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Spectroscopic observations of compact solar flares

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Introduction

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- The SOHO/Coronal Diagnostic Spectrometer provides essential spectroscopic information to understand the characteristics and dynamics of solar coronal features.
- We give a description of the main observational features and what types of measurements (densities, temperatures, flows) are obtained.
- These provide important observational constraints for flare modeling.
- 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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- Berlicki et al., A&A

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) submitted

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

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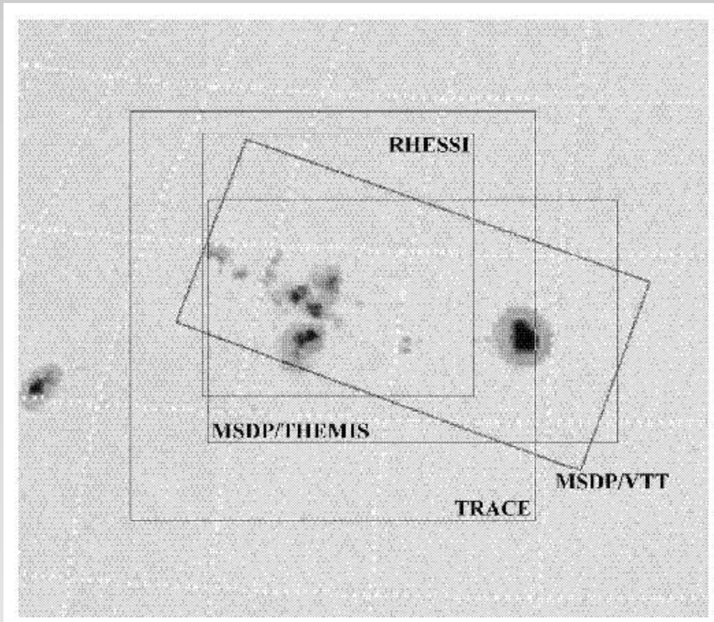
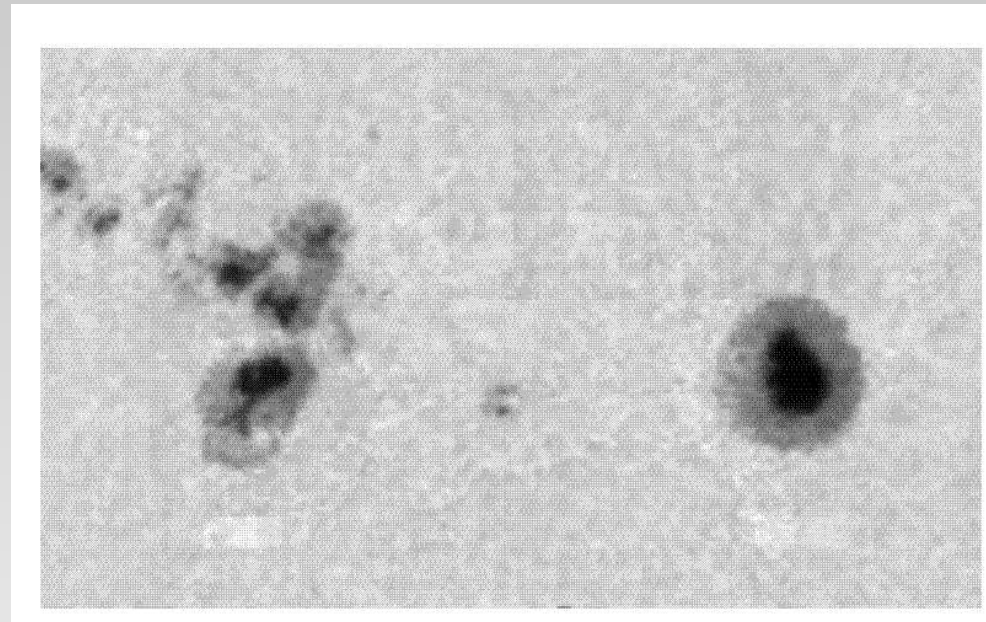
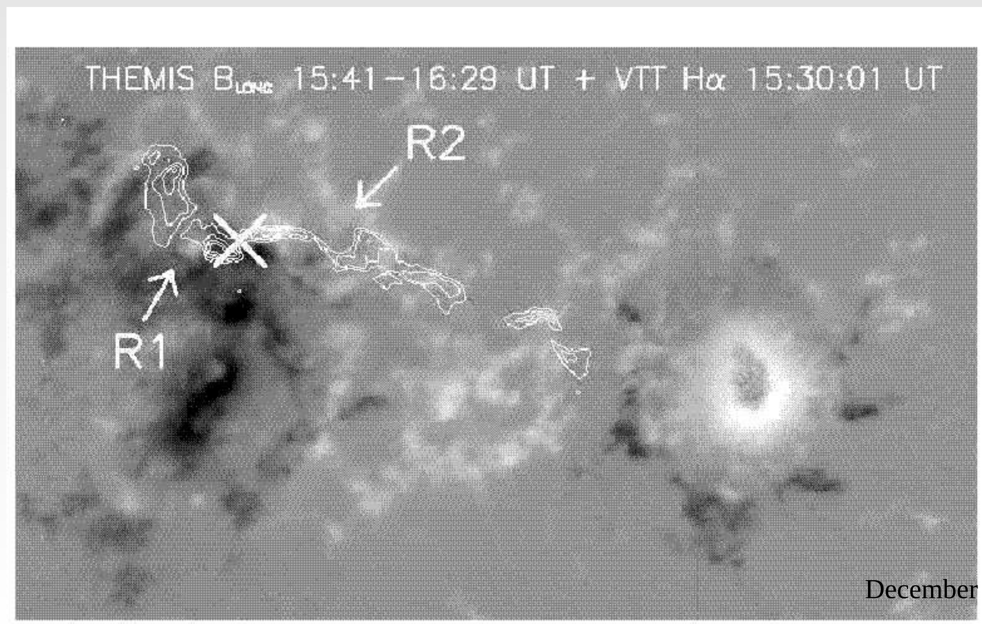


