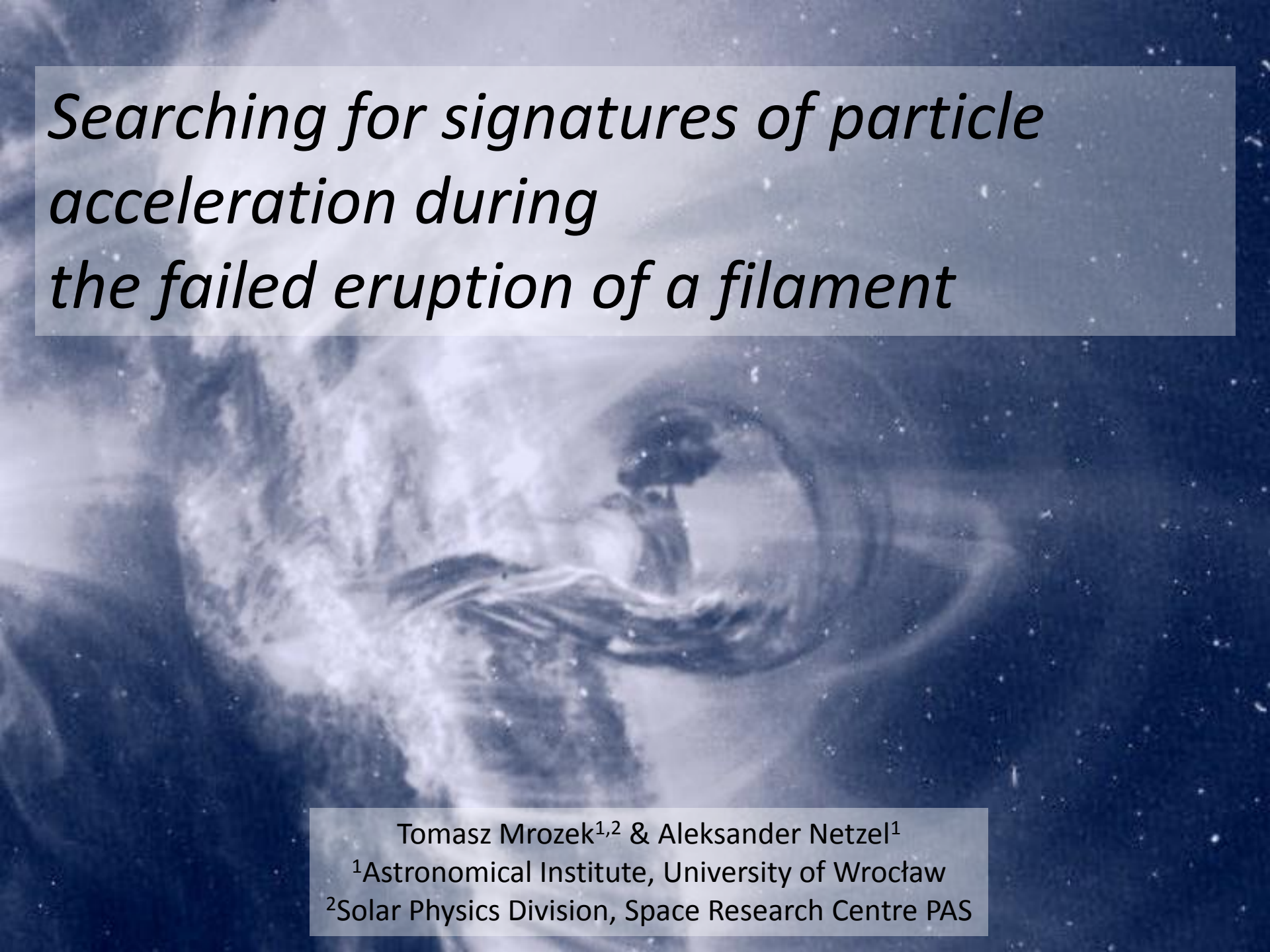


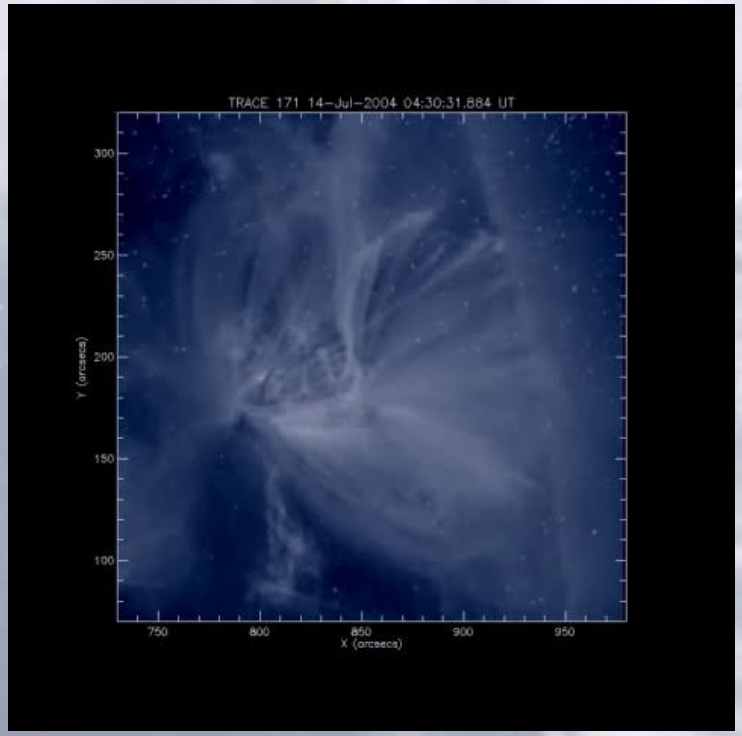
Searching for signatures of particle acceleration during the failed eruption of a filament

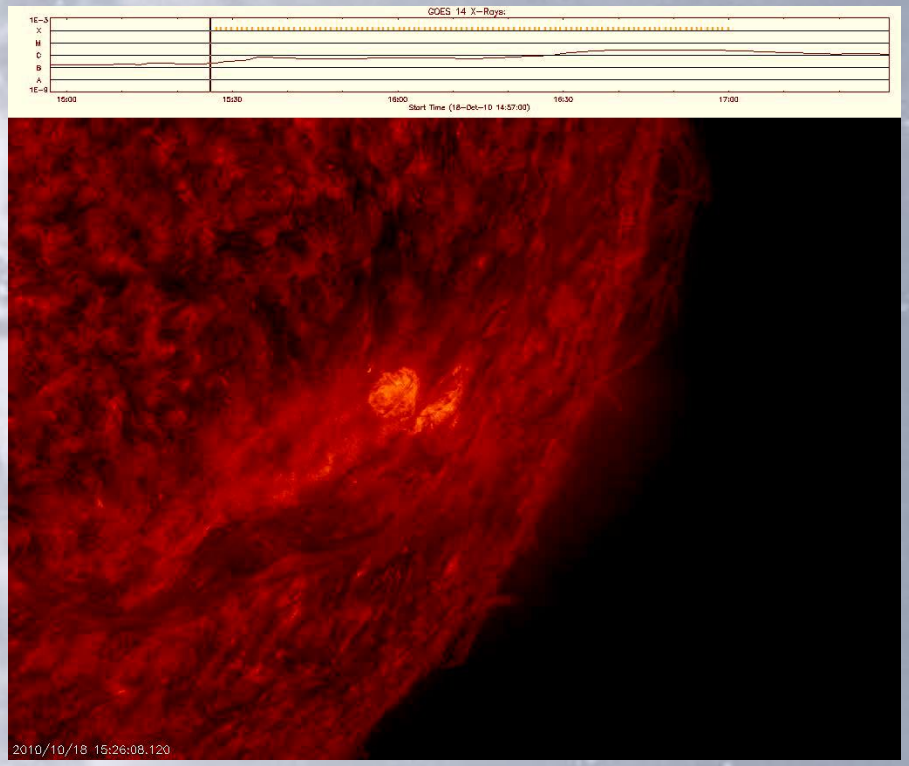
Tomasz Mrozek[1,2] & Aleksander Netzel[1]
[1]Astronomical Institute, University of Wrocław
[2]Solar Physics Division, Space Research Centre PAS

