# The X17 flare of October 28: the gradual phase

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## 1. Introduction

On October 28 2003, AR?? unleashed one of the biggest solar flares (class X17). The event was observed with many instruments, and presented various phases. A description of the event can be found in Schmieder et al (2005).

After a few filament eruptions and the main X 17 X-ray flare, a multiple-ribbon structure formed. The two main ribbons quickly separated. An arcade of EUV loops also formed. Here, we present results on the gradual phase.

At first, the overall morphology of this event fits the standard picture of a two-ribbon flare. Arcades of loops emitting at different temperatures and with a potential configuration are frequently observed. (REFERENCE??) The footpoints of these loops normally are well observed in H$\alpha$, and form the ribbons. During the formation of the loops, the ribbons separate at high speeds.

H$\alpha$ and X-ray observations have often shown the hotter loops located above the cooler loops (Schmieder et al 1996). The density of the loops was estimated to be relatively high ($10^{11}$ cm-3 to $10^{10}$ cm-3) according to the time but usually is lower than the cool loop densities (REFERENCE??). The plasma in the cool loops is often observed to flow down in the legs at speeds which can reach the free fall (50 to 150 km/s). It has been inferred that $10^{16}$-$10^{17}$ g of materal flows through a flare loop system during its life time (Kleczek 1964).

These types of observations have suggested 'standard models' of reconnection of open magnetic field lines in the corona (Kopp and Pneuman 1976, Poletto and Kopp 1986, Forbes and Malherbe 1986, Forbes and Acton 1996). The reconnection of the open field lines occurs at a magnetic X- line which moves upward as the region of closed loops grows. The loops and ribbons are associated with the field lines which map from the X-line to the chromosphere.

The reconnection process naturally explains the existence of high temperature in the hot loops. Thermal condensation (cf. Antiochos and Sturrock 1978) could form the cool loops from the hot loops. Another important process is the evaporation of material that fills directly the hot loops.

However, the observational basis of the 'standard models' have been criticised, and various alternative scenarios have been proposed over the years (see, e.g. Feldman 1996, REFERENCES). One of the main limitations has been a lack of spectroscopic measurements.

For our understanding of flares, it is important to study the role of the mechanisms that replenish/empty the loops (free fall, evaporation and condensation), as well as the processess that create the ribbons (thermal conduction, bremshtrahlung of energetic particles).

The first EUV spectroscopic measurements of a two-ribbon flare were reported in a *letter* by Czaykowska et al (1999). Czaykowska et al (1999) reported on a SOHO/CDS observation of an arcade of hot loops after two hours from the peak of an M6.8 flare. CDS observed downflows at the ends of the hot loops and upflows at the outer edges of the flare ribbons, which coincided with the footpoints of the hot loops. The upflows were seen in Fe XVI ($3 \times 10^6$ K) and Fe XIX ($8 \times 10^6$ K) lines. As the ribbons continued to separate, the upflows continued to remain concentrated at the outer edges of a ribbon. The observed pattern of upflows and downflows was in agreement with models that explain the creation of flare loops by chromospheric evaporation driven by reconnection.

Here we have the opportunity to study the flows of the plasma in a system of postflare loops observed in EUV (CDS, TRACE) in H$\alpha$ (Bialkov, ??). The ribbons are clearly seen in H$\alpha$ and in TRACE 1600Å, while the arcade of loops is seen in the TRACE 195Å band.

## 2. Observations

SOHO/CDS performed various scans of the active region before and during the flare. We present here results from one fast (20 minutes) NIS raster, that we designed to cover a wide range of temperatures (He I 584 Å, log T =4.5; O IV 625.9 Å, log T = 5.3; O V 630 Å, log T = 5.4; Mg X 625 Å, log T = 6.0; Si XII 520.8 Å, log T = 6.3; Fe XIX 592.2 Å, log T = 6.9), and to provide elctron densities. This NIS raster observed the active region during the gradual phase (12:28-12:52 UT, see Fig. 1).

During this time, TRACE 195 and 1600 Å images taken at high-cadence show that the main features are approximately stationary (see Fig. 2). The H$\alpha$ images (see Fig.??) show the locations of the ribbons. The TRACE 1600 Å images (dominated by UV continuum and neutral ion emissions) also clearly indicate the presence of a multiple ribbon structure.

