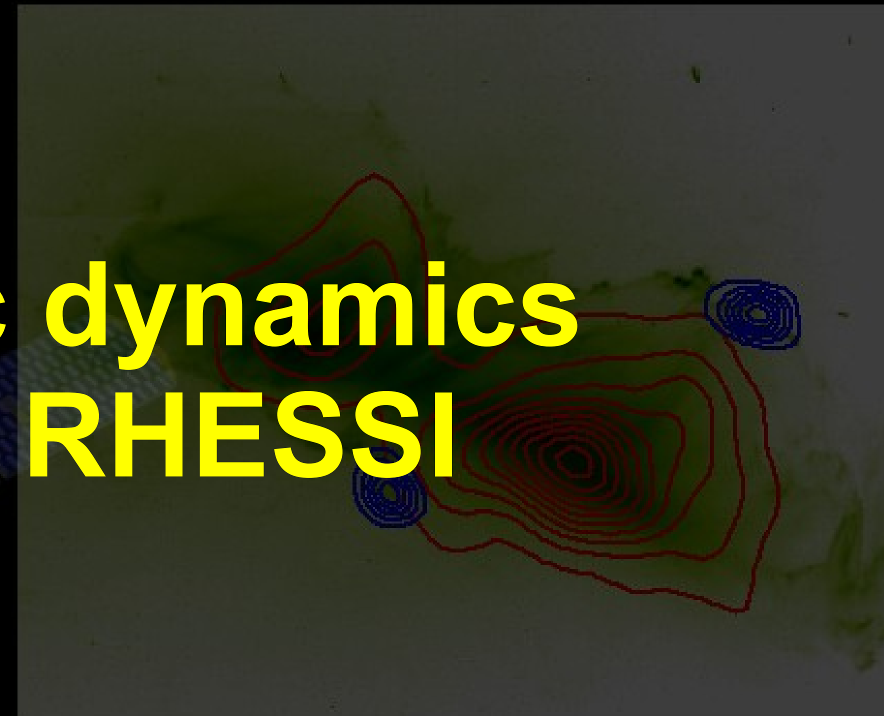
Chromospheric dynamics observed by RHESSI



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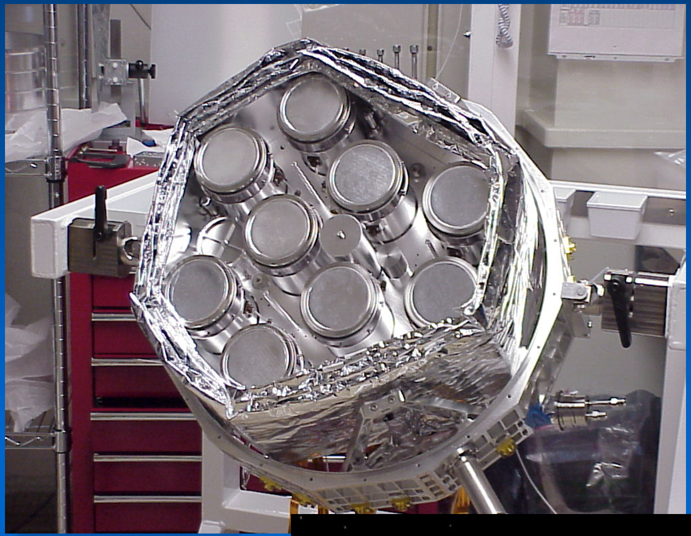
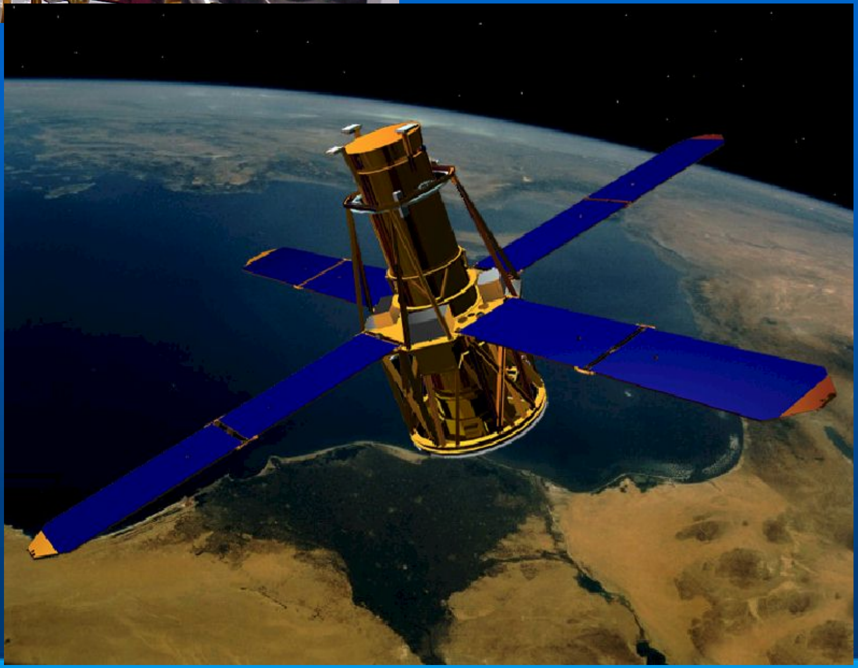
RHESSI





- launched: February 2002

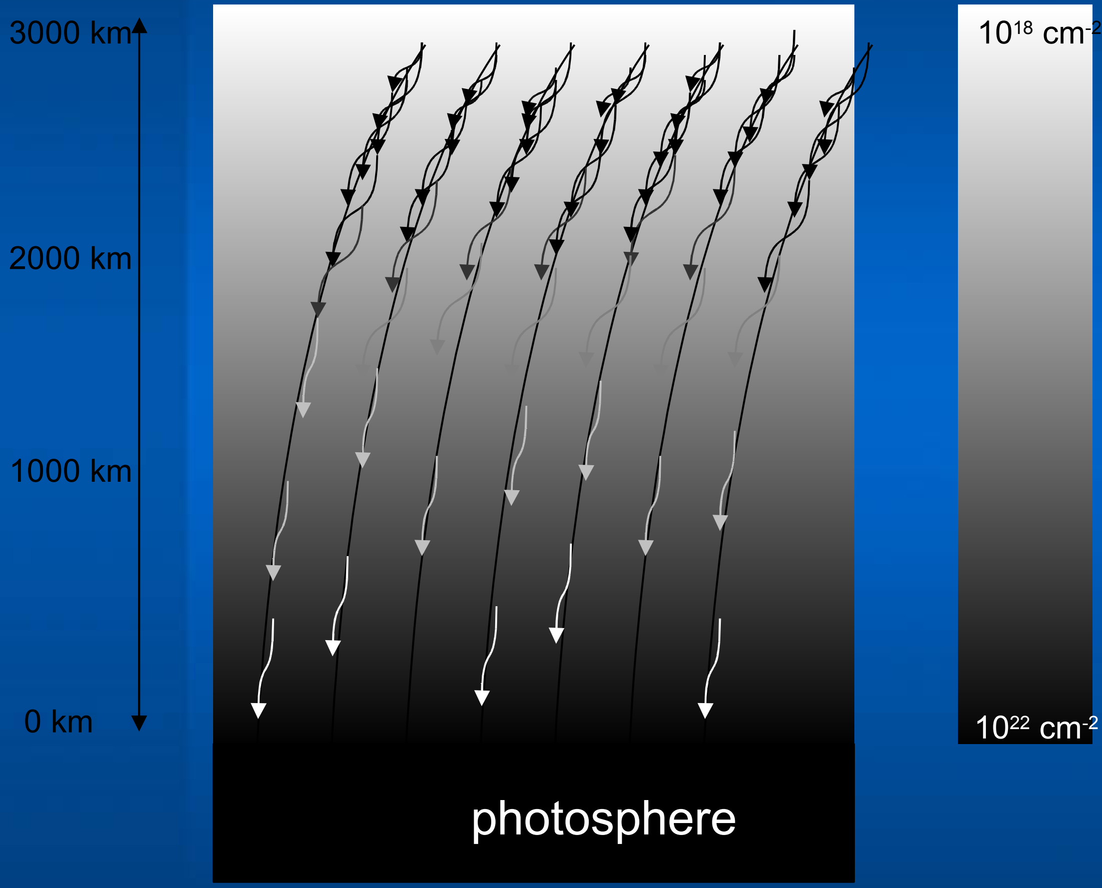
- 9 large germanium detectors

- energy resolution ~ 1 keV

- spatial resolution depends
  on detector selection:
  ~2.5" (maximal)
  ~7" (in practice)

- temporal resolution for
  imaging depends on photon
  statistic, but must be equal
  at least ~2 s (half of the
  RHESSI rotation)

Thick – target model



- Electrons are accelerated high in the corona

- After escaping outside the acceleration site they propagate along magnetic field lines

- Reaching the chromosphere they collide with ambient plasma and produce HXR

- More energetic electrons are able to reach denser, low-lying levels of the chromosphere – we should observe the relation between the energy of HXR sources and their height

