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Letter to the Editor

Macrospicules and blinkers as seen in Shutterless EIT 304 Å

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ABSTRACT

Aims. Small-scale transient phenomena in the solar atmosphere are believed to play a crucial role in the coronal heating and solar wind generation. This study aims at providing new observational evidence on blinkers and macrospicules appearance in imager data and in doing so, establish the long disputed relationship between these phenomena.

Methods. We analyse unique high-cadence images in the transition region He ii 304 Å line obtained in a shutterless mode of the Extreme-ultraviolet Imaging Telescope on board the Solar and Heliospheric Observatory. The data have a cadence of approximately 68 s and a pixel size of 2.62 arcsec. The events are identified through an automatic brightenings identification procedure. Features showing a jet-like structure seen in projection on the disk were selected and their light-curve further analysed.

Results. The temporal evolution of the intensity in three events is shown, two of them seen on-disk as jet-like features and one above the limb. The flux increase, size and duration derived from the light-curve of the on-disk events show an identity with the blinker phenomenon.

Conclusions. The light curves of these events suggest that the off-limb and on-disk features are in fact one and the same phenomenon and therefore that some blinkers are the on-disk counterparts of macrospicules.

Key words. Sun: atmosphere – Sun: transition region – methods: observational – methods: data analysis

1. What do we know about blinkers and macrospicules and their interrelation?

Revealing the nature of various transient small-scale phenomena such as spicules, macrospicules, blinkers, bi-directional jets (also known as explosive events), Extreme-ultraviolet (EUV) network and cell brightenings and nanoflares in the solar atmosphere is of great importance for understanding the fundamental processes such as coronal heating and solar wind generation (for reviews see Walsh & Ireland 2003; Feldman et al. 2005). To achieve this we first have to understand whether the large variety of features is real, or whether we actually observe the same phenomenon but assign it a different name when observed in a particular way, with a particular instrument, or at a particular wavelength (Madjarska & Doyle 2003; Harrison et al. 2003; Brković & Peter 2004; Doyle & Madjarska 2004). After identifying blinkers in SUMER (Solar Ultraviolet Measurements of Emitted Radiation) data, Madjarska & Doyle (2003) concluded that there is no relationship between blinkers and bi-directional jets suggesting that blinkers could be the on-disk signature of EUV spicules. Harrison et al. (2003) unified some of these phenomena considering the different instrumental limitations and the properties of the different transient small-scale phenomena known so far. They found that a number of events such as blinkers, network and cell EUV brightenings can be classified as the same type of phenomenon.

Blinkers represent an enhancement in the intensity of transition region lines and were first identified using Coronal Diagnostic Spectrometer (CDS) observations. They were intensively studied by several authors such as Harrison (1997), Harrison et al. (1999), Bewsher et al. (2002, 2003, 2005), Parnell et al. (2002), Madjarska & Doyle (2003), Doyle et al. (2004), Brooks & Kurokawa (2004) and Brooks et al. (2004). Blinkers occur at the network boundaries, but some were also seen in the intranetwork. They have an average size of about $8'' \times 8''$ and an average lifetime of 16 min. Brković et al. (2001) using observations which permitted a better detection of shorter and longer lived brightenings, determined a lifetime in the range of 3−110 min, with an average duration of 23 min in He i, 16 min in O v and 12 min in Mg ix. The average intensity enhancement found by Harrison et al. (1999) in O v and O iv was 1.48 and 1.43, respectively. The intensity increase was 1.04 for Mg ix and 1.08 for He i, while Brković et al. (2001) found slightly higher values of 1.09 and 1.22, respectively, which could be due to the different method of threshold determination. Blinkers were also studied in detail both in the quiet Sun and active regions by Bewsher et al. (2002) and Parnell et al. (2002). Their analysis of the magnetic fragments in the quiet Sun showed that blinkers preferentially occur above regions of large or strong magnetic fragments with 75% occurring in regions where one polarity dominates. Madjarska & Doyle (2003) using Big Bear Solar Observatory (BBSO) magnetogram observations found that a magnetic flux increase plays a crucial role in the blinker generation. Blinkers show Doppler velocities from −5 to 30 km s^{-1} predominantly red-shifted (Madjarska & Doyle 2003; Bewsher et al. 2003).

