CORONAL BRIGHT POINTS AS TRACERS FOR
SOLAR ROTATION IN OCTOBER–NOVEMBER 1999

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Abstract. Whole-disc full-resolution solar images taken in the extreme ultraviolet part
of the spectrum (Fe XV line at 28.4 nm) with the EIT instrument on board the SOHO
spacecraft were used to visually identify coronal bright points appropriate for solar ro-
tation determination. From the time differences in successive tracer positions amounting
to six hours the solar rotation velocity was determined tracing coronal bright points in
images obtained in October and November 1999. The resulting parameters and profiles
of the solar rotation are presented.

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

1. Introduction

Whole-disc full-resolution solar images obtained with the Extreme Ultra-
 violet Imaging Telescope (EIT) on board the Solar and Heliospheric Ob-
servatory (SOHO) are used to analyse the solar differential rotation and
related phenomena by tracing coronal bright points. Two different proce-
dures of data reduction were developed: an interactive and an automatic
method (Brajša et al., 2001a). A small north-south rotational asymmetry
and fine differences in rotation between several tracer subtypes, point-like
structures (PLS), small loops (SL), and small active regions (SAR), were

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found using the data obtained in June, November, and December 1998 and in March, April, and May 1999 (Brajša et al., 2002). The same data set was used to analyse the properties of the solar surface velocity field (Vršnak et al., 2003). Zones of slow and fast rotation consistent with the pattern of torsional oscillations were observed, indicating that the velocity pattern of coronal bright points statistically reflects the large-scale plasma flows. The subsample of PLSs revealed a latitude-dependent horizontal Reynolds stress indicating an equatorward transport of angular momentum, consistent with the observed differential rotation of the Sun. A method for the simultaneous determination of the true solar synodic rotation velocity and height of tracers was applied (Brajša et al., 2004) and the average height of coronal bright points was found to be 8000 – 12000 km above the solar photosphere. The differential rotation profile of coronal bright points obtained with the interactive method corresponds roughly to the profile determined correlating photospheric magnetic fields and the profile obtained with the automatic method corresponds roughly to the rotation of sunspot groups. Using the same data set, the spatial distribution and north-south latitudinal asymmetry of coronal bright points was investigated by Brajša et al. (2005).

The interactive method was developed in the year 2000 and subsequently seven observers used it to reduce subsets of data from the time period June, November, and December 1998 and March, April, and May 1999 (Brajša et al., 2000; 2001a; 2001b) leading to a homogeneous data set for the whole observing period, as described by Brajša et al. (2002). Further, Mulec et al. (2007) presented preliminary results obtained applying the interactive method to the October 1999 data by four observers (two of them are new ones). Finally, in this work we present results obtained applying the interactive method to the October and November 1999 data by Miran Mulec (Mulec, 2007).

2. Data and Reduction Methods

Whole-disc full-resolution solar filtergrams in the Fe XV line at the wavelength of 28.4 nm from the EIT on board SOHO obtained with the regular cadence of 4 images per day, i.e. one image every 6 hours, were used. However, there were some gaps in the data and the total number of used images were 103 and 87 in October (dates: 1-8 and 12-29) and November (dates:
2-16 and 20-28) 1999, respectively.

The interactive method is based on visual identification of tracers and it was described in detail by Brajša et al. (2001a; 2001b). The bright points are identified in sequences of images and their persistence in consecutive images at approximately the same latitude and shifted along the Central Meridian Distance (CMD) is checked. In this way the observer decides if a particular object should be included or excluded, reducing the possibility of false tracer identification. The rotation velocity (ω) is then calculated measuring the CMD values of identified coronal bright points and fitting them as a function of the time t. Each individual tracer was identified in at least 3 consecutive images and maximal number of images in which tracing of an object was possible amounted to 13 and 9 for the October and November 1999 data, respectively. The time-dependent transformation from the synodic to the sidereal rotation velocity was performed taking into account the variable velocity of the Earth and SOHO around the Sun (e.g., Roša et al., 1995).

As usual, the solar differential rotation velocity is represented by

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

where ω is the sidereal angular rotation velocity in deg/day, b the absolute value of the heliographic latitude (both solar hemispheres were treated together), and A, B the solar differential rotation parameters. The exclusion of extreme rotation velocity values was performed in two steps. All sidereal rotation velocity values lower than 8 deg/day and higher than 18 deg/day were excluded, regardless of the feature’s latitude (first filter). Then the rotation velocity parameters according to Expression (1) were found for all remaining data points. Further, all velocity values differing by 2 deg/day or more from the mean curve were excluded (second filter) and finally new parameters were found using remaining data.