Energy – height relation
(footpoint sources)

Theory:

Brown,J., 1971, *Sol. Phys.*, 18, 489
Brown, J. and McClymont,A.N. 1976, *Sol. Phys.*, 49, 329
Brown, J et al., 2002, *Sol. Phys.*, 210, 373

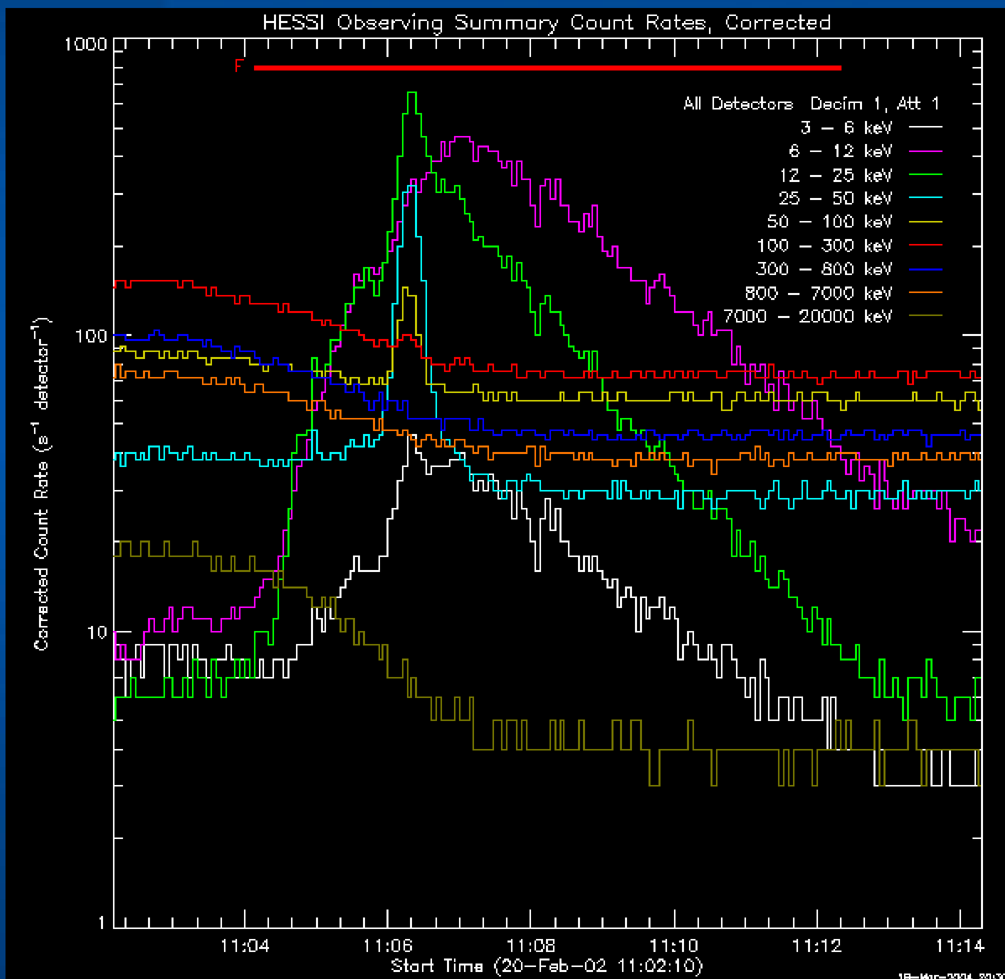
Modelling:

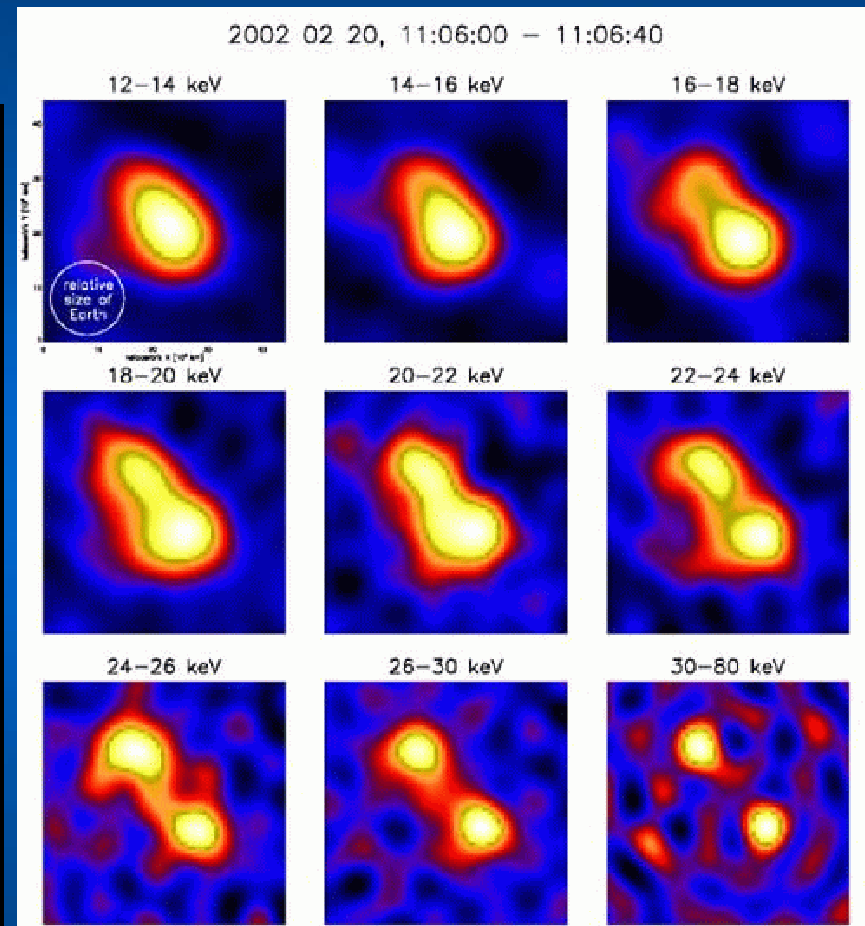
Fletcher, L. 1996, *A&A*, 310, 661

Observations:

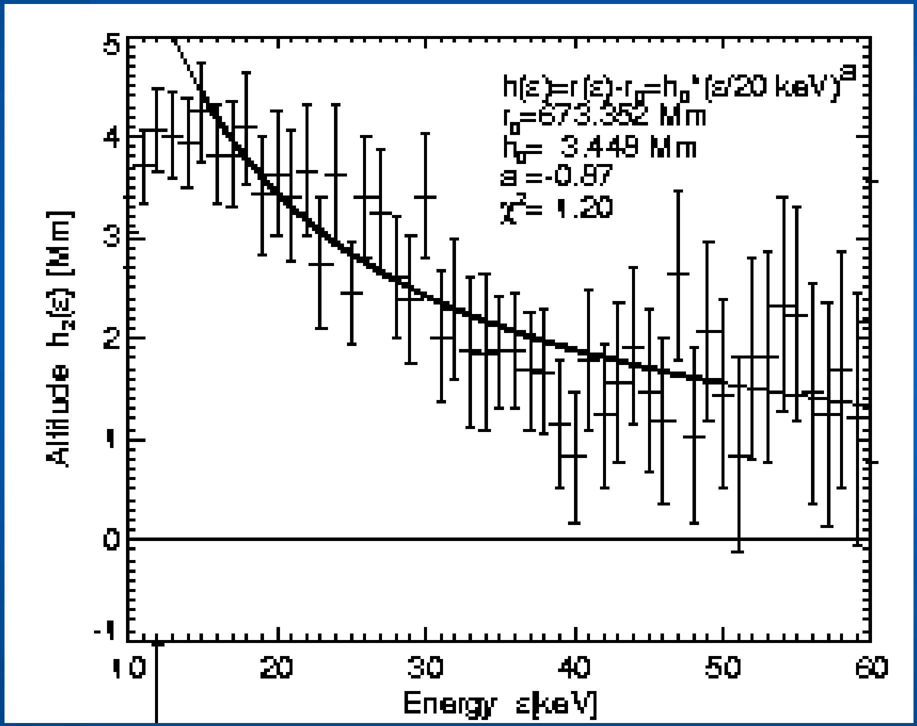
Matsushita et al. 1992, *PASJ*, 44, L89
Aschwanden et al. 2002, *Sol. Phys.*, 210, 383
Mrozek, T. 2006, *Adv. In Space. Res.*, in press

RHESSI (Ashwanden et al. 2002)





RHESSI (Ashwanden et al. 2002)



- E-H relation is observed by RHESSI

- It can be estimated with the power-law function

- Gives possibilty for calculating density structure in the chromosphere

E-H relation (our results)

- we investigated first two years of RHESSI observations

- 17 flares showing the E-H relation observed in at least one footpoint were found

- for 4 flares we were able to investigate temporal evolution of the E-H relation

