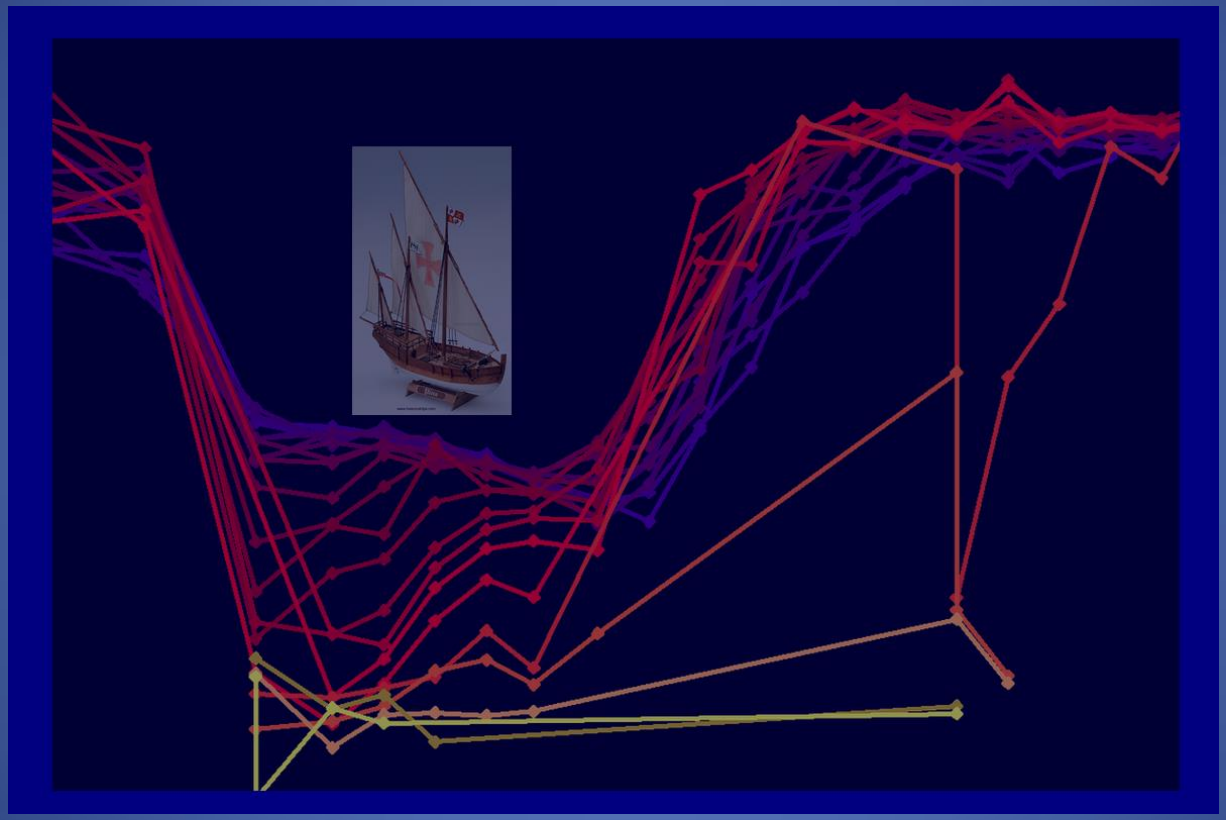
Columbus Flare



T. Mrozek[1,2], S. Kołomański[2], B. Sylwester[1], S. Gburek[1]
[1]Solar Physics Division, Space Research Centre PAS
[2]Astronomical Institute, University of Wrocław

10th anniversary

"Solar Magnetic Phenomena"

Summer School & Workshop

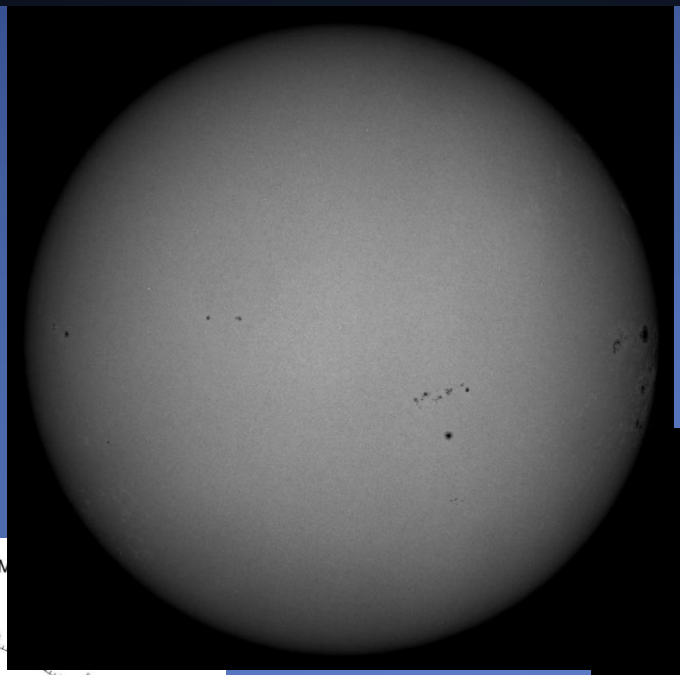
at the Kanzelhöhe Solar Observatory

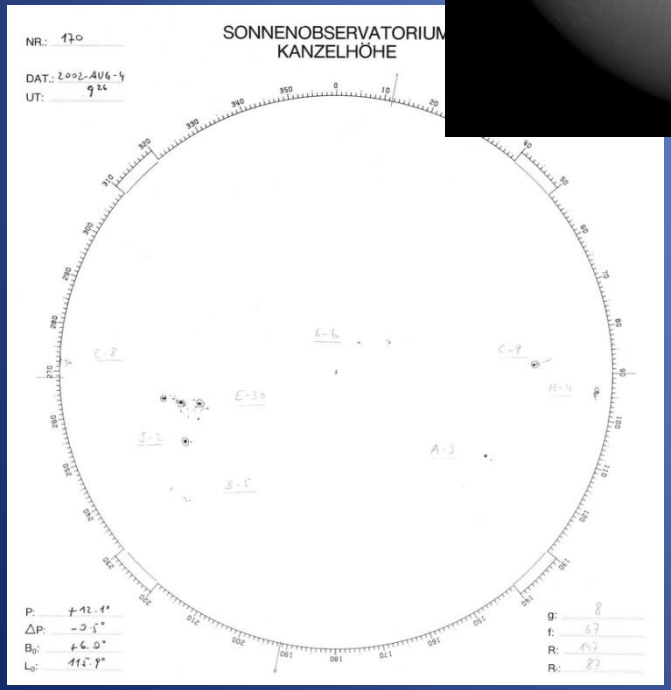
25. Aug. - 5. Sept. 2003

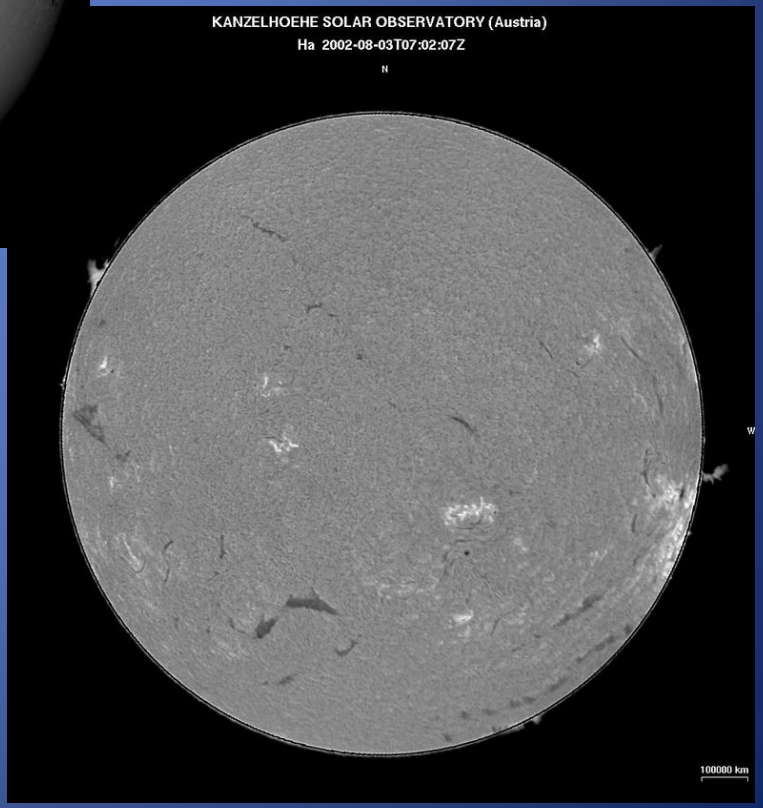
THE IMPULSIVE X-RAY RESPONSE
IN
FLARE FOOTPOINTS

TOMASZ MROZEK
WROCLAW UNIWERSITY
ASTRONOMICAL INSTITUTE
POLAND

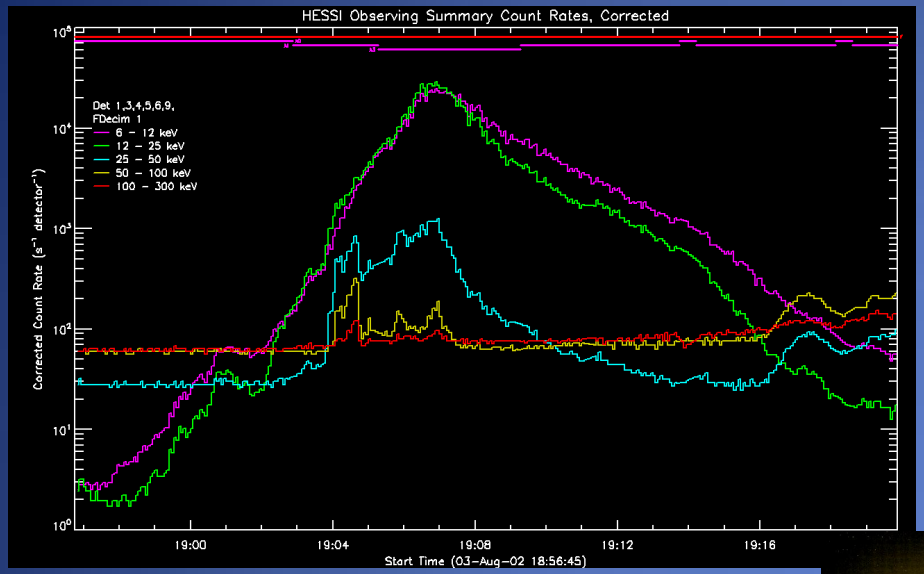
3 August 2002







3 August 2002

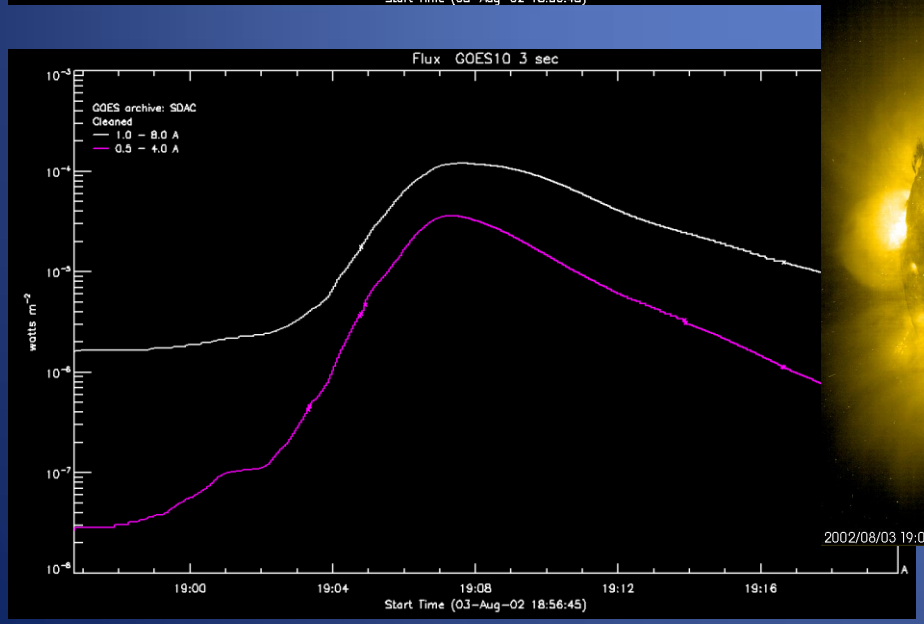


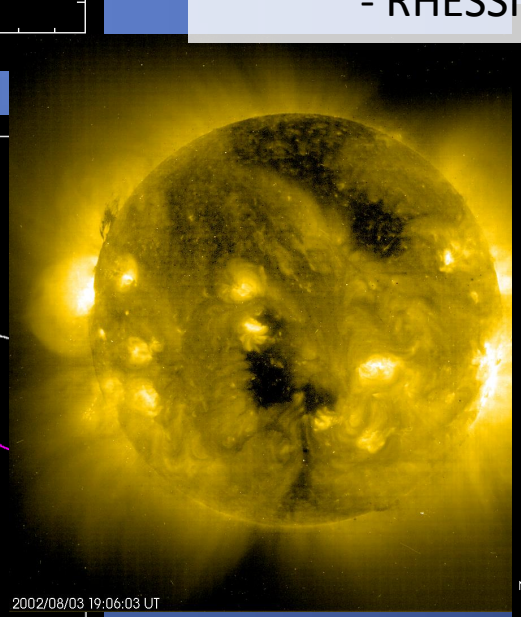
GOES class: X1.5

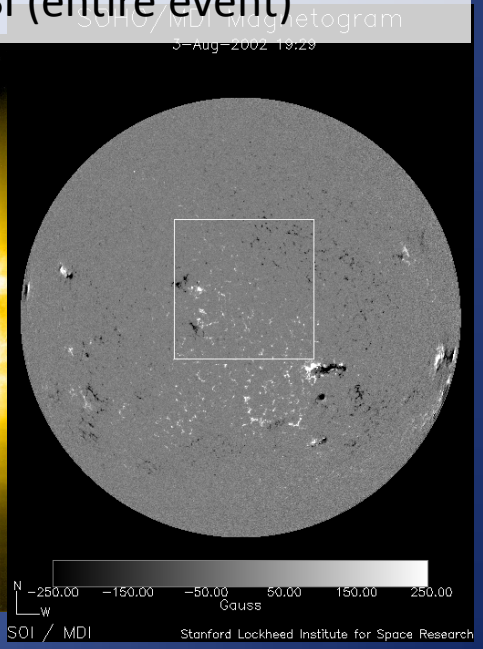
location: S15W70

utilized observations:

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







3 August 2002

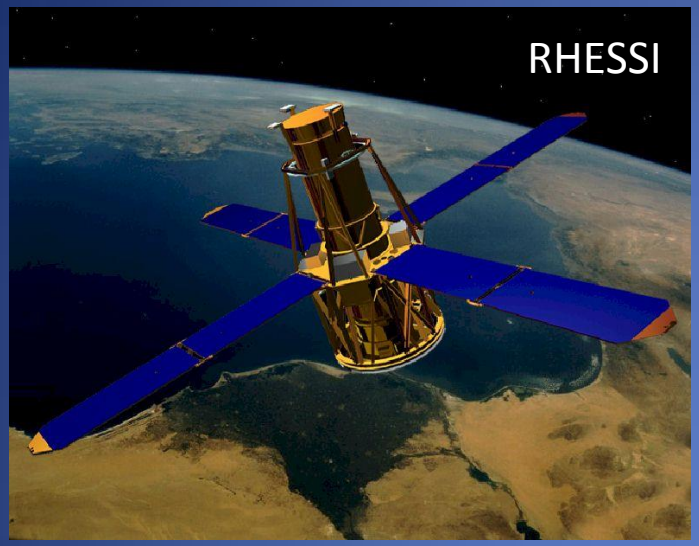
On the evening of 3 August 1492, Columbus departed from Palos de la Frontera with three ships: a larger carrack, the Santa María ex-Gallega ("Galician"), and two smaller caravels, the Pinta ("Painted") and the Santa Clara, nicknamed the Niña (lit. "Girl") …

Pinta

Niña

Santa Maria

Three instruments



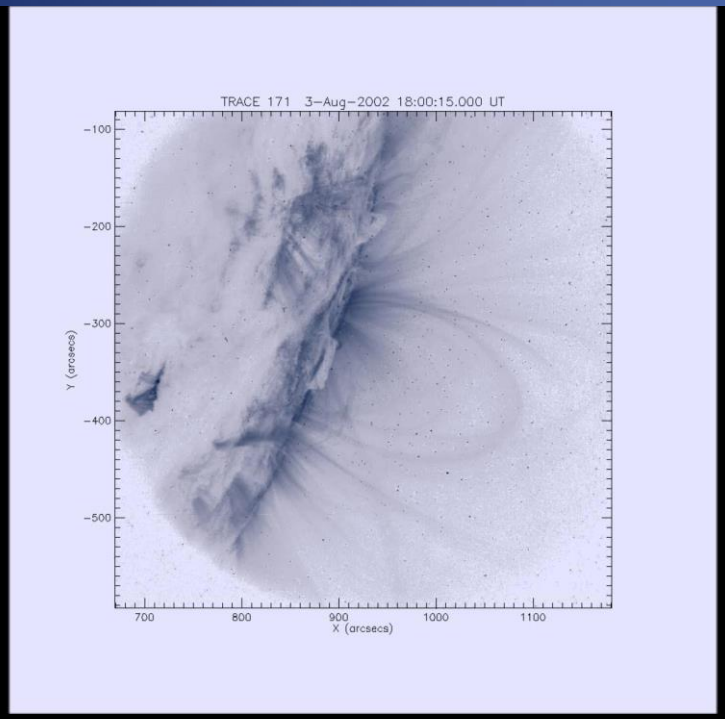
RESIK

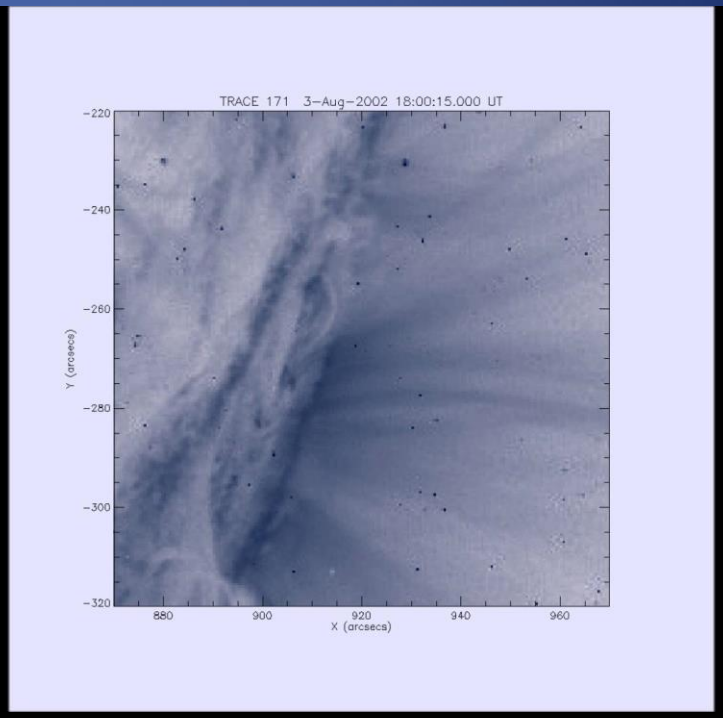
Bragg crystal spectrometer

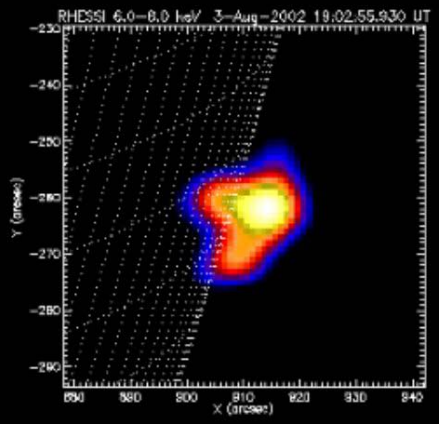
Observed the Sun in four spectral bands: 3.37 - 3.88 Å, 3.82 - 4.33 Å, 4.31 - 4.89 Å and 4.96 - 6.09 Å

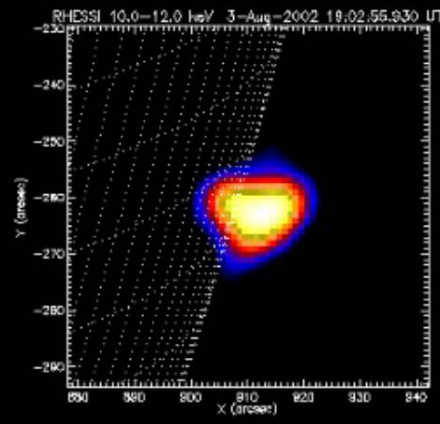
Data packets are available from October 2001 to April 2003: http://www.cbk.pan.wroc.pl/experiments/resik/resik_catalogue.htm