Types of eruption

Gilbert, H.R. i in. 2007, Sol. Phys., 245,287

	Type of eruption	Description
1	Full	Bulk ($\geq$ 90%) of filament mass and magnetic structure escapes the Sun
2	Partial	(a) Entire magnetic structure erupts with some or none of the filament mass (as a result of mass draining)
		(b) Partial eruption of the magnetic structure with some or none of the filament mass (as a result of mass draining and/or settling)
3	Failed	None of the filament mass nor magnetic structure escapes the Sun





Failed eruptions – possible mechanisms of confinement

Forces within the erupting flux rope:
Vršnak 1990, Sol. Phys. 129, 295

Reaching an upper equilibrium:
Vršnak 2001, J. Geophys. Res. 106, 25249
Green et al. 2002, Sol. Phys. 205, 325

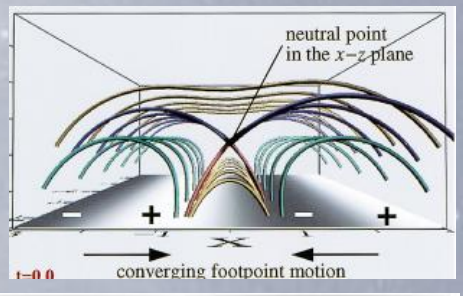
Magnetic tension force and exchange with the background plasma:
Wang and Eheeley 1992, ApJ 392, 310
Archontis and Török 2008, A&A 492, L35

Kink instability and stabilization of erupting filament:
Ji et al. 2003, ApJL 595, 135
Török and Kliem 2005, ApJL 630, 97

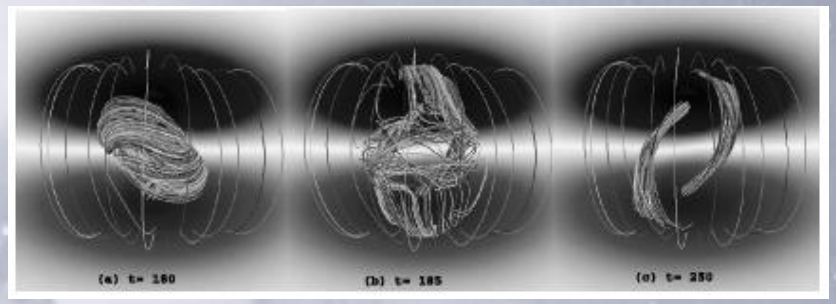
Confinement by the overlying closed magnetic field:
Hirose et al. 2001, ApJ 551, 586

Failed eruptions – the role of the overlying field

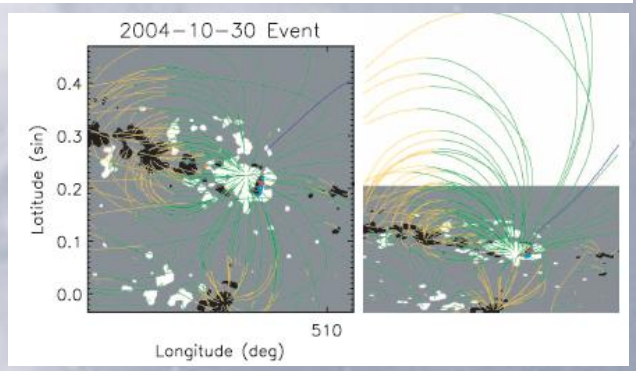
Quadruple model of solar flare:
Uchida et al. 1999, PASJ 51, 553
Hirose et al. 2001, ApJ 551, 586



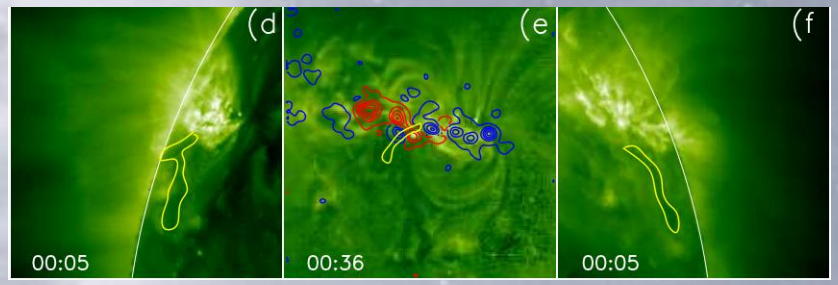
Importance of overlying field was also discussed in theoretical papers by:
Amari and Luciani 1999, ApJ 515, 81
Török and Kliem 2005, ApJL 630, 97
Fan and Gibson 2007, ApJ 668, 1232



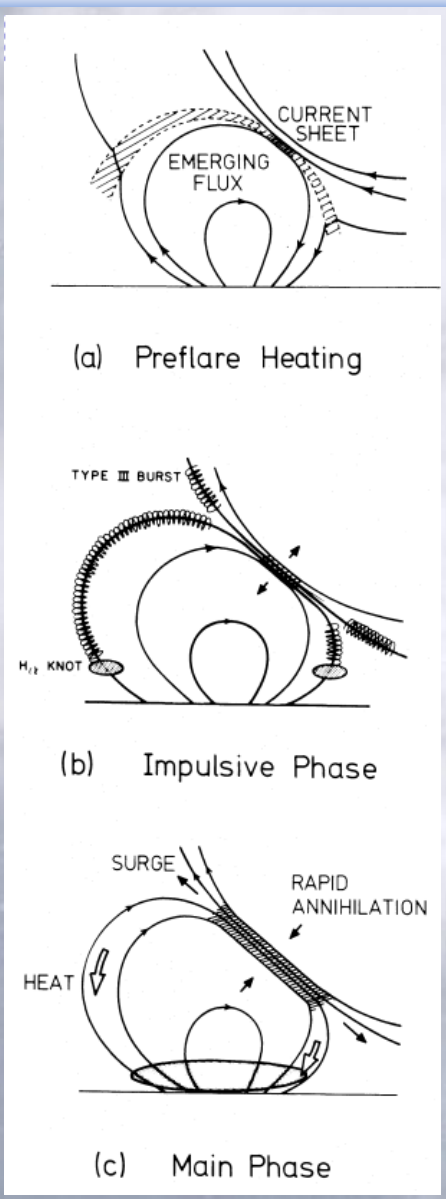
Ratio between field magnitude high and low in the corona has larger values for confined events:
Wang and Zhang 2007, ApJ 665, 1428
Liu 2008, ApJL 679, 151



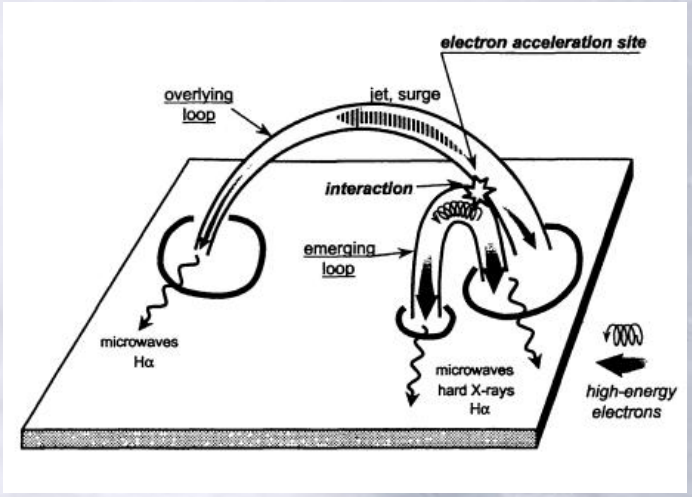
Amount of a kinetic energy which is needed to break through the overlying field:
Shen et al. 2010, arXiv:1011.4906



