ON THE CONNECTION BETWEEN THE DISK AND LIMB EVENTS OBSERVED BY SOHO

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ABSTRACT

Although there has been advancements in understanding the small-scale transient events seen on the Sun at transition region temperatures, it is still not clear what is the connection between the events seen on the disk and those on the limb. In this contribution we investigate different types of short-lived events, such as spicule-like structures, bi-directional jets and blinkers. The data selected for this study were obtained as time series in polar coronal holes by SUMER and EIT (SoHO). The short exposure time, a reduced effect of the solar rotation at the poles and the coverage of both on-disk and off-limb regions, give us an excellent opportunity to analyse the temporal evolution and other spectral characteristics of these events, as well as allowing a comparison between them.

Key words: Sun; transition region; coronal holes; EUV radiation.

1. INTRODUCTION

Small-scale transient events – spicule-like structures, explosive events, blinkers – are frequently seen in chromospheric and transition region lines. They are classified according to the characteristics of their line profile, i.e. the presence of any red/blue wings. Spicule-like structures are common features seen above the limb. They have typical lengths ranging from 5,000 to 15,000 km and lifetimes from 1 to 10 min (Budnik et al. 1998; Wilhelm et al. 2000; Wilhelm 2000). Giant spicules, also named macro-spicules, are observed over 20,000 km off-limb and live over 40 min. On the disk, explosive events are identified as turbulent events and jets (Brueckner & Bartoe 1983). They are characterized by non-Gaussian profiles due to an enhancement in the blue and red wings, with LOS velocities often $>$100 km s^{-1} and a duration of $\approx$1 min. They are thought to be a product of magnetic reconnection. Blinkers are sudden enhancements in flux observed in EUV lines, originally identified with CDS/SoHO. They are predominantly red-shifted (by $\approx$5-25 km s^{-1}) and their lifetime ranges from 5 to 30 min, typically being around 16 min (Bewsher et al. 2002; Madjarska & Doyle 2003). Here, we present some preliminary results on how events seen on the limb relate to those seen on-disk.

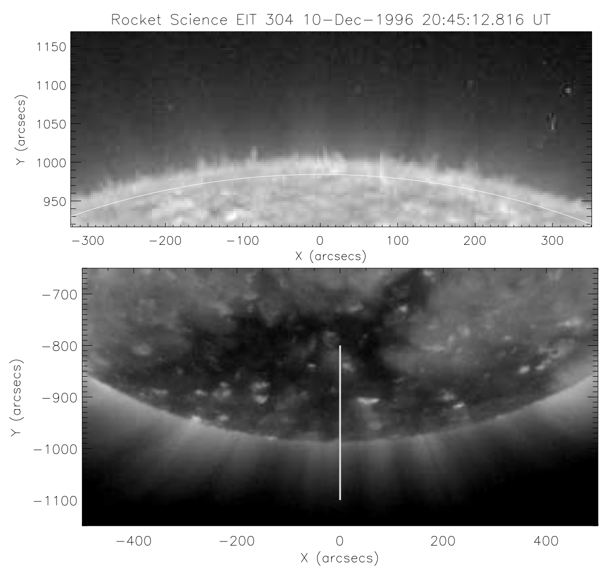

Figure 1. The solar poles in the light emitted by He II *(304 Å) and Fe* XII *(195 Å) formed at temperatures of 0.08 MK and 1.5 MK, respectively (EIT/SoHO). The vertical white line from the southern pole shows the fixed position of the SUMER slit during the time series observation.*

2. DATA

The data were acquired with SoHO's EIT imager (northern pole; data-set I) and SUMER spectrometer (southern pole; data-set II). The characteristics of the data are presented in Table 1. Both data show the temporal evolution of a region on the Sun: two-dimensional images with a cadence of 1/min (EIT) and one-dimensional (on solar$-y$) time series taken with SUMER's detector B, slit 2, with an exposure time of 1 min (see Fig. 1).