- for this time, one event - 3 Aug 2002 flare is investigated in details

03 Aug 2002

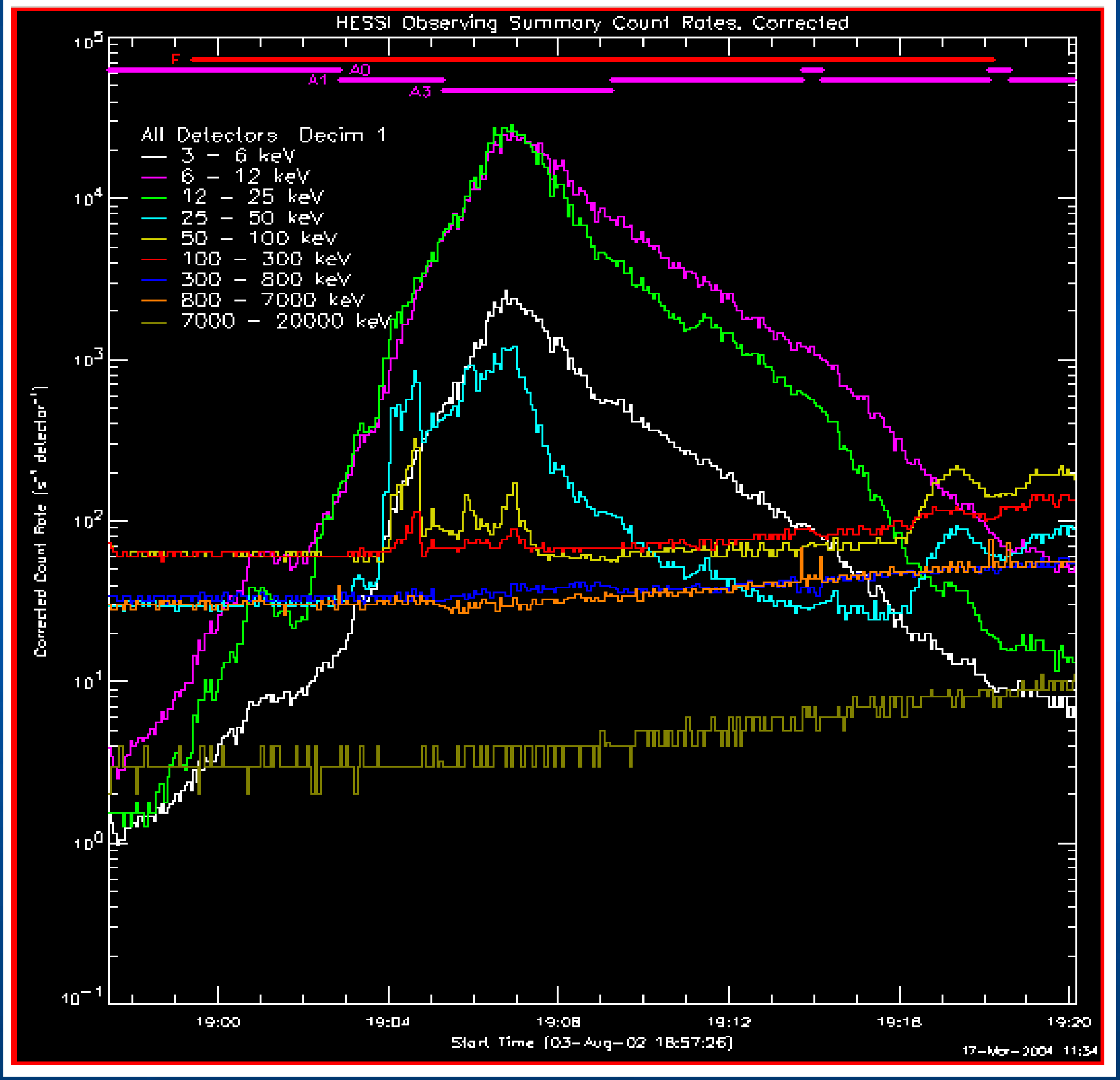
strong flare (X1.5)

located near the west limb (S15W70)

observed by several instruments:

- TRACE (171 Å, 30 s cadence)
- RESIK (2.05 – 3.65 keV)
- RHESSI (entire event)
- images from SOHO, BigBear

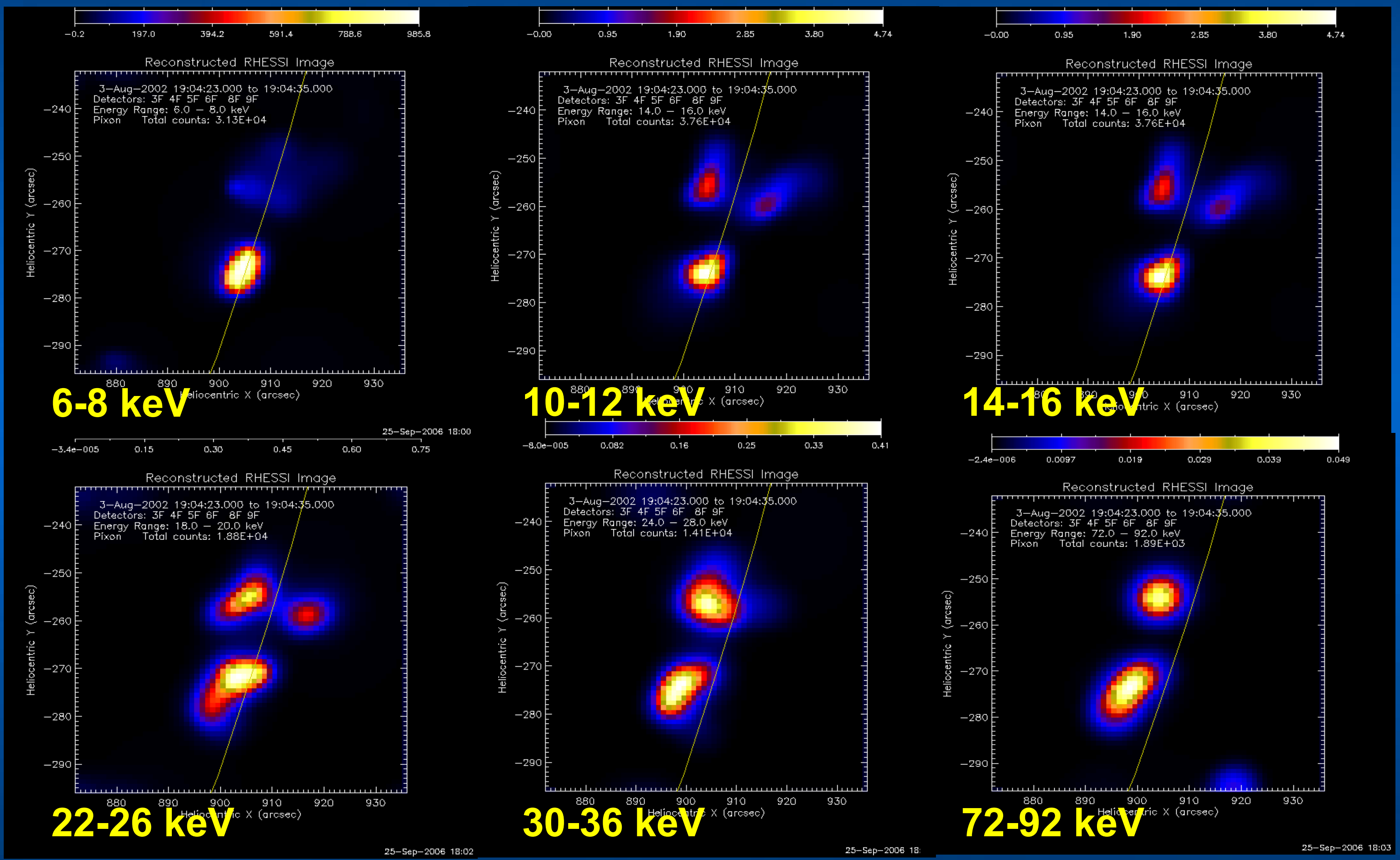
03 Aug 2002 (E-H relation)



