EUV and HXR Signatures of Electron Acceleration during a Failed Eruption of a Filament

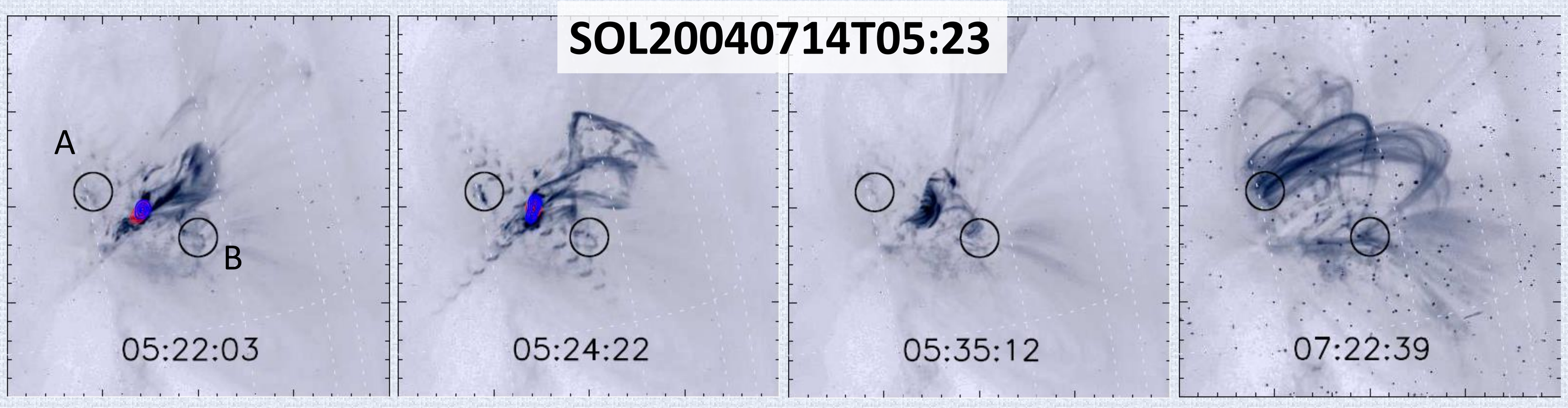
Mrozek, T.[1,2], Kołomański, S.[1], Netzel, A.[1], Gburek, S.[2]

[1] Astronomical Institute, University of Wrocław, Poland

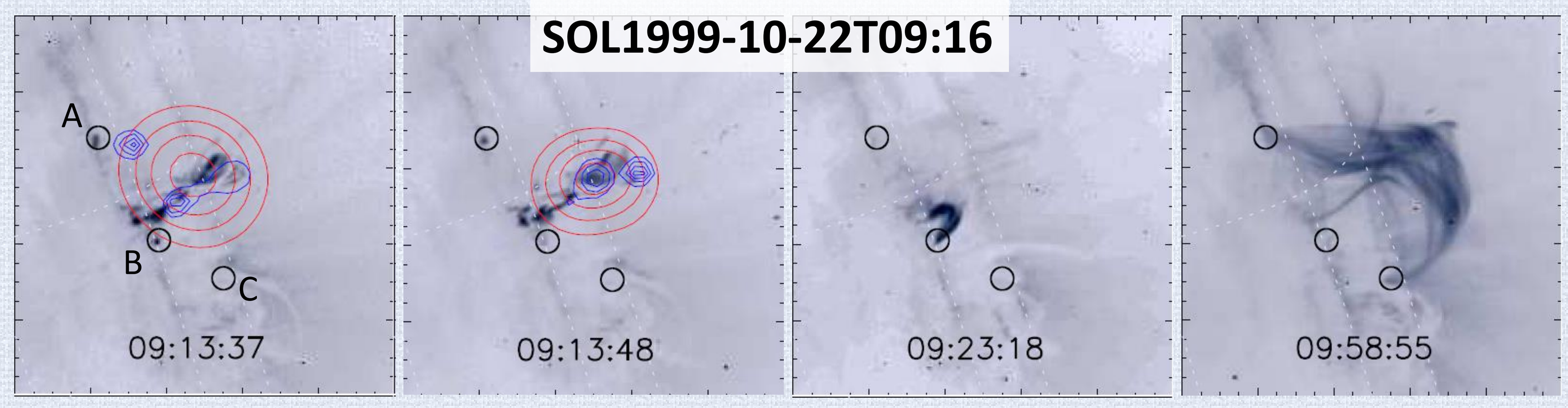
[2]Solar Physics Division, Space Research Centre, Polish Academy of Sciences, Poland

