MOTION OF HIGH LATITUDE SOLAR MICROWAVE SOURCES AND COMPARISON WITH POLAR PROMINENCES

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ABSTRACT

Solar microwave sources at high solar latitudes have been observed with a 14 m radio telescope at the Metsähovi Radio Research Station in Finland. Several observations periods were organized in 1986-1989 in order to detect sources close to the north and south pole of the Sun. Measurements at 22 and 37 GHz (wavelengths 14 and 8 mm respectively) have revealed the existence of high temperature and low temperature regions (relative to the quiet Sun level) at 50-80 degrees. The motions of these regions have been studied and compared with optical measurements of polar prominences.

1. INTRODUCTION

High temperature regions at microwave frequencies near the poles of the Sun have been observed and reported by e.g. Kundu and McCullough (1972), Babin et al. (1976), Efanov et al. (1980a, 1980b), and Kosugi et al. (1986). On the other hand, Schmahl et al. (1981) have observed filaments at 8, 15, 22 and 43 GHz, and have found that about 50% of low temperature regions at 15 and 22 GHz correspond to Hα filaments. Low temperature areas at 8 and 43 GHz were rarely visible.

2. MEASUREMENTS

The first attempts to detect high temperature regions at Hvar Obs.Bull. 13 (1989) 437-447

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high latitudes at Metsähovi were made in October 1979 and the
similar observations were repeated again in 1980 and 1981, but no
evident high latitude sources were found. However, in
September-October 1986 the routine microwave mapping at 37 GHz
revealed clear enhancement of microwave radiation (i.e. high
temperature region) close to the north pole (latitude 50-75 N).
The measurements were made using both right and left hand circular
polarization, Figure 1. The measurements were continued in
1987-1989 and the total number of observation days amounted to
120, with 2-10 solar maps measured each day. During all the
observations periods (6-12 days each) high temperature radiation
was detected daily sometimes close to one of the poles, sometimes
close to the both poles.

Low temperature areas have been detected at 22 and 37
GHz for several years, but in this paper we will only investigate
the extremely low temperature region which was monitored at both
frequencies in July 1982.

3. RESULTS AND DISCUSSIONS

Using the measurements done at Metsähovi we have
concluded that high temperature regions exist close to the solar
poles both during low and high solar activity. The temperature
enhancement at 8 mm wavelength is typically 100-400 K above the
quiet Sun level (7800 K) at that wavelength. On the other hand the
quiet Sun level at 14 mm is estimated to be 9000 K. The high
temperature regions are also extended: in north-south direction
the sources can exist upwards from the latitude of 50 degrees, and
in east-west direction the sources can totally circulate the pole.

Very often there are low temperature areas (50-300 K below the

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3.1. HIGH TEMPERATURE REGIONS

Embedded on the extended sources there are some point-like centers of microwave radiation. These local maximums are long lasting features with a lifetime of at least a few days and they can be used in the estimation of solar rotation rates at high latitudes. For polar microwave high temperature regions (latitudes 50-75) the mean value of the east-to-west sidereal rotation rate was found to be about 10.6 degrees/day. The rotation rate was the same for both northern and southern areas and the dependence on latitude between 50-75 degrees was found to be:

$$\omega = 12.79 - 0.0358 \phi \text{ deg/day}$$  \hspace{1cm} (1)

where $\omega$ is sidereal angular rotation rate and $\phi$ is solar latitude in degrees. If fitted to the function $\omega = A + B \sin^2 \phi + C \sin^4 \phi$ the rotation rate is:

$$\omega = 11.55 + 0.05 \sin^2 \phi - 1.69 \sin^4 \phi \text{ deg/day}$$  \hspace{1cm} (2)

The measured sidereal rotation rate is slower than the one obtained by other methods using for example H$\alpha$ filaments, coronal holes, or spectroscopic measurements. The closest agreement is with the rotation rates of polar magnetic features by Howard (1978) and Snodgrass (1983), and with polar faculae by Makarova and Solonsky (1987), see Figure 3 and the paper of Brajša et al. (1990) in this volume.


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The number of point-like high temperature regions varies a little according to solar central meridian distance, as the points seem to prefer the meridians 10-20 east and 15-25 west. Between these meridians (10 east - 15 west), close to the central meridian there seems to be a slight dimple in the number of sources, see Urpo and Pohjolainen (1987). This may be due to a directivity effect. The high latitude high temperature areas reported here all correspond to the coronal holes reported in the Solar Geophysical Data. However, the intensities, geometrical forms and their changes, and the rotation rates do not correlate.

The possible explanations for the measured polar microwave enhancement of radiation could be connections to coronal holes, to density and temperature variations, or to polar magnetic fields. Our measurements of rotation rate, observed place dependence on central meridian distance and the slight displacement of right and left hand polarized sources support the connection with the solar magnetic fields.

3.2. LOW TEMPERATURE REGIONS

We have studied one very low temperature region which was visible during several days in July 1982, at 22 and 37 GHz (see Tables 1 and 2). Comparison with an Hα filament which was visible at the same time (Solnechnye Dannye and Solar Geophysical Data) is given in Table 3 and Figure 4. We see that the low temperature areas measured at both frequencies are in the same place as the Hα filament. The amounts of temperature depression at 37 GHz are given in Table 2. During July 15, 16 and 17 the temperature fall is about 11% and at July 18 it is about 6%. The "warming" of the low temperature area may be associated with the
disappearing of the Hα filament at July 19. Similar behavior, but with flatter depressions, is also found at 22 GHz (see Table 1).

