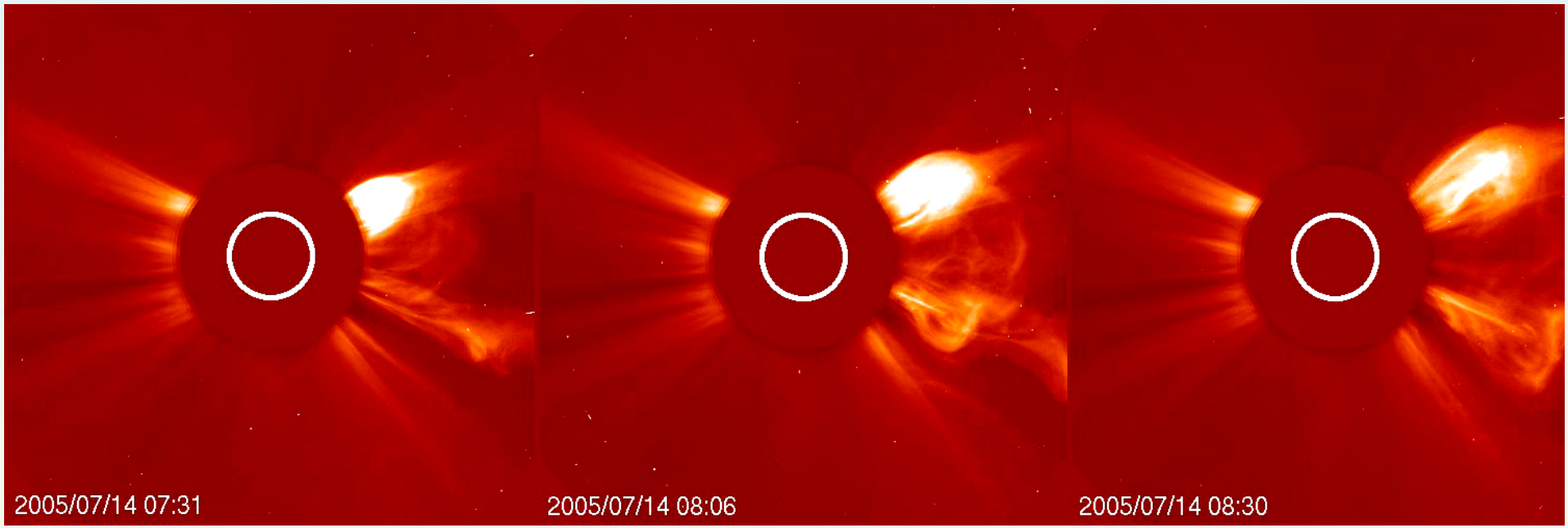
TEST BY OBSERVATIONS FOR NEW MODEL OF LARGE CME/FLARE EVENTS ON THE SUN AND LATE-TYPE STARS

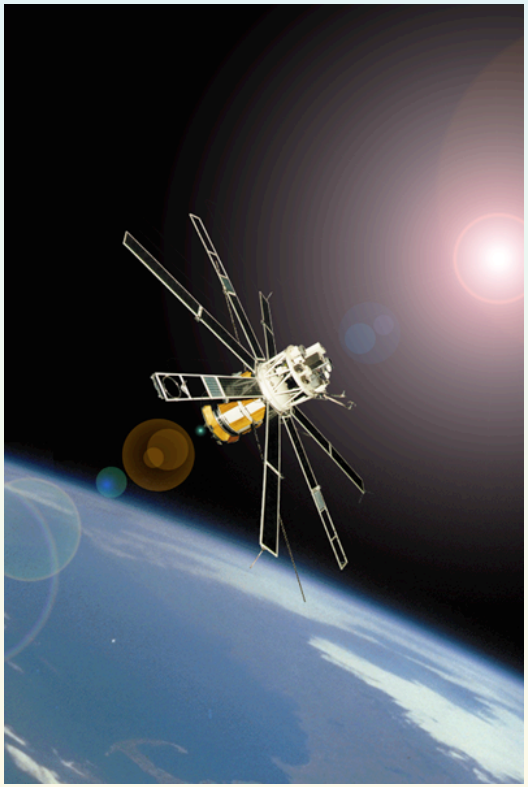
M.A. Livshits (IZMIRAN), M.M.Katsova (SAI MSU)



Wroclaw, December 2008

RESIK-RHESSI-SPIRIT Workshop
Wroclaw, December 6 - 8, 2005

INTERRELATION BETWEEN PROCESSES DURING IMPULSIVE AND POST- ERUPTIVE PHASES AS IT CAN BE TRACED FROM THE CORONAS-F DATA



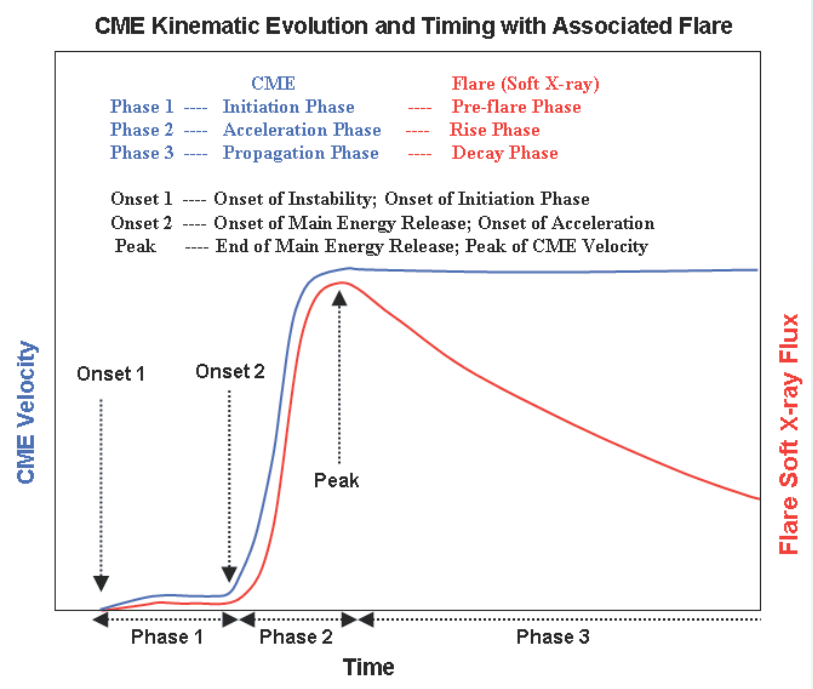
POLISH ACADEMY OF SCIENCES
SPACE RESEARCH CENTRE

Large CME/flare events

A large flare: what's this?