We chose time interval covering the strongest HXR burst

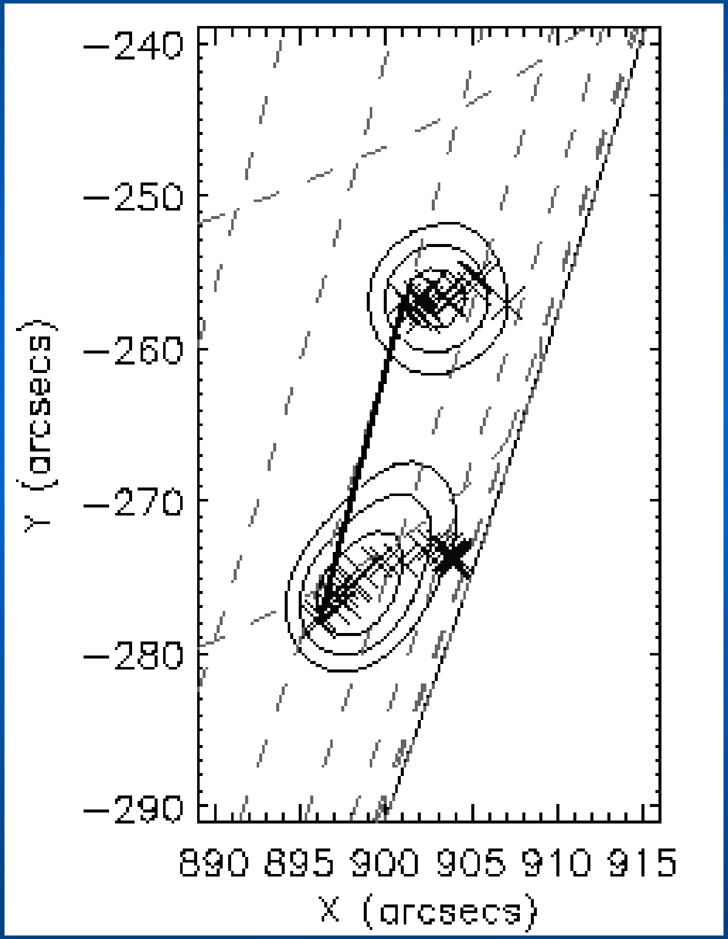
Images were made in several energy ranges

03 Aug 2002



Centroids were calculated for each of observed HXR source

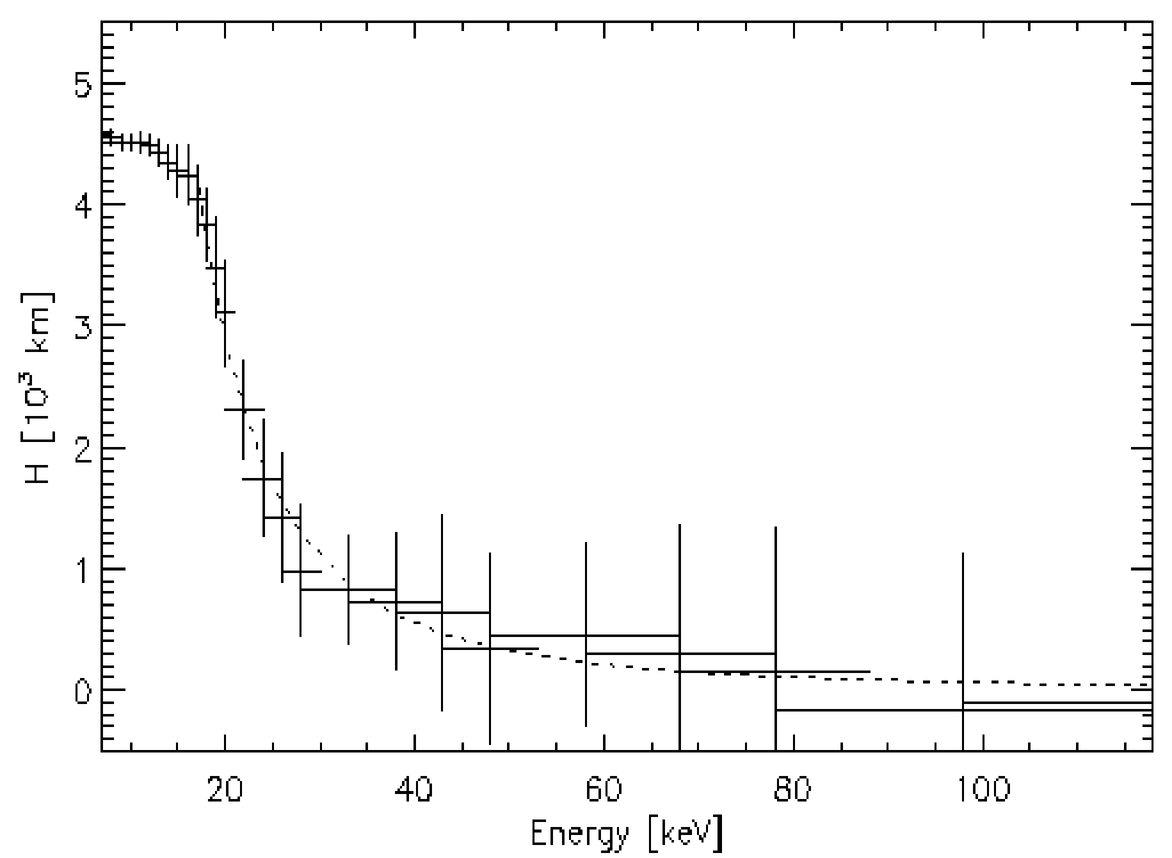
03 Aug 2002



A reference level was defined by centroids obtained for the highest energy.

Height above the reference level for each source was calculated

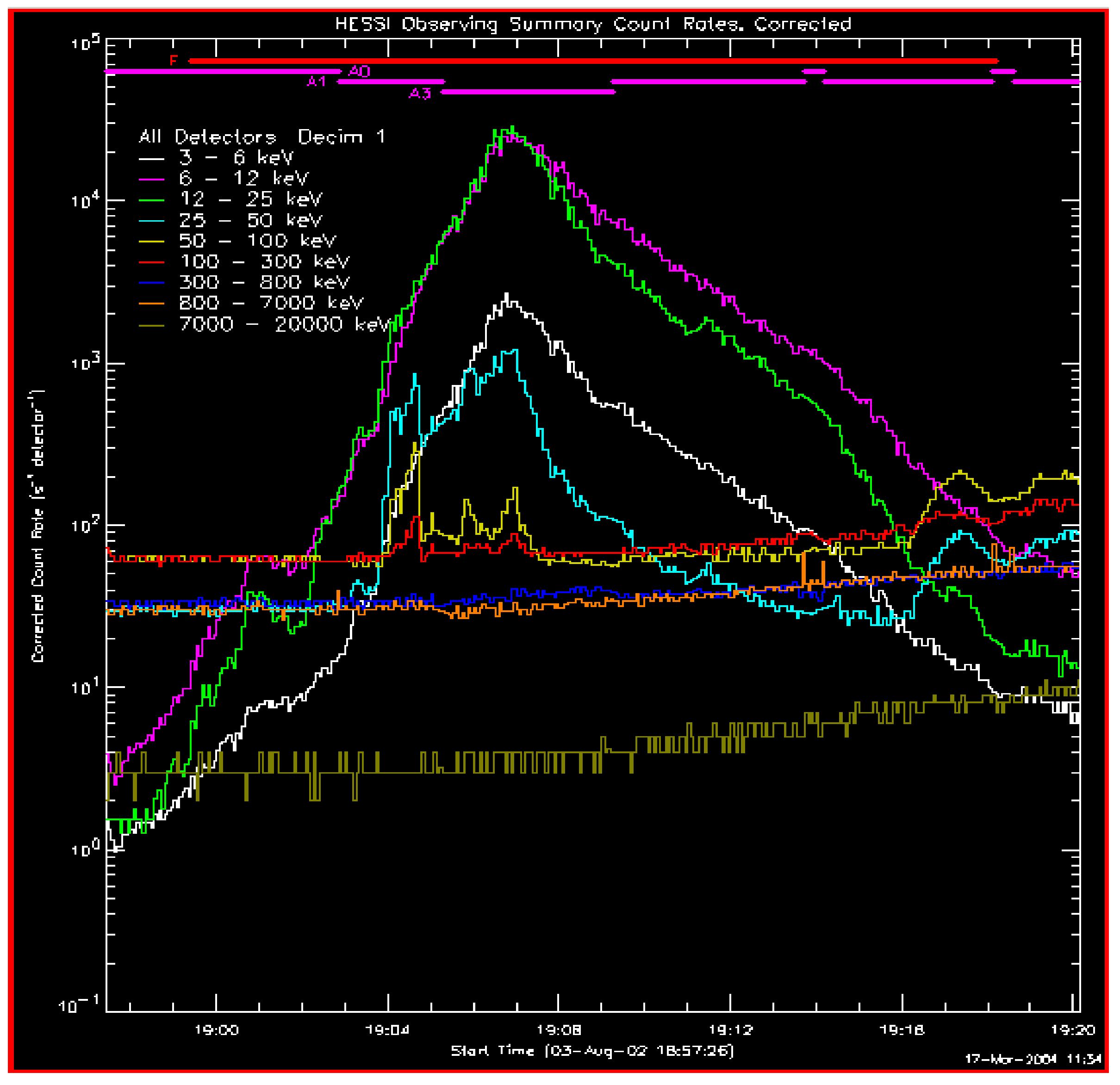
03 Aug 2002



Clearly seen power-law shape above 20 keV reflects location of non-thermal sources