ABSTRACT

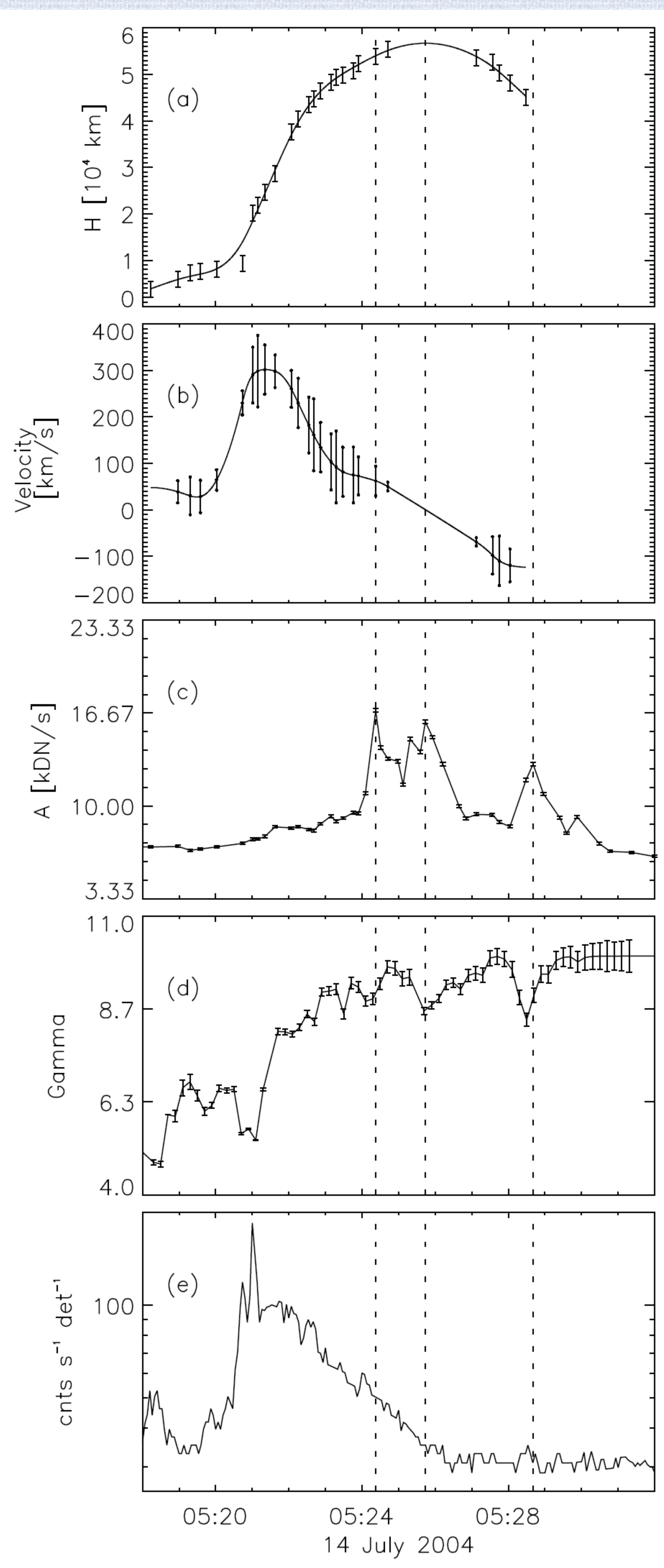
We investigated a group of failed eruptions observed simultaneously in EUVs (TRACE) and HXRs (RHESSI or Yohkoh/HXT). We used semi-automated method to search for abrupt brightness changes in the TRACE field of view. The EUV light curves of a selected area were compared to height profiles of eruption, HXR emission and the HXR spectral index. Detected EUV brightenings are closely related to the eruption velocity decrease, to HXR bursts and to episodes of hardening of the HXR spectra. The EUV-brightened areas are observed far from the flare site, in footpoints of large systems of loops. These are not "post-flare loops", but the system of loops that that are observed at heights equal to the height at which the eruption was observed to stop. The collected set of observational facts suggests that the observed features are caused by the population of non thermal particles that were accelerated during the episodes of interaction of the eruption front with overlying high loops.



