ON THE DETERMINATION OF THE HEIGHT OF MICROWAVE LOW TEMPERATURE REGIONS FROM SOLAR ROTATION MEASUREMENTS

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UDC 523.9-327-77*37 GHz
Conference paper
(Received August 25, 1997; accepted January 15, 1998)

Abstract. A larger angular rotation velocity was measured for microwave LTRs associated with Hα filaments than for the not associated ones. This implies that LTRs not associated with Hα filaments are located at lower heights above the solar photosphere than LTRs associated with Hα filaments. Data from three intervals were analysed (1979-1980, 1981-1982 and 1987-1988) with different percentages of association between LTRs and Hα filaments.

Key words: microwave low brightness temperature regions, solar differential rotation

The solar angular rotation velocity determined by tracing various features in the solar atmosphere depends on the evolutionary stage of the tracer, on the height at which it is observed, on the phase of the solar cycle when the measurements were performed, on the strength and configuration

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of magnetic and velocity fields, etc. A search for a difference in the solar angular rotation velocity for two classes of microwave Low brightness Temperature Regions (LTRs), associated and not associated with Hα filaments (Vršnak et al., 1992), was performed. Such a difference, if interpreted as a consequence of projection effects would imply that these two classes of microwave perturbers have different heights above the photosphere. A general method to determine the solar synodic angular rotation velocity and the height of tracers from the apparent tracer’s positions projected on the photosphere was developed in details by Roša et al. (1998), relying on the work of Förster (1979). The effects of the tracer’s height on the measured angular rotation velocities were discussed in particular for e. g. sunspots (Balthasar and Wöhl, 1983), for tracers in microwaves (Liu and Kundu, 1976) and for Hα filaments (Adams and Tang, 1977; Brajša et al., 1991).

In our analysis, diurnal full-disc solar maps taken with the 14 m radio telescope of the Metsähovi Radio Research Station, Helsinki University of Technology at the frequency of 37 GHz (8 mm) were used (Urpo, Pohjolainen and Teräsranta, 1992). At this frequency the beam width of the telescope amounts to 2.4 arc minutes on the sky, while the estimated quiet Sun level is approximately 7800 K in the brightness temperature scale. The identified LTRs were traced during their passage over the solar disc, and from each identified LTR, one rotation velocity was determined, regardless of the number of tracing days.

An association between a LTR and a Hα filament was considered positive if the distance between them, as measured on daily full-disk solar maps (Metsähovi maps for LTRs and Solnechnye Dannye Byulleten for Hα filaments), was less than the radio telescope beam size for more than half of observing days.

As usually, the solar differential rotation is represented by:

\[ \omega(b) = A + B \sin^2 b + C \sin^4 b \]  \hspace{1cm} (1)

where \( \omega \) represents the sidereal angular rotation velocity in degrees per day, \( b \) the heliographic latitude, and \( A, B, C \) the solar rotation velocity parameters. Both solar hemispheres were treated together for the years 1979-1980, 1981-1982 and 1987-1988 and no height correction was applied.
The number of determined rotation velocity values for these years amounted to 170. The mean values of the solar sidereal angular rotation velocities, with error bars indicating standard errors of the means as well as with two- and three-parameter fits ($C=0$ and $B=C$) from Equation (1), are presented in Figures 1, 2 and 3. In Figure 1, all data are presented, in Figure 2 only those data for LTRs associated with H$\alpha$ filaments and in Figure 3 only those data when the LTRs were not associated with H$\alpha$ filaments.

**TABLE I**

Solar sidereal angular rotation velocity determined by tracing LTRs

The deduced parameters from the expression (1) are given for positive and negative association of LTRs and H$\alpha$ filaments

$M$ - the standard error; $C = 0$ or $B = C$

<table>
<thead>
<tr>
<th>association</th>
<th>$A$</th>
<th>$M_A$</th>
<th>$B$</th>
<th>$M_B$</th>
<th>$C$</th>
<th>$M_C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>all</td>
<td>14.26</td>
<td>0.11</td>
<td>-2.00</td>
<td>0.44</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>all</td>
<td>14.23</td>
<td>0.10</td>
<td>-1.36</td>
<td>0.30</td>
<td>-1.36</td>
<td>0.30</td>
</tr>
<tr>
<td>yes</td>
<td>14.48</td>
<td>0.14</td>
<td>-2.59</td>
<td>0.53</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>yes</td>
<td>14.44</td>
<td>0.13</td>
<td>-1.76</td>
<td>0.35</td>
<td>-1.76</td>
<td>0.35</td>
</tr>
<tr>
<td>no</td>
<td>14.02</td>
<td>0.16</td>
<td>-2.13</td>
<td>0.72</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>no</td>
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<td>0.16</td>
<td>-1.40</td>
<td>0.48</td>
<td>-1.40</td>
<td>0.48</td>
</tr>
</tbody>
</table>

The preliminary results indicate larger measured rotation velocity values for LTRs associated with H$\alpha$ filaments and smaller ones for LTRs not associated with H$\alpha$ filaments (Table I; Figures 2, 3 and 4). The larger angular rotation velocity measured for LTRs associated with H$\alpha$ filaments is interpreted as a consequence of projection effects (Brajša et al., 1991; Roša et al., 1998), implying that LTRs not associated with H$\alpha$ filaments are located at lower heights than the ones associated with H$\alpha$ filaments. The difference in the angular rotation velocities of these two classes of LTRs has values between 0.2 and 0.5 degrees per day (Figure 4), corresponding to a height difference amounting up to 20000 km (Figure 4 in the paper by Brajša et al., 1997).