Low energy part of the curve is purely thermal

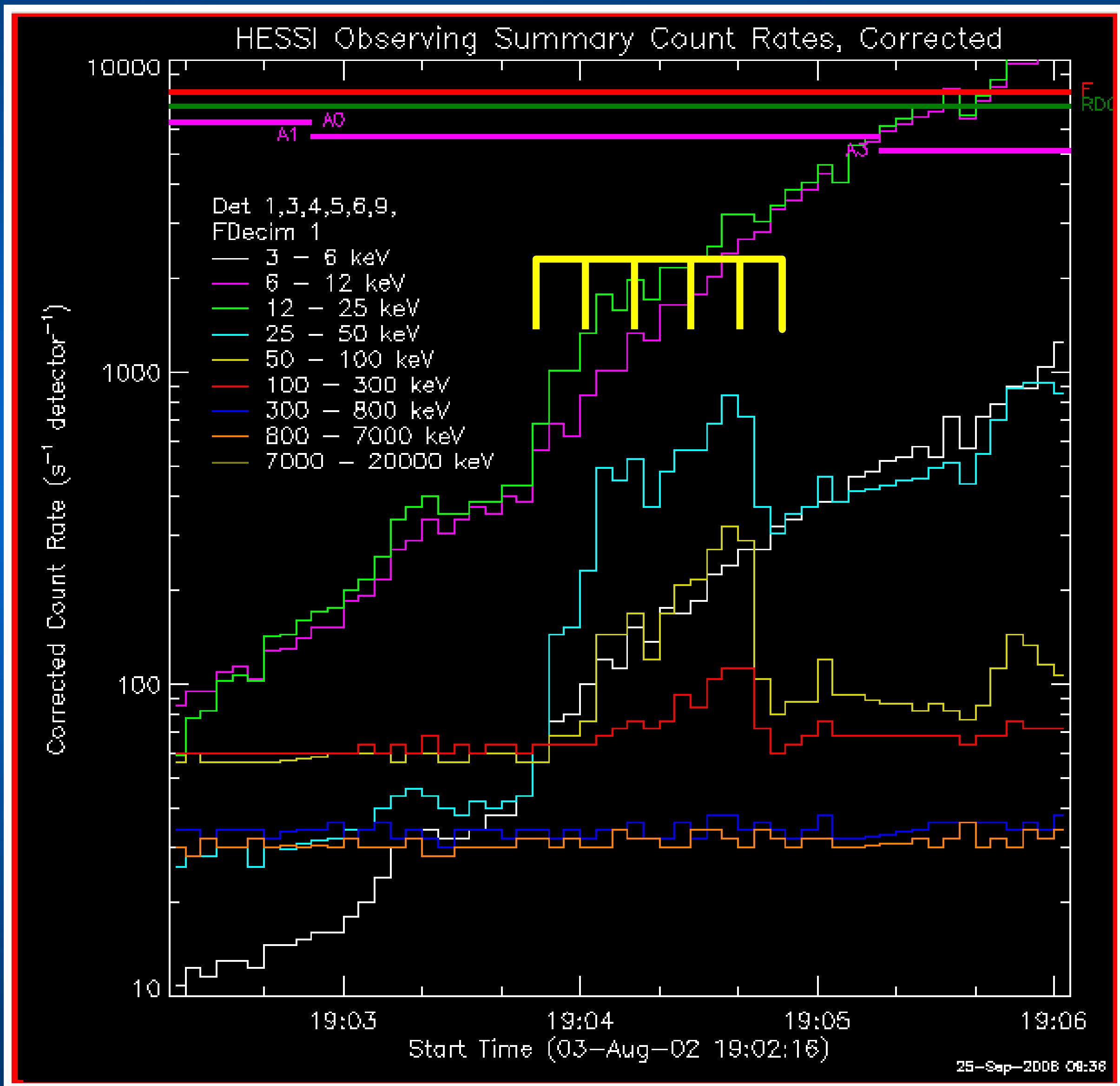
03 Aug 2002



First HXR peak is very strong

It means that high-energy electrons propagate through the chromosphere which is undisturbed by previous beam of electrons

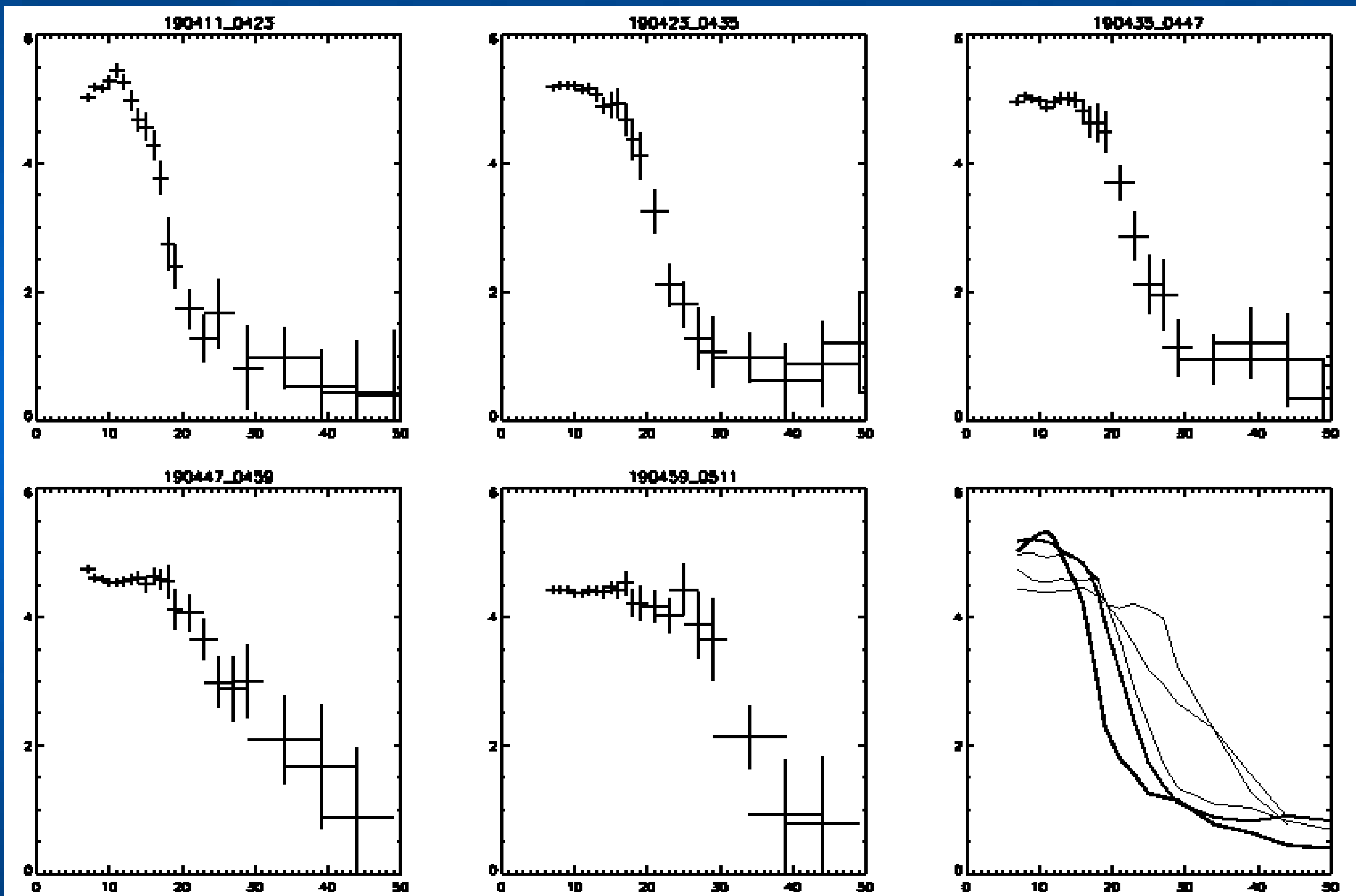
03 Aug 2002



Time interval covering this peak was divided into five 12 s subintervals

Five E-H relations were obtained that gives possibilty for basic analysis of temporal evolution