3. Results

All solar rotation velocities remaining after an application of the first and the second filter described above and corresponding differential rotation curves are presented in Figures 1 and 2 for the October and November 1999 data, respectively. In Figure 3 the similar is presented for the data from both months under consideration. The corresponding differential rotation
Table I: Fit parameters for 160 coronal bright points traced in October 1999 for both hemispheres taken together (upper panel). After the first order filtering 158 points remained, after the second one 149. Fit parameters for 210 coronal bright points traced in November 1999 for both hemispheres taken together (middle panel). After the first order filtering 205 points remained, after the second one 184. Fit parameters for 370 coronal bright points from both months October and November 1999 and for both hemispheres treated together (lower panel). After the first order filtering 363 points remained, after the second one 333.

<table>
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<th>October 1999</th>
<th></th>
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<tbody>
<tr>
<td>unfiltered</td>
<td>1st filter</td>
<td>2nd filter</td>
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<tr>
<td>(A = 14.612)</td>
<td>(A = 14.653)</td>
<td>(A = 14.6726)</td>
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</tr>
<tr>
<td>(B = -2.976)</td>
<td>(B = -3.167)</td>
<td>(B = -3.081)</td>
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<tr>
<td>(n = 160)</td>
<td>(n = 158)</td>
<td>(n = 149)</td>
<td></td>
</tr>
<tr>
<td>(\sigma_A = 0.133)</td>
<td>(\sigma_A = 0.1074)</td>
<td>(\sigma_A = 0.0826)</td>
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<tr>
<td>(\sigma_B = 0.357)</td>
<td>(\sigma_B = 0.2961)</td>
<td>(\sigma_B = 0.2407)</td>
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<tr>
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<tr>
<td>(A = 14.7153)</td>
<td>(A = 14.7)</td>
<td>(A = 14.661)</td>
<td></td>
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<tr>
<td>(B = -3.116)</td>
<td>(B = -3.47)</td>
<td>(B = -3.564)</td>
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<tr>
<td>(n = 210)</td>
<td>(n = 205)</td>
<td>(n = 184)</td>
<td></td>
</tr>
<tr>
<td>(\sigma_A = 0.192)</td>
<td>(\sigma_A = 0.1357)</td>
<td>(\sigma_A = 0.0917)</td>
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<tr>
<td>(\sigma_B = 0.423)</td>
<td>(\sigma_B = 0.3041)</td>
<td>(\sigma_B = 0.2255)</td>
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<tr>
<td>(A = 14.663)</td>
<td>(A = 14.681)</td>
<td>(A = 14.673)</td>
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<tr>
<td>(B = -3.042)</td>
<td>(B = -3.362)</td>
<td>(B = -3.405)</td>
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<tr>
<td>(n = 370)</td>
<td>(n = 363)</td>
<td>(n = 333)</td>
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<tr>
<td>(\sigma_A = 0.1193)</td>
<td>(\sigma_A = 0.0876)</td>
<td>(\sigma_A = 0.0621)</td>
</tr>
<tr>
<td>(\sigma_B = 0.2836)</td>
<td>(\sigma_B = 0.213)</td>
<td>(\sigma_B = 0.1634)</td>
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Figure 1: Differential rotation for 160 coronal bright points traced in October 1999. The data were filtered two times, as explained in text, and both hemispheres were treated together. The data points excluded by the second filter 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 dotted lines. The full line gives the differential rotation curve of the filtered data (stars). It is defined by the differential rotation parameters given in the right column of Table I.

parameters from Expression (1) are given for data from the two months separately and taken together (Table I).

4. Discussion and Conclusion

The interactive method of the solar rotation determination tracing coronal bright points in SOHO-EIT images is very time consuming as compared to the automatic method. However, the main advantage of the interactive method is that experienced observers can avoid false object identification due to the visual tracing. Further, the interactive method enables tracing long-living structures also and distinguishing between the three tracer subtypes.

In the present work solar differential rotation is determined tracing coronal bright points in SOHO-EIT images taken in October and November.
Figure 2: As Figure 1 for 210 coronal bright points traced in November 1999; see also Table I.

Figure 3: As Figure 1 for 370 coronal bright points traced in October and November 1999; see also Table I.
1999, applying the interactive method. A comparison of the results for these
two months reveals almost the same equatorial rotation velocity (the pa-
rameter $A$) and the non-vanishing difference of the rotational gradient (the
parameter $B$) with increasing latitude. However, this difference is statisti-
cally significant only on the 1 $\sigma$ level.

Results presented in this work complement already existing results ob-
tained with the interactive method (6 months) with data from 2 additional
months. This will enable composing an extended homogeneous data set,
based on the interactive method. It will be suitable for various further ana-
lyses, such as a comparison of the interactive and automatic methods on a
monthly basis and an investigation of a possible relationship between the
solar rotation and activity, which will be performed in a subsequent paper.

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