Microwave and UV observations of filaments with SOHO and the VLA

C. E. Alissandrakis
Section of Astro-Geophysics, Department of Physics, University of Ioannina, 45110 Ioannina, Greece

F. Drago
University of Florence, Italy

T. Bastian
National Radio Astronomy Observatory, Soccoro, NM 87801, USA

K. Bocchialini, J.-P. Delaboudiniere, P. Lemaire, J.-C. Vial
Institut d'Astrophysique Spatiale, CNRS-Université de Paris XI, Batiment 121, 91405 Orsay Cedex, France

R. A. Harrison
Rutherford Appleton Laboratory, Space Science Department, Chilton, Didcot, Oxfordshire OX11 0QX, UK

B. Thompson
Applied Research Corporation, Code 682.1, NASA/GSFC, Greenbelt, MD 20771, USA

Abstract. Observations performed in coordination between SOHO instruments and ground-based observatories offer the unique possibility to derive information simultaneously in several wavelengths formed at different altitudes and/or temperatures in the solar atmosphere. The SUMER and CDS spectrometers, the imaging telescope EIT aboard SOHO, and the VLA provide complementary information in the UV and the radio ranges. We illustrate such a coordination with observations of filaments in the transition region, performed in July 1996. The observations in the UV between 10^4 and 10^6 K provide the differential emission measure as a function of temperature; this can be used to compute the expected brightness temperature in the microwave range and check models of the filament-corona transition region.

1. Introduction

Filaments (prominences, when seen at the limb) are masses of cold chromospheric gas embedded in the hot coronal plasma. Around them a transition
region (TR) exists, in which the temperature rises steeply from $10^4$ to $10^6$ K. The only way to observe this TR is by means of UV lines and microwave radio emission. Observations of UV lines formed at several temperatures between $10^4$ and $10^6$ K can provide the differential emission measure (DEM) as a function of temperature: this function, inserted in the radio transfer equation, can supply the expected brightness temperatures ($T_b$) in the microwaves range ($1\text{cm} \leq \lambda \leq 20\text{cm}$).

It has been noticed that, when this is done, the resulting $T_b$ is much higher than the observed (Chiuderi Drago, 1989). It must be pointed out, however, that this comparison has been done using UV observations of nine prominences, performed by Schmahl and Orrall (1976) during the Skylab mission, with the microwave $T_b$ derived from all filament observations existing in the literature. A possible explanation of this strong disagreement is that the UV observations were done on prominences at the limb while, as already mentioned, all radio observations were performed on filaments on the disk. The TR’s analyzed in the two cases are therefore different, being at the top of the filament for the microwaves and at the side for the UV lines. In these two TR’s the angle $\theta$ between the magnetic field and the temperature gradient, which strongly influences the thermal conduction, could have very different values.

It has been shown by Chiuderi and Chiuderi Drago (1991) that, if one takes into account the dependence of the conductive flux on $\cos^2 \theta$, the DEM becomes proportional to $\cos \theta$; therefore, at the prominence top, where the angle $\theta$ is very close to 90°, the DEM should be much lower than at the prominence side where, according to Leroy (1989), $30^\circ \leq \theta \leq 90^\circ$. Scaling the DEM derived from the UV lines, assuming $\theta = 60^\circ$, to $\theta \simeq 90^\circ$ and then computing the expected $T_b$, the agreement with the observations becomes very good. This computation has been done for angles $\theta \simeq 90^\circ$, but not for $\theta = 90^\circ$, since in this latter case the transverse conductivity, instead of the parallel one, must be used ($F_{c,1} \ll F_{c,\parallel}$ for $\theta \leq 89^\circ.8$) and it is very unlikely that in any astrophysical situation the angle $\theta$ remains exactly 90° within 1 percent along all the ray path.

In order to resolve the discrepancy between radio and UV observations and check the validity of the above assumption it is necessary to have observations of the same filament in the UV and radio wavelength ranges. This was the motivation for the present coordinated observations with SOHO and the VLA.

2. Observations

The dates of VLA observations are shown in Table 1. The scheduling was strict, therefore we had to hope that a suitable filament target would be present on the disk at the time of the VLA observations, which is not always the case during the minimum of the solar cycle. During July 13 and 26, the VLA time was shared between filament and active region observations. The SOHO instruments involved were SUMER, CDS and EIT.

The selection of the target was made by monitoring solar images through the network, in particular at the sites of SOHO, the Big Bear Solar Observatory, the Kitt Peak National Observatory and the Nobeyama Radioheliograph; there was also direct contact with the observatories of Athens, Catania and BBSO. For the actual observing Tim Bastian was at the VLA and one member of the
Table 1. Dates of VLA/SOHO Observations

<table>
<thead>
<tr>
<th>Date (1996)</th>
<th>UT</th>
<th>Pointing</th>
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<tbody>
<tr>
<td>July 8</td>
<td>1714-2214</td>
<td>W15 S35</td>
</tr>
<tr>
<td>July 13</td>
<td>1743-2243</td>
<td>E70 N35</td>
</tr>
<tr>
<td>July 16</td>
<td>1432-1932</td>
<td>W30 S38</td>
</tr>
<tr>
<td>July 28</td>
<td>1548-2048</td>
<td>W41 N41</td>
</tr>
</tbody>
</table>

Figure 1. VLA images of the filament on July 28, 1996 (top row). The middle row shows images from the Nobeyama Radioheliograph (July 28 and 29), BBSO Hα and KPNO HeI 10830 Å (July 27). The bottom row shows EIT images in He II (304 Å), Fe IX/X (171 Å), Fe XII (195 Å) and Fe XV (284 Å)
SUMER team was at Goddard. The contact between Soccoro-Goddard-Orsay-Florence-Ioannina was mainly by e-mail, with occasional use of the telephone.

During the first period a small filament was observed with the VLA, but SOHO could not observe it because it was involved in another project. On July 13, there was no filament on the disk and we pointed at a location where a small prominence, visible at the limb two days before, should have been; unfortunately the images did not show evidence of even a small filament. The situation was similar on July 16; we pointed at a suspect filament which was simply not there.

Our last chance to observe a filament was on July 28, and a filament was indeed observed! Figure 1 shows the VLA images of the filament region at 2, 3.6, 6 and 21 cm; the spatial resolution ranges from 4″ at 2 cm to 40″ at 21 cm. These are preliminary images, not cleaned for the effects of sidelobes. Note also that at 2 cm the VLA cannot see extended structures due to incomplete sampling of the short spatial scales and that the resolution at 21 cm is limited. The filament was quite obvious in the images of the Nobeyama Radioheliograph at 1.7 cm, 16 hours before and 8 hours after our observations. It was also prominent in Hα and in the infrared He I line. It was barely visible in He II (304 Å) line, and rather weak in the Fe IX/X, Fe XII and Fe XV lines. The filament appears as a prominent absorption feature in the SUMER image taken in the Ne VII (770 Å) line (Figure 2).

3. Discussion

The most serious problem was the lack of an appropriate target during most of the time; we would not have had this problem if the VLA schedule was flexible. More flexibility in the pointing of the SOHO instruments, which we had to specify one day in advance would also have been desirable. We note that the
split of the VLA time between filament and active region observations did not affect the quality of the observations. The data are currently under analysis.

Acknowledgments. The authors are grateful to the SOHO and VLA support teams for running the observations. The selection of the target would not have been possible without the images provided by the SOHO data base, by the Big Bear Solar Observatory, the Kitt Peak National Observatory and the Nobeyama Radio Observatory in their WWW sites and the additional information given by the observatories of Athens and Catania.

References