In Figure 5 the ratio of the number of solar rotation velocities determined from LTRs associated with H$\alpha$ filaments and the number of all veloc-
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ities (LTRs associated and not associated with Hα filaments) is presented in percents for the three intervals. Each interval is treated independently, so that the total percentage for each column is 100%. During the years 1979-1980 the association rate between LTRs and Hα filaments amounted to 66%, during the years 1981-1982 it amounted to 59% and during the years 1987-1988 it was only 35%. These percentages can be compared with the ones obtained by Vršnak et al. (1992) who found a 60 - 70% association rate between positions of LTRs and Hα filaments drawn in synoptic charts (Meudon data) as an average value for the years 1979, 1980, 1981, 1982, 1987, 1988 and 1989. The association rate from the first two intervals (1979-1980 and 1981-1982) corresponds roughly to the one found by Vršnak et al. (1992), while the association rate in the third interval (1987-1988) was substantially lower than the average value obtained by Vršnak et al. (1992). This disagreement may be a consequence of a smaller number of LTRs present in the third interval as compared with the number of LTRs in the first two intervals (Figures 6, 7 and 8), so that the relatively smaller association rate from the third interval contributes less to the average value.

The association rate of LTRs and Hα filaments depends on the phase of the solar cycle; as the cycle develops, the association rate declines (Figure 5). So, the contribution of LTRs associated with Hα filaments (which gives a larger angular rotation velocity due to projection effects) is decreasing during these three intervals of observations. A larger solar angular rotation velocity determined by tracing all LTRs was found in the 1979-1980 interval and a smaller one in the 1981-1982 and 1987-1988 intervals (Brajša et al., 1997), and we believe that the interpretation of this phenomenon is related to different percentages of association between LTRs and filaments during these three intervals. Further, it is also important to inspect the latitudinal distribution of identified LTRs (Figures 6, 7 and 8). It can be seen that there were only few LTRs at latitudes larger than 50 degrees, and therefore the rotation profiles in Figure 4 were cut off at 50 degrees.
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Fig. 1. Mean values of solar sidereal angular rotation velocities (×) obtained by tracing LTRs in 10° latitude bands are presented for all data; full and dotted lines represent the two- and three-parameter fits from Equation (1), respectively.

Fig. 2. The same as in Fig. 1, but only for LTRs associated with Hα filaments.

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Fig. 3. The same as in Fig. 1, but only for LTRs not associated with Hα filaments.

Fig. 4. Solar rotation profiles for the two classes of LTRs: full line - LTRs associated with Hα filaments; dashed line - LTRs not associated with Hα filaments.
Fig. 5. Percentage of association between LTRs and Hα filaments for the three intervals. The difference up to 100 % represents the percentage of LTRs not associated with Hα filaments for each column independently.

Fig. 6. The distribution of the number of LTRs according to the absolute value of the solar latitude for the years 1979-1980.
Fig. 7. The same as in Fig. 6, but for the years 1981-1982.

Fig. 8. The same as in Fig. 6, but for the years 1987-1988.
Finally, let us note that in this paper only preliminary results are presented, while a more complete treatment of the topic, including the reduction of the data from the years 1989-1991 and applying procedures with statistical weights and orthogonal functions, as well as the residual method, is in progress.

Acknowledgements

R. B. expresses his gratitude to the Deutsche Forschungsgemeinschaft and Ministry for Science and Technology, Republic of Croatia for financial support, which enabled him to work on the topic of this paper during his visits to the Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany.

The authors are very thankful to Drs. Ž. Andreić (Ruđer Bošković Institute, Zagreb), D. Špoljarić (Faculty of Geodesy, Zagreb) and V. Vujnović (University Computing Centre, Zagreb) for valuable help in the reduction of data in this and related research topics.

References

O ODREĐIVANJU VISINE NISKOTEMPERATURNIH
PODRUČJA MIKROVALNOG ZRAČENJA POMOĆU
MJERENJA BRZINE ROTACIJE SUNCA

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UDK 523.9-327-77*37 GHz
Izlaganje sa znanstvenog skupa
(Primljeno 25. kolovoza 1997.; prihvaćeno 15. siječnja 1998.)

Sažetak. Praćenjem položaja niskotemperaturnih područja mikrovalnog zračenja
na Suncu (NTP) prostorno povezanih s Hα filamentima ustanovljena je veća kutna
brzina rotacije u odnosu na brzinu rotacije određenu pomoću NTP koja nisu
povezana s Hα filamentima. Iz toga slijedi manja visina u odnosu na fotosferu
onih NTP koja nisu povezana s filamentima u odnosu na NTP koja jesu povezana
tijekom kojih je ustanovljen različit brojčani udio NTP povezanih s filamentima u
odnosu na ukupni broj NTP.

Ključne riječi: niskotemperaturna područja mikrovalnog zračenja, diferencijalna
rotacija Sunca