ISSN 0351–2657
HOBUD7 26(1) 1 (2004)

PROPER MOTIONS OF SUNSPOTS - NEW DATA AND FURTHER RESULTS

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UDC 523.???
contribution
(Received updated December 23, 2003; accepted ?? ??, 2002)

Abstract. The attempts to investigate patterns of motions of main spot components and small pores in complex sunspot groups were continued. The data discussed stem mainly from observations at Hvar/HR and Tatranská Lomnica/SK. Two historic collections of photographics plates are included: The plate archives of the former Fraunhofer Institut and that of photographic plates taken at Skalnate Pleso/SK.

Key words: sunspot groups - proper motions

1. Introduction

The motivations to investigate proper motions in sunspot groups and several examples were given by Wöhl et al. (2003) - in the following referenced as Paper I. In Paper I we concentrated on reductions of data available from Debrecen and MDI on SoHO. This time we give examples of peculiar observations in data obtained in the last years at

Tatranská Lomnica and from the old archives of photographic images on plates of the former Fraunhofer Institut (now: Kiepenheuer-Institut für Sonnenphysik).

2. The recent data sets

2.1. Images taken at Hvar observatory

The method and instruments to collect sequences of videos of sunspot groups at Hvar have been described in detail in Paper I. Here we continue in Table I with the list of data collected during about the last year.

From the analog tapes with the video sequences all images can now be digitized "online" (without personal interaction) using a new system - based on a frame grabber and an APPLE G4 workstation - available at the KIS. Then the best images can be selected by a computer program. Neither the complete digitization nor the selection process has been done with all available tapes. This process has only been tested with a few sample data.

Table I: Observed video sequences at Hvar October 2002 until October 2003

Time interval	observing days	observed sunspot groups (different NOAA numbers)	video sequences obtained
2002 Oct.	9	13	53
2003 Jan.	7	7	11
2003 Feb.	10	5	55
2003 Mar.	6	13	68
2003 Apr.	3	6	14
2003 May	16	15	90
2003 June	28	23	297
2003 July	23	25	83
2003 Aug.	15	25	79
2003 Sep.	21	21	159
2003 Oct.	11	8	65
total	149	161	974

2.2. Digital sunspot positions from Tatranská Lomnica

The drawing of precise positions of sunspot groups at Tatranská Lomnica continued with in general one drawing per day. For some periods more than one drawing per day is available. A summary of the last months of data collection is given in Table II.

Table II: Observed sunspot groups at Tatranská Lomnica October 2002 until September 2003

Time interval	observing days	observed sunspot groups (different NOAA numbers)
2002 October – December	23	62
2003 January – March	34	76
2003 April – June	47	71
2003 July – September	40	77
total	144	286

2.3. A peculiar result of differential rotation of bipolar groups

When selecting by chance the bipolar group NOAA 9878 observed at Hvar and with digitized positions at Tatranská Lomnica two interesting results were found: The leading part of that group was nearer to the solar equator as compared to the following part by about 0.5 deg and the latter part rotated about 0.33 deg/day quicker as compared to the leading part.

A more detailed reduction of all available digitized sunspot group positions taken at Tatranská Lomnica was compared with the subsample of bipolar groups. The mean sidereal differential rotation law with B for the latitude for 73 sunspot groups observed 1997 until 2002 is:

$$\omega = (14.41 \pm 0.09) - (2.75 \pm 0.78) * \sin^2 (B) \text{ [deg/day]}$$

as compared to that given by Balthasar et al. (1986) from all Greenwich sunspot groups:

$$\omega = (14.551 \pm 0.006) - (2.87 \pm 0.06) * \sin^2 (B) \text{ [deg/day]}$$

This is a remarkably good agreement. The smaller equatorial rotation velocity of the sample of our sunspot groups can easily be ex-