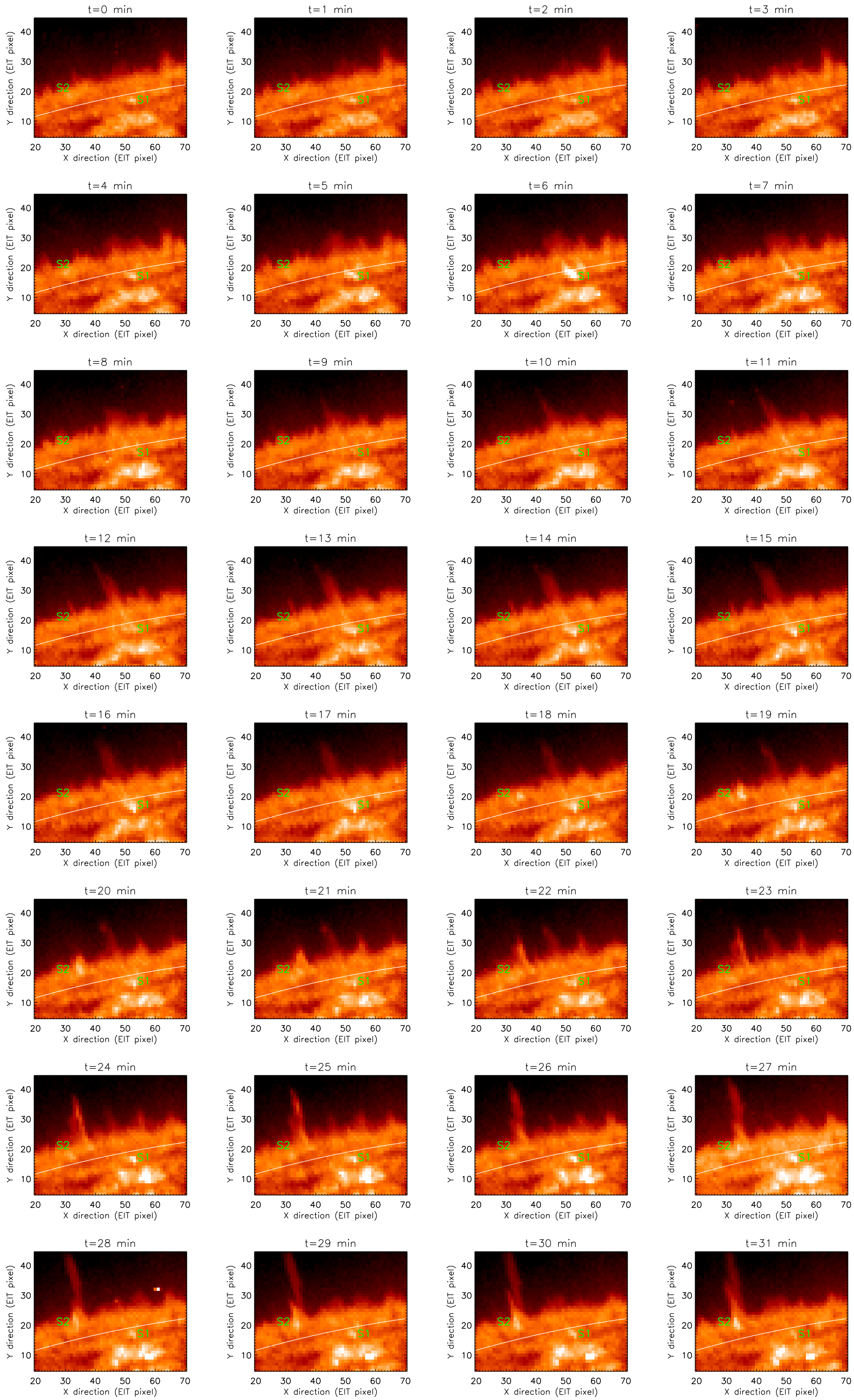

Figure 2. The time evolution from t = 0 to 31 min of a small region taken from data-set Ib (EIT, He II *304 Å). The sites marked with 'S1' and 'S2' are the footpoints of two giant spicules.*

Table 1. EIT and SUMER observations of polar coronal holes.

Item	Instrument	Date	Time UTC	Wavelength (nm)	Exposure time (s)
Data-set Ia	EIT*	10/12/1996	16:00 - 17:01	He II 30.4	32
Data-set Ib	EIT*	10/12/1996	20:45 - 21:46	He II 30.4	32
Data-set II	SUMER**	25/02/1997	00:03 - 13:58	N IV 76.5	60

Remarks: *Cadence: 1 per min; **Detector B and slit 2 (1″ ×300″) were used.

