PROPER MOTIONS OF SUNSPOTS - NEW DATA AND FURTHER RESULTS

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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 photographic plates are included: The plate archives of the former Fraunhofer Institute 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 Institute (now: Kiepenheuer-Institut für Sonnenphysik).

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Hvar Observatory, Faculty of Geodesy • Provided by the NASA Astrophysics Data System
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>
<thead>
<tr>
<th>Time interval</th>
<th>Observing days</th>
<th>Observed sunspot groups (different NOAA numbers)</th>
<th>Video sequences obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002 Oct.</td>
<td>9</td>
<td>13</td>
<td>53</td>
</tr>
<tr>
<td>2003 Jan.</td>
<td>7</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>2003 Feb.</td>
<td>10</td>
<td>5</td>
<td>55</td>
</tr>
<tr>
<td>2003 Mar.</td>
<td>6</td>
<td>13</td>
<td>68</td>
</tr>
<tr>
<td>2003 Apr.</td>
<td>3</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>2003 May</td>
<td>16</td>
<td>15</td>
<td>90</td>
</tr>
<tr>
<td>2003 June</td>
<td>28</td>
<td>23</td>
<td>297</td>
</tr>
<tr>
<td>2003 July</td>
<td>23</td>
<td>25</td>
<td>83</td>
</tr>
<tr>
<td>2003 Aug.</td>
<td>15</td>
<td>25</td>
<td>79</td>
</tr>
<tr>
<td>2003 Sep.</td>
<td>21</td>
<td>21</td>
<td>159</td>
</tr>
<tr>
<td>2003 Oct.</td>
<td>11</td>
<td>8</td>
<td>65</td>
</tr>
<tr>
<td>total</td>
<td>149</td>
<td>161</td>
<td>974</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Observing days</th>
<th>Observed sunspot groups (different NOAA numbers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002 October – December</td>
<td>23</td>
<td>62</td>
</tr>
<tr>
<td>2003 January – March</td>
<td>34</td>
<td>76</td>
</tr>
<tr>
<td>2003 April – June</td>
<td>47</td>
<td>71</td>
</tr>
<tr>
<td>2003 July – September</td>
<td>40</td>
<td>77</td>
</tr>
<tr>
<td>total</td>
<td>144</td>
<td>286</td>
</tr>
</tbody>
</table>

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:

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

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

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

This is a remarkably good agreement. The smaller equatorial rotation velocity of the sample of our sunspot groups can easily be explained 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 \(\sigma\) level - quicker as the following
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.

parts; the difference is + (0.26 ± 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 Figure 1, the numerical value for all 18 parts of the groups is - again in sidereal rotation velocity:

\[ \omega = (14.30 \pm 0.13) + (1.49 \pm 2.07) \cdot \sin^2 (B) \text{ [deg/day]} \]
3. Historic plate collections

3.1. Photographic plates of the former Fraunhofer Institute

As already mentioned in section 2.6 of Paper I solar images taken in integral light for the former Fraunhofer Institute (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 extremely 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 \((14.95 \pm 0.17) \text{ [deg]}\) from the four daily values given in the Greenwich Photoheliographic Results. The alignment procedure applied for the 8 images resulted in a latitude of \((15.00 \pm 0.20) \text{ [deg]}\). In Figure 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 Figure 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 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 Figures 1 and 2 of Paper I.

Additional results could not yet be produced, because similar archives of thousands of spectroheliograms in \(H_\alpha\) 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 $9 \times 12$ cm with solar disk diameters of 8 or 9 cm and 285 images on plates of $13 \times 18$ 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).

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References

VLASTITA GIBANJA SUNČEVIH PJEGA - NOVI PODACI I REZULTATI

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Izlaganje sa znanstvenog skupa

Sažetak. Nastavljeno je istraživanje uzoraka gibanja glavnih pjega i malih pora u složenim grupama Sunčevih pjega. Uglavnom su korišteni podaci opažanja s opservatorija Hvar/HR i Tatranská Lomnica/SK. Pridodane su i dvije povijesne zbirke fotografskih ploča: arhiv ploča bivšeg Frauenhoferovog instituta i arhiv ploča snimljenih na Opservatoriju Skalnate Pleso/SK.

Ključne riječi: grupe Sunčevih pjega - vlastita gibanja

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