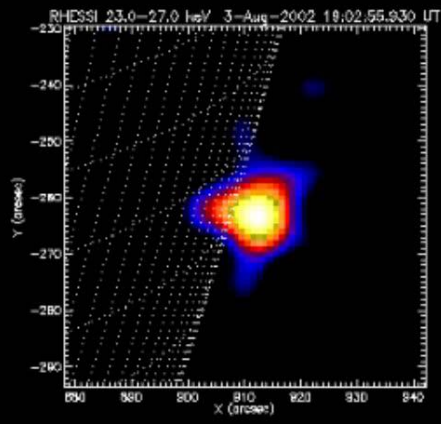
3 August 2002

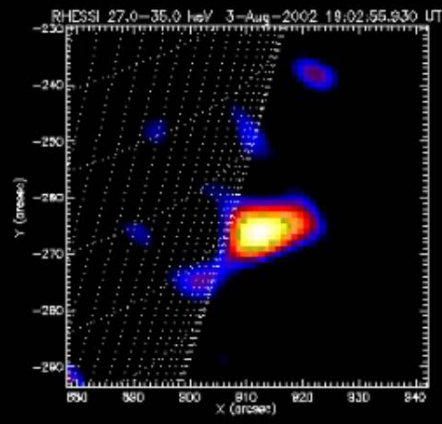




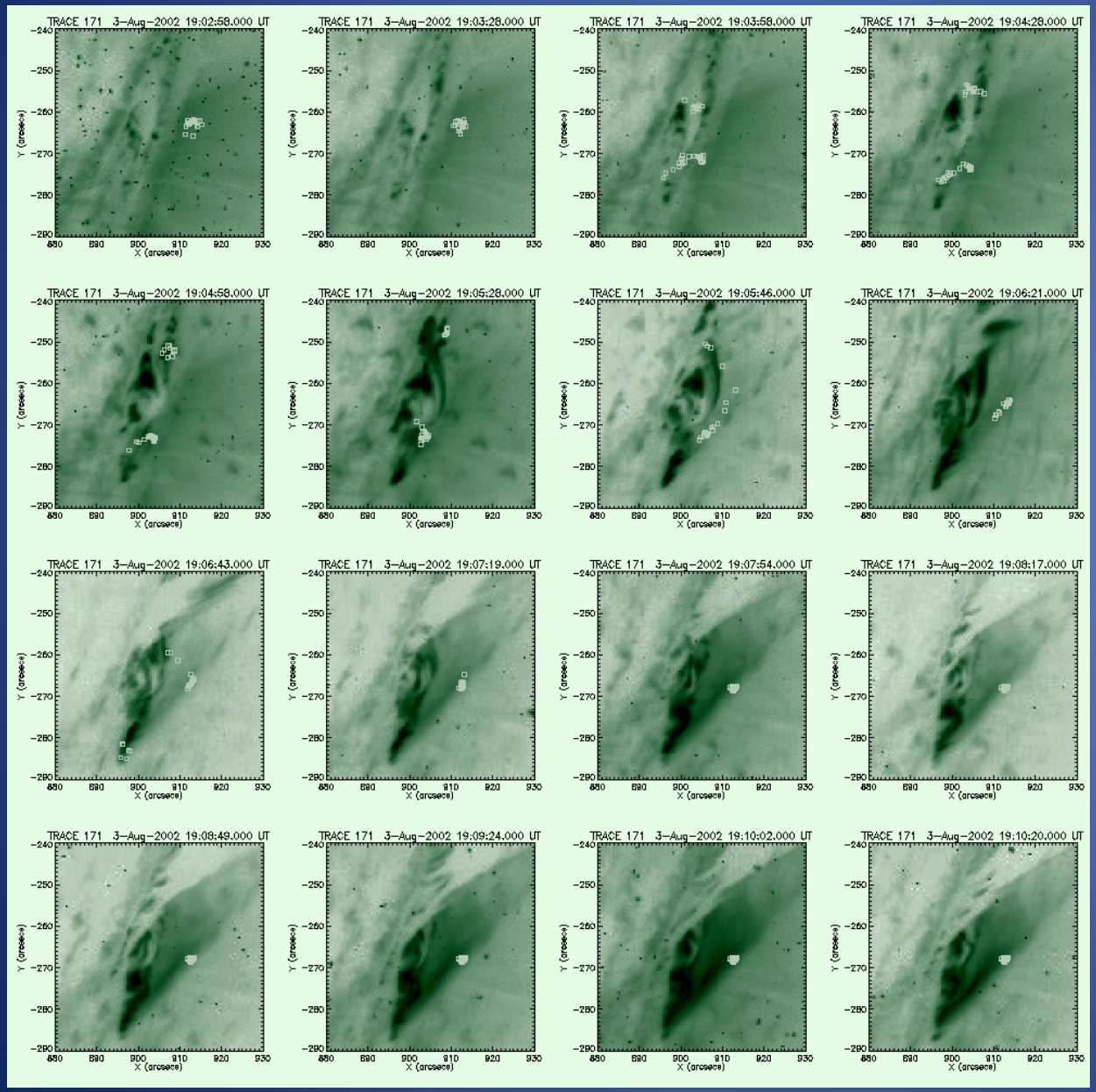








3 August 2002



First minutes of flare evolution – coronal source

Footpoints are visible since ~19:04 UT

Correlation with EUV footpoints is visible

Starting from ~19:07 UT coronal source dominates again

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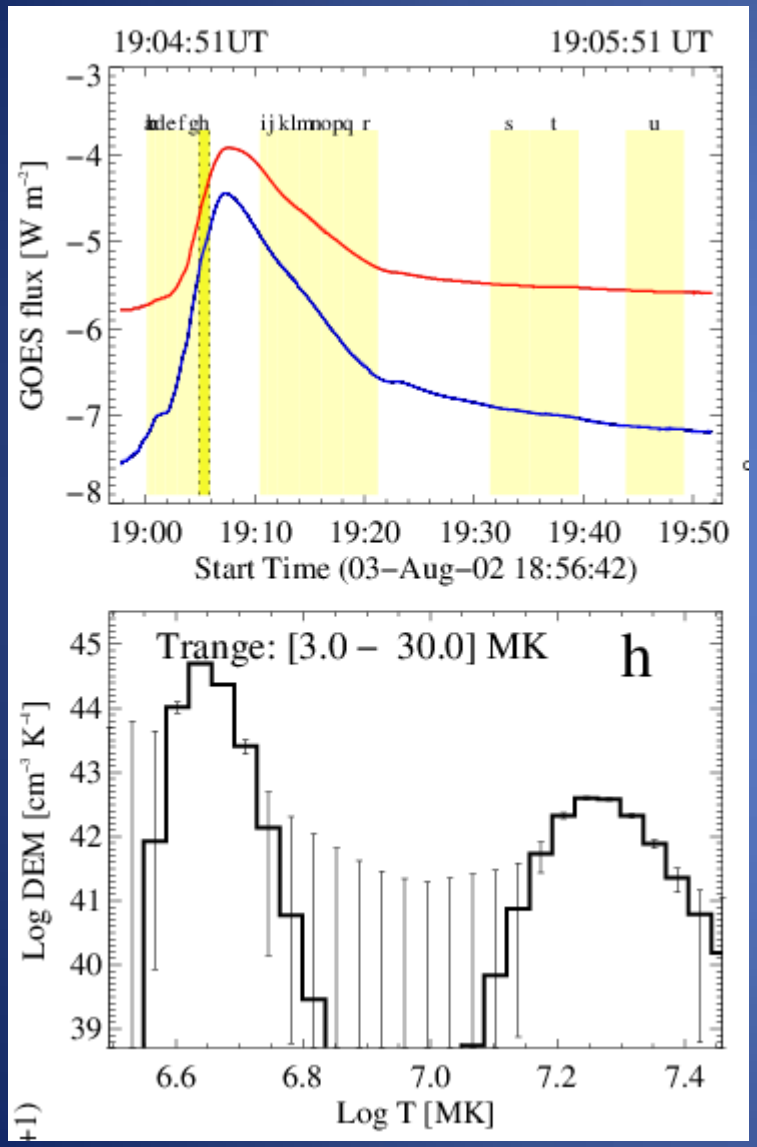
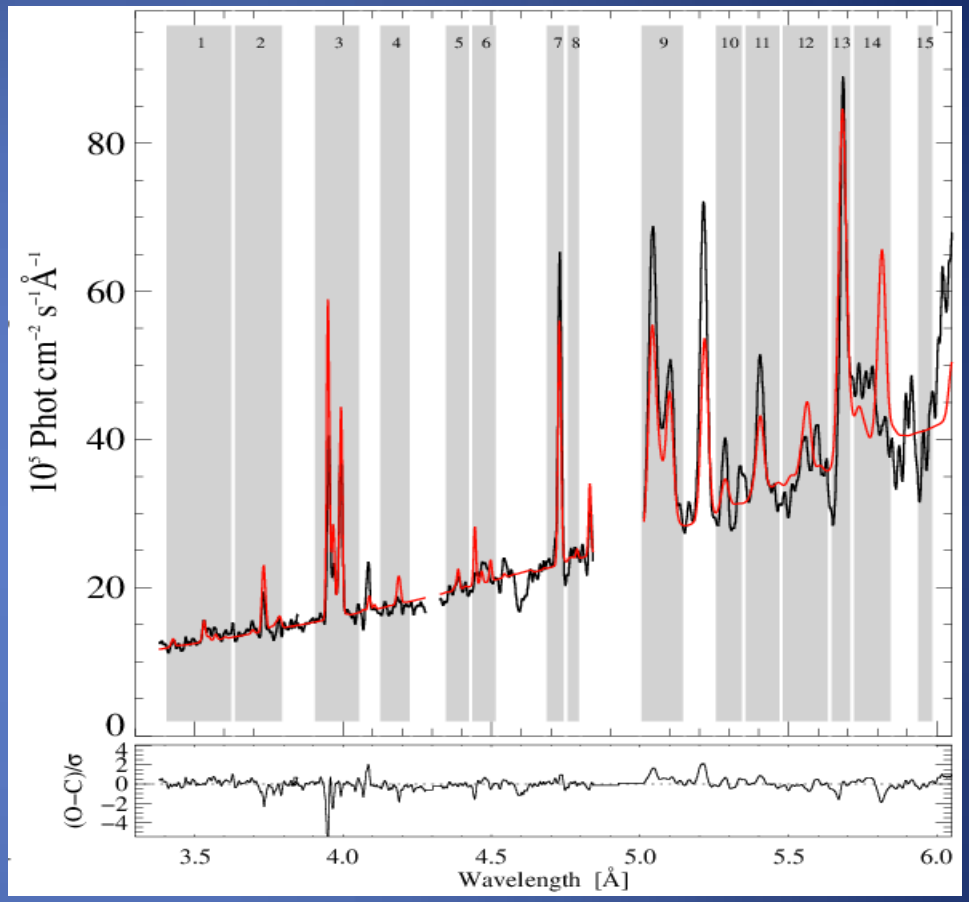
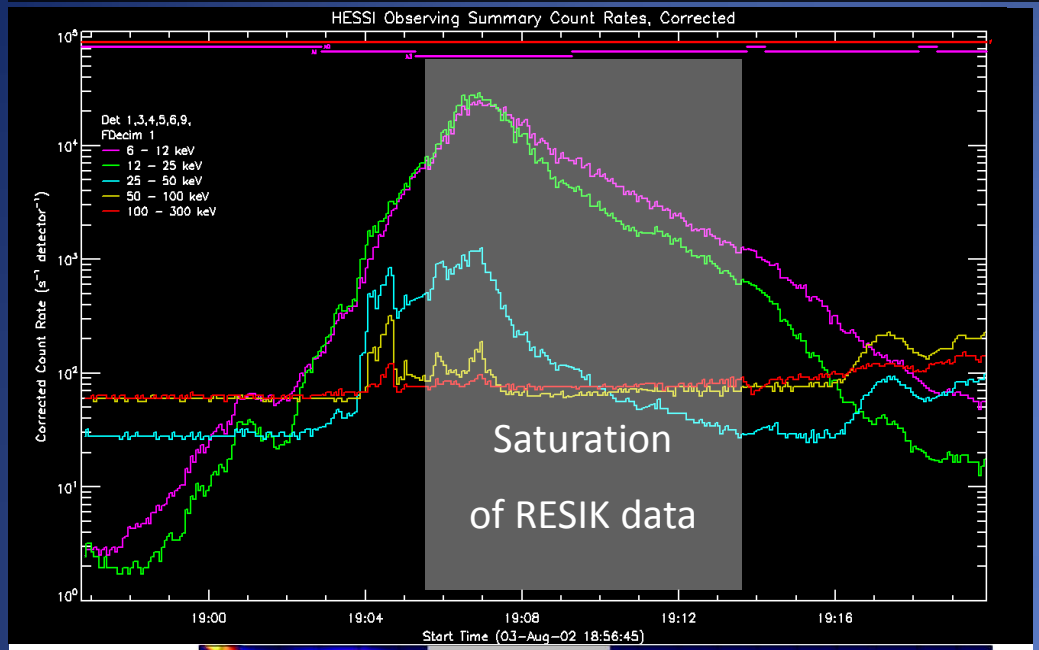
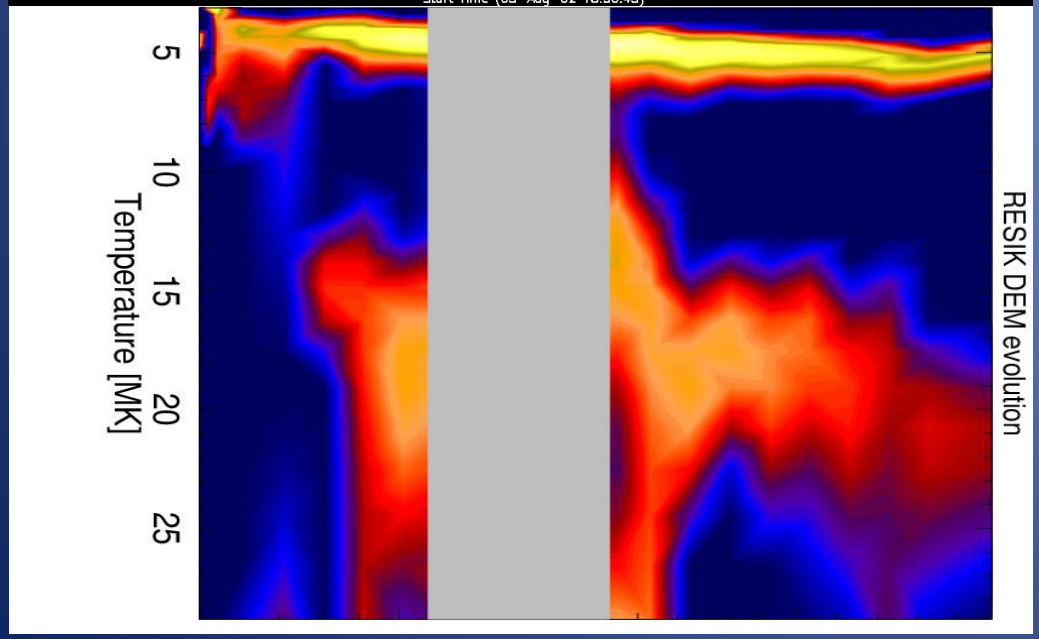




RESIK spectra were fitted with a use of Withbroe-Sylwester algorithm for a number of accumulated spectra

3 August 2002





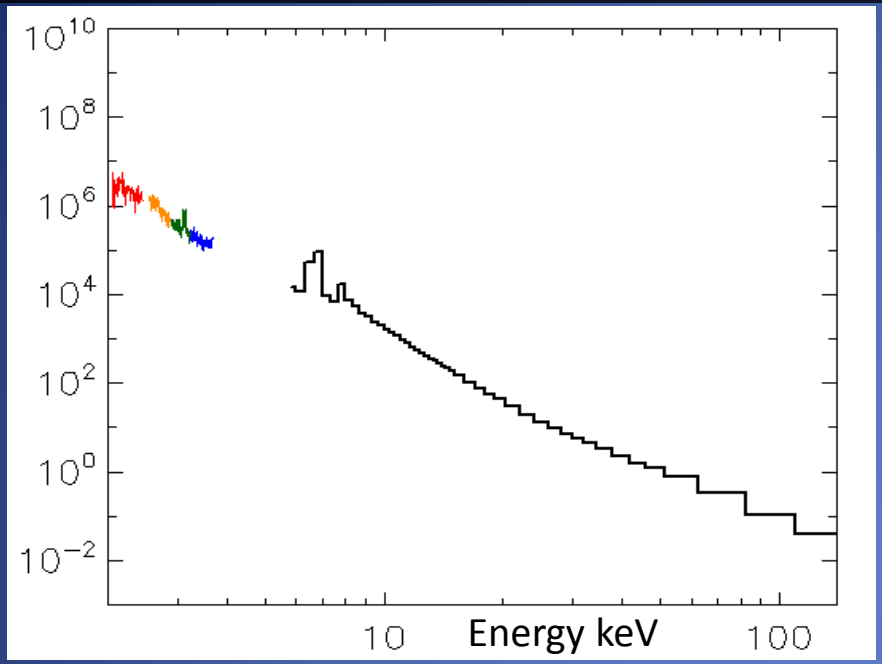
During the main phase RESIK detectors were saturated.