Priest et al. (2002) suggested four different mechanisms which could explain the blinker appearance: heating of cool

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spicular material, containment of plasma in low-lying loops in the network, thermal linking of cool and hot plasma in response to a coronal heating event, or a cooling and draining of hot coronal plasma when coronal heating is switched off. They suggested that, in each case, a blinker could be produced by the granular compression of a network junction.

The properties of Hα solar spicules were first revealed by Beckers (1968, 1972). They are jet-like structures seen above the solar limb with apparent velocities of $\approx$30 km s^{-1}. After having reached a maximum height (on average from 6500 to 9500 km), they are either seen falling towards the chromosphere or fading out. Spicules were also seen in EUV lines (first in SKYLAB He II 304 Å reported by Bohlin et al. 1975) showing a bigger size and a longer lifetime. Because of their size compared to the well-known Hα spicules, they were named as macrospicules. Following the identification of macrospicules in EUV He II 304 Å, Moore et al. (1977) reported their counterpart in the Hα line. Recently, Yamauchi et al. (2004, 2005) revealed that Hα macrospicules show two different types of structure: spiked jet (83% of the studied events) and an eruptive loop (10%), suggesting a different formation mechanism.

O'Shea et al. (2005) suggested a close relationship between blinkers and macrospicules. The authors found that blinkers occur above regions of dynamic activity and that they produce evacuation events and quasi-periodic oscillations. So far, blinkers observations were limited to only spectroscopic observations. In this work we will consider the well known properties of both phenomena and try to identify blinker phenomena in high cadence EIT (Extreme-ultraviolet Imaging Telescope) He II 304 Å data.

2. Data description, reduction and analysis

We use unique high-cadence EIT data obtained in the 304 Å passband. The images are produced with the shutter remaining open, permitting a 68 s cadence. The angular pixel size of the images is 2.″62 and the field-of-view (FOV) covers 1090″ × 1090″. The instrument produces 120 images during 2 h 20 min. The shutterless campaigns[1] started in 2001 and continue until present with 10 campaigns so far. They are obtained always simultaneously with TRACE and various CDS observing programs. In a few cases high resolution Michelson Doppler Imager magnetograms are available.

The data require special treatment because the images are read while still exposing (for more details see De Groof et al. 2004). The images are reduced including smear image removal, dark image subtraction, degridding, flat field, filter factor and normalization response corrections. The data analysis includes automatic identification of brightenings on the disk and above the limb (following the identification method applied by Brković et al. 2001). From all identified brightenings only propagating brightenings (e.g. jet-like features) on the disk were selected visually and their light curves were derived including the background and the 1σ standard deviation. We applied three criteria for blinkers recognition: a minimum size of 2×2 pixels^2, taking into account that the EIT spatial resolution is ∼5.″5. An upper limit was not needed to be set as we did not find so far any feature (or propagating brightening) in the EIT quiet Sun data larger than the largest blinker we know from the literature. Only eruptive prominences could be seen as a larger feature but their appearance is easy to identify. The second criterion is the duration,