The main two ribbons R1 and R2 (WHERE HARD X-RAY EMISSION SEEN BY RHESSI IS PRESENT) are located above the main sunspots of opposite polarity. A third ribbon structure, that formed in the location where the filament erupted, is also present. The ribbon R3 is seen in the TRACE 1600 Å as an almost straight line of emission, overlying a region of mixed polarity. During the CDS scan (20m), there is no measurable motion of the ribbons (NEED TO CHECK-PERHAPS JUST A COUPLE OF TRACE PIXELS-GDZ).

In the TRACE 195 Å, an arcade of hot loops that connect the two ribbons R1 and R2 is visible. The sequence of TRACE 195 Å images show apparent flows toward the ribbons, with loops continuously appearing and disappearing.

CDS observed the arcade of hot loops, and also shows that strong emission at all temperatures (from O V to Fe XIX) is present.

Strong downflows ($v \simeq 50 - 100$ km/s ), in particular at transition region temperatures are observed in O V near the footpoints of the loops , which are located at the ribbons R1 and R2. Thes flows are close to the free fall velocity.

The free fall velocity depends on the gas pressure height in the loops: at $10^6$ K H = 50 000 km then v=0 at $10^5$ K H=5000 km then v$\simeq$10 km/s at $10^4$ K H=500 km then v$\simeq$100 km/s

Strong downflows are also present in two regions that have loops structures connected to them, on the eastern side of R1.

Strong upflows in all TR (e.g. OV) and coronal lines (e.g. Mg X) are observed in the regions just outside the ribbons, in particular in the region outside R1, coincident with the dark region in the TRACE 195 Å band. This region forms immediately after the formation of the

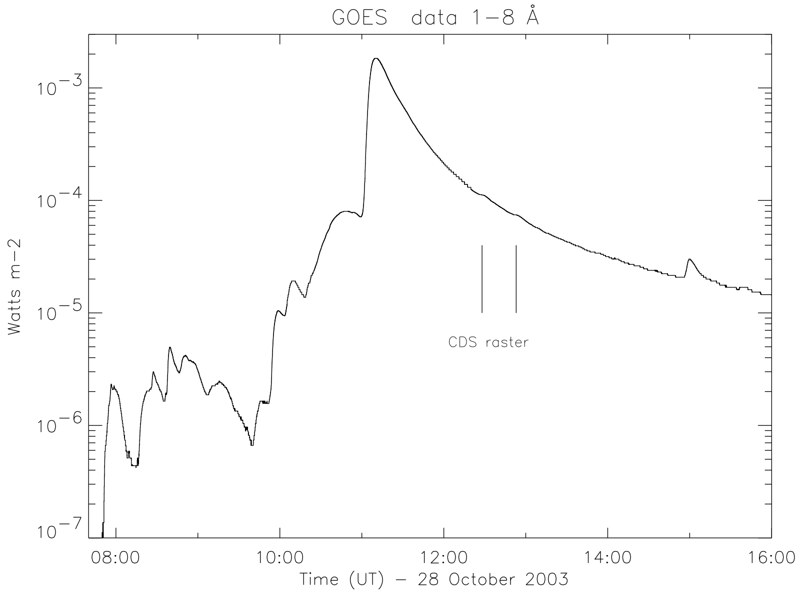


*Figure 1.* Evolution of the GOES X-ray fluxes during the October 28, 2003 X17 flare, with the timing of the CDS raster.

two ribbons and lasts as long as the ribbons. It is interesting to notice that there is no similar region on the outer edge of the other ribbon R2. Also that, contary to what reported by Czaykowska et al (1999), no measurable flows in Fe XIX are observed.

I WILL ADD A SEQUENCE OF EIT 195 IMAGES DURING THE FLARE AND WITH A LARGE FOV.

Another system of hot loops connecting R3 to both R1 and R2 are clearly visible in TRACE 195 Å. This suggests the presence of opposite polarities along R3. It is interesting to notice that R3 is visible soon after the two main ribbons form, in the same location of the filament that previously erupted.

Flows in TRACE 1600 Å from R3 to R1 are seen. However, flows are not observed in TRACE 195 Å or in the CDS lines. The central part of R3 is also the location of the strongest emission in TRACE 195 Å and in all spectral lines above 1 MK. The peak emission in the flare line Fe XIX is also at this location. This suggests that the dominant contribution to the TRACE 195 Å is due to Fe XXIV.

