Small-scale transient phenomena in TRACE and SUMER co-observations

M.S. Madjarska
Max-Planck-Institute Sonnensystemforschung
Outline

Background on:
  X-ray and EUV Jets
  Transient loop flows & explosive events
Observational material – SUMER, TRACE & MDI
Jets or high velocity flows?
Small-scale transient flows
How important is it to do imaging spectroscopy?!
Based on two articles:

“Jets or high velocity flows revealed in high cadence spectrometer and imager co-observations “

M.S. Madjarska, J.G. Doyle, Innes, D. & Curdt, W.

accepted for publication in ApJL

Transient small-scale flows in simultaneous spectrometer and imager observations: How important is it to do imaging spectroscopy?

M.S. Madjarska, J.G. Doyle, & W. Curdt

to be submitted to A&A
Background

Solar atmosphere – highly dynamic at all scales seen both in imager http://tcrb.nrl.navy.mil/~iuu/eqch/xrt_20070418.html and spectroscopic data - non-Gaussian profiles and brightenings

Courtesy D. Innes
Outline

Background on:

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- Transient flows

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Jets or high velocity flows?

Small-scale flows

How important is to have imaging spectroscopy?!
X-ray Jets

Size - $5 \times 10^3 - 4 \times 10^5$ km

Velocity - 30 - 300 km/s

Kinetic energy – $10^{25} - 10^{28}$ ergs

Produced by magnetic reconnection and represent the evaporation flow resulting from the reconnection heating.

Shibata et al. 1992
EUV Jets

Simultaneously seen in absorption and emission in TRACE Fe IX/X 171 Å

Figure 1. The 19 August 1998 jet at 07:30 UT is an excellent example of a one-sided (anemone) type jet (left) while the 28 May 1998 jet at 18:40 UT presents the more complicated structure of a two-sided loop jet (right).

Alexander & Fletcher 2000
The simulations

Yokoyama & Shibata 1995

oblique field

horizontal field

Yokoyama & Shibata 1995
Yokoyama & Shibata, 1995
EUV Jets

In TRACE 171 Å, EIT 195 Å and CDS He I 522 Å and O V 629 Å

Derived relative Doppler shift up to 300 km/s in CDS O V 629 Å

The jet is seen to emit in a wide temperature range from 10 000 (He I) to 2.5 MK (Fe XVI)

Lin et al. 2006
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Observational material

NOAA 8558 on 1999 June 2

SUMER slit position
SUMER

Slit 0.3" × 120"

25 sec exp time

Table 1: The observed spectral lines

<table>
<thead>
<tr>
<th>Ion</th>
<th>λ (Å)</th>
<th>log(T)_{max}</th>
<th>Comment</th>
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<tbody>
<tr>
<td>N v</td>
<td>1238.82</td>
<td>5.3</td>
<td></td>
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<tr>
<td>C i</td>
<td>1244.60</td>
<td>4.0</td>
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<tr>
<td></td>
<td>1248.88</td>
<td></td>
<td>blend</td>
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<td>O iv/2</td>
<td>1249.90</td>
<td>4.6</td>
<td>blend</td>
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<tr>
<td>Si x/2</td>
<td>1249.41</td>
<td>5.2</td>
<td>blend</td>
</tr>
<tr>
<td>C</td>
<td>1250.25</td>
<td>5.0</td>
<td>blend</td>
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<td>Mg x/2</td>
<td>1250.42</td>
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<tr>
<td>S ii</td>
<td>1259.44</td>
<td>4.1</td>
<td></td>
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</tbody>
</table>

Note: The expression /2 means that the spectral line was observed in second order. The comment “blend” means that the spectral line is blending a close by line.
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Features analysis

TRACE 171 Å

EV3
Features analysis

The peak radiance averaged over 10 pixels along the SUMER slit.
Features analysis

The peak radiance averaged over 7 pixels along the SUMER slit.
Features analysis: temperature
Features analysis: temporal evolution and velocity
Features analysis: temporal evolution

EV2

Rad (counts)  Rad (counts)  Rad (counts)  Rad (counts)  Doppler shift (km/s)  Doppler shift (km/s)  Doppler shift (km/s)  Doppler shift (km/s)
Discussion

- EUV transients in active region in simultaneous high-cadence and high spatial resolution imager and spectrometer data
- Events were studied in spectral lines – $10^4 – 10^6$ K
- Doppler shifts from 90 to 160 km/s
- no signature of the events at chromospheric temperatures
- cooling of the jet
- Although the features appear in the imager data as jets seen in projection on the disk the spectral line profiles suggest that the plasma has been driven along a curved large-scale magnetic structure, a pre-existing loop
The future

- Magneto-hydrodynamic simulations with the results converted into observable quantities to be then compared with the present data
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Background: loop flows

- since the Skylab mission – 70 km/s red-shifted emission in active region loops, but none in the quiet Sun (Mariska & Dowdy 1992)
- SoHO/CDS – 50 km/s blue-shift in a loop Brekke et al. (1997)
- Winebarger et al. (2001) – flows in a bundle of active region loops in TRACE – 2-20 km/s
- Winebarger et al. (2002) – 40 km/s in SUMER data
- Teriaca et al. (2004) – supersonic siphon-like flow (130 km/s) in small-scale quiet Sun loop (SUMER OVI 1031 Å)
Background: explosive events

- identified by their non-Gaussian profiles
- seen so far at $T$ from $4 \times 10^4$ to $6 \times 10^5$ K
- $3^\prime - 5^\prime$
- lifetime – 60 to 300 s
- above complex magnetic fields (Innes 2001)
- appear in bursts separated by 3-5 min (Ning et al. 2004)
- very limited observations in imager and spectrometer data (Winebarger et al. 2001)
Analysis
Analysis
Flows (c) and (d) in more detail.
Analysis

Normalized profiles during the events
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The cold flow

The hot flow
TRACE response function
Discussion

✓ Numerous transient flows in the plage area of an active region
✓ Represent plasma blobs moving from one footpoint to the other of a pre-existing loop
✓ Show all variety of line profiles
✓ Hardly present at coronal temperatures (to be checked with EIS/Hinode)
✓ The solar atmosphere through imaging and spectroscopy in order to avoid mis-interpretation of the observed features