[1] http://sidc.oma.be/EIT/High-cadence/

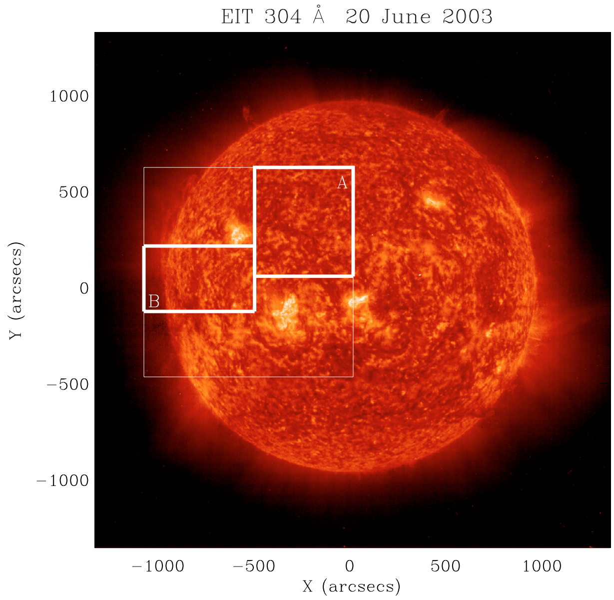

Fig. 1. Full disk EIT image obtained prior to the Shutterless campaign on June 20 2003 in the 304 Å passband. The thin line box shows the shutterless FOV while the two rectangular thick line boxes outline the on-disk and the close-to-limb areas considered in this study.

which was chosen to be close (±10 min) to the average duration of 16 min obtained by Bewsher et al. (2001). Lastly, we adopt a minimum intensity increase of 1.2. In this letter we present the first results from a dataset obtained on 2003 June 20 from 17:00 until 19:20 UT. The EIT FOV during these observations is shown in Fig. 1.

3. Results and discussion

The aim of the present study is to establish the relationship (if it exists) between events such as blinkers and macrospicules. The analysis of the automatically identified brightenings revealed the presence of a large number of events, many of them representing jet-like features seen in projection on the disk. The footpoints of the jets are located in the network and their size and duration suggest macrospicule phenomena. Yamauchi et al. (2005) described the appearance of macrospicules on the disk showing a few examples from 78 identified macrospicules in images obtained at BBSO in Hα line center, Hα–0.6 Å and Ca II K line. These macrospicules are similar in size, appearance and location to the features identified in our dataset which leads us to the conclusion that the observed EUV jets are indeed the EUV counterparts of Hα macrospicules. Moore et al. (1977) using simultaneous Hα and EUV observations already showed that EUV macrospicules represent the same feature but seen in Hα. The two (Hα and He II 304 Å) features appeared quite similar in size, shape, motion and duration. Wang (1998) comparing BBSO Hα images at 0.65 Å, line center, –0.65 Å and EIT He II 304 Å images found that all identified He II 304 Å macrospicules have a counterpart in Hα. Their analysis shows, however, that the morphology in the two lines is different, which is probably due to the different resolution of the data (up to 10 times lower for EIT), the formation temperature of Hα and the temperature range covered by the He II 304 Å passband. One of the possible interpretation of the different appearance is that the He II 304 Å macrospicules are the "hot" surroundings of the "cold" Hα macrospicules.

