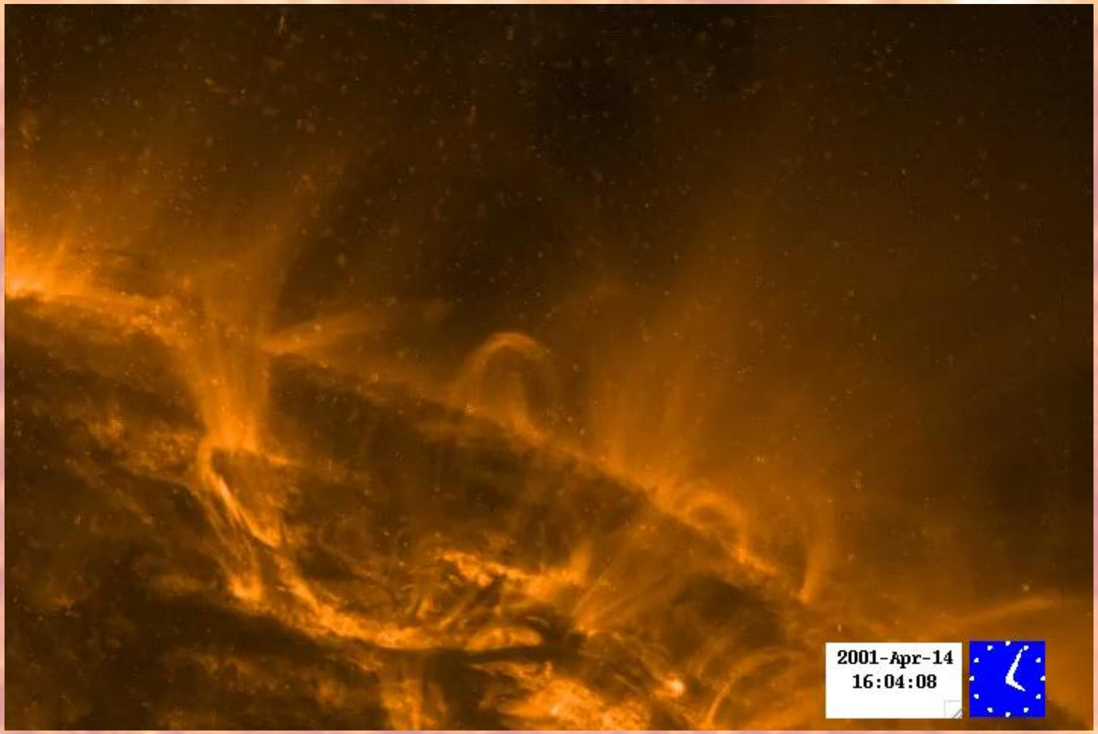
HXR sources during the failed eruptions of filaments: observed and predicted

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

1. Astronomical Institute, University of Wrocław, Poland
2.Solar Physics Division, Space Research Centre, Polish Academy of Sciences, Poland

Types of eruptions

Gilbert, H. R., Alexander, D., & Liu, R. 2007, Sol. Phys., 245, 287:



1. ***Full*** - most (≥ 90%) of filament mass and magnetic structure is erupted.

2. ***Partial***:

   - class A – the eruption of the entire magnetic structure with small amount or even no mass.

   - class B – the partial eruption of magnetic structure with some or none mass.

3. ***Failed*** - neither of mass nor magnetic structure escapes from the Sun.

Mechanisms that lead to failed eruptions

- **kink instability**

  Török & Kliem 2005, ApJ, 630, L97

- **reaching an upper equilibrium**

  Vršnak 2001, J. Geophys. Res., 106, 25249;
  Green et al., 2002, Sol. Phys., 205, 325

- **forces within erupting flux rope**

  Vršnak 1990, Sol. Phys., 129, 295

- **magnetic tension force and momentum exchange with the background plasma**

  Wang & Sheeley 1992, ApJ, 392, 310;
  Archontis & Török 2008, A&A, 492, L35

- **insufficient energy released in the low corona**

  Shen et al.2011, Res. in Astr. and Astroph., 11, 594

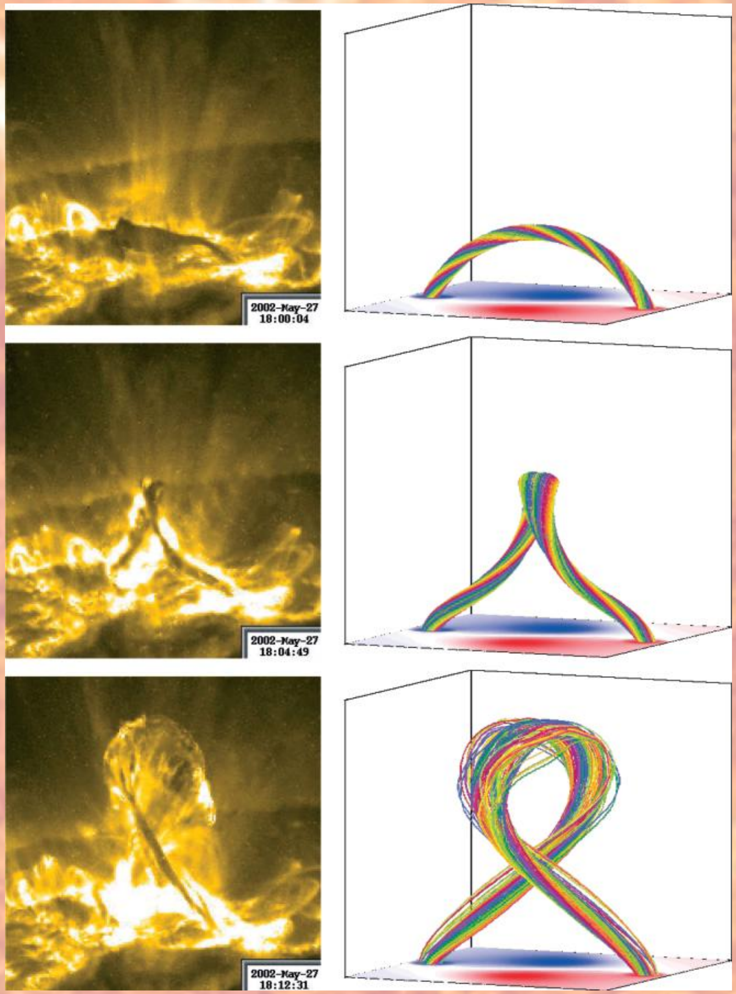
- **confinement by the overlying coronal magnetic field**