Motivation

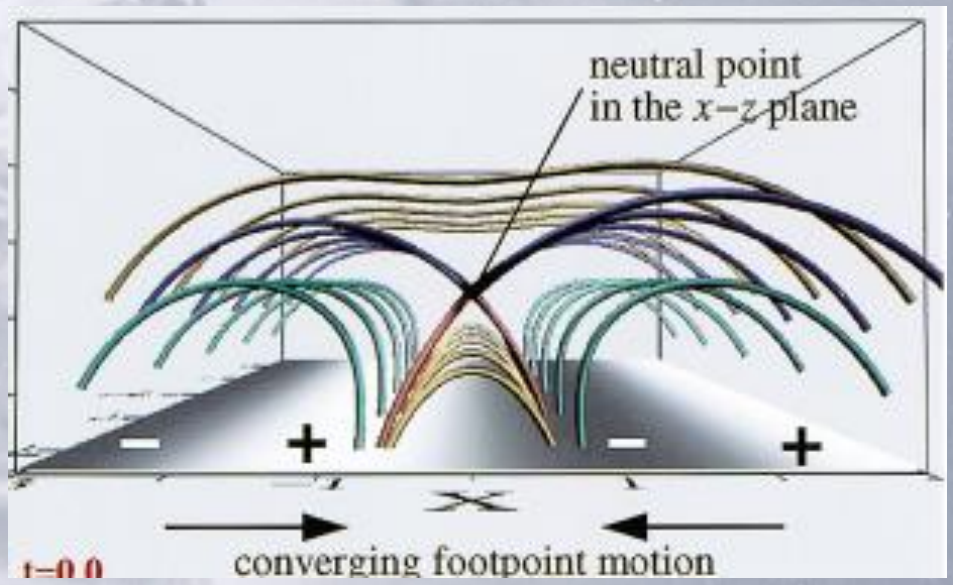


Heyvaerts et al. 1977, ApJ 216, 123



Hanaoka 1999, PASJ 51, 483

Search for brightenings that trace the interaction between eruption and overlying field



Hirose et al. 2001, ApJ 551, 586

Events

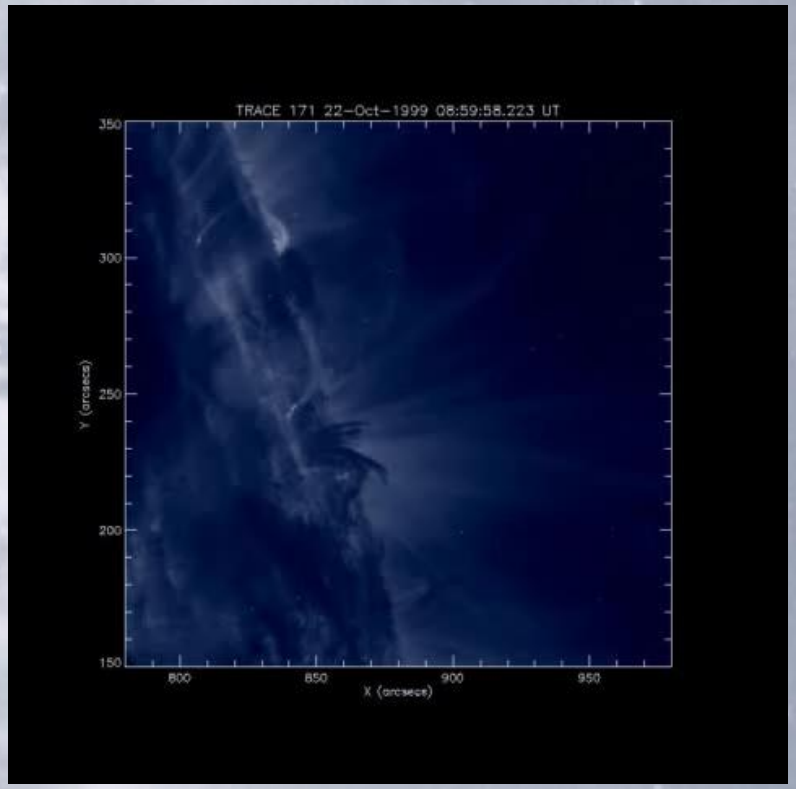
date	time (eruption)	flare (start-max)	GOES class
22 Oct 1999	9:11-9:24 UT	9:10-9:16 UT	C4.8
19 Jun 2000	23:10-23:35 UT	no flare reported	-
14 Jul 2004	5:17-5:23 UT	5:02-5:23 UT	M6.2

10 failed eruption events found in TRACE database

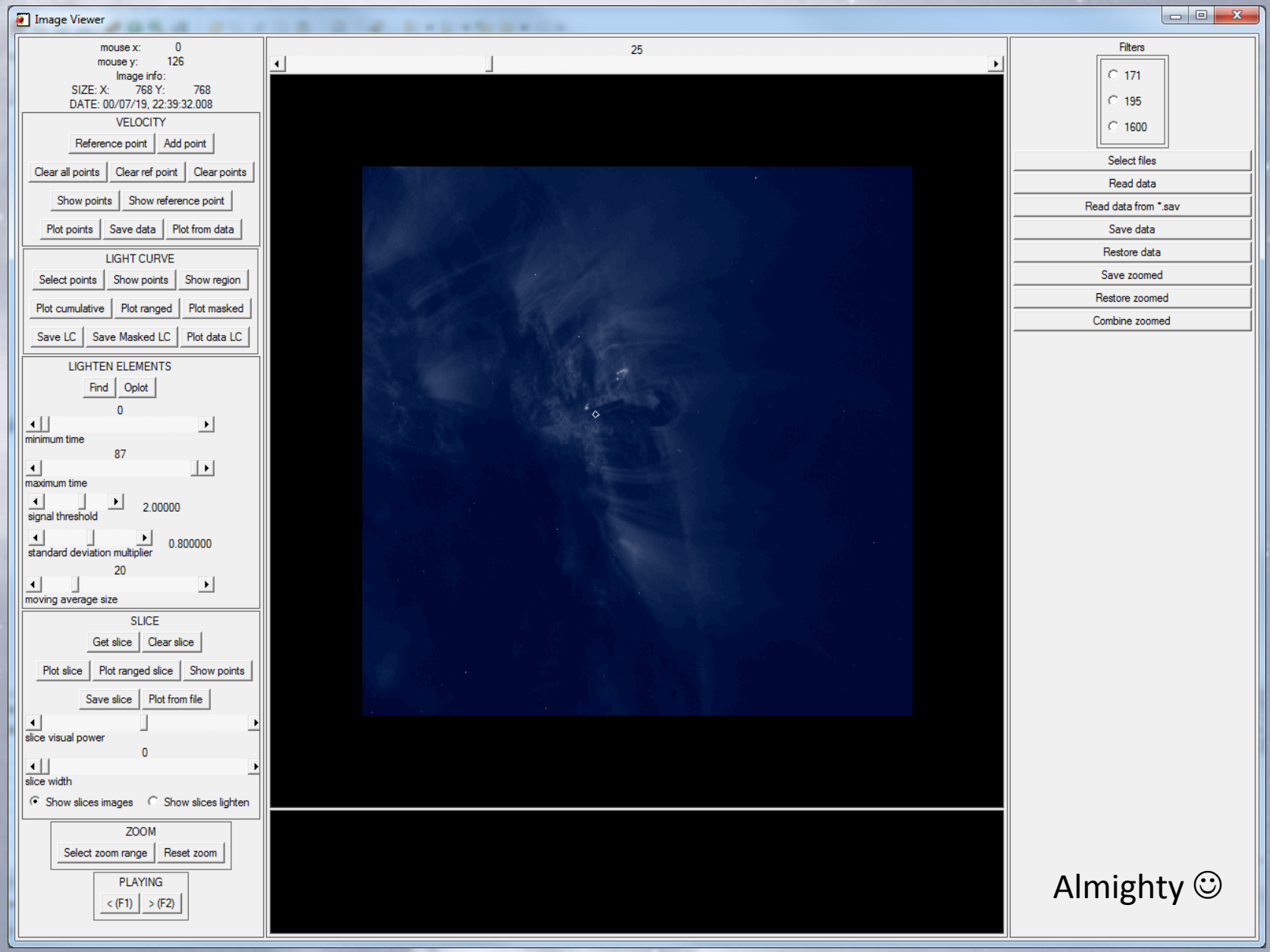
mainly observed by TRACE in EUV range (171 Å or 195 Å)

some of them are visible in UV range (1600 Å) simultaneously

we are looking into SDO/AIA database (2 events found)

