# *RHESSI and SphinX Common Observations of Solar Flares*

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# *Introduction*

In solar physics we do not have photometric standards – flares are transient events and there is no two the same flares.

The observations of one event made with different instruments is extremely important if only possible.

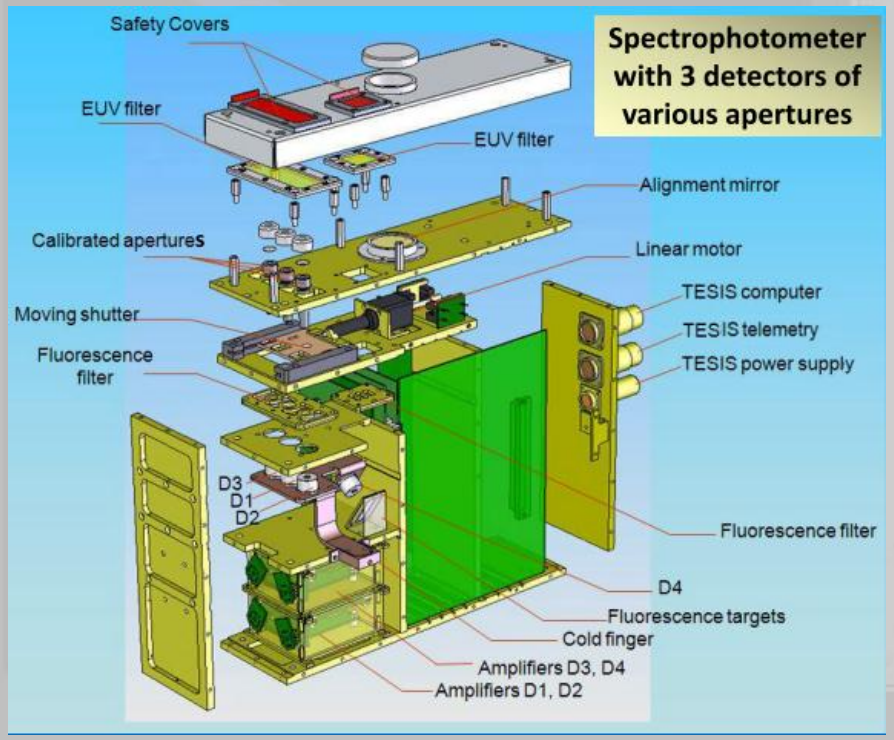
In 2009 we had three instruments that observed the Sun in similar energy band: SphinX, RHESSI and GOES.

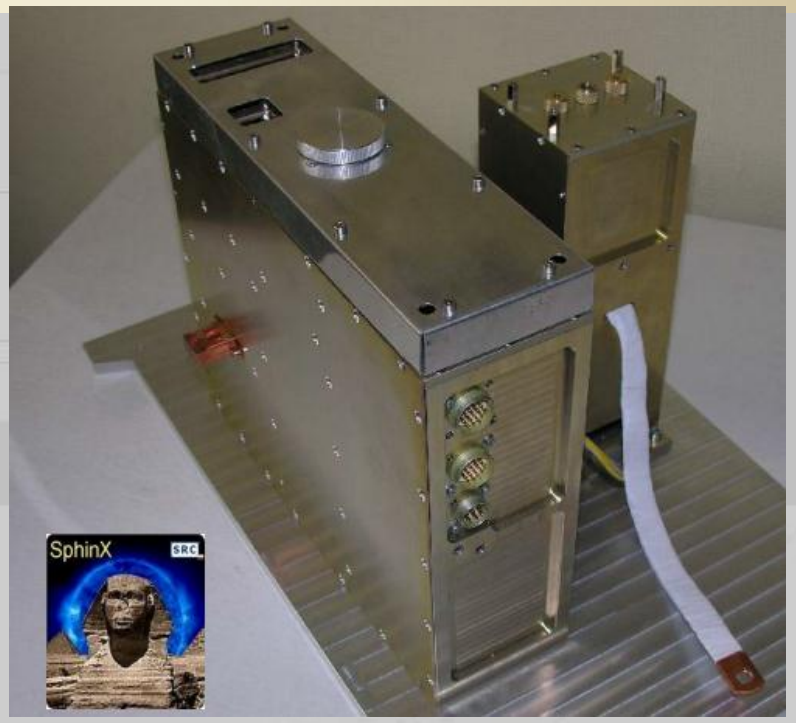
**Aim: to compare data obtained by two (three) different instruments**

# Solar Photometer in X-rays (SphinX)

**Goal: to measure the X-ray emission of the Sun in the ~1.2 – 15 keV band**

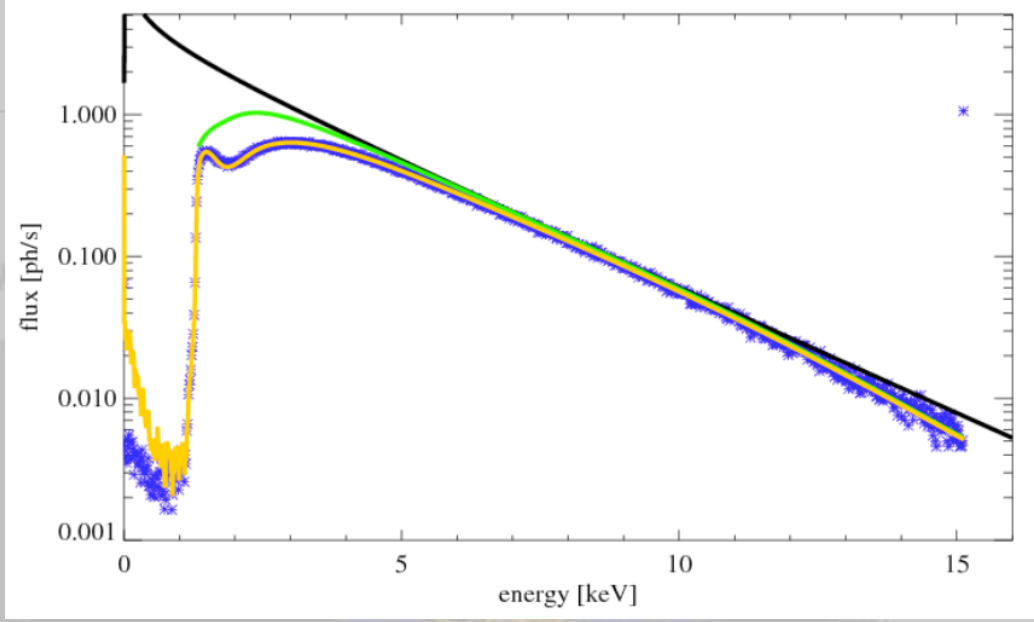
**Method: energy and arrival time are measured for each photon**




- **energy range: 1.2 – 15 keV**
- **time resolution: ~0.00001 s**
- **sensitivity: 100x better than GOES XRM**
- **energy resolution: ~0.4 keV**

