RHESSI observation of extremely long persisting HXR sources – SphinX wanted immediately

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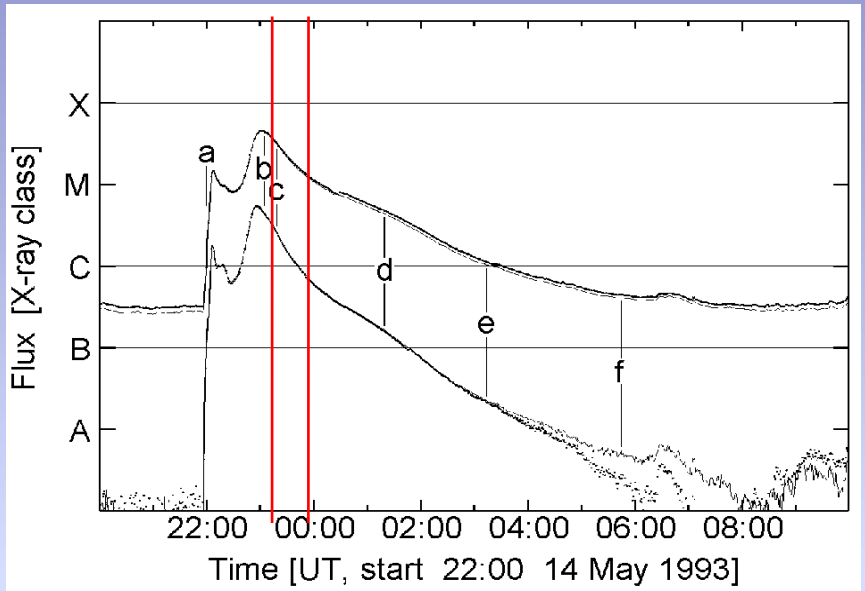
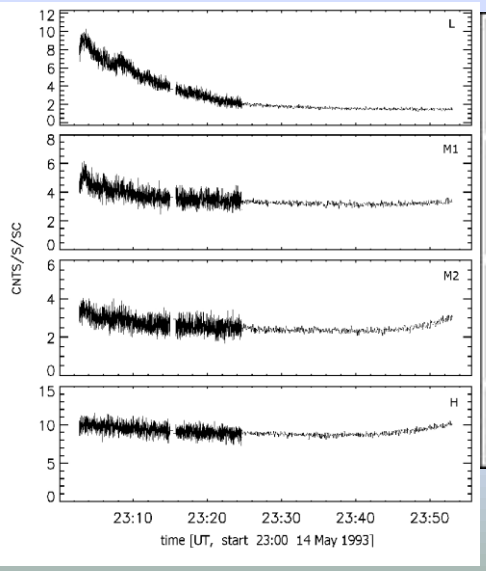
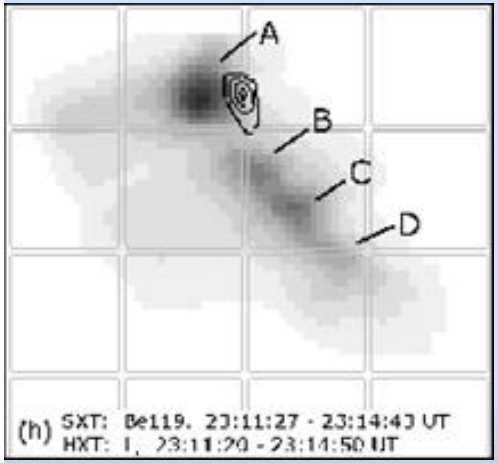
Long duration event (LDE)







Kołomański 2006

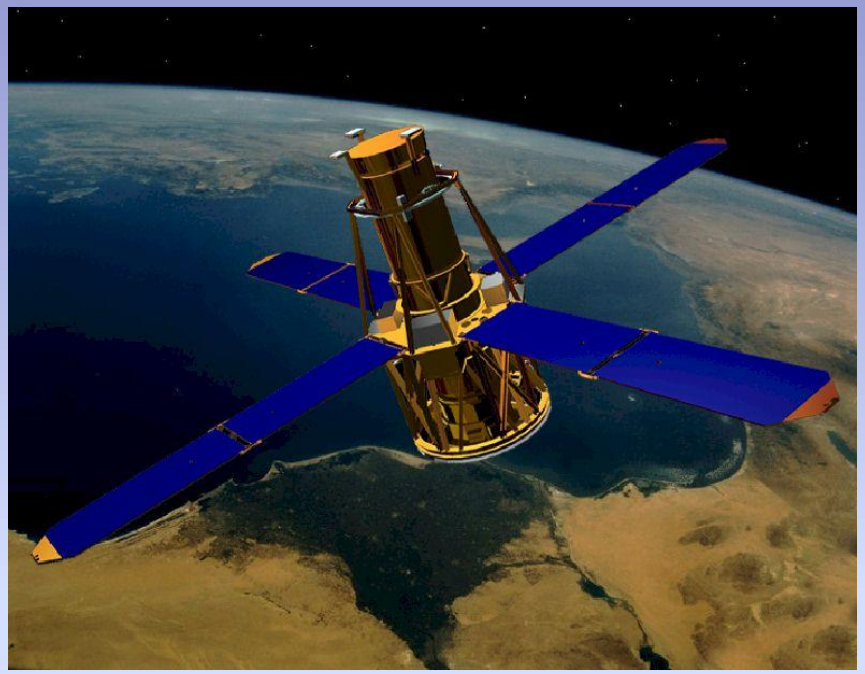
Soft X-ray

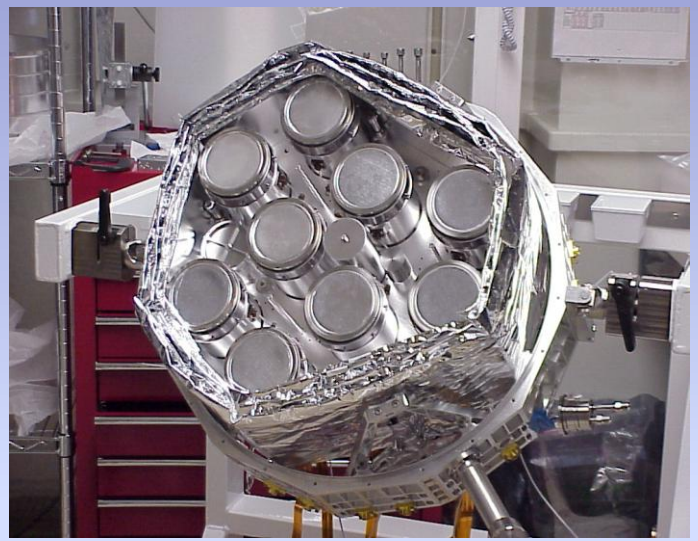
-decay phase lasts several hours
-well observed loop-top sources with sizes $1.0\text{-}1.5 \times 10^4$ km
-continuous energy release – energy balance, chromospheric evaporation

Hard X-ray

-observed up to 40 minutes after the maximum (light curves) – HXT L channel
-large (1 arc min) and expanding source visible near the loop-top SXR source
-unclear nature – thermal or non-thermal
-regardless of the nature, the existence of the HXR source long after the maximum demands the energy release process

RHESSI & LDEs - motivation



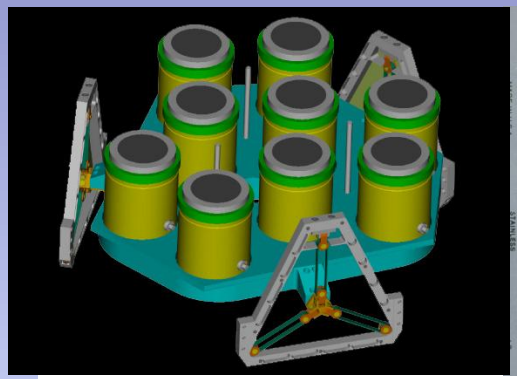


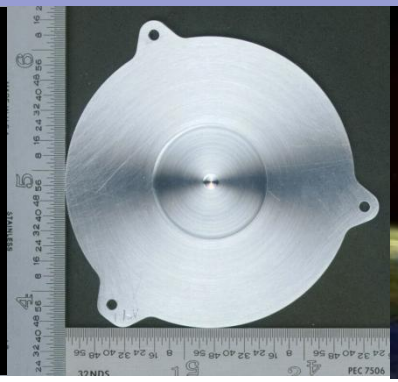
Better spatial resolution – more detailed investigation of sources

