Proc. of Kofu Symposium, NRO Report No. 360, July, 1994

MICROFLARES AND THEIR RELATED EVENTS

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Abstract

We have studied in detail two series of events that occur in two separate active regions on October 9 and June 15, 1980 during the period of SMM observations. These events can be considered as typical of a class of solar compact subflares. The events have been studied using simultaneous UVSP (C IV) and Meudon (Hα) data, and for the brighter event we also use X-ray data from HXIS. Characteristics of microflares are derived. The simplest microflare may be composed of a large number of small events, some of which appear to be triggered by earlier events in the same series.

1. Introduction

The observations have been described in two previous papers (Schmieder *et al.* 1991, Fontenla *et al.* 1994) and relate to solar activity in 1980 during the period of operation of the Solar Maximum Mission (SMM). The SMM data was from the Ultra-Violet Spectrometer and Polarimeter (UVSP) in the line of C IV and the X-ray data was from the Hard X-ray Imaging Spectrometer (HXIS) at energies from 3.5 - 30 keV. The Hα data was from the Multi-Channel Subtractive Double Pass (MSDP) spectrograph at the Observatory of Paris, Meudon. In both series of events there is a subflare - a faint one on October 9, observed simultaneously in C IV and Hα and a brighter one on June 15 which was also seen in X-rays. In this paper we will report both on the nature of the microflares and on the secondary events the initial small burst appears to trigger.

2. Microflares

The microflares are short lived, with a very fast rise (1 min) and a slower exponential-like decay in the 3.5 - 8.0 keV band. A burst registered in the 16-30 keV band for the June

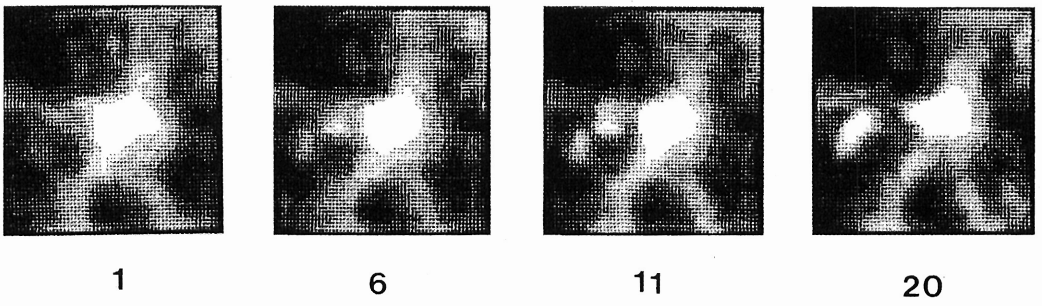

Fig. 1. Some selected small C IV rasters showing the propagation of the brightenings (Schmieder *et al. 1991*)

15 event lasting $\sim$15 s indicates the presence of hot material at temperatures in the 1.6 - 2.7 × 10 ^{7} K domain. The total energy release can be estimated to be about 10^{28} erg, assuming an electron density of 3×10^{11} cm^{-3} (Table 1). Assuming homogeneous plasma in temperature and in density an upper limit volume is estimated $\sim 2\times 10^{24}$ cm^{-3} from the emission measurement. The HXIS data indicate a full emission hightly localized (8"×8"). The X-ray emitting material would be contained in a cylindrical loop of 6000 km long and with a section of 800 km, and although this is smaller than the spatial resolution of HXIS the images are consistent with these dimensions (see Fontenla *et al.*, 1994 for details). Extrapolating previous model calculations (Fontenla *et al.* 1991) we infer that a large fraction ($\sim$ 70%) of the hot plasma energy was dissipated by UV radiation (mainly in Lyα, but also in other lines) at the small footpoint kernels (consisting of two loops, 2000 km long and with a diameter of $\sim$800 km.

Both microflares are clearly connected to magnetic field evolution, but with different characteristics. On October 9 the location of the kernel corresponds to a magnetic polarity "wedge" carving into an opposite polarity region. On June 15 the location of the microflare corresponds to a location where there was some evidence of emergence of a small magnetic inclusion. Thus, both locations are characterized by changes in the magnetic field.

Table 1. Characteristics of the microflare and secondary events on June 15 1980

History	Time UT	X-ray	Energy erg	N_e cm^{-3}	Area cm^2	Flux erg cm^{-2}s^{-1}
pre-event	07:49	soft	4×10^{25}	2.6×10^{9}		6×10^{4}
microflare	08:01	soft/hard	8.6×10^{27}	3×10^{11}	1.4×10^{15}	1.4×10^{10}
secondary event	08:04	soft	4×10^{25}	2.6×10^{9}	3×10^{16}	type III burst
third event	08:15	soft	4×10^{25}	2.6×10^{9}		C IV blueshift

3. Propagation of the disturbance on October 9 1980

The microflare detected in C IV line was accompanied by a series of C IV brightenings with energies much smaller than the microflare. They occurred along the polarity inversion line (PIL) of the microflare location (Fig.1). The PIL was occupied by a filament where twisting

