SUMER, UVCS AND LASCO OBSERVATIONS OF SMALL-SCALE EJECTA

L. Teriaca(1), W. Curdt(1), G. Poletto(1)

(1)Max-Planck-Institut für Aeronomie, Max-Planck Str. 2, 37191 Katlenburg-Lindau, Germany. Email: teriaca@linmp.de, curdt@linmp.de

(1)INAF - Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Florence, Italy. Email: poletto@arcetri.astro.it

ABSTRACT

During the fall 2002 SOHO-Sun-Ulysses quadrature, coordinated SUMER/UVCS observations were carried out off the west limb. Data were acquired over six consecutive days in several lines formed in the 2 $10^3$ - $10^6$ K temperature range. The center of the SUMER slit was placed around 1.13 Rs and oriented in the north south direction, while the UVCS slit was set tangent to the solar limb at altitudes ranging between 1.6 and 2.1 Rs. On 19 and 20 November SUMER observed repeated transient events characterized by a strong increase of the intensity of transition region and Hydrogen Lyman α and β lines with large line broadenings and line of sight velocities, while little if any variation was seen in lines formed around 10$^6$ K. The duration of these events varies between 10-15 minutes up to 1 hour. The SUMER events are associated to streamer-like outflows seen in LASCO images and, in the case of the larger 19 November event, with a small jet travelling at ~400 km/s across the LASCO C2 field of view.

1. INTRODUCTION

During the last solar minimum LASCO [1] images showed long, linear structures propagating outward from the solar polar coronal holes with a frequency of about three to four per day [2, 3]. These polar jets were discovered to be the extension of bright jetlike features seen in images obtained with EIT [4] in the Fe XII 195 Å waveband [5]. They seem to originate from bright points or ephemeral regions inside polar coronal holes [3] and by the time they reach the LASCO C2 field of view (2 – 6 Rs) they show very similar bulk velocities (~250 km/s) suggesting that they are incorporated into the ambient solar wind [6]. Around solar maximum, coronal jets have been observed also at low latitudes, originating very often from active regions located nearby the boundaries of non-polar coronal holes. Typically, a series of jets were emitted by the same active region over a period of several days. Coronal jets could, hence, be the result of reconnection between open and closed magnetic structures [7].

On November 2002 AR NOAA 10192 was just south of a low-latitude coronal hole and crossed the west limb between the 19 and 20 November 2002. Over the same days SUMER observed repeated transient events characterized by strong brightening of the transition region (TR) and Hydrogen Ly α and β lines with large line broadenings and line of sight velocities, while little if any variation was seen in lines formed at coronal temperatures ($10^6$ K). The two larger events are presented here. The relationship between the activity in the high corona and the transient events observed at lower level by SUMER is discussed.

2. OBSERVATIONS

The observations here discussed were obtained during the November 2002 SOHO-Sun-Ulysses quadrature and consists of SUMER [8] spectra taken at 1.13 Rs (slit centre) and UVCS [9] spectra taken with the slit tangent to the limb at 1.6, 1.8, 2.1 Rs. The observational layout is shown in Fig. 1. SUMER spectra were obtained from 09:00 to 14:47 UT exposing detector A for 300 s in 5 different spectral windows as outlined in Table 1. The UVCS observations started at 6:41 UT at 1.6 Rs, then the slit was moved to 1.8 Rs at 7:30 UT and, finally, to 2.1 Rs from 09:24 to 12:36 UT. The last group of observations is simultaneous with those of SUMER. UVCS spectra were obtained in the O VI channel (984 - 1080 Å) with a 150 µm wide slit and 200 s exposures.

Fig. 1: Composite image of the solar corona from EIT-195 Å (green) and LASCO C2 (blue). The positions of the SUMER and UVCS slits are shown with solid lines on the EIT and LASCO images, respectively.
Fig. 2: Sequence of logarithmically scaled EIT images in the Fe XII 195 Å waveband (top) together with their running difference (bottom) for the 19/11/2002 event. The white line marks the position of the SUMER slit.

A convex mirror between the grating and the O VI detector allows to focus the H I Ly α and the Mg X 610 – 625 doublet (in second order) onto the O VI detector. SUMER and UVCS spectra were reduced using standard IDL routines from within the provided software trees.