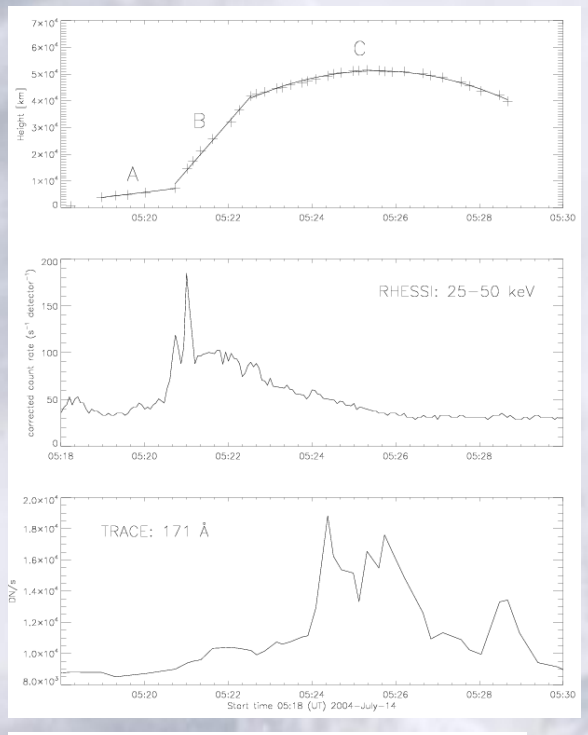


Searching for brightenings



Almighty ☺

14 Jul 2004 (Mrozek 2011, Sol. Phys. 270, 191)

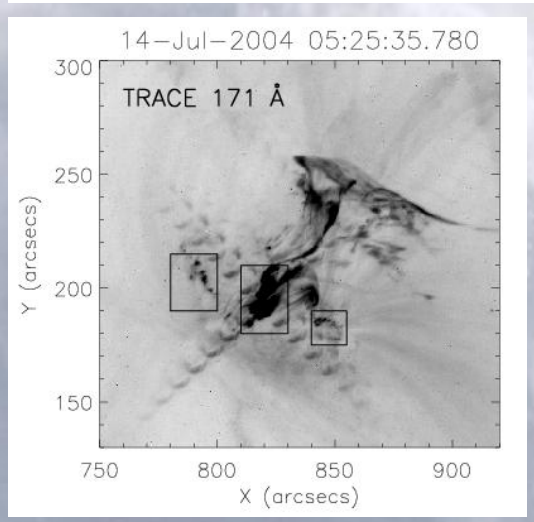


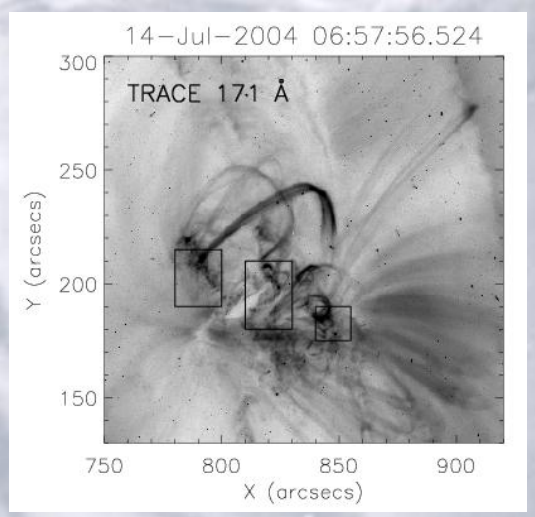
brightenings observed outside flaring structure

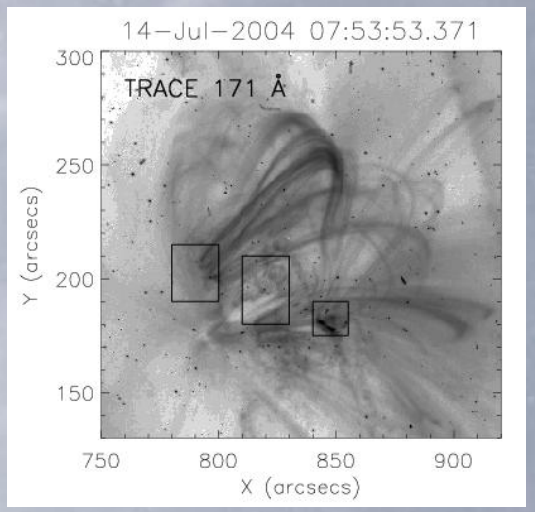
spatialy correlated with overlying loops visible about hour later – these are not post-flare loops!