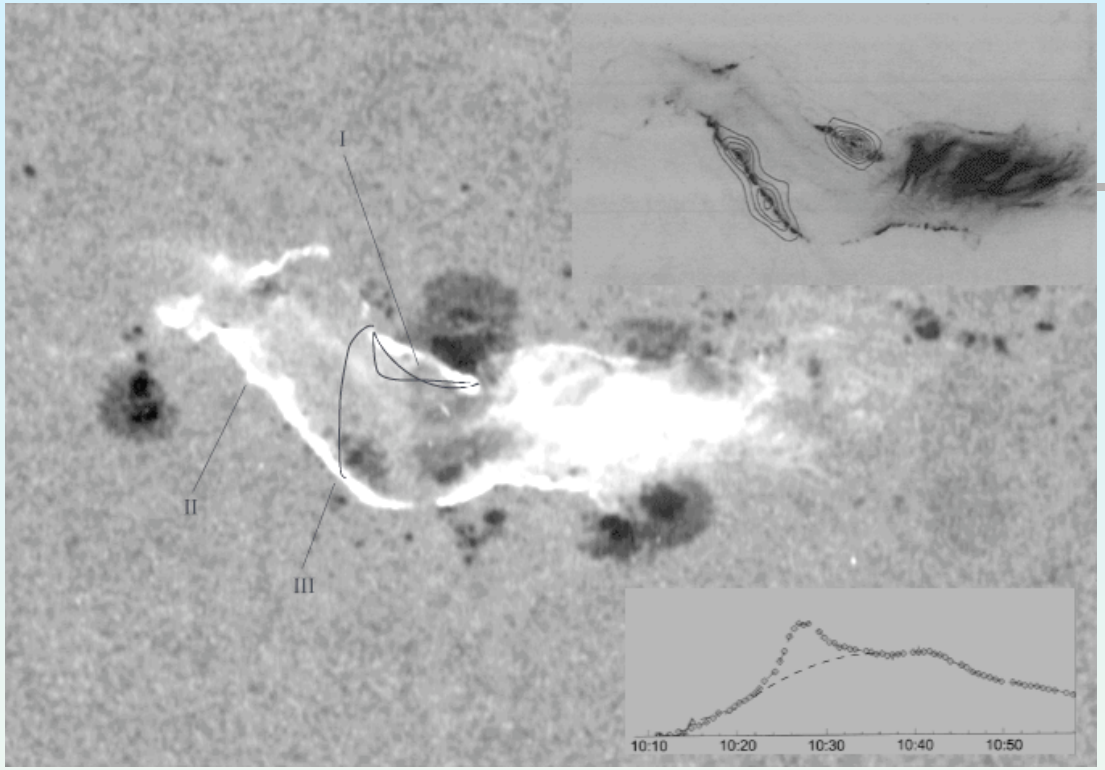
- Two stages of large non-stationary phenomena: primary energy release and formation of post-eruptive arcade
- Physical plasma parameters near to the top of arches
- Some samples for post-eruptive processes: 21.April 2004,

  25.January 2007
- A stellar analog of such very large events
- Some problems for further investigations



J. Zhang and K. P. Dere
ApJ, 649:1100-1109, 2006

On particle acceleration



Isophotes of the hard X-rays against emission at 195 A.

The 195 A emission against the white-light image

Time profile of the 171 A emission in the source I .

14.07.2000
10:19 -- 10:28 UT
time of γ-burst

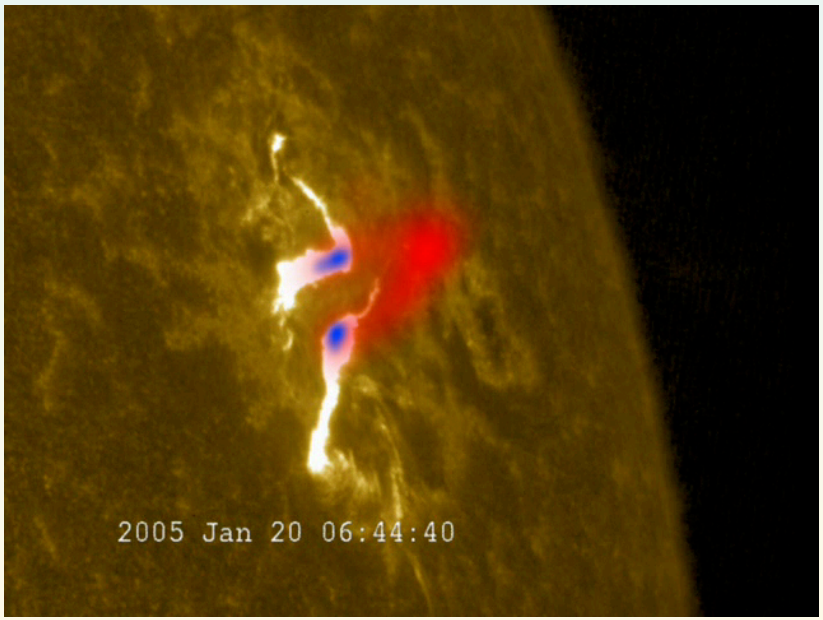
LIVSHITS M.A., BELOV A.V. 2004
Astron.Reports **48**, 665, " WHERE AND WHEN ARE SOLAR COSMIC RAYS ACCELERATED MOST EFFICIENTLY ?"

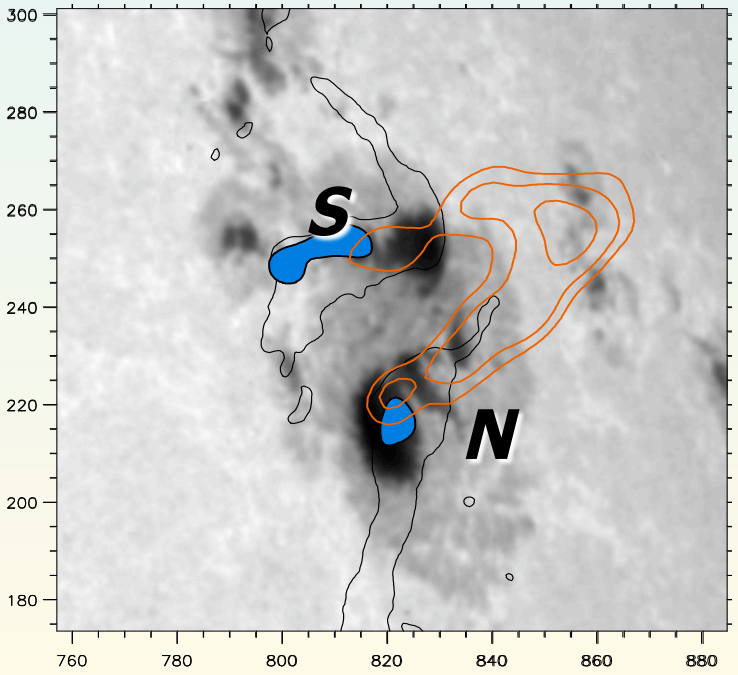
See also.: **Y.Yan, M.J.Ashwanden, S.Wang, and Y.Deng,** Sol. Phys. **204**, 29 (2001). ***h* =*15 000 ± 5 000 km***

January 20, 2005

V.V.Grechnev,· V.G.Kurt, ·I.M.Chertok, ·A.M. Uralov, H.Nakajima, A.T.Altyntsev, A.V.Belov,· B.Yu.Yushkov, S.N.Kuznetsov, · L.K. Kashapova, N.S. Meshalkina, · N.P. Prestage

The January 20, 2005 *big solar flare and its relation to Solar Energetic Particles, Sol. Phys. 2008*