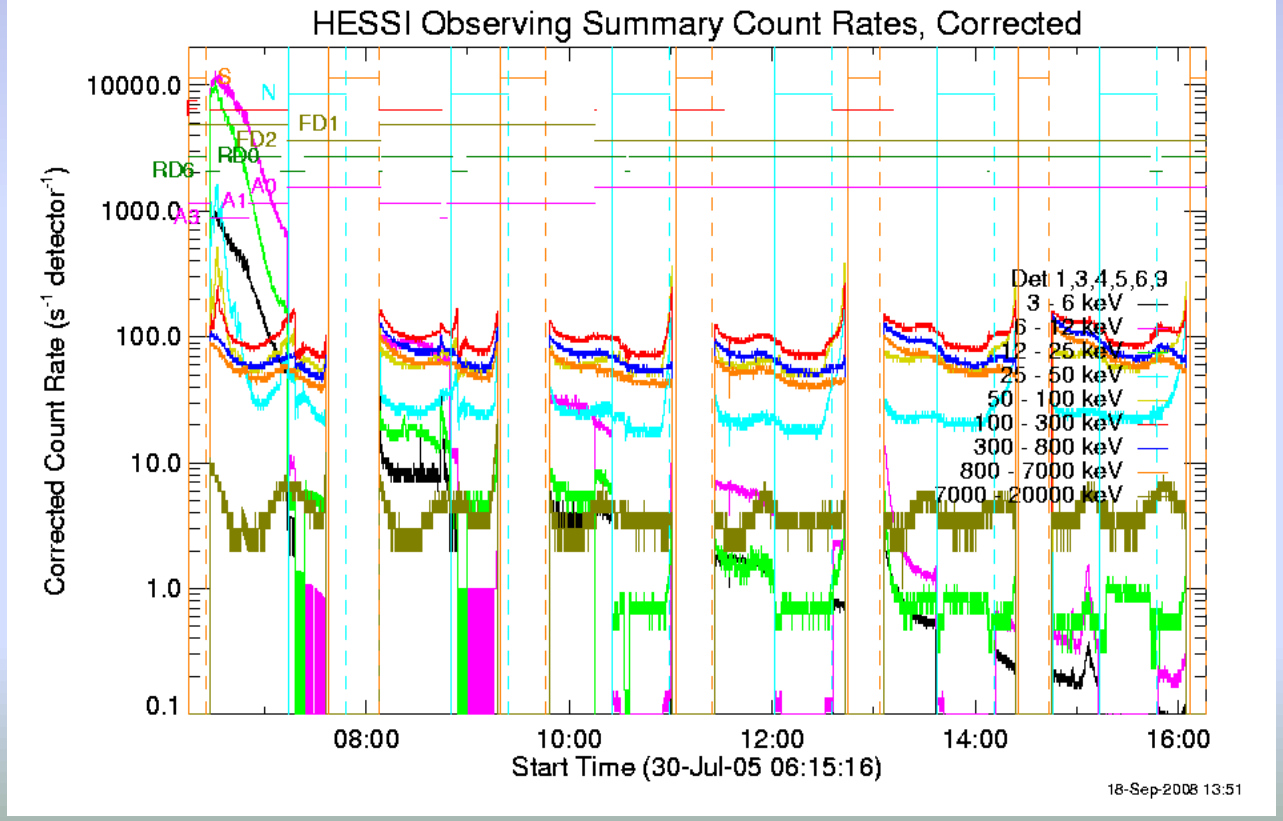
Better sensitivity - weak, coronal sources could be detected long after the maximum of the flare

Better energy resolution – more detailed analysis of LDEs spectra

Difficulties



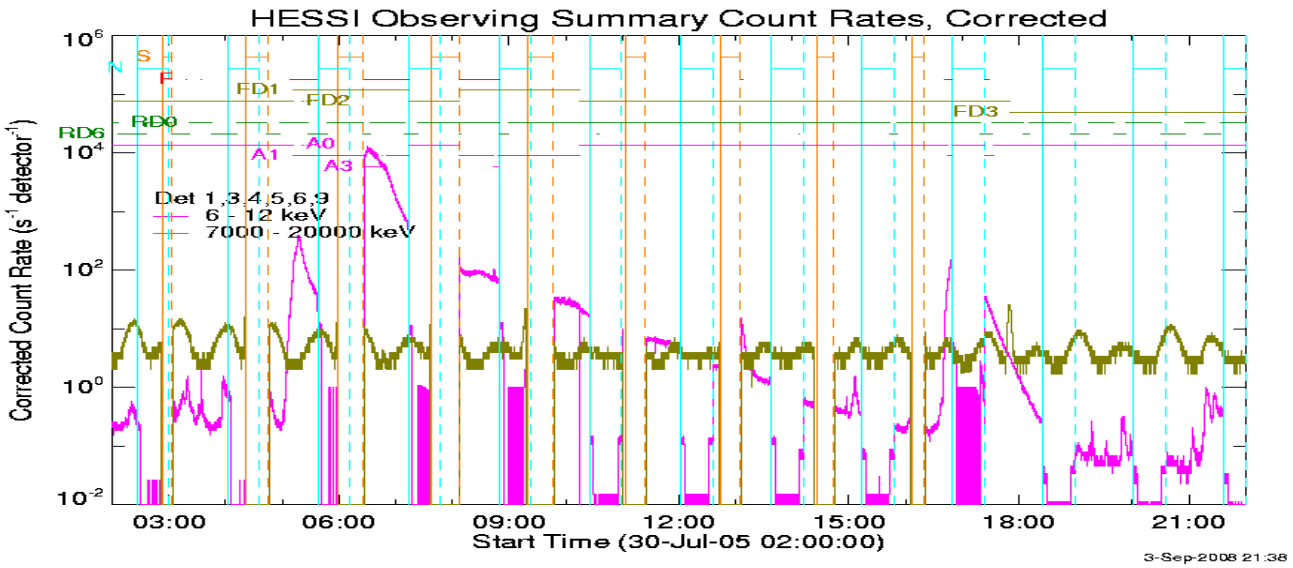


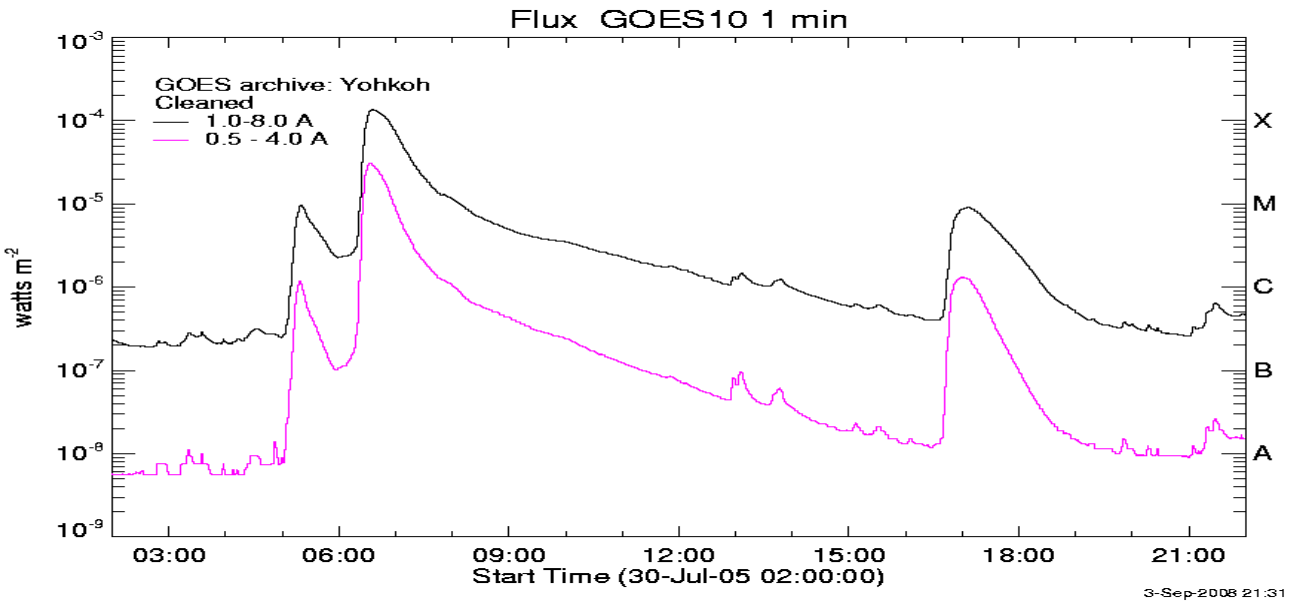


Main difficulties:

- **pile-up**
- **attenuators**
- **orbital background**

RHESSI & LDE





Feb. 2002 – Feb. 2008

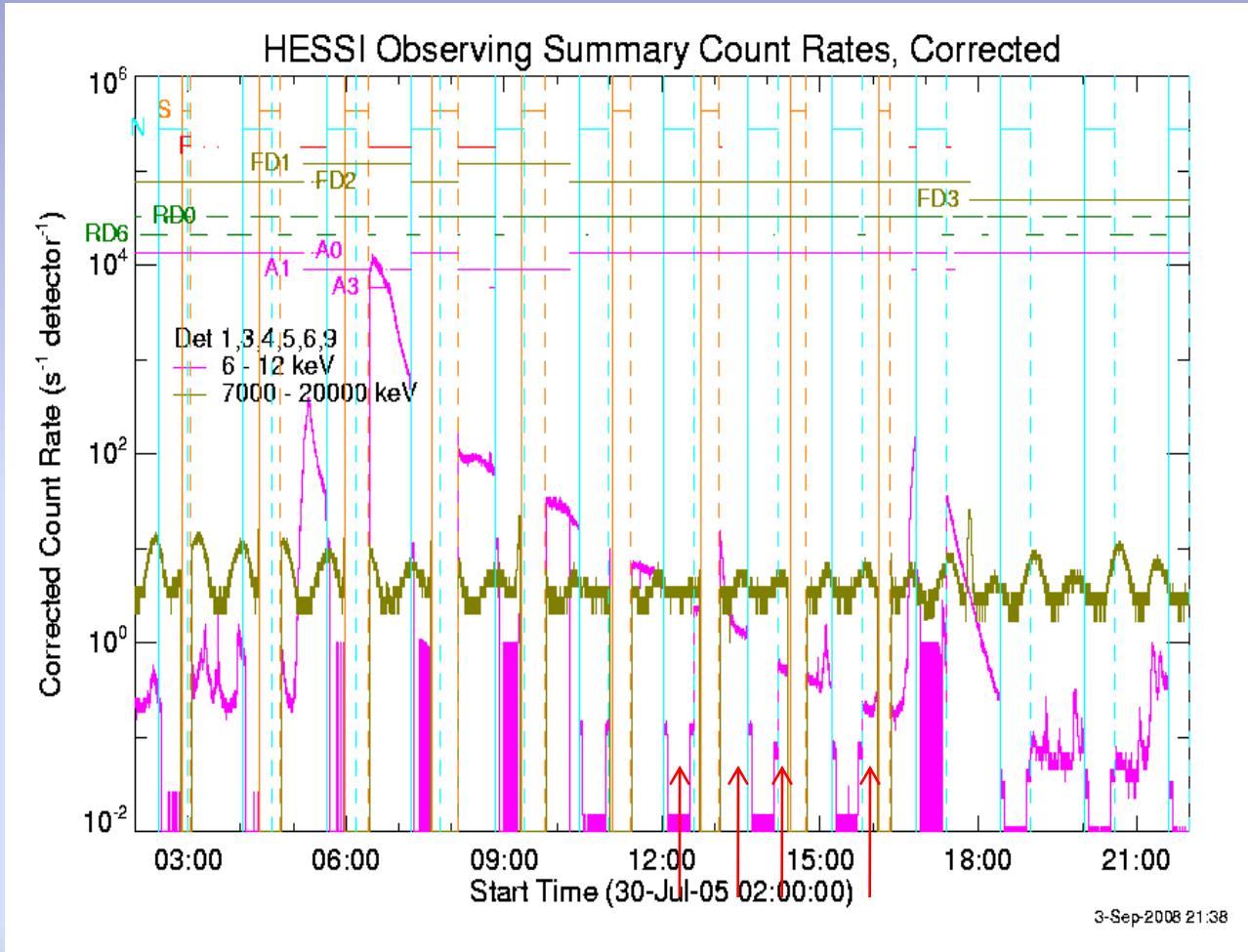
~ 160 LDE flares found with the use of GOES lightcurves

~ 50 which last longer than 3 hours in RHESSI observations (6-12 keV)

The example:

July 30th, 2005
X1.3
>10 h

Method



Several hours after the flare maximum the HXR signal is very weak:

- 2-minute intervals

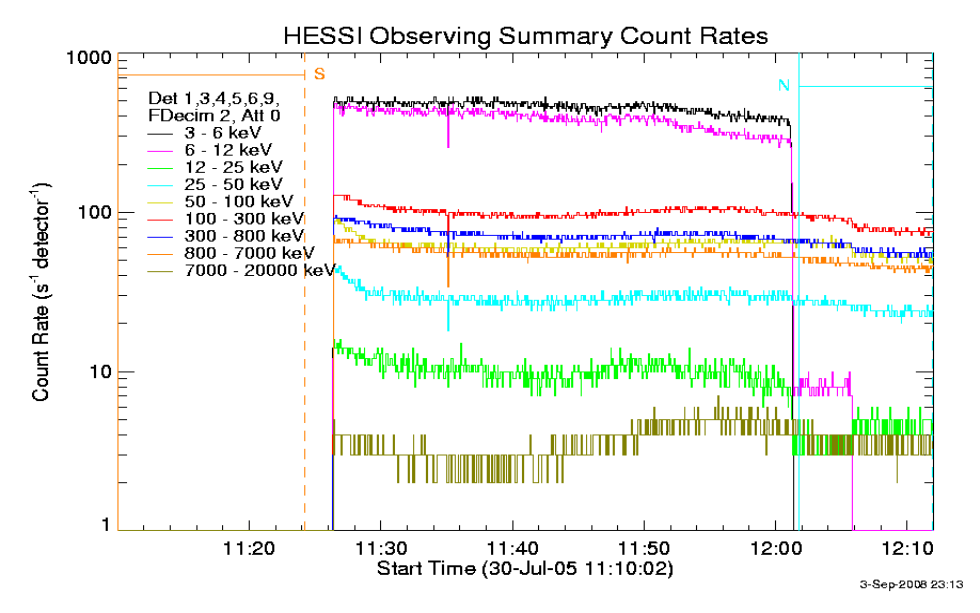
- attenuators out

- outside the radiation belts

- far from the SAA

Thus, for 10 hours decay we have only few time intervals for imaging and spectroscopy