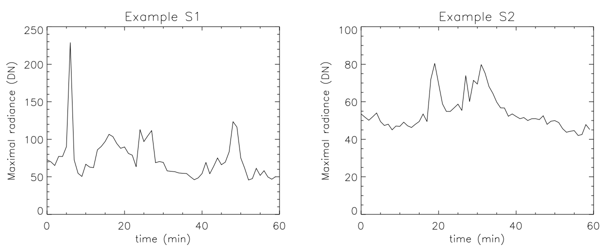

Figure 3. Local maximum radiance varying with time for sites 'S1' and 'S2' (data-set Ib, EIT). Site 'S2' is located above the limb at a height of about 8,000 km.

3. RESULTS

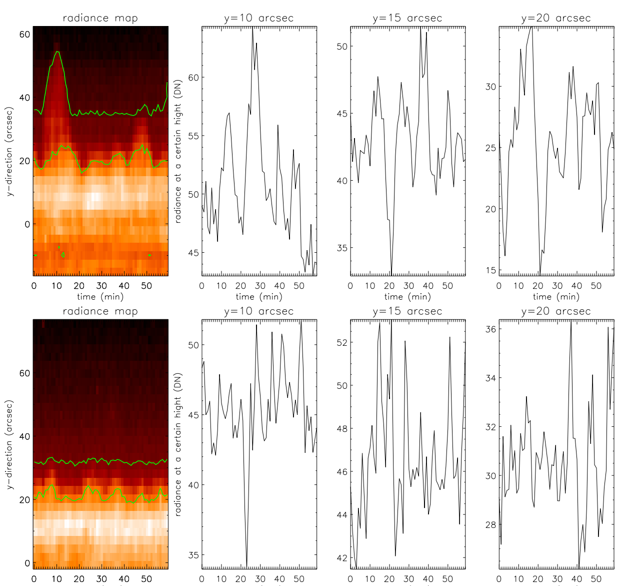

Figure 4. He II radiance versus time at fixed position along the solar-x direction at heights of 10, 15 and 20″ on solar-y.

For enquiring more into the characteristics of spicule-like structures seen at the limb and the connections between them and other small-scale brightenings seen on the solar disk, we identify a few events from our two data-sets.

Fig. 2 shows the time evolution from t = 0 to 31 min of a small region taken from data-set Ib (in the He II line). We investigate two sites marked with 'S1' and 'S2', which are the foot-points of two giant spicules. The local maximum radiance varying with time is plotted for both these sites in Fig. 3. Note that 'S2' is located above the limb at a height of ≈ 8,000 km.

In Fig. 4 we show the radiance versus time at fixed positions along x=0″ (upper panel) and -242″ (lower panel) from data-set Ia, to mimic the SUMER observational mode as discussed in Xia et al. (2005). The colour images are plotted like a time-series in SUMER data. The other plots show radiance varying with time at heights of 10″, 15″ and 20″. They show the re-occurrence of spicule structures at the same location during the 1 hour observation, with a period of about 10 min seen in the left panels. However, one finds sub-structures with a shorter period viewed at different heights; many of them have a period of 3-5 min. This confirms our previous study on the dynamics of spicules in which we have used SUMER data with fixed position of the slit (Xia et al. 2005).

To see how spicule-like structures might appear on the solar disk, we look at temporal series data taken in a polar coronal hole in the N IV 765 Å line on the disk. Fig. 5 shows the radiance map (top panel) and the Dopplergram (bottom; the Doppler shift, plotted as ± 15 km s^{-1}, is shown relative to its average value). One can observe the temporal change between red and blue shift in the Dopplergram and the temporal brightness variation in the radiance map. We suggest that these variations are closely related to what we have seen on the limb.

For a closer inspection of the plasma behaviour as seen in the SUMER data, in Fig. 6 we show a one-dimensional section taken from Fig. 5 at solar-y=107″ and t = 215 to 320 min. The solid curve shows the Doppler shift (relative to its average value) and dotted curve, the radiance of the N IV line, varying with time. Both radiance and Doppler shift show a quasi-periodic variation, with a period of about 15 min. The radiance enhancement factor is larger than 2. This resembles blinkers, which have a mean lifetime of 16 min and a mean radiance enhancement factor of 1.8 (Bewsher et al. 2002).