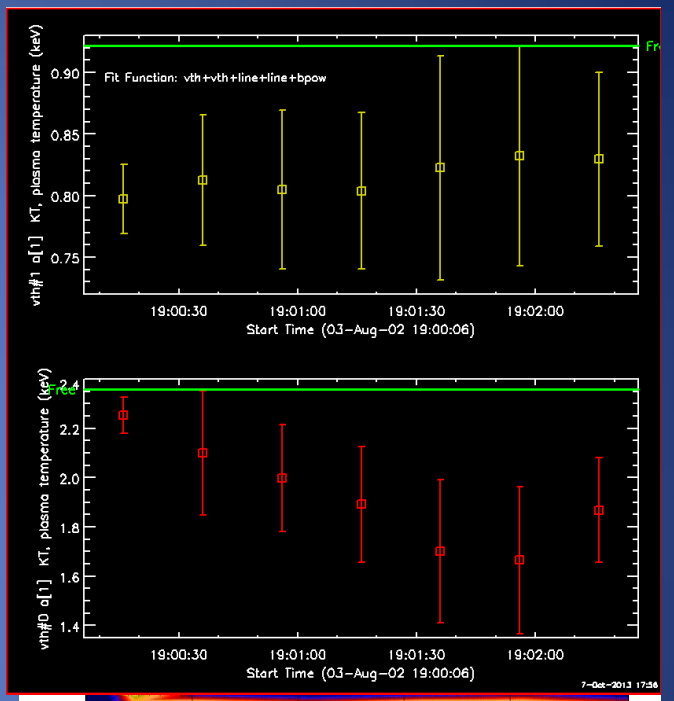
The hot component was visible since ~19:03 UT.

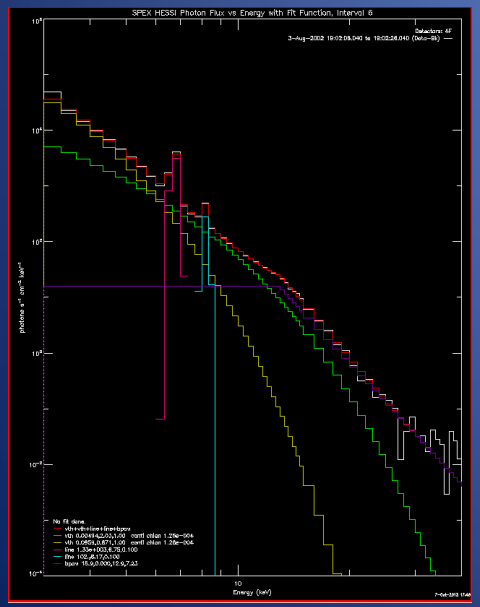
The warm component was present during entire event.

RHESSI data were not affected by attenuator before 19:03 UT which gave a chance for comparison data from both instruments.

3 August 2002

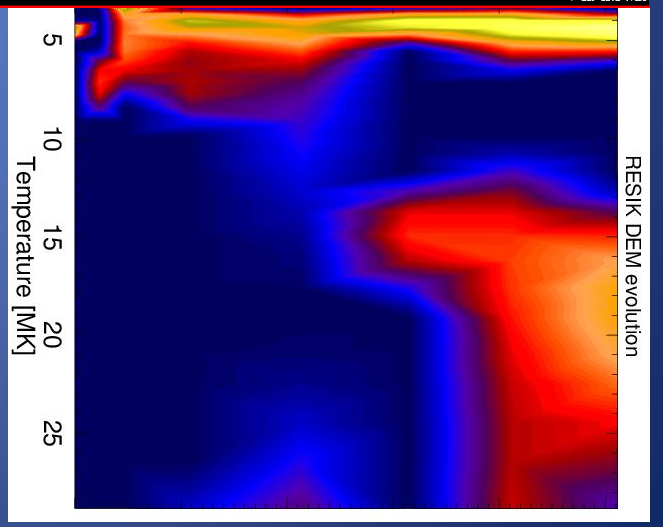




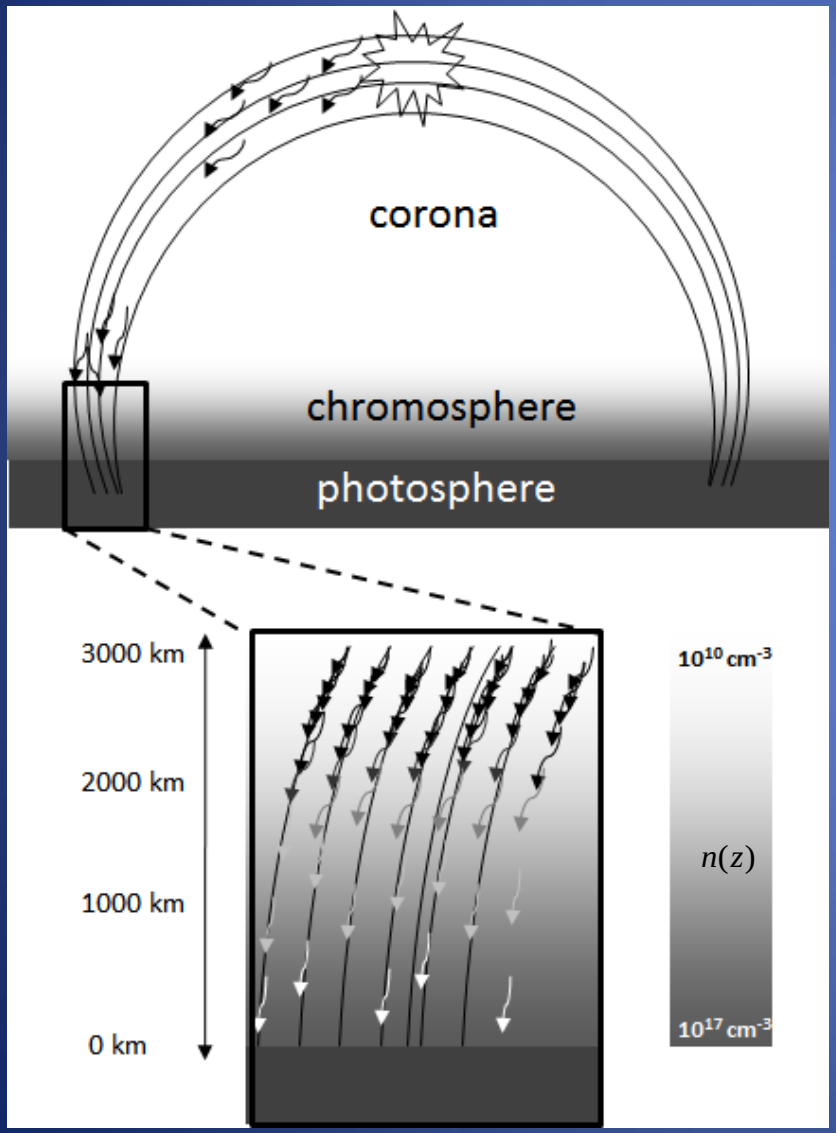


RHESSI spectra were fitted with two thermal components, two gaussians and broken power-law.

Temperatures from RHESSI are slightly above RESIK ones.



Energy-height relation



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

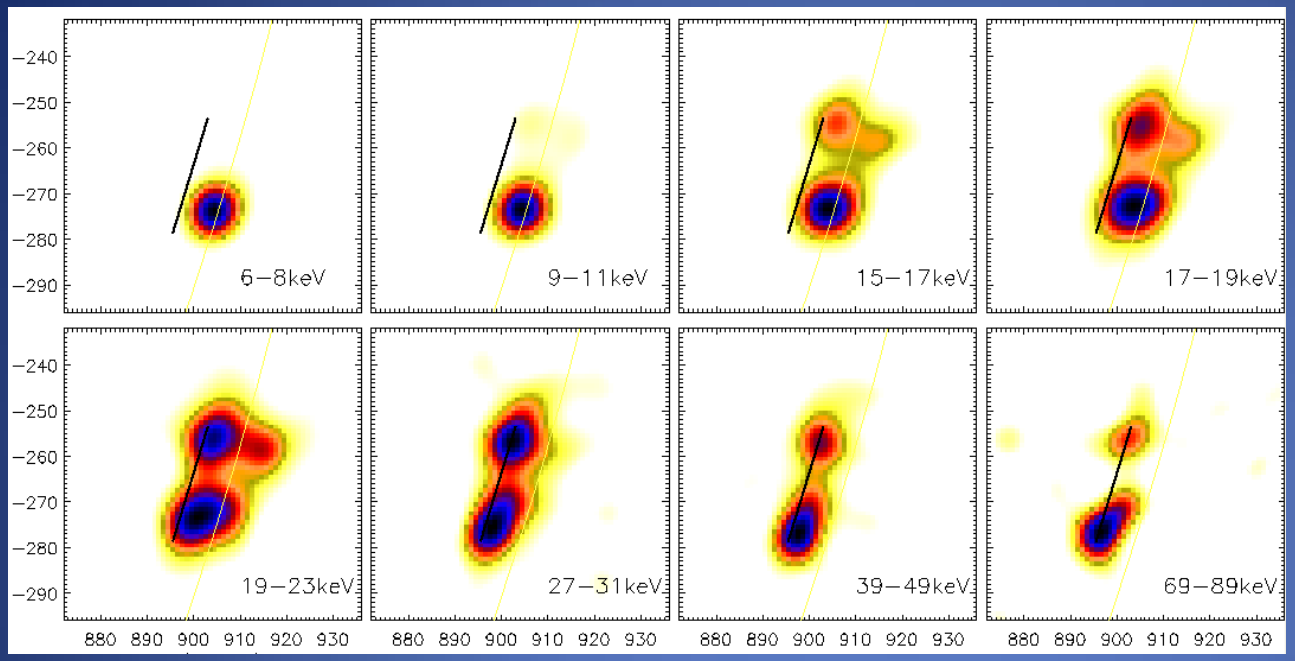
$$E(E_0, N) = \left(E_0^2 - 2KN\right)^{1/2}$$