TABLE 1: Times of observations and positions of a very low temperature region at 22 GHz which was visible in July 1982. 
\( \beta \) - latitude, CMD - central meridian distance; both in degrees. 
\( \Delta T \) - temperature drop in Kelvins

<table>
<thead>
<tr>
<th>Date</th>
<th>UT</th>
<th>( \beta )</th>
<th>CMD</th>
<th>( \Delta T )</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>13.37-14.03</td>
<td>52.7</td>
<td>-34.6</td>
<td>-720</td>
</tr>
<tr>
<td>15</td>
<td>06.57-07.24</td>
<td>54.8</td>
<td>-24.8</td>
<td>-630</td>
</tr>
<tr>
<td>16</td>
<td>06.54-07.20</td>
<td>54.3</td>
<td>-5.3</td>
<td>-550</td>
</tr>
<tr>
<td>17</td>
<td>07.30-07.57</td>
<td>54.8</td>
<td>8.5</td>
<td>-590</td>
</tr>
<tr>
<td>18</td>
<td>07.36-08.02</td>
<td>48.0</td>
<td>19.0</td>
<td>-320</td>
</tr>
</tbody>
</table>

TABLE 2: The same as Table 1, but at 37 GHz;

<table>
<thead>
<tr>
<th>Date</th>
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<th>( \beta )</th>
<th>CMD</th>
<th>( \Delta T )</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>08.59-09.26</td>
<td>52.2</td>
<td>-23.4</td>
<td>-900</td>
</tr>
<tr>
<td>16</td>
<td>07.32-07.58</td>
<td>55.9</td>
<td>-9.7</td>
<td>-850</td>
</tr>
<tr>
<td>17</td>
<td>08.05-08.31</td>
<td>53.1</td>
<td>4.4</td>
<td>-860</td>
</tr>
<tr>
<td>18</td>
<td>08.07-08.33</td>
<td>48.9</td>
<td>16.6</td>
<td>-470</td>
</tr>
</tbody>
</table>

TABLE 3: Comparison of \( \mu \)-wave low temperature regions (this work) and Hα filament (Soln. Dann.) from July 1982. 
\( \beta \) - latitude, \( \lambda \) - longitude; both in degrees.

<table>
<thead>
<tr>
<th>Date</th>
<th>22 GHz ( \beta ) ( \lambda )</th>
<th>37 GHz ( \beta ) ( \lambda )</th>
<th>Hα ( \beta ) ( \lambda )</th>
</tr>
</thead>
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<tr>
<td>14</td>
<td>53 293</td>
<td>55 294</td>
<td>50 291</td>
</tr>
<tr>
<td>15</td>
<td>55 294</td>
<td>52 295</td>
<td>55 296</td>
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<td>54 301</td>
<td>56 295</td>
<td>55 297</td>
</tr>
<tr>
<td>17</td>
<td>55 301</td>
<td>53 295</td>
<td>52 297</td>
</tr>
<tr>
<td>18</td>
<td>48 298</td>
<td>49 295</td>
<td>52 299</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

The results of the radio measurements of the Sun at 22 and 37 GHz on high solar latitudes imply that high temperature areas correspond to polar faculae while low temperature areas correspond to polar prominences. This is in agreement with some other results (see e.g. Tandberg-Hanssen 1974). The principal cause of the observed lower temperature area is the absorption by the filament.

REFERENCES


Solnecnye Dannya 1982, No. 7.


FIGURE 1: Microwave radiation maps measured with both right hand and left hand circular polarization on October 5, 1986, at 37 GHz at Metsahovi. Note high temperature areas close to the north pole.

FIGURE 2: Enlarged solar map showing the north pole with low temperature areas below the enhanced polar region. Map measured at Metsahovi on August 27, 1987. Contours 0.2% of the quiet Sun level.

FIGURE 3: Curves of the sidereal rotation rate (deg/day) vs. solar latitude.

circles) polar crown filaments, Brajša et al. (1990)
1) filaments, d’Azambuja (1948), after Schroter (1985)
2) & 3) polar faculae, after Makarova & Solonsky (1987)
4) photosphere, spectroscopic, Howard & Harvey (1970)
5) polar faculae, Waldmeier (1955) & Muller (1954),
after Hansen et al. (1969)
6) high temperature regions at 37 GHz, present work

NOTE CONCERNING FIGURES 2, 4a, 4b: Thick, bold lines denote low
temperature isothermes, while thin, gray lines denote high
temperature isothermes.
FIGURE 4a: Microwave radiation map measured at 22 GHz on 16 July 1982.

FIGURE 4b: The same as Figure 4a, but at 37 GHz.


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**FIGURE 4c**: Hα filament, 16 July 1982, (Soln. Dann.).
GIBANJE SUNČEVIH MIKROVALNIH IZVORA NA VISOKIM SIRINAMA I USPOREDBA S POLARNIM PROMINENCIJAMA

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izlaganje

\textbf{Sažetak:} Sa Radio-istraživačke postaje Metsähovi, Finska, opažani su 14 m radioteleskopom izvori mikrovalnog zračenja na visokim heliografskim širinama. Tijekom 1986-1989. održano je nekoliko opažačkih kampanja da bi se ustanovili izvori blizu sjevernog i južnog pola Sunca. Mjerenjima na 22 i 37 GHz (odnosno na valnim dužinama od 14 i 8 mm) ustanovljeno je postojanje visokotemperaturnih i niskotemperaturnih područja (relativno prema razini zračenja mirnog Sunca) između 50 i 80 stupnjeva heliografske širine. Istražena su gibanja tih izvora i uspoređena sa s rotacionim gibanjima polarnih prominencija.