Temporal evolution of the E-H relation

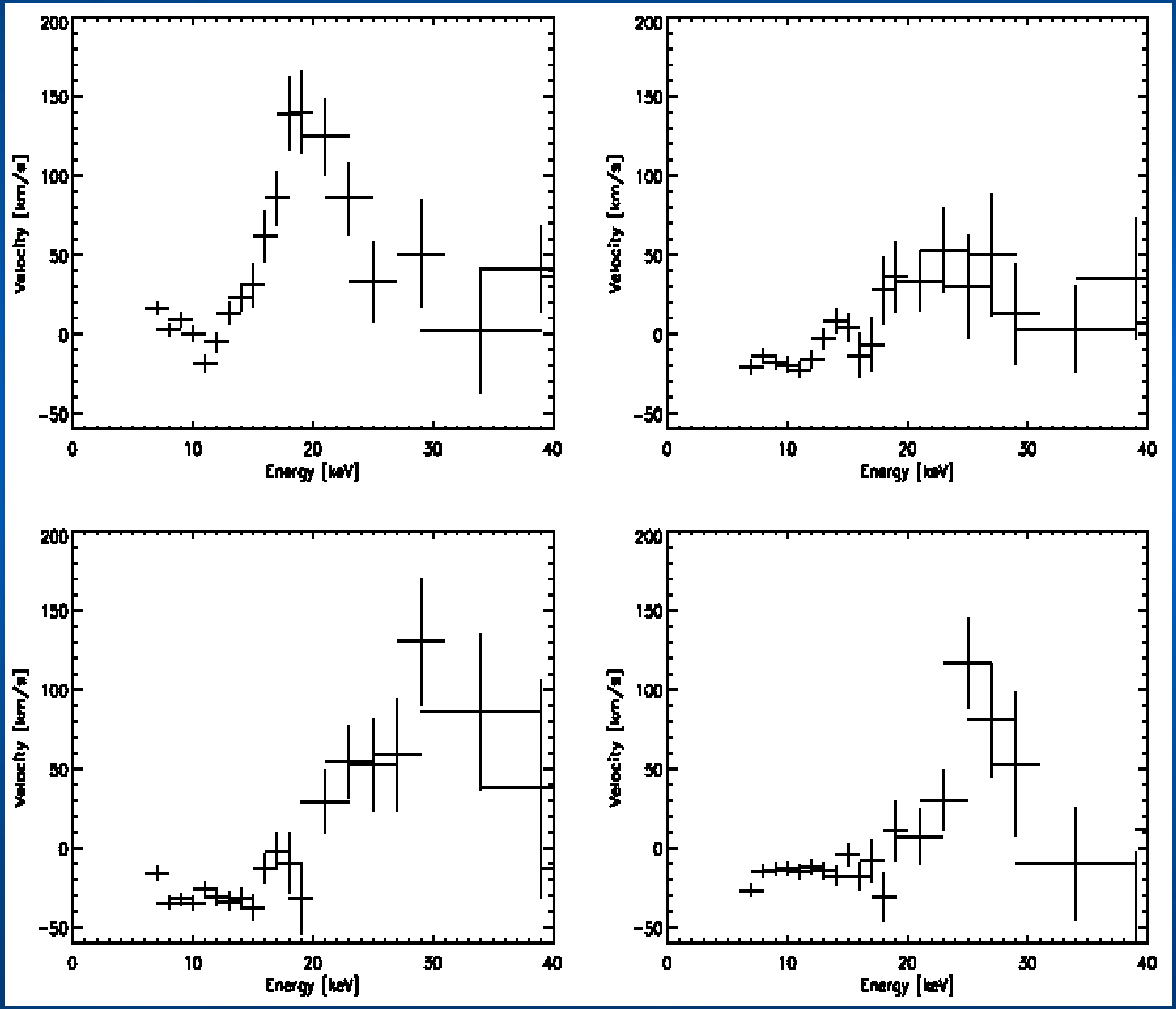


Low-energy, thermal part moves downward. This can be driven by electron beam momentum.

Non-thermal, power-law curve changes its shape showing systematical upward flows

Consecutive E-H relations were used for velocity estimation

Temporal evolution of the E-H relation

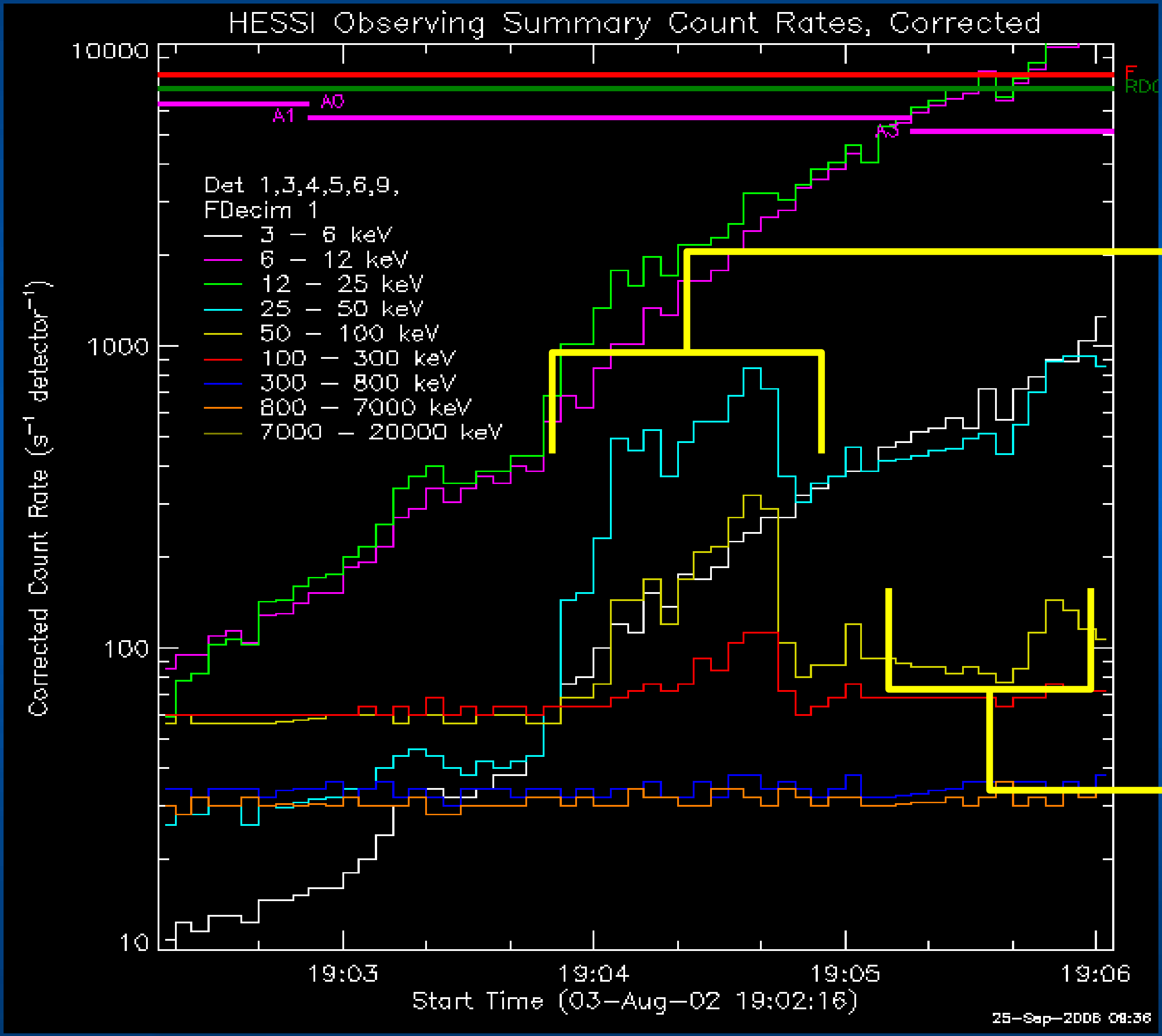


This is not velocity of plasma blobs!

It is the velocity of changes of density structure in the chromosphere and transition region

Simultaneous upflows and downflows without signifant evaporation above the transition region.