$$N_s(E_0) = \frac{E_0^2}{2K}$$

$$N_s(z) = \int_z^{z_{\max}} n(z')dz'$$

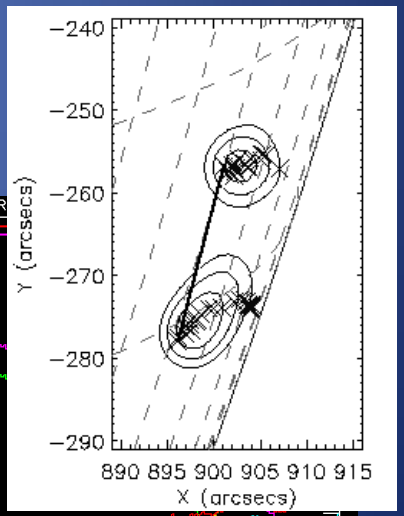
$$n(z)$$

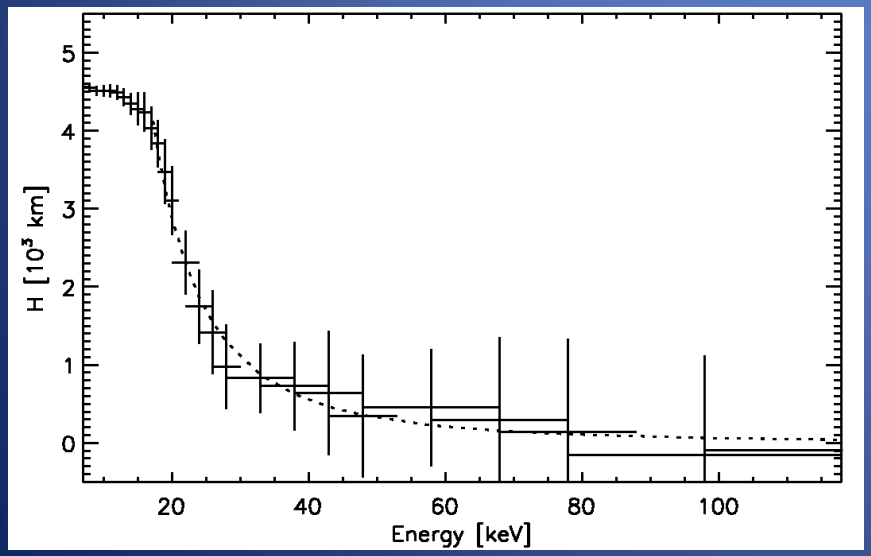
Energy-height relation



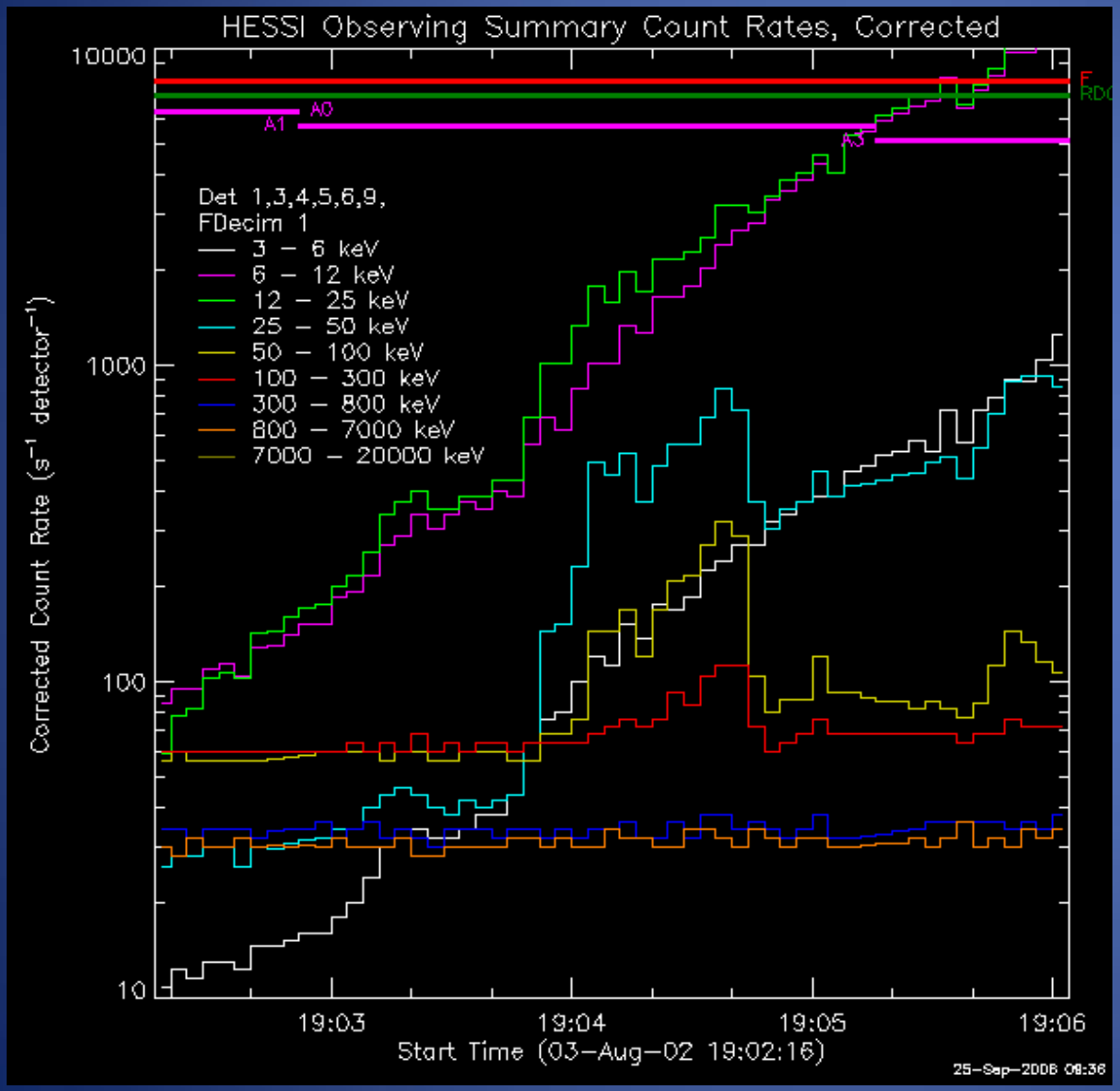
Main HXR peak:
19:04 – 19:05 UT

Reference level defined with highest-energy sources





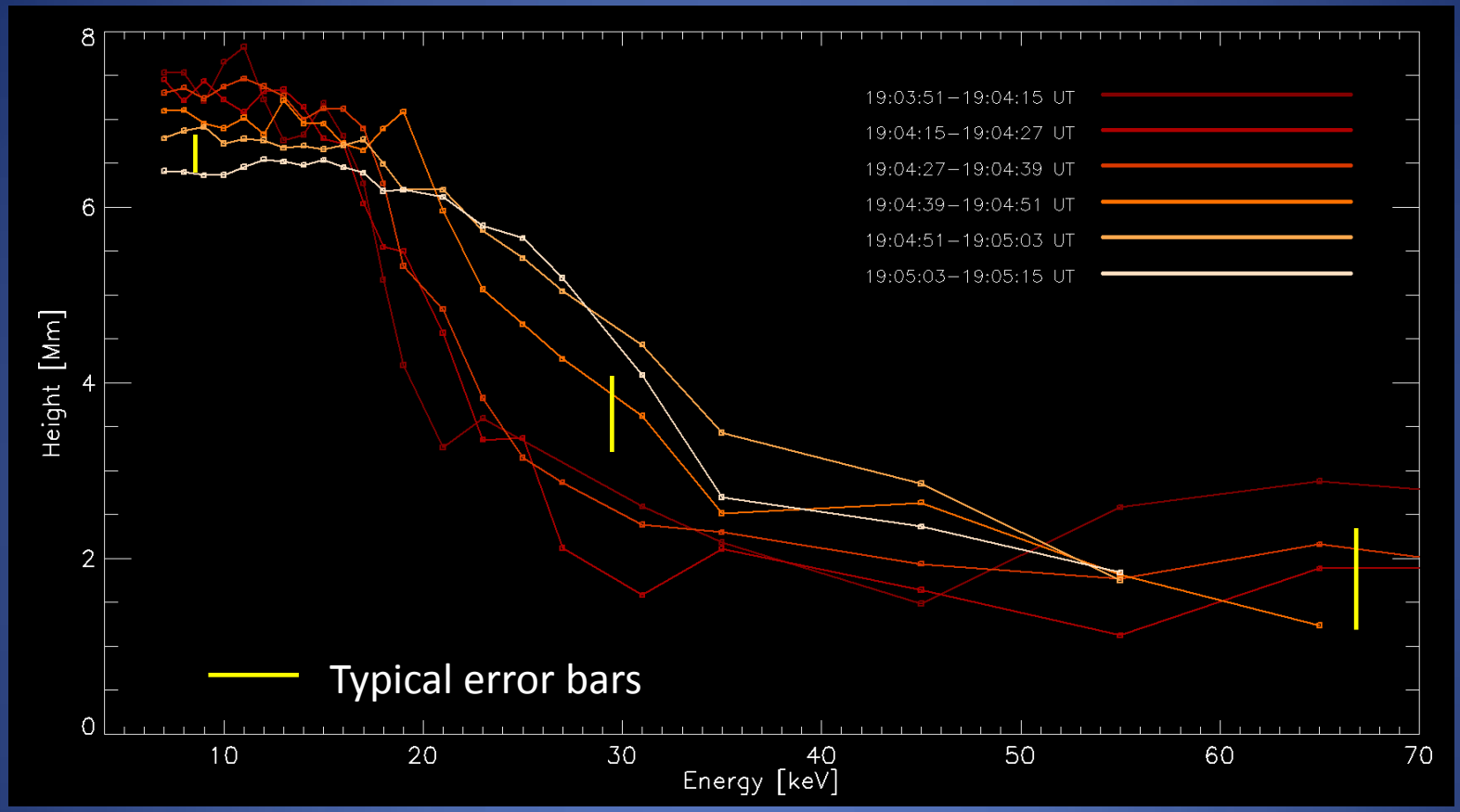
Energy-height relation: time evolution



Six consecutive time intervals covering main peak

Six consecutive E-H relations were obtained – possibilty for analysis of column density evolution