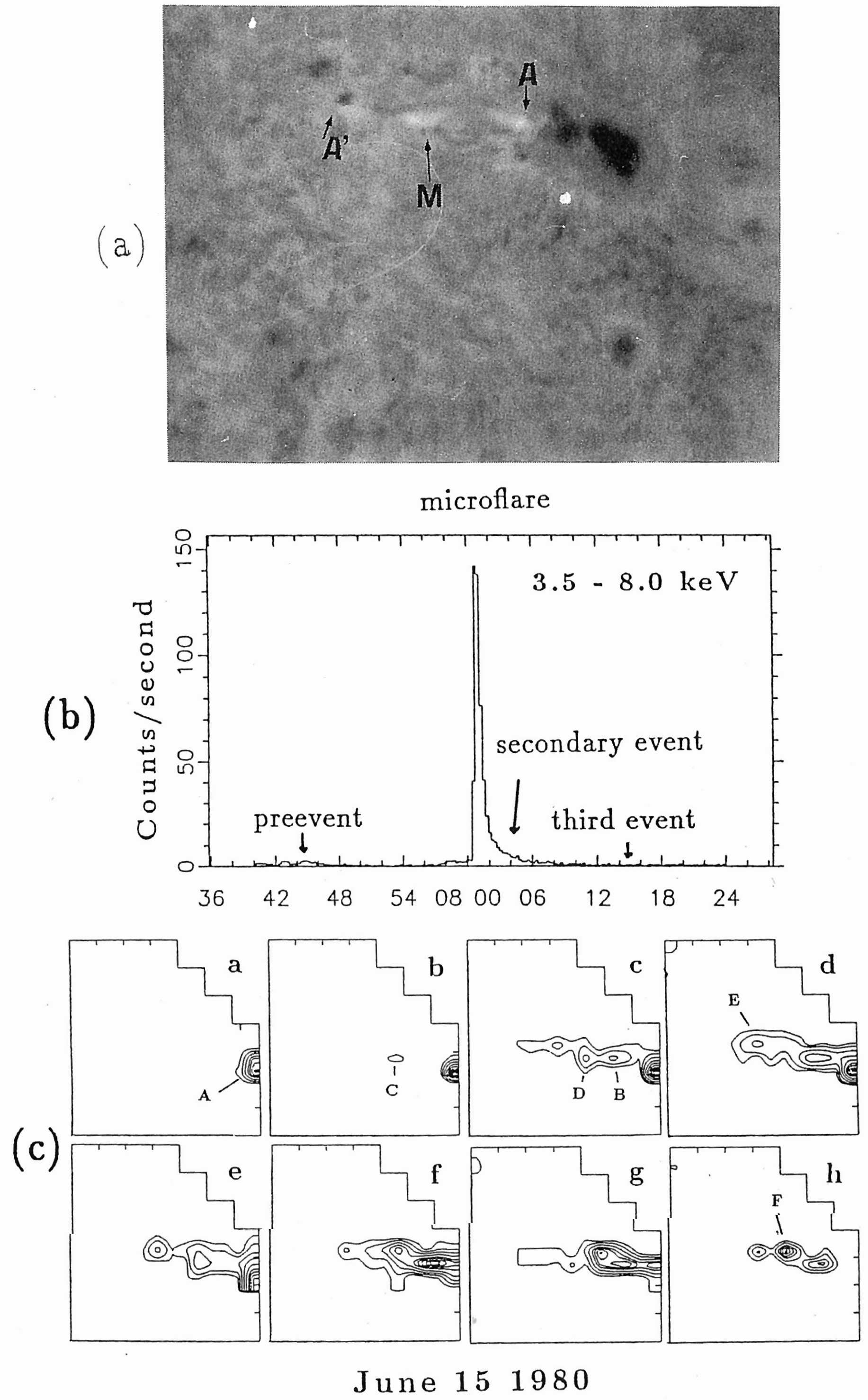

Fig. 2. (a) Observations in Hα -0.5 Å of the 3 flare kernels at 08:03:55 UT on June 15 1980 (Debrecen) (b) 3.5-8.0 keV X-ray intensity of the whole flare region, (c) 3.5-5.5 keV X-ray images for the duration of the flare and post flare activity (A, B, C -similar to M-, D, E) (Fontenla *et al.* 1994)

motions were detected (Schmieder *et al.* 1991). These secondary events seem to have been triggered by the microflare, but they are not the consequence of a direct energy flow and rather they are the result of releases of energy stored at each location (but a small amount of energy). The triggering agent may have been a fast- or an Alfvén- mode wave. Another interpretation may be that the whole PIL experienced an almost simultaneous disturbance, but this is hard to believe given that the speed of the propagating disturbance is $\sim$600 km s^{-1}.

4. Secondary events of June 15 1980

There are two kinds of secondary events described in Table 1. One kind are the events occurring at the location of the microflare but at different times, both before and after the microflare. This behavior indicates that the events before are probably not just precursors of the main event but are simply independent events which continue occurring even after the main flare is over. The magnitude of these events in X-rays was very close to the detection threshold, but the coincidence of their location and time with the UV brightenings indicates that they are real events. Their energy is probably about two orders of magnitude (10^{26} erg) smaller than that of the microflare.

Another kind of secondary event associated with the microflare is the almost simultaneous brightening seen at locations far away from the main event (Fig.2 points A, M, A'). These events are located on the separatrix of the potential magnetic field that was described by Démoulin et al (1993) for this region. Thus these events are also probably triggered by the microflare, but this time by the propagation of a slow- or Alfvén-mode MHD disturbance and along a separatrix, and they are releases of locally stored energy. One of the secondary events is indeed not so much a brightening but just a high velocity C IV event about 11 minutes after and about $30''$ away from the microflare site. However, its location near where a previous secondary brightening was observed at the time of the microflare, the occurrence of a secondary event at the same location of the microflare, and the faint C IV arch which connects to the high-velocity event to the microflare, all indicate that the remote event is also an energy release (in a different form) triggered by events at the microflare site.

5. Conclusion

All the evidence suggests that often a number of small events seem associated with compact microflares that occur at locations where evolution of complex magnetic fields is occurring. Also, the energy releases are somewhat independent in nature and are due to energy locally stored; their characteristics can be widely variable. Often several events may occur very much in the "same" location given our limited spatial resolution. This raises the possibility that many of the simplest microflares we observe may actually be composed of a large number of even smaller events. It is then likely that the events are triggered successively.

References

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