Spectroscopic observations of compact solar flares

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Introduction

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- CDS observations of a compact M1 flare that occurred on October 22 2002, also observed from the ground in chromospheric lines and by RHESSI.
- The flare occurred in a region of strong and mixed magnetic polarity, was compact and lasted only a short time.

Papers – I

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Evolution and magnetic topology of the M 1.0 flare of October 22, 2002

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Abstract. In this paper we analyse an M1.0 confined flare observed mainly during its gradual phase. We used the data taken during a coordinated observational campaign between ground based instruments (THEMIS and VTT) and space observatories (SoHO/CDS and MDI, TRACE and RHESSI). We use these multi–wavelength observations to study the morphology and evolution of the flare, to analyse its gradual phase and to understand the role of various heating mechanisms. During the flare, RHESSI observed emission only within 3 – 25 keV spectral range. The RHESSI spectra indicate that the emission of the flare was mainly of thermal origin with a small non–thermal component observed between 10 and 20 keV. The temperature of plasma obtained from the fitting of the RHESSI X–ray spectra was between 8.5 and 14 MK. The lower temperature limit is typical for a plasma contained in post flare loops observed in X–rays. Higher temperatures were observed during a secondary peak of emission corresponding to a small impulsive event. The SoHO/CDS observations performed in EUV Fe XIX line also confirm the presence of a hot plasma at temperatures similar to those obtained from RHESSI spectra. Besides, the EUV structures were located at the same place as RHESSI X–ray emission. The magnetic topology analysis of the AR coming from a linear force–free field extrapolation explains the observed features of the gradual phase of the flare i.e. the asymmetry of the ribbons and their fast propagation. The combination of the multi–wavelength observations with the magnetic model further suggests that the onset of the flare would be due to the reconnection of an emerging flux in a sheared magnetic configuration.

Key words. Sun: flares – Sun: X-rays – Sun: magnetic fields

- Del Zanna et al. (2004) in preparation

Papers – II

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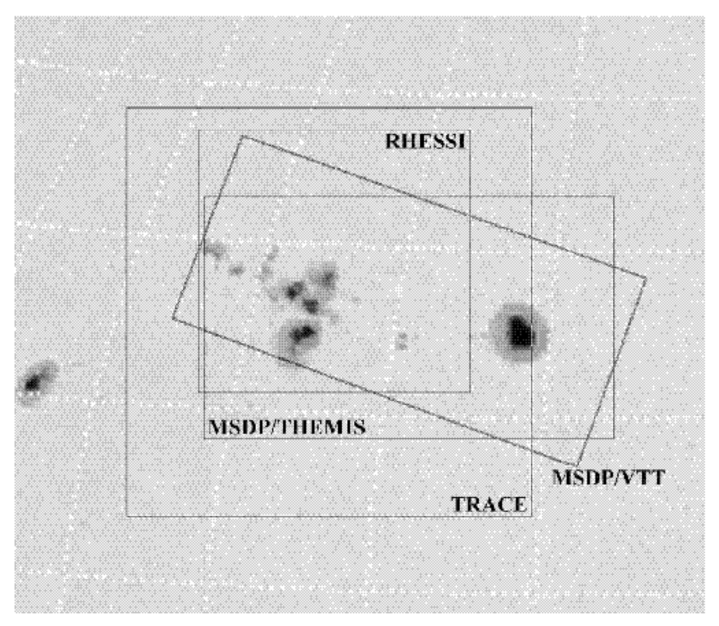
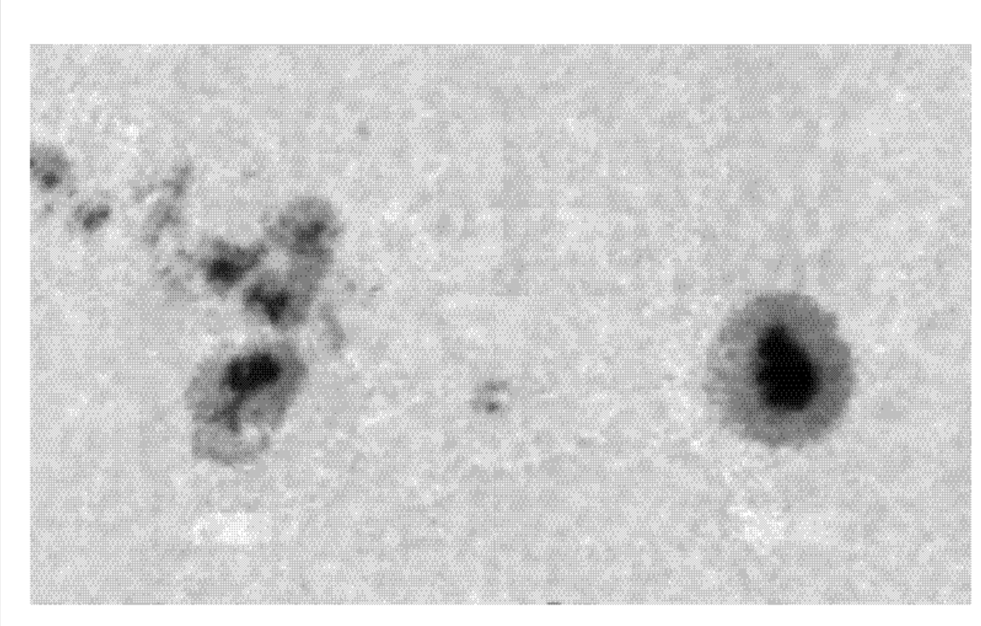
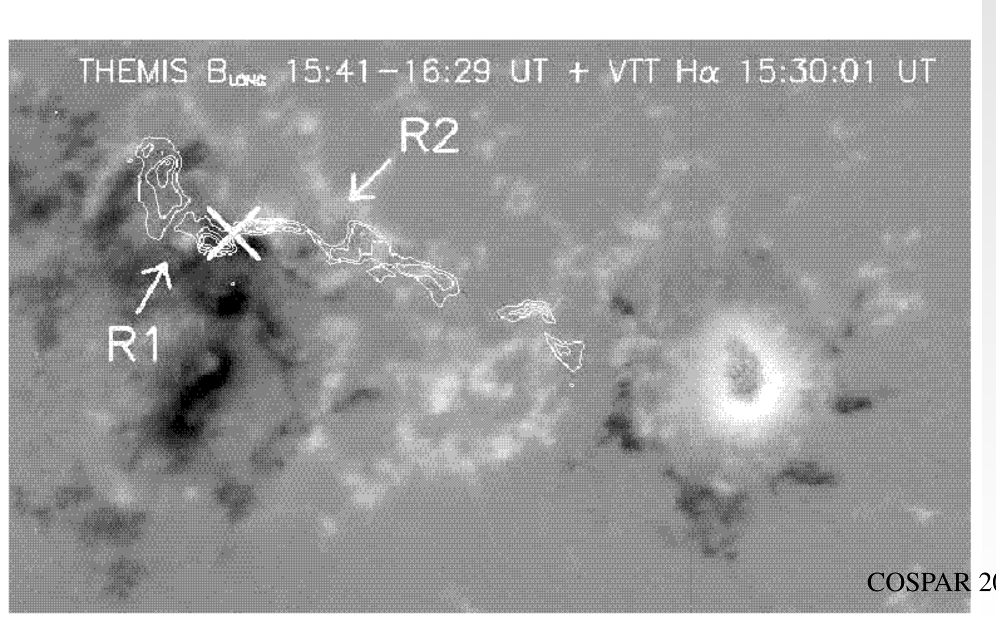
- On general aspects of quiescent ARs:
  -Del Zanna & Mason 2003, A&A, 406, 1089
  -Del Zanna 2003, A&A, 406, L5
- On chromospheric evaporation:
  -Mason et al. 1986, ApJ, 309,435
  -Zarro et al., 1988, ApJ, 333, L99
  -Del Zanna et al. (COSPAR 2000), 2002, Adv. Space Res., 30, 551
- Time dependent and non-equilibrium effects:
  -Bradshaw, Del Zanna & Mason, A&A, 2004, in press