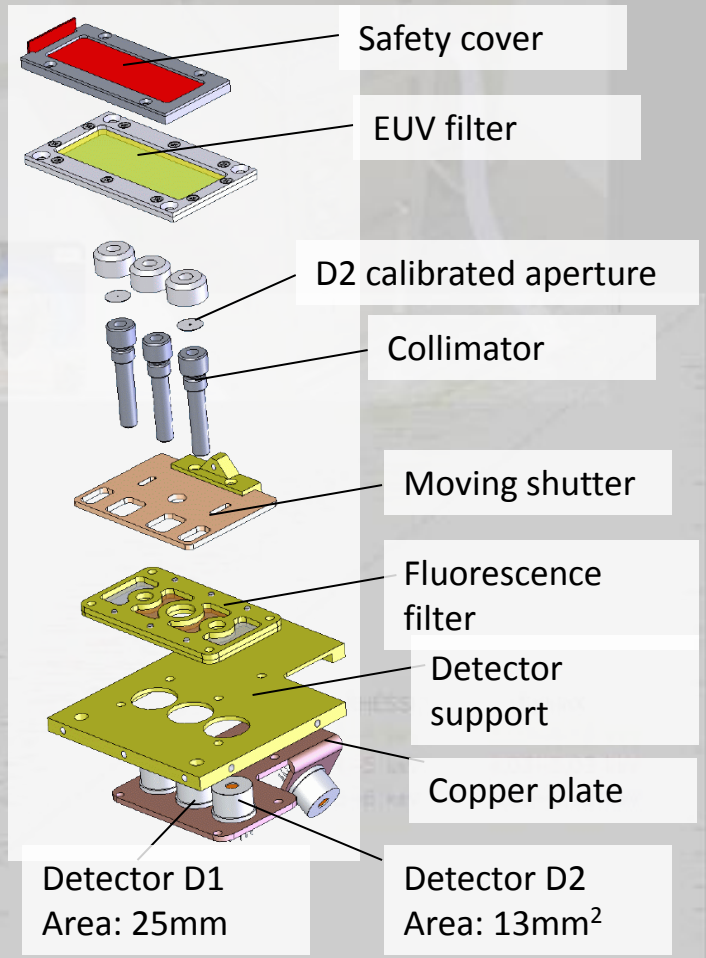
# SphinX - Polish concept, design & manufacture



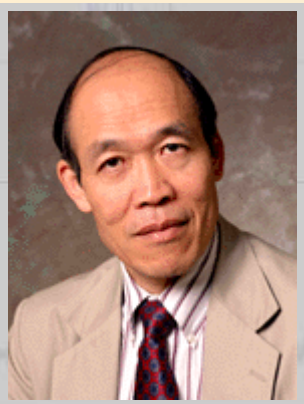

**black – the BESSY synchrotron input spectrum**
**blue – overplotted response of SphinX D1 detector (300 spectra)**
**green – nominal effective areas**
**yellow – the optimum theory model**

**The agreement is better than 5% in the energy band where SphinX detectors are the most sensitive.**

## SphinX optical entrance



# *RHESSI (Ramaty High Energy Solar Spectroscopic Imager)*



**1942 - 2012**

**- launched: February 2002**

**- 9 large germanium detectors**

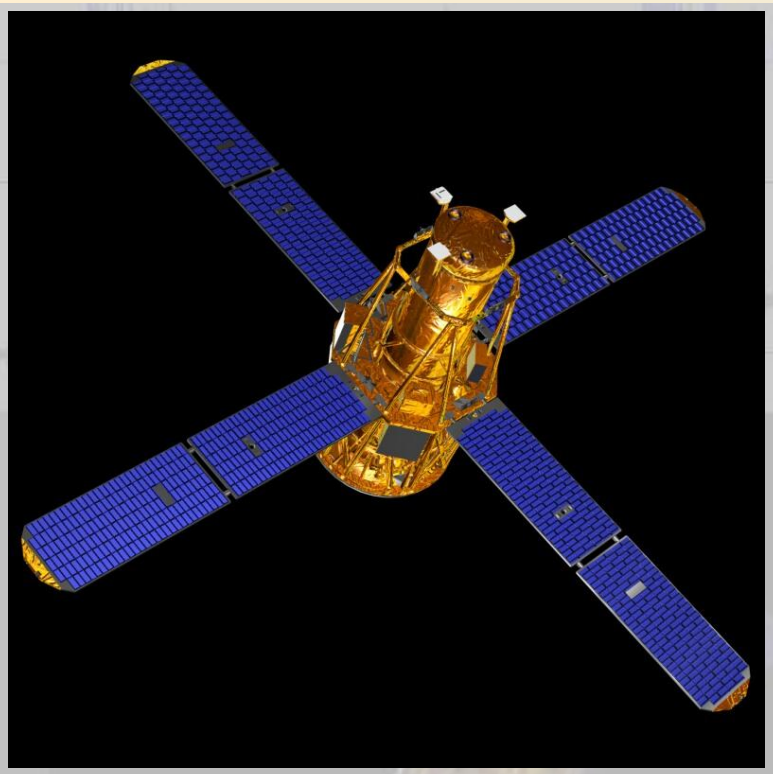
**- observations in the 3 keV – 20 Mev energy range**

**- energy resolution 1 keV - 5keV**

**- time resolution is related to rotation period ~4 s (images), time resolution of lightcurves may be improved by some demodulation methods**

**- lower sensitivity (2009) in comparison to first year (2002) due to radiation damage, but still is able to observe even smallest flares** (at present the sensitivity is better thanks to annealing performed in March 2010)

# *Motivation*



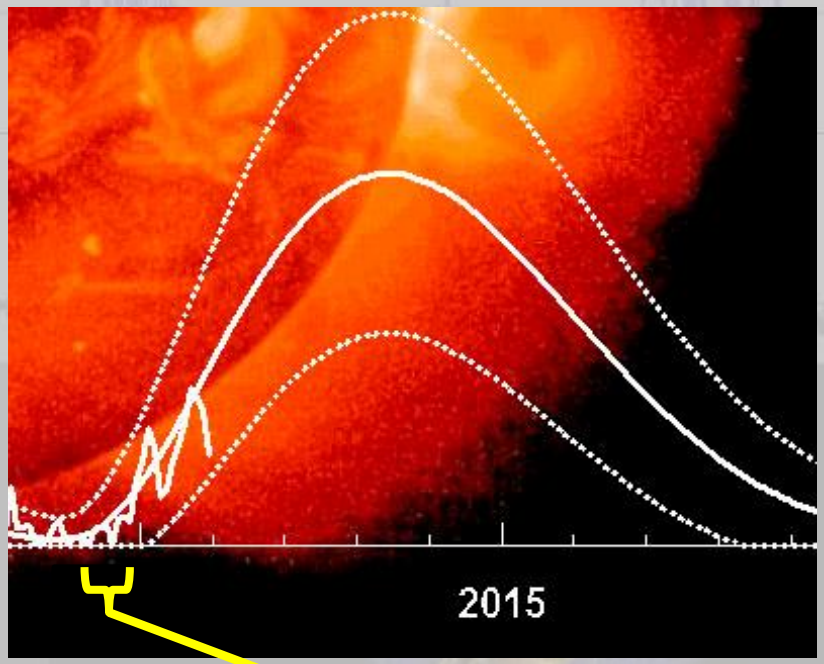

**Motivation:**

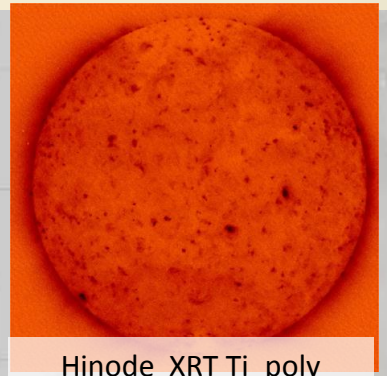
**- observations overlap in the energy range 3-15 keV**