high correlation with height changes

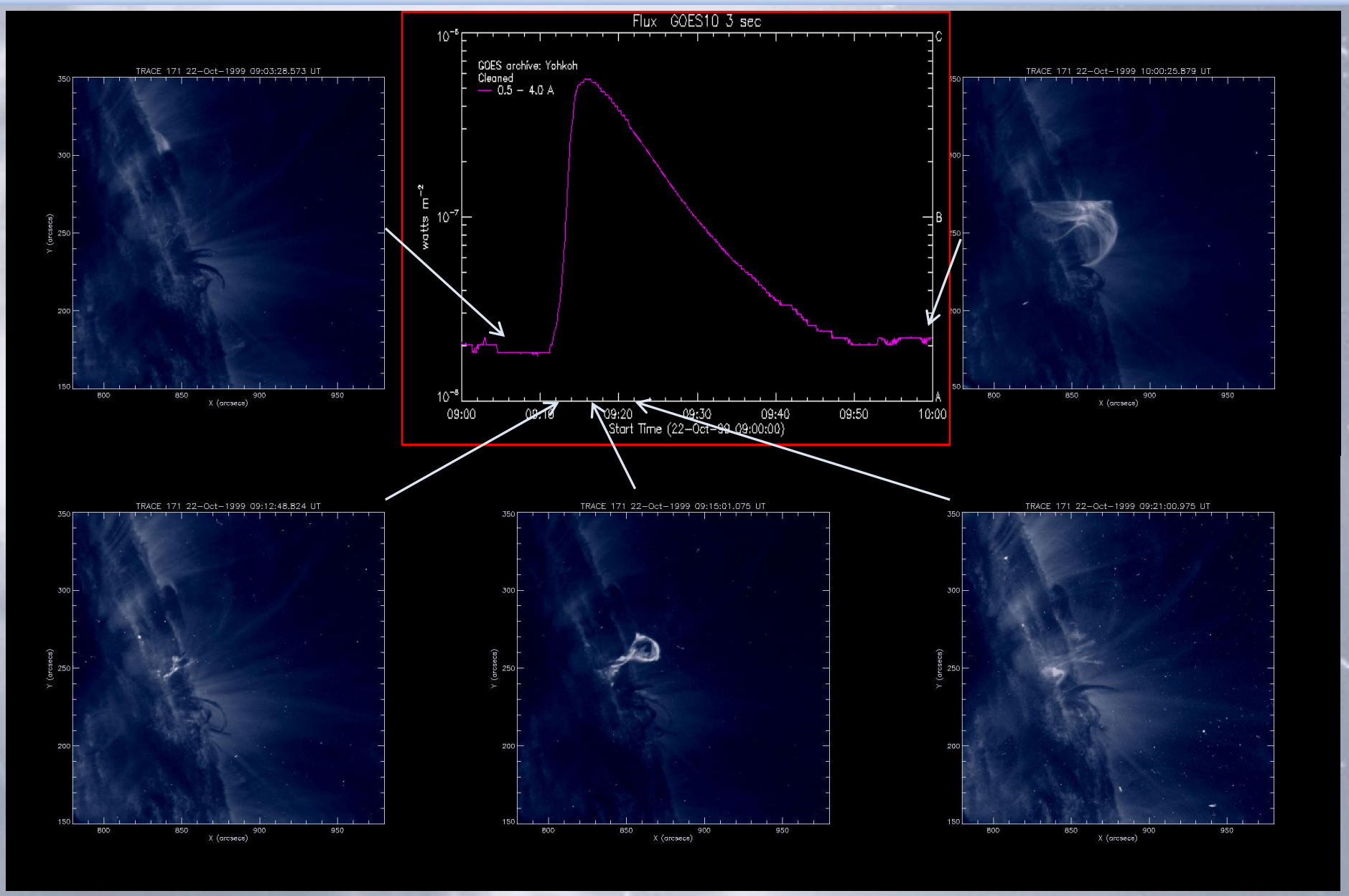
smal increase in HXR in the same time



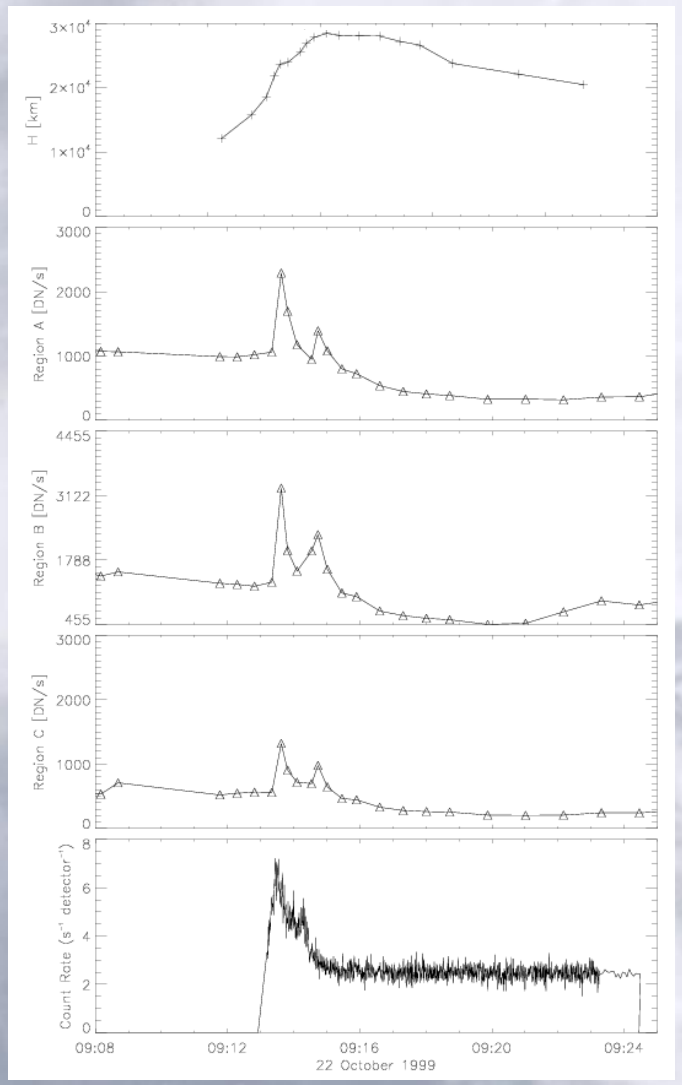


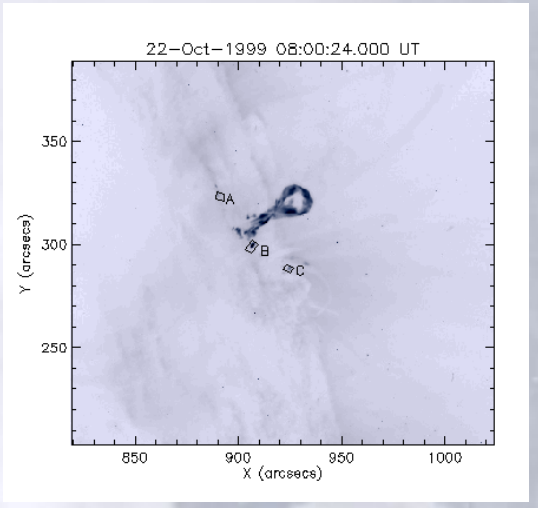


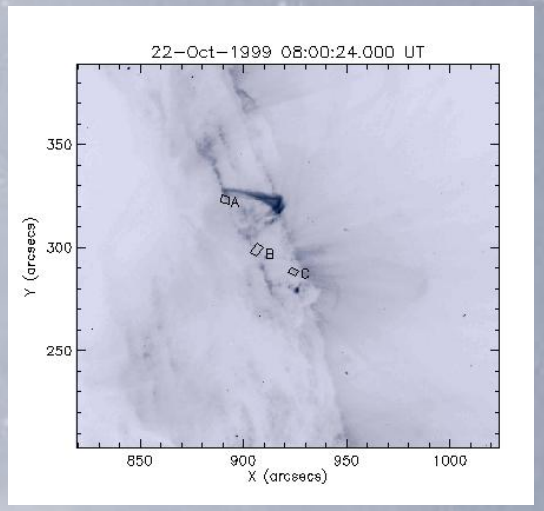
22 Oct 1999

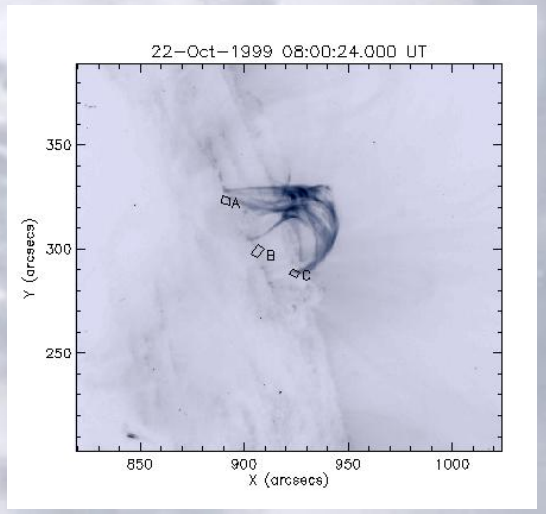

Flux GOES10 3 sec
GOES archive: Yohkoh
Cleaned
0.5 – 4.0 A
watts m^{-2}
10^{-5}
10^{-7}
10^{-8}
C
B
A
09:00
09:10
09:20
09:30
09:40
09:50
10:00
Start Time (22-Oct-99 09:00:00)
TRACE 171 22-Oct-1999 09:03:28.573 UT
TRACE 171 22-Oct-1999 10:00:25.879 UT
TRACE 171 22-Oct-1999 09:12:48.824 UT
TRACE 171 22-Oct-1999 09:15:01.075 UT
TRACE 171 22-Oct-1999 09:21:00.975 UT
Y (arcsecs)
X (arcsecs)