RHESSI

Red

25-50 keV

Blue

50-100 keV

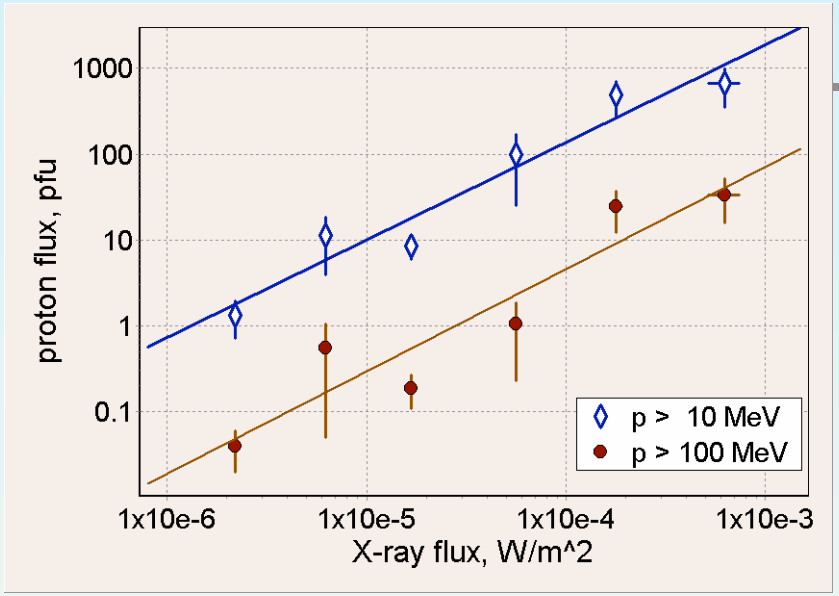
20.01.2005

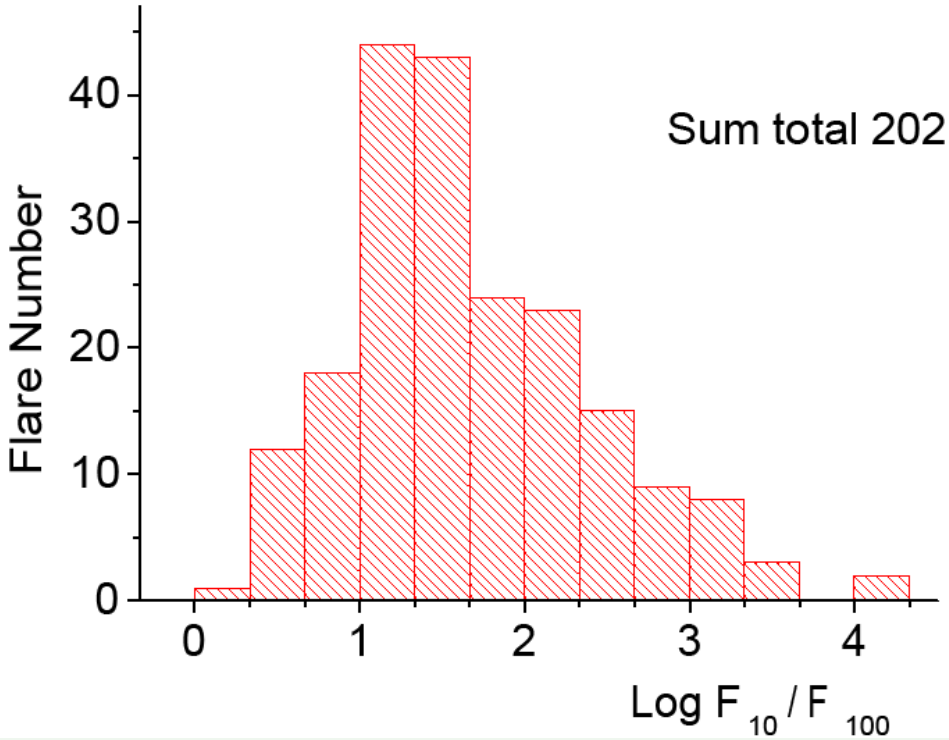
GRECHNEV V.V. et al. The January 20, 2005 big solar flare and its relation to Solar Energetic Particles, Sol. Phys. 2008

Evidences in favour of acceleration (at least up to subrelativistic energies) of particles than are responsible for both flare radiation and for SEP/GLE in the flare region, but not in the shock wave in front of the CME.

HISTOGRAM

C M X





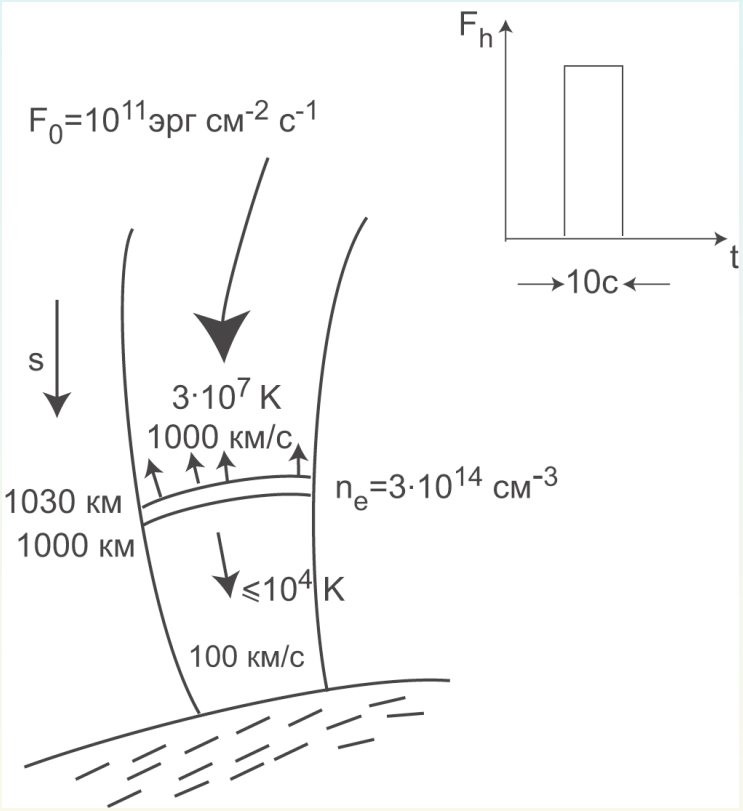
A.R.OSOKIN, M.A.LIVSHITS, A.B.BELOV. 2007.
"Sources of efficient acceleration of solar flare particles: observational aspect"
***Astron. Reports*. 51**, 577-587

Powerful non-stationary events (X-Ray flares stronger than M3)

Thus, we adopt conditionally that a large CME/flare event is a phenomenon where there is a source of explosive acceleration of particles up to relativistic energies.
It occurs during a half of all M3 flares and in any X-flare.

These events happen due to instability of the large-scale magnetic configuration.
Every large CME/flare event evolves depending from feature of the magnetic configuration and characteristics of associated plasma ejection.

The impulsive flare

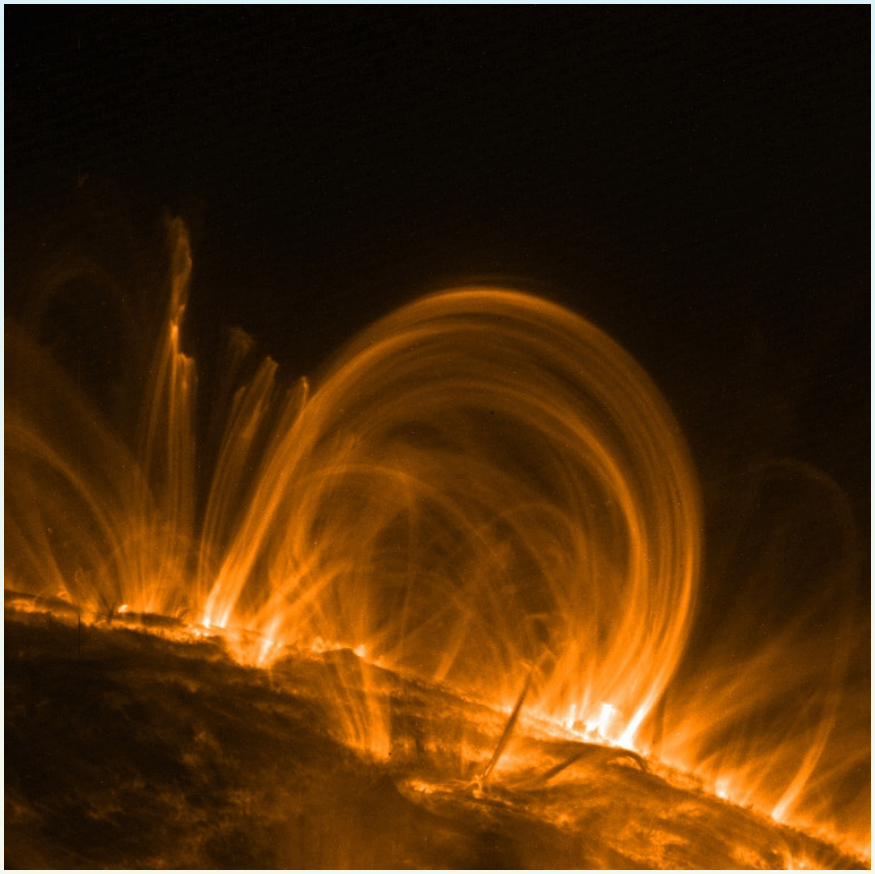


- *The scenario of impulsive flares, in particular, the gas-dynamic response of the chromosphere to heating by accelerated electrons is well-studied.*

