IS FLARING ACTIVITY PRESENT IN THE CHROMOSPHERIC NETWORK?

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ABSTRACT

We search for lower-atmospheric signatures of "network flares", i.e. flaring activity occurring in the quiet chromospheric network. To this end we use data obtained during a coordinated SOHO-Ground Based observing campaign devoted to the study of minor activity phenomena. During a period of 1 h, and over a field of view of 2' x 2', we observe only one event that can be unambiguously classified as a (micro) flare, covering an area of a few arcsec, and having a total thermal energy of about 10^28 erg.

Key words: chromospheric network; solar flares; microflares.

1. INTRODUCTION

In the last few years, the availability of several space-borne solar instruments with imaging capabilities, especially on board YOHKOH and SOHO, has revealed a panoply of weak transient events occurring in the upper solar atmosphere (Shimizu et al. 1994; Harrison 1997; Berghmans & Clette 1999). These transient events occur also over quiet regions of the Sun, and much attention has been given to the possibility that they represent flaring events occurring above the chromospheric magnetic network ("network flares", see Harrison 1997; Innes et al. 1997; Krucker et al. 1997). If confirmed, their presence could have important consequences on the issue of coronal heating: depending on their energy content and distribution, and rate of occurrence, they could provide enough energy to heat the corona (see reviews in Ulmschneider et al. 1991).

The ubiquity of the magnetic network, over the solar surface and during the entire solar cycle, is of course an important characteristic that could help explaining coronal temperatures also outside active latitudes and at solar minimum. However, we must remind that very often the transient events observed in higher atmosphere of the quiet Sun are measured as simple intensity fluctuations at one or few wavelengths, i.e. they lack an undisputable identification as flares. In order to do this, one has to look for distinctive signatures of the flaring phenomenon, such as hard X-ray bursts, polarization in radio emission, downward motions in the lower atmosphere during the impulsive phase, etc.

In this paper, we search for lower atmospheric signatures of (small) flares in the magnetic network, using observations specifically planned for studies of minor activity phenomena.

2. OBSERVATIONS

The observations presented in this paper have been obtained within the SOHO-JOP #37 activities. This project was designed to study the dynamical properties of minor solar activity phenomena and was based on coordinated observing programs between the "R.B. Dunn" Tower Telescope at NSO/Sacramento Peak and SOHO. To obtain a continuous height coverage of the solar atmosphere, a cluster of narrow band filters at NSO/SP obtained sequences of monochromatic images of the photosphere and lower chromosphere. On board SOHO, SUMER (Wilhelm et al. 1995) acquired raster scans of the region under study in Ly\beta and O VI 1032 Å, spanning the higher chromosphere and the transition region. For telemetry reasons, only the moments of the spectral profiles were transmitted to the ground. The Horizontal spectrograph (HSG) at NSO acquired occasional spectra of network bright points in the Ca II-K and H\beta lines. MDI was in high resolution mode at the time of these observations, and provided a continuous mapping of the longitudinal magnetic and velocity fields, and pseudo-continuum intensities.

The performances of the various instruments are summarized in Table 1. All NSO images have been acquired simultaneously, with the same image scale and field of view (FOV).

SOHO-JOP #37 was activated during the period 15-19 Aug. 1996 as an engineering run, and on 14-20 Oct. 1996 as a coordinated SOHO-JOP. Unfortunately, during the latter period SUMER had serious problems on the slit positioning system, so we decided to analyse firstly the engineering run data. A period of constant good seeing conditions (better than 1") longer than 1 hour was obtained on Aug. 15.
Figure 1. FOV (2 arcmin$^2$) of the analysed area, shown in several spectral signatures. The small white box frames the location of the network flare described in the text.
Table 1. Summary of the SOHO-JOP #37 observing performances

<table>
<thead>
<tr>
<th>Instrument</th>
<th>FOV</th>
<th>spatial resol.</th>
<th>Observing λ (Å)</th>
<th>FWHM (Å)</th>
<th>Δt (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UBF</td>
<td>2' x 2'</td>
<td>0.5'' x 0.5''</td>
<td>5889.9 (NaD2)</td>
<td>0.2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5875.6 (Hα)</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6562.8 (Hα)</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6561.3 (Hα - 1.5 Å)</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Zeiss</td>
<td>2' x 2'</td>
<td>0.5'' x 0.5''</td>
<td>6564.3 (Hα + 1.5 Å)</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5500</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>White Light</td>
<td>2' x 2'</td>
<td>0.5'' x 0.5''</td>
<td>3904-3941 (CaII K)</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>HSG</td>
<td>0.75'' x 2'</td>
<td>0.75'' x 0.36''</td>
<td>4094-4108 (Hδ)</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>MDI</td>
<td>10' x 6'</td>
<td>0.6'' x 0.6''</td>
<td>6768 (Ni I)</td>
<td>0.1</td>
<td>60</td>
</tr>
<tr>
<td>SUMER</td>
<td>2' x 2'</td>
<td>1'' x 1.14''</td>
<td>1026 (Lyβ)</td>
<td></td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>(raster scan)</td>
<td></td>
<td>1032 (O VI)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. DATA ANALYSIS

