MICROFLARES AND LOOP OSCILLATIONS

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ABSTRACT

Microflares are small A to C class X-ray brightenings that occur at a rate of about 10 per hour in an average active region (Shimizu et al., 1992). They show signatures of non-thermal emission in RHESSI X-ray spectra and are seen as an important link between large-scale flares and the intangible nanoflares that have been proposed as the energy source for the active region corona. In this contribution we analyze microflare loop brightenings seen in the Fe XIX line with SUMER. For the two active regions studied, we find an Fe XIX loop brightening rate significantly higher than soft X-ray microflares. Almost half the events have Fe XIX Doppler shift oscillations. We summarize the basic characteristics of the oscillations and discuss their importance in the context of models of microflare loop excitation.

Key words: microflares, Doppler shift, coronal loop oscillations.

1. INTRODUCTION

The Soft X-ray Telescope on Yohkoh sattelite observed, on the solar disk, frequent small flare-like brightenings of compact loops, the so-called "active-region transient brightenings" (Shimizu et al., 1992). Their frequency correlates with the total soft X-ray flux of the observed active regions (Fig 1). Recent SOHO/SUMER spectroscopic observations on the solar limb have revealed strongly damped slow-mode oscillations in the hot coronal loops (Wang et al. 2002, 2003a, b, Kliem et al. 2002). They can be seen in the hot flare-like EUV lines (mainly lines belonging to the ion Fe XIX and Fe XXI) as intensity and Doppler shift fluctuations with large initial Doppler velocities. They are more clearly detected in the Doppler shift signal than in intensity.

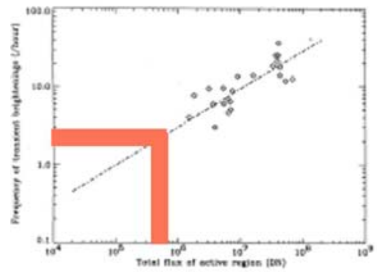

Figure 1.

2. OBSERVATIONS

2.1. SXT microflares

In this paper observations of two active regions (AR 9167 and AR 9176) at the east limb are analyzed. SXT and GOES observations are used to identify and classify the microflares. The rate of the Soft X-ray brightenings varies between 1-10 per hour. The small active region AR 9167 observed by SUMER was expected to produce about 2 per hour. The brightenings are mostly loops but only 10 % have loop length greater than 50" (Fig 2), so would reach the height of the SUMER slit (30" off limb). The expected event rate at the position of the SUMER slit is thus one every 5 hours.

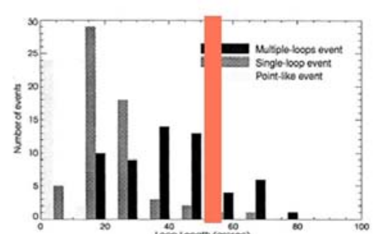

Figure 2.

Proc. SOHO 17 – 10 Years of SOHO and Beyond, Giardini Naxos, Sicily, Italy
7 – 12 May 2006 (ESA SP-617, July 2006)

2.2. Fe XIX microflares

SUMER observed at a fixed position in the corona as the active region loops rotated around the east limb of the Sun onto the disk (figure 3). The loop system AR 9167 was observed for about four days in the lines $Fe\ XIX$ ($10^7 K$), $Ca\ XIII$ ($10^6\ K$), $S\ III$ ($5 * 10^4\ K$). The observations in the emission line of $Fe\ XIX$ 1118 Å are shown in the figure 4.

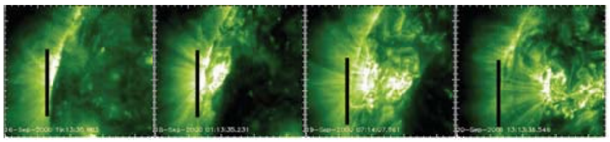

Figure 3. The EIT 195 Å *images with the position of the slit indicated are displayed above.*

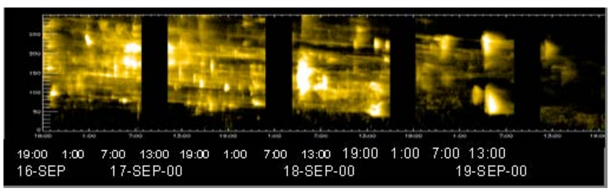

Figure 4. Microflares observed in the emission line $Fe\ XIX$ 1118 Å *with the maximum formation temperature* $10^{6.9} K$.

Like SXT microflares most Fe XIX events correspond to GOES B or C-type flares (figure 5) with the average thermal energy of 10^{28} ergs. The observed rate of the Fe XIX brightenings was 3 per hour (figure 6), 15 times higher than the rate of the SXT microflares. The average duration of the $Fe\ XIX$ brightenings is 33 minutes, ranging from 6 to 157 minutes.