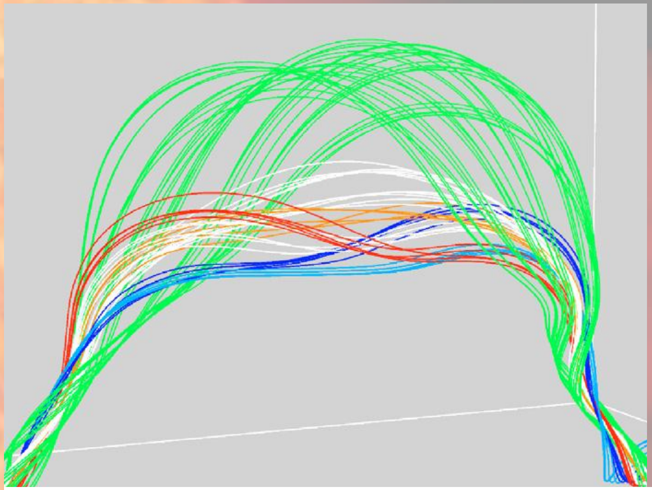
  Hirose et al. 2001, ApJ,551, 586;
  Wang & Zhang 2007, ApJ, 665, 1428;
  Liu 2008, ApJ, 679, L151;
  Mrozek 2011, Sol. Phys., 270, 191

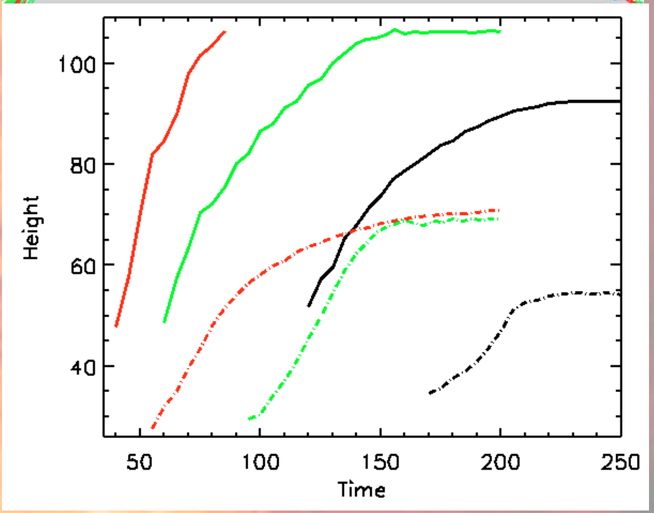
The role of the overlying magnetic field

The decrease of the overlying magnetic field with height is a key factor leading to the failed eruption.

Török & Kliem 2005, ApJ, 630, L97



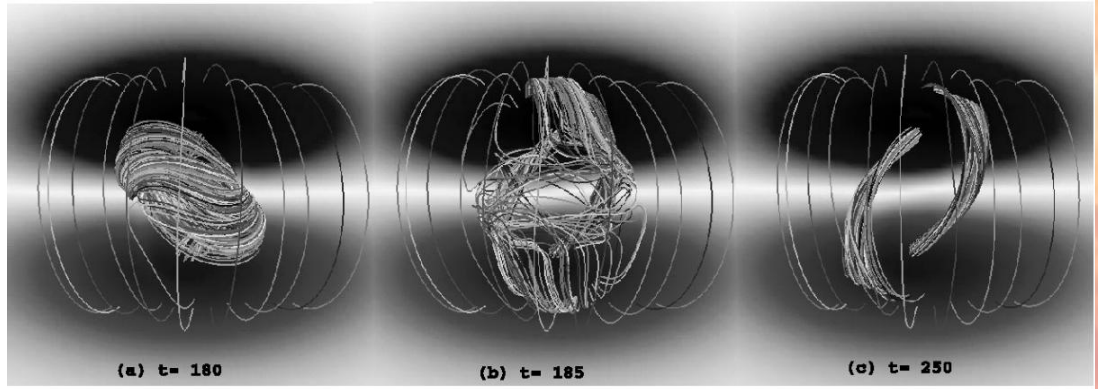




The evolution of a flux rope (and the whole flux system) after its emergence is dependent on ambient magnetic field

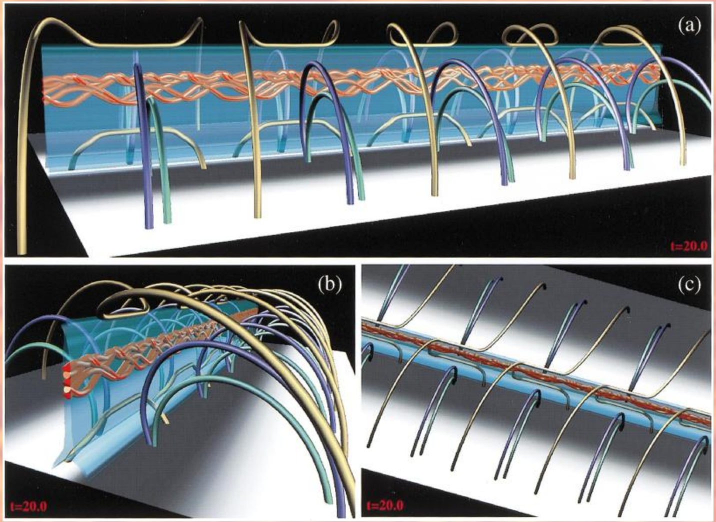
Archontis & Török 2008, A&A, 492, L35

The role of the overlying magnetic field



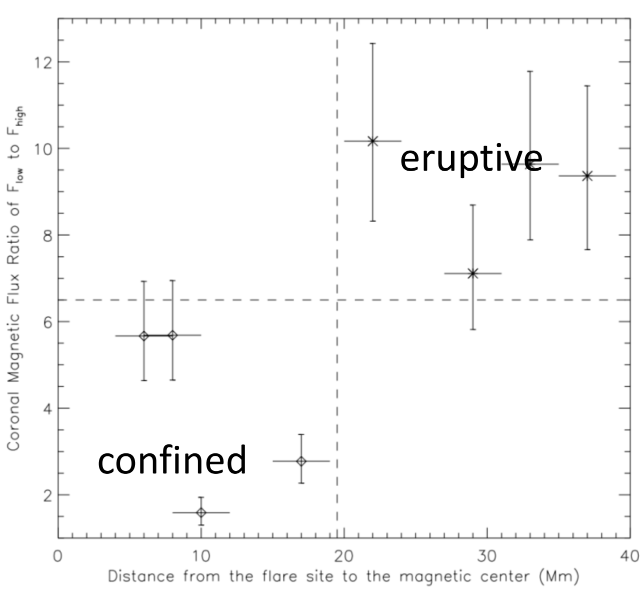
„… erupting magnetic flux during its evolution could reconnect with the overlying arcade and remain confined…"

Amari & Luciani 1999, ApJ, 515, L81



„…the upward motion of the dark filament may eventually be arrested by the overlying closed field."