3. THE 19/11/2002 EVENT

In Fig. 2 a sequence of EIT 195 images (top) and their running differences (bottom), illustrate the eruption of a small loop. The eruption is first seen at 11:46 UT and peaks between 12:00 and 12:12 UT. Fig. 3 shows the temporal evolution of the N V 1238.8 & 1242.8 Å (log T/K=5.25) lines and of the coronal Fe XII 1242 Å (log T/K=6.12). The event first appears at the bottom of the SUMER slit (around 1.07 Rₜ) just before 12:00 UT as (~200 km/s) blueshifted emission in the N V lines.

Table 1. Summary of the daily SUMER observations from 18 to 22 November 2002.

<table>
<thead>
<tr>
<th>Start (UT)</th>
<th>Nº spectra</th>
<th>Spectral range (first order)</th>
<th>Prominent lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:01</td>
<td>10</td>
<td>1464 – 1508Å</td>
<td>Si XII 499.4 (1.9 10⁶ K) Mg IX 749.6 (9.8 10⁶ K)</td>
</tr>
<tr>
<td>09:51</td>
<td>10</td>
<td>1418 – 1462Å</td>
<td>Si VIII 1440.5 (8.1 10⁶ K) Fe XX 721.6 (8.3 10⁶ K) Si VIII 1445.8 (8.1 10⁶ K)</td>
</tr>
<tr>
<td>10:41</td>
<td>10</td>
<td>1376 – 1420Å</td>
<td>Si IV 1393.8 (7.0 10⁶ K) O IV 1399.8 (1.7 10⁶ K) O IV 1401.2 (1.7 10⁶ K) Si IV 1402.8 (7.0 10⁶ K) Mg IX 706.1 (9.8 10⁶ K)</td>
</tr>
<tr>
<td>11:31</td>
<td>20</td>
<td>1205 – 1250Å</td>
<td>Ly α 1215.7 (1.0 10⁶ K) Mg X 609.8 (1.1 10⁶ K) N V 1238.8 (1.8 10⁶ K) Fe XII 1242.0 (1.3 10⁶ K) N V 1242.8 (1.8 10⁶ K)</td>
</tr>
<tr>
<td>13:12</td>
<td>20</td>
<td>1011 – 1056Å</td>
<td>Ly β 1025.7 (1.0 10⁶ K) O VI 1031.9 (3.0 10⁶ K) O VI 1037.6 (3.0 10⁶ K)</td>
</tr>
</tbody>
</table>

Fig. 3. Logarithmically scaled SUMER spectra of the event shown in Fig. 2. Only the part of the slit shown in Fig. 2 is displayed. The spectra show the N V 1238.8 and 1242.8 Å lines (log T/K 5.25) together with the Fe XII 1242 Å (log T/K=6.12) line. The white bar marks velocity intervals of ±200 km/s. The N V lines outside of the brightening are entirely due to scattered light from the disk. The center of the scattered profile is used as rest wavelength. Starting times for 300s exposures are given at the top of each spectrum. On the third panel of the top row the plus symbols sign the position of line ghosts produced by the high countrate registered in Ly α (only in the 12:01:50 UT spectrum).
Fig. 4: Sequence of LASCO C2 images (top) together with their running differences for the 19/11/2002 event (bottom). The images in the top panel are in logarithmic scale. The UVCS slit is represented by a white solid line at the time data have been acquired and as a dashed line at later times. The black dashed line shows the radial passing through the position along the SUMER slit where the dynamic event shown in Fig. 3 is observed.

Note that the N V lines outside of the brightening are entirely due to scattered light from the disk and the center of the scattered profile is used as rest wavelength. The blueshifted emission appears to move northward along the slit in the following spectra and, from 12:16 UT onwards, also a weaker redshifted emission shows up at a different location. Eventually, only the redshifted component is visible after 12:22 UT while no relevant line of sight velocities are observed after 12:36 UT. The observations could suggest a bi-directional jet accelerated outward from a reconnection site moving upward with a velocity of ~25 km/s.

Note that the Fe XII 1242 Å in the SUMER spectra is almost unaffected by the brightening hinting to a contamination of the EIT 195 Å band from cooler lines like, possibly, Fe VIII (log T/K 5.64) [10].