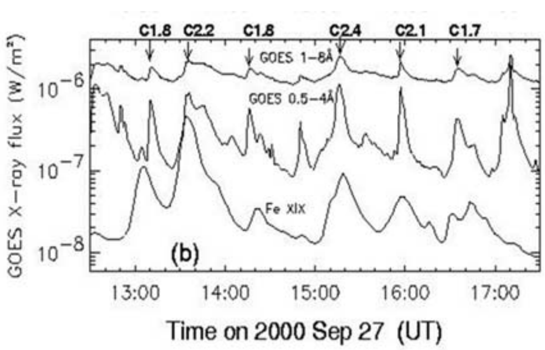

Figure 5. Light curve of the $Fe\ XIX$ *line integrated along the slit (bold line) and light curves of GOES full sun soft X-ray flux through 1-8 Å and 0.5-4 ÅṪhe flux of GOES 0.5-4 Å is multiplied by a factor of 10 (Wang et al., 2006).*

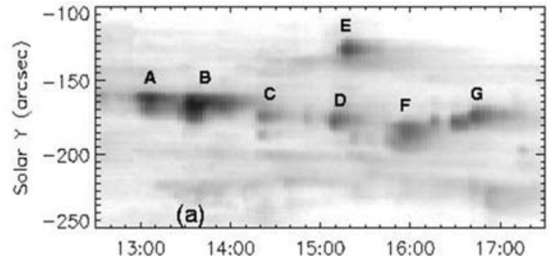

Figure 6. Intensity time series of the $Fe\ XIX$ *line detected at the upper part of the slit shown in figure 3 (Wang et al., 2006).*

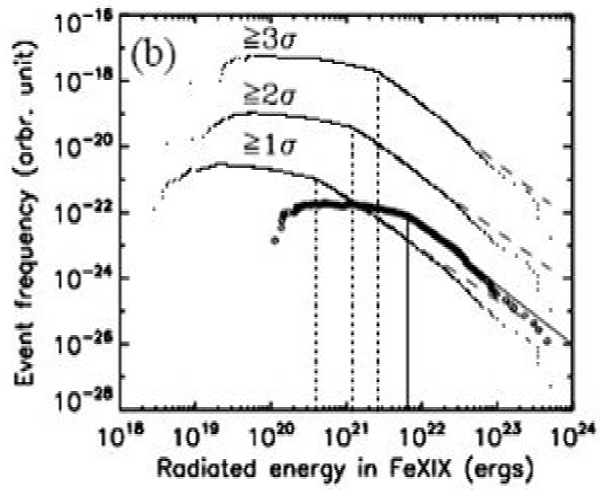

Figure 7. The energy distribution of the $Fe\ XIX$ *brightenings is a power law with index 1.7-1.8, in consistency with the SXT microflares (Wang et al., 2006).*

3. DOPPLER SHIFT OSCILLATIONS

Oscillations are found in many different events. Time series of Fe XIX spectra show the line shifts at various positions through events. Time is in minutes and velocity is -/+200 on the left/right. Letters label different events. (A) lasts several hours and has two oscillation events. It is difficult to separate the oscillations from the background. The damping time of the second event is twice the first. (B) lasts one period with no Fe XIX brightness change in the event. Both (D) and (E) last about two periods and show brightness changes. A standing sound wave has period phase shift in intensity and velocity a feature of most events.

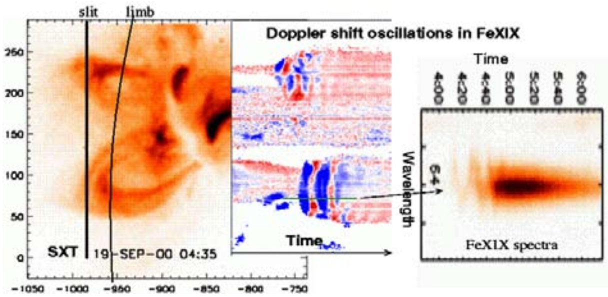

Figure 8. *Left: SXT loops overlaid with SUMER slit and the solar limb. Middle: time series of Doppler shifts along the slit. Red/Blue +/- 30 km/s. Right: evolution of $Fe\ XIX$ spectra at the position of the green line in the middle picture.*

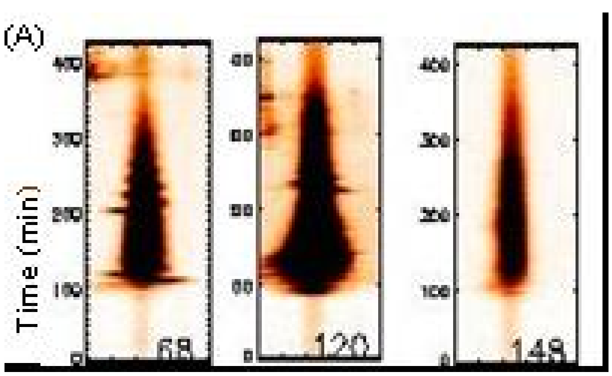

Figure 9. *Sample figure showing how an encapsulated PostScript graphic may be included. This example is for a single column figure.*