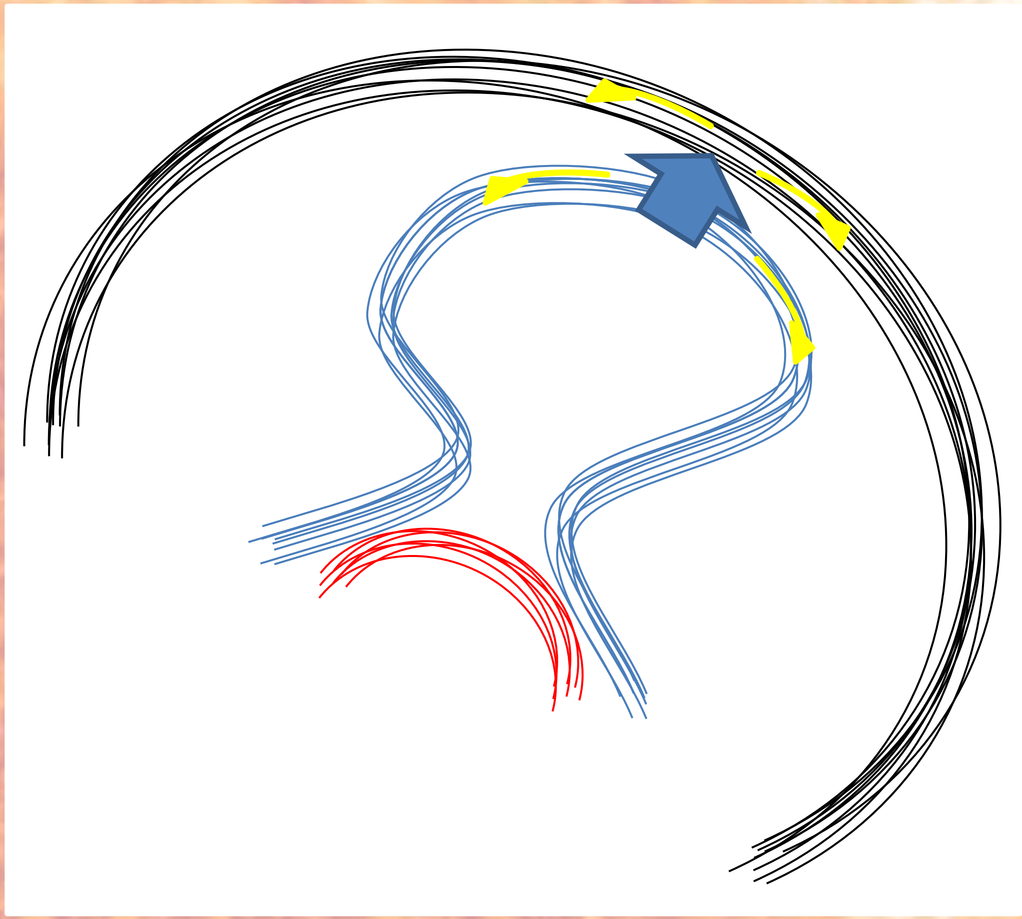
Hirose et al. 2001, ApJ,551, 586



The confined events were observed closer to the center of an active region (the strongest magnetic field)

Wang & Zhang 2007, ApJ, 665, 1428

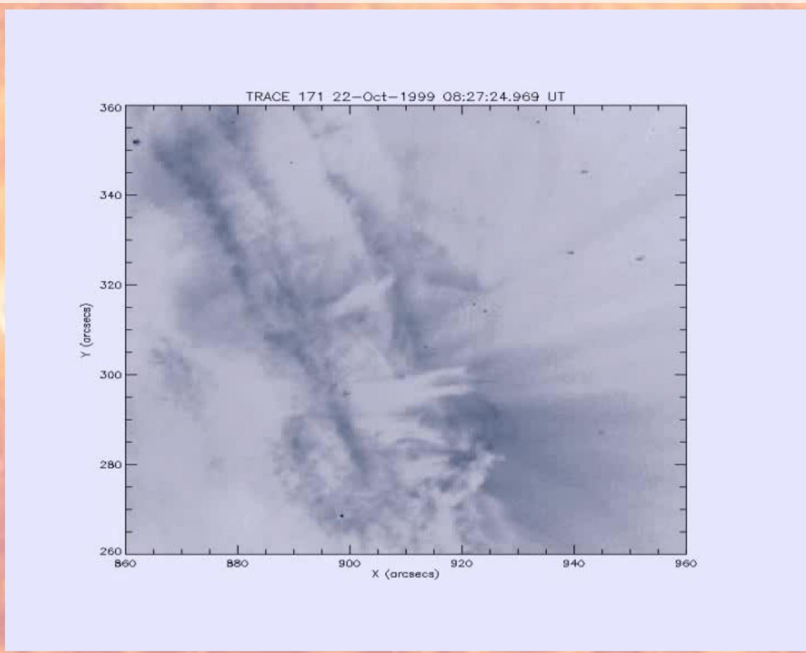
Motivation



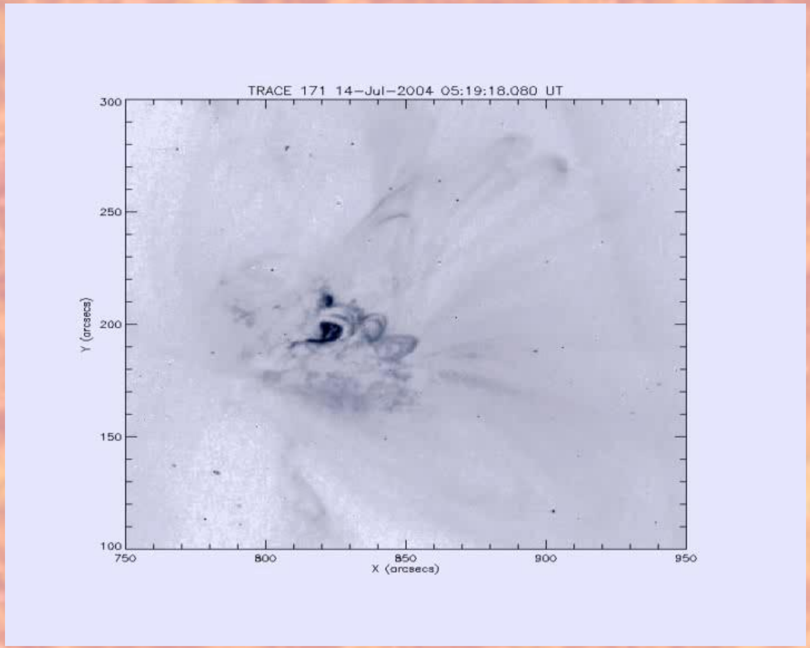
Assuming that during the evolution of the eruption there are episodes of interaction with overlying field we can expect some signatures of the presence of non-thermal electrons.