The FOV observed on 15 Aug. 1996 is shown in Fig. 1 in several wavelengths. All the data were acquired with the same orientation (Solar North up). The NSO frames (after the usual CCD restoration and correction procedures) and the MDI ones have been overlayed with a precision better than 1'' at each given time by means of rigid translations and linear scale adjustments. We did not perform any de-stretching procedure on the ground-based images. The SUMER maps were then aligned with the other data by comparing the Hα line center images with the Lyβ zero-order moment maps. However, since every SUMER raster scan was obtained over a period of about 8 minutes, their alignment with the rest of the data was not as good. We estimate the overlapping precision at about 2.3''.

The FOV contained portion of the quiet Sun, and the small active region NOAA 7984. The pattern of chromospheric network is well visible in NaD2 and Hα+1.5 Å lines and in the B1 map, but it becomes much more diffuse in Lyβ and O VI, although the intensities of these two lines, measured over areas delimited by the chromospheric network, are always higher than the average quiet levels. The spatial correspondence between the NaD2 network points and the magnetic structures is very good. The NaD2 network points are coincident in position, size and shape with the corresponding magnetic patches at any given time, and one can see that changes in the characteristics of the NaD2 bright points reflect almost perfectly those of the magnetic features.

To unambiguously identify the network bright points (NBP) we first selected, on the available spectra, bright features showing strong K2 peaks and enhanced wings emission in CaII K. These same points showed enhanced emission in Hδ, although the profile remained in absorption. Since the NBPs lifetime is typically longer than 10 minutes (Rutten & Uitenbroek 1991), we further required that these points be visible for the entire observing period in the NaD2 images. We identified a total of 11 NBPs with the required characteristics. Many other “bright points” are visible on the average NaD2 image of Fig. 1; however, we do not consider them in this work since no corresponding CaII K spectra are available.

4. LIGHT CURVES

To check for the presence of flaring episodes, we analysed the light curves relative to the different bright points at different wavelengths. For the spectral signatures clearly showing the network bright patches (NaD2, Hα 0.0, Hα ± 1.5 Å), we selected for each NBP an area that contained it throughout the whole period of observation. The light curves were then obtained by averaging the intensities values for the pixels within these areas that exceeded a selected threshold value. This threshold value was of the order of 2% for Hα wings up to 5-10% for other signatures, having normalized to 1 the mean quiet level.

For all the other spectral signatures (viz., MDI velocity, continuum, Lyβ and O VI) where the NBPs were not clearly discernible from the background, the light curves were obtained by averaging the measured quantities over the corresponding magnetic areas.

Examples of light curves are given in Fig. 2.

From the photospheric and low-chromospheric emissions light curves we can state that the temporal variations of the emission are small in amplitude and semi-regular in their temporal distribution. None of the NBPs analysed displays any sudden intensity enhancement that could suggest the presence of a transient phenomenon such as a (micro) flare. The relative fluctuations in various spectral signatures are not obviously in phase with each other. Due to the very low temporal resolution of the SUMER data it is very difficult to give reliable conclusions on their temporal variations, which are nevertheless present (see Fig. 2).

The mean values of the measured parameters are summarized in Table 2.

5. ASYMMETRIES IN LINE-OF-SIGHT VELOCITY

A red asymmetry in the Hα wings has been recognized as an important signature of the impulsive phase of flares in the lower chromosphere. This asymmetry signals a downward plasma flow, consequence
Figure 2. Light curves, obtained in several spectral signatures, for the NBP showing flaring activity (left side) and for one of the non-flaring NBP (right side).
of a sudden plasma compression, due to either particle beam precipitation, or conduction front propagation (Ichimoto & Kuratomi 1986; Gan et al. 1991). Canfield & Metcalf (1987) demonstrated that such a signature is present also in very small events, named microflares, that involve very small portions of the atmosphere (few arcsec$^2$) and release less than $10^{28}$ ergs in the process. Since we have simultaneous observations in the Hα far wings at ±1.5 Å, we looked for such asymmetries in the NBP's under study. If revealed, they would indicate the presence of a transient event much more clearly than just intensity variations.

After careful equalization of the average values for each pixel of the FOV in the 2 wavelength channels, the difference between the Hα + 1.5 Å and the Hα – 1.5 Å intensities was taken for each time and each pixel. Converting these intensity differences by means of the conventional doppler rule, we obtain the line-of-sight velocity for all the frames. As for the light curves described above, we averaged the velocity values over the areas of the 11 NBP's.