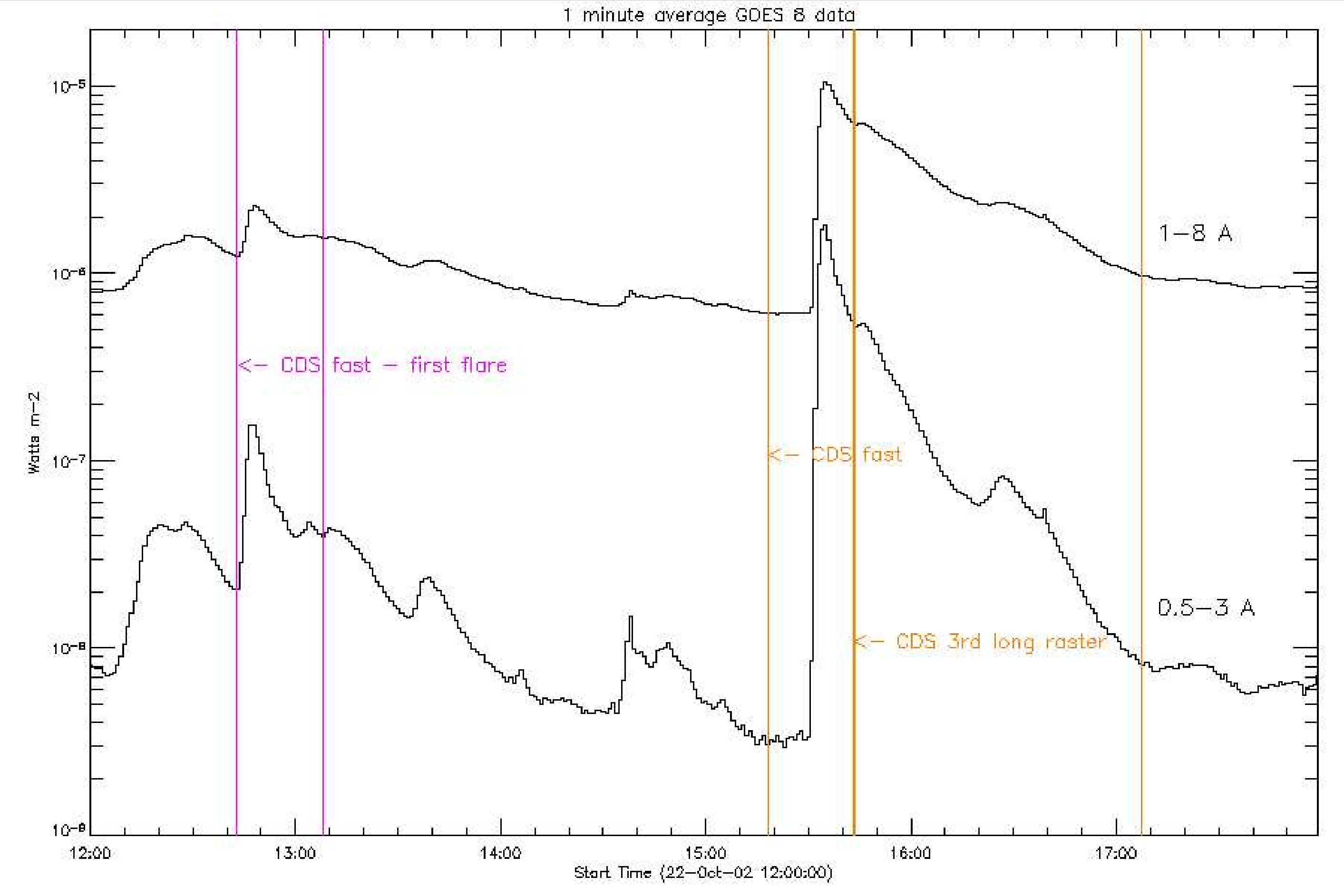




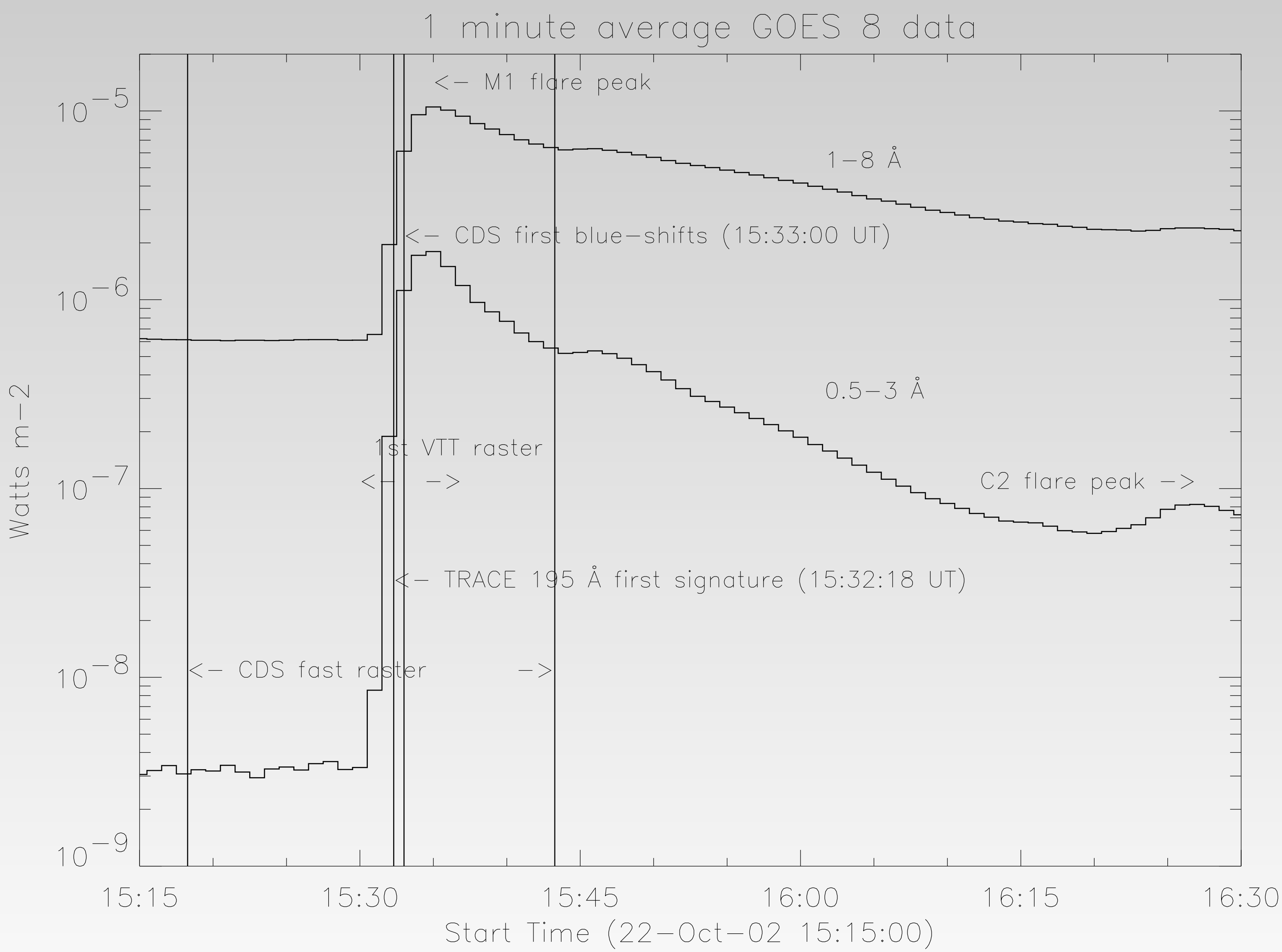
Overview II

- 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

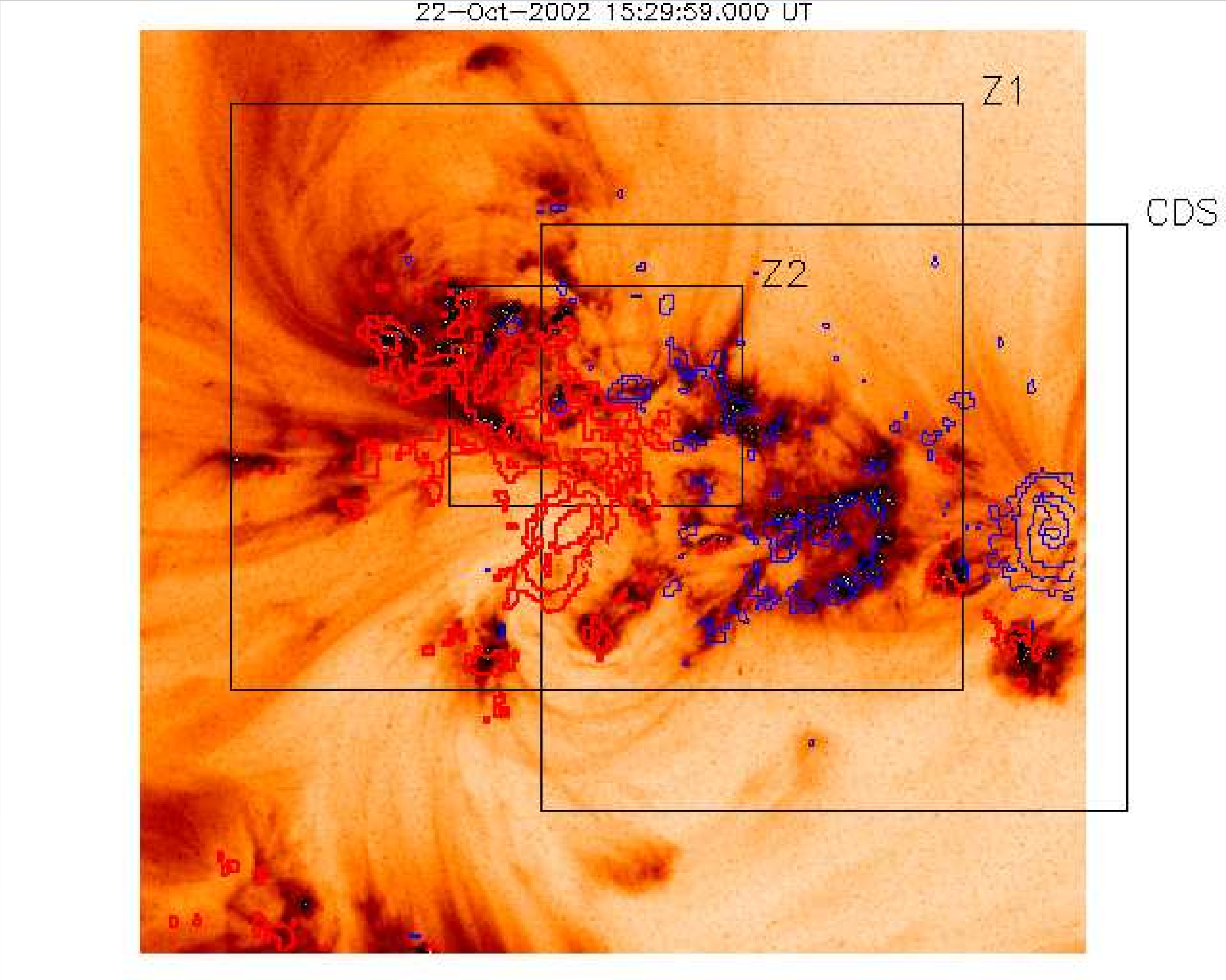