**- SphinX is absolutely calibrated, RHESSI is well explored due to 10 years of observations**

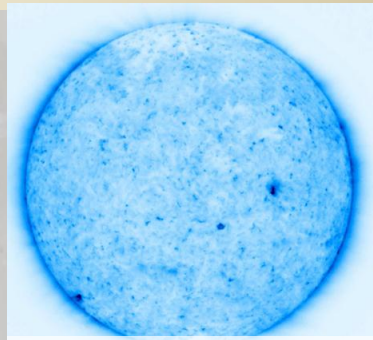
**- possibility for extending spectral fits to energy of the order of 1 keV – improvement of spectral fits in the lowest energies observed by RHESSI**

# *Observational period*



Hinode XRT Ti_poly
2009 Sept. 15 15:47:31

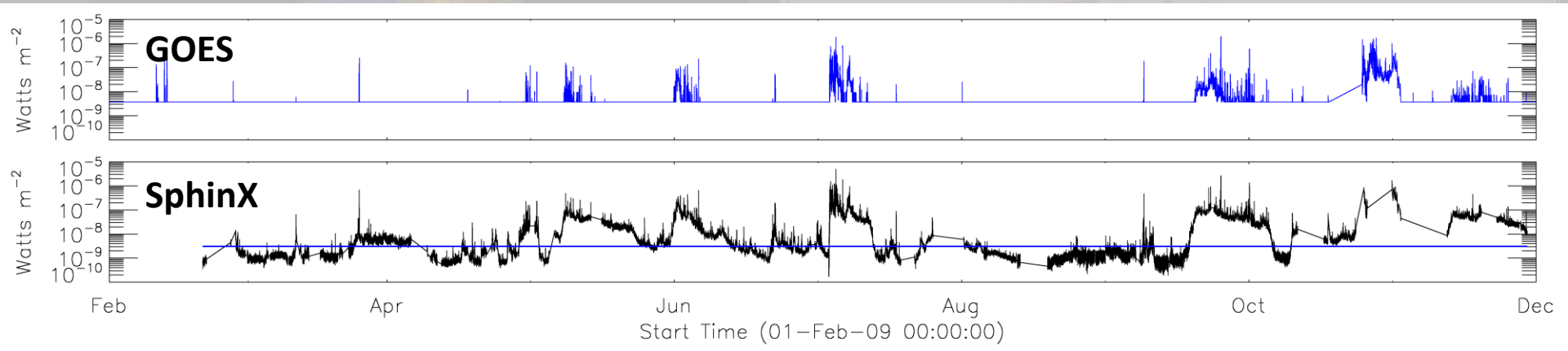


TESIS 171 Å 2009 Sept.
15 16:24:27 UT

- **extremely low activity**

- **mainly A,B – class flares, few C-class**

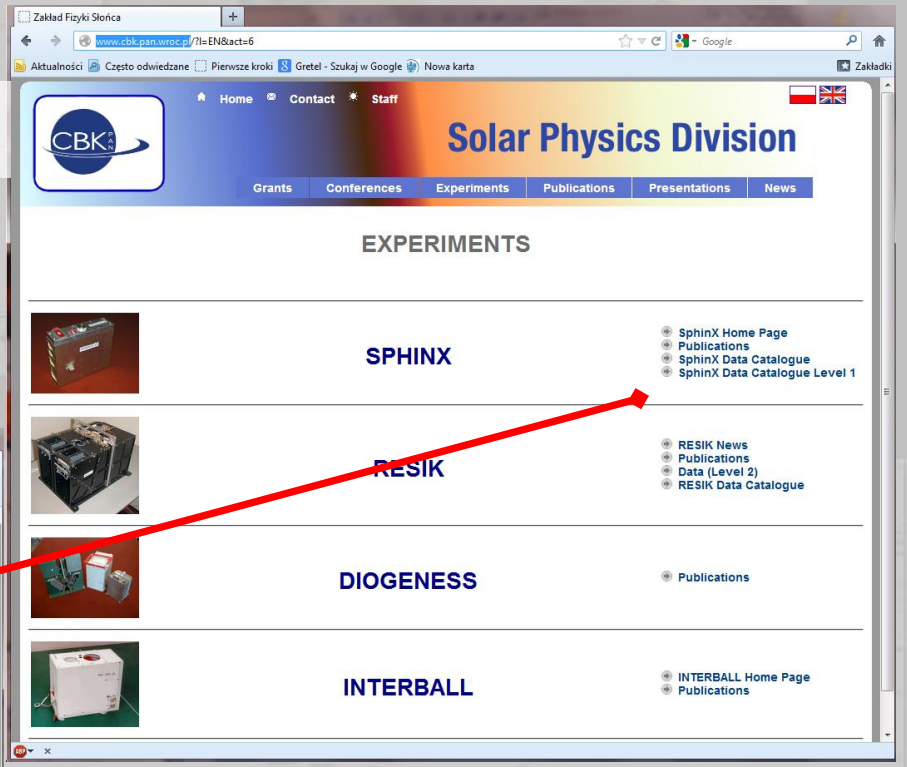
- **decreased sensitivity of RHESSI detectors due to radiation damage, but even smallest A-class events are clearly seen in data**