The fact that the hottest emission occurs in R3 suggests that the dominant heating takes place there.

WHAT IS R3 ????

THE TRACE MOVIES AND THE LOOPS THAT CONNECT R2 WITH R3 SEEM TO RULE OUT THAT R3 IS HIGH IN THE CORONA.

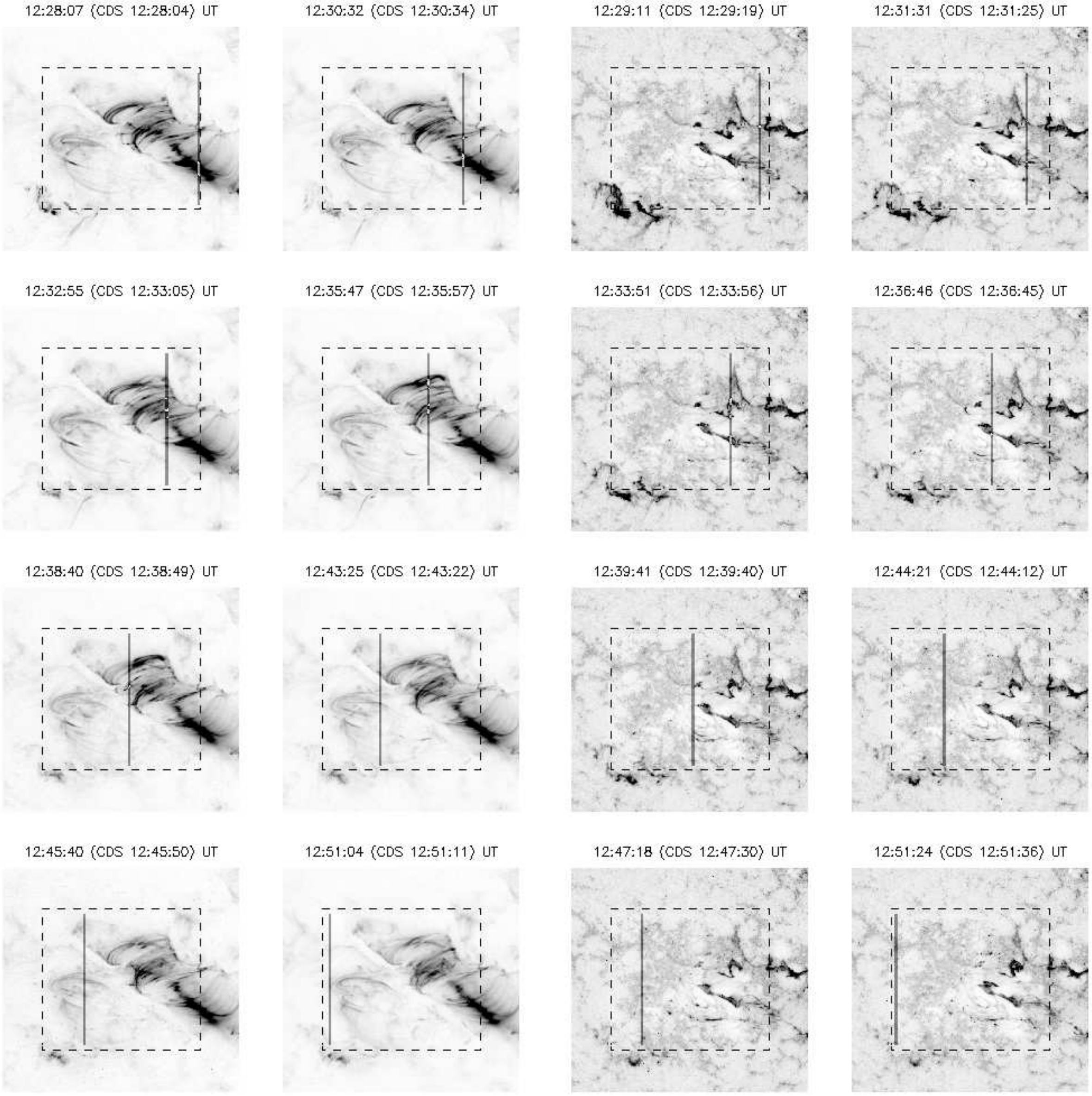


*Figure 2.* Sequence of TRACE 195, 1600 Å images during the CDS raster, shown with the same intensity scale. The FOV of the CDS raster, and the position of the slit. Notice that overall the loop structures seen in TRACE 195 Å and the ribbon structures seen in TRACE 1600 Å remain largely unchanged.