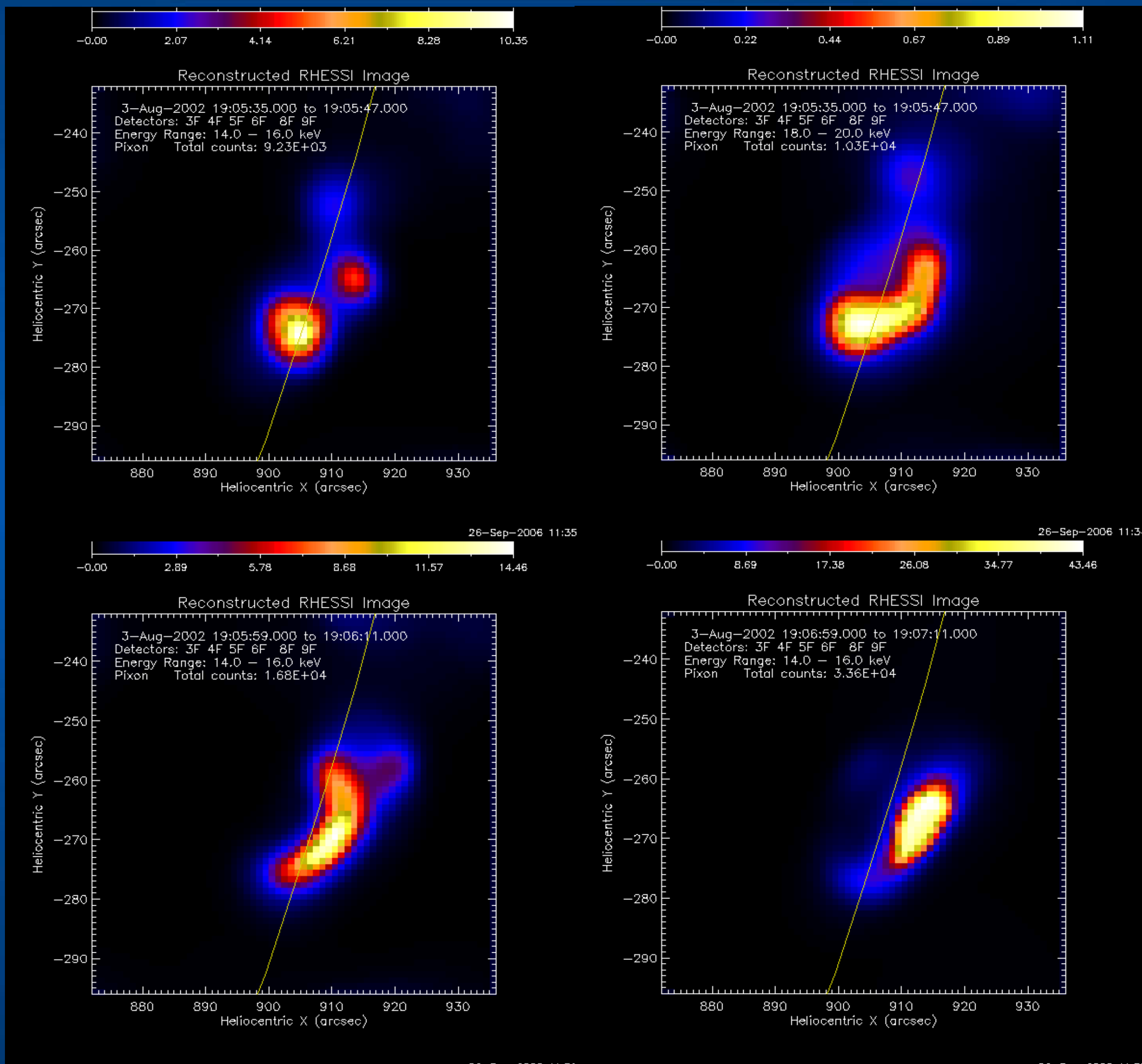
Temporal evolution of the E-H relation



No significant plasma flows above the transition region

What does happen when we have no significant beam of electrons?

Chromospheric evaporation

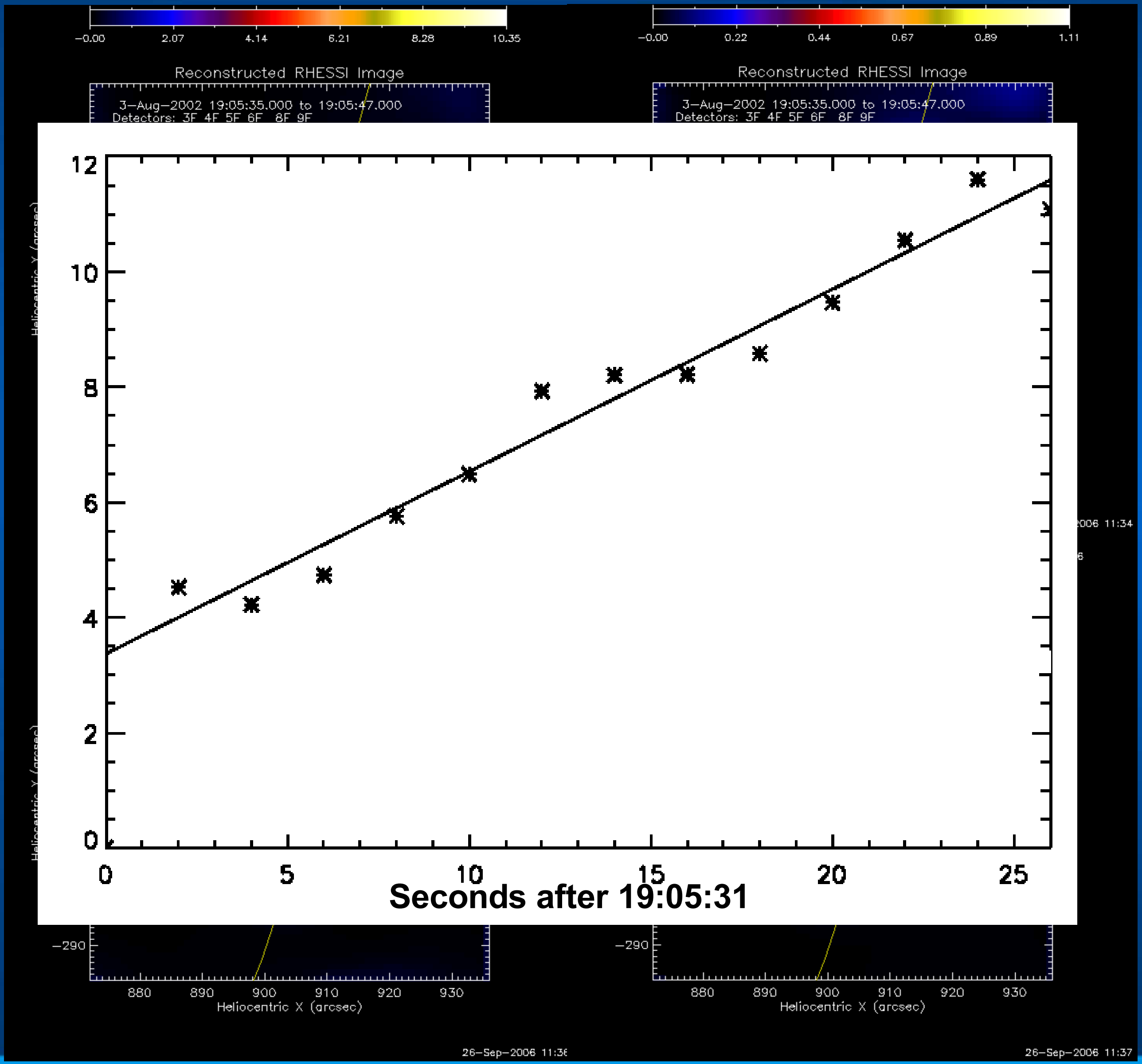


Images made in the range of 16-20 keV

Source is thermal

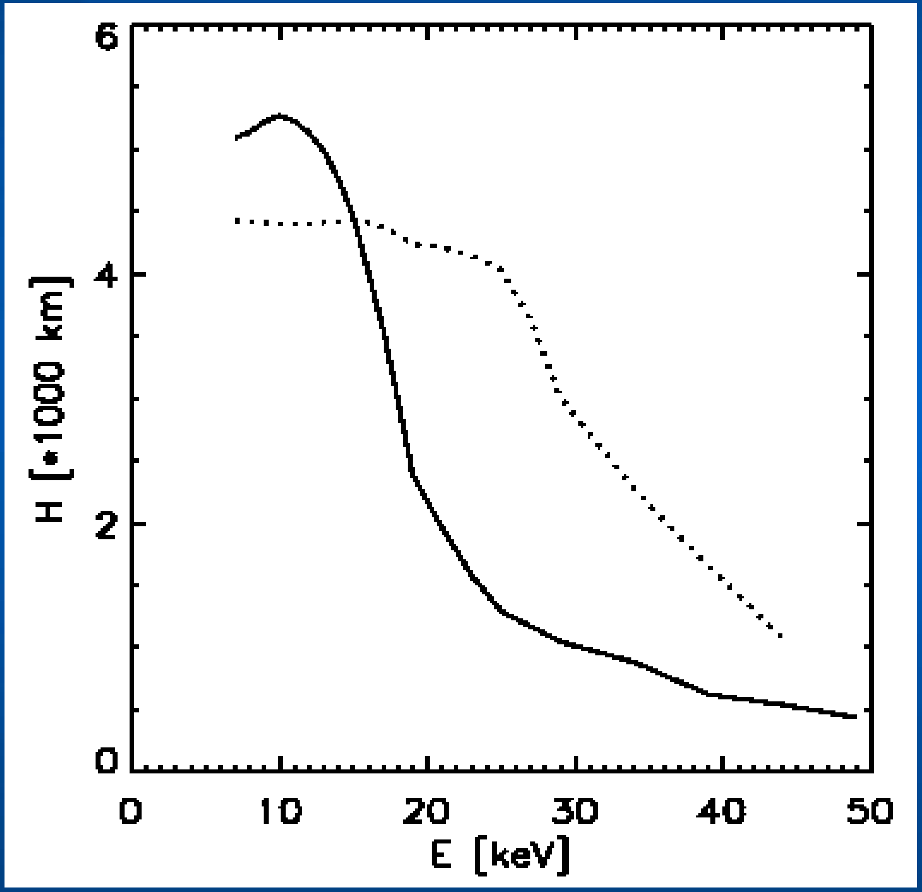
Clear changes of the source structure connected with the chromospheric evaporation

Chromospheric evaporation



Velocity is about 230 km/s – it is typical value of the chromospheric evaporation