22 Oct 1999





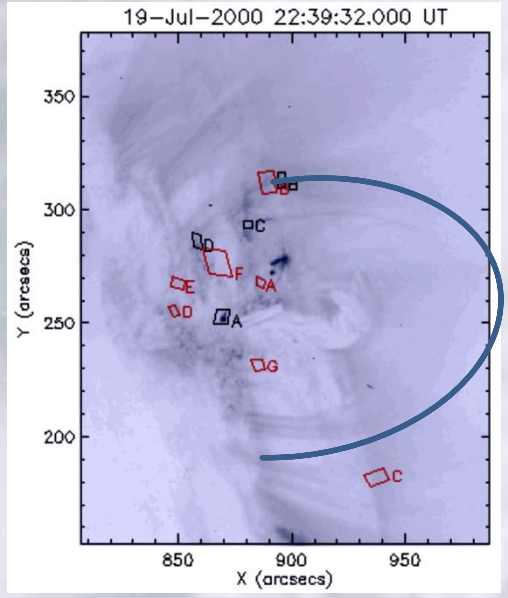


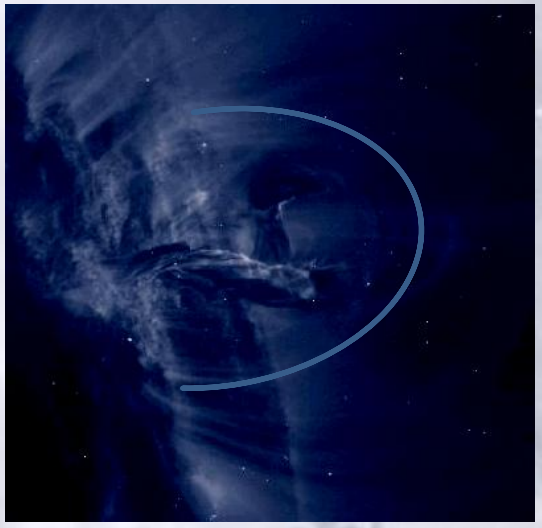


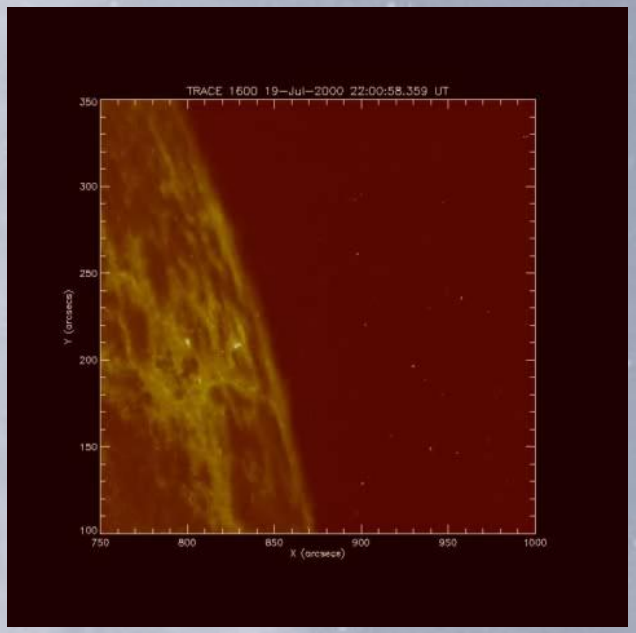
Brightenings are strongly correlated:

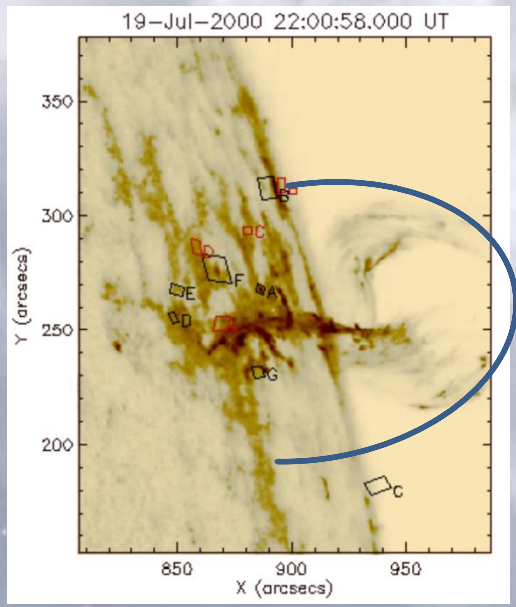
-temporaly – with height changes
- spatialy – with footpoints of overlying loops

19 Jul 2000









two phases were observed

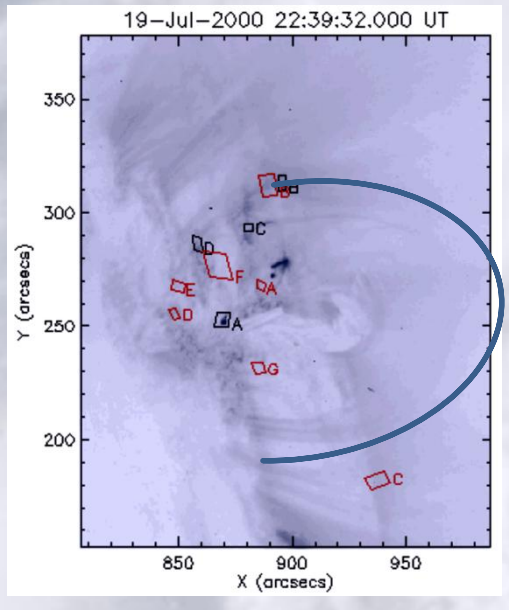
the eruption front is broken (due to reconnection with overlying field?)

brightenings seen in EUV (171 Å) and UV (1600 Å) ranges

some of them are spatially correlated

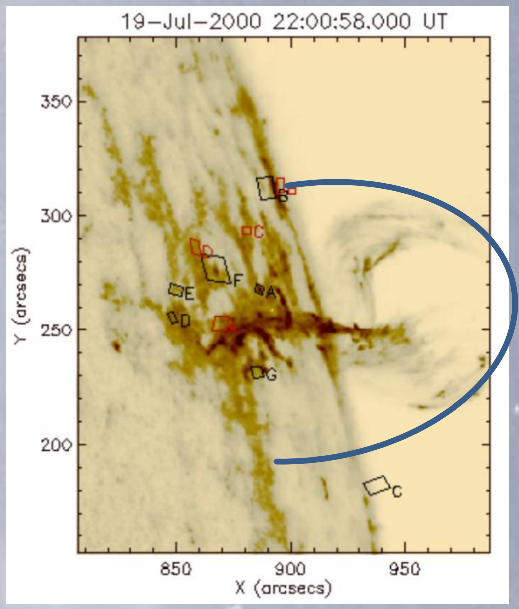
mass motion (falling free material) is observed close to the eruption front

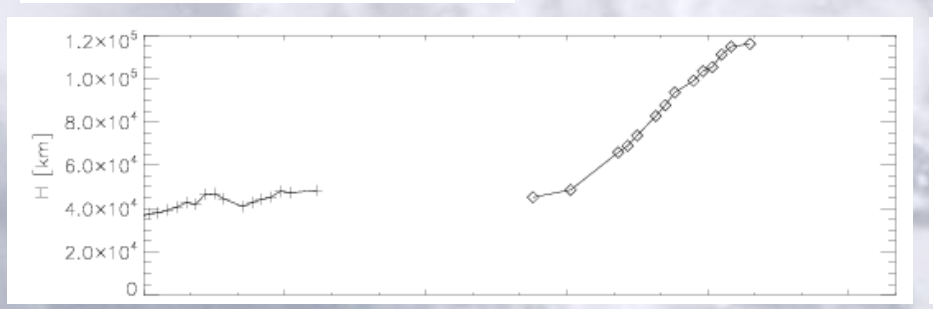
19 Jul 2000

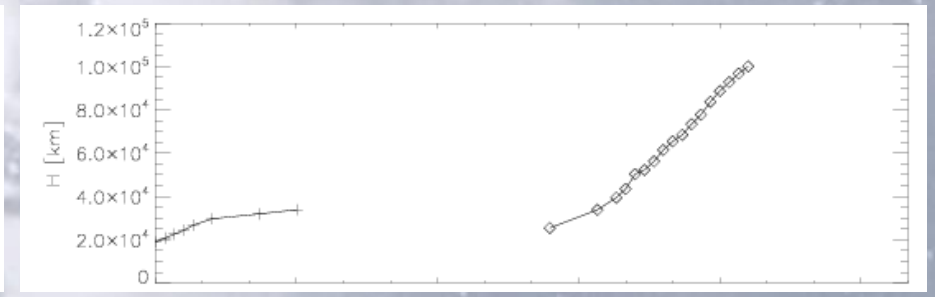


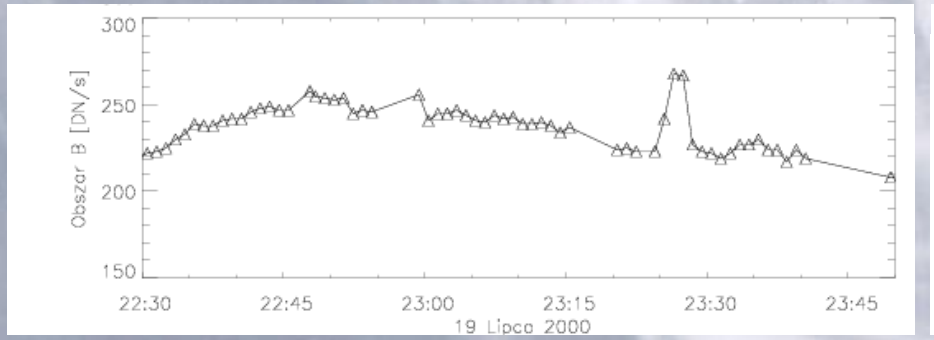
falling free mass also produce some brightenings which are fainter and observed after interaction