Overview III - GOES

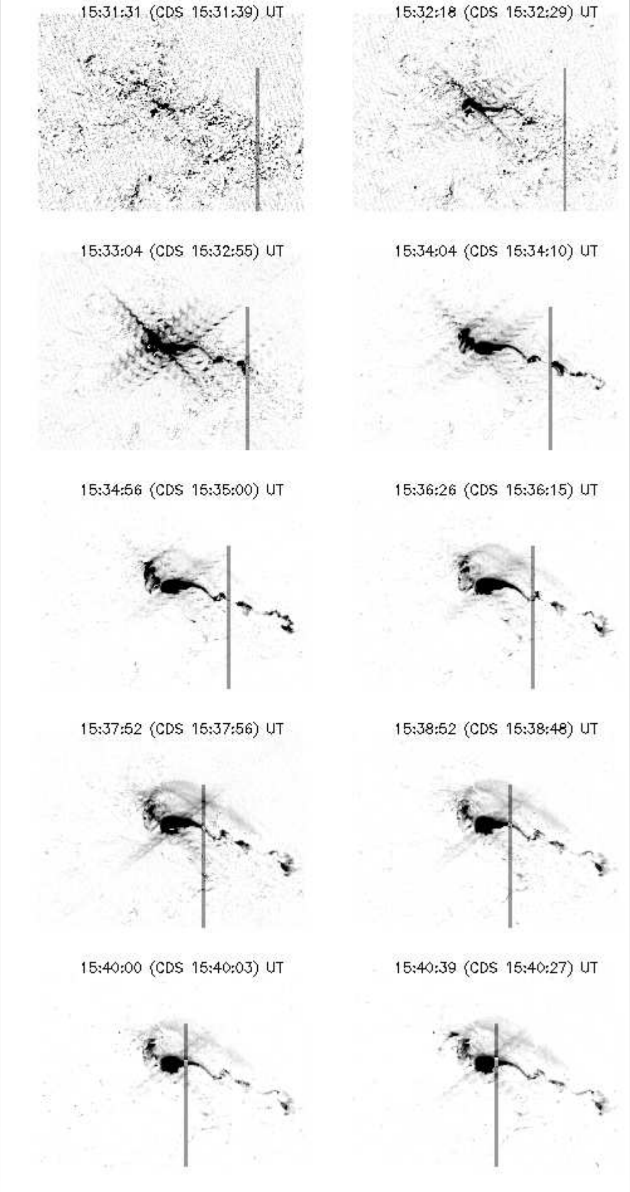


The AR before the M1 flare

TRACE 195 Å with MDI contours

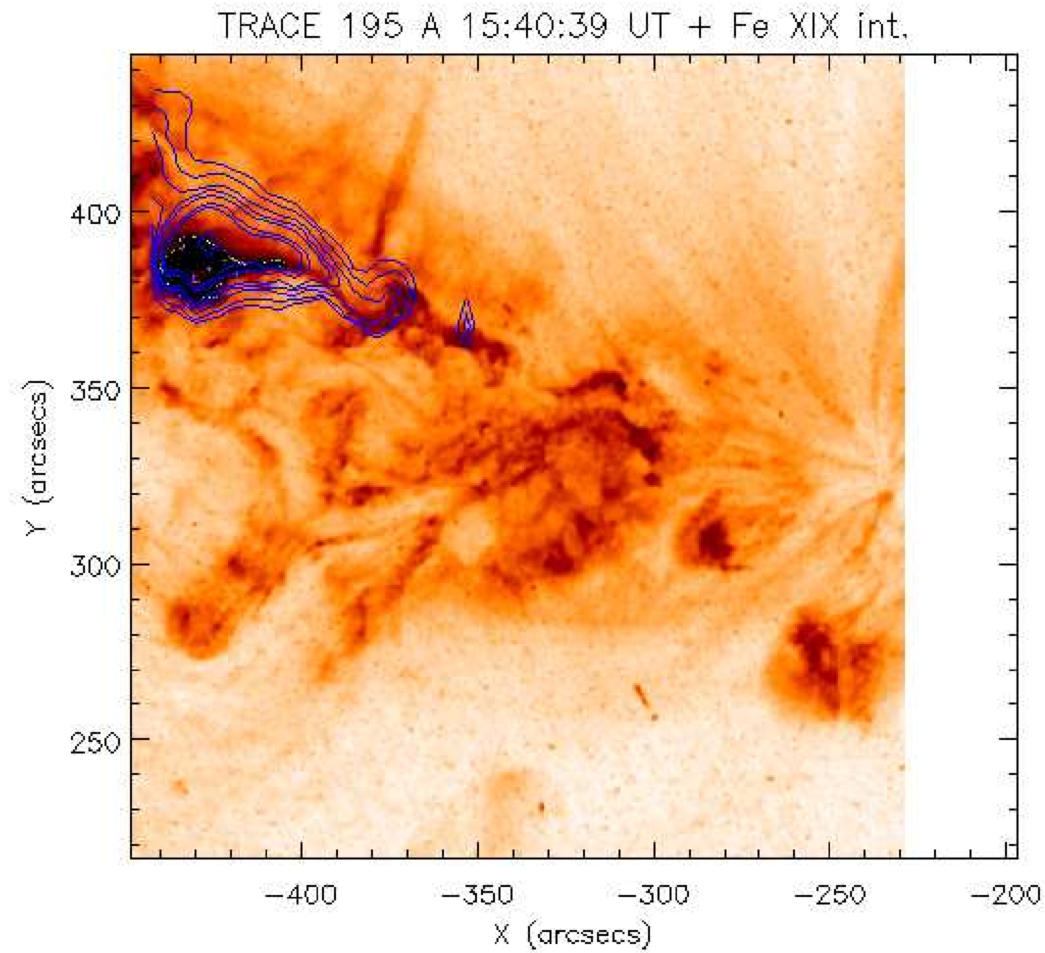


The M1 flare - TRACE (area Z1)