Overview I


RHESSI
MSDP/THEMIS
MSDP/VTT
TRACE




THEMIS B 15:41–16:29 UT + VTT Hα 15:30:01 UT
R2
R1

Overview II

- THEMIS observed continuously between 15:41–17:26 UT.
- TRACE and VTT/MSDP observations were performed during the whole flare.
- VTT/MSDP observations in Hα 9 scans between 15:30 and 16:17 UT
- TRACE high cadence (40 s) in the 195 Å band between 15:29 and 15:41 UT

Overview III - GOES

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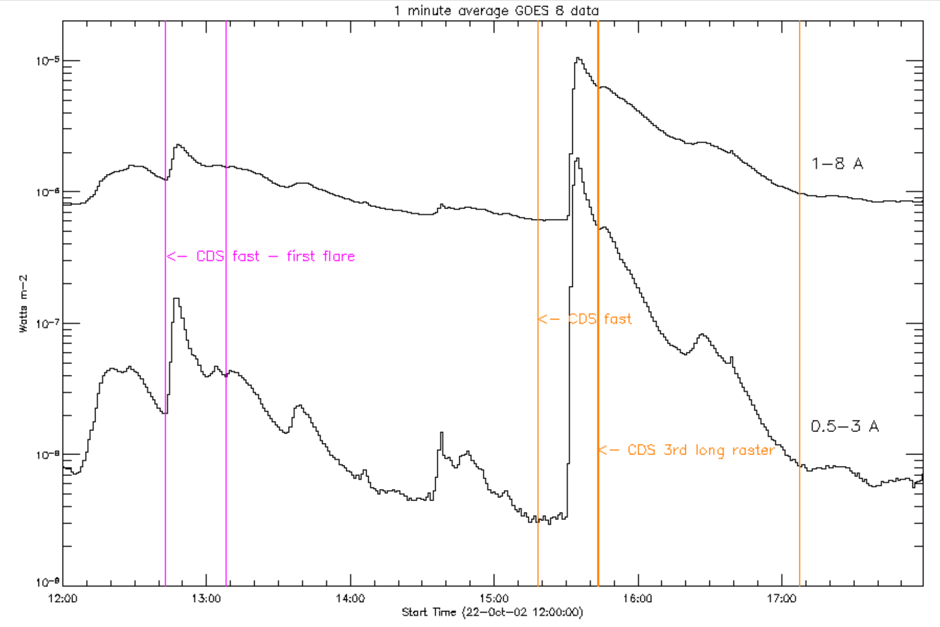

