DETERMINATION OF THE SOLAR ROTATION TRACING EUV BRIGHT POINTS WITH THE AUTOMATIC METHOD

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Abstract. Full-disc solar images in the extreme ultraviolet part of the spectrum from the SOHO spacecraft (instrument EIT, data in the spectral line of Fe XV at the wavelength of 28.4 nm) are used for the solar rotation determination tracing coronal bright points. From the time differences in tracer positions, approximately six hours, the solar rotation velocity is determined automatically for image sequences in several time intervals from June 4, 1998 to May 22, 1999. The resulting rotational profiles are mutually compared.

Key words: solar rotation - coronal bright points - SOHO-EIT

1. Introduction

Solar differential rotation is a statistical phenomenon and researchers often have to reduce very large data sets. In addition to optical and radio data obtained from the ground-based observatories, in recent years

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large amount of data suitable for the solar rotation analysis in different spectral ranges was provided by the satellites Yohkoh and SOHO. So, automatic methods of data reduction with computers, which can speed up the analysis significantly, can be very useful. However, the results are usually very sensitive on the input numerical parameters and the main problem is the correct identification of tracers used for the rotation velocity determination (e.g., Brajša et al., 1996; Weber et al., 1999).

In the present work coronal bright points observed in the EUV part of the spectrum in full-disc SOHO-EIT images were used as tracers for the determination of the solar rotation with the automatic method. The automatic method of data reduction was introduced by Brajša et al. (2001a). In the present paper the results obtained with the automatic method in different time intervals between June 4, 1998 and May 22, 1999 are described, while in the accompanying paper by Brajša et al. (2001b) the results obtained by the interactive method for the same data set are presented. To keep the notation consistent with that paper, the papers by Brajša et al. (2000; 2001a; 2001b) will be further on denoted as Papers I, II, and IV, respectively.

2. The Data Set and Reduction Method

The data set is described in Paper IV, where in Table I the time period from June 4, 1998 to May 22, 1999 is divided into six time intervals and the numbers of images in each of them are also given. In the present case, the data reduction was performed also separately in these six time intervals (Table I) which will be further on denoted only by the names of the months, as in Paper IV.

The automatic method of solar rotation velocity determination was described in detail in Paper II. It relies on the IDL procedure ”Regions Of Interest (ROI) segmentation”. The ROI parameters which can be preset are the sharpness of the subimages ($S$), their circumference ($C$) and the intensity of their brightness ($I$). In the present work following ROI parameters are used: $S$ was limited from 30 to 255 relative units, $C$ was limited by 30 to 80 pixels and $I$ was limited by 100 to 600 relative intensity units. The centres of the selected small subimages
**Table I:** Solar sidereal rotation velocity parameters (deg/day) from Expression (1) obtained for six time intervals with the automatic method ($M$ represents the standard error). The parameters are calculated for the filtered data after the two-step exclusion process described in the text.

<table>
<thead>
<tr>
<th>Time interval</th>
<th>$n_1$</th>
<th>$n_2$</th>
<th>$A \pm M_A$</th>
<th>$-B \pm M_B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1998</td>
<td>201</td>
<td>178</td>
<td>$14.54 \pm 0.09$</td>
<td>$2.91 \pm 0.39$</td>
</tr>
<tr>
<td>November 1998</td>
<td>118</td>
<td>105</td>
<td>$14.25 \pm 0.13$</td>
<td>$2.16 \pm 0.53$</td>
</tr>
<tr>
<td>December 1998</td>
<td>259</td>
<td>225</td>
<td>$14.54 \pm 0.08$</td>
<td>$2.81 \pm 0.28$</td>
</tr>
<tr>
<td>March 1999</td>
<td>346</td>
<td>298</td>
<td>$14.67 \pm 0.07$</td>
<td>$3.42 \pm 0.30$</td>
</tr>
<tr>
<td>April 1999</td>
<td>491</td>
<td>436</td>
<td>$14.44 \pm 0.06$</td>
<td>$1.87 \pm 0.26$</td>
</tr>
<tr>
<td>May 1999</td>
<td>295</td>
<td>261</td>
<td>$14.46 \pm 0.08$</td>
<td>$2.41 \pm 0.31$</td>
</tr>
</tbody>
</table>

were automatically traced in triplets of consecutive full-disc solar images taken every 6 hours; the last image in a triplet being the first one in the next triplet. Sequences of images taken 12 or 18 hours apart were not used here, unlike in the interactive method, when this was occasionally the case. In the automatic method the allowed latitudinal variation of the traced feature was 1 deg (from one image to the next) and results only within a defined velocity range were taken into account, as described below.

The improved solar disc coordinates (the solar radius and the position of the solar disc centre in EIT pixels) provided by Auchère et al. (1998) were used as described in Paper II, where preliminary results obtained with the automatic method for the data from time intervals June and December 1998 were also presented. However, the ROI parameters $C$ and $I$, as well as the filtering procedure chosen here are somewhat different from what was selected earlier in that work.