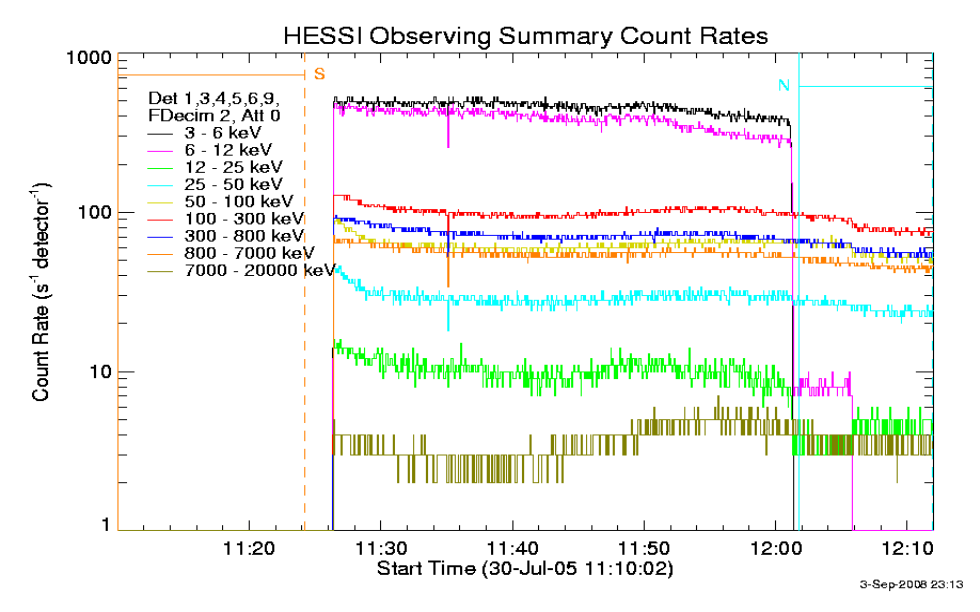
Method



Images:

Time interval: 11:38 – 11:40
Grids: 3,4,5,6,8,9
Pixel size: 1”

Method



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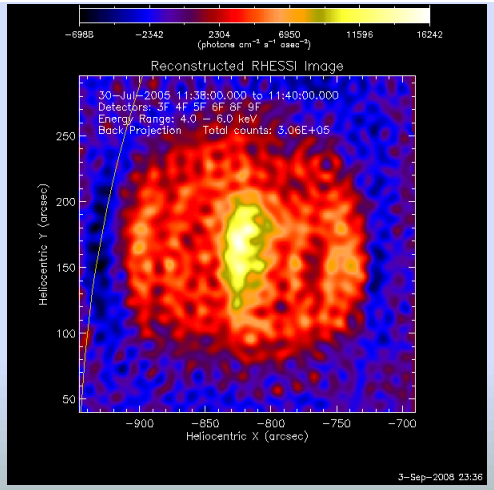
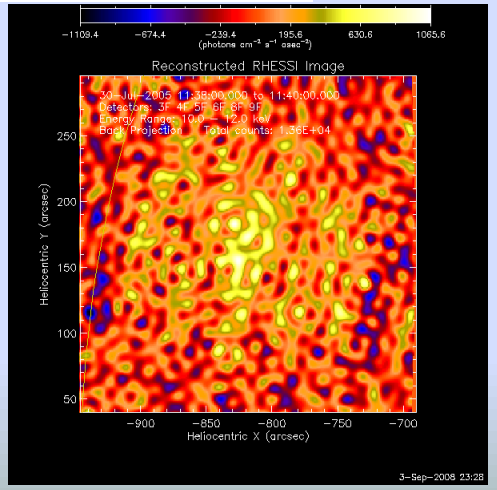
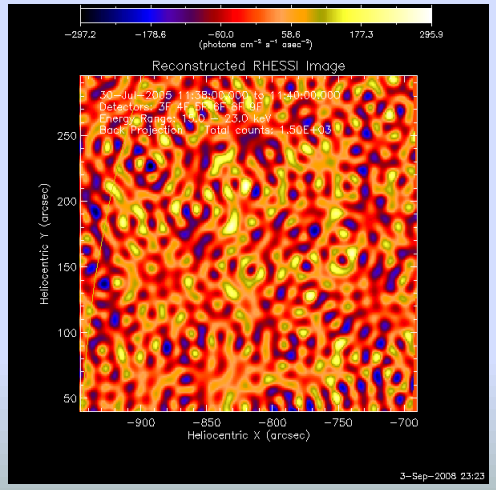


4-6 keV

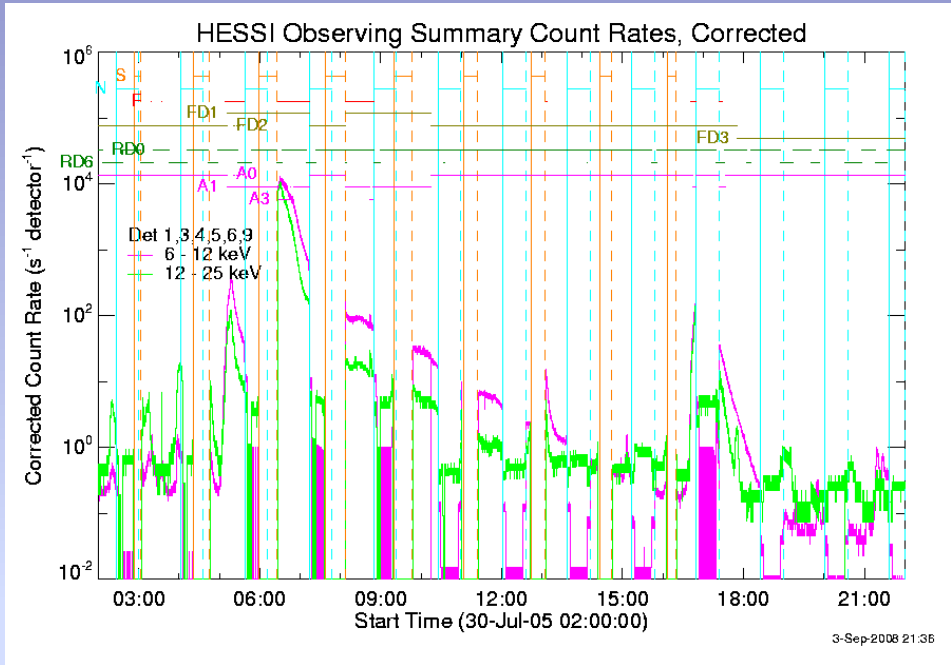


10-12 keV



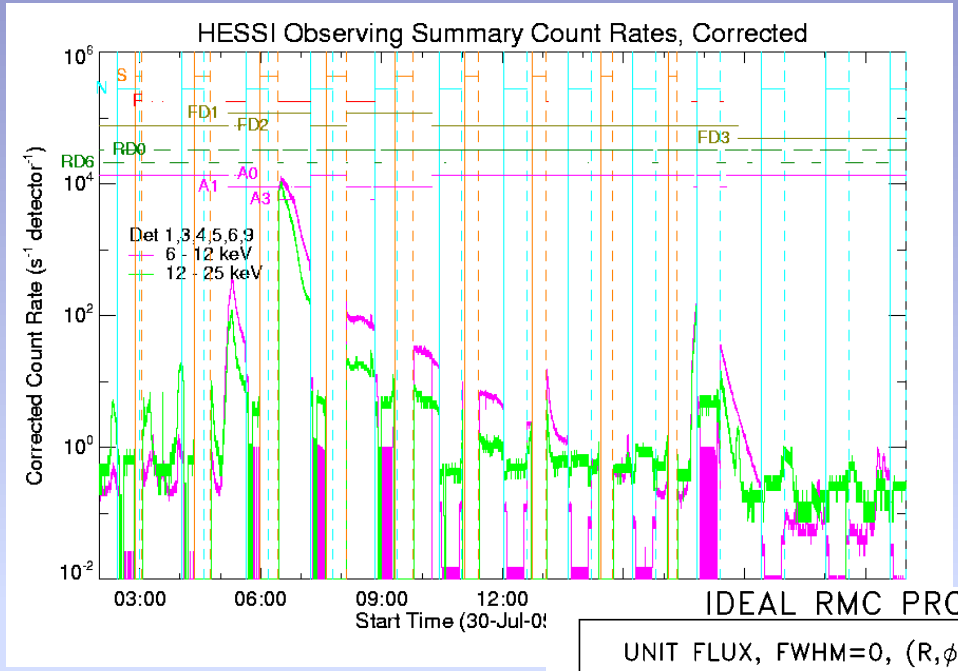
15-23 keV

Method



The signal in the 12-25 keV interval is observed (11:40 UT – 6 hours after the maximum) - why we can't obtain images?