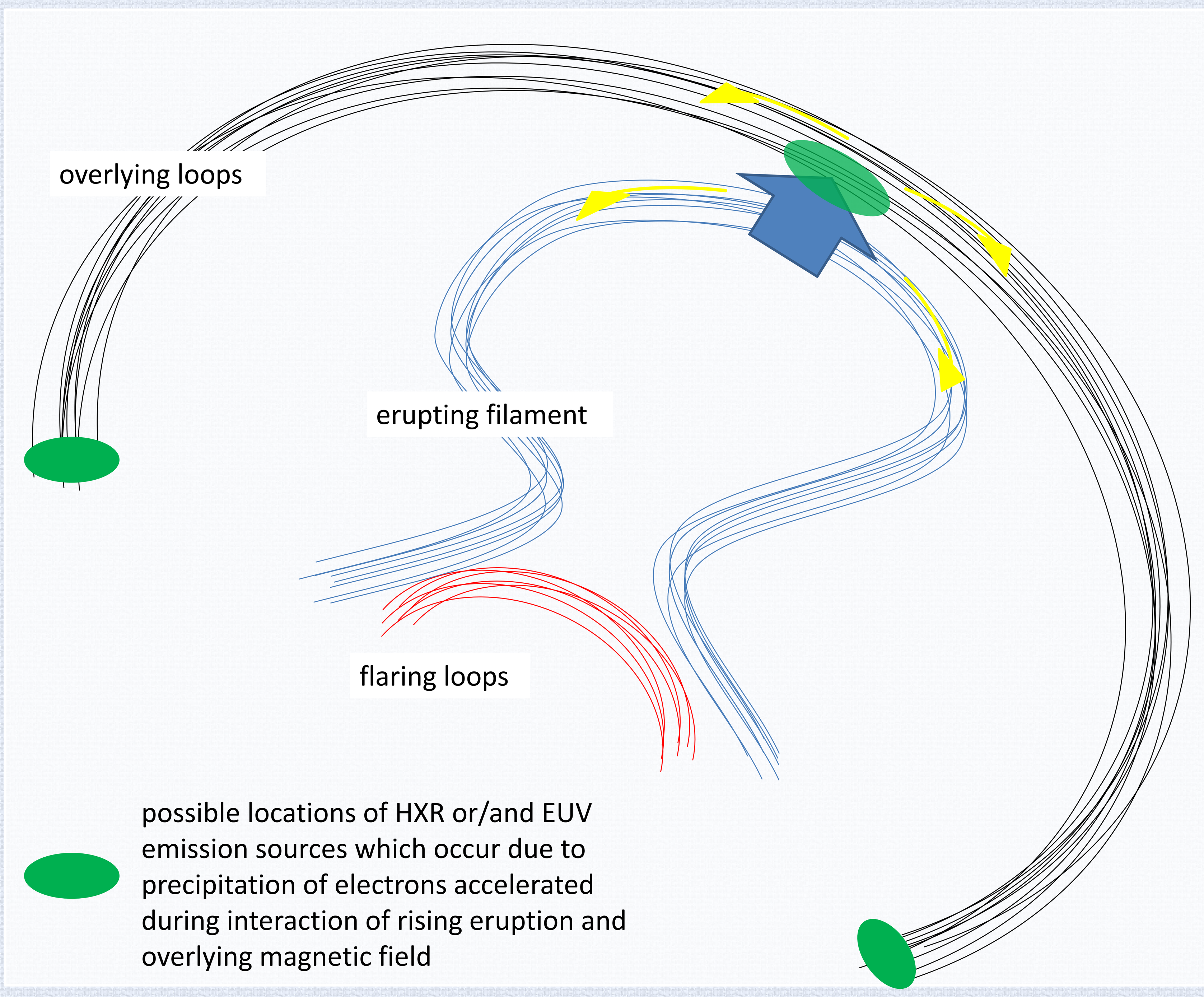
Set of *TRACE* 171 Å images taken for several moments during the event accompanied by a M6.2 flare. This event was also analyzed by Mrozek (2011) as an example of a failed eruption that started vertical oscillations of overlying coronal loops. Locations of EUV brightening are cricled. Reconstructed HXR contours are marked for *RHESSI* energy bands 6-12 keV (red line) and 25-50 keV (blue line). The system of high loops is visible from 6:57 UT. Their altitude (5.5*10^4 km) corresponds to the altitude, at which eruption was confined in the first phase. Moreover, foot points of the overlying loops are at locations in which we found EUV brightenings during the deceleration of the eruption.