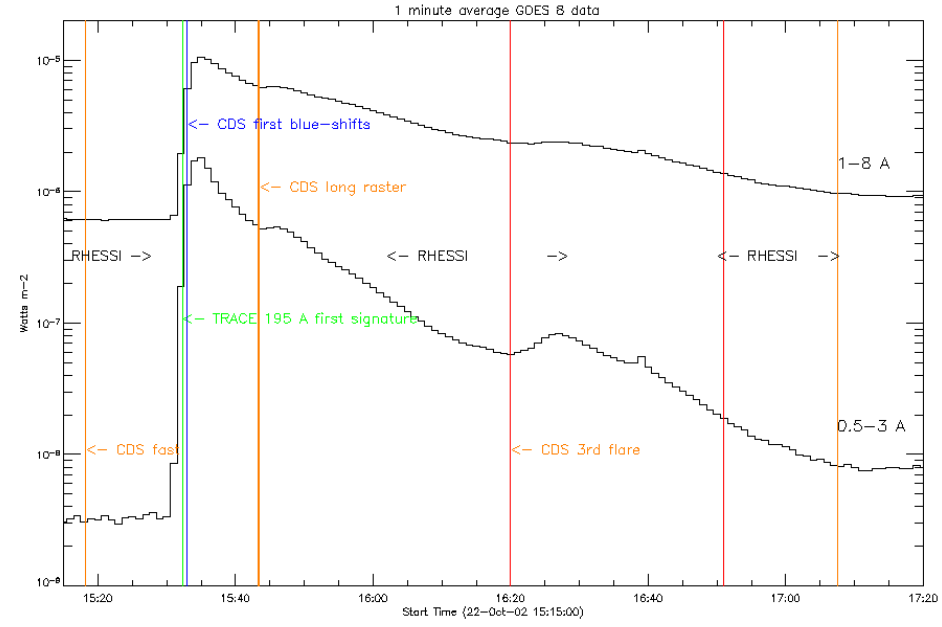

RHESSI

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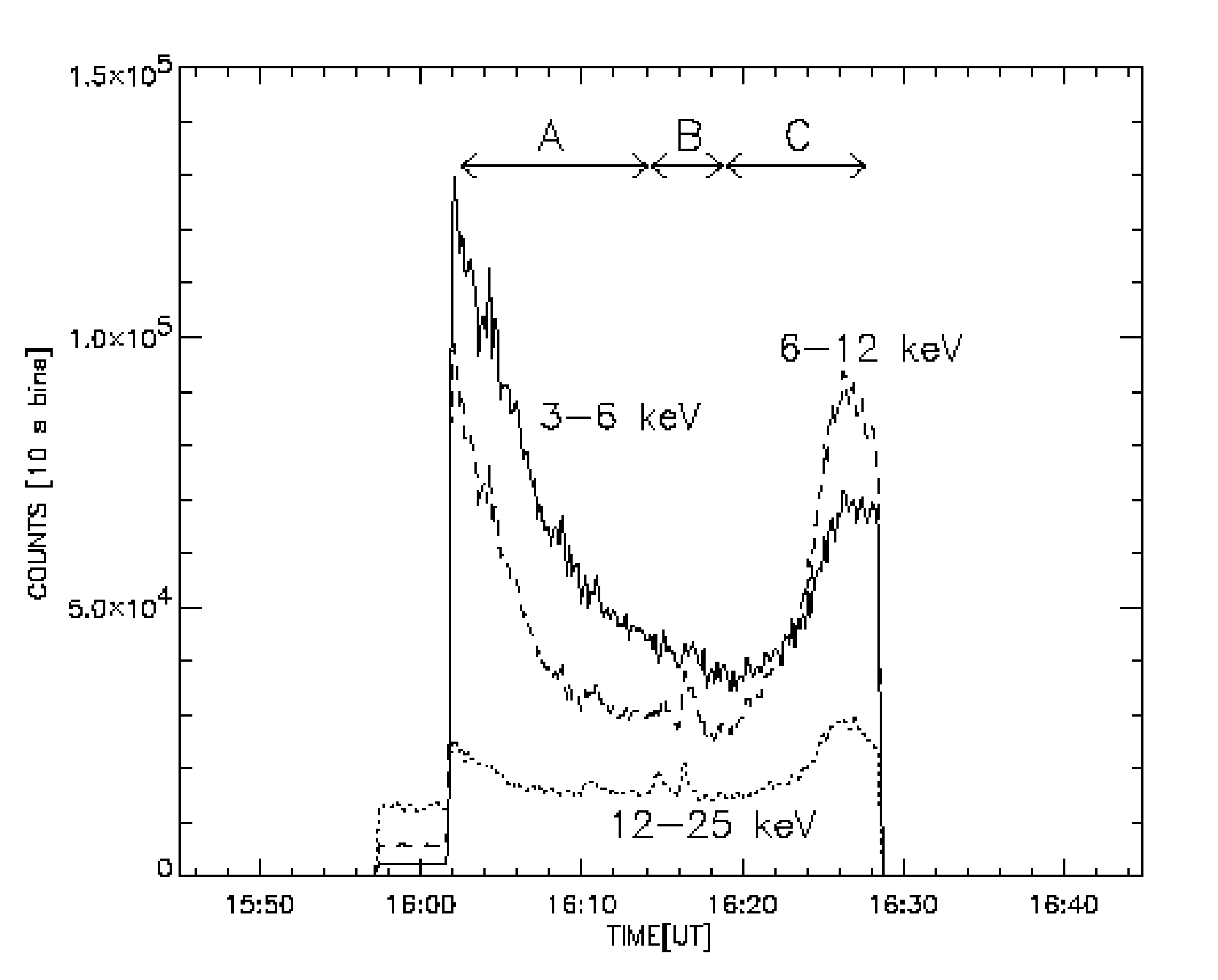
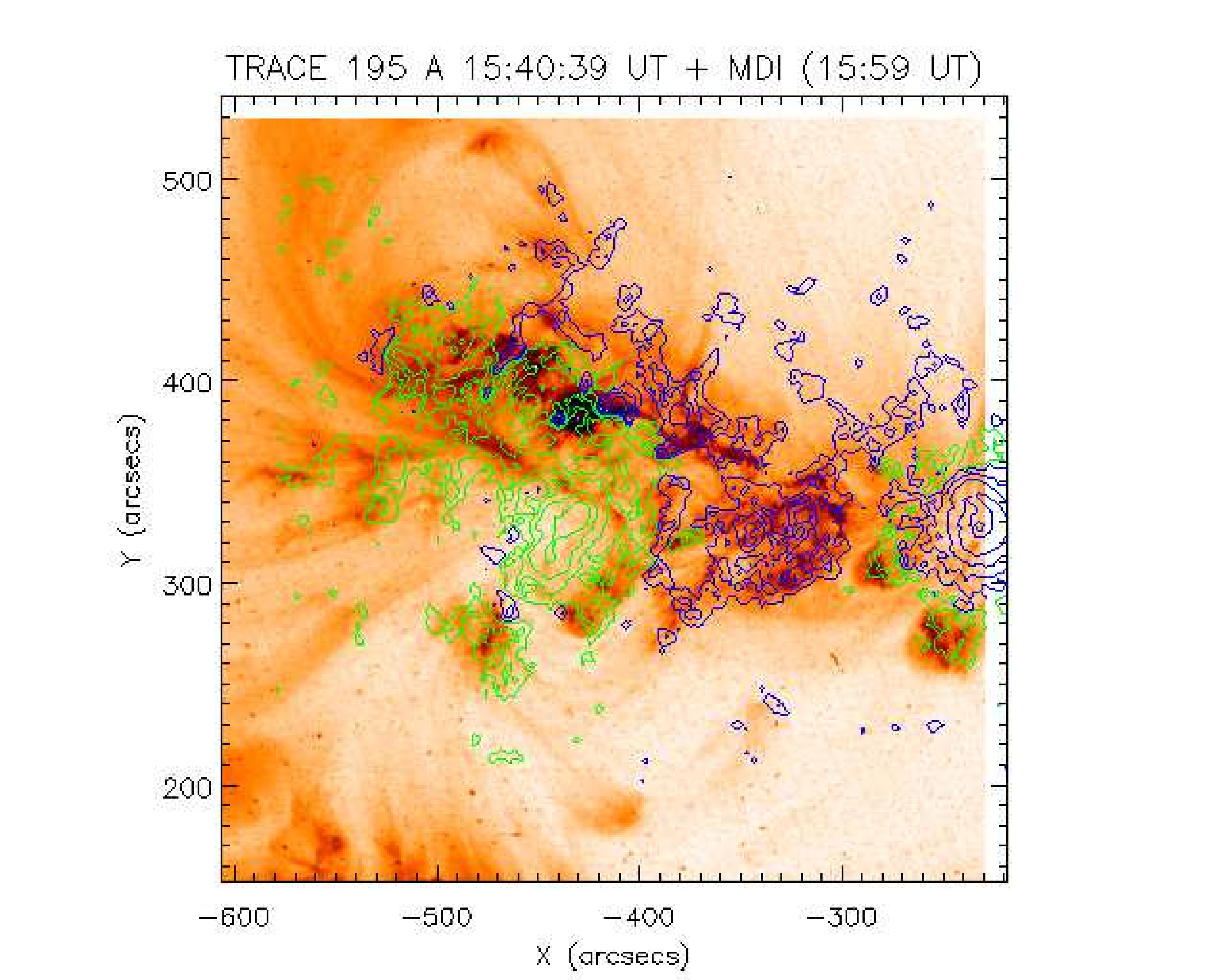
RHESSI counts rates (the 12–25 keV band are multiplied by a factor of 10).



