QUIET-SUN CHROMOSPHERIC NETWORK EVOLUTION

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ABSTRACT

Using the SUMER/SOHO spectrometer we have observed the same quiet-Sun area during several days in a set of eight spectral lines of the transition region. Line intensity maps of the rastered areas are used to separate the interior of the supergranular cells from the network. Then, following the evolution of the supergranular pattern, we measure the variations of intensity and the Doppler shifts at several temperatures of formation of the transition region. We find that the overall flow velocity of the cell interior and the network generally decays within ten hours, which represents a significant part of the supergranular lifetime.

Key words: Sun; transition region; chromospheric network.

1. INTRODUCTION

The extension of the chromospheric network up to the base of the corona has being a subject of extensive studies and modeling. Measurements of the average quiet-Sun velocities in the Transition Region (TR) are presented in several papers (Brekke (1993), Chae et al. (1998), Peter & Judge (1999)). Predominant Doppler redshifts of the lines were found: the corresponding average velocities increase from 1-2 km/s near 1000 K to 11-13 km/s near 2 x 10^5 K; blueshifts occur above 4 x 10^5 K. Distinct difference in the line shifts have been found between quiet-Sun and coronal areas. A snapshot of the shifts in the polar coronal hole and in the quiet network has been published by Hassler et al. (1999). Stucki et al. (2000) made an attempt to relate the average flow velocities with the supergranular network. No attempt was made to take into account of the structure of the cell interior and network, and to follow the local temporal evolution of the Doppler shift in these structures.

Using a subset of the data obtained during several consecutive days over the same quiet Sun solar area by SUMER (Solar Ultraviolet Measurements of Emitted Radiation) on SOHO (Solar and Heliospheric Observatory) we have already reported preliminary results concerning the variation of the velocity field (Lemaire et al., 2002). Here we report the progress made in the analysis of the same set of observations.

2. OBSERVATIONS AND DATA REDUCTION

2.1. Observations

The data were collected with the SUMER instrument between 2 July 1996, 18:03 UT and 6 July 1996, 21:54 UT as part of JOP022. The SUMER instrument has been described in detail previously (Wilhelm et al. (1995), Lemaire et al. (1997) and Wilhelm et al. (1997)). For these observations the 1 x 300 arcsec\(^2\) slit was selected for the raster scan of the images. Two lines at four different spectral positions have been chosen: the N III 99.16 nm (6.3 x 10^4 K) and the Ne VI 99.93nm (4.5 x 10^5 K) profiles, the O IV 140.48 nm and the O IV 140.7 nm (1.6 x 10^5 K) profiles, the C IV 154.83 nm (1.0 x 10^5 K) and the Ne VIII 77.04 nm (8.0 x 10^5 K) profiles, the S VI 93.3 nm (2.0 x 10^5 K) and the H Ly 94.0 nm (1.8 x 10^5 K) profiles, were simultaneously recorded two by two.

The first spatial scan starts in the increasing solar.x direction at solar.x = -587 arcsec and solar.y = 217 arcsec (heliocentric coordinates of the slit center) using S VI and H Ly lines and takes one hour. The second raster scan is done in the reverse direction in the N III and the Ne VI lines. The third raster is done in the increasing solar.x direction in the two O VI lines. The fourth raster is done in the opposite direction in the C VI and the Ne VIII lines. Every 2 hr, an offset of 20 arcsec permits to nearly compensate for the solar rotation.

The cycle of 4 rasters, one in each set of lines, for 4 hr total duration, is repeated 25 times. Each scan is made of 232 steps of 0.76 arcsec and uses the 1 x 300 arcsec\(^2\) slit. In each step of the scan the two line profiles are recorded within the 25 pixels (0.11 nm) window on the A detector during the 15 seconds exposure time.
2.2. Data Analysis

Figure 1. 260 x 291 arcsec$^2$ maps of the S\textsc{vii} line (4 July 1996, at respectively 06:01 UT and 10:01 UT) after correction for the solar rotation. Top: intensity map $(I)$. Bottom: velocity map (-18 km s$^{-1}$ blueshift to 18 km s$^{-1}$ redshift).

Each profile window was reduced using the latest version of the detector A distortion correction (the flat-field correction was performed on-board). For each spatial pixel we have line profiles, but as the count number was low we made a running average over 3 pixels along the slit ($\sim$3 arcsecs) and 4 scanning steps ($\sim$3 arcsecs). For each averaged spatial pixel the line profiles were fitted by a gaussian and a constant. The parameters of the lines (intensity, position, width and background) are registered. Between 2 scans, the grating/wavelength mechanisms have moved and a repositioning uncertainty of $\pm$ 1 step has to be taken into account. To improve the line positions, for each scan a time-averaged line profile of each pixel of the slit is fitted by a gaussian. The line shifts are computed from this average position. To check the accuracy of the line positions all references profiles along the slit are shifted to obtain the same average spectral position; the residual errors have a distribution with $\sigma = 0.255$ pixel and $\sigma = 0.135$ pixel respectively for C\textsc{iv} and Ne\textsc{viii} (or 1.0 pm and 0.28 pm). Then for each scan we have established the pixel to pixel matrix correction which takes into account the accurate solar differential rotation, and all the scans are seen as centered on the meridian.