The *TRACE* 171 Å images taken during the event. Locations of found brightenings are circled in every image. HXR contours are marked for HXT L (red line) and M1 (blue line) channels. M1 sources are correlated with EUV brightening and are also observed at the top of the eruption. The associated flare was classified as C4.8 according to *GOES*. EIT/LASCO C2 recorded CME that took place in the same time but in opposite side of the solar disk. Flaring loop was visible in TRACE image around 9:23 UT and it is correlated with brightening area B. The overlying high system of loops is visible around 10:00. Foot points of this system are correlated to remained two brightening areas.



The HXR light curves and the HXR photon spectral index evolution show some interesting coincidences with EUV brightenings and kinematics of the eruption. Namely, we do not observe any significant brightenings of the area A during the impulsive phase, which suggests that there is no connection between the flare and the region A. We detected significant changes of brightness of this region during the braking of the eruption. The strong EUV brightenings were accompanied by the very small HXR brightenings (12-25 keV). There are also simultaneous episodes of the spectral hardening. Taking into account the overall behavior we conclude that the area A is a good example of an area that was hit by non-thermal electrons accelerated during the eruption braking due to interaction with overlying field.

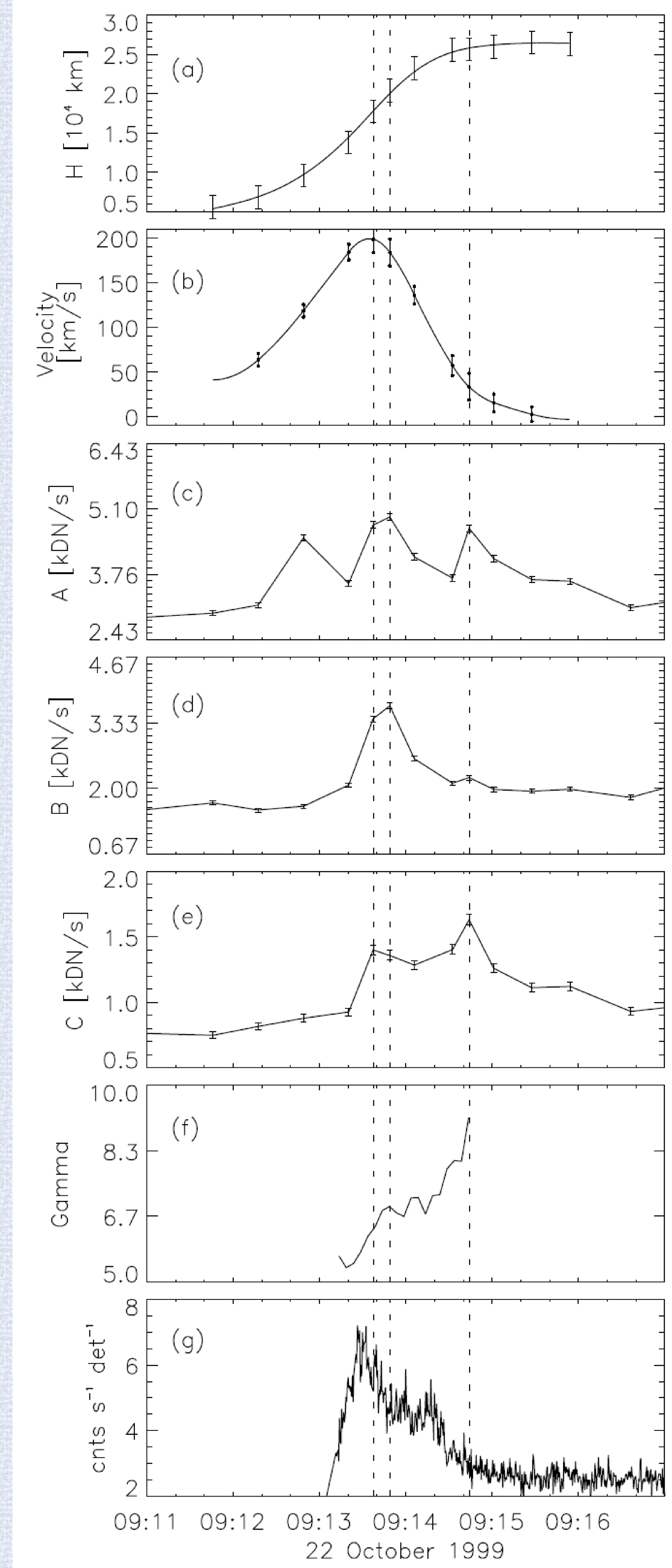


Proposed scenario

The rising eruption, after the initial acceleration, is slowed down by the interaction with overlying magnetic field. The overlying field lines are not directly visible during the eruption. In the points where the interaction between the erupting structure and the overlying magnetic loops happens, particles are being accelerated to non-thermal velocities. Next, the particles propagate along magnetic field lines down to the transition region and the chromosphere where they collide with dense matter and produce EUV brightenings. If the chromospheric evaporation occurs then the loops are filled with plasma and after cooling to about 1 MK they became visible in *TRACE* 171 Å images.