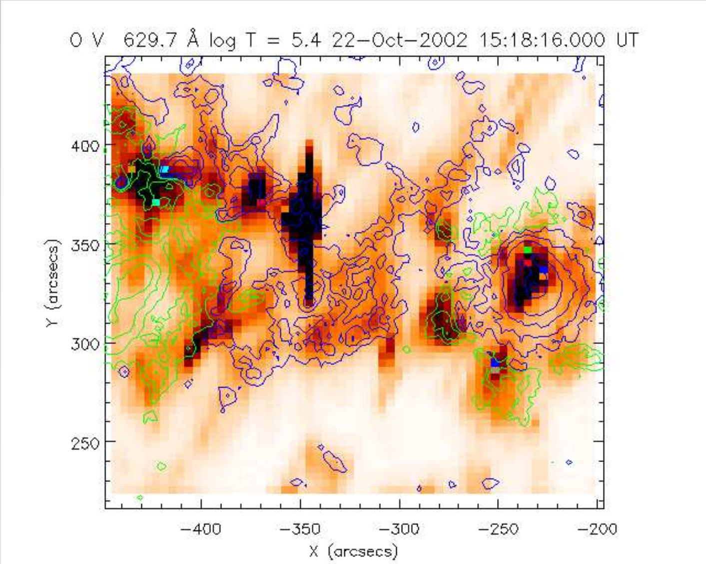


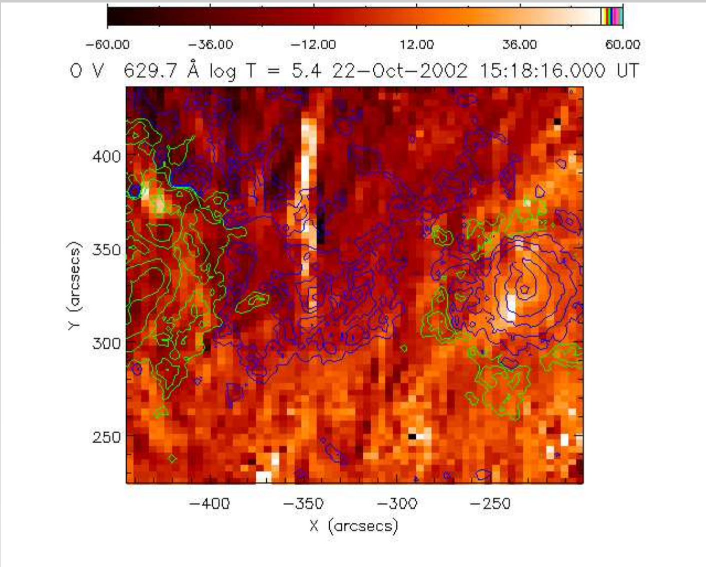
The M1 flare

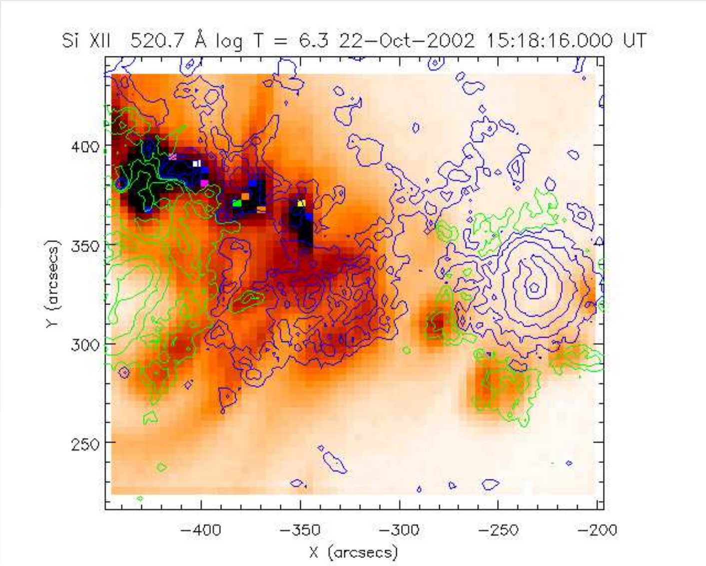
CDS FOV - TRACE 195 Å + contours of Fe XIX intensity

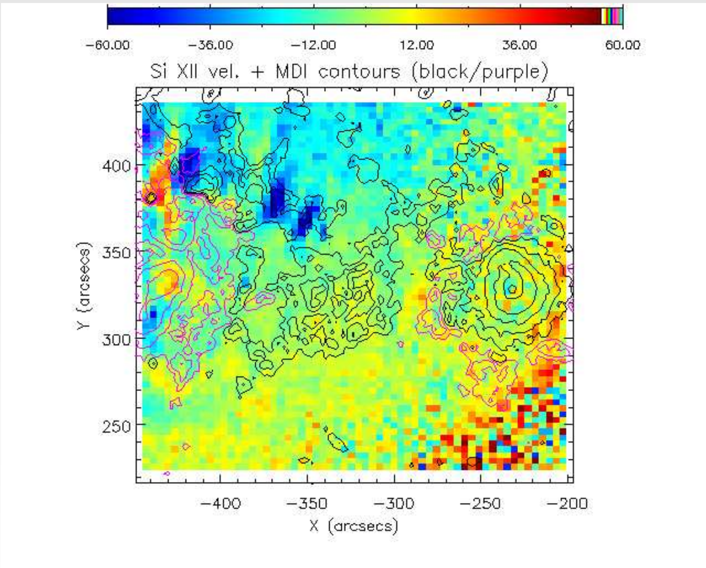


The M1 flare - CDS









The M1 flare - CDS – Zoom in

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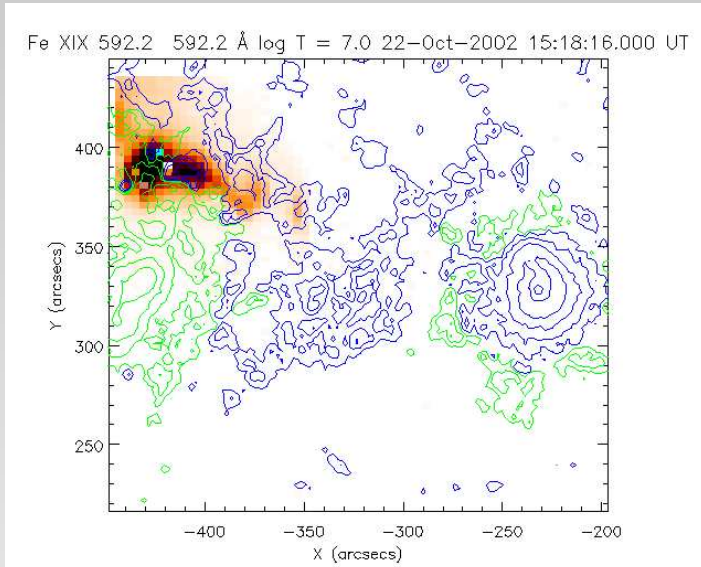

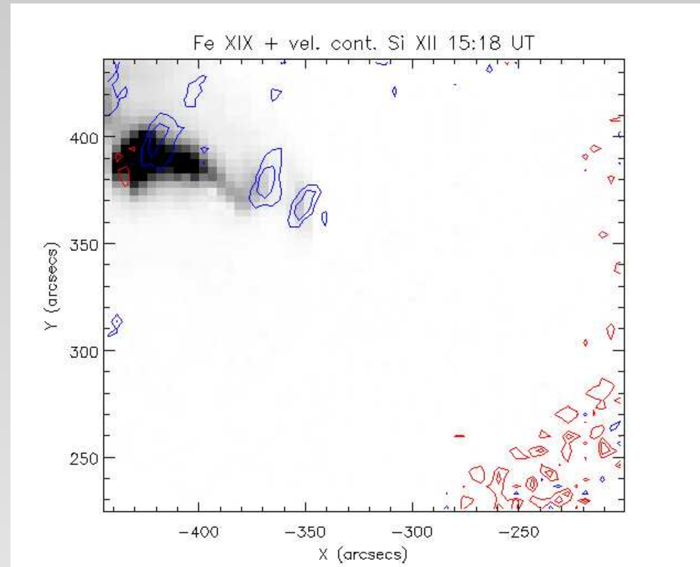

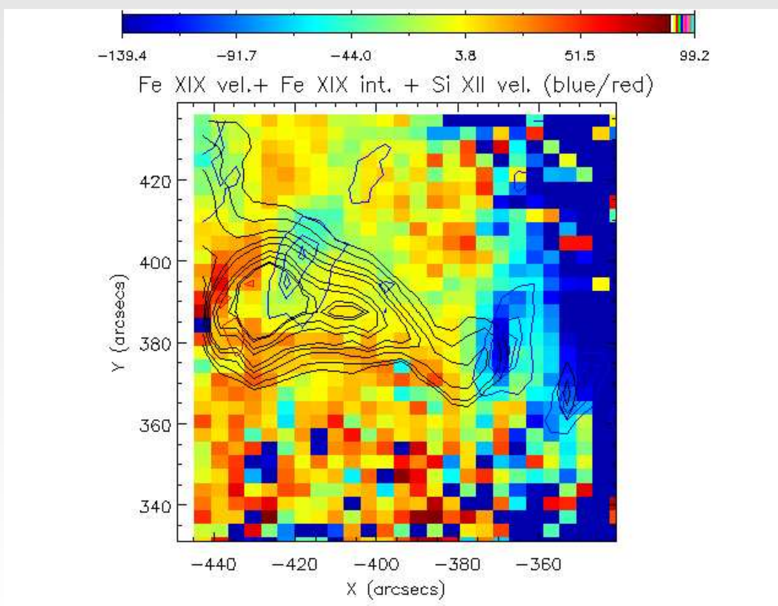

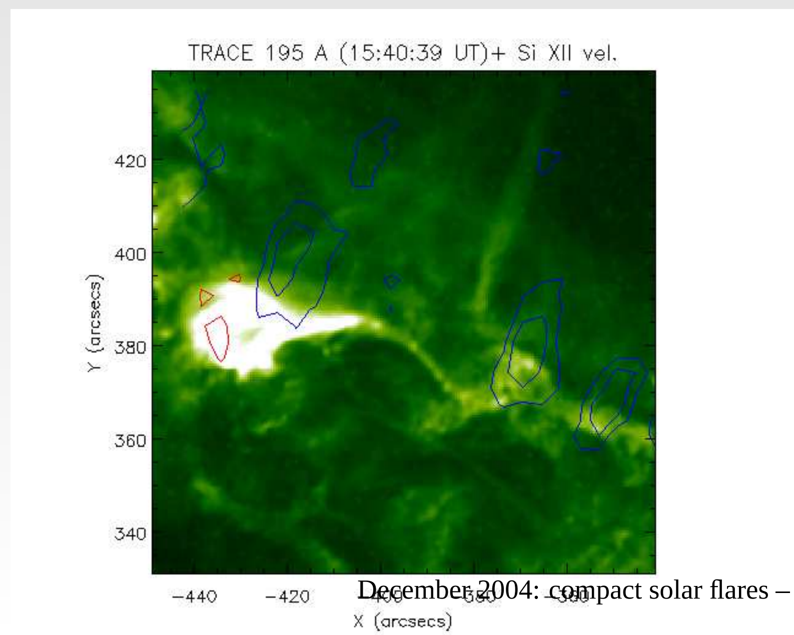

Wavelength calibration

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The wavelength calibration was remarkably stable.