Movies

MDI MDI movie
MDI - during the M1 flare MDI movie
TRACE 195 Å TRACE movie

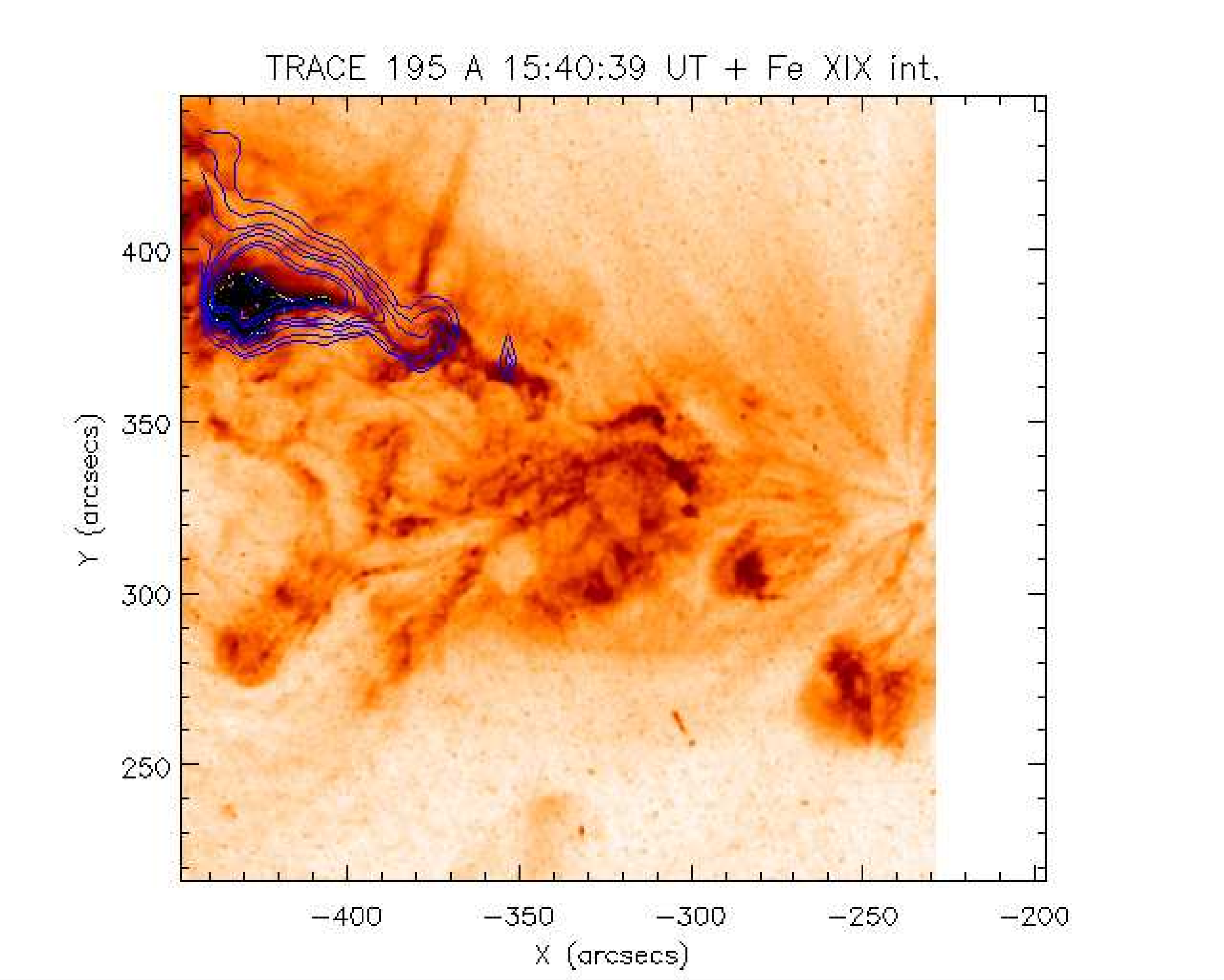
The M1 flare



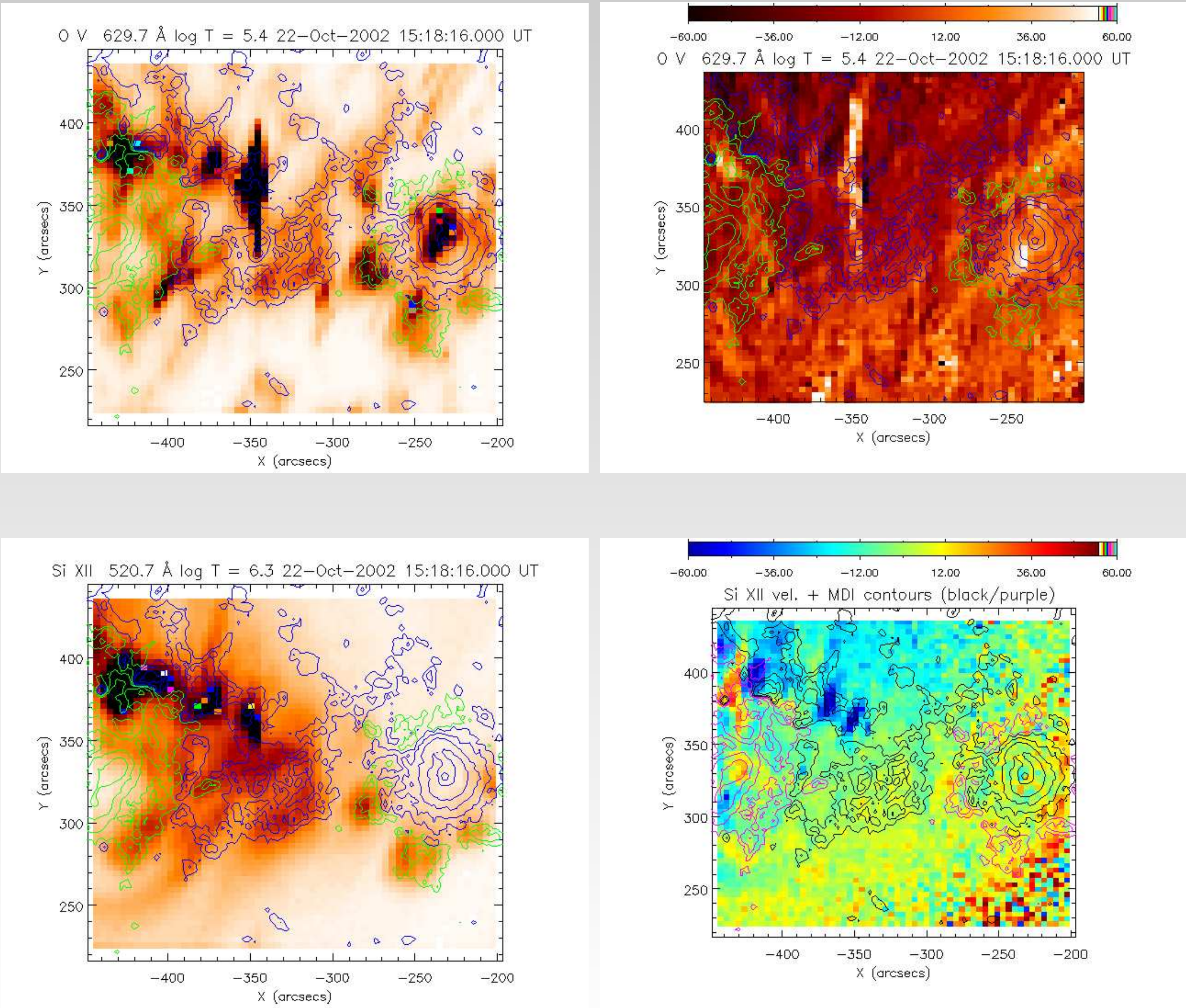
TRACE 195 A 15:40:39 UT + MDI (15:59 UT)
500
400
300
200
Y (arcsecs)
−600
−500
−400
−300
X (arcsecs)