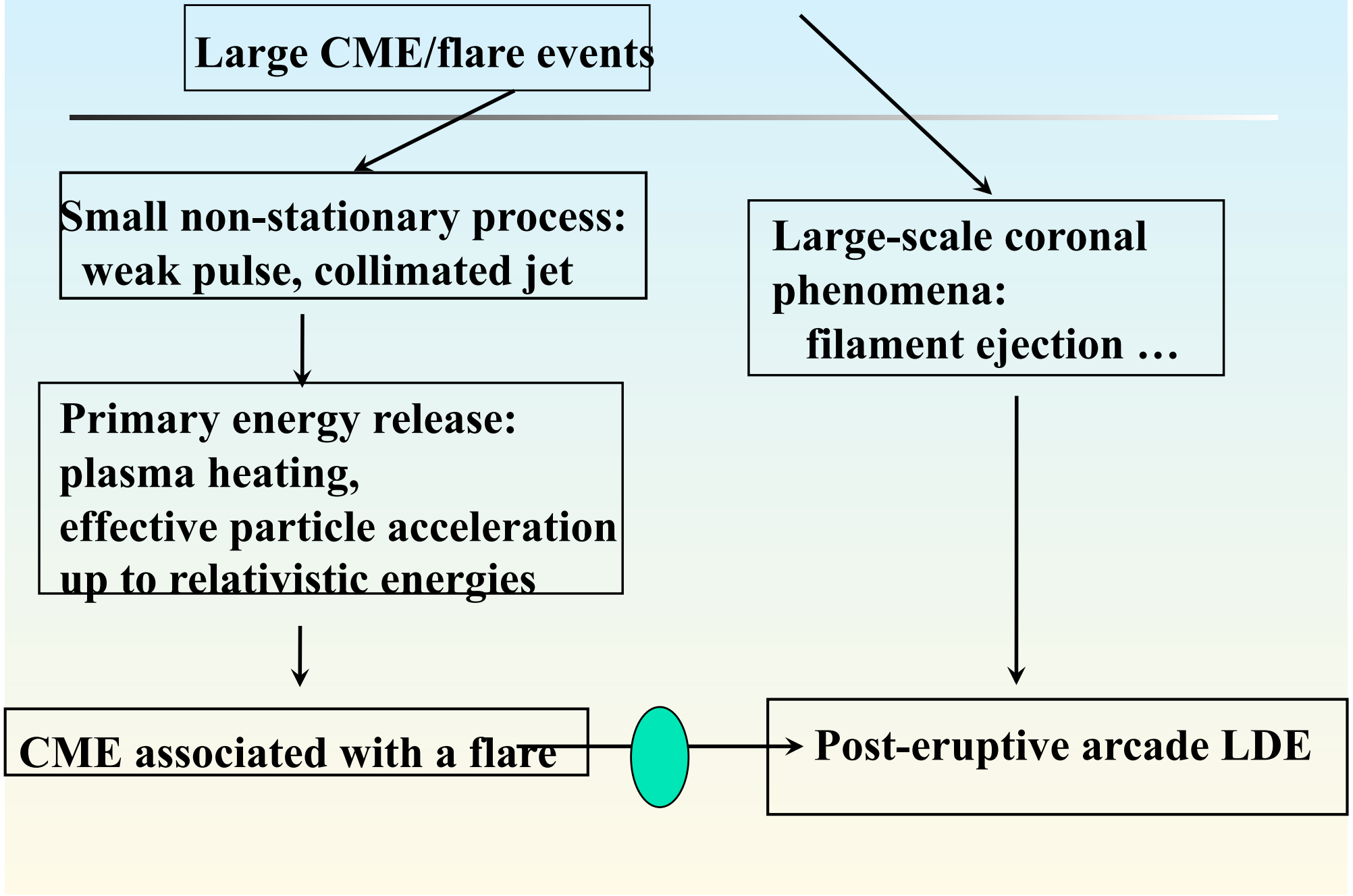
The explosive evaporation leads to the upward motion of the hot gas and downward motion of the low-T condensation. Therefore the coronal loop fills up gradually with the hot plasma.

Two stages in development of large non-stationary phenomena:

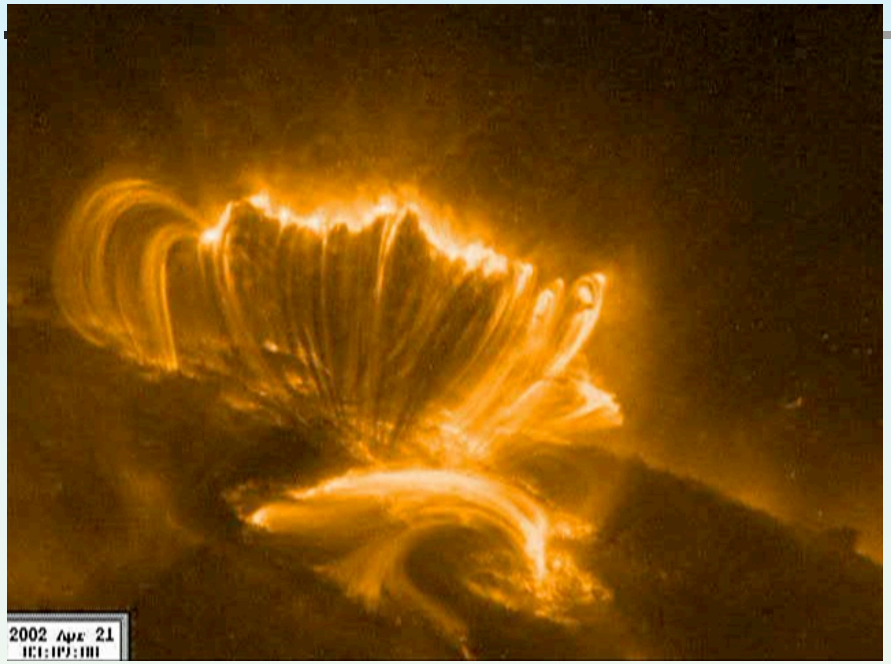
1 - primary energy release

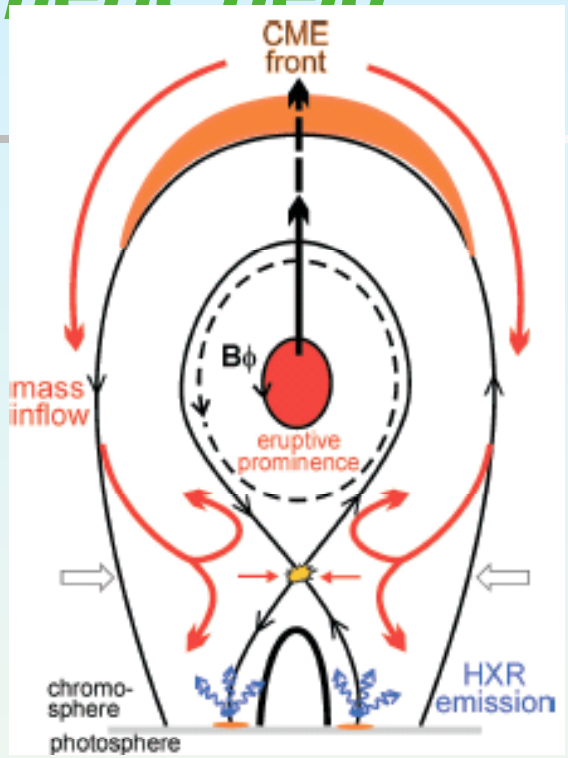


Formation of post-eruptive arcade



Propagation of a flare along the neutral line of the large-scale magnetic field





- 2002, April 21

TRACE, 195 A,

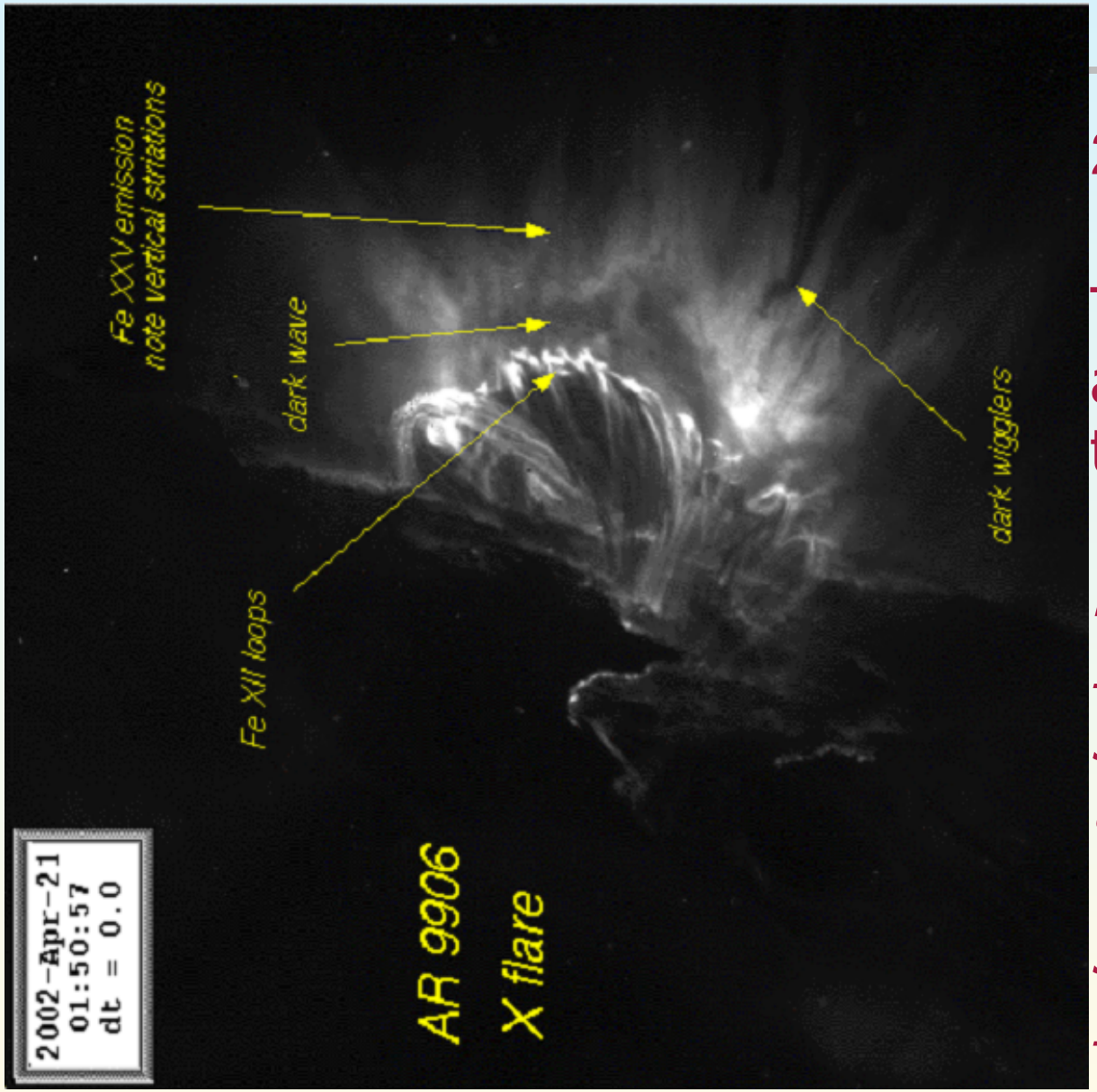
Fe XII Loops

X 1.5 , S14 W84

Relation between CME Acceleration Profile and Flare Energy Release derived from Combined STEREO and RHESSI Observations,

M.Temmer et al., 12th European Solar Physics Meeting, Freiburg, 2008.

TRACE, 2002, April 21



Dark, finger-like features - "tadpoles" (Sheeley et al., ApJ, 2004, **616**, 1224)

5 – 10 min

Their velocities early on are – 100-600 km/s, then decrease fast.

LASCO/C2*: 2-4 R_Sun*

In upward plasma stream tadpoles move toward the Sun with velocities up to 100 km/s.

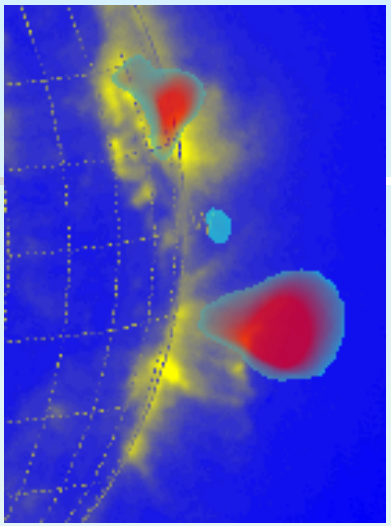
It lasts around 10 hours

Observational test for the model

- ***Estimation of the plasma beta at the top of arches***
- ***Observation of the hot gas cloud in tens minutes after the impulsive phase***

«The Spider» in the MgXII line image

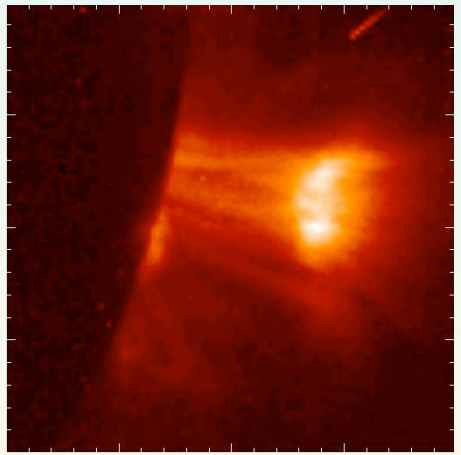
Coronas-F: SPIRIT
MgXII 8,42 Å/
FeXI 175 Å



- H ~ 100 thousands km
- T = 6 – 12; **7** MK
- N_e = 10^9 –10^{10}; **$2 \cdot 10^9$** cm^{-3}
- For B = 10 G [Lin et al., 2004, ApJL, 613, 177]:

$\beta = 2nkT/(B^2/8\pi) = 0{,}4 – 8.3$; **0,97**

Yohkoh/SXT (T > 2,5 MK)