If nonthermal electrons occur in large, overlying magnetic loops then signatures of their presence have to be observed at some distance from the flare and the associated eruption. – No masking

Two events

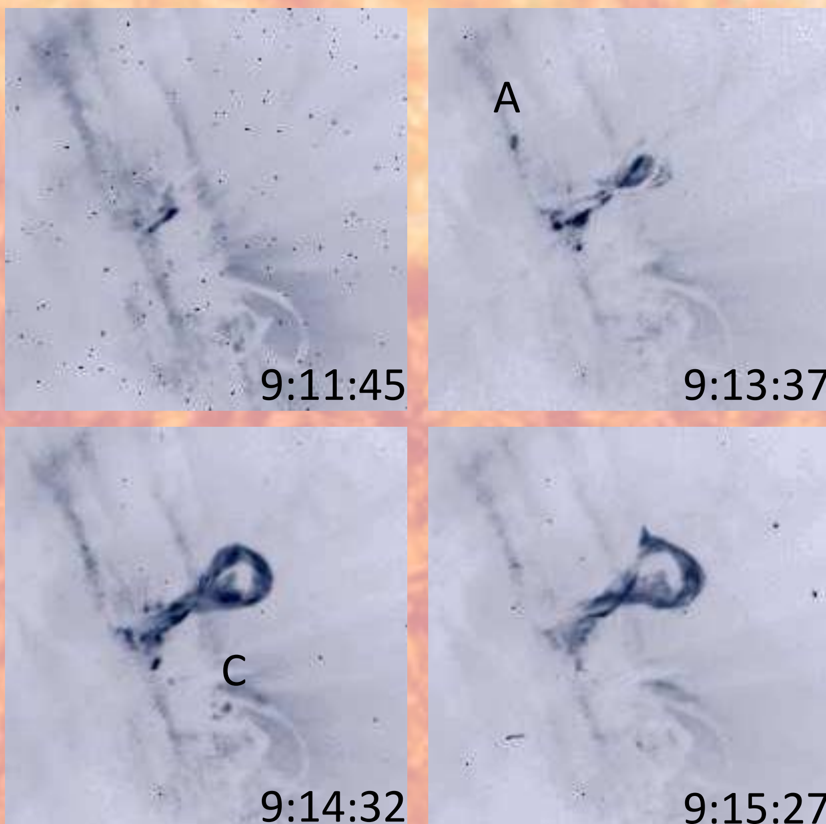


Date	**22-OCT-1999**
Flare	
GOES class	**C4.8**
location	**N20W76**
maximum	**09:16**
Eruption max. height	**30000 km**
Utilized observations	**TRACE 171 Å** **Yohkoh/HXT**



Date	**14-JUL-2004**
Flare	
GOES class	**M6.2**
location	**N12W62**
maximum	**05:23**
Eruption max. height	**60000 km**
Utilized observations	**TRACE 171 Å** **RHESSI**

Searching for EUV brightenings

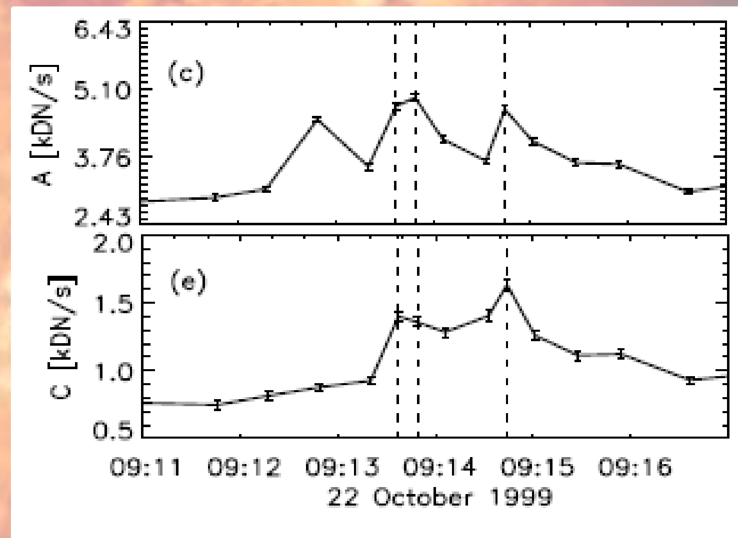


Searching for brightenings was performed with a semi-automated method.

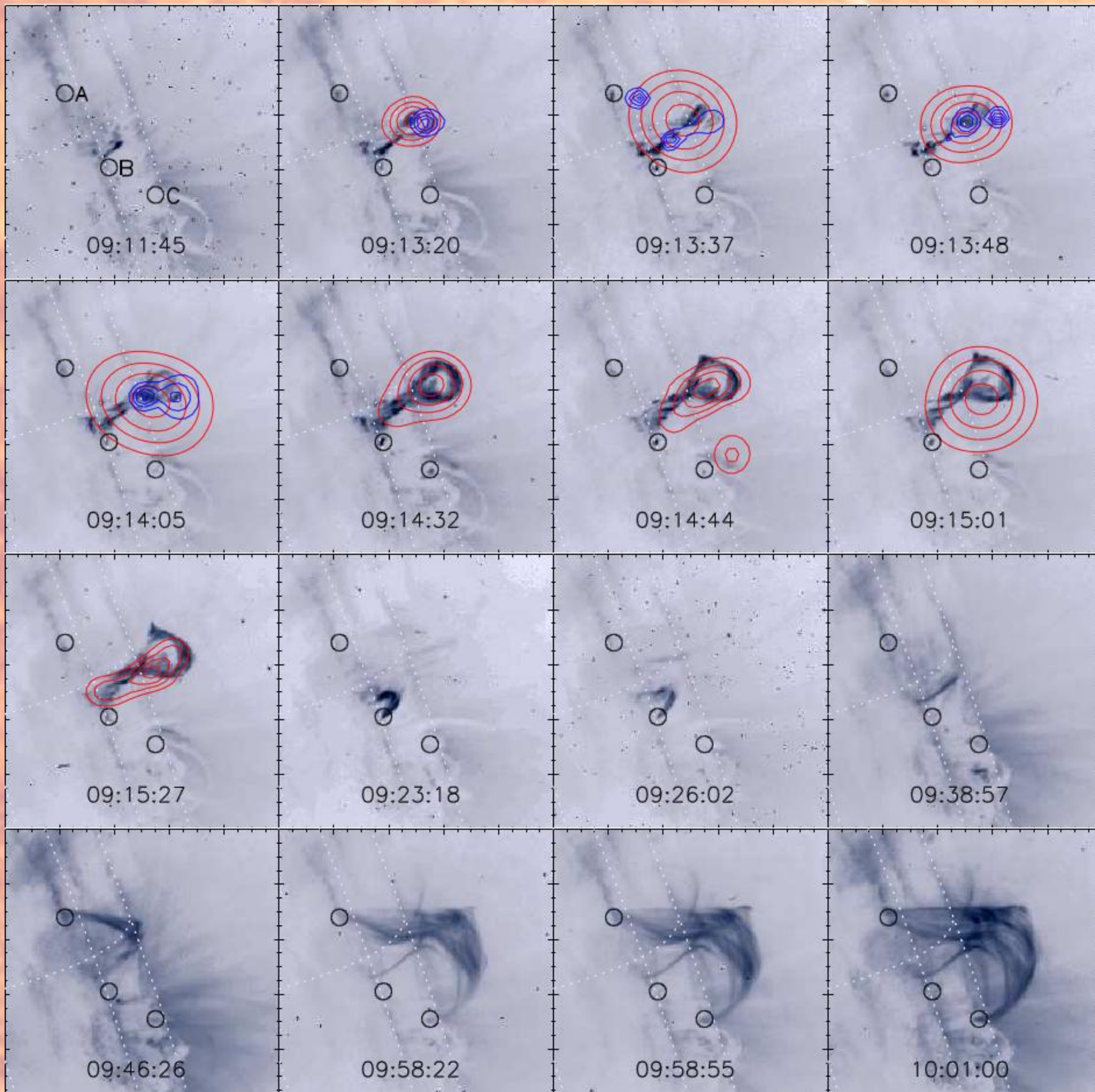
Images were searched for pixels that showed a sudden increase in brighteness.