The M1 flare

CDS FOV - TRACE 195 Å + contours of Fe XIX intensity



The M1 flare - CDS



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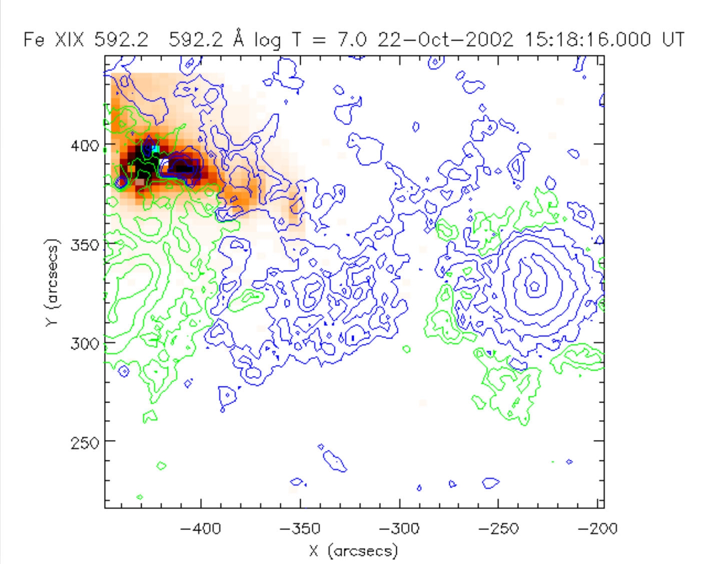
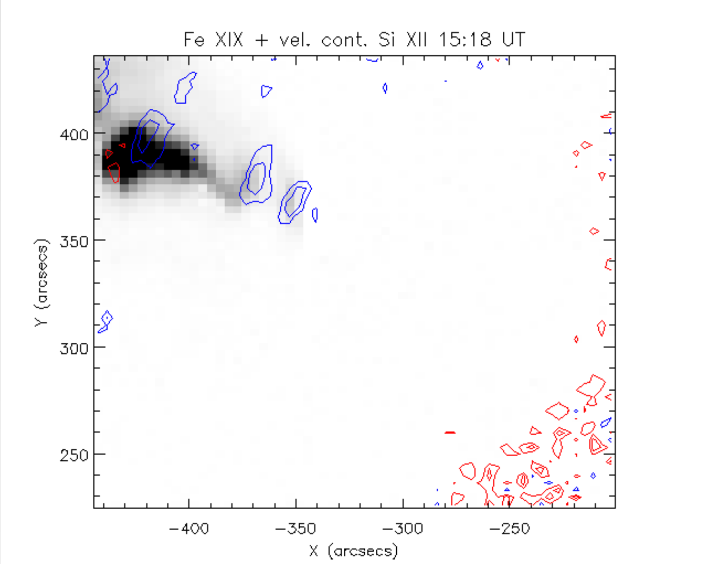
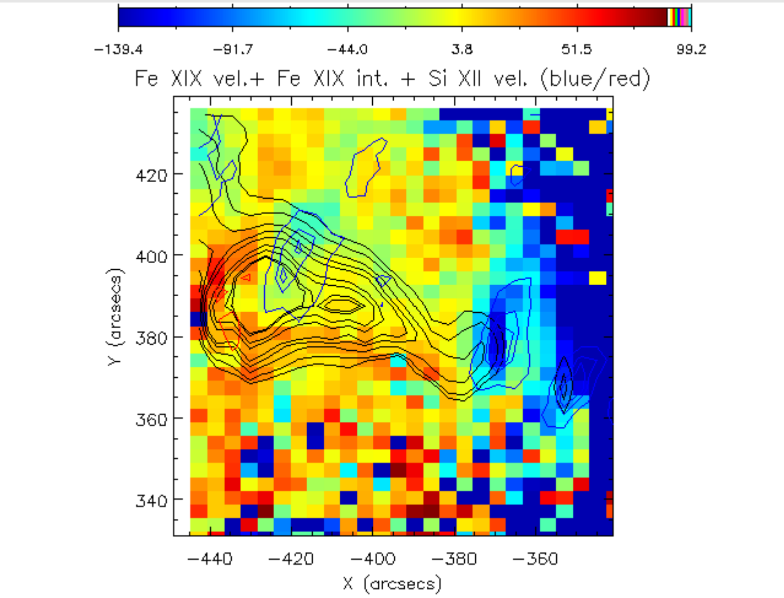
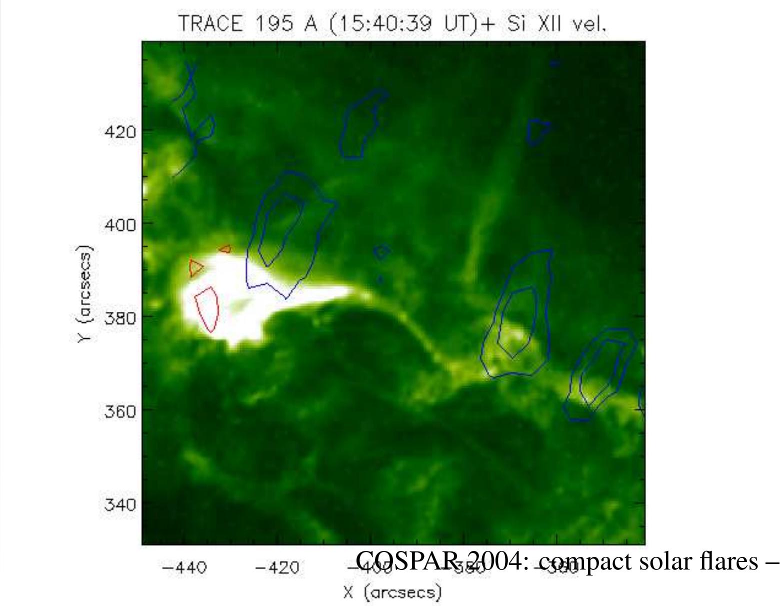
The M1 flare - CDS – Zoom in









Wavelength calibration

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The wavelength calibration was remarkably stable.
Uncertainty in the derivation of velocities of the order of 5–10 km/s.

λ_{st} (Å)	520.665	522.210	542.07	550.06	553.34	555.263	557.765	558.594	562.803	592
λ (s26055)	520.675	522.208	542.031	550.070	553.365	555.252	557.758	558.590	562.791	592
v (s26055)	5	-1	-21	5	13	-6	-3	-2	-6	-
λ (s26059)	520.664	522.211	542.061	550.066	553.354	555.260	557.769	558.622	562.812	592
v (s26059)	0	0	-4	3	7	-1	1	15	5	-

The Fe XIX case

Our calibration, based on this small sample, provides a wavelength of 592.16 Å, in excellent agreement with Skylab measurements.
Lawson & Peackok (1980) reviewed $n = 2 \rightarrow n = 2$ transitions, and suggested an energy for the 2s 2 2p 4 $^1D_2$ level of 168770 cm^{-1}.
$\rightarrow \lambda = 592.522$ Å
$\rightarrow$ the considerable difference of 183. km/s compared to our result.