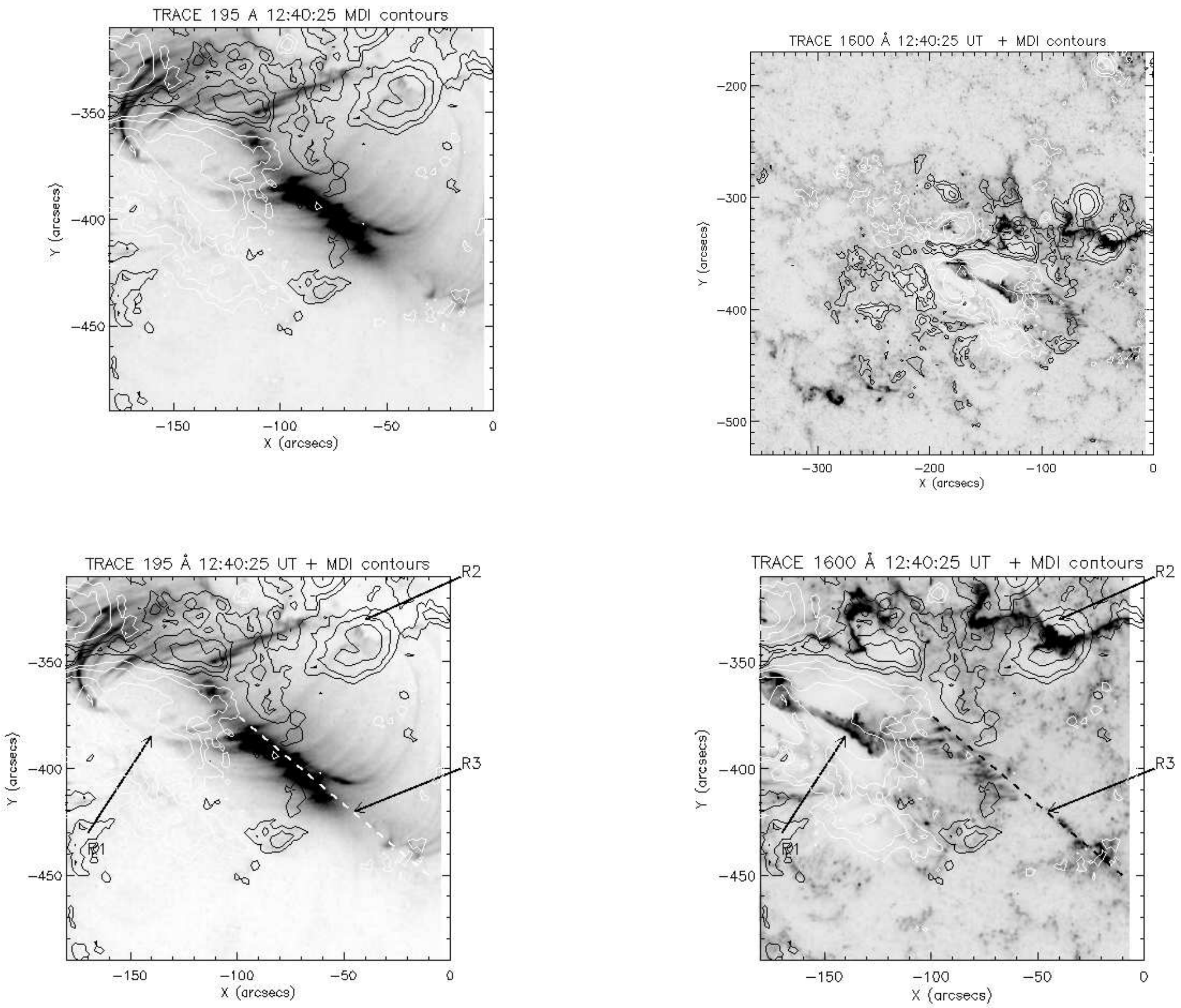


*Figure 3.* TRACE 195, 1600 Å images, with contours from the SOHO/MDI magnetogram (200, 500, 1000 G). Notice the arcade of loops seen in TRACE 195 Å connecting the ribbon structures R1, R2 which are located above the sunspot regions of opposite polarity. Also note the system of loops in TRACE 195 Å which connects the ribbon R3 to R1 and R2. The ribbon R3 is seen in TRACE 1600 Å as an almost straight line of emission. Flows in TRACE 1600 Å from R3 to R1 are seen. The central part of R3 is also the location of the strongest emission in TRACE 195 Å.