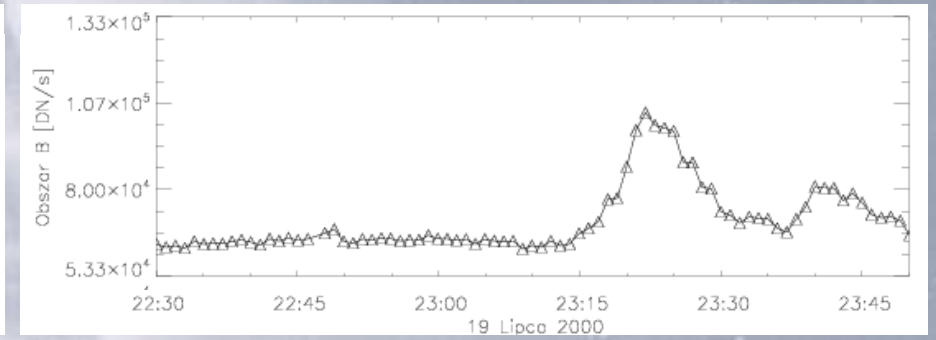
we do not observe HXR sources correlated with the brightenings



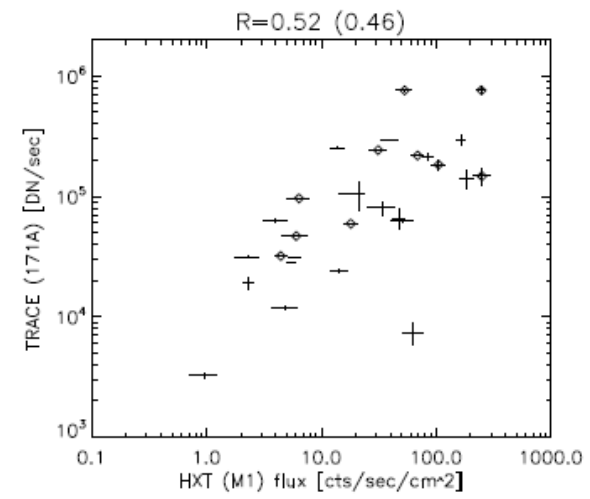


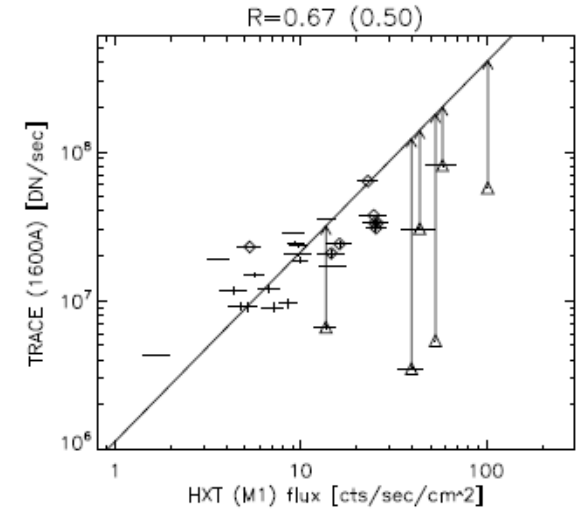


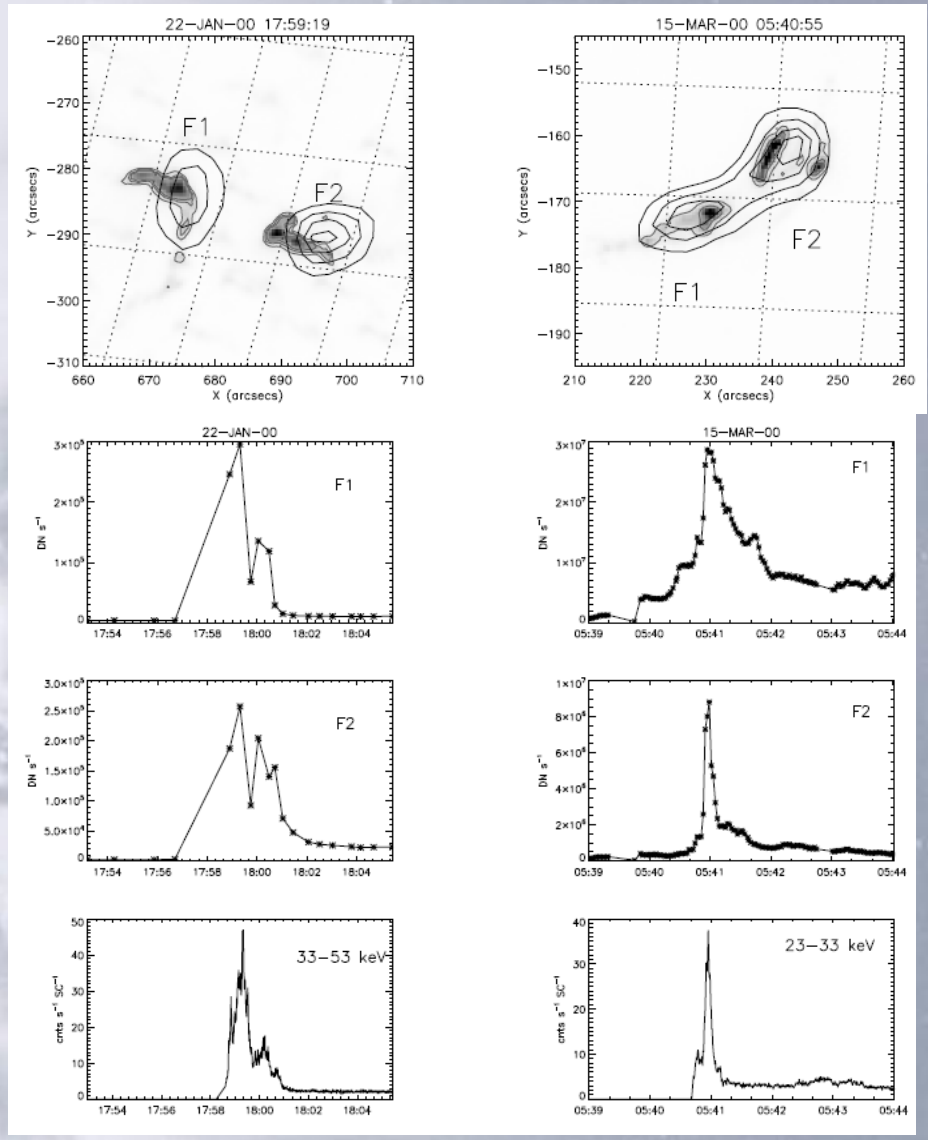




Why we do not observe HXR emission?