Selected areas

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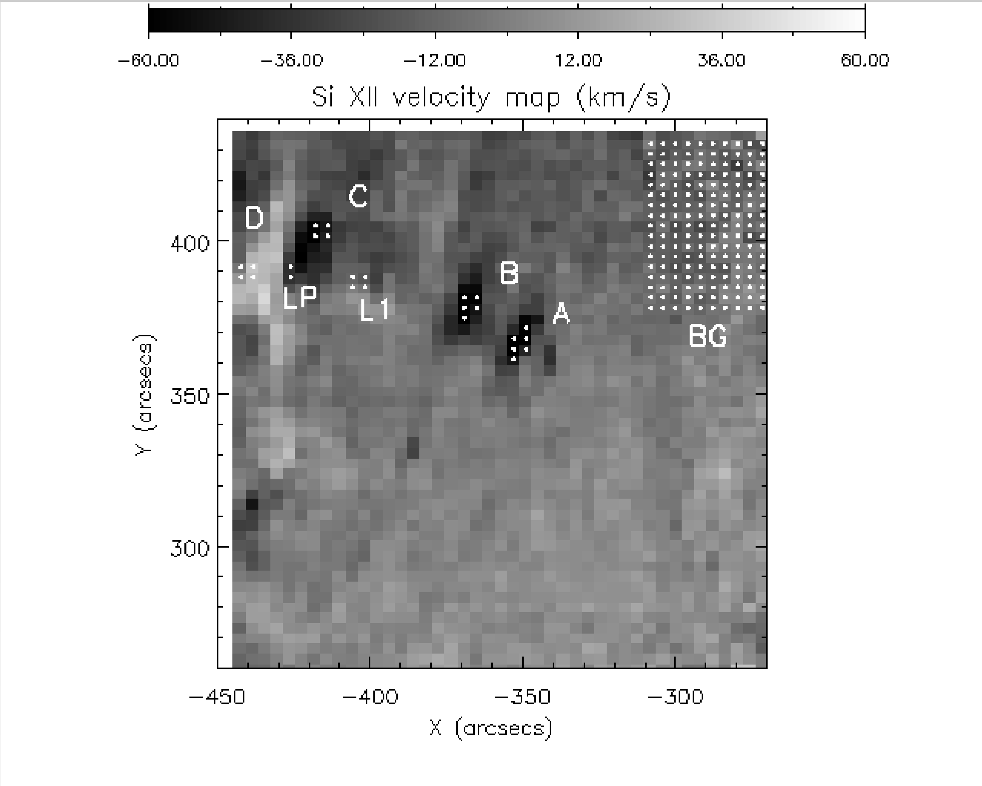

Si XII velocity map, with the areas selected for further analysis. Areas A,B,C correspond to regions of strong blue-shifts, while area D of red-shift. Region LP corresponds to the area of peak Fe XIX intensity, while region L1 is where the central part of the