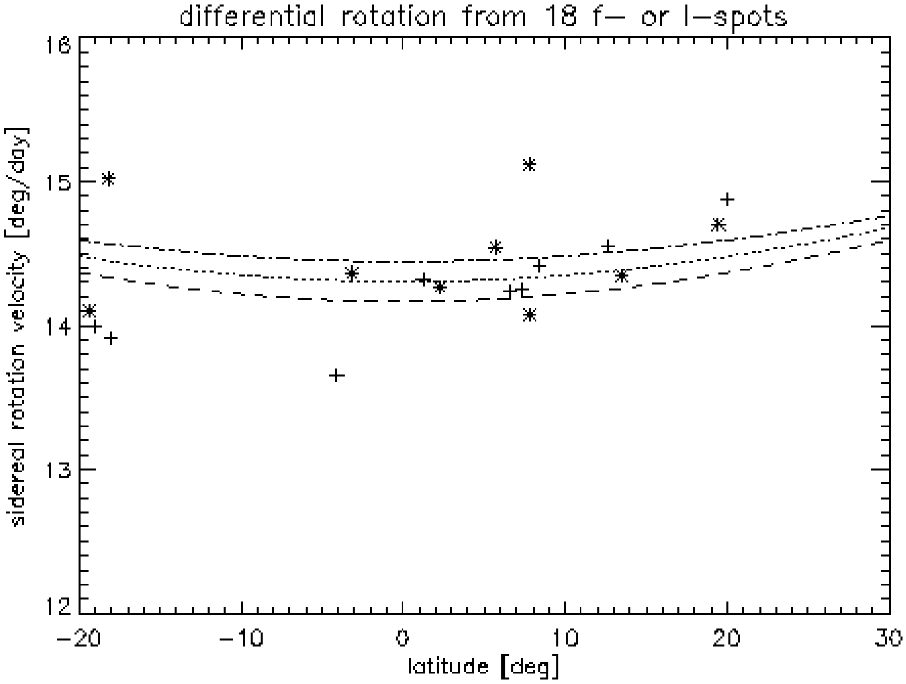

Figure 1: The sidereal rotation velocities of the 18 components of 9 bipolar sunspot groups are given (asterisks for leading and crosses for following parts, respectively). Their mean differential rotation law is fitted (dotted line) as well as the differential rotation law for the quicker leading parts of the sunspot groups (dash-dotted, upper curve) and that for the slower following parts (dashed, lower curve) are indicated.

plained by a selection of rather stable sunspot groups, which rotate slower as compared to all sunspot groups.

Reducing the available bipolar positions of the 9 NOAA groups 9454, 9455, 9456, 9871, 9878, 9880, 9881, 9887 and 9901, respectively, gives different results: They show no difference of the latitude for leading parts as compared to following parts, the difference is -(0.007 $\pm$ 0.25) [deg]. Their leading parts rotate - significant on a one σ level - quicker as the following parts; the difference is +(0.26 $\pm$ 0.17) [deg/day] and thus just the opposite as found for the sample selected by chance.

Even more puzzling is that both fractions and the mean show differential rotation laws with slower rotation nearer to the solar equator as compared to higher latitudes - although not significant. The individual values as well as the fits are given in Fig.1, the numerical value for all 18 parts of the groups is - again in sidereal rotation velocity:

$$\omega = (14.30 \pm 0.13) + (1.49 \pm 2.07) * \sin^2 (B) \text{ [deg/day]}$$

3. Historic plate collections

3.1. Photographic plates of the former Fraunhofer Institut

As already mentioned in section 2.6 of Paper I solar images taken in integral light for the former Fraunhofer Institut (now Kiepenheuer-Institut für Sonnenphysik) between 1939 and 1977 were inspected by one of the authors (H.W.) within the year 2002. The mean diameter of the solar images on these plates, which were exposed at at least ten different observatories in Europe, is 7.5 cm.

The main reason for the inspection was to select useful images from the useless rest. Indeed about 80 % of the about 12000 plates inspected were thrown away. The main interest was in series of solar images taken during high solar activity and with a high spatial resolution. For this paper a set of 8 images taken from September 18 until 21, 1957 - a period of extreme high daily sunspot relative numbers up to 334 - was digitized. A special procedure was applied to align the rotation axis of the sun on each image - which was only roughly marked on a few of them - according to the position of a stable sunspot group (Greenwich No. 18205): The latitude of this group was derived as (14.95 ± 0.17) [deg] from the four daily values given in the Greenwich Photoheliographic Results. The alignment procedure applied for the 8 images resulted in a latitude of (15.00 ± 0.20) [deg]. In Fig.2 a section of the plate taken September 21, 1957 on 7:20 UT at the Schauinsland observatory is given. The large leading and following parts of the sunspot group in the left part of Fig.2 were used to determine their motions as compared to the reference group.