Conclusions

- The characteristics analyzed (height, velocity, HXR photon spectral index, EUV brightenings, HXR ligh curves) are time correlated. Usually an HXR peak and the minimum of a HXR photon spectral index are observed a few seconds before an EUV brightening.
- The maximum EUV intensity of selected regions was observed during the deceleration of an eruption front.
- The EUV brightenings were found with a use of a semi-automated method. They are in exact positions as the observed foot points of the large systems of loops that are observed tens of minutes after the eruption braking episodes. These loops are not typical 'post-flare loops'.
- The heights of the large system of loops are almost the same as the maximum height reached by the eruption. Together with the fact that the brightenings are observed in foot points of these loops, it suggests that the loops exist before the beginning of the eruption, but for some reasons (temperature, density) are not visible.
- The interaction with the eruption causes the heating of the loops and, after being cooled down, 30-90~minutes later the loops become visible in EUV.
- In one case we detected very weak HXR emission (23-33~keV) located exactly at the front of the eruption. It may suggest that some energy is released at the places of interaction between the eruption front and the overlying magnetic field structures.



The first two plots show height and velocity against time. The presented measurements of height have been fitted with the use of cubic splines. The velocity is a derivative of the obtained fit. Next three plots present light curves for brightening regions A, B and C. Next is gamma against time. Last plot is HXR light curve obtained from HXT instrument aboard *Yohkoh* in the M1 channel. In all plots vertical dashed lines represent maxima of light curves for brightening regions. EUV brightenings are observed when the eruption slowed down.

References

Mrozek, T. 2011, Solar Physics 270, 191

Netzel, A., Mrozek, T., Kołomański, S., and Gburek, S. 2012, A&A 548, 89

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