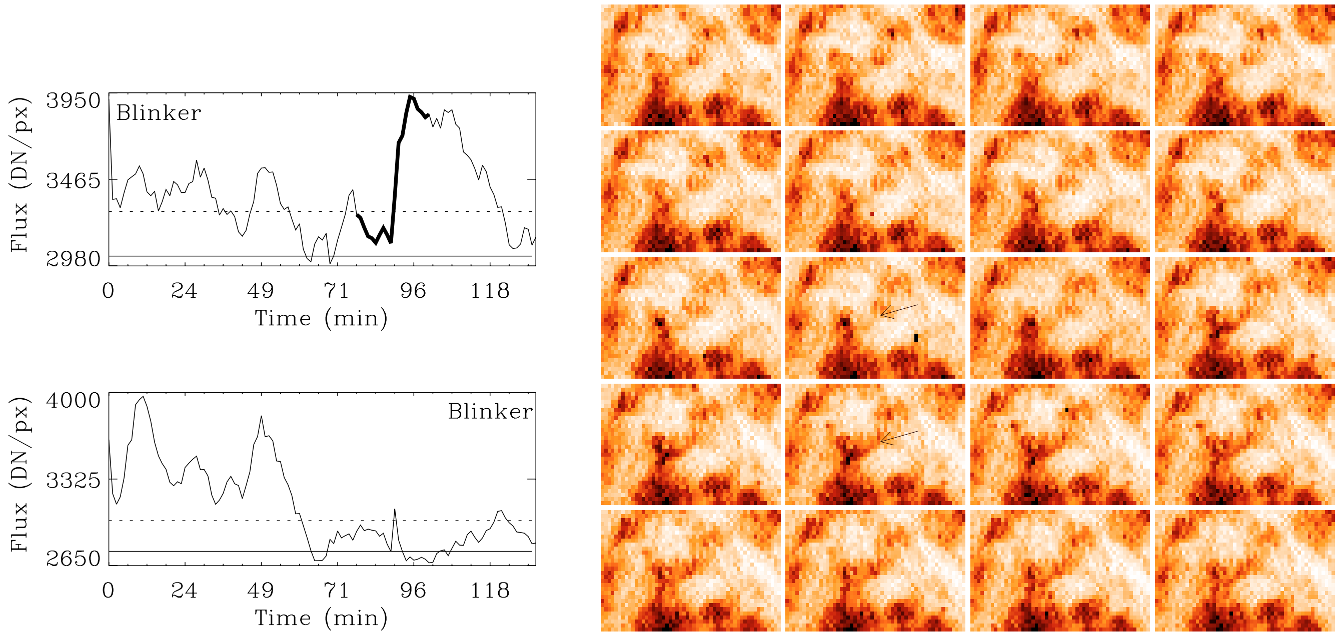

Fig. 2. *Left*: intensity obtained integrating over an area of a reappearing ejection seen in projection on the solar disk. The thicker line corresponds to the images shown in the right-hand panel. The continuous line represents the background and the dotted line a 1σ standard deviation. *Right*: reversed color intensity image obtained in the EIT 304 Å passband showing an example of the plasma jet seen in projection on the disk. The size of the images is 140″ × 81″. Arrows point to a plasma jet. Also see `http://star.arm.ac.uk/~madj/blinker/animation.gif`.

We selected only features which have a jet-like appearance seen above the dark intranetwork (note that the network brightness can be stronger than the macrospicule one). This also reduces the probability of including other features registered along the line-of-sight. The next step was to produce a light-curve by integrating the flux over the area covering the feature. Figure 1 shows two areas (A and B) selected in such a way that the presence of active regions in the FOV is avoided. In Fig. 2 we present the flux from two jet-like events which were clearly seen evolving above the dark intranetwork. The events were selected from the FOV "A" shown in Fig. 1. The temporal evolution of all features in the FOV "A" can be seen at `http://star.arm.ac.uk/~madj/blinker/animation.gif`. Figure 2 also shows a series of images where a jet-like structure is seen evolving above the intranetwork with footpoints located in the network junctions.

Applying the methods outlined in Sect. 2 for intensity evaluation, we find that an average flux increase for the examples presented in this letter is 1.3 with durations between 8 and 25 min. According to the blinker identification criteria this classifies the features analysed here as the so-called blinkers. The blinker in Fig. 2 (upper panel) has a size of 40″ × 15″ and the second one 10″ × 13″. To support further the evidence that some of the blinker phenomena are in fact the on-disk counterpart of macrospicules we produced also a light-curve from a macrospicule on the limb (Fig. 3). The macrospicule size is approximately 20″ × 25″ showing an intensity increase of 1.2 and 1.4 and a duration of 8 and 16 min, respectively.

Having analysed a small fraction of the large observational material we can conclude that some of the transient phenomena named as blinkers seen on the solar disk with the CDS and SUMER spectrometer are the on-disk counterpart of EUV macrospicules phenomena. The events presented here are jet-like features showing the same behaviour as Hα macrospicules. It is difficult or even impossible for us to resolve loop structures as seen in the Yamauchi et al. (2005) data.