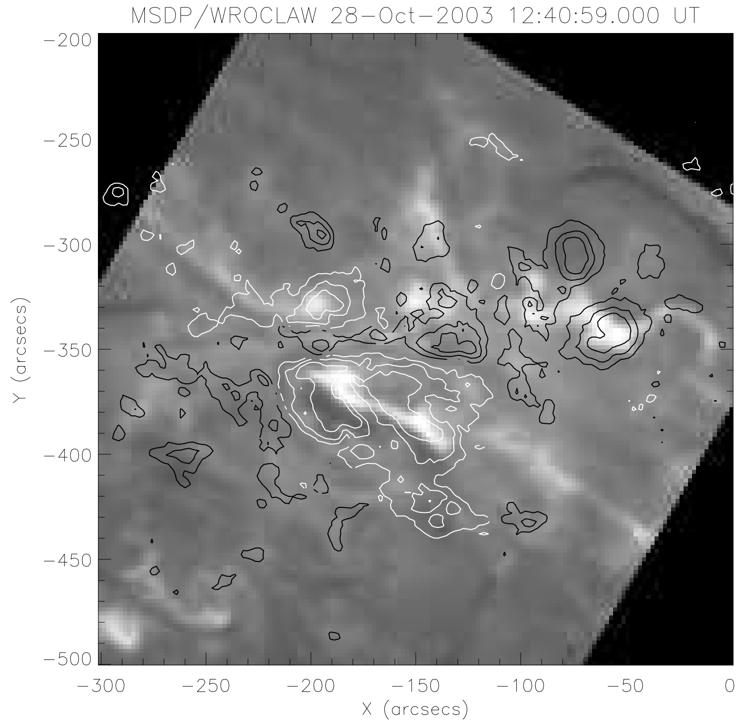


*Figure 4.* H$\alpha$ observation from Bialkov, with contours of SOHO/MDI magnetograms. Note the similarity with the TRACE 1600 Å image and the presence of the three ribbon structures.

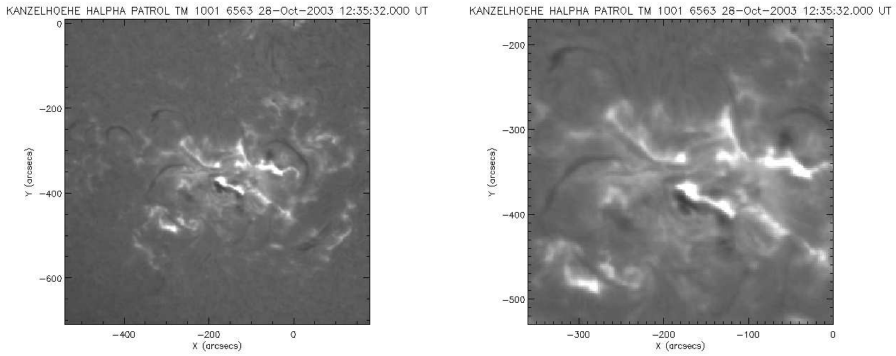


*Figure 5.* H$\alpha$ image obtained during the CDS raster, showing the entire active region and the area of the TRACE field of view. Note the similarities with the TRACE 1600 Å image

I HAVE LOOKED AT H-ALPHA IMAGES 2-3 HOURS LATER BUT IT DOES NOT APPEAR THAT THE FILAMENT REFORMS WHERE R3 IS. R3 SEEMS TO FADE AWAY AS R1 AND R2 DO.

WHAT ARE THE H-ALPHA DATA TELLING US ?

PLAN OF THINGS TO ADD:

-MEASUREMENTS OF CDS DENSITIES AND FLOWS IN A FEW KEY POINTS:

-ALONG R1, R2, R3

-IN THE REGION OF THE ARCADE

- THE DARK REGION WITH UPFLOWS

We should be able to give some estimates of cooling times.