Method



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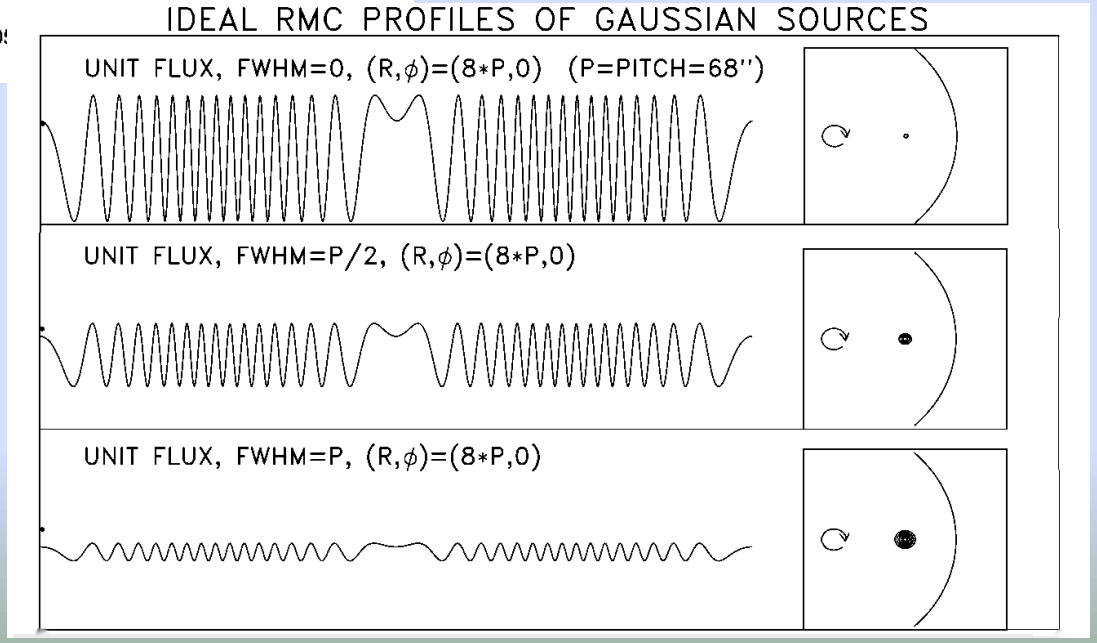
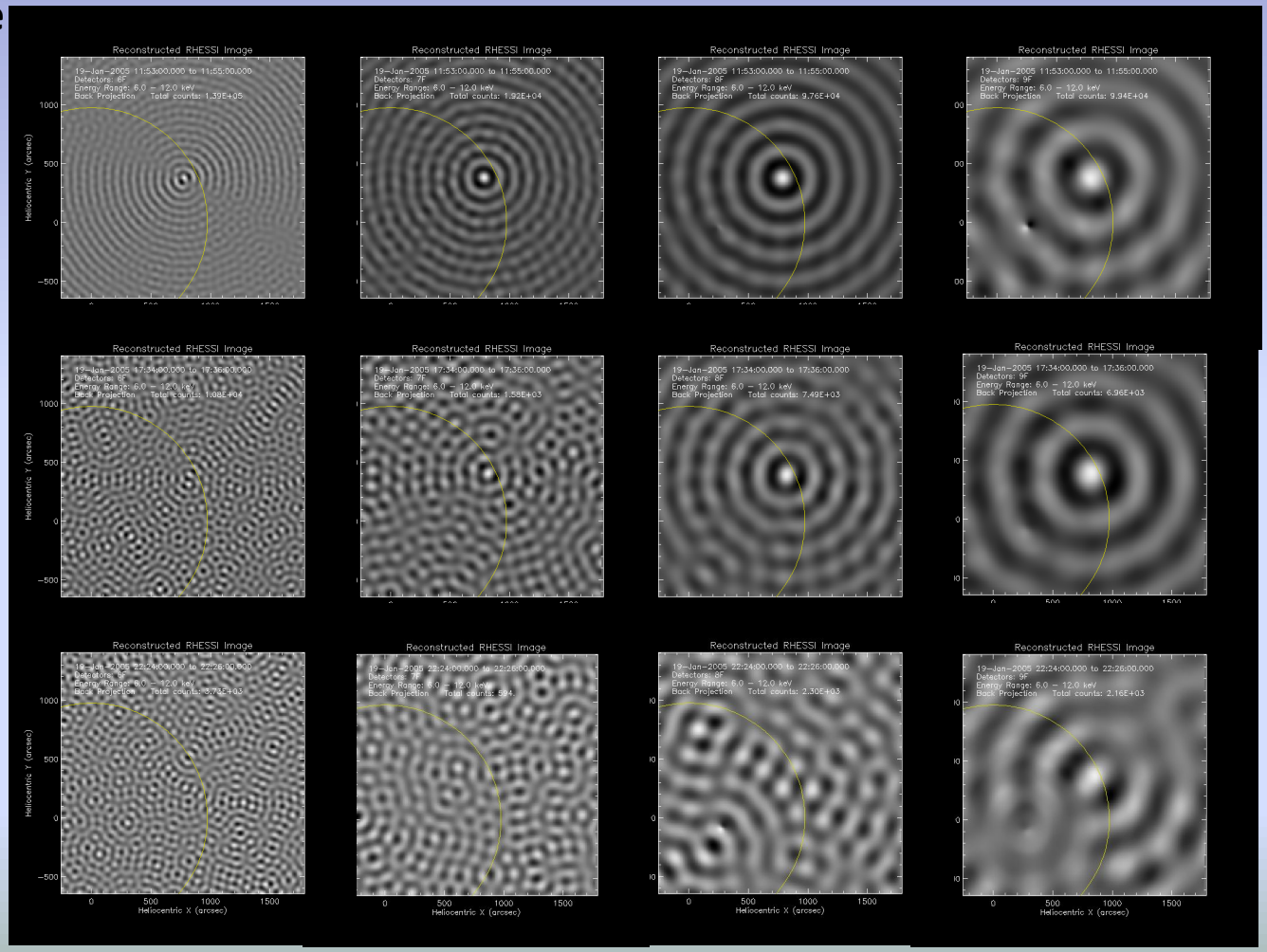


Because of the actual size of the source? – let's look at the single-detector images