Uncertainty in the derivation of velocities of the order of 5–10 km/s.

	Si XII	He I	Ne IV	Al XI	O IV	Ca X	Ne VI	Fe XII	Mg X	C
λ_{st}	520.665	522.210	542.07	550.06	555.263	557.765	562.803	592.60	624.941	629
λ_1	520.675	522.208	542.031	550.070	555.252	557.758	562.791	592.590	624.936	629
v_1	5	-1	-21	5	-6	-3	-6	-5	-2	
λ_2	520.664	522.211	542.061	550.066	555.260	557.769	562.812	592.597	624.932	629
v_2	0	0	-4	3	-1	1	5	-1	-4	

Selected areas

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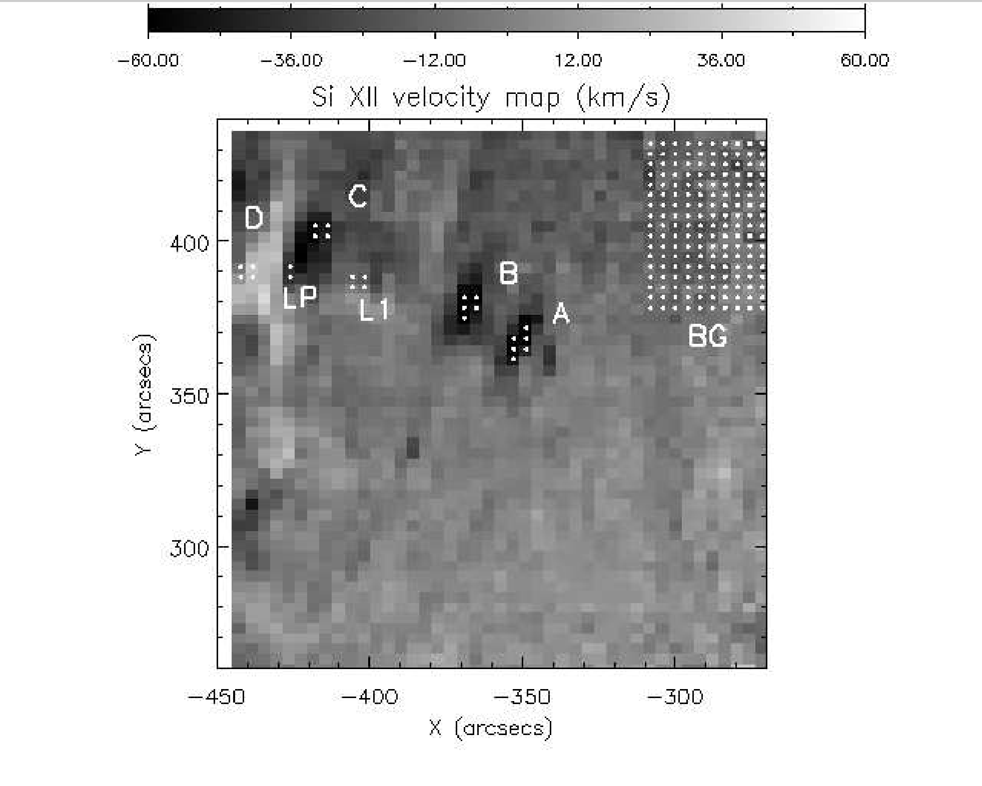

Si XII velocity map, with the areas selected for further analysis. Areas A,B,C correspond to regions of strong blue-shifts, while area D of red-shift. Region LP corresponds to the area of peak Fe XIX intensity, while region L1 is where the central part of the flare loop is located. Region BG is a ‘background’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

The Fe XIX case

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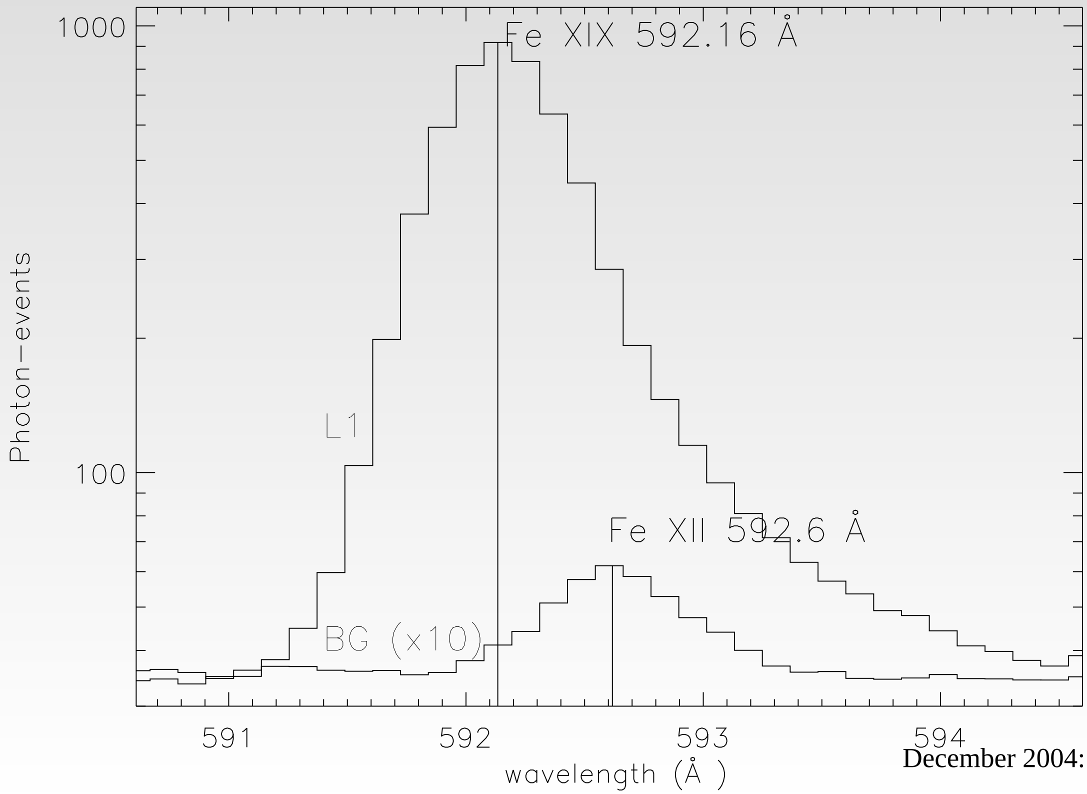
Our calibration, based on this small sample, provides a wavelength of 592.16 Å, in excellent agreement with Skylab measurements.
Lawson & Peackok (1980) reviewed $n = 2 \rightarrow n = 2$ transitions, and suggested an energy for the 2s 2 2p 4 $^1D_2$ level of 168770 cm^{-1}.
$\rightarrow \lambda = 592.522$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