flare loop is located. Region BG is a ‘background’ reference region.

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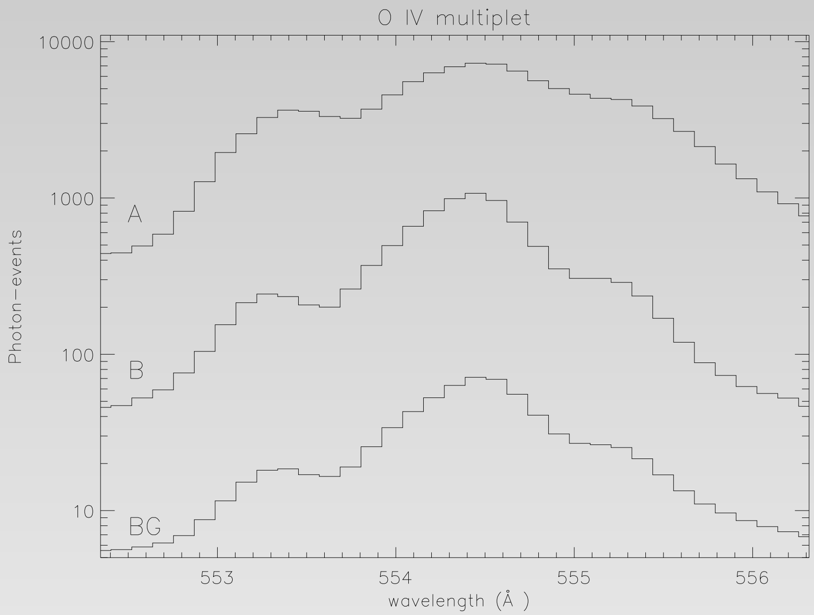
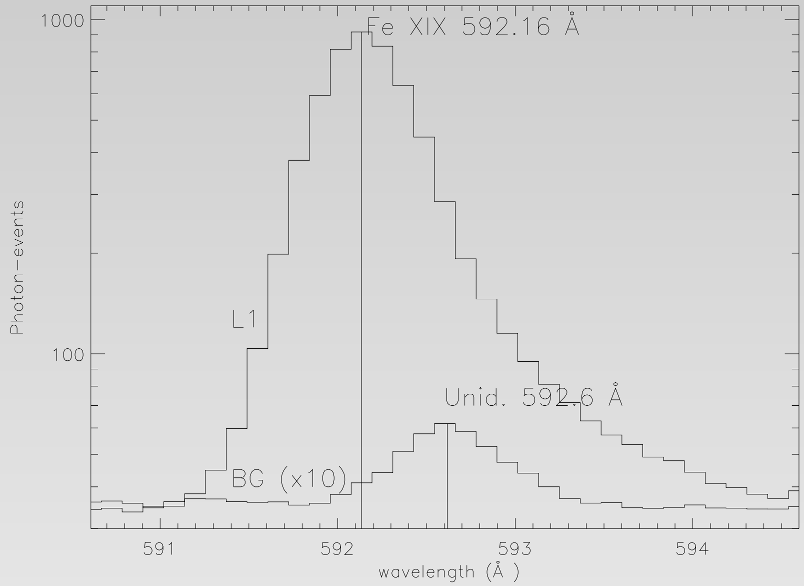
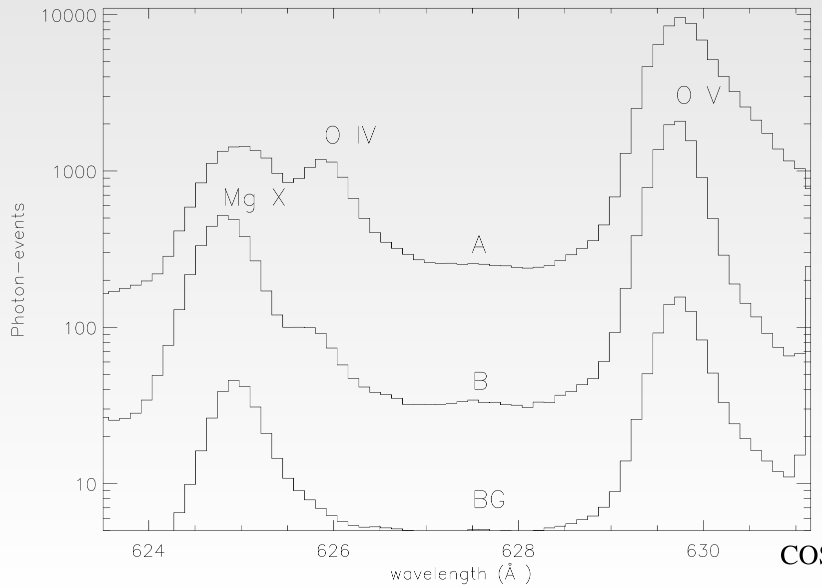
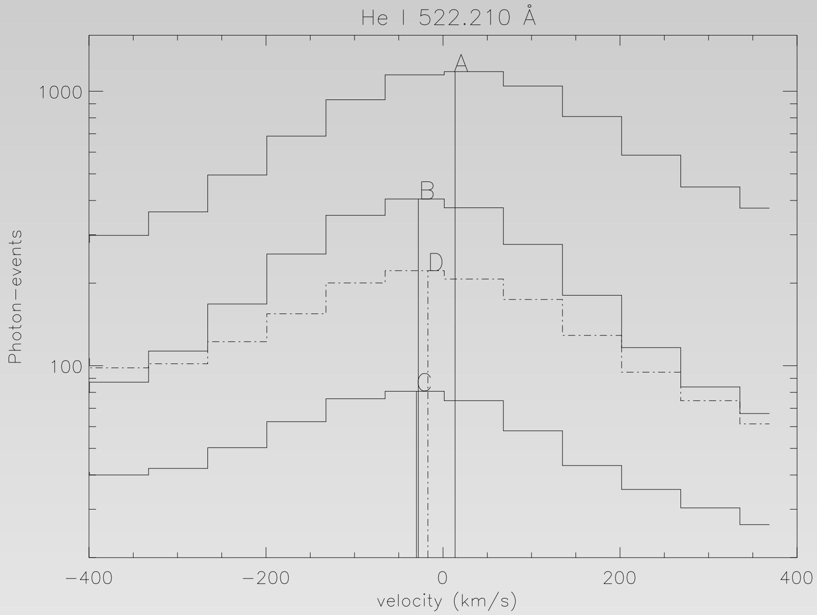
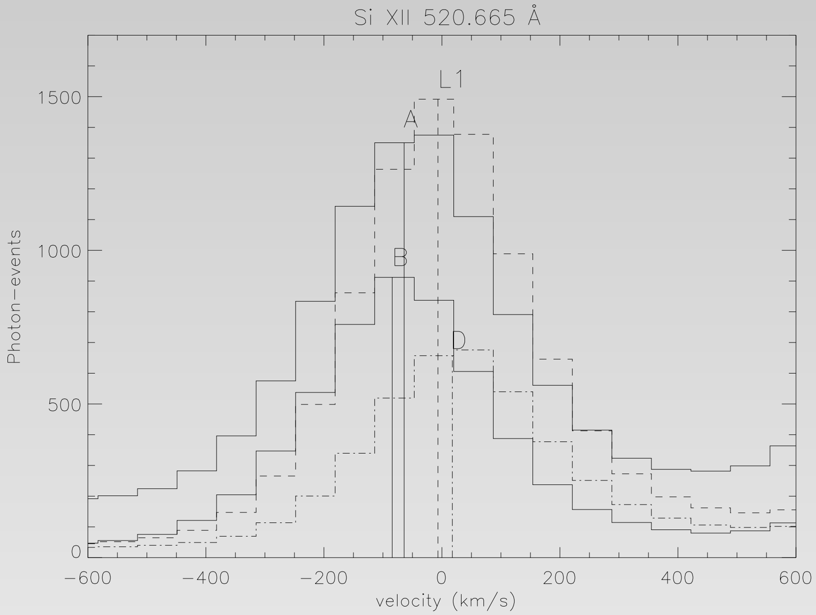
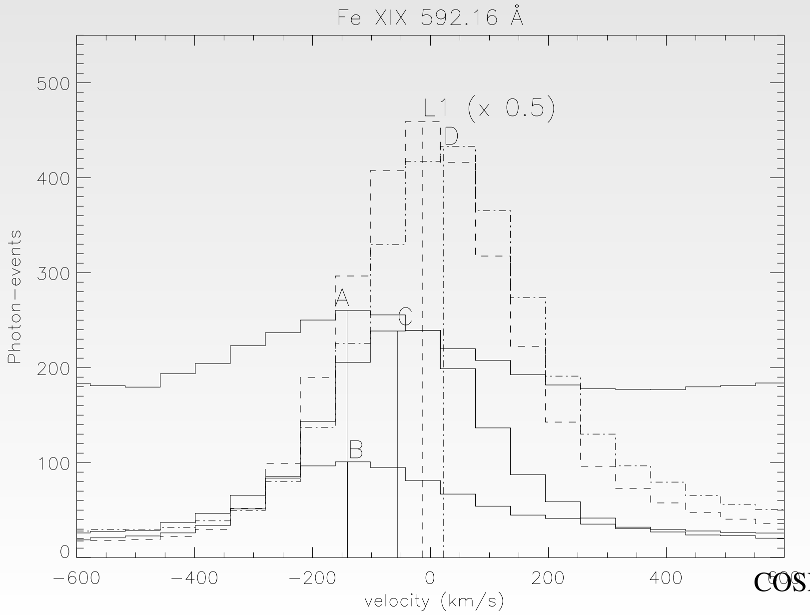