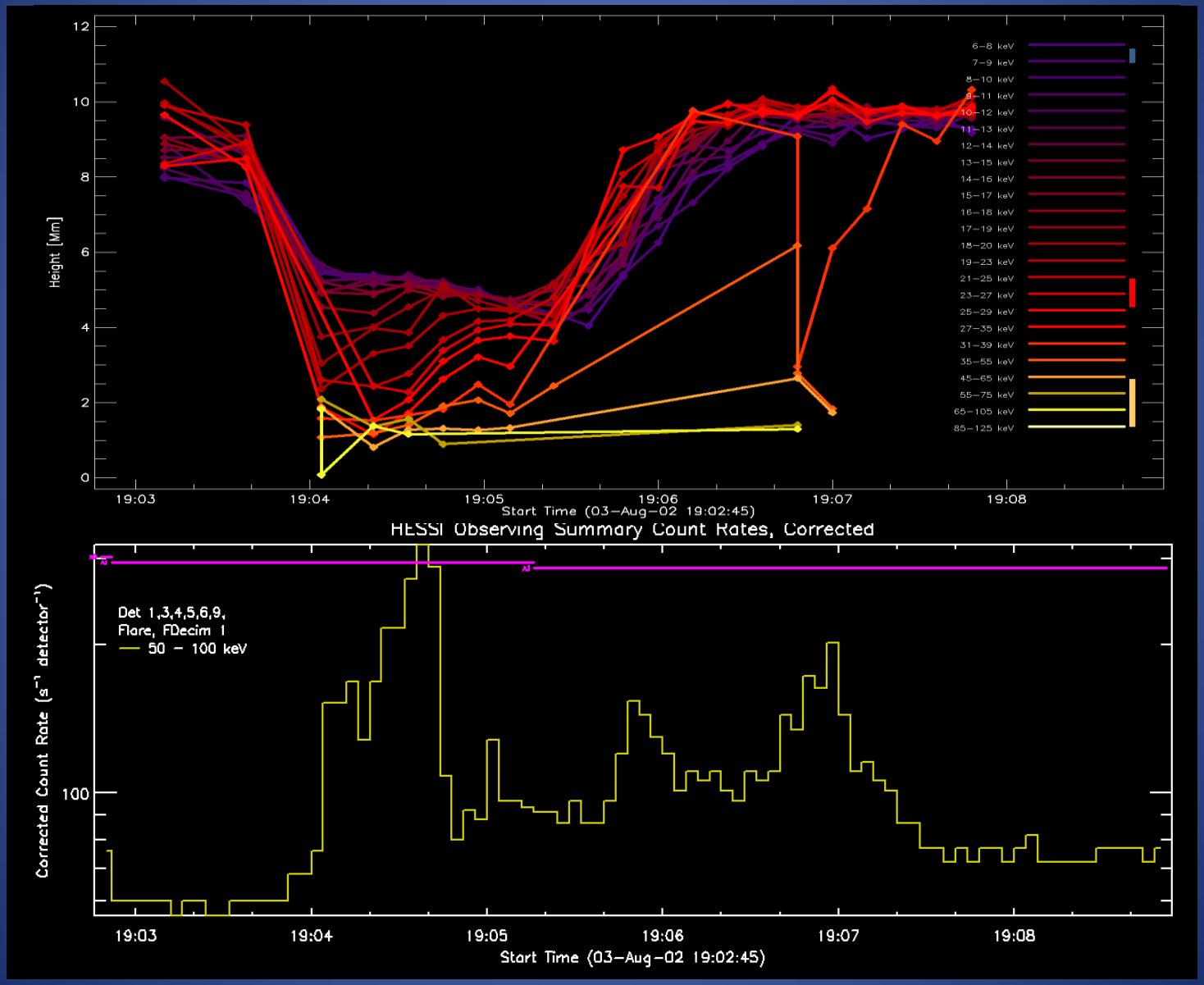
Energy-height relation: time evolution



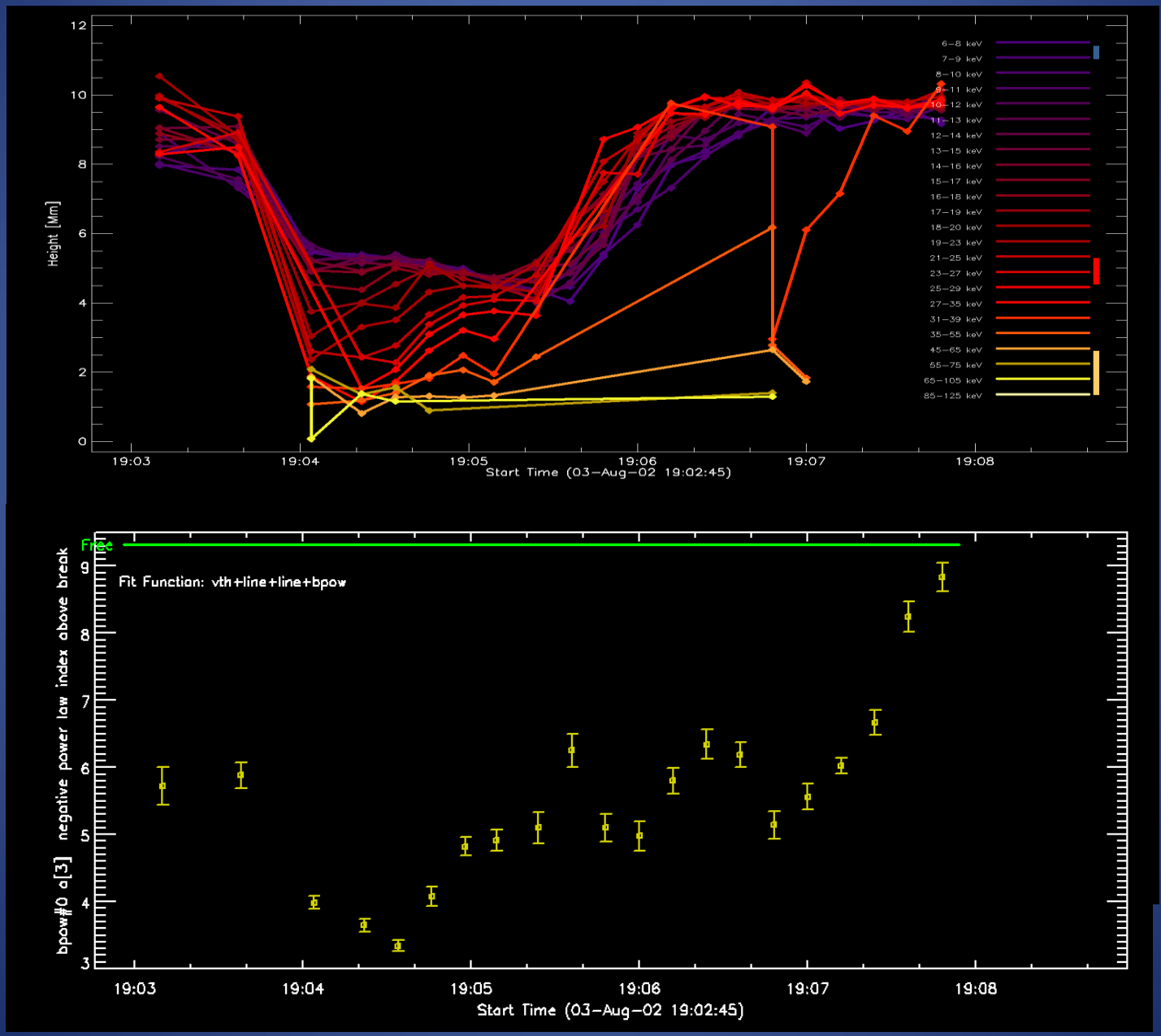
Observed changes may be caused by changesof column density or electron spectrum index

$$\frac{dI}{dz} \sim (\delta - 1)\frac{1}{\varepsilon}\left(\frac{E_1^2}{2K}\right)^{\frac{\delta}{2}} N^{1+a-\frac{\delta}{2}} B\left(\frac{1}{1+\frac{\varepsilon^2}{2KN(z)}}, \frac{\delta}{2}, \frac{1}{2}\right)$$