The increased signal should appear for at least two subsequent images.

The group of neighboring brightened pixels constitutes an area of brightening.



EUV brightenings, HXR sources



22-OCT-1999

HXT/L 14-23 keV
HXT/M1 23-33keV

Three EUV brightenings were found

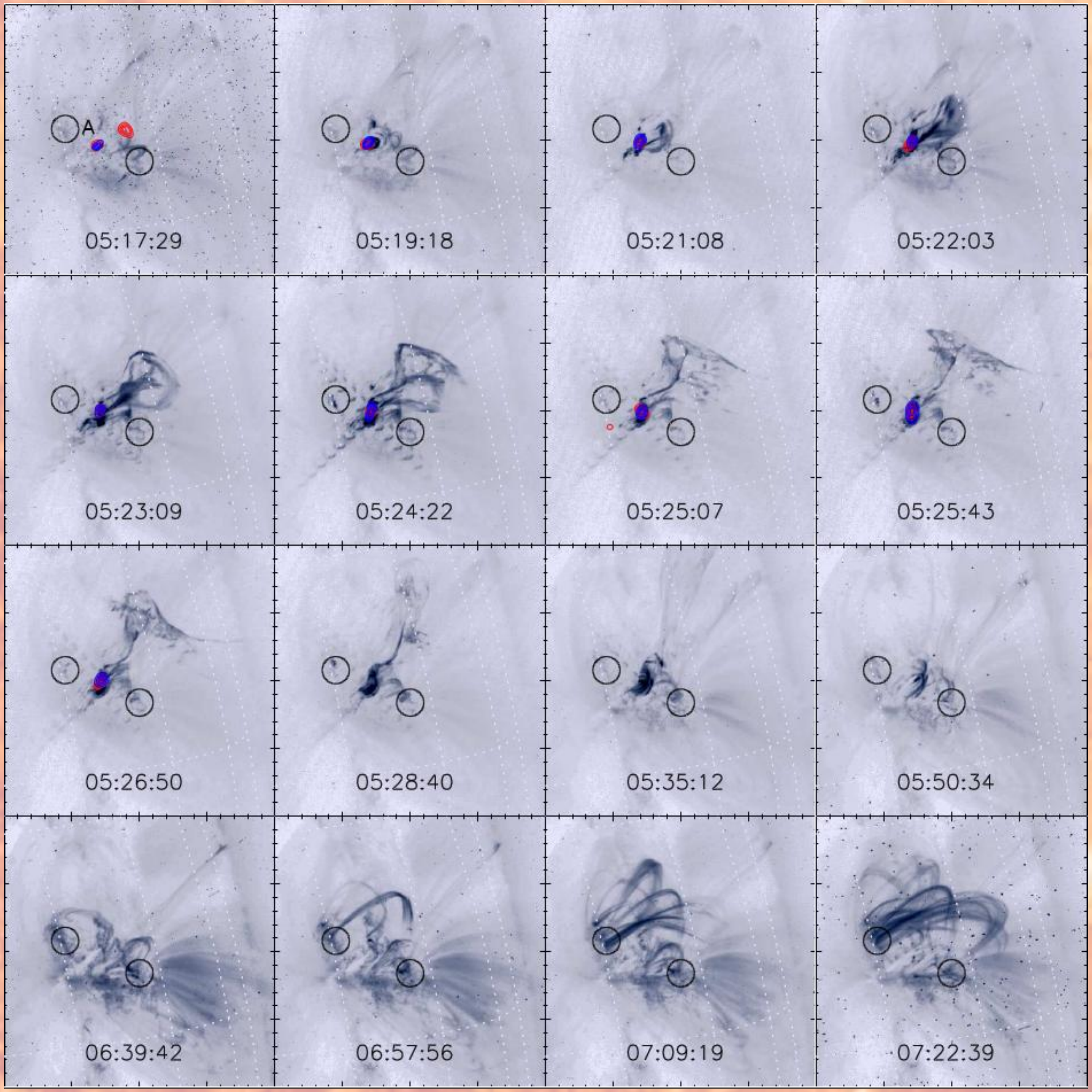
HXR sources correlate with eruption front and EUV brightenings

System of large loops visible 30 minutes after the flare maximum

EUV brightenings are spatially correlated with post-flare loops and foot points of large magnetic structures

Their heights fits the maximum height of the eruption

EUV brightenings, HXR sources



14-JUL-2004

RHESSI 12-25 keV

RHESSI 25-50keV

Compact HXR sources spatially correlated with flaring structure.

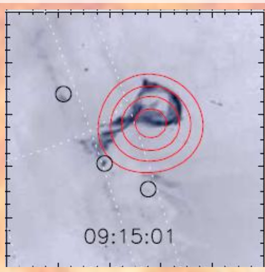
Two EUV brightenings found

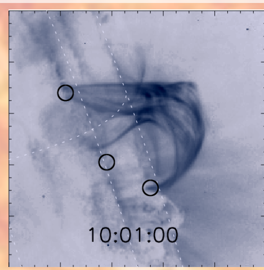
System of large loops visible 80 minutes after the flare maximum

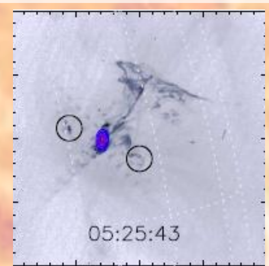
EUV brightenings are spatially correlated with foot points of large magnetic structures

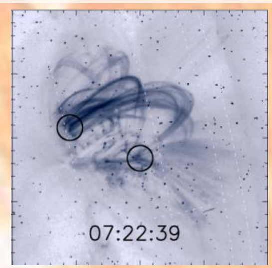
They are not post-flare loops!