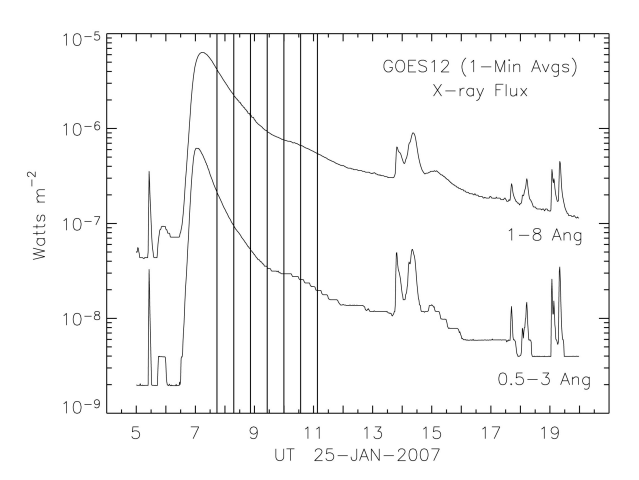


Grechnev, ..Bogachev..,Kusin..,
Borovik,…Livshits, PASJ, 2006

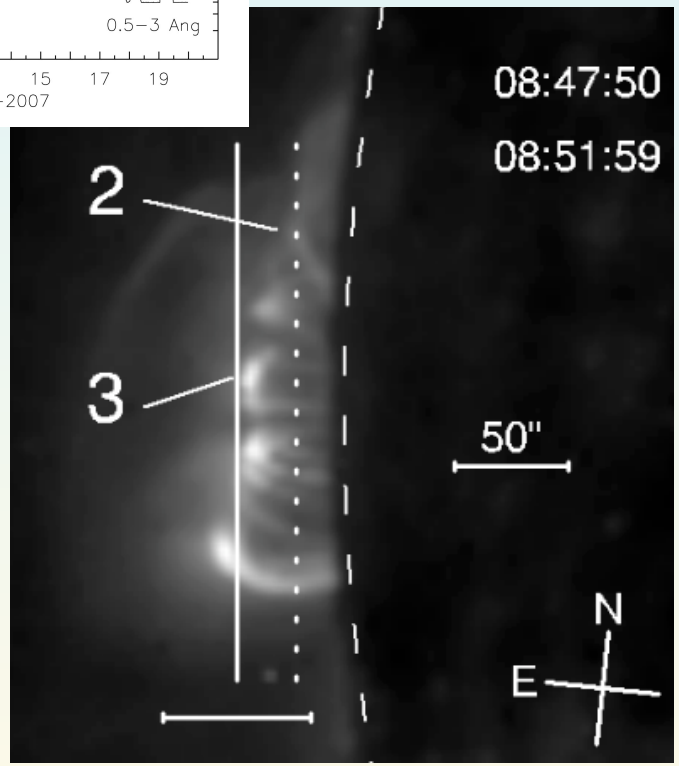
October 22, 2001, ~9 UT

Post-eruptive arcade formation in 25 January, 2007 CME/flare limb event: microwave observations with the RATAN-600 radio telescope

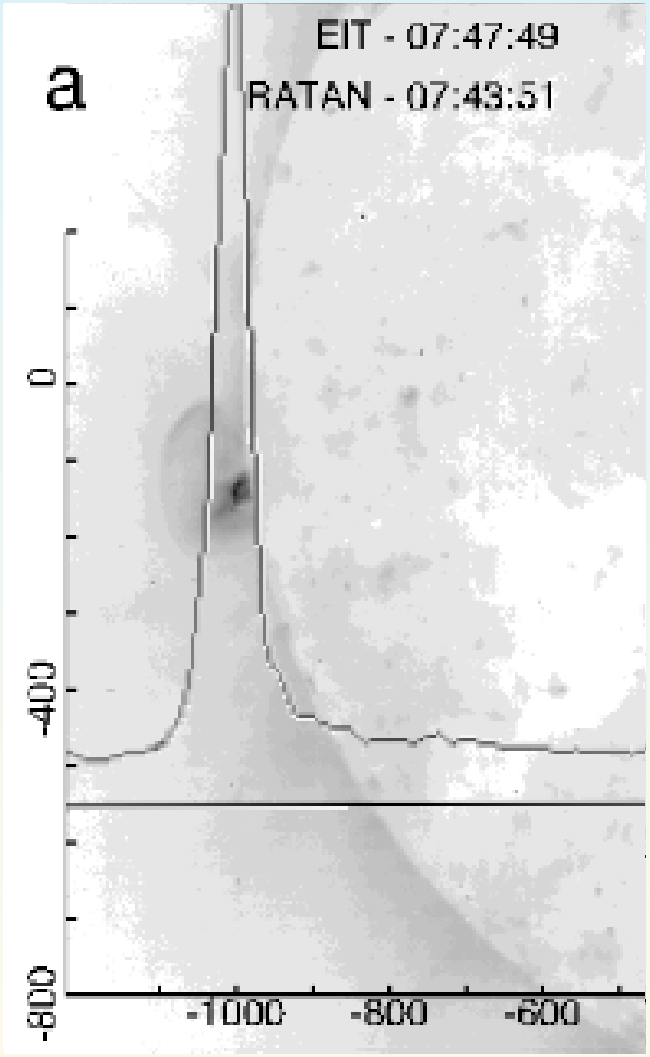
Grigorieva, Borovik, Livshits, Abramov-Maximov, Opeikina, Bogod, Korzhavin



