

# High velocity Doppler shift observations of 10 MK flare plasma

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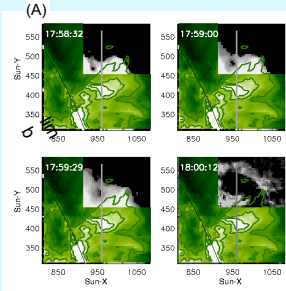
## Abstract

SUMER observations in the corona above limb active regions have detected high Doppler shifts at the time of flares in high temperature lines in three situations

- 1) At CME onset as the active region loops disrupt
- 2) At the top of a supra-arcade at the time of downflows
- 3) Oscillating post flare loops

All observations are at a fixed position with cadence 1 to 5 min. Questions arising from the observations and their resolution by Solar-B are suggested.

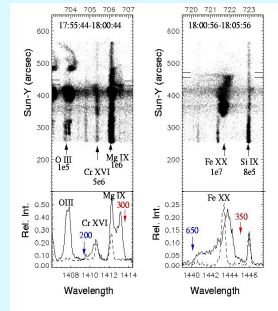
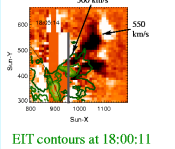
## 1. CME and M7.6 flare on 9 May 1999 An explosive start?



### Coronal loop destruction

*Left:* An optical front races through the corona at the time of the hard X-ray burst. *Bottom:* Followed by SXR plasma ejection. *Right:* Multi-temperature plasma acceleration.

### SXT difference image between 18:05:14 and 18:04:14



SUMER spectra at the time of the optical front (left) and the SXT plasmoid (right). Both red and blue shifts are seen. All observed lines are affected  $10^7$ - $10^8$  K. In the first spectrum the OIII appears to align with the optical front. In the second, FeXX high velocity red and blue shifted emission coaligns with the original site of the SXR plasmoid. The original loops appear to be blown apart rather than simply pushed outward. (Innes et al. Ap J. 2001)

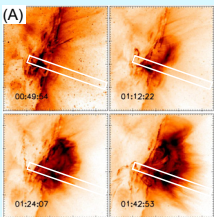
The top images show the SUMER stigmatic spectra, taken with an exposure time 5 min. Below are spectra integrated along the slit at the positions marked with extended ticks. The dotted line is the unshifted spectrum seen 3.5 hrs later.

What temperature is the optical front? – The O III height matches the front position. Catching fast cold fronts will be difficult. They are fast, faint and start early. Need limb flares.

Is the hot plasma expanding in all directions? The Fe XX shifts are both red and blue. Requires EIS and XRT statistics from many events. Limb and disk flares.

What happens to the original loops? – Mg IX is accelerated and disappears. Wide temperature range with EIS and high cadence XRT.

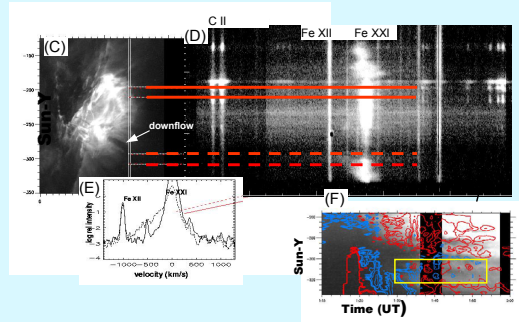
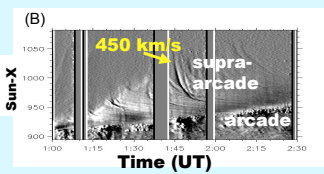
## 2. CME and X1.5 flare on 21 Apr 2001 800 km/s reconnection flow ?



(A) TRACE 195 images (B) Time series of TRACE 195 at the position of the white box.

### 800 km/s line shifts on the edge of flare downflows.

*Left:* Images of arcade's evolution. *Bottom:* Up- and downflows in the arcade. *Right:* SUMER Doppler shifts.



The SUMER spectrum 1330-1370 at 1:26:33 UT. High shifts in FeXXI 1354 are seen along the tail of a large downflow.

(C) Trace 195 image (D) SUMER spectrum at position of the white vertical line. (E) Integrated spectra between dashed and solid red lines. (F) Time series of line center shifts along the lower one third of the slit. Note the periodic red and blue shifts inside the yellow box.

Other downflows in this event also coincide with large FeXXI shifts (Innes et al. Sol. Phys 2003). In addition, the high FeXXI shifts were found at the same time as RHESSI hard X-ray bursts, at 1:15 and 1:27 UT. Asai et al. suggest there is a close connection between arcade downflows and hard X-ray bursts from observations of a similar event on 2002 July 23.

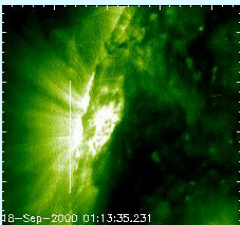
This is the only large arcade that SUMER observed.

Are the Doppler shifts real? EIS observations above large arcades.

What is the temperature/density in downflow head/tail and edge?

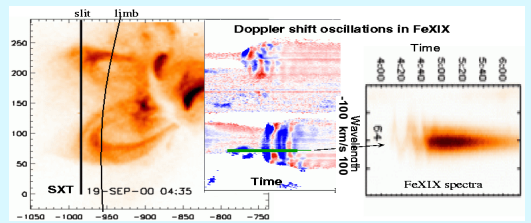
Multi-temperature high cadence EIS and XRT of limb flares.

## 3. X-ray loop oscillations Standing sound waves ?



### Hot coronal loop oscillations

*Left:* The active region corona over 12 hours. *Bottom:* Typical FeXIX Doppler shift oscillations. *Right:* The SXT loops and Doppler shifts oscillations

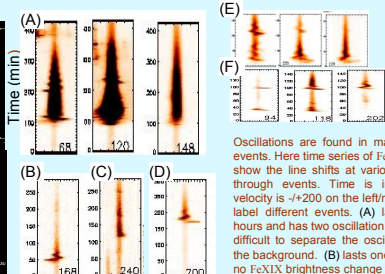


*Left:* SXT loops overlaid with SUMER slit and the solar limb. *Middle:* time series of Doppler shifts along the slit. Red/Blue +/- 30 km/s. *Right:* evolution of FeXIX spectra at the position of the green line in the middle picture.

Do the loops move? Simultaneous high cadence, high resolution images of both limb and disk loops.

Does the trigger come from footpoint or corona? Spectral images.

Do loops of all sizes oscillate with a period twice the sound crossing time? Observe different loop sizes in active regions, bright points and trans-equatorial loops.



Oscillations are found in many different events. Here time series of FeXIX spectra show the line shifts at various positions through events. Time is in min, 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. (B) lasts one period with no FeXIX brightness change in the event. Both (D) and (E) last about two periods and show brightness changes. A standing sound wave has 1/4 period phase shift in intensity and velocity.

12 hour Fe XIX time series at the position of the white line in the EIT 195 picture above.