Mass estimation

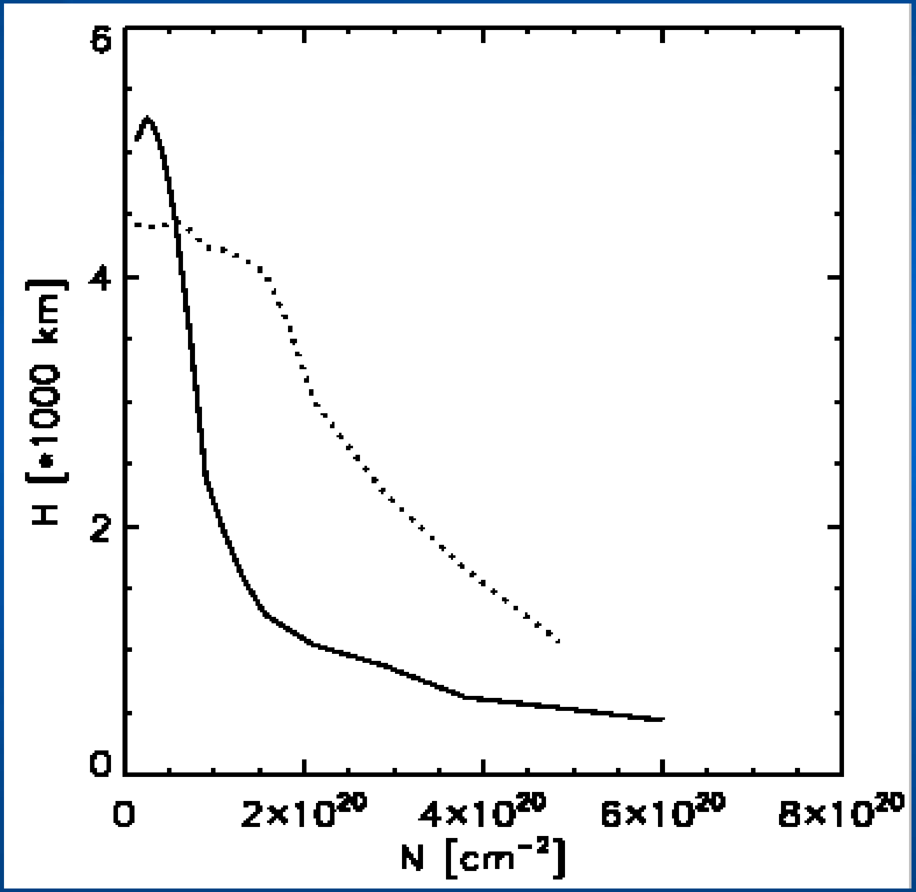


Two E-H relations obtained at the begining and the end of the main peak

$N(h) \sim E^2$

We took only purely non-thermal sources and calculated difference in the column density at several levels

Mass estimation

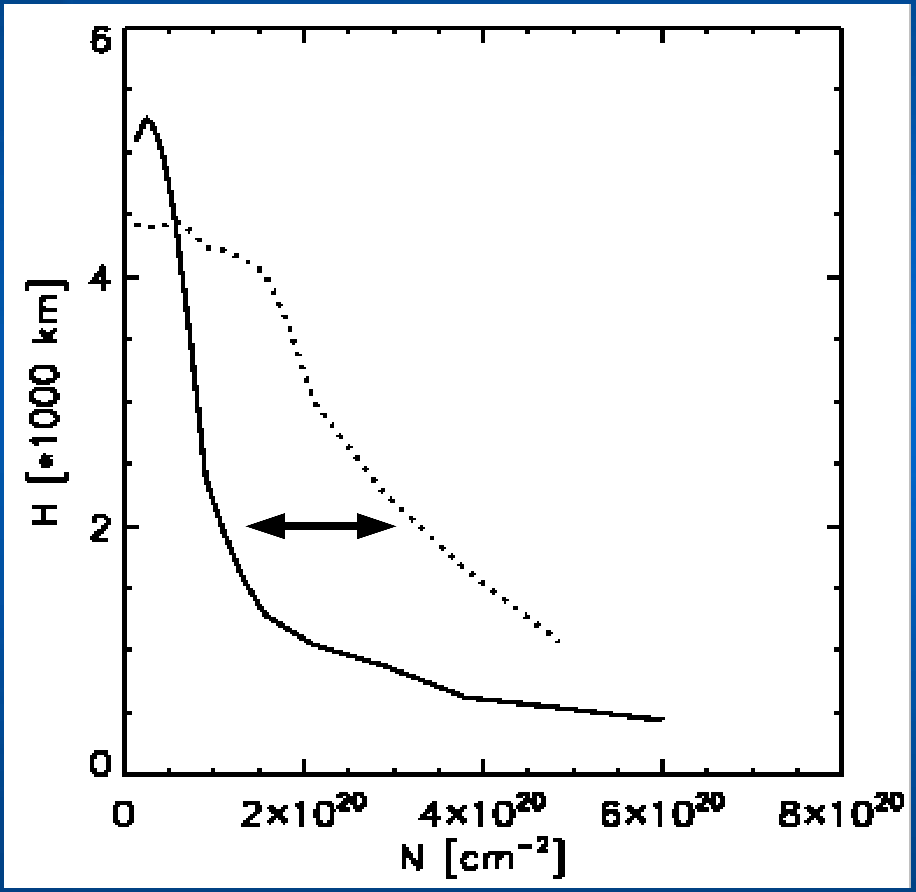


Two curves taken at the begining and the end of the main peak

$N(h) \sim E^2$

We took only purely non-thermal sources and calculated difference in the column density at several levels

Mass estimation



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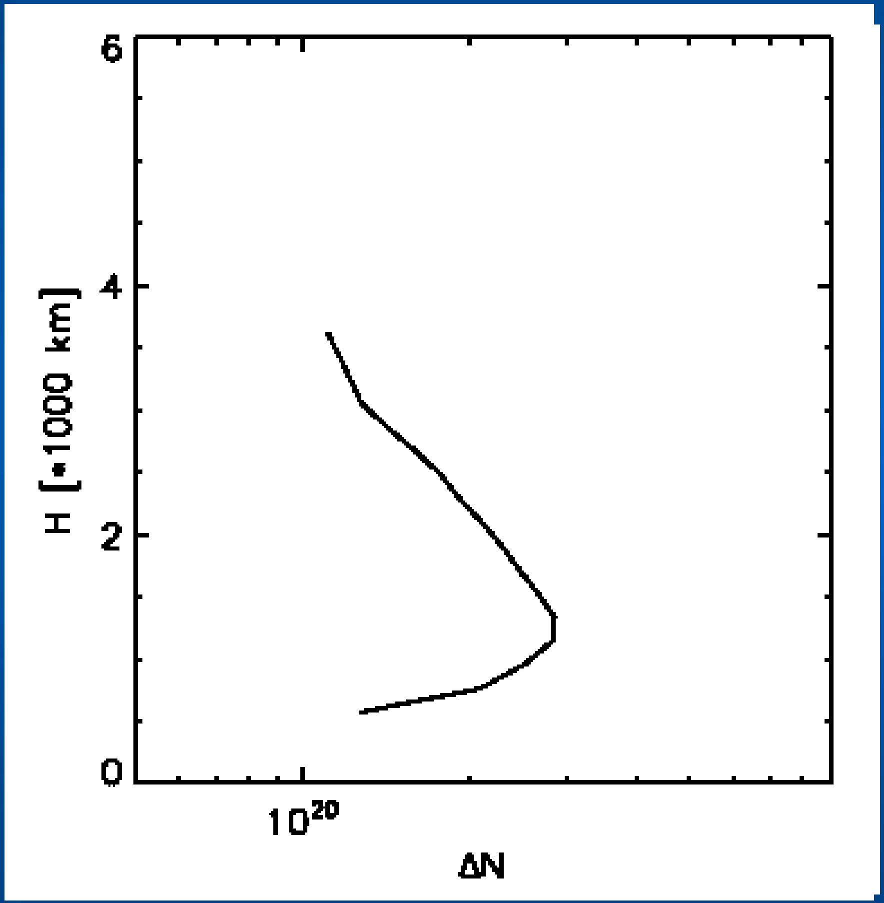

Difference between column densities can be transferred to difference of masses

Additional mass above 1000 km is about $5x10^{13}$ g

Comparing EM in the loop-top kernel before the peak and during the maximum of the flare we obtained: $8x10^{13}$ g

Conclusions

Using non-thermal electrons as a tool we can obtain useful information about plasma distribution inside the flare loop.

The E-H relation reflects column density. Its evolution with time gives significant information about very first stage of the chromospheric evaporation.

During the HXR burst we observe simultaneous upflows and downflows in the chromosphere and transition region.
There was no detectable emission of plasma that moves above the transition region.

Moving feature was observed just after the HXR burst. Estimated velocity is equal to 230 km/s.

Conclusions

Mass evaporated from one footpoint is almost equal to additional mass which was detected inside the loop-top kernel.

This kind of analysis gives a possibility for detailed analysis of the plasma flows in the chromosphere during the impulsive phase of solar flares.

Obtained results should be verified with the usage of observations made in different wavelengts. Hα observations seems to be very useful in such analysis.

Detailed modelling is strongly required!


THANK YOU FOR YOUR ATTENTION