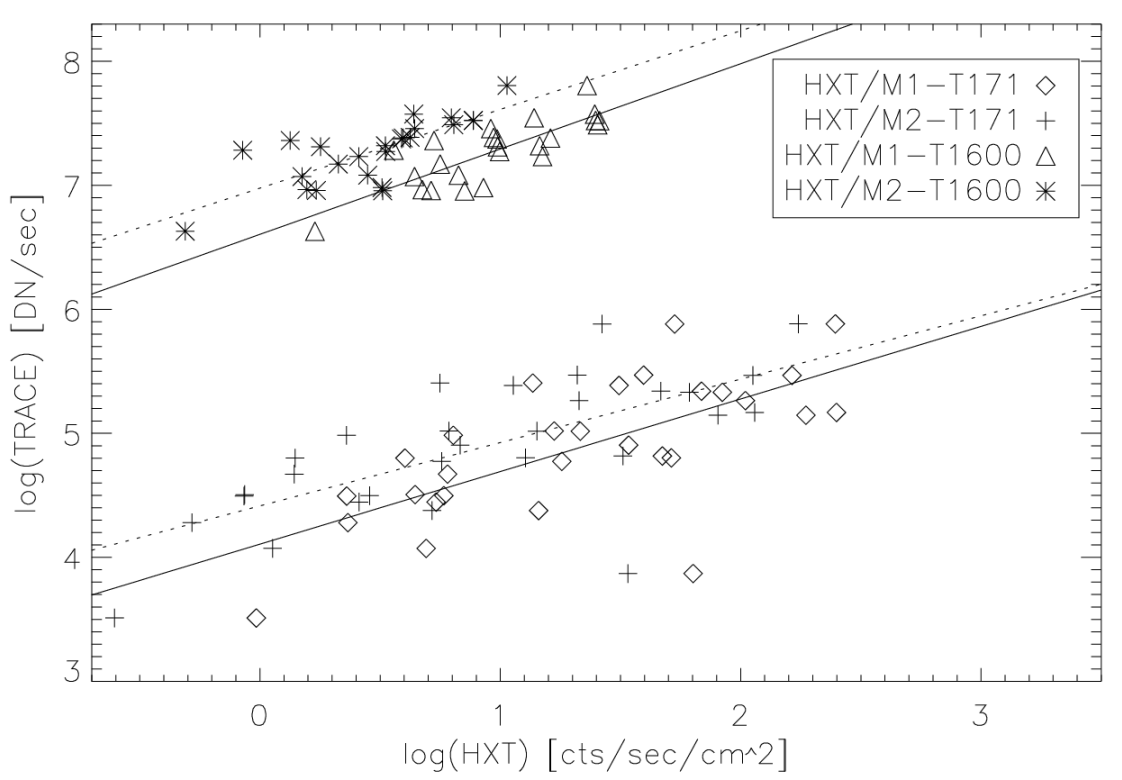






Mrozek, Tomczak and Gburek 2007, A&A 472, 945

HXR sources flux estimation



expected HXR sources are too faint to be detected with present instrumentation

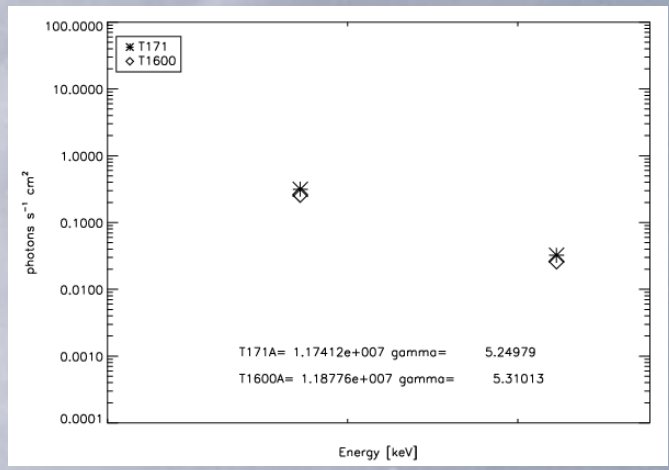
with the use of EUV/UV – HXR correlations obtained for flare footpoints we estimated the spectra of these hypothetical sources:

$$F = A\varepsilon^{-gamma}$$

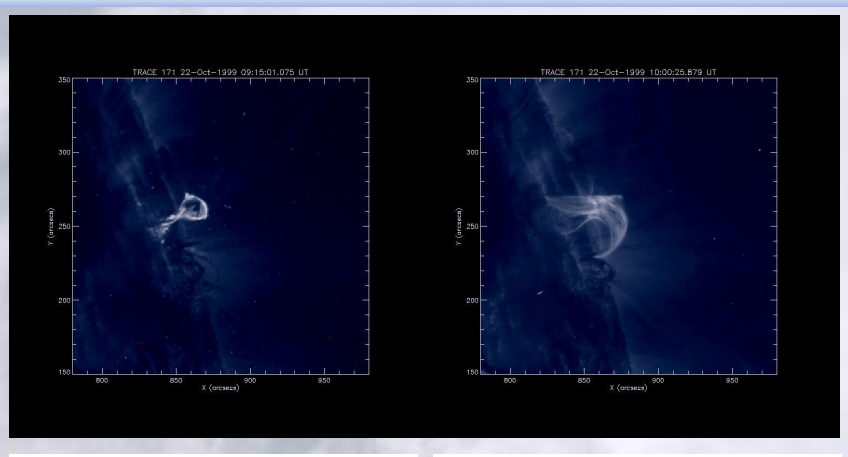
gamma ~ 5.3

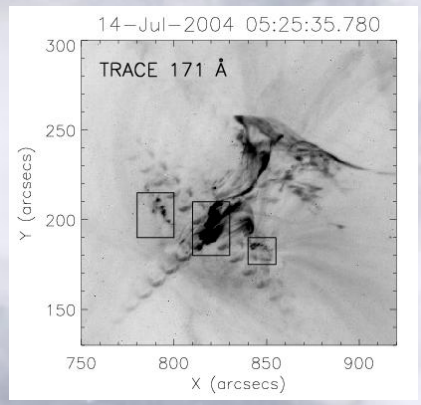
A ~ 1.2×10^7

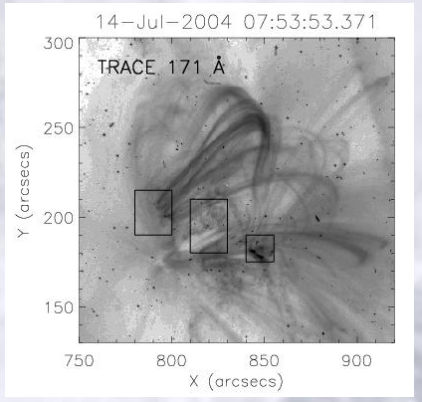
date	T171 [DN/s]	T1600 [DN/s]
22 Oct 1999	1500 – 3000	
19 Jun 2000	300 – 2500	$3 \times 10^4 – 2 \times 10^5$
14 Jul 2004	2×10^4	$> 5 \times 10^6$

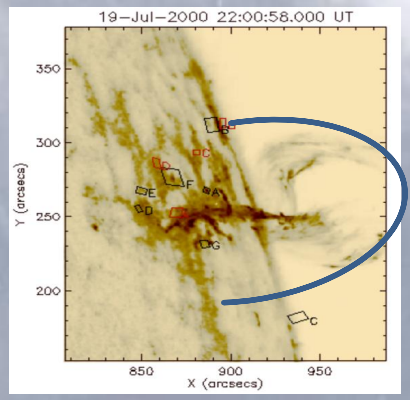


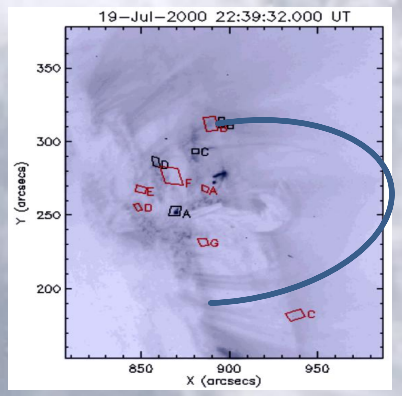
Overall picture











Observed features:

-brightenings outside the flaring structure

- no overlying loops visible during interaction (empty loops?)

-brightenigs are correlated with velocity changes and HXR emission (but no source detected, yet)

- overlying system of loops visible after the eruption

- brightenings are observed at the footpoints of overlying loops

Plans for the future

Observations:

- investigation of the entire group of selected events
- confined eruptions from XPEs catalogue
- SDO/AIA events
- other events and other wavelengths
- reconstruction of HXR sources with existing data (possibly it can be made for 14 July 2004 event)

There is need for modeling:

- what happens during the interaction between two magnetic systems (we have height changes, EUV/UV fluxes, sizes of brightenig areas etc.)
- energy distribution of accelerated electrons and atmospheric response in different wavelenghts