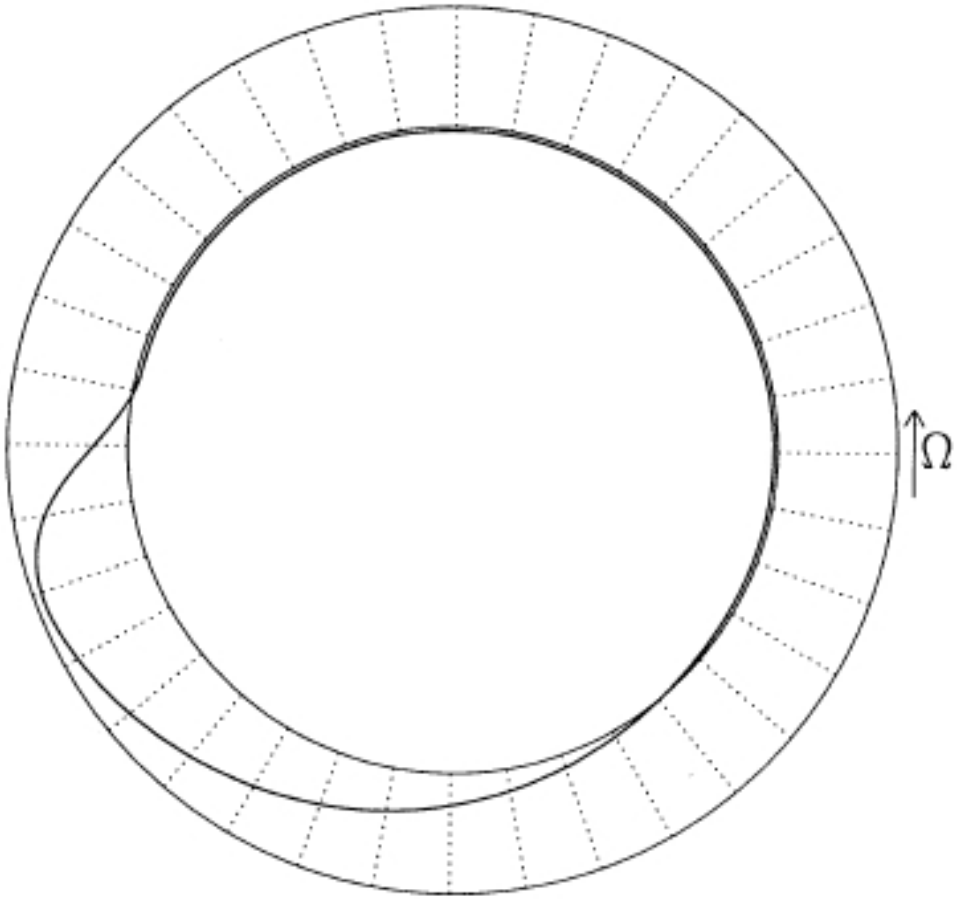
Sunspot group development

Sunspot group decay - preliminary results

References

Summary, conclusions

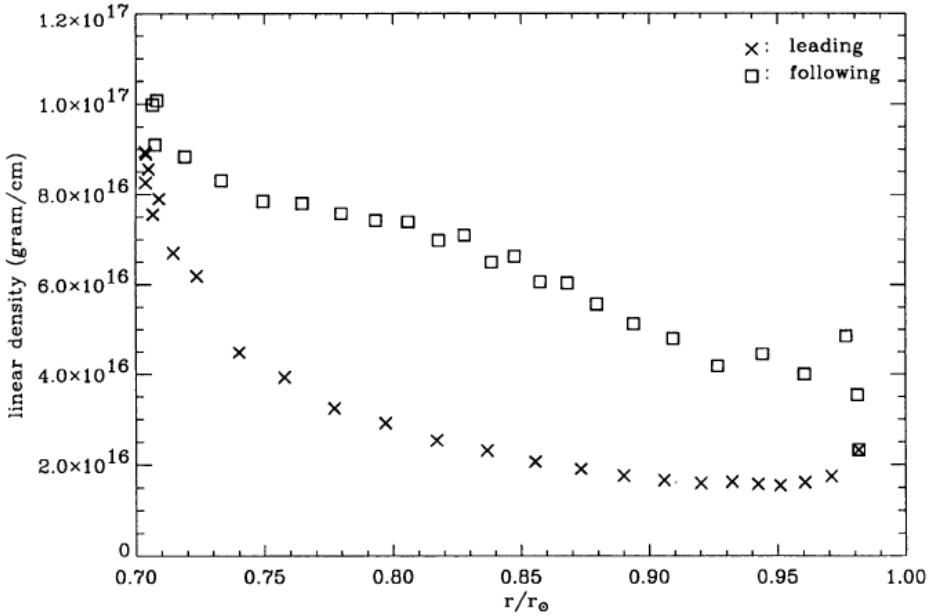
Emerging - shifts

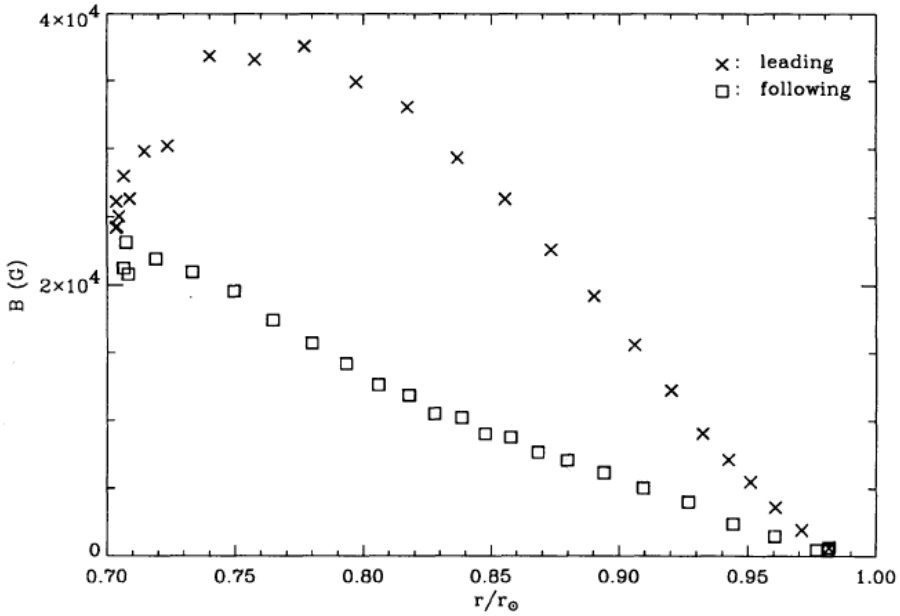


(Caligari et al.: 1995, *ApJ.*, **441**, 886)

The following part emerging with higher angle while the leading part follows it with smaller angle.
The leading part shifts forward, while the following one remains close to the first position.

Asymmetry





(Fan et al.: 1993, *ApJ.*, **405**, 390)

The Coriolis force makes a retrograde plasma current in the emerging flux tube, thus the plasma density decreases while the magnetic flux density increases in the leading part.

Outlook

Database - High temporal resolution

Sunspot group development

Sunspot group decay - preliminary results

References

Summary, conclusions

The schedule of emerging is:

- The distance of the leading-following parts depends on the sunspot group area.
- The leading part consists of less but larger sunspots than the following one.
- The following part remains at its first appearance, while the leading part shifts forward depending on the whole area.
- The growth rate depends on the maximal area of the sunspot group.
- The leading part is growing faster.
- The following part reaches later its maximum state.

The schedule of decay is:

- The decay rates of the two different parts are similar.
- The leading part shifts more backward during the decay, while the following part remains close to its first position or moves forward.

Thank you for your attention!