POLAR CROWN FILAMENTS AND SOLAR DIFFERENTIAL ROTATION AT HIGH LATITUDES

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ABSTRACT

Rotation rates of 124 polar crown filaments are determined. Filaments are traced on Hα filtergrams taken at Sonnenobservatorium Kanzelhöhe, University of Graz, Austria, in the period 1979-1987, covering heliographic latitude ranges between 35°-80°. The lifetime of tracers varied from 1 to 6 days. Special care was taken to measure the positions of the footpoints of prominences, and the correction for an average height of 0.5%, 1% and 1.5% of the Solar radius was applied. The results were connected to those of Adams and Tang (1977) (prominences in latitude range 0°-35°), and are compared to other measurements.

1. INTRODUCTION

d'Azambuja and d'Azambuja (1948) were the first to measure the differential rotation of the Sun by tracing filaments. They have studied several hundreds "long-lived" filaments, i.e. those which have passed the central meridian two or more times in the zone between the Solar equator and 70 degrees of heliographic latitude. Bruzek (1961) traced polar crown filaments and has obtained similar results as d'Azambuja and d'Azambuja (see Hansen et al. 1969). Adams and Tang (1977) have studied "short-lived" filaments (just one passage across the Solar disc) below 35 degrees heliographic latitude. However, we feel that there is still a lack of measurements on polar crown filament rotation rates.


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2. Measurements

Rotation rates of 124 polar crown filaments are determined. The filaments are traced on Hα filtergrams taken at the Sonnenobservatorium Kanzelhöhе, University of Graz, Austria, in the period 1979-1987, covering the latitude ranges between 35°-80°. The lifetime of the tracers varied from 1 to 6 days and statistical weights were assigned according to the duration of the tracing: one day - s.w.=1, two days - s.w.=2, etc. (It was found that the shape of the differential rotation curve does not depend on this procedure, see Fig. 1 and 2.) For the analysed intervals the time difference between the chosen successive photographs was about 1 hour. Special care was taken to measure the positions of the footpoints of prominences, and the correction for an average height of 1% of the Solar radius was applied (Adams and Tang, 1977). Differences in taking different statistical weights (Figure 1) and the one in which all obtained rotation rates have the same statistical weight (s.w.=1), regardless of the tracing time are much smaller than the errors of measurement (Figure 2) and the general behaviour is the same in both cases.

3. Results

The results were connected to those of Adams and Tang (prominences in the latitude range 0°-35°). The least square fit (Murdin 1979) to the function

\[ \omega = A - B \sin^2 \phi \]  

(1)

gives the values of the parameters A and B, which are compared to other results given in Table 1, and Fig. 3. In the above expression \( \omega \) is the sidereal angular rotation rate, and \( \phi \) is the latitude. Parameters of fitting to the function

\[ \omega = A + B \sin^2 \phi + C \sin^4 \phi \quad (2) \]

are given in Table 2, for various heights above the Solar photosphere (see also Fig. 4).

Table 1.: Parameters of equation (1) in deg/day from different sources

<table>
<thead>
<tr>
<th>Tracer</th>
<th>A</th>
<th>B</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunspots</td>
<td>14.38±0.01</td>
<td>2.57±0.07</td>
<td>Lustig (1983)</td>
</tr>
<tr>
<td>Filaments</td>
<td>14.48</td>
<td>2.16</td>
<td>d'Azambuja(^2) (1948), after Schröter (1985)</td>
</tr>
<tr>
<td>Filaments</td>
<td>14.4</td>
<td>1.4</td>
<td>Adams &amp; Tang (1977)</td>
</tr>
<tr>
<td>Filaments</td>
<td>14.83±0.17</td>
<td>3.3±0.3</td>
<td>present work</td>
</tr>
</tbody>
</table>

Table 2.: Parameters of eq. (2). Our errors in determination of the parameters A, B and C are 0.15, 0.9 and 0.9 respectively.

<table>
<thead>
<tr>
<th>Method/tracer</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>photosph./spec.</td>
<td>13.76</td>
<td>-1.74</td>
<td>-2.19</td>
<td>Howard &amp; Harvey (1970)</td>
</tr>
<tr>
<td>filaments</td>
<td>14.42</td>
<td>-1.40</td>
<td>-1.33</td>
<td>d'Azambuja(^2) (1948) after Mouradian et al. (1987)</td>
</tr>
<tr>
<td>polar faculae</td>
<td>13.11</td>
<td>-1.65</td>
<td>-0.22</td>
<td>Makarova &amp; Solonsky (1987)</td>
</tr>
<tr>
<td>pol.high temp. reg. at 37 GHz</td>
<td>11.55</td>
<td>+0.05</td>
<td>-1.69</td>
<td>Urpo et al. (1989)</td>
</tr>
<tr>
<td>fil. h/R=0.5%</td>
<td>14.46</td>
<td>-0.33</td>
<td>-2.74</td>
<td>present work</td>
</tr>
<tr>
<td>fil. h/R=1%</td>
<td>14.45</td>
<td>-0.11</td>
<td>-3.69</td>
<td>present work</td>
</tr>
<tr>
<td>fil. h/R=1.5%</td>
<td>14.40</td>
<td>+0.86</td>
<td>-5.64</td>
<td>present work</td>
</tr>
</tbody>
</table>