It is remarkable that the scale and quality of *this section of a*

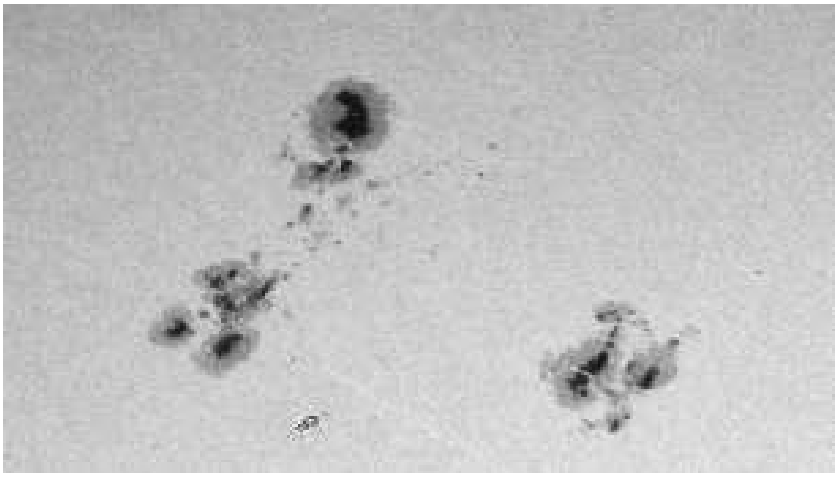

Figure 2: Section of the western part of the integral solar disk image taken September 21, 1957 at 7:20 UT on the Schauinsland solar observatory. There is no alignment applied: The east west direction on the sun equals to the diagonal from the lower left to the upper right of the image. The direction to the northern solar pole is from the image center to the upper left corner. The width of the image equals to about 570 arcseconds, the height to 330 arcseconds.

digitized full disk image are comparable with the samples of modern digital images of *fractions of the solar disk* taken by MDI on SoHO and at the Hvar observatory as given in Figs. 1 and 2 of Paper I.

Additional results could not yet be produced, because similar archives of thousands of spectroheliograms in H_α and Ca II K3 have to be inspected too. More historic details and many sample images are given in the section of public relations of www.kis.uni-freiburg.de.

3.2. Integral images taken at Skalnate Pleso/SK

Similar archives of old images of the sun taken in integral light is available in Slovakia. There are nearly 5000 images taken on plates of 9 * 12 cm with solar disk diameters of 8 or 9 cm and 285 images on plates of 13 * 18 cm with solar disk diameters of 10 cm. All these plates were exposed between 1958 and 1988, except in the years 1976/77 and 1979/80 when no images were taken.

4. Conclusions

It was shown by a few examples that the investigation of images collected for proper motion analyses showed peculiar results similar to those e.g. described by McIntosh (1981). A detailed investigation - as already announced in Paper I - is still necessary. Hopefully a joint effort will be undertaken to keep the described and other historic plate collections, as well as make them usable for the solar community. In a special panel discussion at the end of the meeting a collection of information about archives of such images was announced. This may e.g. complement a list of synoptic data collections compiled for the Joint Organization for Solar Observations (JOSO) by Mein and Wöhl (1989).

Acknowledgements

We thank the assistants at Tatranská Lomnica, P. Bendík and L. Scheirich, for their support in the sunspot drawings and digitization. The observations at Hvar were mainly performed by the observing assistant, N. Novak. The cleaning and digitization of the historic images was performed by I. David at Freiburg. SoHO (Solar and Heliospheric Observatory) is a project of international cooperation between ESA and NASA. We thank the VEGA 3015 for support.

References

Balthasar, H., Vázquez, M., Wöhl, H.: 1986, *Astron. Astrophys.* **155**, 87.

McIntosh, P.S.: 1981, in L.E. Cram, J.H. Thomas (eds.), *The Physics of Sunspots*, NSO, Sacramento Peak, Sunspot, 7

Mein, P., Wöhl, H.: 1989, in: *Godoli, G. (ed.): Joint Organization for Solar Observations, Annual Report* **1988**, 46.

Wöhl, H., Brajša, R., Kučera, A., Ruždjak, V., Rybák, J.: 2003, *Hvar Obs. Bull.* **27**, 1 (Paper I).

VLASTITA GIBANJA GRUPA SUNČEVIH PJEGA

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UDK 523.???
Pozvani pregledni članak
(Primljeno 11. listopada 2002.; prihvaćeno ??. ?? 2002.)

Sažetak. Opisani su pokušaji istraživanja ustrojstava gibanja glavnih pjega i malih pora u kompleksnim grupama Sunčevih pjega. Podaci koji su korišteni do sada potječu s opservatorija Hvar/HR, Tatranská Lomnica/SK, Izaña/E, Debrecen/H i s instrumenta MDI sa satelita SoHO. Prikazuju se prethodni rezultati.

Ključne riječi: grupe Sunčevih pjega - vlastita gibanja

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