Method

grid number

time

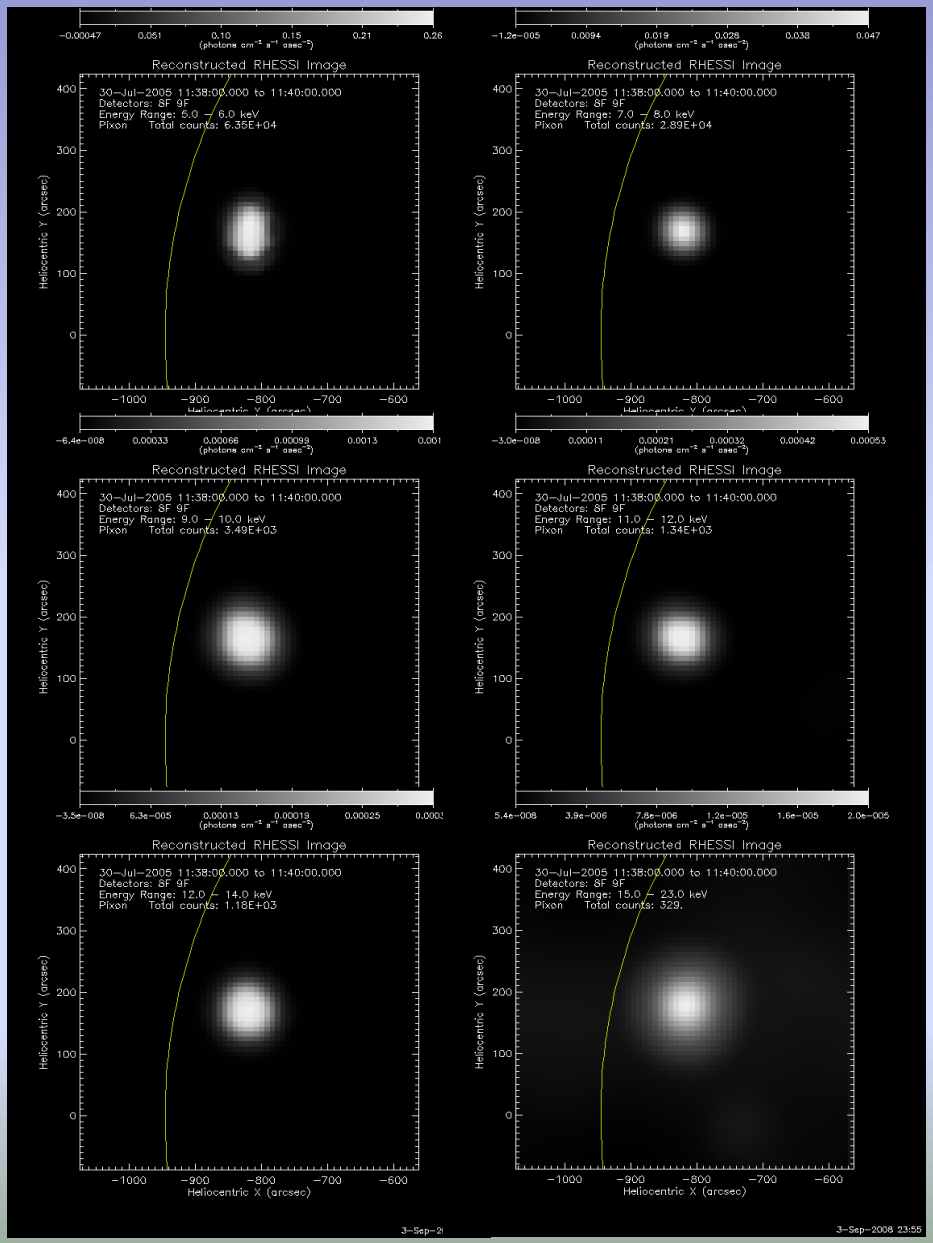


The size of sources changes

When the diameter of the source is larger than the FWHM of given grid then the modulation vanishes and the source is no longer observed with this grid.

For this reason we have to choose grids in more flexible way

Method

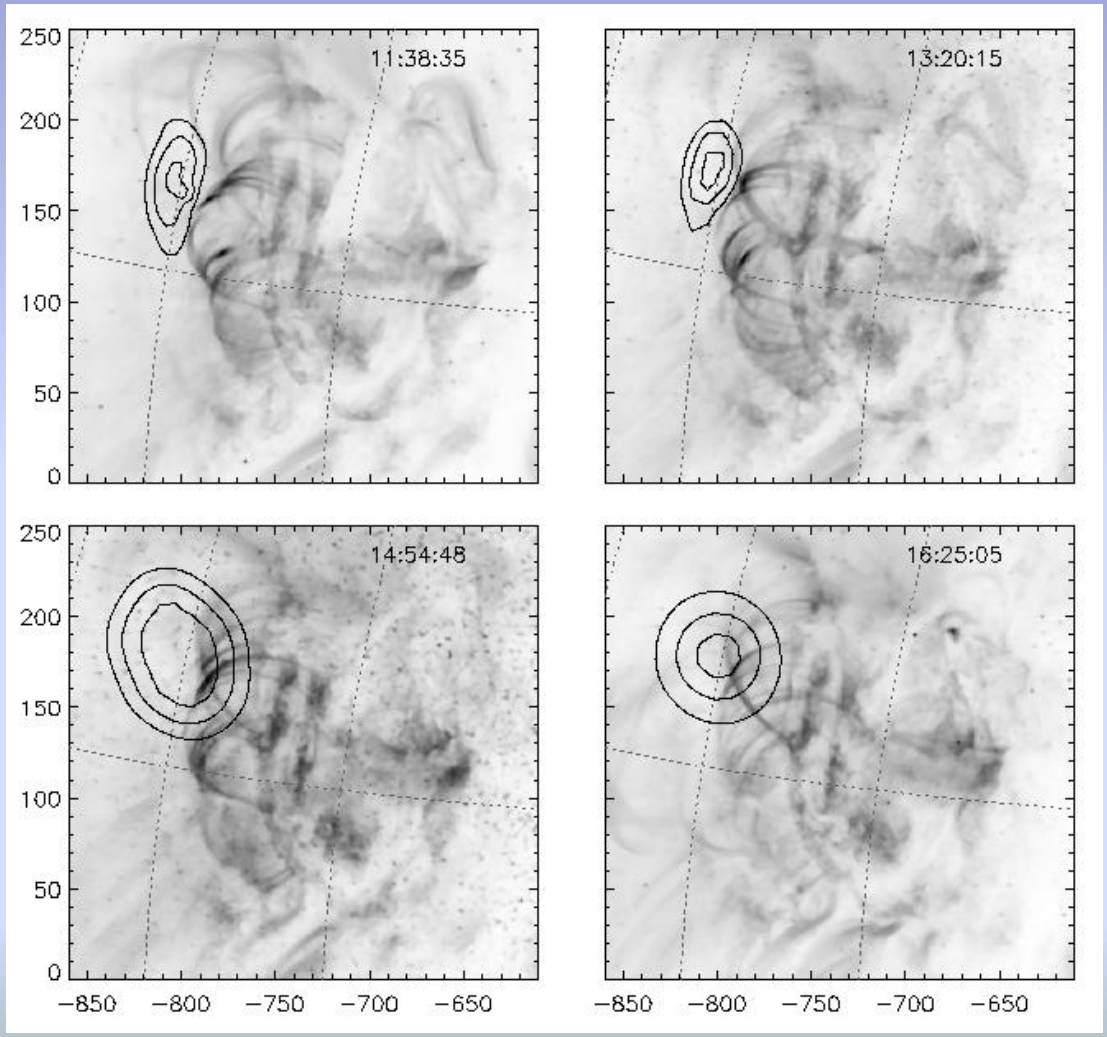


As the result we obtain well resolved sources.

Time interval:	**11:38 – 11:40**
Grids #:	**8,9**
Algorithm:	**PIXON**
Energy ranges [keV]:	**5-6, 7-8, 9-10, 11-12, 12-14, 15-23**

FWHM of the grid #7 is about 60 arc sec

30 July 2005 - images



Comparison with TRACE 171 Å

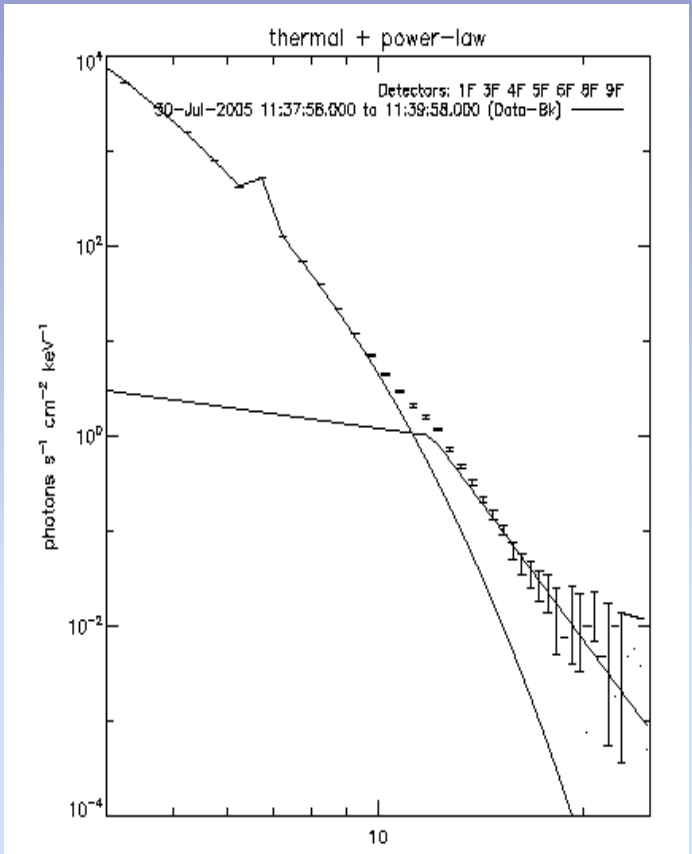
RHESSI images reconstructed with the use of PIXON method