### 3. Results

As usually, the solar differential rotation velocity is represented by

$$\omega(b) = A + B \sin^2 b,$$

where $\omega$ is the sidereal angular rotation velocity in deg/day, $b$ the he-
Figure 1: Solar sidereal rotation velocity values obtained tracing coronal bright points in both hemispheres with the automatic method in June 1998. The data points excluded by the second filter, as described in text, are shown by crosses. The fitted differential rotation curve using all data points presented in the Figure, as well as the error ranges differing by 2 deg/day are denoted by the dashed lines. The full line (parameters are given in Table I) describes the differential rotation curve of the filtered data (stars).

The solar spin parameter was characterized by the latitudinal variation of the rotation velocity, and $A$, $B$ the solar differential rotation velocity parameters (Table I). Both solar hemispheres were treated together. The exclusion of the extreme rotation velocity values was performed in two steps, similarly as in Paper IV. In the numerical identification of tracers, all synodic rotation velocities lower than 7 deg/day and higher than 17 deg/day were excluded, regardless of the bright point’s latitude. This corresponds roughly to sidereal rotation velocities of 8 and 18 deg/day. Then, rotation velocity parameters from Expression (1) were found for all remaining data points ($n_1$ in Table I). Further, a filter shifting in the latitude, excluding all velocity values which differ by 2 deg/day or more from the mean curve, was imposed on the data.
Figure 2: The same as in Figure 1, for November 1998.

and finally new parameters were found for the remaining $n_2$ velocities (Table I). Both differential rotation curves and the thresholds of the filter are presented in Figures 1–6 for each of the six time intervals separately, while sets of the differential rotation parameters are presented in Table I.

4. Discussion

Let us firstly compare the solar differential rotation parameters from Equation (1) obtained for the June and December 1998 data, in the present work (Table I) and in Paper II (Table 5). The difference between these two cases is that slightly different ROI parameters and filtering of extreme velocities were applied. In the present work the adjustable ROI parameters were selected in such a way that the automatic method of data reduction resembles as much as possible the visual method, taking into account the experience gained in the meantime. Similarly, the two-step velocity filter was also modified in com-
Figure 3: The same as in Figure 1, for December 1998.

parison with the filter applied earlier. In the present case (Table I) the numbers of used tracers are smaller, the rotation parameter $A$ is lower and the absolute value of the rotation parameter $B$ is higher than in Paper II.

Now a comparison between the results obtained with the automatic method (present work, Table I) and with the interactive method (Paper IV, Tables II–VI) will be made. The dispersion of the values of the differential rotation parameters $A$ and $B$ determined in different time intervals is similar for the results of the two methods. Many of the extreme values of the parameters were obtained reducing the data from November 1998. This is not surprising, since this was the shortest time interval (Paper IV, Table I).

The linear correlation coefficient calculated for different sets of solar rotation parameters is often used in the analysis and comparison of rotational properties deduced from different data sequences (e.g., Komm et al., 1992; Komm, Howard, and Harvey, 1993). For six pairs of solar rotation parameters $A$ and $B$ given in Table I the linear correlation

coefficient is $-0.82$. This anticorrelation means that the parameters $A$ and $B$ are not fully independent, i.e., higher values of the equatorial parameter $A$ come often together with lower (more negative) values of the differential parameter $B$. So, the differential rotation curves often cross each other at low or medium latitudes representing on the average the same rotational velocity in broad latitudinal ranges. Let us also mention that the linear correlation coefficient of parameters $A$ and $B$ for the June 1998 data reduced by five observers with the interactive method (Paper IV, Tables II–VI) amounts to $-0.61$ and for a part of the June 1998 data reduced by four observers with the interactive method (Paper I, Table I) amounts to $-0.95$.

5. Conclusions

This paper continues our work on the solar differential rotation determined tracing coronal bright points with the automatic method started in Paper II. The automatic method is further developed becoming now
more similar to the interactive one. The results obtained with these two methods are compared and the data sets are prepared for further analysis as discussed in Paper IV. With the automatic method large data sets can be reduced in the same way using the same preset numerical conditions. The data analysis applying the automatic method can be performed faster than with the interactive method which is important in case of the huge amount of data available from SOHO-EIT (Hochedez et al., 2001), and especially when the analysis will be extended further to sequences of images taken with a higher cadence than in the case of the data presently used (Berghmans, McKenzie, and Clette, 2001).

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Figure 6: The same as in Figure 1, for May 1999.

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References


H. WÖHL ET AL.: SOLAR ROTATION WITH AUTOMATIC METHOD


ODREĐIVANJE ROTACIJE SUNCA PRAĆENJEM SVIJETLIH TOČAKA OPAŽANIH U DALEKOM ULTRALJUBIČASTOM DIJELU SPEKTRA AUTOMATSKIM POSTUPKOM

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