## 3. Discussion and conclusions

## Acknowledgements

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TRACE

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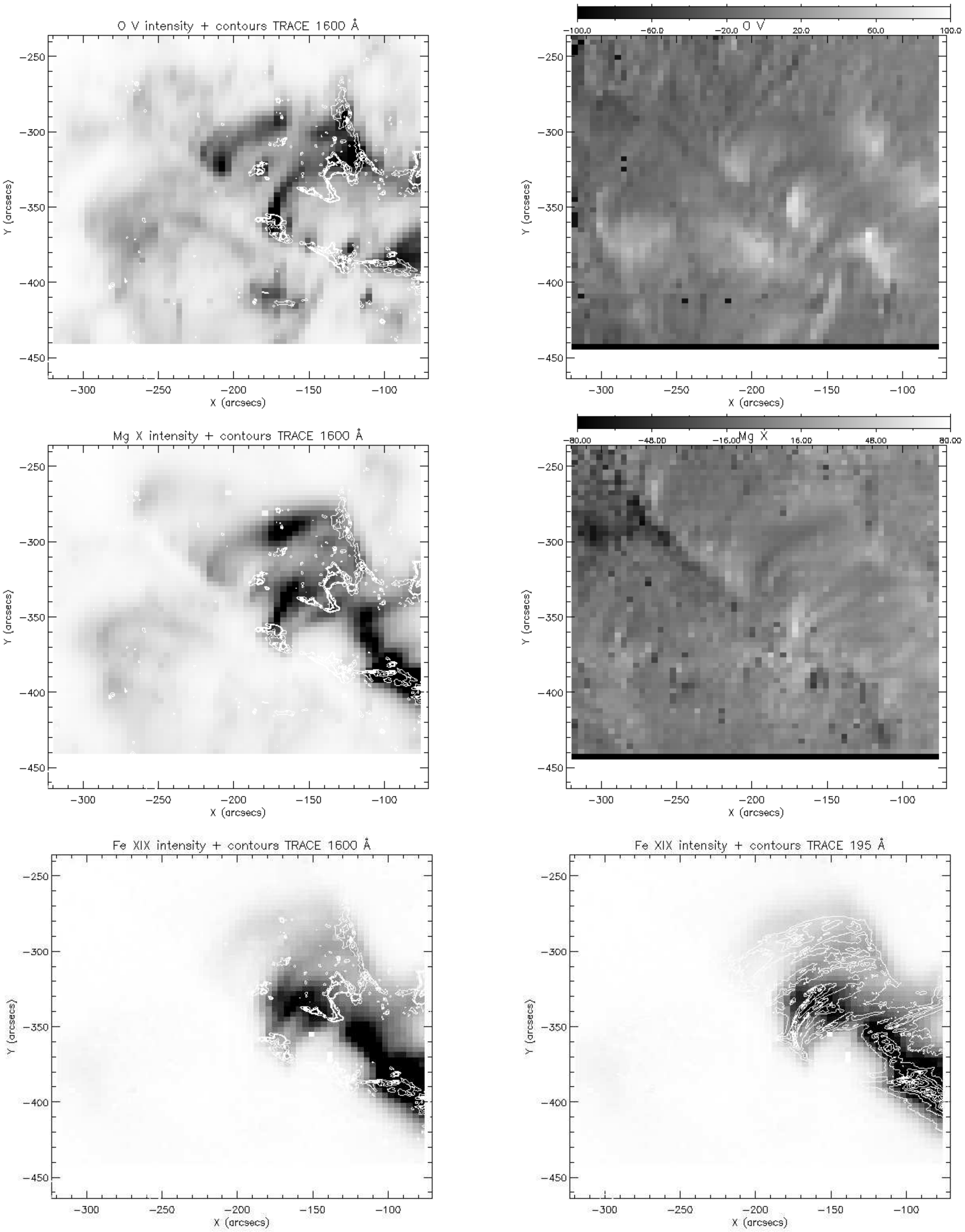


*Figure 6.* From top to bottom: CDS intensity and velocity maps in O V, Mg X with contours of the TRACE 1600 Å intensity; intensity in Fe XIX with contours of TRACE 1600,195 Å intensities. Strong downflows ($v \simeq 50 - 100$ km/s ) in the ribbons are observed.