6-7 keV

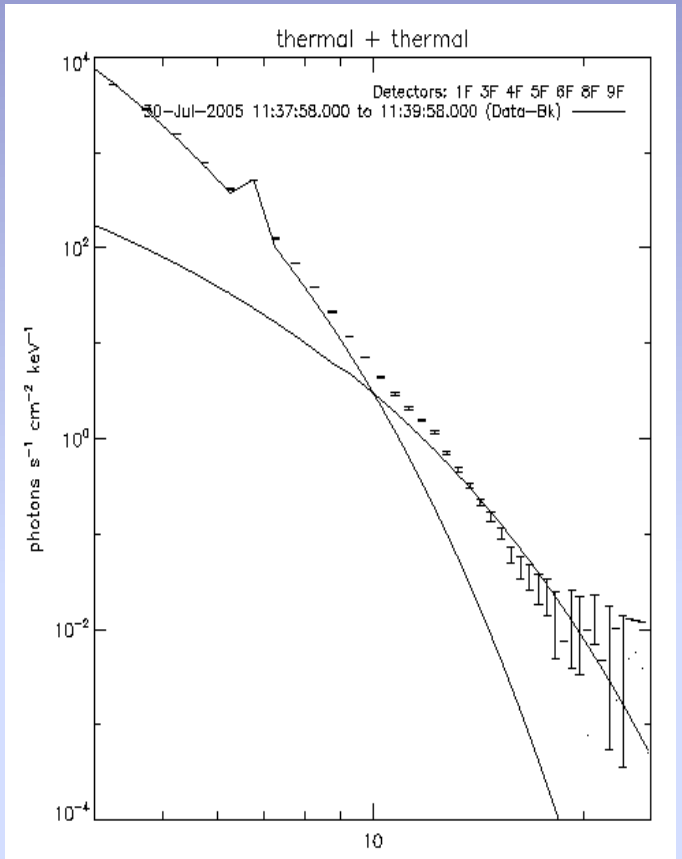
All sources (for a given time, different energy) are located in the same region

What is the nature of this source?

30 July 2005 - spectra



11:39 UT



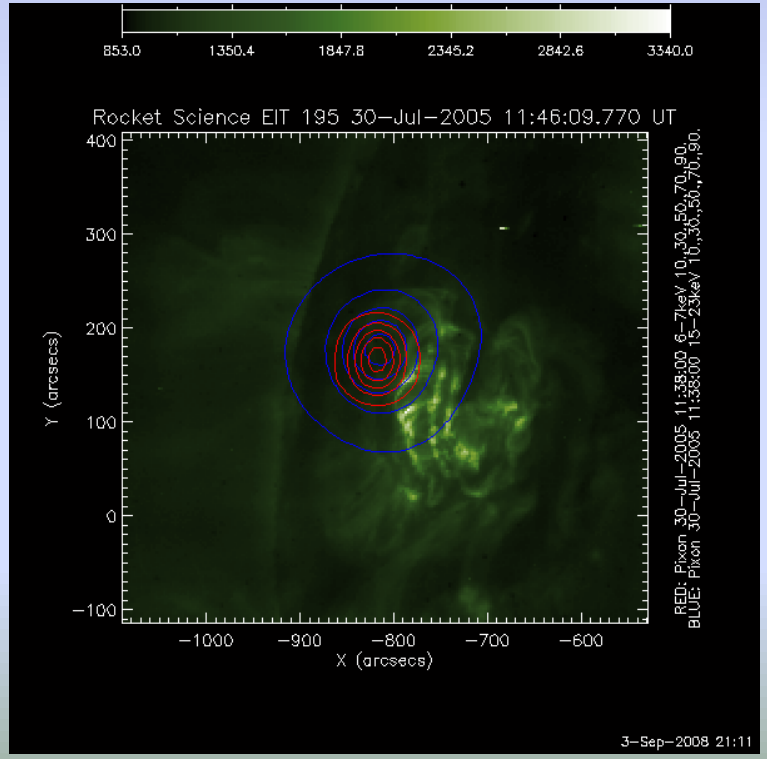
EM: 5.2x10^{47}cm^{-3}, T: 10.3 MK
E_B: 12.0 keV, γ_{AB}: 10.0

EM: 9.3x10^{47}cm^{-3}, T: 9.3 MK
EM: 6.4x10^{45}cm^{-3}, T: 20 MK

Even with the capabilities of RHESSI we are not able to determine the nature of the emission above 10 keV

30 July 2005

	11:39	13:20	14:54	16:25
H [Mm]	74.4	85.8	87.0	88.7
T [MK]	10.3	8.9	8.1	7.4
EM [10^{47} cm^{-3}]	5.2	4.4	1.9	1.4
E_H [erg cm^{-3} s^{-1}]	0.0 – 0.36	0.0 – 0.13	0.0 – 0.027	0.0 – 0.018



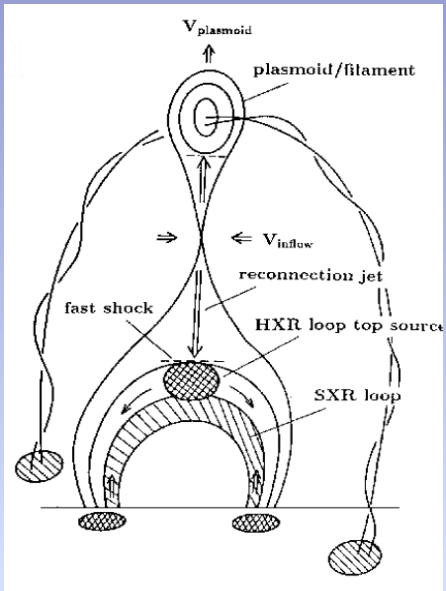
Typical size of the long persisting HXR source is of the order of 10^4 km

It rised with the speed less than 1 km s^{-1}

To balance the thermal and conductive losses we need a heating rate of the order of 0.1 erg $s^{-1}cm^{-3}$ (10^{27} erg s^{-1} from the whole volume)

The energy release lasting for 6-10 hours is a great challenge for existing flare models

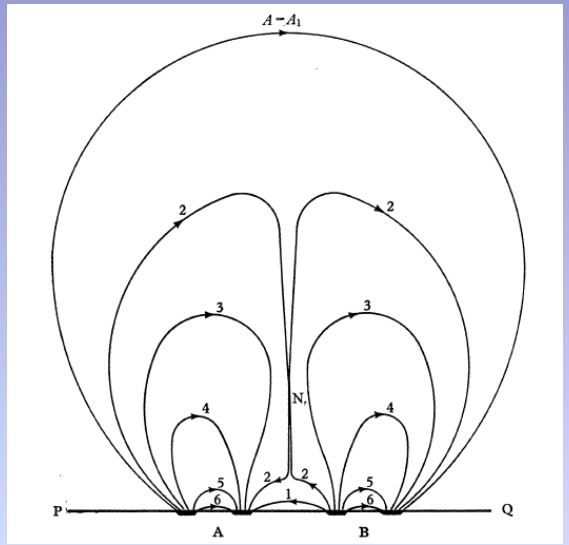
Models, models…



Shibata 1995

The main driver of the whole process is the eruption of the filament

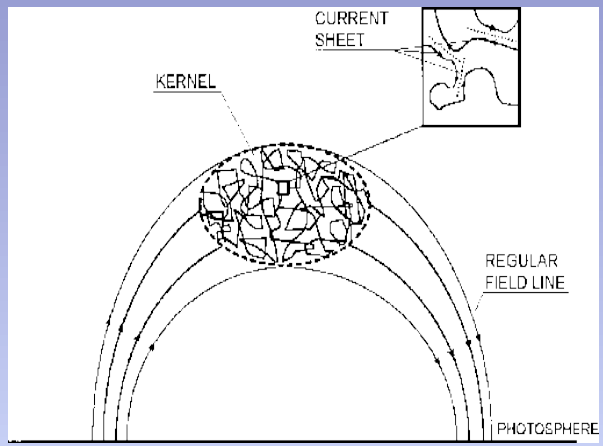
The several hours long energy release cannot be explained with this scenario.