Xia et al. (2005) showed with SUMER data that EUV spicules and macrospicules both show blue and red-shifted emission when seen rising from the solar surface. The Doppler velocities obtained by Madjarska & Doyle (2003) during two out of three blinkers also showed both blue and red-shifted emission (see Figs. 4e and 6e in their paper). Dere et al. (1989) found the rising velocity of macrospicules to be 10–150 km s^{-1}. All this strongly supports a possible relationship between some blinkers and macrospicules. The results of Xia et al. (2004) on Doppler shifts in macrospicules and Yamauchi et al. (2004, 2005) on macrospicules apparent motions and evolution make us believe that EUV macrospicules have the same behaviour as seen in spicules, i.e. the macrospicules probably propagate upward and then fade away with some of the material falling back towards the solar surface. Some macrospicules probably fall back forming a loop as seen in Hα macrospicules.

Chae et al. (2000) and Madjarska & Doyle (2003) identified blinkers in SUMER data as a series of short-lived, small-scale brightenings lasting about 2–3 min, and having a typical size of about 3″–5″. This is consistent with the suggestion by Xia et al. (2005) that macrospicules comprise of a group of spicules. The work on this project will evolve further by extracting information on a larger number of events. We are planning new observational campaigns performing joint CDS, EIT (high-cadence in the 304 Å passband) and ground based high cadence Hα & G-band sub-arcsec images. We believe that further analysis on the EIT shutterless data supported by these additional observations will bring a better understanding for the large variety of transient phenomena and their relationship and tell us whether or not many of these transient features have a common origin. Several authors have proposed magnetic reconnection driven by collisions of photospheric features as the starting point for all of these transient features. For example, Ryutova et al. (2000) proposed a sequence of events starting from cancellation of photospheric magnetic fields, which pass through shock formation,

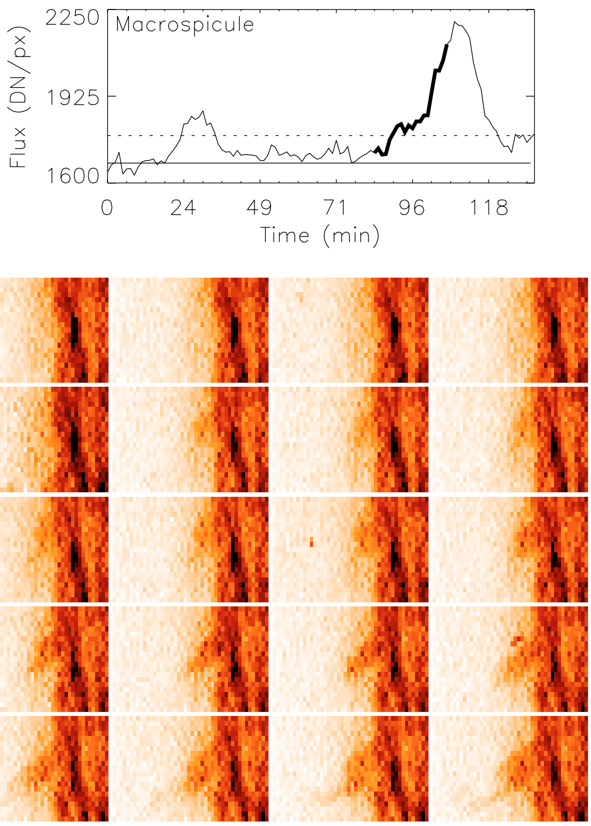

Fig. 3. *Top*: intensity obtained integrating over an area of a macrospicule. The thicker line corresponds to the images shown in the lower panel. The continuous line represents the background and the dotted line a 1σ standard deviation. *Bottom*: reversed color intensity image obtained in the EIT 304 Å passband showing an example of a macrospicule. The size of the images is $118'' \times 100''$.

resulting in transition region jets or micro-flares. Hence, starting from the collision of flux tubes, if the angle between resulting shocks is head-on then only small flows are produced (i.e. only a brightening, termed a blinker). If the shocks have the correct angle then flows are produced (i.e. explosive events jets or perhaps spicules). The present data certainly show that some of the blinkers are indeed the on-disk counterparts of macrospicules.

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