We turn now our attention to the upper corona. Fig. 4 shows the LASCO C2 images (top) together with their running differences (bottom). The LASCO images, as well as the UVCS spectra (not shown), show the tail of a CME erupted around 03:30 UT. The long-term effects of the CME aftermath have been removed by normalising the time series obtained at each pixel along the UVCS slit to a second order polynomial fit. The normalised data do not show any hint of transients on time scales shorter than 20-30 minutes. However, from the LASCO running differences it is possible to see a couple of small outflowing structures. One of them moves at polar angles (measured counterclockwise from the solar north pole) smaller than that of the radial through the SUMER dynamic event (indicated by the black dashed line in the lower panels of Fig. 4), increasing its polar angle while it moves outward, hence it is surely not related to our SUMER event. However, there is another structure moving at polar angles larger than that of the radial through the SUMER event. Fig. 5 shows a time-height plot for this small ejecta. A linear fit (dashed line) to the height-time positions obtained from the last three difference images on Fig. 4, yields a speed of 400 ± 30 km/s, so that the jet should have left the solar surface around 12:00 UT, in full agreement with the SUMER and EIT observations. A second order fit (dotted line) could account for a small deceleration but, again, gives an onset time consistent with the SUMER and EIT observations. Fig. 5 also explains why the ejecta was not detected by UVCS: very likely it crossed the UVCS slit just after the end of the observations.

Fig. 5. Height-Time plot for the small ejecta observed by LASCO. The asterisks mark the time range from 11:55 to 12:26 UT when large velocities were seen in SUMER spectra. The solid line is a linear fit to the LASCO points, while the dotted line is a parabolic fit. The solid line indicates the time covered by UVCS data.
4. **THE 20/11/2002 EVENT**

On the following day SUMER and EIT observed several other dynamic events, the larger of which is shown in Fig 6. In SUMER spectra (see Fig. 7) the event is first observed in the exposure starting at 11:16:31 as ~70 km/s blueshifted emission in all the observed TR lines. The event peaks in the successive spectrum with very broad TR line profiles showing both blue and redshifted emission up to 150 km/s. The center of the scattered light profile is used as rest wavelength.

Using the Si VIII 1445/1440 density sensitive line ratio it is possible to derive a pre-event electron density of \((5\pm1)\times10^6\) cm\(^{-3}\), while at the peak of the event (11:21:31 UT) an electron density of \((2\pm0.7)\times10^6\) cm\(^{-3}\) was found using the O IV 1401/1399 density sensitive line ratio (see Fig. 7).

Although the LASCO running differences (see Fig. 8 bottom) give some indication of outflowing material at the location of the 19 November event, we cannot identify any precise feature that might be associated with the dynamic event observed by SUMER and EIT. Moreover, the analysis of the UVCS data did not show any signature of the passage of a jet. Although this could simply mean that the ejecta was too faint to be detected, we cannot exclude other possibilities. We notice that up to 35 minutes before the event a very localized region along the SUMER slit was showing emission in the flare line Fe XX 721 (log T/K=6.92). The signature built up slowly over the 50 minutes during which the line was recorded (see Table 1) at the same location where the dynamic event will later appear. Fig. 9 shows the profiles along the slit obtained in different lines after averaging over the 50 minutes interval during which each spectral window was observed (see Table 1). We speculate, as an alternative explanation, that the SUMER/EIT dynamic event could be the manifestation of the cooling of a hot loop. The time scales (35 min or shorter) would be of the same order as those indicated by Bradshaw & Mason [11] for a model of a cooling loop.

5. **CONCLUSION**

On 19 and 20 November 2002 SUMER detected several highly dynamic transient events above an active region crossing the solar limb. The active region was just south of a low latitude polar coronal hole. For at least one of the events observed by SUMER we have been able to identify in LASCO images an ejecta moving outward at about 400 km/s.

![Fig. 6: Same as Fig. 2 for the 20/11/2003 event.](image)

![Fig. 7: Logarithmically scaled SUMER spectra of the event shown in Fig. 6. The spectra show the 1396 – 1413 Å spectral range. O IV 1397.7, 1399.8 & 1401.2 Å lines (log T/K=5.23) suitable for density diagnostics, together with the Si IV 1402.8 Å (log T/K=4.84) and the Mg IX 706 Å (log T/K= 5.99 T/K) lines can be easily identified. The white bar marks velocity intervals of ±200 km/s. The TR lines outside of the brightening are entirely due to scattered light from the disk. The centre of the scattered profile is used as rest wavelength. Starting times for 300s exposures are given at the top of each spectrum.](image)
Fig. 8: Same as Fig. 4 for the 20/11/2002 event.

Fig. 9: Intensity profiles along the SUMER slit on 20 November 2002, before the dynamic event. Each point is obtained integrating over 10 pixels along the slit.

This seems to confirm that high levels of activity may result from the interaction of an active region and a close-by coronal hole. These may include the injection of cold plasmoids in the upper corona where, eventually, they may be incorporated in the solar wind.

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