Sweet, P. A. 1958

Emergence of the new flux is the main driver in this model.

This idea was recently resurrected by Uchida et al. (1999) and Hirose et al. (2001)



Jakimiec, J., et al. 1998

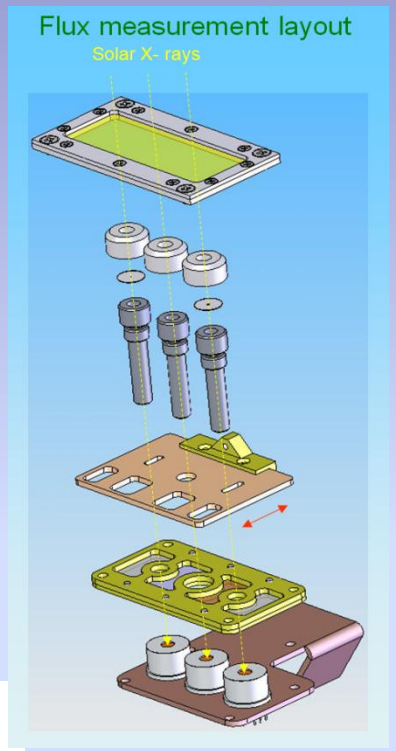
The existence of the turbulent (highly tangled) magnetic field in the loop-top source could keep up the energy release for long time due to small reconnections inside the structure.

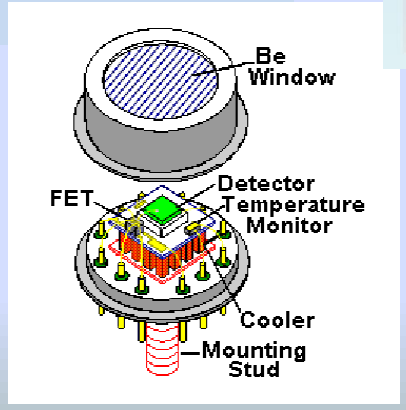
It explains the spatial correlation between the thermal and non-thermal/hot sources observed in the late phase of LDEs

SphinX – the next step

Spectral range: 0.5-15 keV (20-0.8 Å) in 256 channels
Spectral resolution: 250-290 eV
Time resolution: nominal 1 sec for quiet Sun conditions, down to 0.01s in flares.
Photon arrival time measured to 1 μs accuracy (in Time Stamping Mode)

Detectors (four units):
Amptek, Peltier cooled Si PIN diodes.
Detectors' support plate thermally connected to external heat radiator via heat sink pipe.





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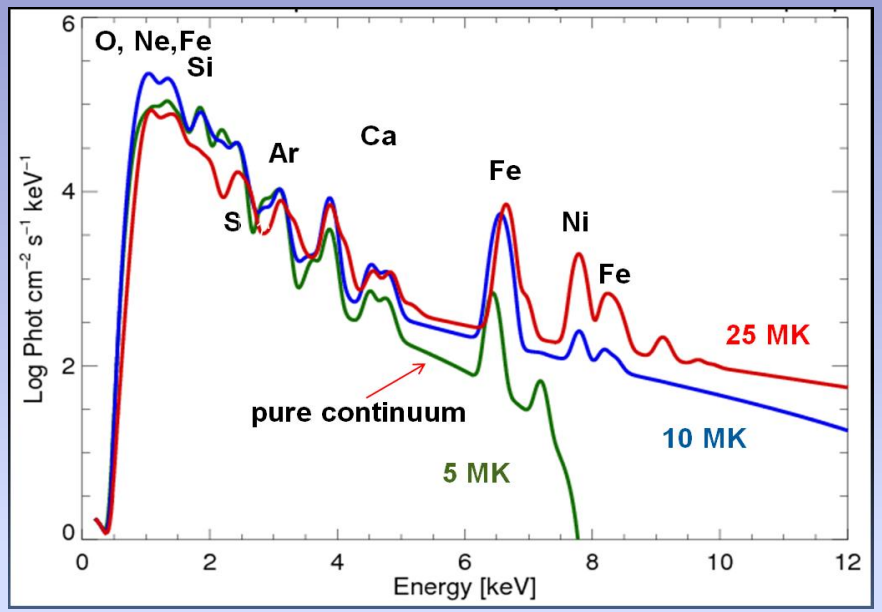
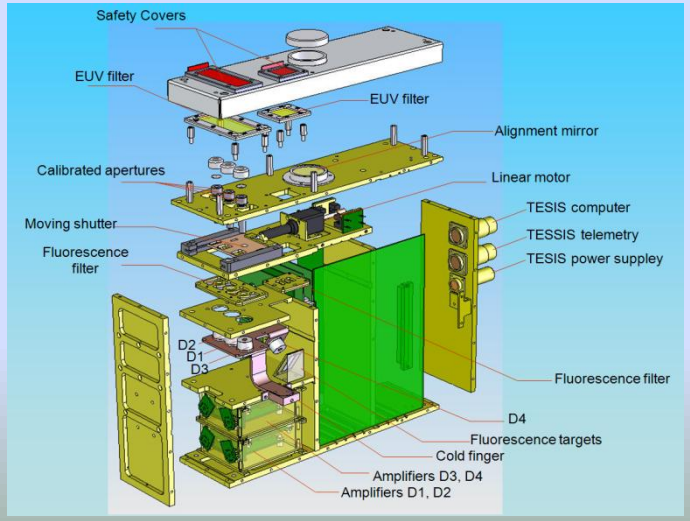


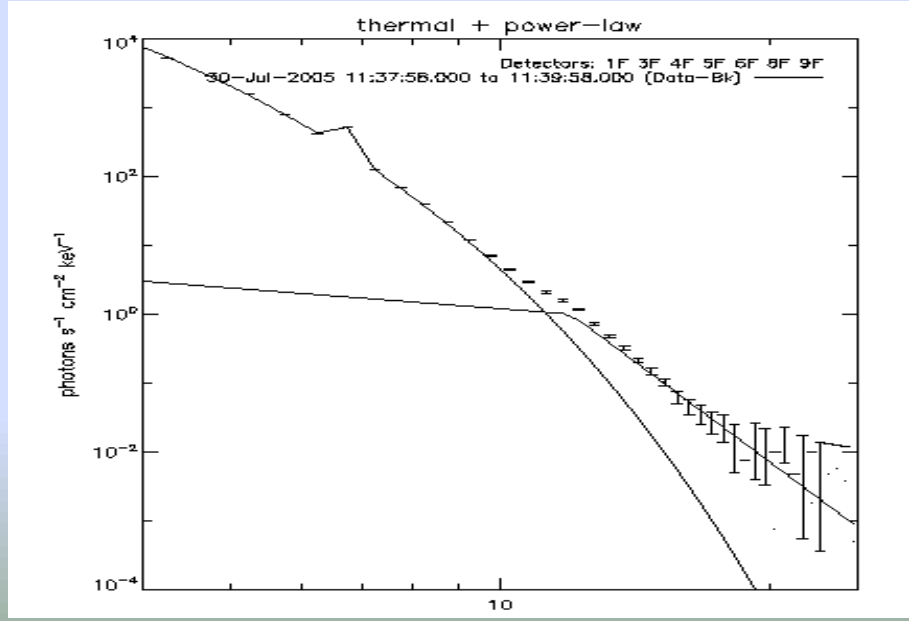
The energy range – exactly what we need

Energy resolution – about 3 times better

Time resolution – possible investigation of elementary energy release episodes during the decay phase

Well resolved details in this range – more precise analysis of the nature of LDE sources





Conclusions

LDEs are well observed by RHESSI. The analysis is complicated due to attenuators, radiation belts, SAA, but not impossible.

HXR sources (above 10 keV) are visible even 6 hours after the maximum of the flare.

Long-lasting HXR sources are located above structures observed in the EUV range. Observed sources are large and grow with time.

The spectral analysis of the sources suggests that at least two components are observed. One is the hot (about 10 MK) and the second is a very hot (20 MK) or steep non-thermal component – SphinX will give an answer.

The observed features imply the existence of the energy release process which lasts several hours – the challenge for flare models.