An example of 2 consecutive maps in S\textsc{vii} line is given in Figure 1. The absolute Doppler velocity of each line is obtained by using the average velocity of each scan shifted by +9 km s$^{-1}$ for the S\textsc{vii} line. This average value is extracted from Figure 6 in the Peter & Judge (1999) paper, which also gives +6 km s$^{-1}$ for the C\textsc{iv} line, +10 km s$^{-1}$ for the O\textsc{iv} line, +4 km s$^{-1}$ for the N\textsc{iii}, +0 km s$^{-1}$ for the Ne\textsc{vii} line and -3 km s$^{-1}$ for the Ne\textsc{viii} line. To discriminate within the structure (cell interior, network, intermediate) of the quiet solar TR, we proceed as follow:

- the intensity and Doppler images are binned and normalized over 5 x 5 arcsec$^2$. Such images, expanded to the same size as the original are shown in Figure 2 for comparison with Figure 1:
  - the cut in intensity between cell and network is done using the average of the binned data in two steps: first computing the average, then taking the average of the intensities lower than 3 times this computed average.
  - cell bins are defined as intensities lower than 0.9 times the average; network bins have intensities higher than 1.1 times the average; intermediate bins are between. Using a histogram of the intensity of the first raster in S\textsc{vii} line, the separations between cell, network and intermediate is shown in Figure 3.
  - for each class the corresponding velocities are sub-

Figure 2. The data of Figure 1 are binned (5 x 5 arcsec$^2$) and expanded for comparison.

Figure 3. The plot of the histogram of the first S\textsc{vii} binned intensity map with the dotted lines to separate cell, intermediate and network. The full line gives the location of the averaged intensity.

divided in three subclasses: blue ($\leq$1 km s$^{-1}$), mean (between -1 km s$^{-1}$ and +1 km s$^{-1}$), and red ($\geq$1 km s$^{-1}$).

- at the same location, from one scan to the following one we keep track of the velocities, e.g., if the velocities stay in the same class and subclass and the same 5 x 5 arcsec$^2$, a value of one is added. At some locations the same class and subclass of velocities can be followed in several scans.
The results are shown on Figure 4 for each line. The full lines correspond to cells and the dotted lines to network. The line formation temperature is decreasing from top left to bottom right. The total number of bins in each class (cell, intermediate and network) is respectively in the range 1100-1300, 170-340 and 570-720. For each spectral line the permanent flow duration for most bins lasts several hours. In a few locations, the velocity flow, in the same direction, continues for more than ten hours, which represent a significant part of the network life time (Shrijver et al., 1997).

In the raster maps for each line, we have established the number of bins in cell, network and intermediate, and the relative part of blueshifts and redshifts in all the rasters. The results are shown on Table 1. There is a strong indication of a significant blueshift in Ne VIII in all classes of the quiet Sun. This prominent blueshift disappears in lines with a lower ionization temperature, and the redshifts are common mainly for all temperatures below $4.5 \times 10^{5}$ K in cell and network.

3. DISCUSSION AND CONCLUSION

Several results have been obtained during this study which depend on the selection criteria chosen for the analysis. The modification of the criteria may change the quantitative values obtained but should not modify the qualitative results:
- the criterion chosen for the separation between cell and network may give too much weight to cells. This will be examined in another paper.
- the $5 \times 5$ arcsec$^2$ binning may produce a loss of information. In a following paper we will try to use running averaging. The profiles will be extracted after this averaging, instead of averaging the already computed Doppler shifts.
- the absolute Doppler velocities are strongly related to the averaged velocities determined by Peter & Judge (1999). A study of the variation of these reference velocities within the error bars published needs to be done.

In this paper we have used a delicate reduction process concerning 5 continuous days of observation following the same quiet Sun area in several lines spanning the transition region temperature range. Continuous velocity flows have been detected and
Table 1. Velocity properties for cell, intermediate and network regions from the scan in the different lines. For each spectral line the line used to define the relative area of the structure is mentioned in the first column as "area (...)". Then, for each class we give the relative number of blueshifted and redshifted bins.

<table>
<thead>
<tr>
<th></th>
<th>cell blueshift</th>
<th>cell redshift</th>
<th>intermediate blueshift</th>
<th>intermediate redshift</th>
<th>network blueshift</th>
<th>network redshift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ne VIII area (C IV)</td>
<td>0.58</td>
<td>0.10</td>
<td>0.32</td>
<td>0.96</td>
<td>0.01</td>
<td>0.97</td>
</tr>
<tr>
<td>Ne VI area (N III)</td>
<td>0.60</td>
<td>0.08</td>
<td>0.30</td>
<td>0.08</td>
<td>0.64</td>
<td>0.06</td>
</tr>
<tr>
<td>S VI area (S VI)</td>
<td>0.62</td>
<td>0.09</td>
<td>0.29</td>
<td>0.02</td>
<td>0.89</td>
<td>0.01</td>
</tr>
<tr>
<td>O IV area (O IV)</td>
<td>0.50</td>
<td>0.16</td>
<td>0.34</td>
<td>0.03</td>
<td>0.93</td>
<td>0.01</td>
</tr>
<tr>
<td>C IV area (C IV)</td>
<td>0.58</td>
<td>0.10</td>
<td>0.32</td>
<td>0.11</td>
<td>0.72</td>
<td>0.05</td>
</tr>
<tr>
<td>N III area (N III)</td>
<td>0.60</td>
<td>0.08</td>
<td>0.30</td>
<td>0.21</td>
<td>0.43</td>
<td>0.10</td>
</tr>
</tbody>
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found to sustain for several hours (more than 10 hours in few locations) which affect a significant part of the cell-network structure. This analysis will be pursued to determine the influence of the selection criteria and to include the line widths.

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REFERENCES