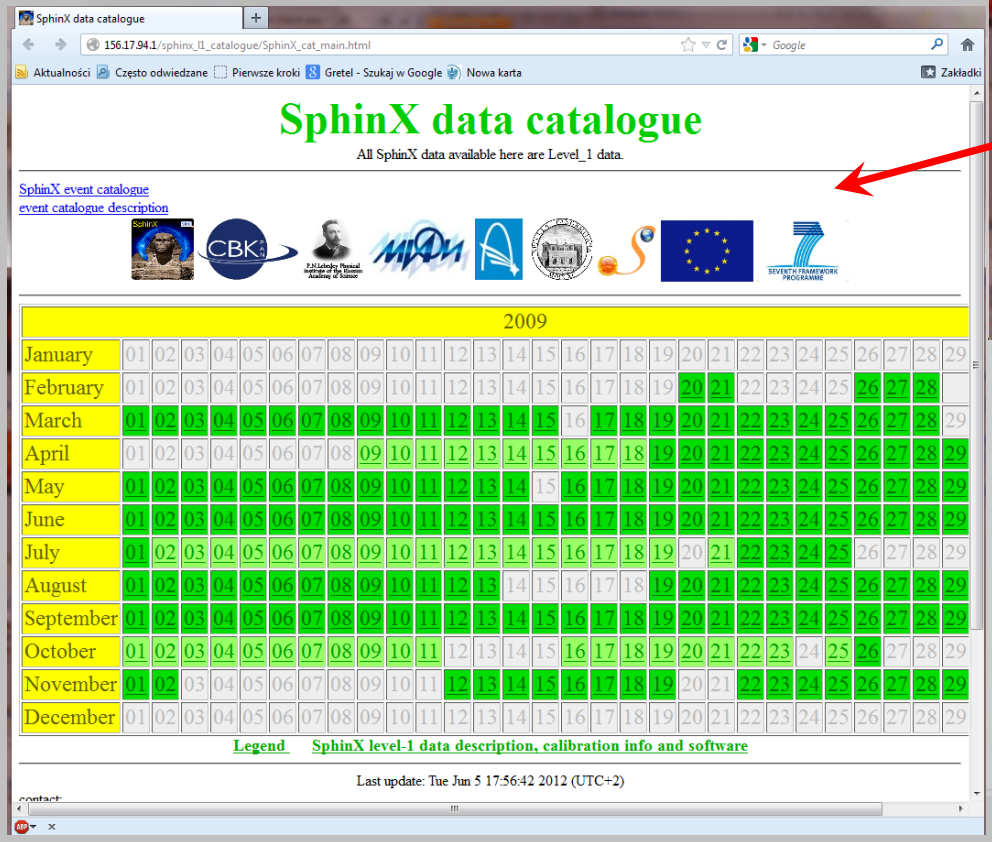


# *Flares selection*

## SphinX data access is public

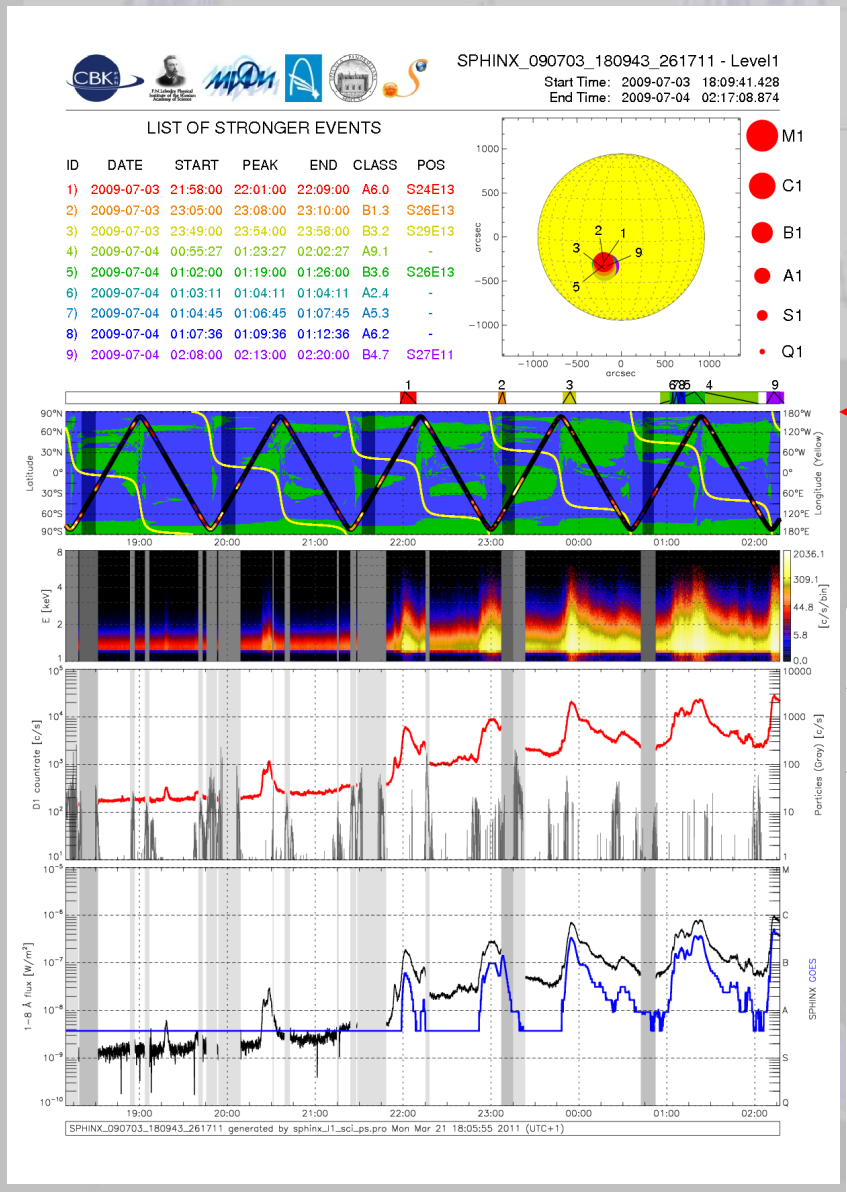
**www.cbk.pan.wroc.pl**

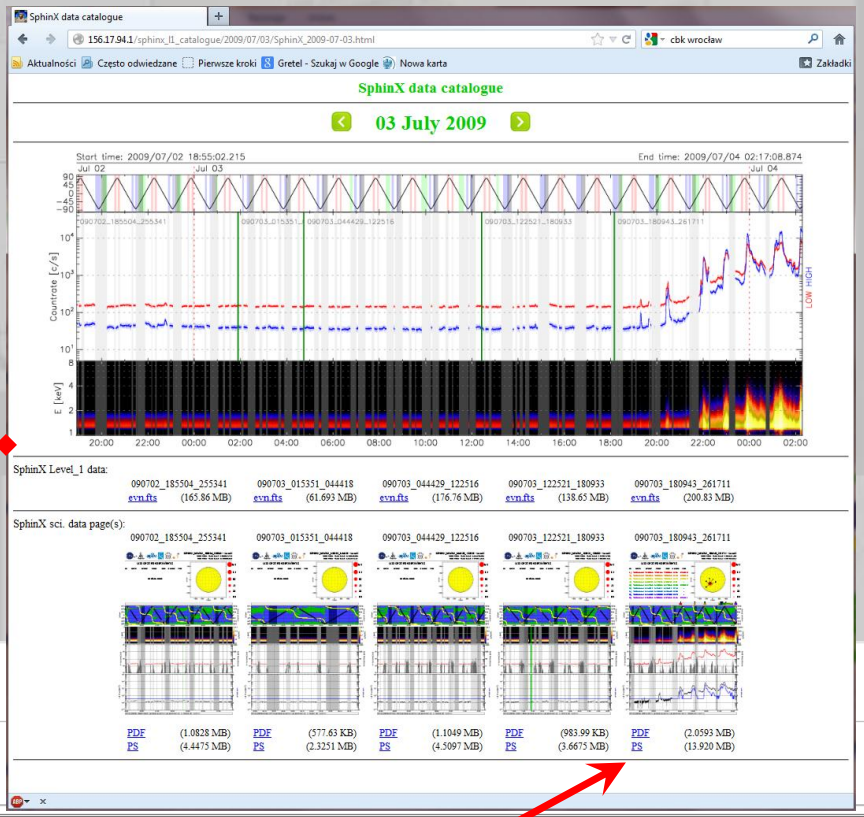


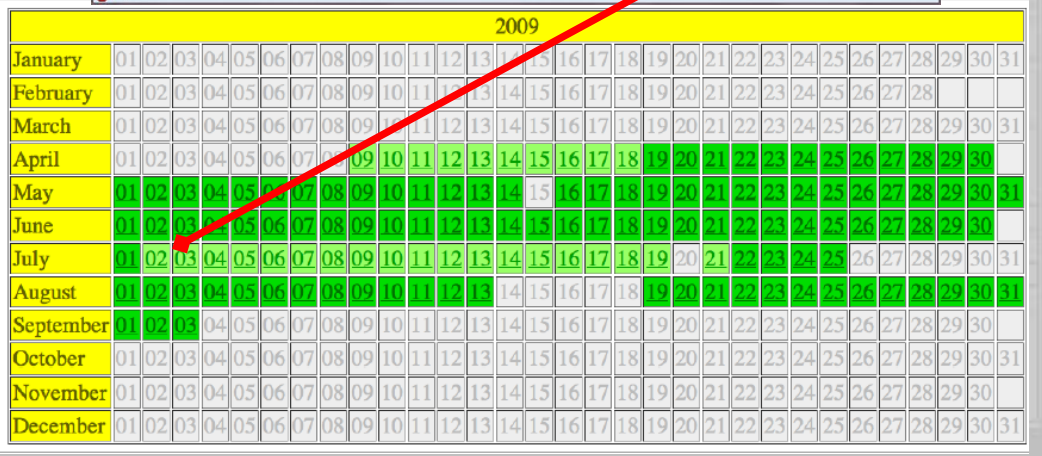




- All data reformatted and converted to Level_1
- Time interval 20 February – 29 November 2009
- Most instrumental problems resolved
- Diagonal part of detector matrix used for now