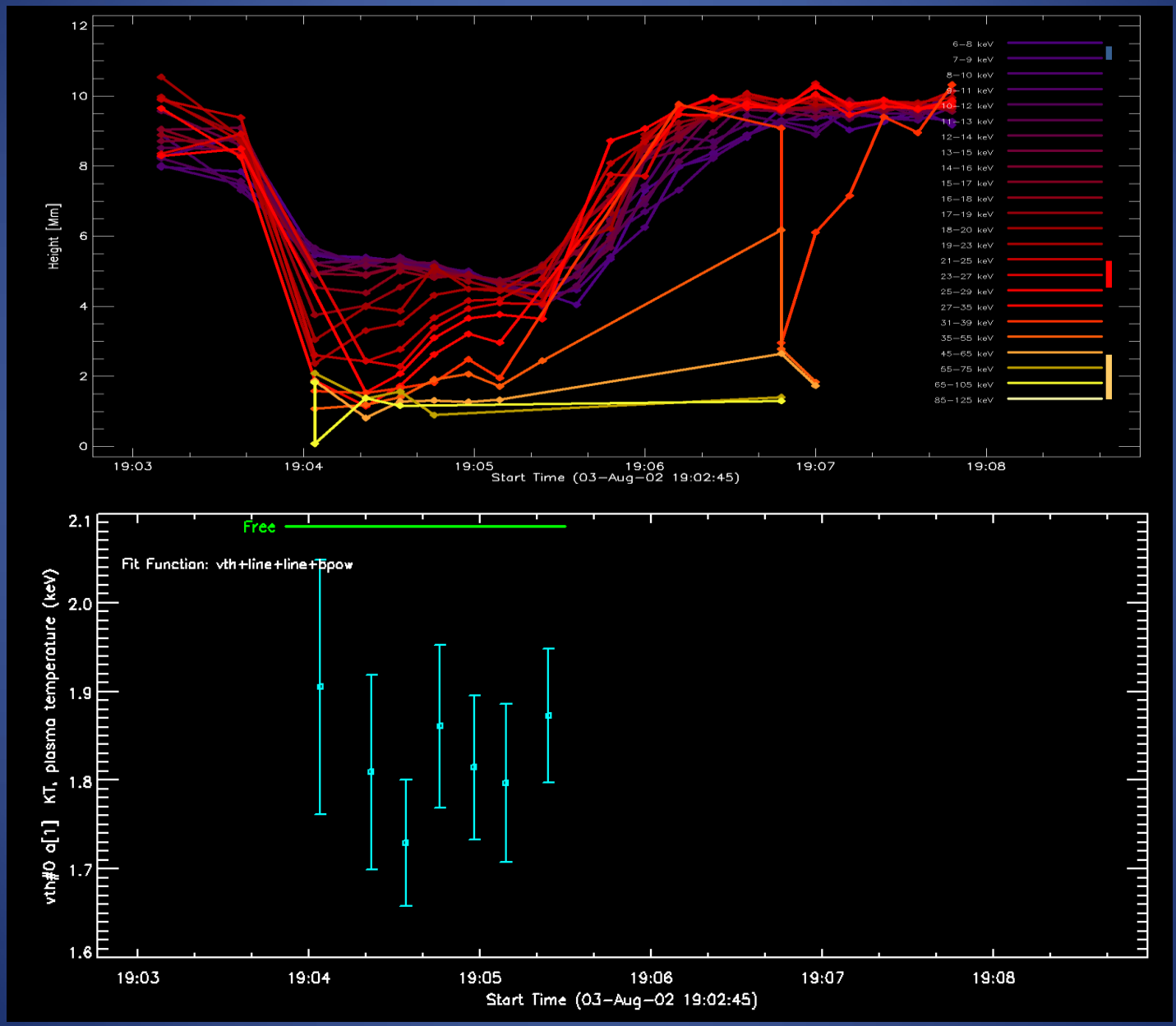
Energy-height relation: time evolution



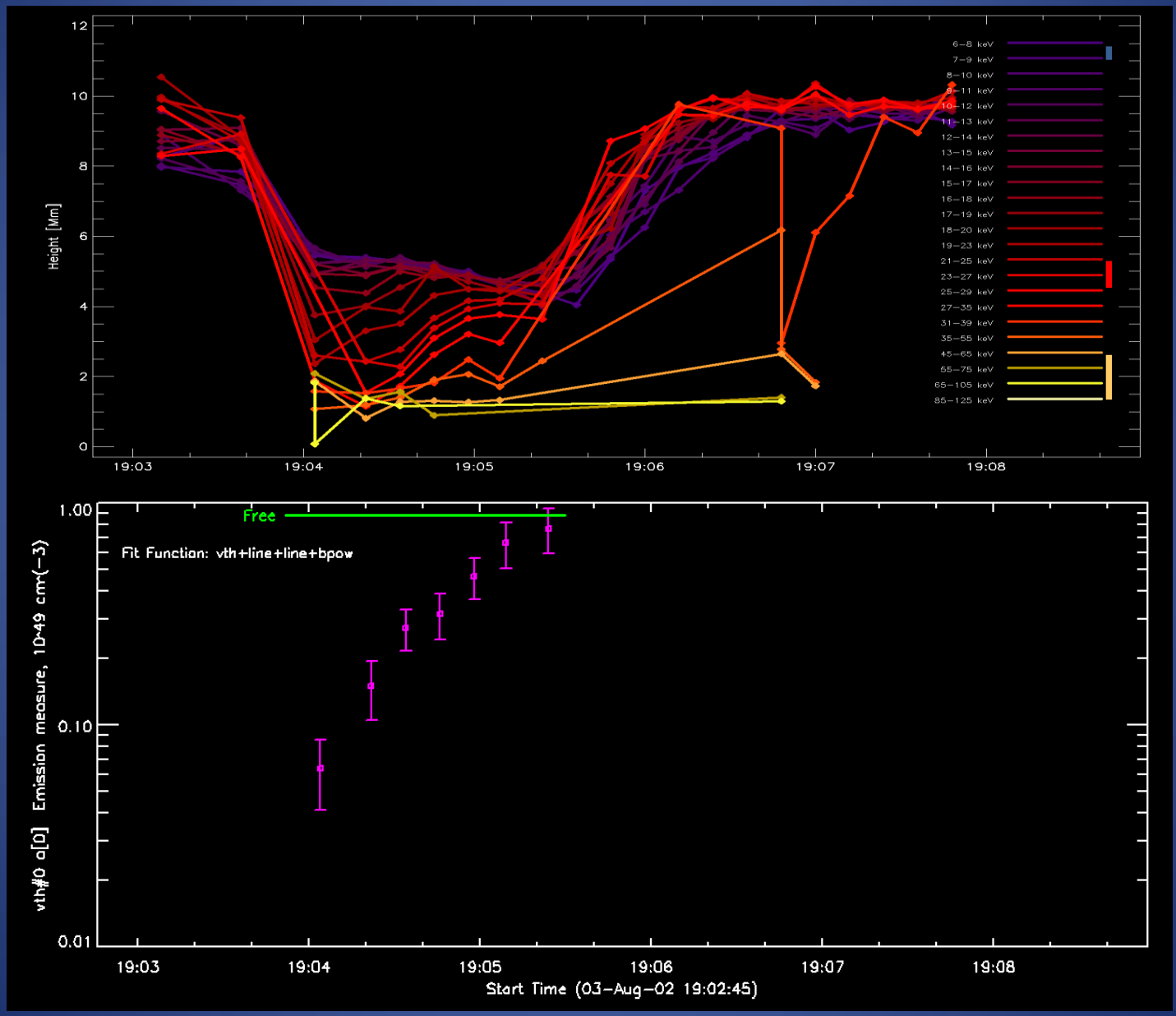
Energy-height relation: time evolution



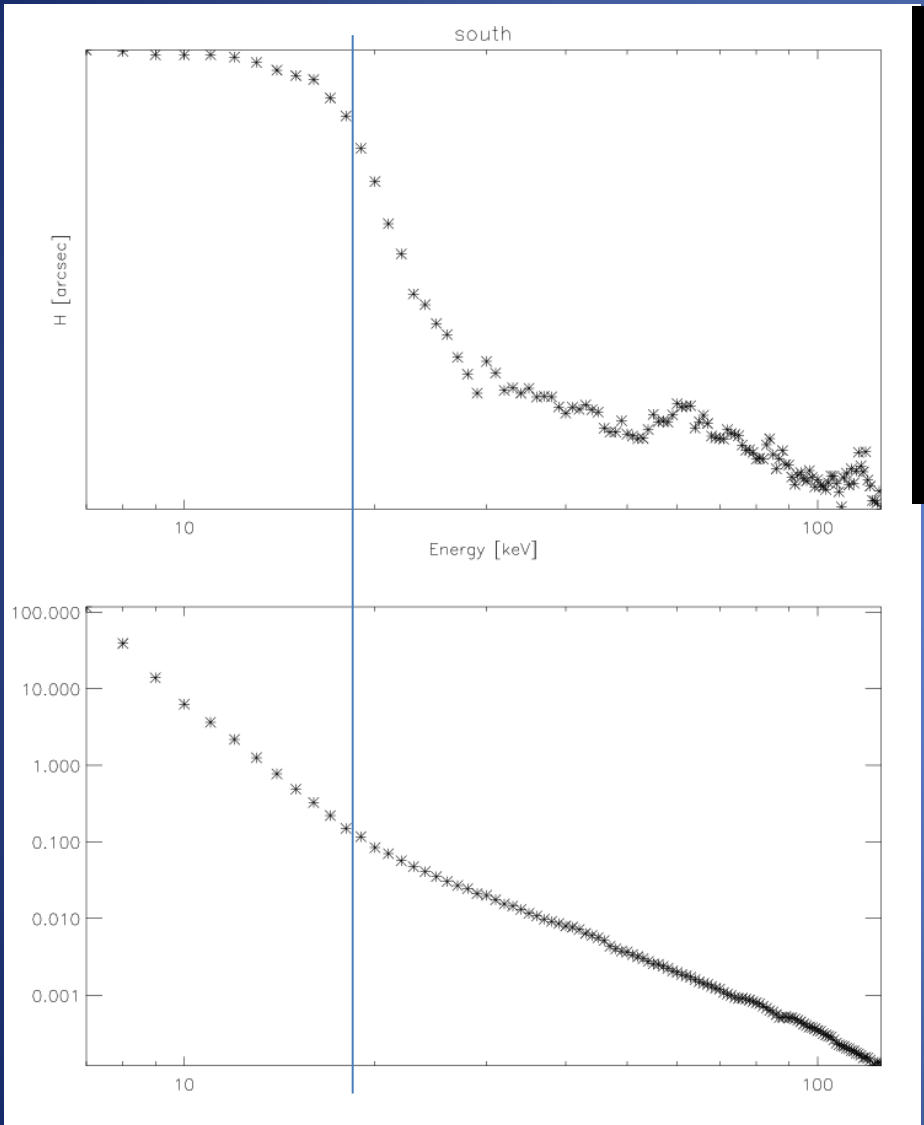
Energy-height relation: time evolution

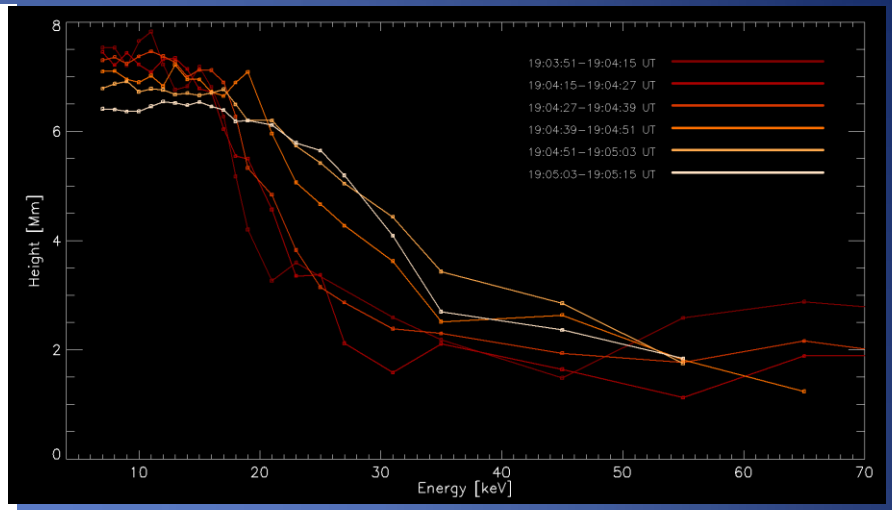


Energy-height relation: time evolution



Dynamics



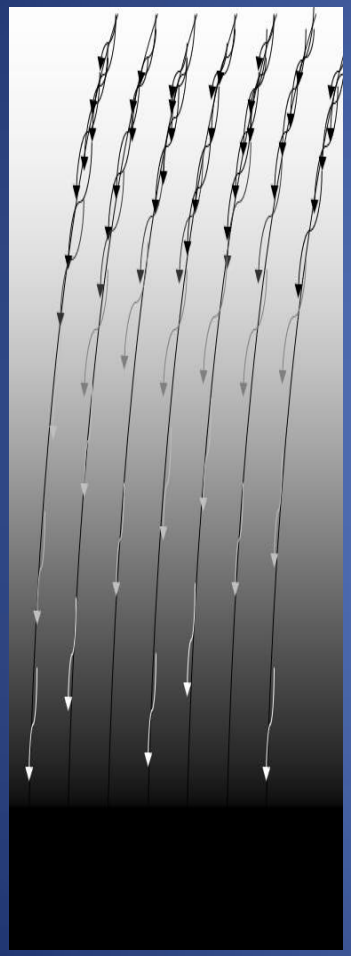


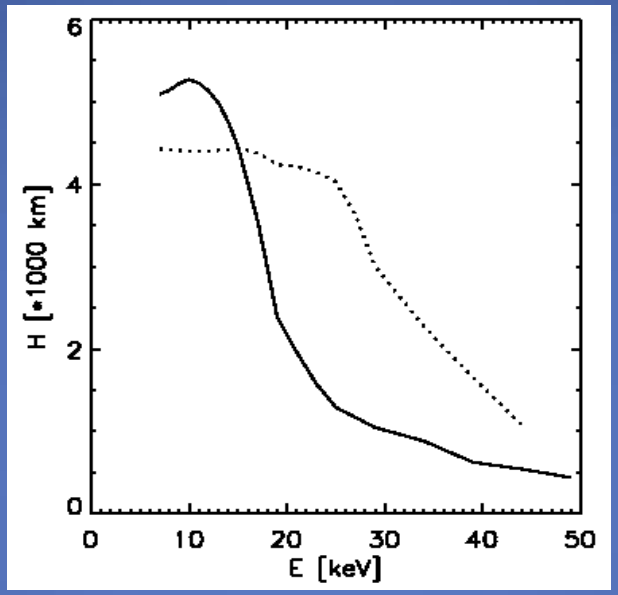
Low energy part of the curve is purely thermal – footpoint with very high temperature(?)

Non-thermal sources are visible above 20 keV

Assuming the relation depends on a column density we may trace the plasma dynamics in footpoint and above.

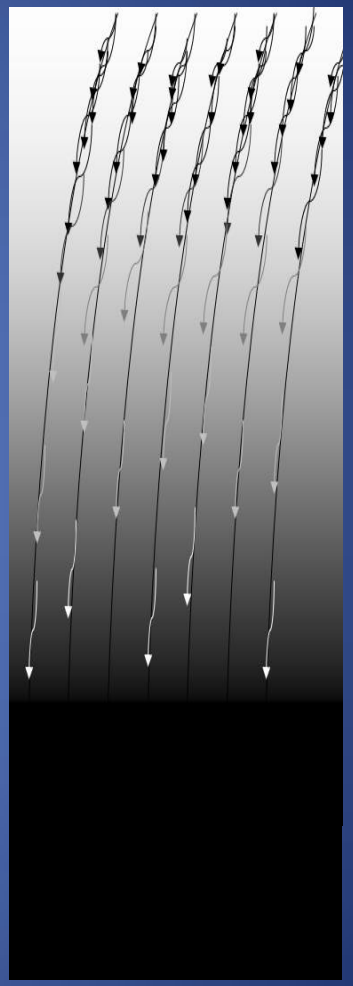
Dynamics





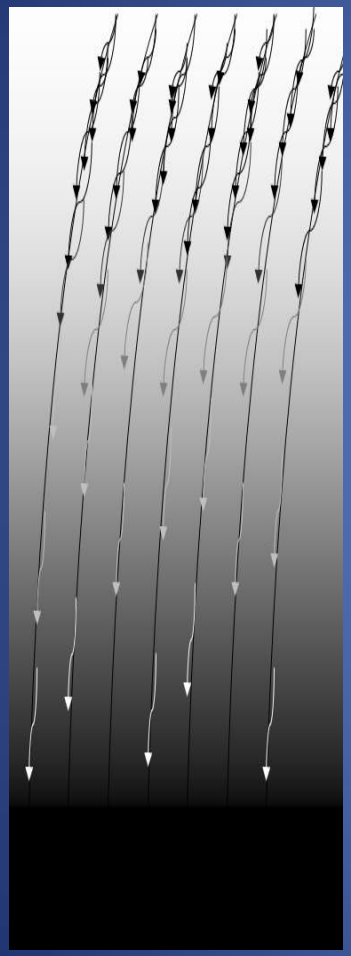
h_0, E_0, N_1

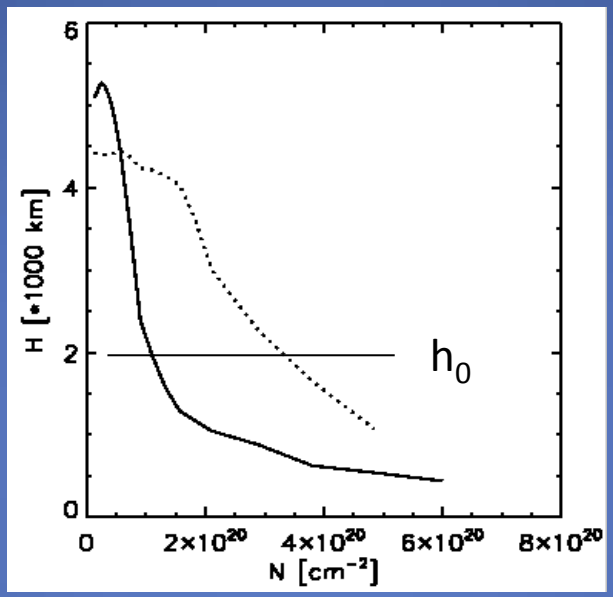
h_0, E_0, N_0



Energy-height relation may be transferred to energy-column density relation

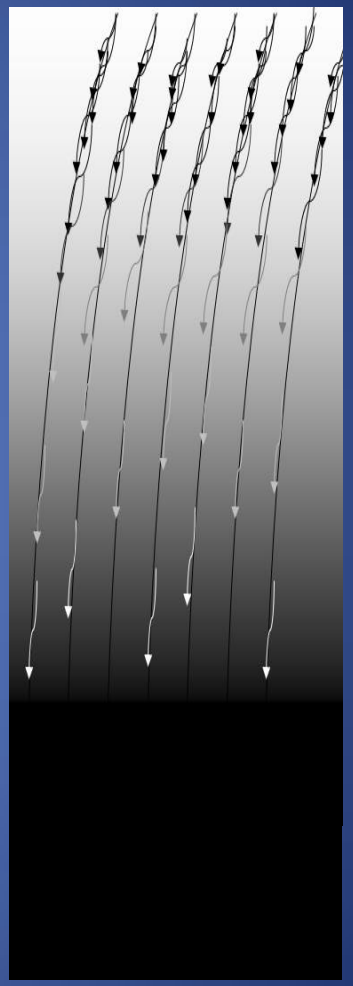
Dynamics





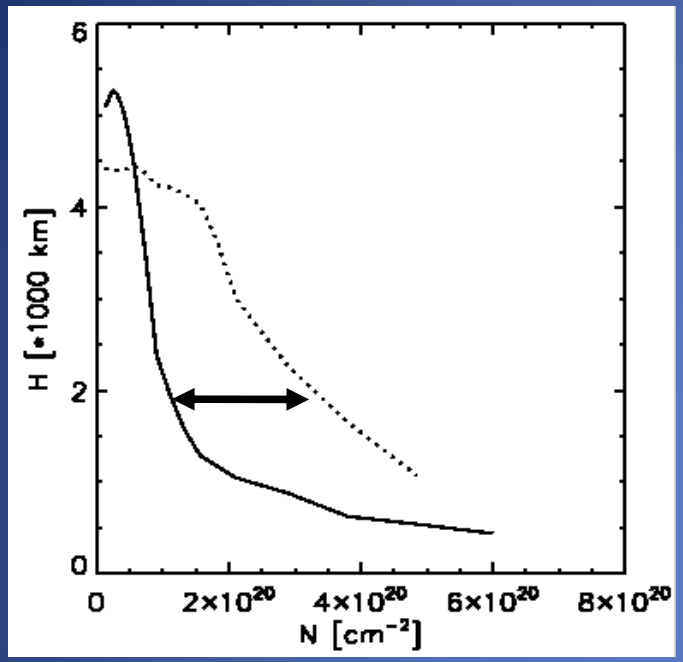
h_0, E_0, N_1

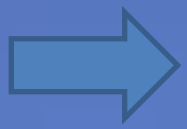
h_0, E_0, N_0

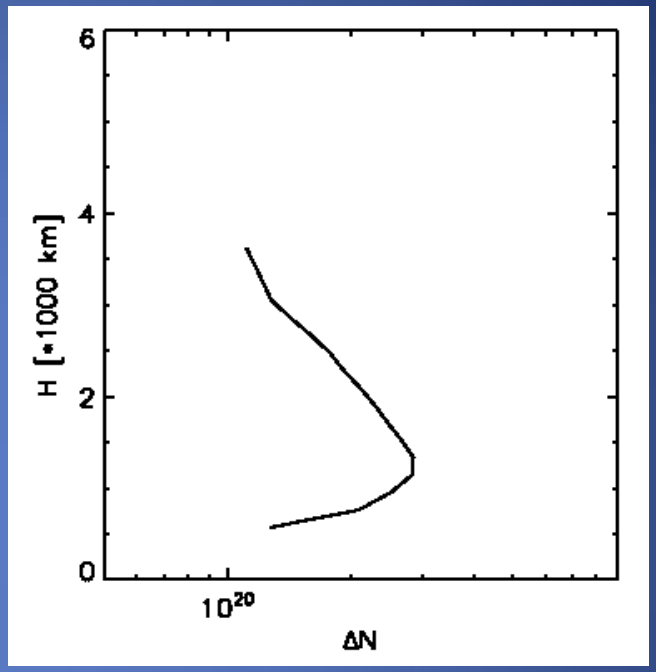


Difference between column densities calculated at several levels may be transferred to difference of masses