Densities from O IV

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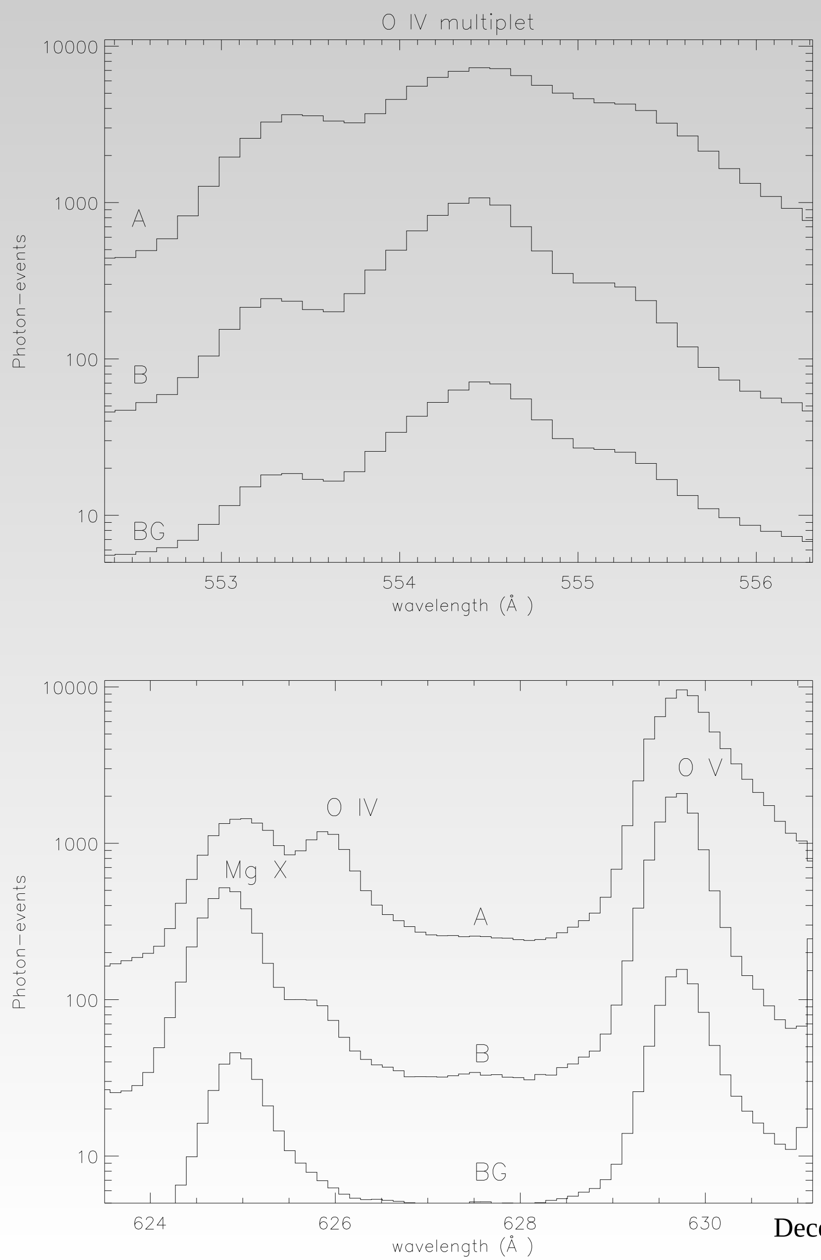
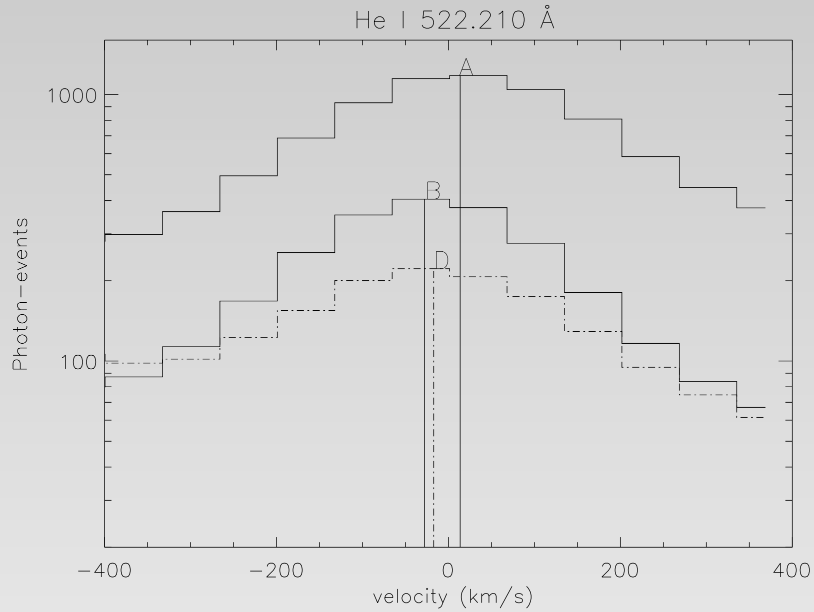
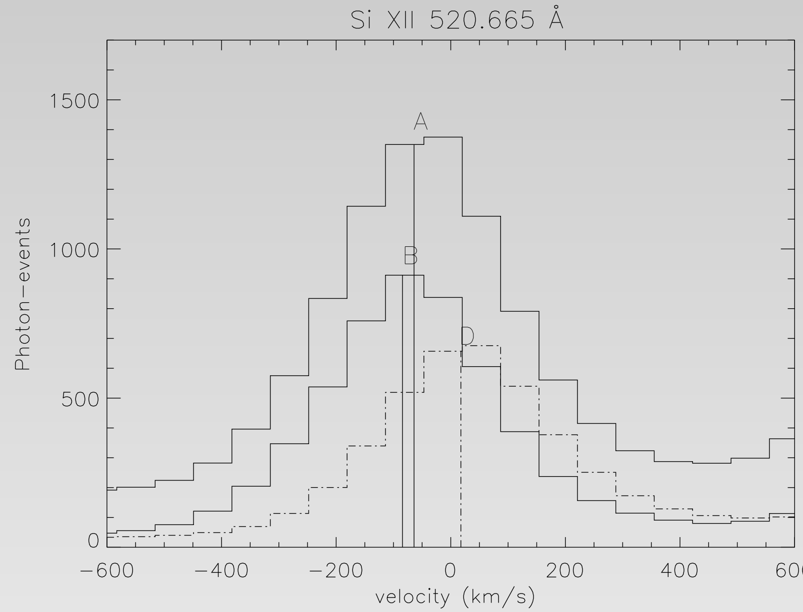
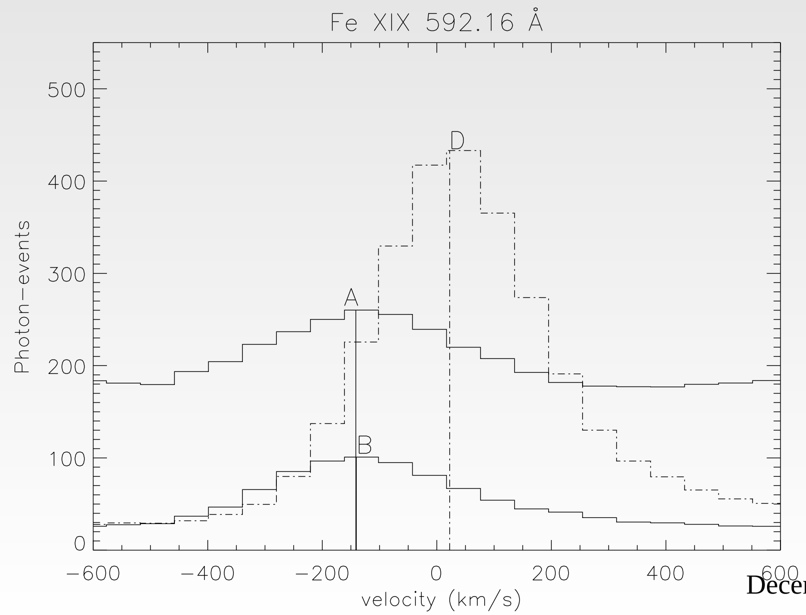