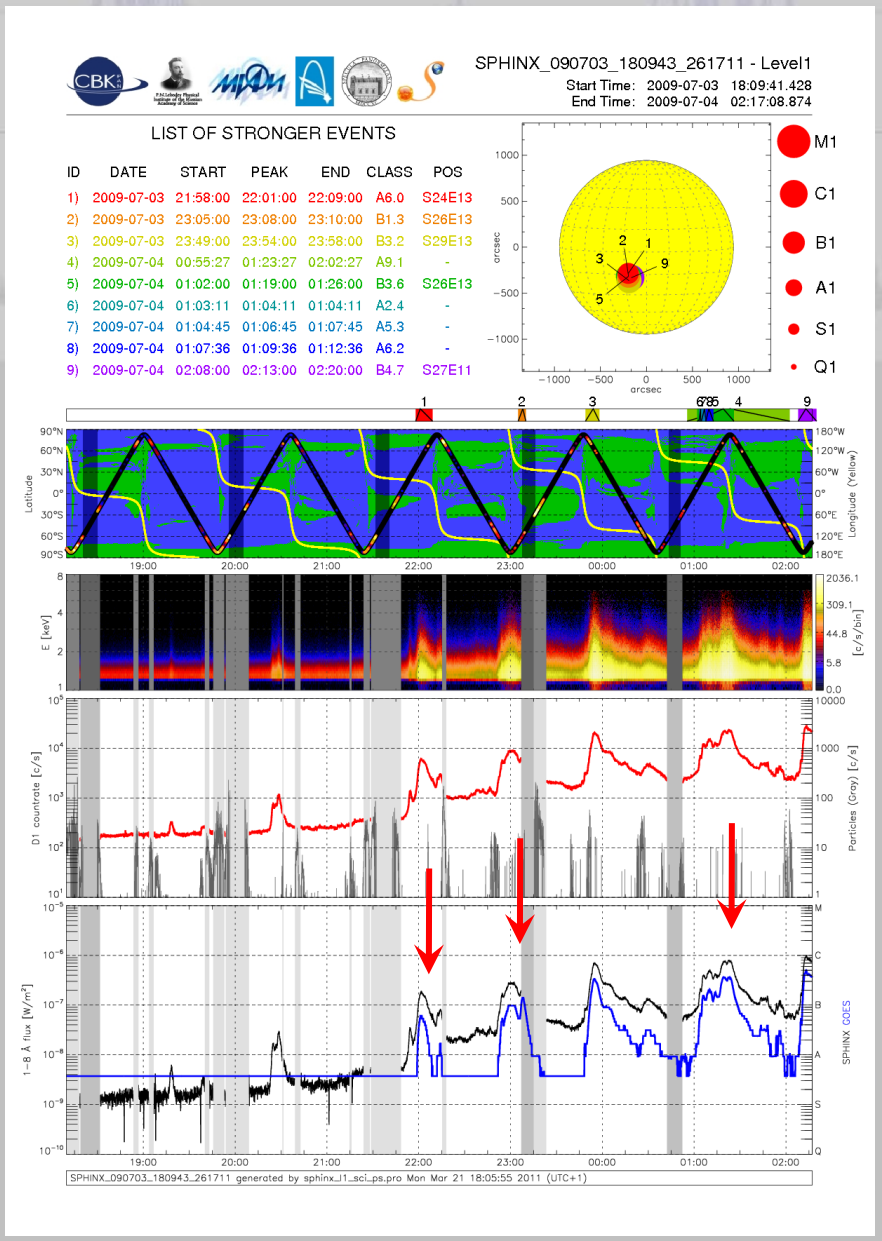
# *Flares selection*

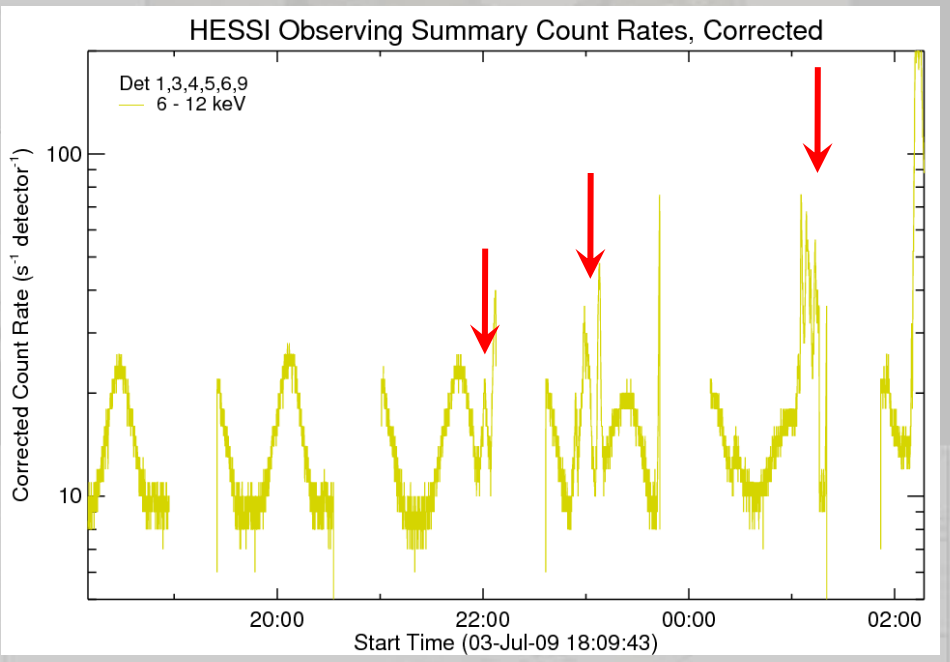


# *Flares selection*



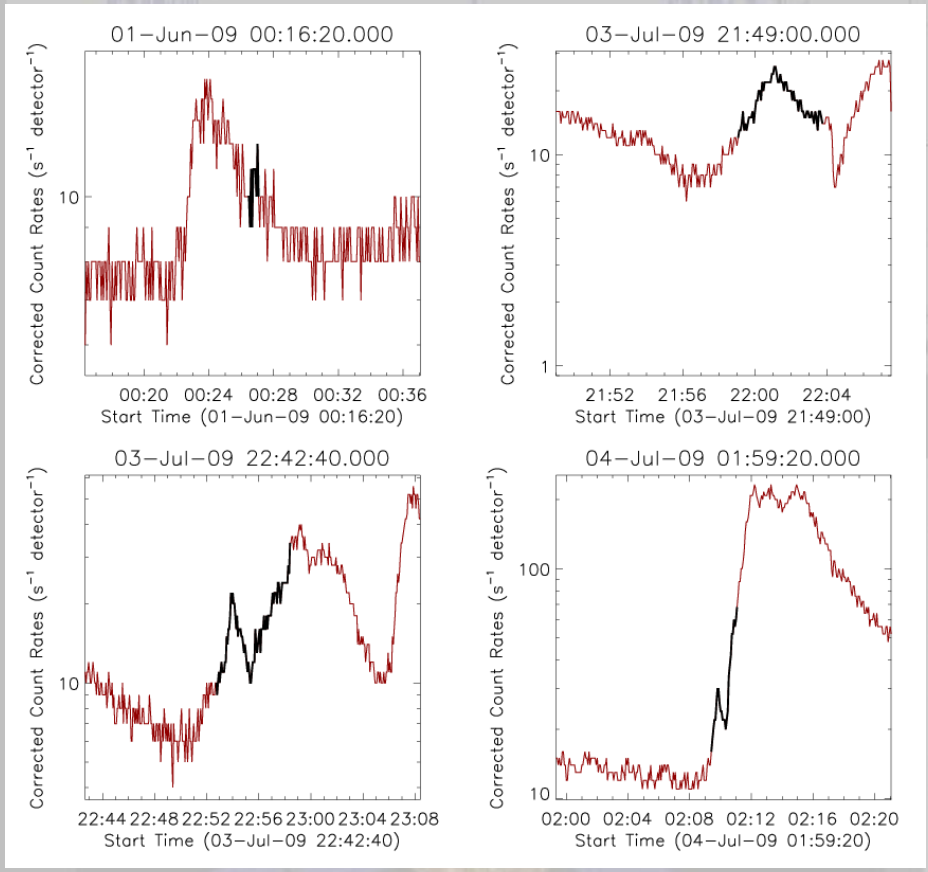

Flares were chosen by the inspection of RHESSI and SphinX data catalogues

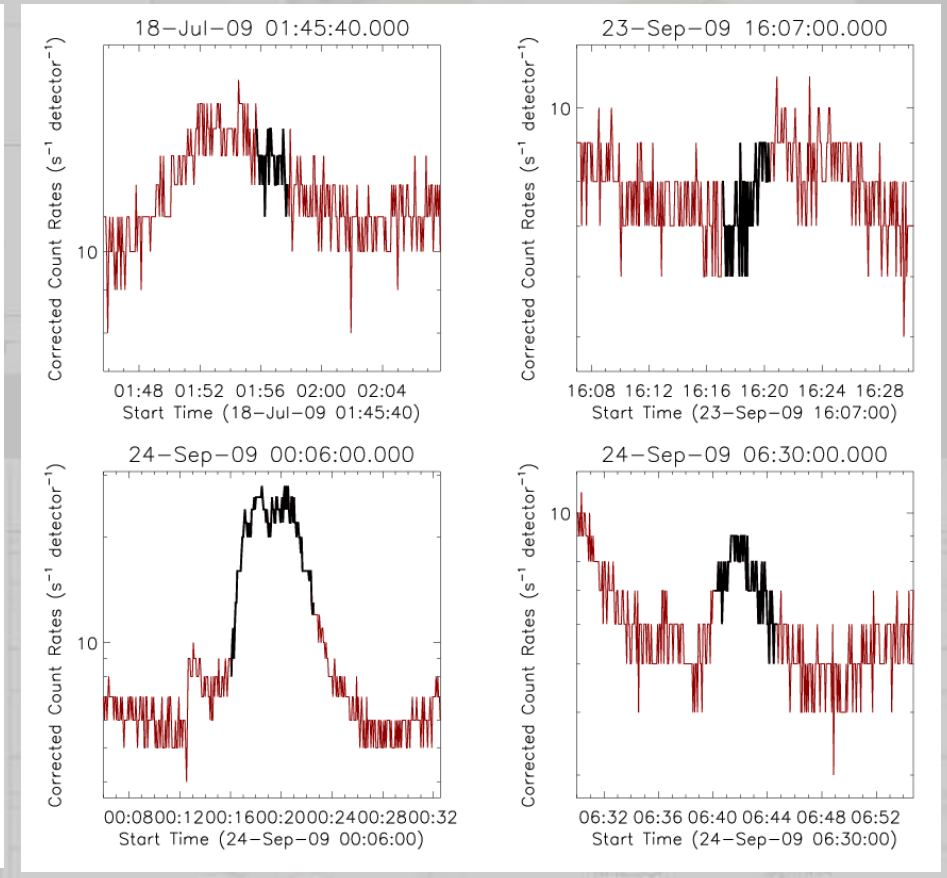
37 common RHESSI and SphinX observations of flares have been found

GOES classes from A1.2 to C1.0