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**Figure 1:**
Sidereal rotation rates (deg/day) vs. latitude for both solar hemispheres. Statistical weights were ascribed in proportion to the duration of filament tracing. Dots represent 5 degree bin averages for the "raw data", i.e. without any height correction.

**Figure 2:**
The same as in Figure 1, but with statistical weights equal to one; i.e. regardless of the tracing duration.
4. DISCUSSION AND CONCLUSIONS

The obtained differential rotation curve, without any height correction (Fig. 1 and 2) shows an increase of rotation rates at high Solar latitudes. Possibly this can be related to a similar behaviour of the Sun's magnetic field pattern (Stenflo 1989), which could be connected with rigidly rotating patterns of large scale magnetic fields on the Sun (Sheeley et al. 1987). Another explanation could be projection effects due to the height of the measured objects. When such a correction is applied (which depends on latitude) the increase of rotation rate at high latitudes disappears. On the other hand Mouradian et al. (1987) and Mouradian and Soru-Escaut (1989) found that some filaments show rigid rotation. Maybe this can explain our result, but one must have in mind that our results are obtained from 5 latitude degrees bin averages, so that eventual individual behaviour of filament rotation rates is merged in the averages.

Adams and Tang (1977) claim that the constant $A$ (expression (1)) depends on the assumed value for the height of the measured features, but the magnitude of the decrease of the rotation rate with latitude (given by $B$ in expression (1)) is essentially independent of that assumed height. We have found that this is true for the low latitude range ($0-35$ degrees) for which in fact Adams's and Tang's work was performed. However, when the entire latitude range is analysed, a quite opposite situation is found: the coefficient $A$ is practically independent on height, whereas the coefficients $B$ and $C$ depend on height (see Table 2), which can be seen also in Figure 4. Performing analytical calculations and numerical simulations we found that at low latitudes the amount of the height correction does not depend

significantly on the latitude, while at high latitudes it does. This can explain the observed behaviour.

We have investigated how the rotation rate depends on the position of the measured filaments on the Sun’s disc (i.e. on central meridian distance – CMD) for the same latitude. The measured excess of rotation rates at large CMD may be explained with projection effects. However, the calculated values, for a given height, are grouped much closer together than the observed ones, so by such an analysis we can not determined the true height of the measured objects.

There is a possible relationship between polar crown filaments and the low temperature areas at 37 GHz. On the other hand, high temperature microwave sources at high solar latitudes may be connected with polar faculae (Urpo et al. 1989).
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Figure 3:
Curves of the sidereal rotation rate (deg/day) vs. solar latitude
+ filaments, Adams & Tang (1977)
circles: polar crown filaments, present work
1) filaments, d'Azambuja (1948), after Schröter (1985)
2) & 3) polar faculae, after Makarova & Solonsky (1987)
4) photosphere, spectroscopic, Howard & Harvey (1970)
5) polar faculae, Waldmeier (1955) & Müller (1954),
after Hansen et. al. (1969)
6) enhancement of microwave radiation at 37 GHz,
Urpo & Pohjolainen (1987)

Figure 4:
Curves of the solar rotation rate for various heights using a fit
to the function (2). Present work.
REFERENCES


FILAMENTI POLARNE KRUNE I DIFERENCIJALNA ROTACIJA SUNCA NA VISOKIM ŠIRINAMA

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Sažetak: Određuju se brzine rotacije 124 filamenta polarne krune. Gibanje filamenta se prati na Hα filtergramima snimljenim na Sonnenobservatorium Kanzelhöhe u periodu 1979-1987 i pokriva se pojas helioografskih širina od 35° - 80°. Vremena životnih mjerenih filamenta iznosila su 1-6 dana. Posebna pažnja posvećena je mjerenju nožišta filamenta i korištenju su korekcije za prosječne visine od 0.5% , 1% i 1.5% Sunčevog radijusa. Rezultati mjerenja se povezuju se mjerenjima Adamsa i Tanga (1977) za prominencije u pojasu širine 0°-35° i usporeduju s drugim mjerenjima diferencijalne rotacije Sunca.