Dynamics







The „maximum" informs how much mass was moved between levels

Additional mass above 1000 km: 5×10^{13} g

ΔEM (EM at the maximum minus initial EM for loop top) : 8×10^{13} g

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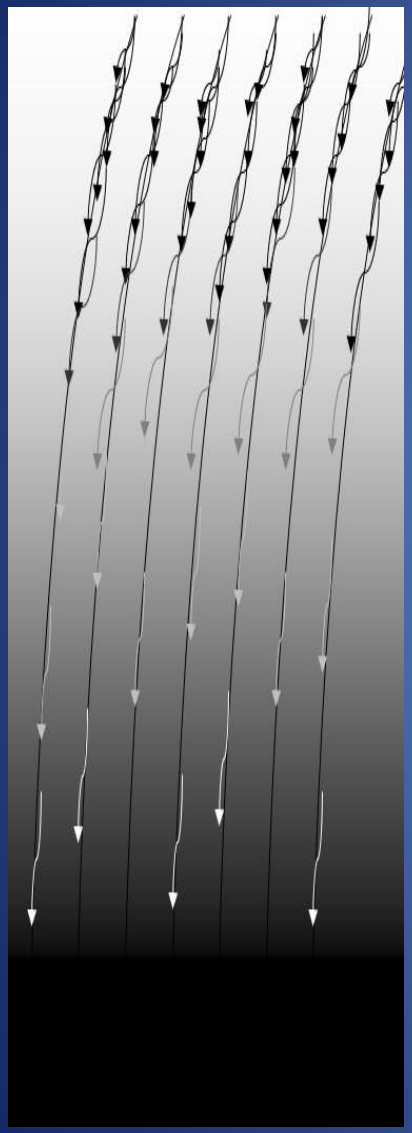
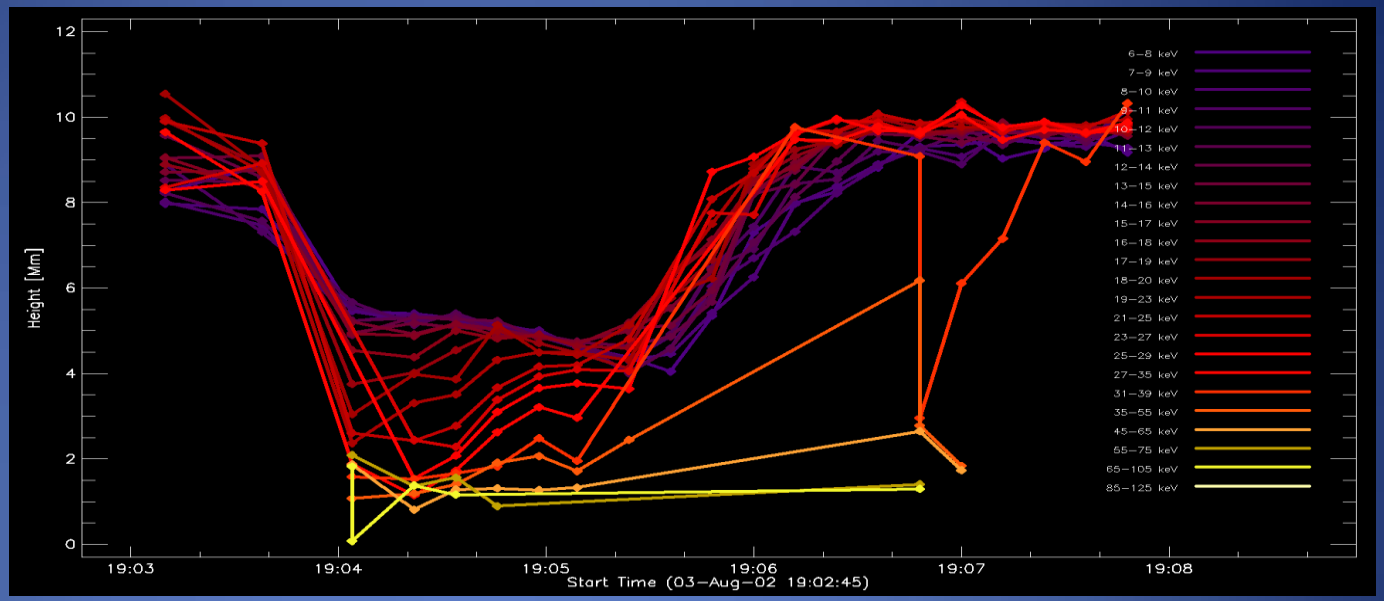


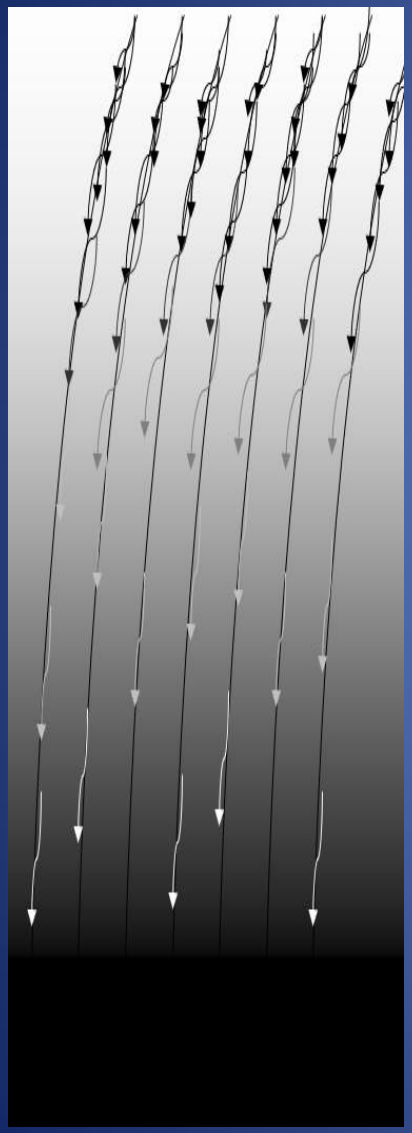


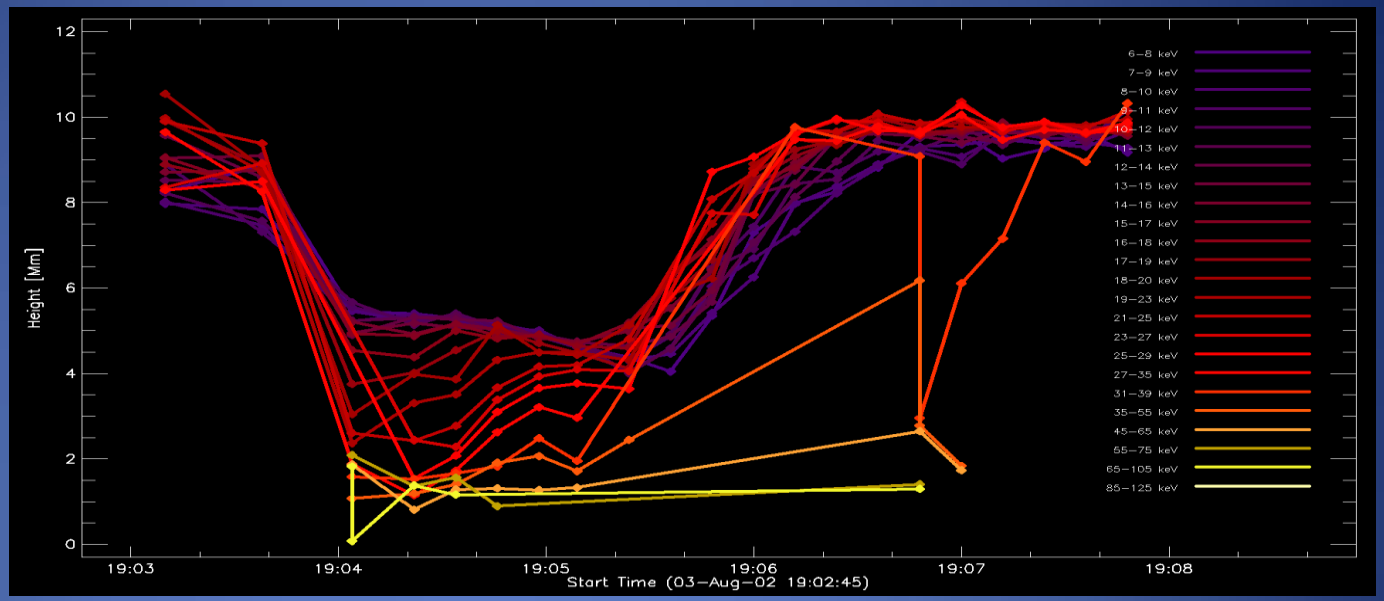
Starting from 19:05:20 UT we observe sources moving along leg with speed ~200 km/s

Non-thermal energy (main peak): 1.6×10^{30} ergs

Kinetic energy (we estimated mass) of evaporated plasma: 10^{28} ergs

Summary



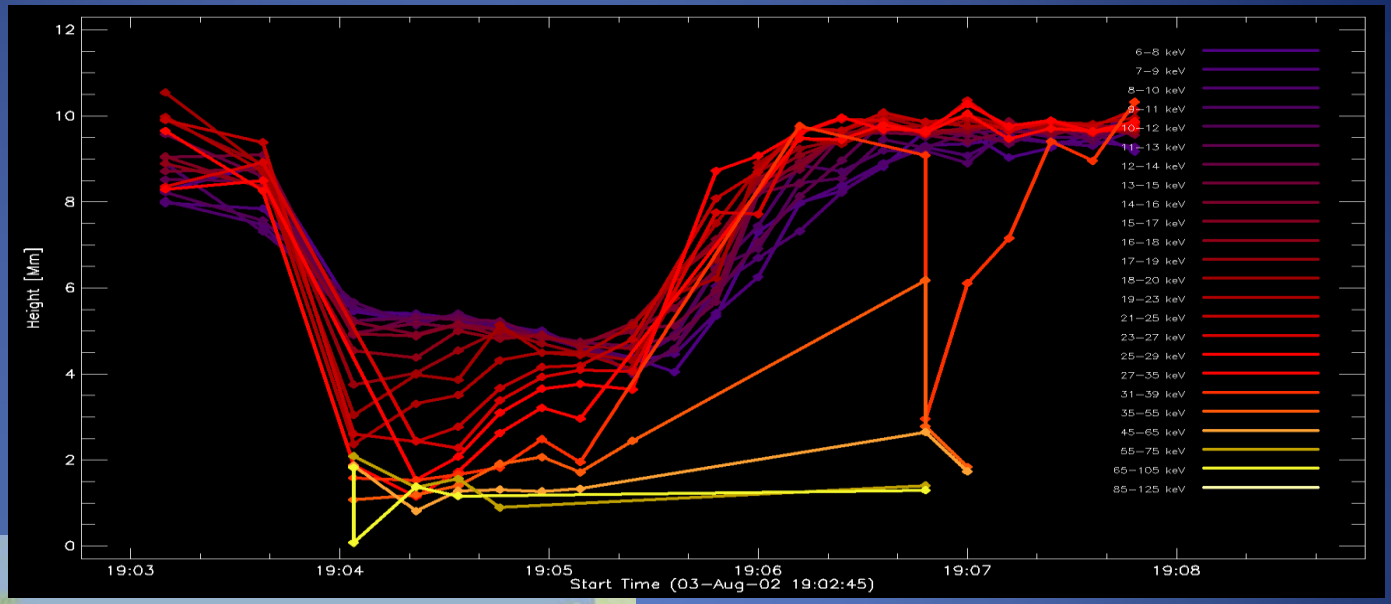


Hot footpoint (20 MK) was observed during impulsive phase

Treating electrons as a tool that probes chromospheric density we are able to calculate the mass evaporated during the chromospheric evaporation process.

HXR images have a huge potential for analysing the energy deposition by non-thermal electrons.

Epilogue


Height [Mm]
Start Time (03-Aug-02 19:02:45)
6-8 keV
7-9 keV
8-10 keV
9-11 keV
10-12 keV
11-13 keV
12-14 keV
13-15 keV
14-16 keV
15-17 keV
16-18 keV
17-19 keV
18-20 keV
19-23 keV
21-25 keV
23-27 keV
25-29 keV
27-35 keV
31-39 keV
35-55 keV
45-65 keV
55-75 keV
65-105 keV
85-125 keV


North Atlantic Ocean
Bay of Biscay
Portugal
España (Spain)
المغرب (Morocco)
الصحراء الغربية (Western Sahara)
موريتانيا (Mauritania)
Mali
Burkina Faso
Guinée (Guinea)
Ghana
Cuba
Puerto Rico
Caribbean Sea
Venezuela
Guyana
Suriname
Colombia
QC
NB
PE
NS
ME
VT
NH
MA
CT
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