Locations on the disk and on the limb

# *Selected data*



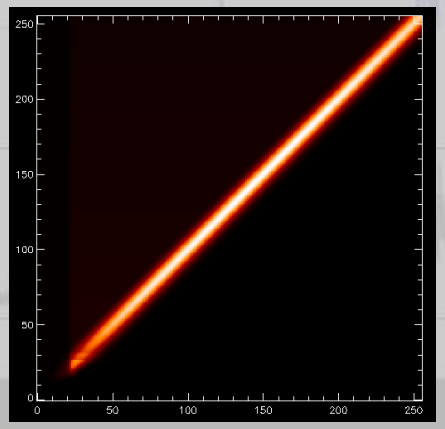




Red – RHESSI data, Black – SphinX observations

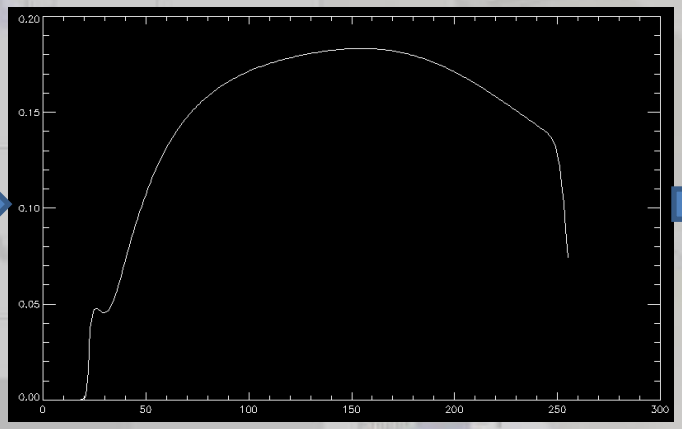
- 12 flares well observed by RHESSI (far from SAA, outside radiation belts)
- 12 s time intervals (244 intervals)
- energy range: 3-8 keV (16 energy bands, $\Delta E$=0.3 keV)