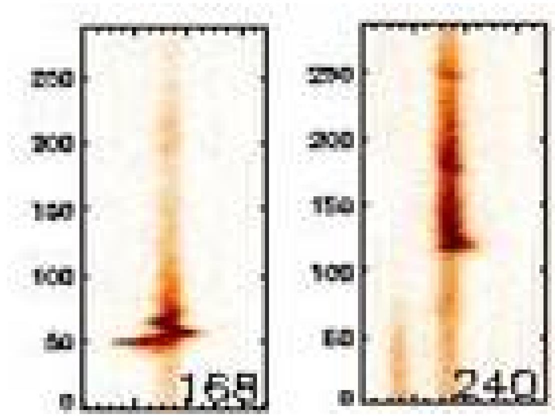

Figure 10. *Sample figure showing how an encapsulated PostScript graphic may be included. This example is for a single column figure.*

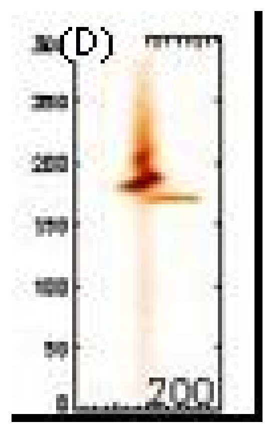

Figure 11. *Sample figure showing how an encapsulated PostScript graphic may be included. This example is for a single column figure.*

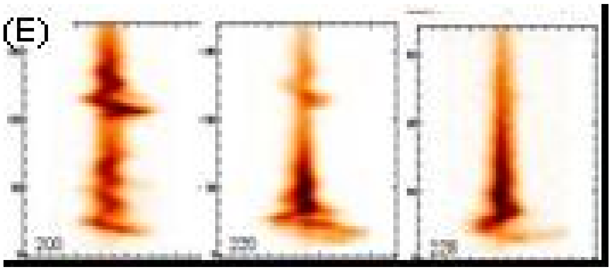

Figure 12. Sample figure showing how an encapsulated PostScript graphic may be included. This example is for a single column figure.

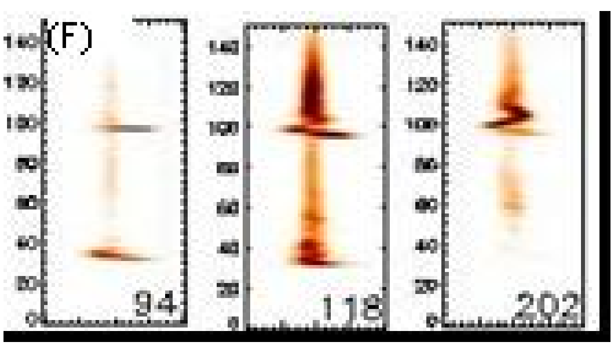

Figure 13. Sample figure showing how an encapsulated PostScript graphic may be included. This example is for a single column figure.

3.1. Fe XIX oscillation periods

A large fraction of the $Fe\ XIX$ brightenings are associated with Doppler shift oscillation. As the AR rotates onto the disk the periods decrease from 14 to 8 min and then increase again as the AR moves from the limb (figure 14). For a sound wave, the period, $P \sim 2L/c_s$, where L is loop length, c_s is sound speed. When the active region is at the limb lower lying, shorter loops are seen.

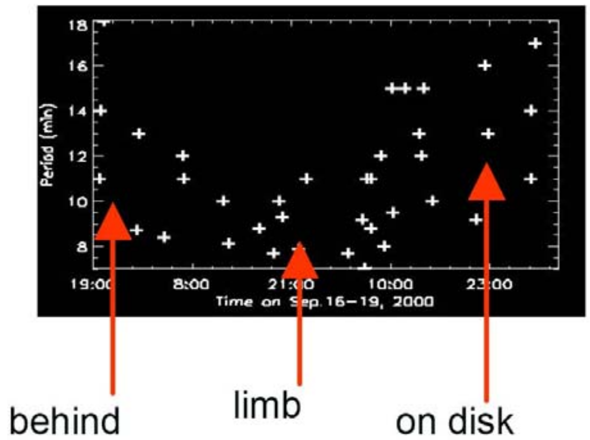

Figure 14.

3.2. Statistics

ACKNOWLEDGMENTS

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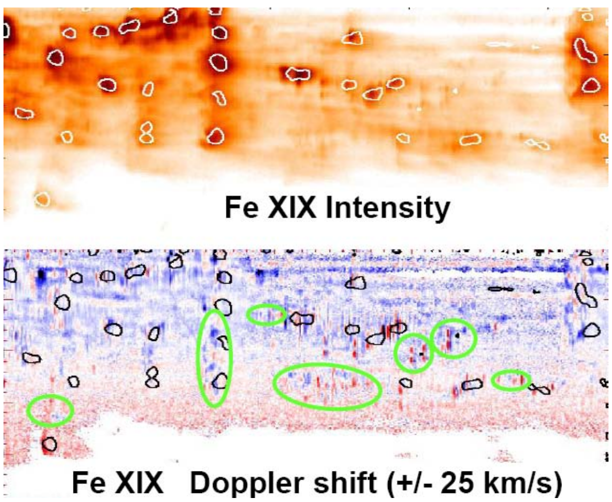

Figure 15.