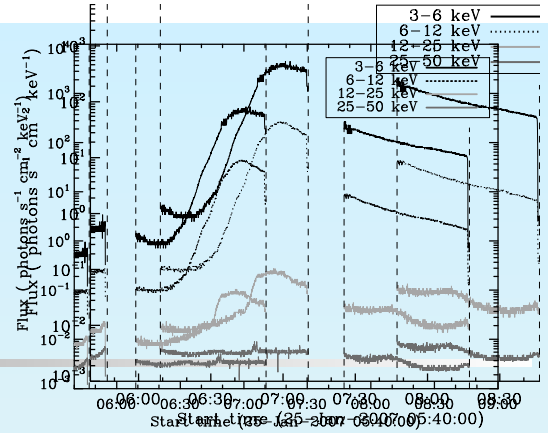
C 6.3 S08E90
Max 07:14 UT

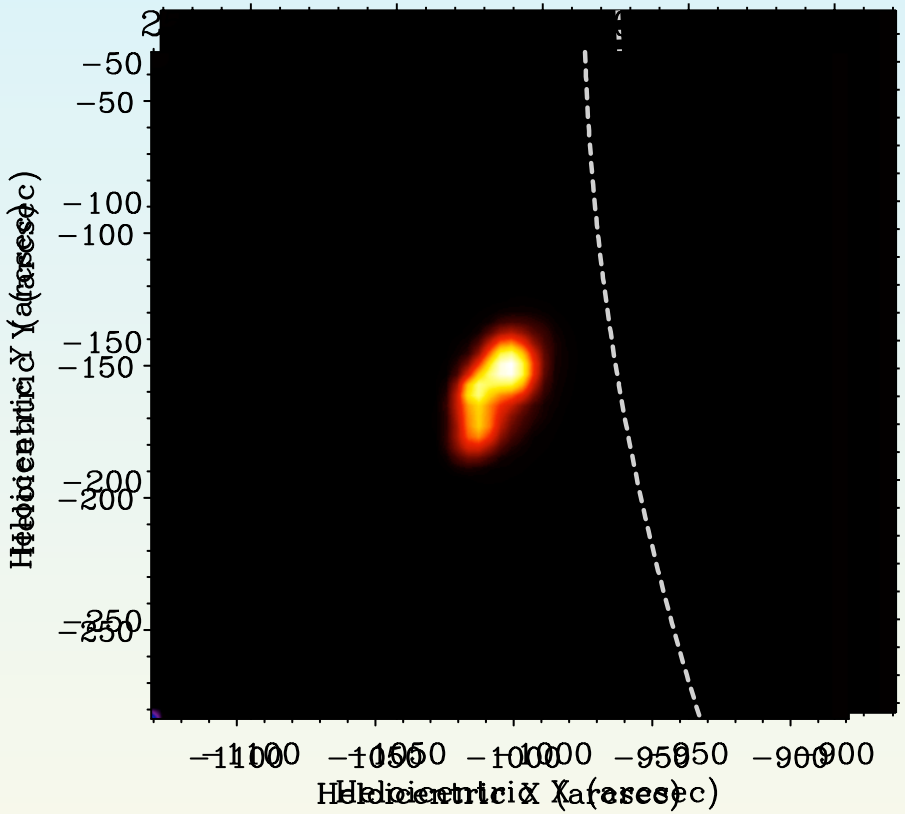


UT
07:44
08:18
08:52
09:26
09:59
10:34
11:08



RHESSI

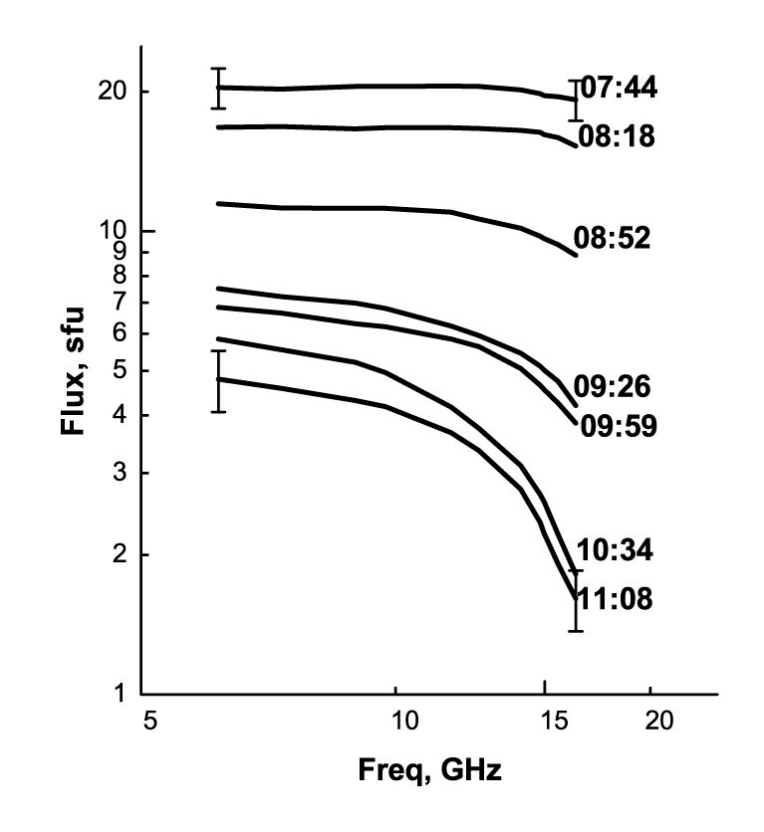




06:55 UT

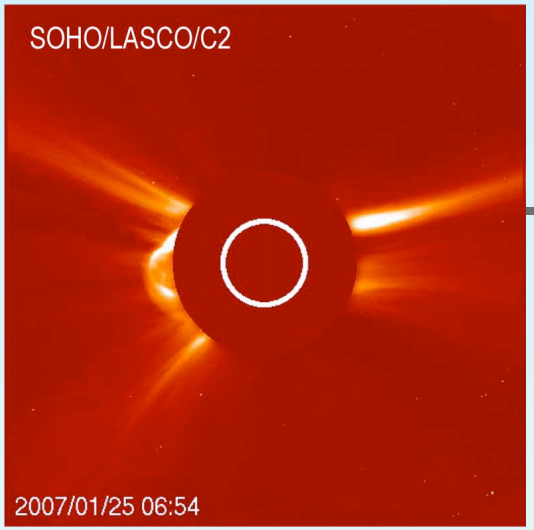
RHESSI, 6-12 keV

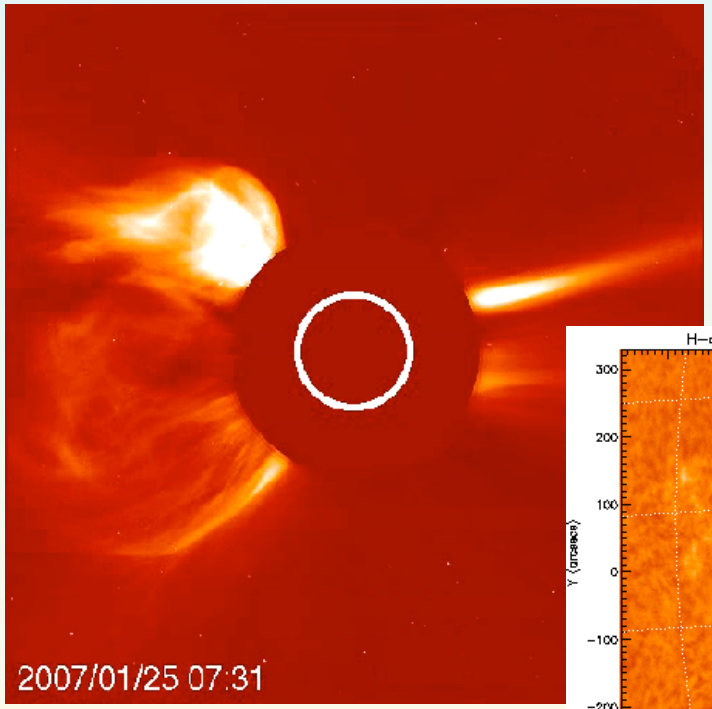
The Microwave and X-Ray spectra

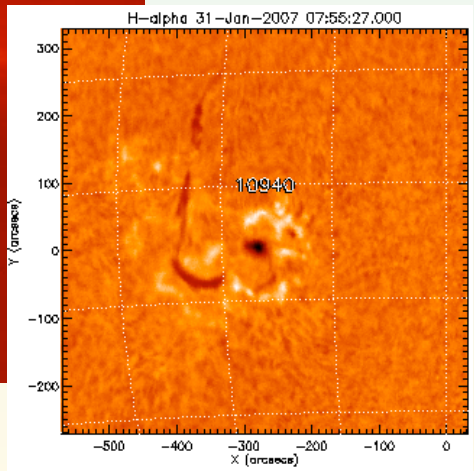


	EM×10^48	T×10^6 [K]	
07:44	14.6	~3	**RATAN-600**

CME - SOHO C2 - STEREO





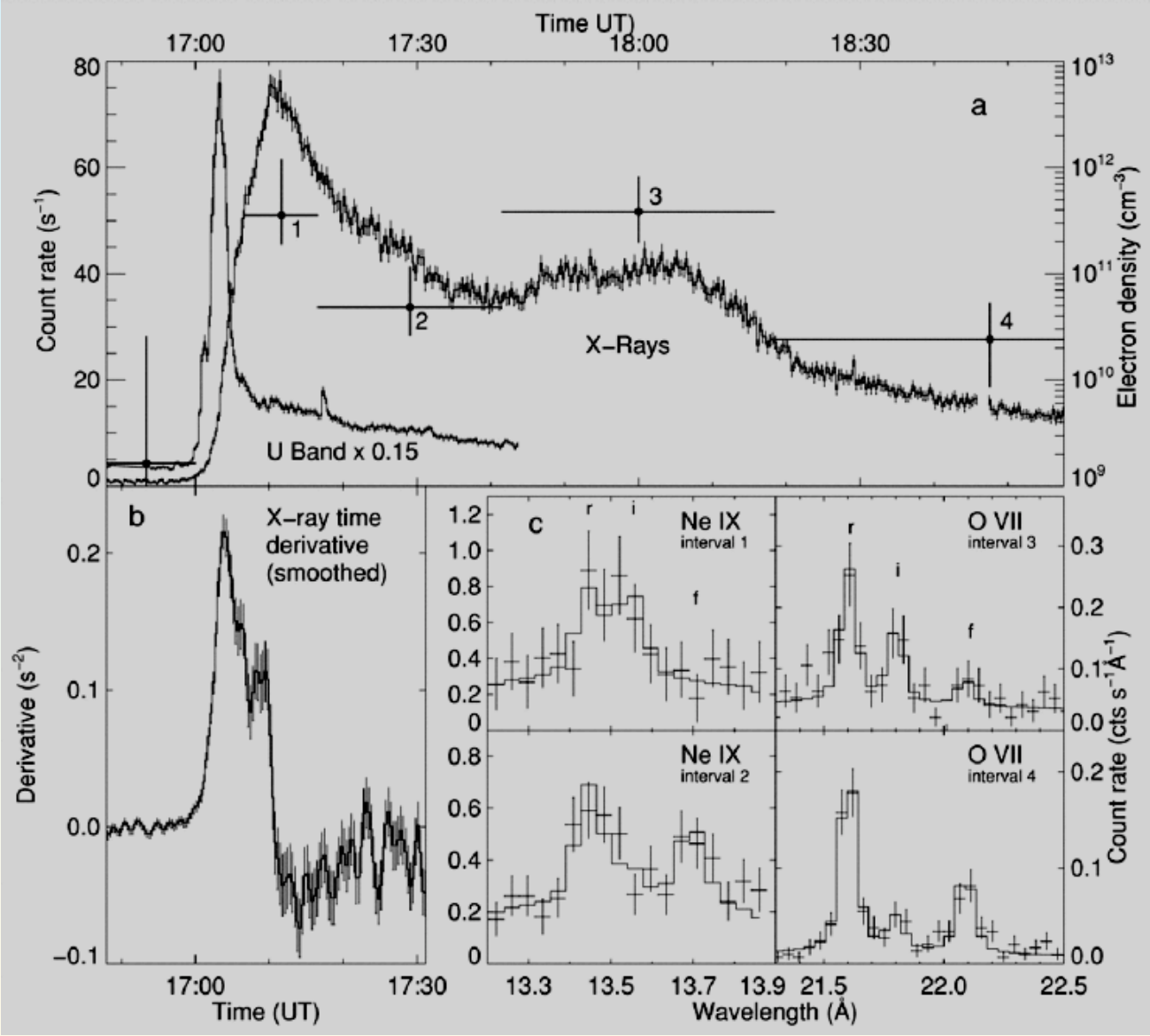


The CME mass estimated from a difference image between 07:31 and 06:05 is 5 10E15 g

NOAA 10940, 31.01.2005

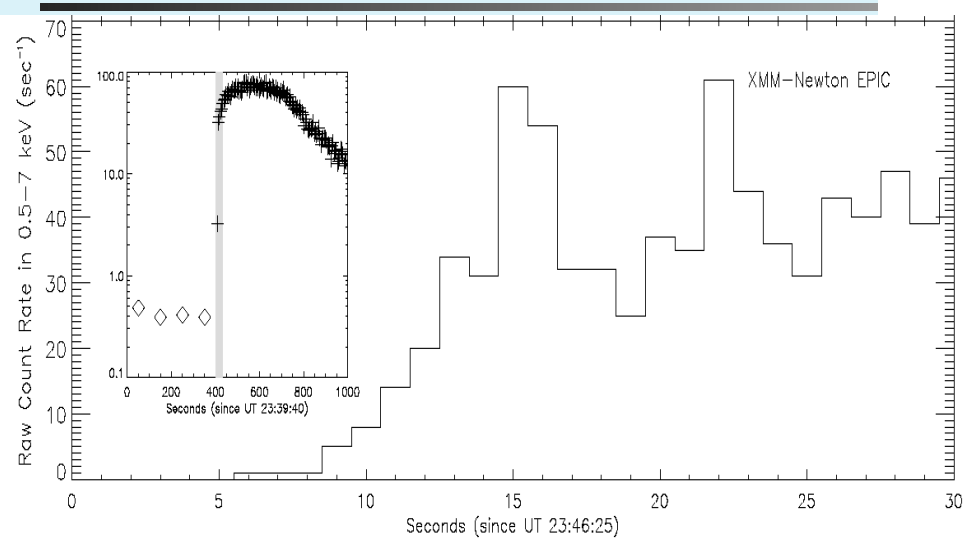
Ejection toward NE from the spot

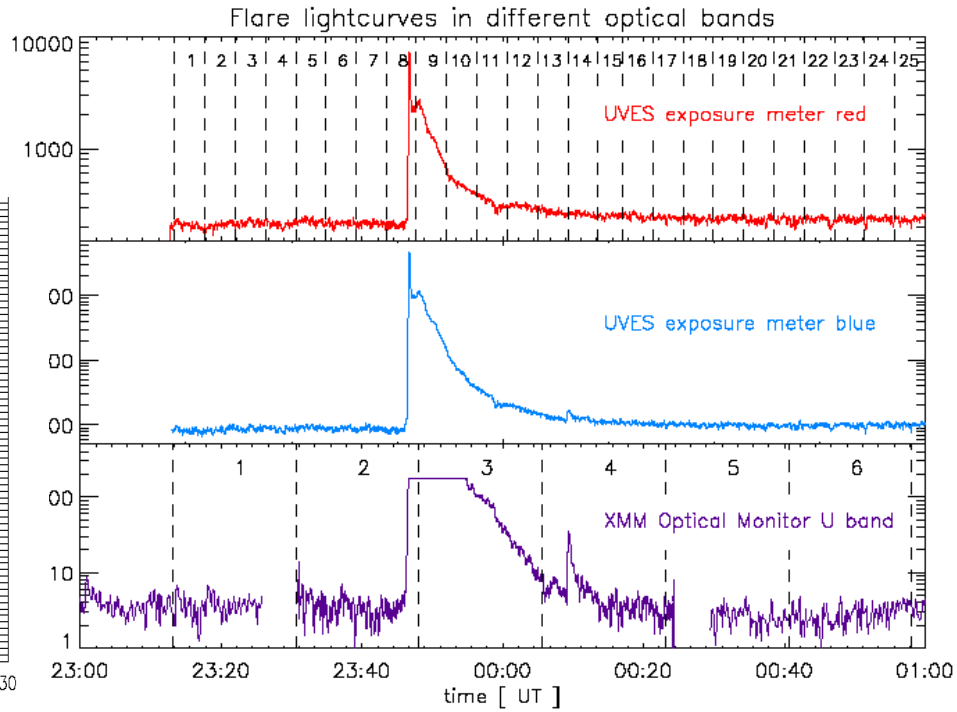
Flare on Prox Cen



- ***This is a stellar analog of the typical solar X-flare***

May 19th 2006 Flare on CN Leo





- A coronal explosion on the flare star CN Leonis
  J.H.M.M. Schmitt, F. Reale, C. Liefke, U. Wolter, B. Fuhrmeister, A. Reiners, G. Peres

* Multiwavelength observations of a giant flare on CN Leonis, I. The chromosphere as seen in the optical spectra
B. Fuhrmeister, C. Liefke, J. H. M. M. Schmitt, and A. Reiners

CONCLUSION

-CME associated with the flare is an interlink between two stages of development of large non-stationary event.
-A big amount of plasma, staying on the corona after CME and helping on formation the post-eruptive arcade, is detected. Subsequent falling down of matter under influence of reconnection in the coronal current sheet is competitive with the MHD-process of propagation of the flare along the neutral line of the large-scale magnetic field.

FURTHER GOALS

- **Study of the hard X-Ray flare radiation and search for mechanisms of the primary energy release and particle acceleration;**

- **Localization of small-scale sources in the primary process and interaction between them;**

- **Further analysis of interrelation between both stages of the CME/flare event.**