He I 522.210 Å
Photon−events
velocity (km/s)
A
B
D


Si XII 520.665 Å
Photon−events
velocity (km/s)
A
B
D


Fe XIX 592.16 Å
Photon−events
velocity (km/s)
A
B
D

Velocities, densities

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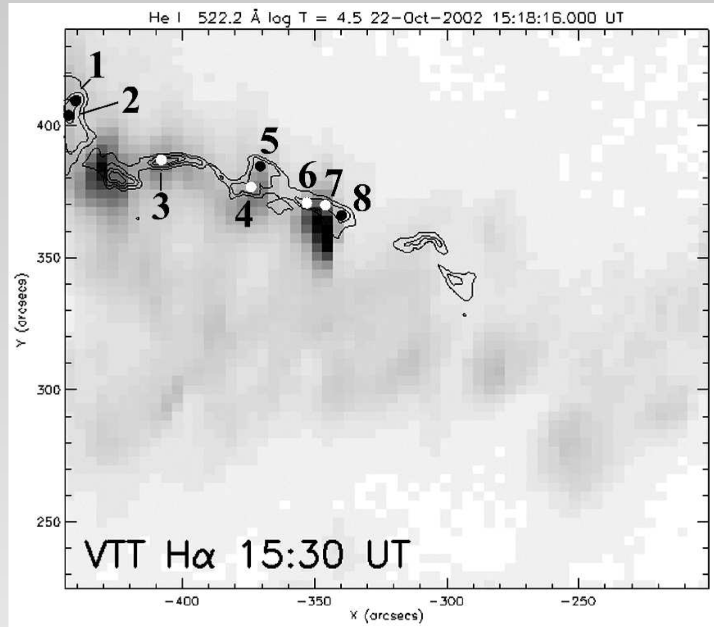
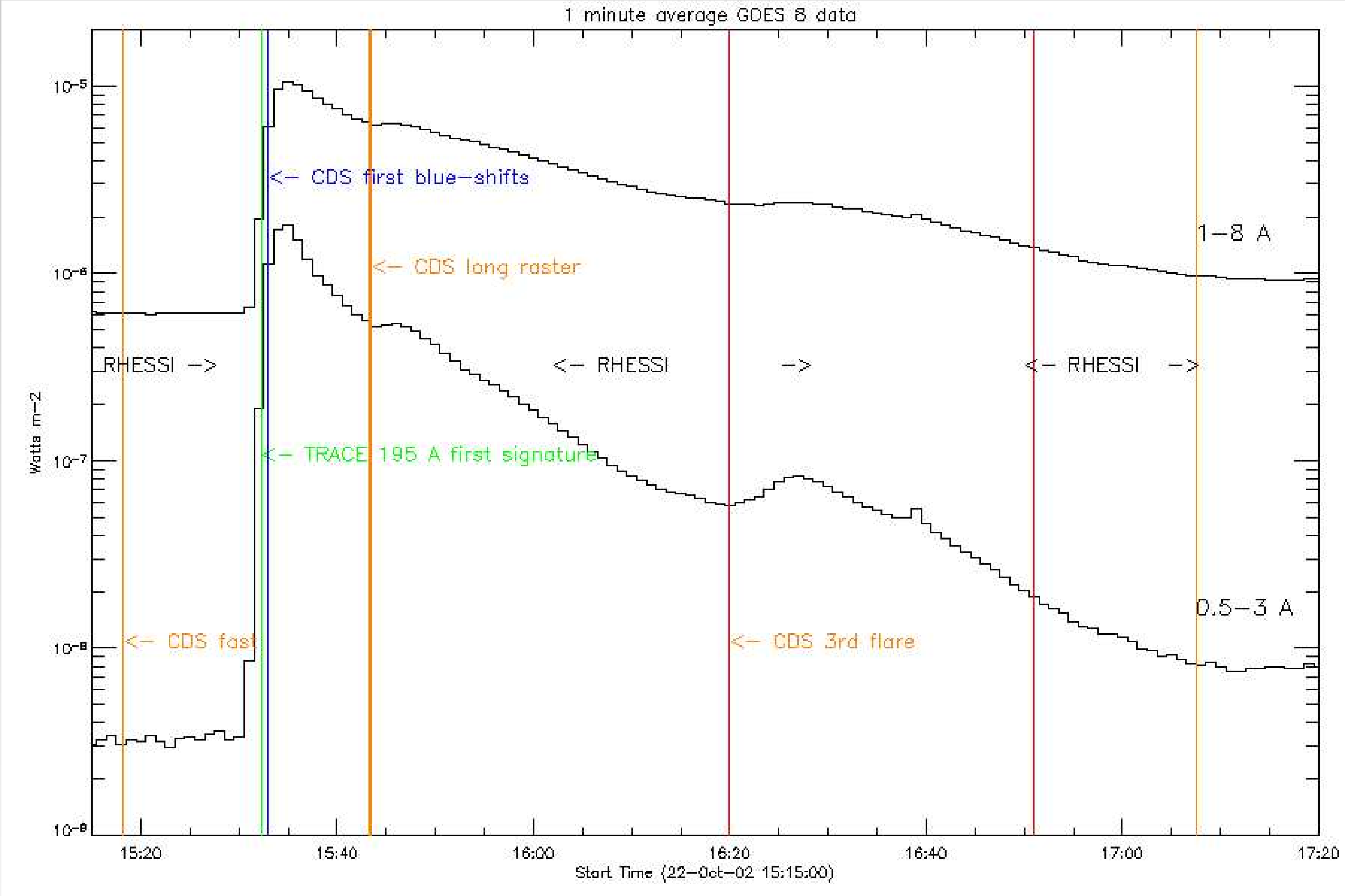
Region	A	B	C	D	L1	LP	BG
He I v	13	-27	-30	-17	-17	-36	-22
I	2393	770	112	377	751	1293	16
$FWHM$	0.61	0.53	0.51	0.56	0.51	0.51	0.50
O IV(a) v	(33)	-21	-24	13	0	-20	0
I	(9818)	598	80	237	252	686	33
O IV(b) I	2333	111	-	-	-	-	-
N_e (O IV)	$2\ 10^{11}$	$0.9\ 10^{11}$	-	-	-	-	-
O V v	(23)	-25	-21	0	-12	-28	-4
I	(33226)	5038	721	2490	2840	6782	387
$FWHM$	(0.70)	0.50	0.50	0.55	0.50	0.50	0.50
Mg X v	(14)	-62	-51	29	-17	-37	-5
I	(5910)	1630	656	1205	1781	17093	118
$FWHM$	(0.80)	0.59	0.53	0.58	0.58	0.52	0.52
Si XII v	-64	-84	-54	17	-6	-40	-10
I	2756	1847	839	1378	2818	16748	63
$FWHM$	0.59	0.55	0.50	0.55	0.51	0.50	0.50
Fe XIX v	-141	-140	-56	22	-13	-26	-
I	294	272	694	1271	2721	7544	≤ 0.5
$FWHM$	0.68	0.65	0.56	0.59	0.57	0.55	-

VTT Hα



Area	log $\tau_{\rm m}$	V_0[km s^{-1}]
1	-0.4	downfbw (?)
2	-0.2	downfbw (?)
3	$+0.4$	$+10.0$
4	$+1.0$	-1.9
5	$+0.1$	-3.8
6	-0.8	-9.4
7	-0.1	-5.6

Later flare - GOES



Later flare - RHESSI

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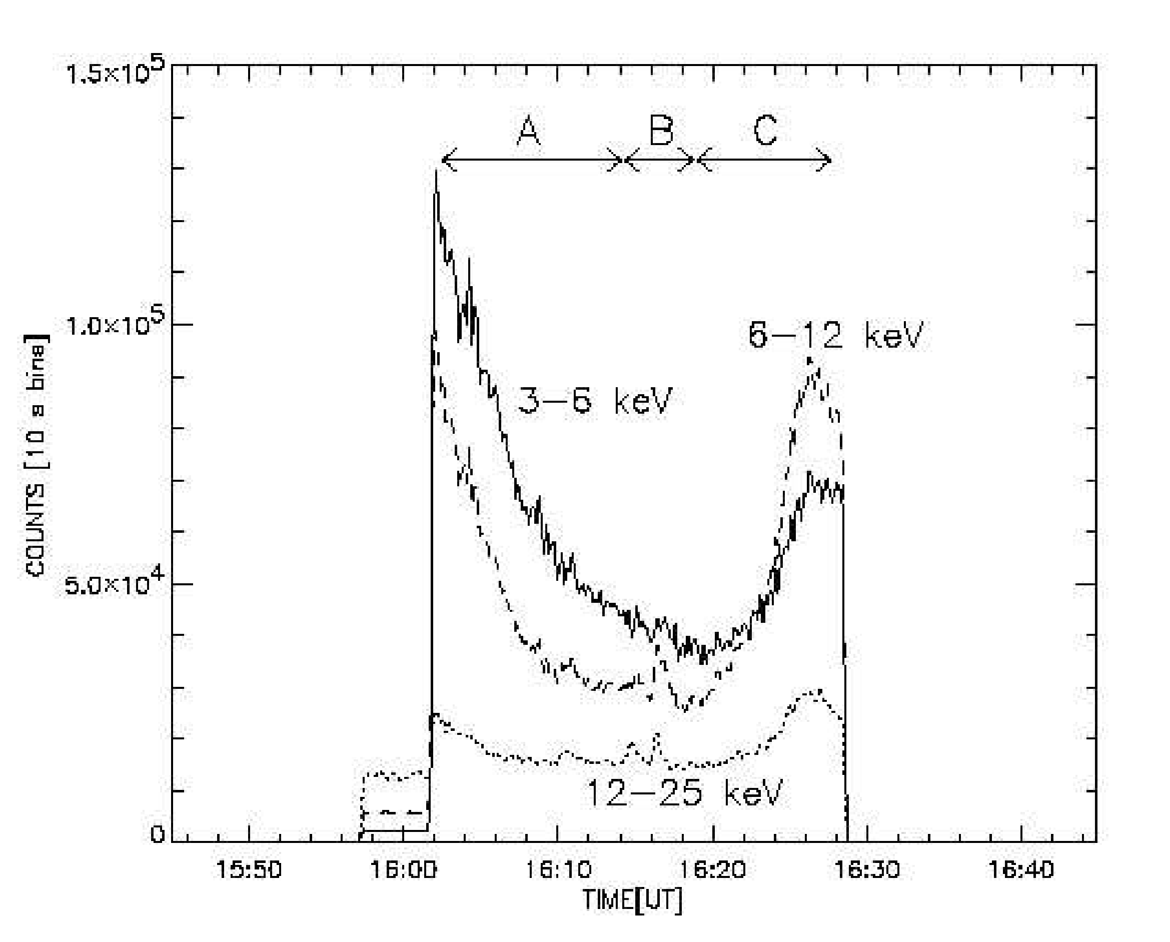
RHESSI counts rates (the 12–25 keV band are multiplied by a factor of 10).