The velocities obtained were all within the uncertainty of the method (about ±1.0 Km/s) but for one of the NBP, evidenced in Fig. 1 with a white box. Fig. 3 gives the temporal evolution of the line-of-sight velocity of this particular bright point, and of another for comparison. Three spikes of downward velocities (respectively of + 2.0 Km/s at 15:29 UT, of +2.7 Km/s at 15:33 UT and of +3.7 Km/s at 15:41 UT) were present, with each spike lasting approximately 1.5 min. This behaviour is consistent with what reported in the literature for the impulsive phase of several flares (Canfield et al. 1990; Cauzzi et al. 1996). Hence we tentatively consider this signature as evidence that sudden downward compressions occur on this particular NBP. This is the location where compressions (either due to particle beams or by thermal conduction fronts), originated by magnetic reconnection processes in the corona, are stopped in the denser layers of the solar atmosphere.

6. SOFT-X RAY EMISSION

One of the observational evidences for the occurrence of magnetic reconnection is given by the presence of soft X-ray (SXR) bursts associated (in space and time) with more direct signatures such as hard X-ray bursts, polarization of radio emission etc. We then searched for SXR signals associated with the line-of-sight velocity outbursts measured between 15:30 and 15:50 UT.

During this period, GOES recorded an A6 burst in both channels (0.5–4 and 1–8 Å), starting around 15:30 UT with maximum peak at 15:43 UT. The temporal distribution of the SXR emission in the 1–8 Å band is shown in Fig. 4 (relative units), superimposed to the line-of-sight velocity outbursts described in the previous section. The temporal coincidence is quite good, and provides support to the idea of a flaring episode in one (and only one) of the analysed NBP's.

Since the GOES signals are total disk flux measurements, no information on the spatial location of this burst can be obtained. Unfortunately, during this period YOHKOH was in its night-time, so it also could not provide direct information. However, we tried to check if other regions on the visible disk could be the source of the SXR signal. Looking at the YOHKOH SXT full-disk frames before and after the considered time lag (15:30–15:50 UT), it is evident that only 2 active regions were present: a brighter one at the west limb (NOAA 7982), setting toward the invisible horizon of the sun, and the one (NOAA 7984) present in our FOV. We analysed the FFI and PPI frames of both NOAA 7982 and 7984 for a couple of hours before our observing period and for about one hour after. The SXR emission of NOAA 7982 was decreasing very slowly (at a rate of about ~0.3%/hour), throughout this whole time interval. On the other hand, NOAA 7984 showed global intensity fluctuations of about ±2%/hour. These facts convinced us to associate the SXR GOES burst, shown in Fig. 4, to the area of NOAA 7984, viz. within our FOV.

An estimate of the thermal energy content of the coronal plasma emitting the GOES burst can be obtained. The GOES background was really at minimum levels during the considered time lag (about

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$10^{-8}$ Wm$^{-2}$ for the 1–8 Å channel), so the SXR flux measured during the event can safely be considered as totally originated by the burst. Dr. Enrico Landi (1999, private communication) kindly provided us the calculations of the power emitted by an isothermal solar plasma, per unit of emission measure (EM), at several temperatures (between $10^4$ and $10^8$ K).

According to the method normally used to interpret GOES data (Thomas et al. 1985), we compared the ratio of the GOES channels power fluxes (0.5–4 Å/1–8 Å) with the ratios of Landi’s theoretical spectra, multiplied respectively, by the efficiency of the 0.5–4 Å and of the 1–8 Å cameras. In this way, we derive a color temperature of about 3.6 MK, which can be assumed as an estimate of the electron temperature $T_e$ emitting the analysed SXR burst. The comparison of the measured power fluxes, scaled to the solar surface, with the theoretical spectrum at 3.6 MK allows us to derive an EM of the order of $2 \times 10^{47}$ cm$^{-3}$. The total thermal energy content of the coronal plasma emitting the GOES burst is then $E_{th} = \frac{1}{2}N_{tot}k_BT_e \sim 10^{28}$ erg. These values are consistent with those quoted by Feldman et al. (1997) for microflares of A6 GOES type.

### 7. CONCLUSIONS

The main conclusion to the question opened by the title of this paper is **YES**, we do observe a “network flare” occurring at the location of a chromospheric network bright point. This event is clearly indicated by line-of-sight velocity outburst, associated to a very faint SXR event, while intensity variations do not show any peculiar behaviour with respect to the other network points.

However, only one such episode is recorded, over a $2' \times 2'$ FOV, and about 1 h of observing time. Two previous episodes of chromospheric downward motion do not have detectable corresponding SXR signals; they could be related to the so-called precursor phase of the flare. The “occurrence rate” is consistent with the values reported by Krucker et al. (1997), that observed 4 flaring episodes over a larger field of view and on a longer period, but we feel uneasy in extrapolating it into a global occurrence rate for the whole Sun. It must also be noted that Krucker et al. (1997) report total thermal energy of the network flares about two orders of magnitude smaller than what we observed.

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