He I 522.210 Å
Photon−events
velocity (km/s)
1000
100
−400
−200
0
200
400
A
B
C
D


Si XII 520.665 Å
Photon−events
velocity (km/s)
1500
1000
500
0
−600
−400
−200
0
200
400
600
L1
A
B
D


Fe XIX 592.16 Å
Photon−events
velocity (km/s)
500
400
300
200
100
0
−600
−400
−200
0
200
400
L1 (x 0.5)
D
A
C
B

Region	A	B	C	D	L1	LP	BG
v He I (km/s)	13	-27	-30	-17			
v Si XII (km/s)	-64	-84	-54	17	-6	-40	
v Fe XIX (km/s)	-141	-140	-56	22	-13	-26	-

Post-flare CDS raster 15:43–17:07 UT

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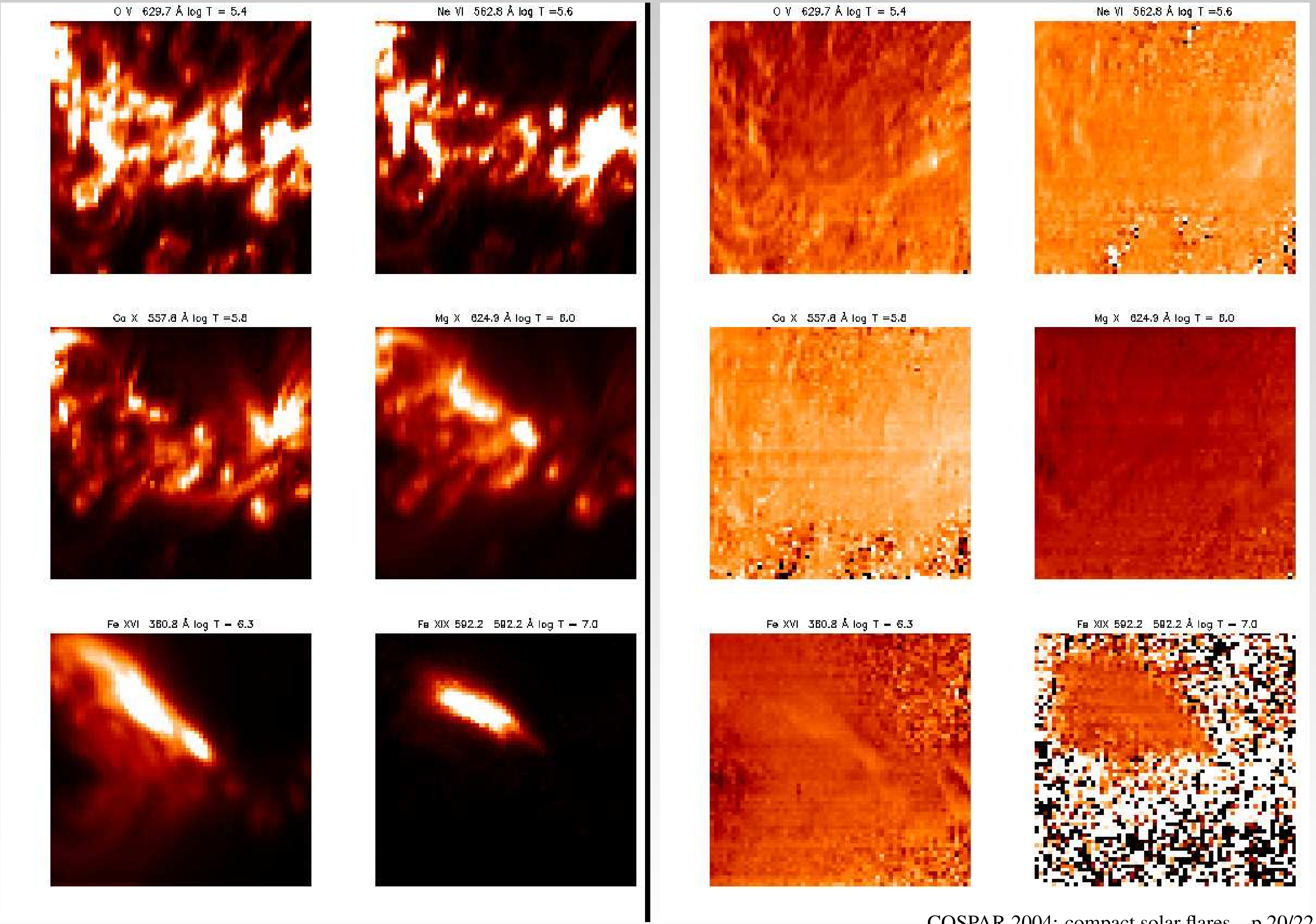
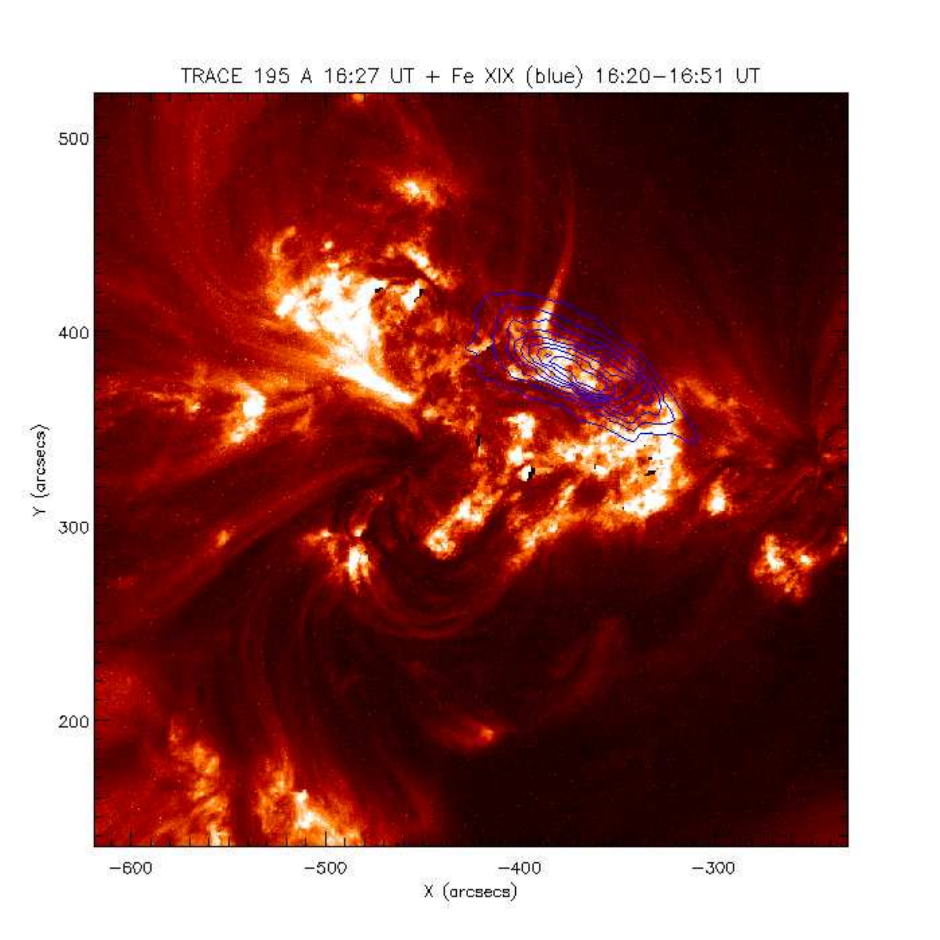
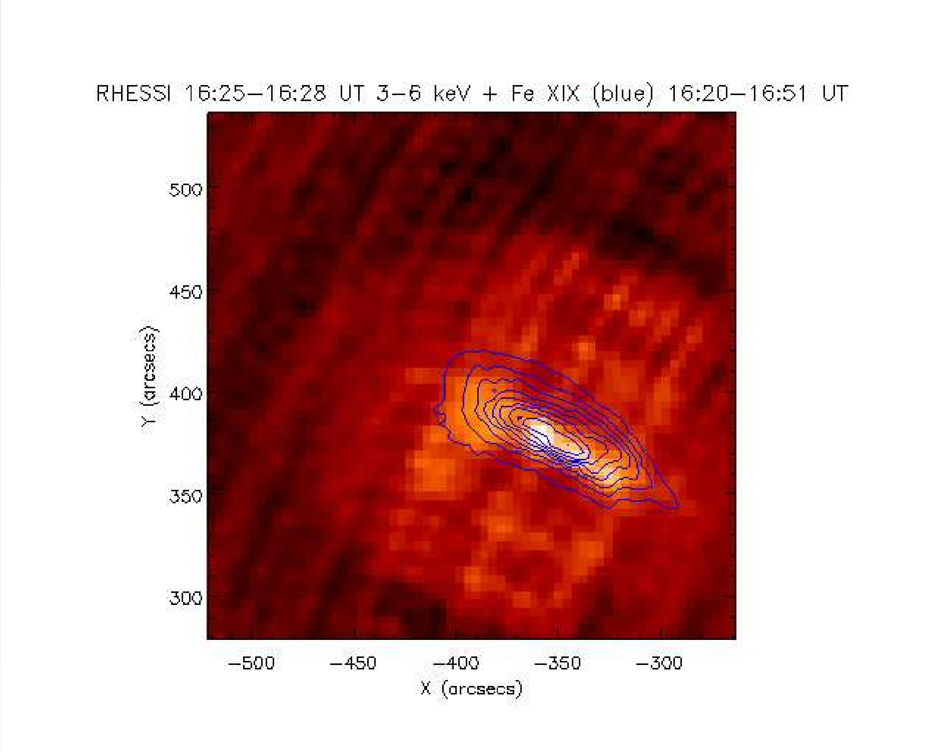


Post-flare CDS raster – II





Summary of preliminary results

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- Strong blue-shifts in lines emitted in the 1-8 MK range are observed at the bases of hot Fe XIX structures.
- The hot structures are also clearly visible in the TRACE 195 Å band
- The hot structures match the thermal emission as seen by RHESSI
- The peak Fe XIX emission, recorded between 15:35 and 15:43 UT, occurred just above the region of strong mixed polarity.
- The TRACE 195 Å emission is co-spatial with the CDS Fe XIX emission, which suggests that the bulk of the TRACE 195 Å emission at the flare site is due to Fe XXIV.
- Transition region densities can be estimated using O IV.

Acknowledgements
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