Post-flare CDS raster 15:43–17:07 UT

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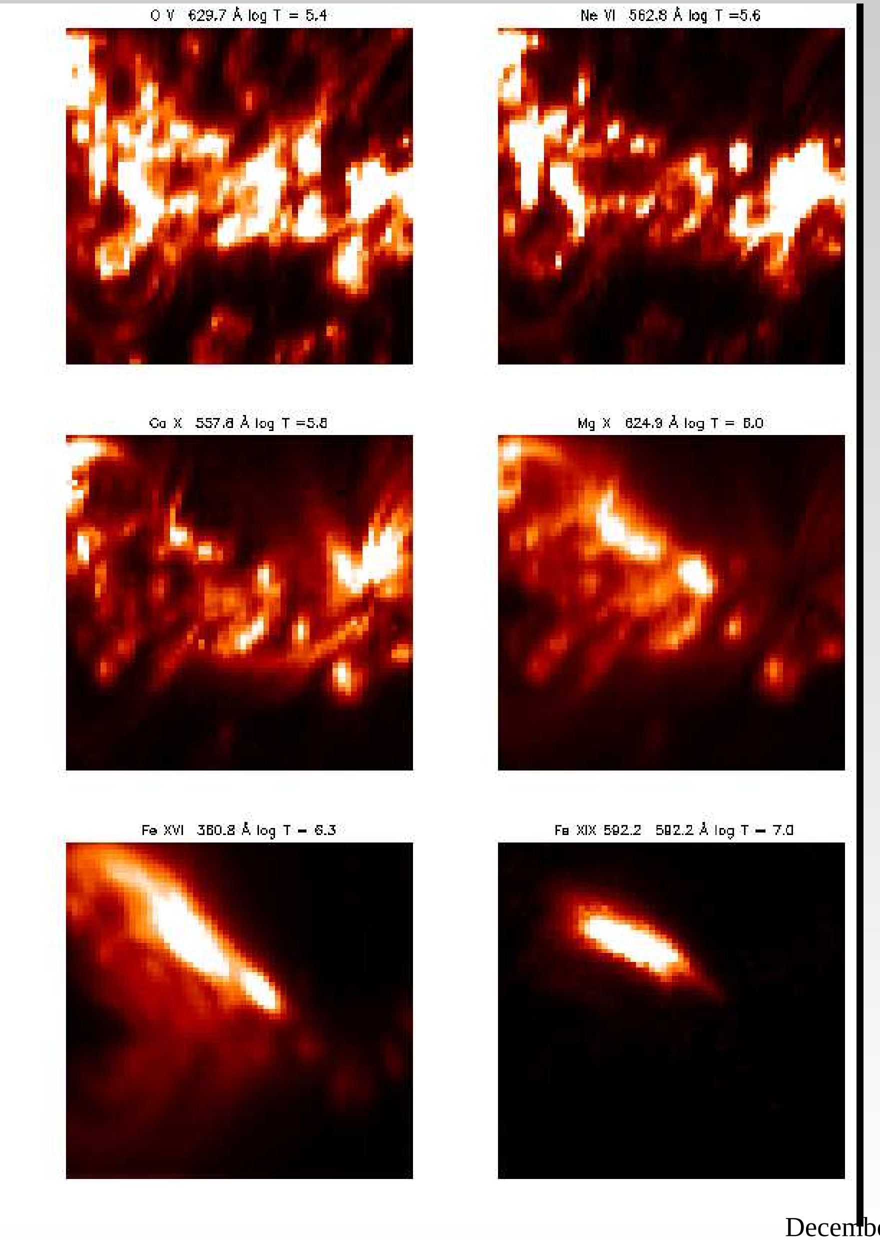
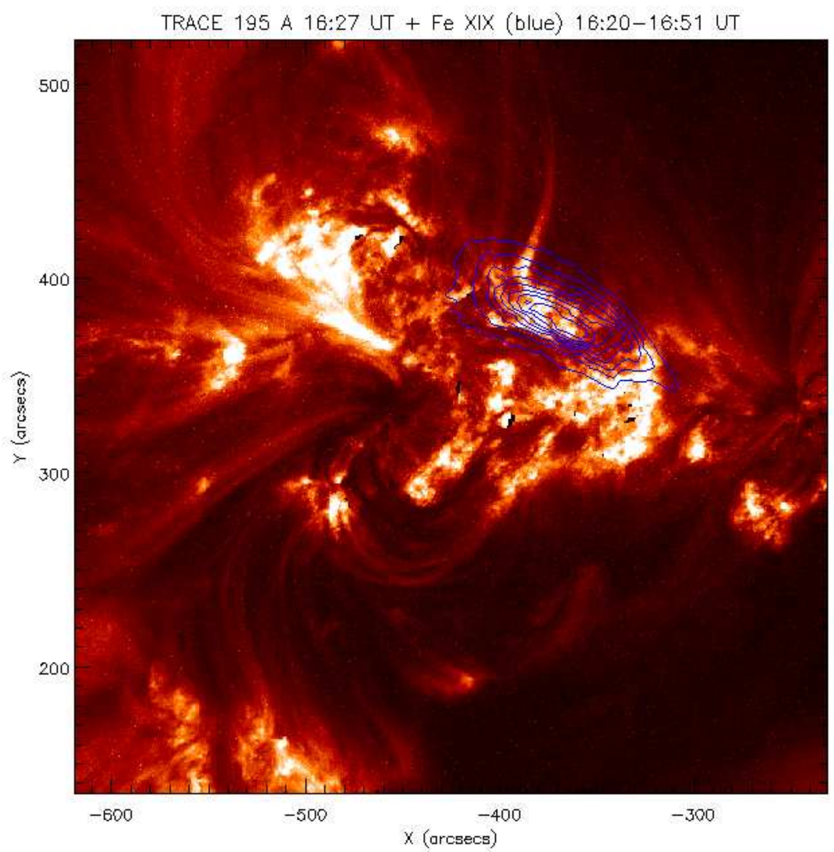
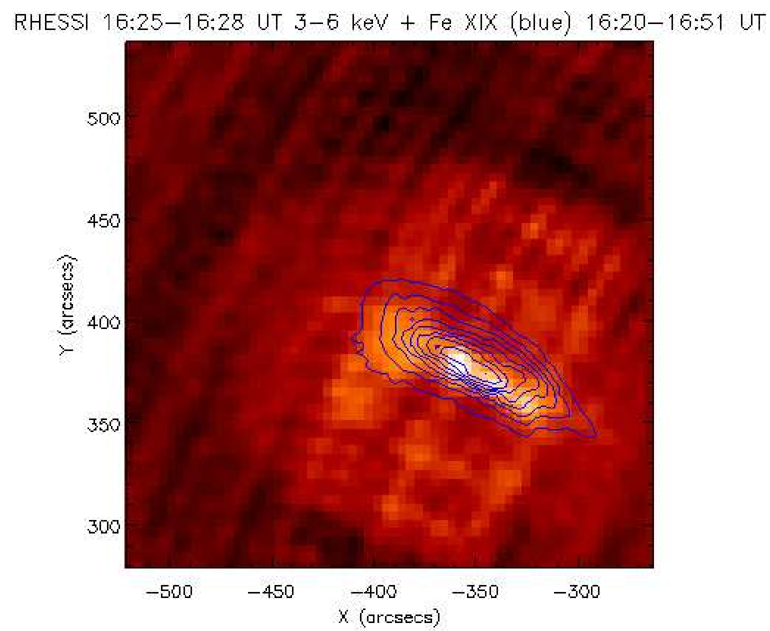


Post-flare CDS raster – II





Summary of 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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