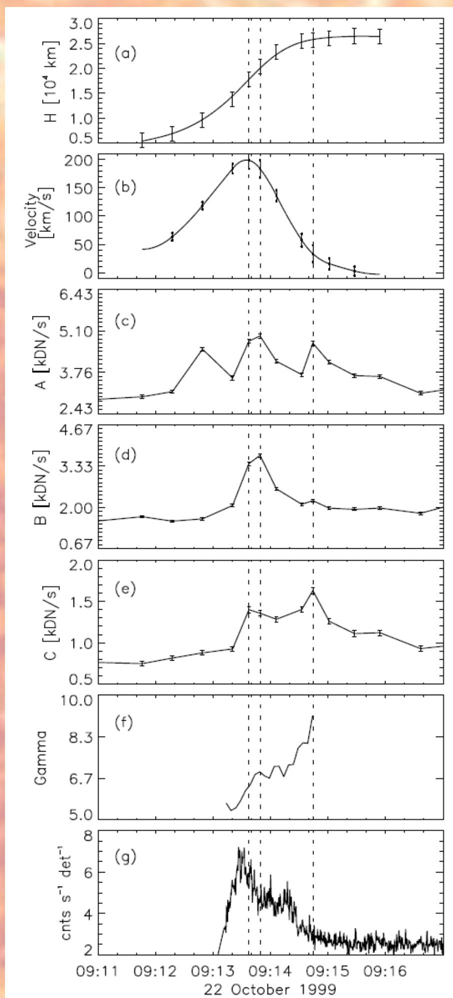
Time correlations

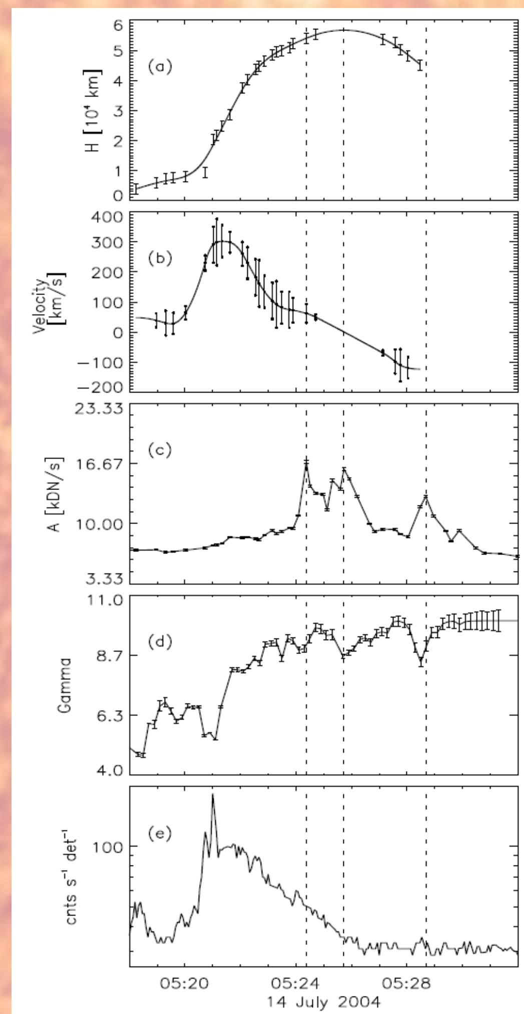












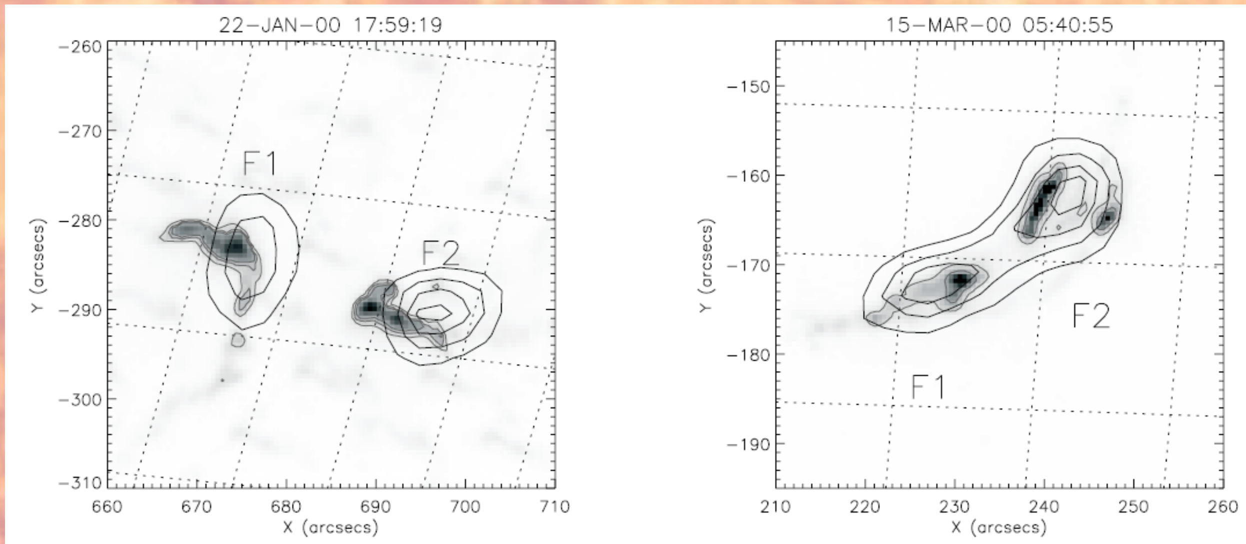
Height of the eruption front was fitted with cubic splines.

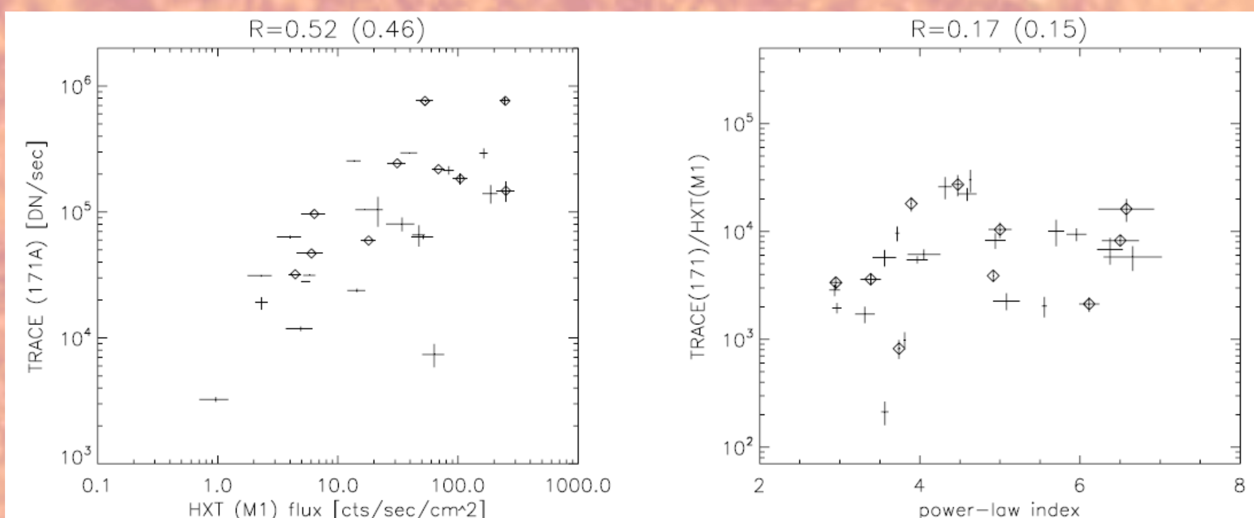
The velocity is a derivative of the fit.