# *Fluxes comparison*

**cnts $s^{-1}$**

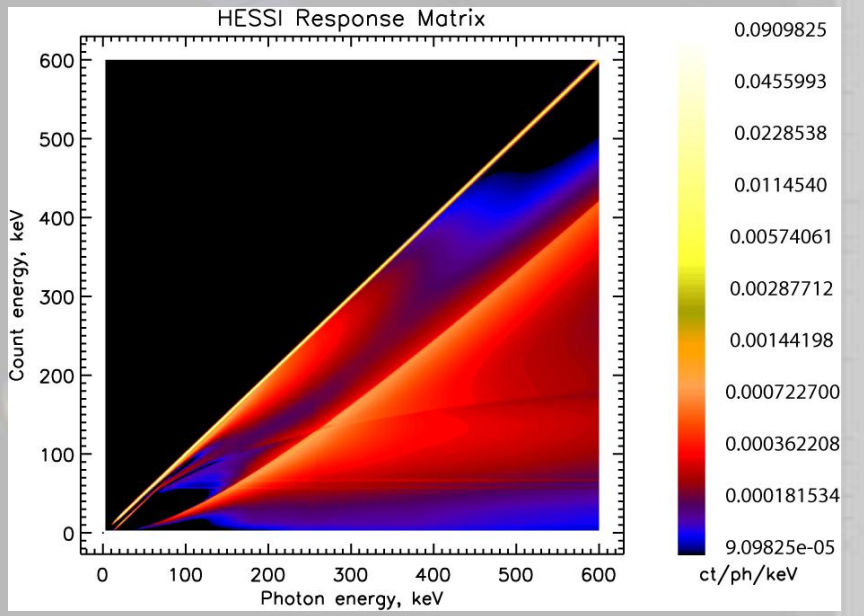



**SphinX DRM**



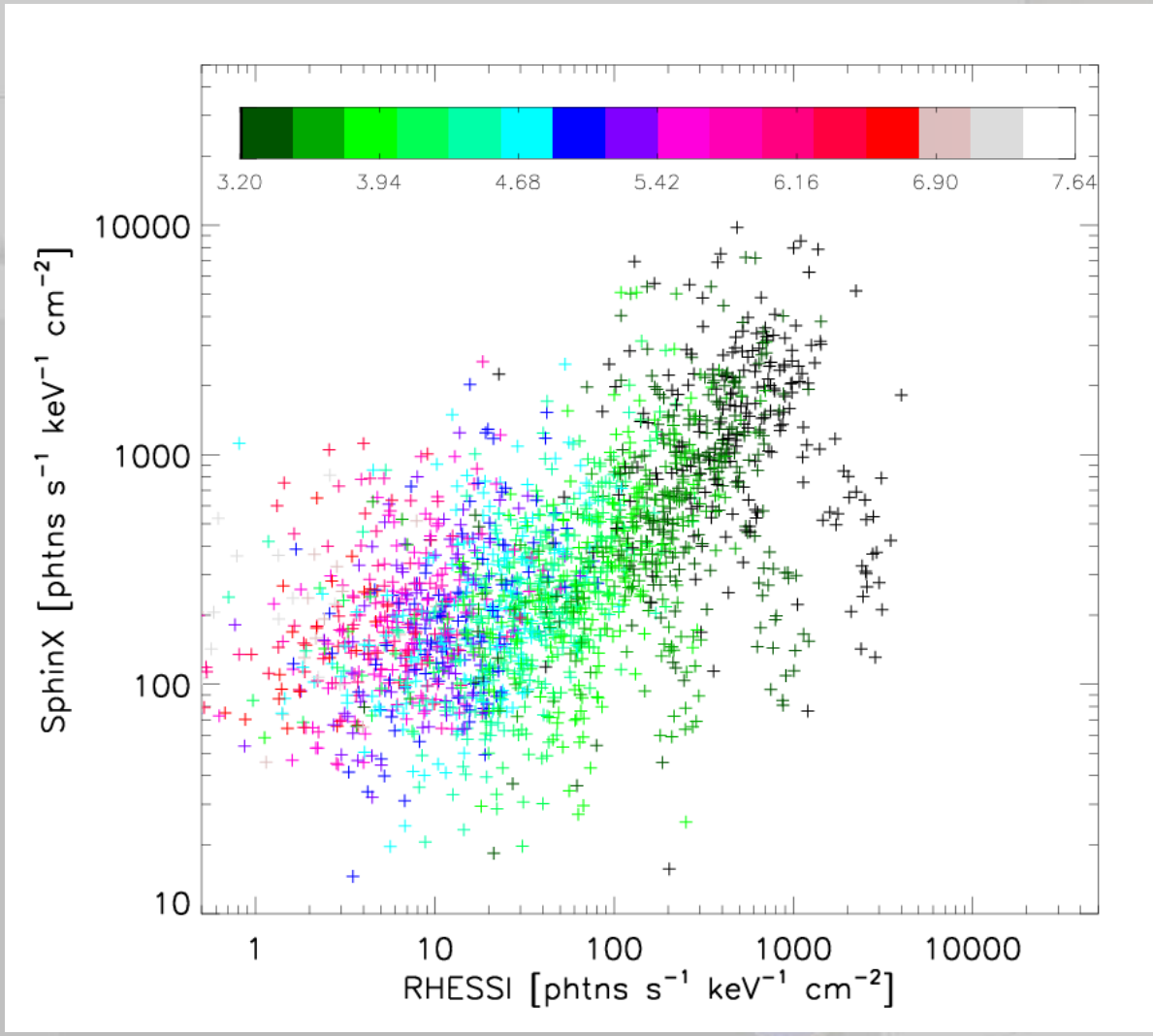

**conversion factors**

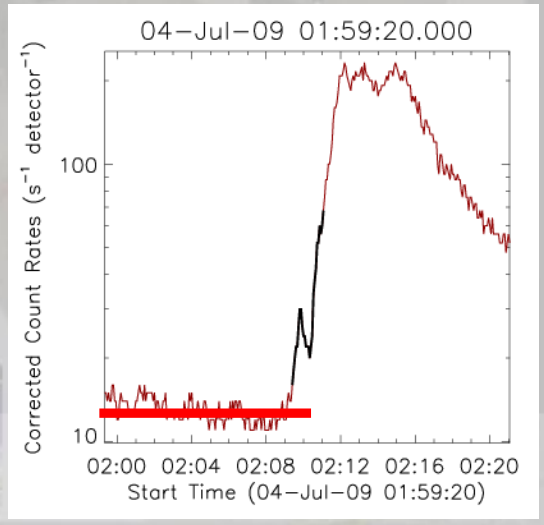
**phtns $s^{-1}$ $keV^{-1}$ $cm^{-2}$**




RHESSI DRM – we took diagonal elements only – good approximation for extremely weak flares