O'Shea et al. (2005), following the 'recipe' for identifying blinkers as outlined in Brković et al. (2001), were able to identify blinkers at some off-limb locations. They found that these blinkers occur above regions of dynamic activity, that produce evacuation events and quasi-periodic oscillations. These results would suggest that blinkers, including those on the disk, are likely to be the result of heating of cool spicular material.

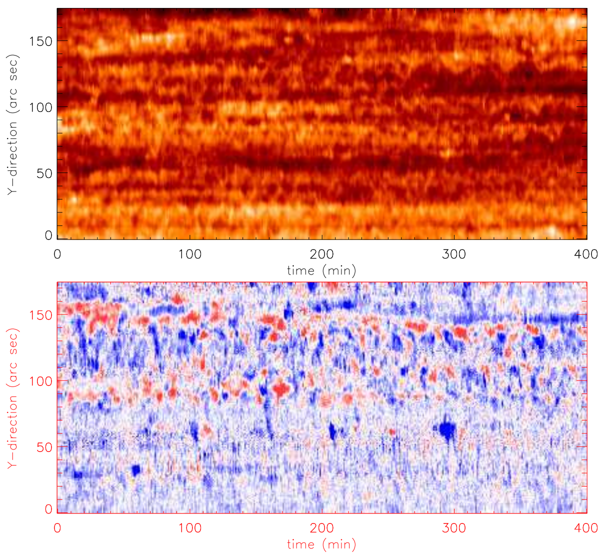

Figure 5. Polar coronal hole (data-set II, SUMER) seen in the N IV *line on the disk. Top: radiance map; bottom: Dopplergram (±15 km s^{-1}; Doppler shift is relative to the average value).*

4. SUMMARY

We have combined the time series data obtained by SUMER and EIT on SoHO to study the possible connection between the disk and limb small-scale transient events. Some preliminary results are summarized as follows:

(1) The study done with EIT data confirms our previous results derived from SUMER data, i.e., the spicule-like structures seen in EUV lines viewed on the limb occur repeatedly with an obvious period of $\approx$ 10 min. The substructures inside one spicule display re-occurrence with a period of 3-5 min.

(2) Preliminary results show evidence that a giant spicule could be driven by a series of bursts, each with a short duration. These short bursts could be observed as explosive events on the disk. Therefore, this would confirm our previous study, in which we suggested that long macro-spicules are comprised of a group of high spicules (Xia et al. 2005).

(3) On the disk, sometimes both radiance and Doppler shift show a quasi-periodic variation with a period of about 15 min. Such brightness variation resembles blinkers. The relationship between spicules and blinkers has been discussed by e.g. Priest et al. (2002) – theoretical and Madjarska & Doyle (2003) – observational, and more recently by O'Shea et al. (2005), all suggesting a possible connection between them and the spicules. From our study, we agree that a long-lived spicule (macro-spicule) could be observed as a blinker on the solar disk.

Although we have presented here some preliminary results that would link macro-spicules with blinkers as well as with bursts of explosive events on the disk, more detailed analyses with high resolution data need to be done in order to establish a definitive connection between various events (bi-directional jets, EUV brigtenings and spicules) occurring in the solar transition region.

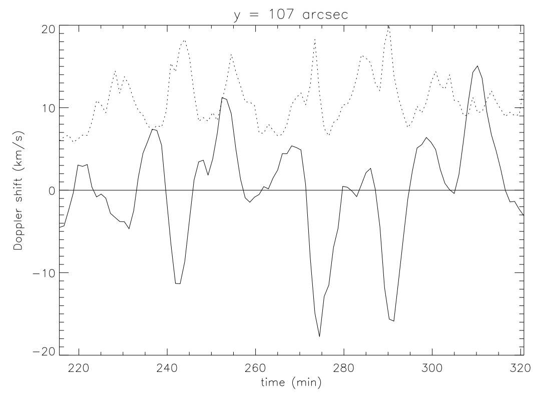

Figure 6. A segment plot taken from data-set II (solar-y=107″ and t = 215 to 320 min) showing the Doppler shift (solid curve, relative to its average value) and radiance (dotted curve) of the N IV *line varying with time.*

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