The maximum EUV intensity of selected regions was observed during the deceleration of an eruption front.

For the 14-JUL-2004 event the correlation between EUV brightenings and gamma index is observed

HXR emission in solar flare foot points





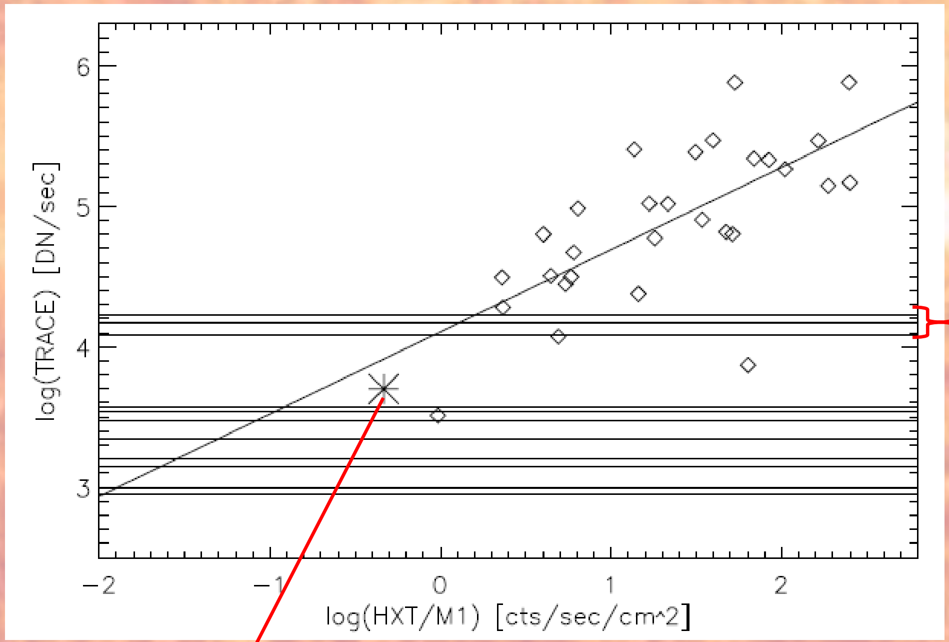
Mrozek et al. 2007,
A&A 472, 945

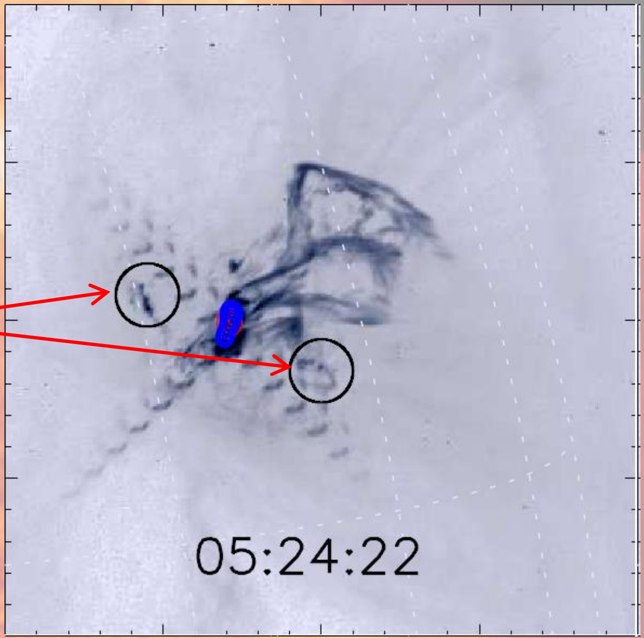
Quantitative analysis of SXR, EUV and UV fluxes and HXR emission in solar flare foot points

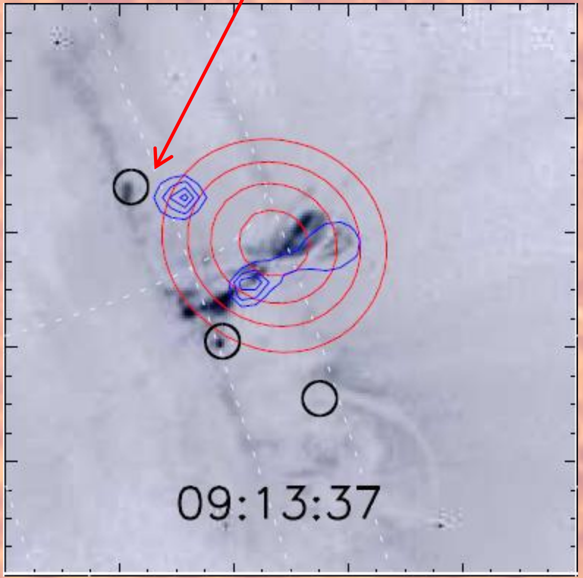
Correltations between fluxes and HXR spectral index

Obtained results may be used for estimating the HXR source parameters using the EUV source characteristics

HXR emission in footpoints of large magnetic structures







diamonds –TRACE 171 Å and HXT/M1 signals *(Mrozek et al. 2007, A&A, 472, 945*)

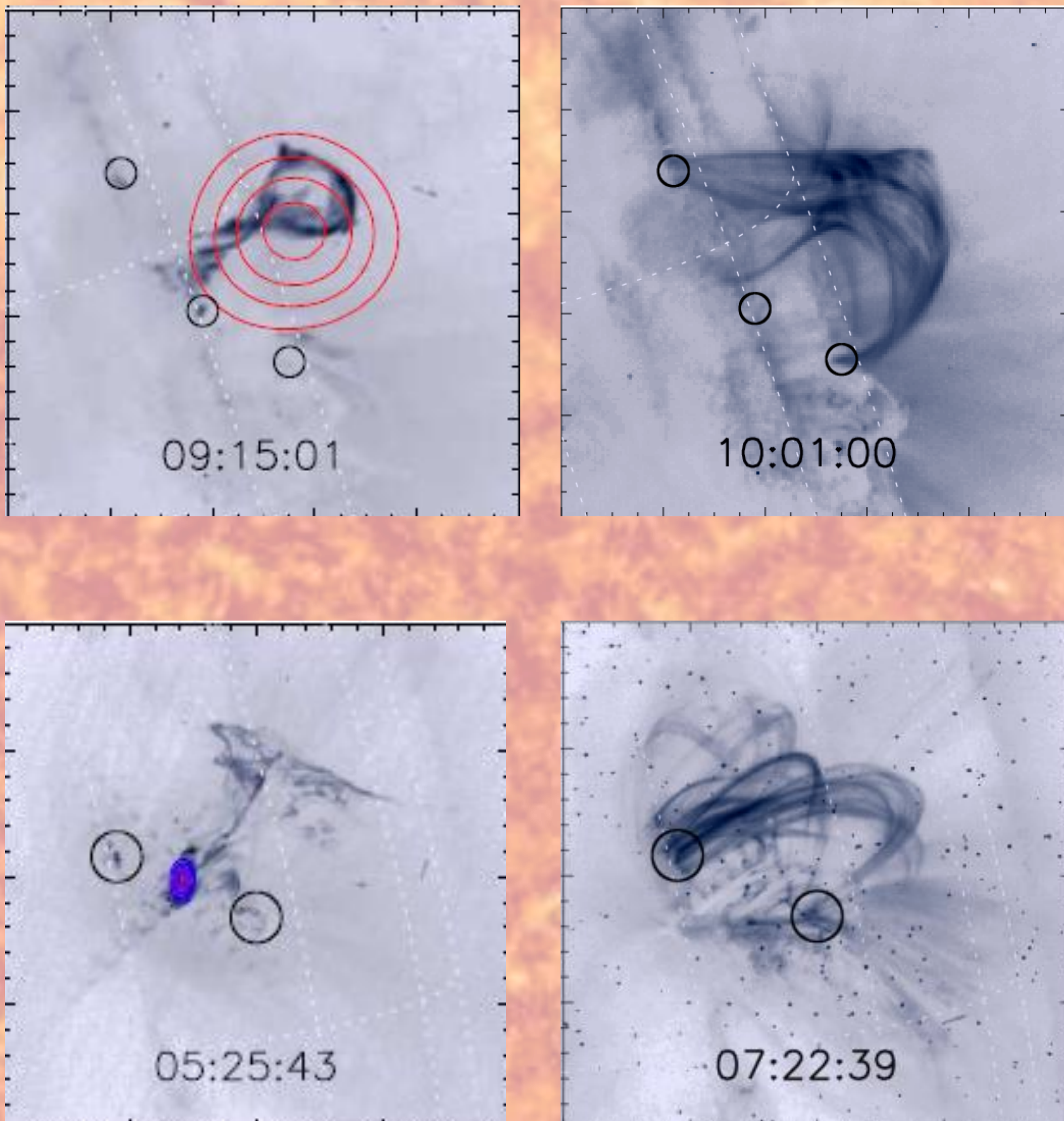
asterisk – EUV brightening (A) and HXT/M1 source for 22-OCT-1999

horizontal lines – maximum intensity of EUV brightenings for all analysed events

HXR sources that correlate with analysed EUV brightenings should be ~10 times weaker than weakest footpoints observed.

The estimated energy deposited by non thermal electrons is about 10^{28}erg

Why so important?



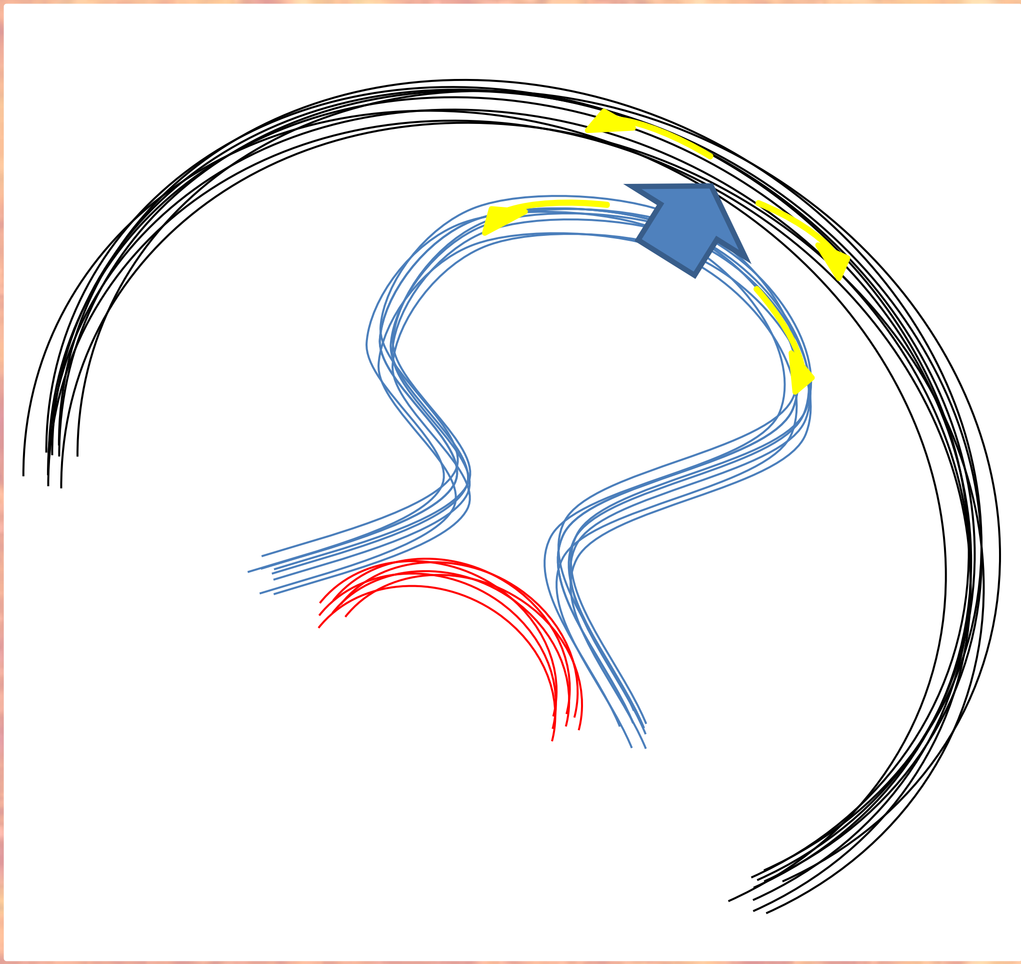
There is no high system of loops observed before the eruption

Thus, we conclude that the plasma has low density in these loops

Because of low density accelerated electrons reach chromosphere with very low interactions during the propagation

The characteristics of HXR sources in foot points of overlying magnetic structures are more straightforward related to the acceleration region and acceleration mechanism.

Conclusions



Netzel, A., Mrozek, T., Kołomański, S., and Gburek,S. arXiv:1209.0123v1, A&A accepted

- The characteristics analyzed (height, velocity, gamma index, EUV brightenings, HXR ligh curves) are time correlated.
- The heights of the large system of loops are almost the same as the maximum height reached by the eruption.
- The EUV brightenings are observed in foot points of these loops. In one case HXR emission was observed.
- In one case we detected weak HXR emission (23-33 keV) located exactly at the front of the eruption.
- Expected HXR sources connected with the EUV brightenings are weak and may rarely be observed with the present instruments, but give a new diagnostic method for non thermal particles that propagate within loops.