# *Fluxes comparison*



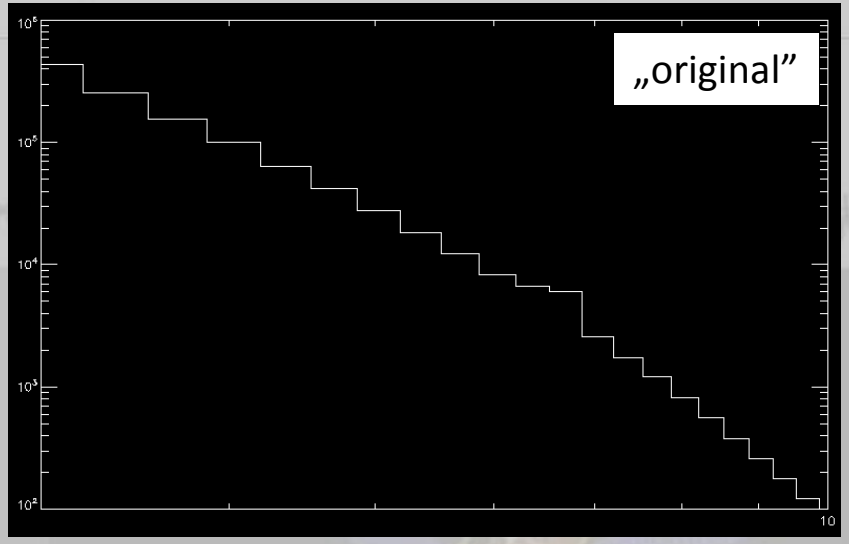

**background subtracted fluxes for all time intervals**

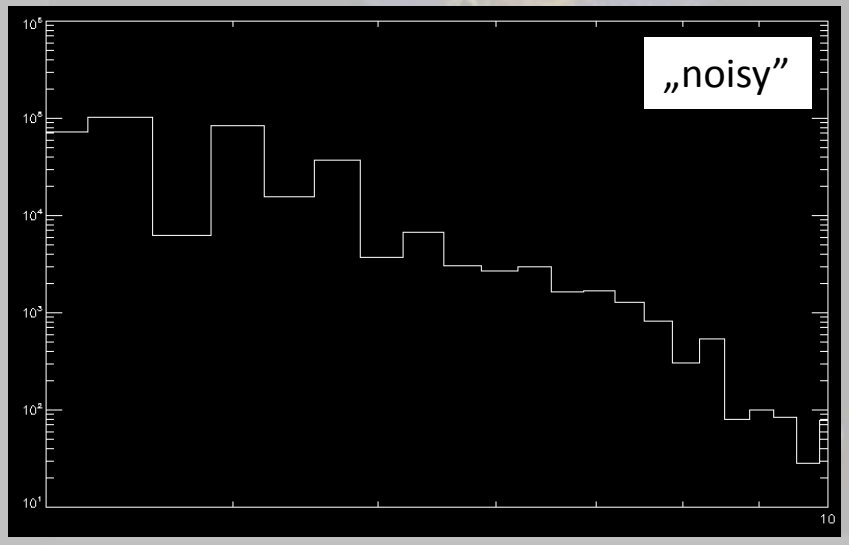
**wide variety of events, phases, physical parameters -> large spread of points**

**SphinX data are „real” up to 5 keV. In individual cases it may be up to 7 keV.**

# *Data self-consistency*

dE=0.3keV, EM=$10^{49}$cm$^{-3}$, T=1 keV

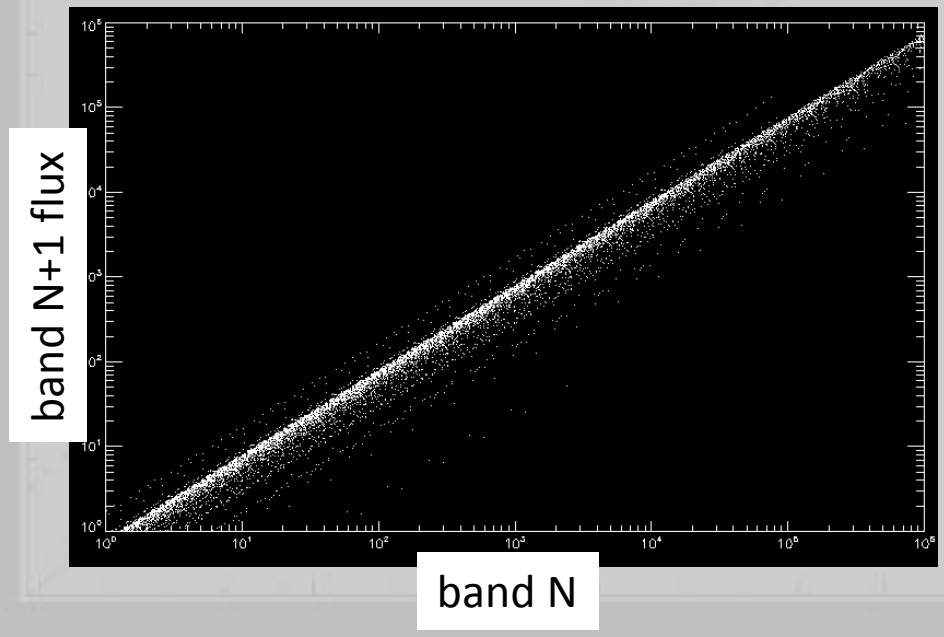


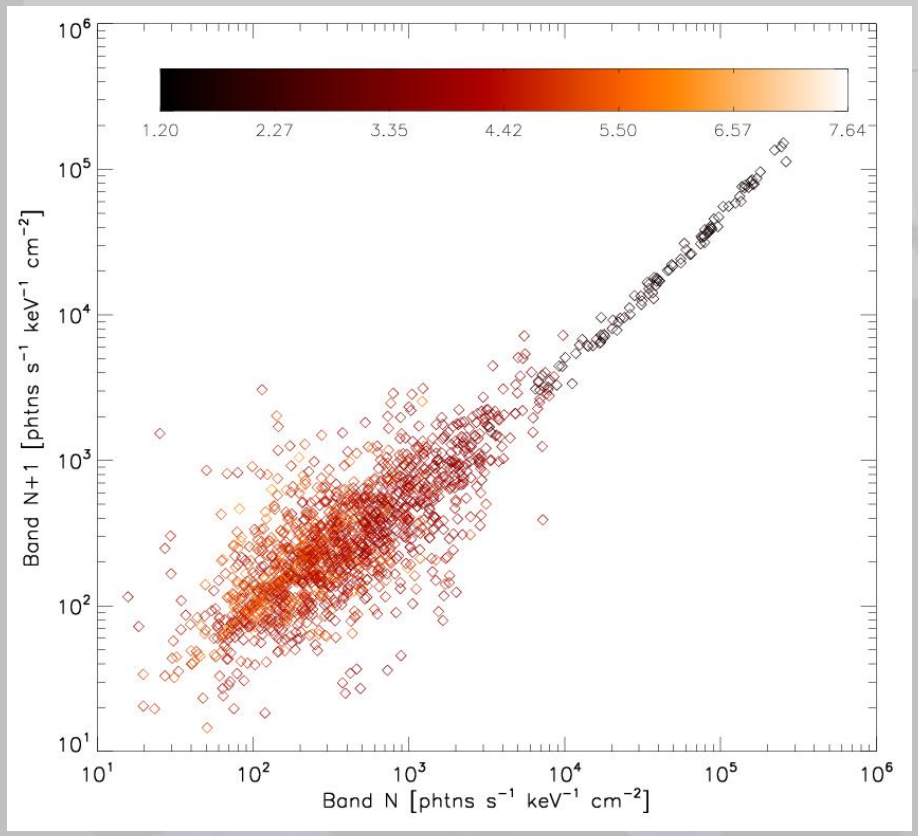

Where is located the end of real SphinX measurements?

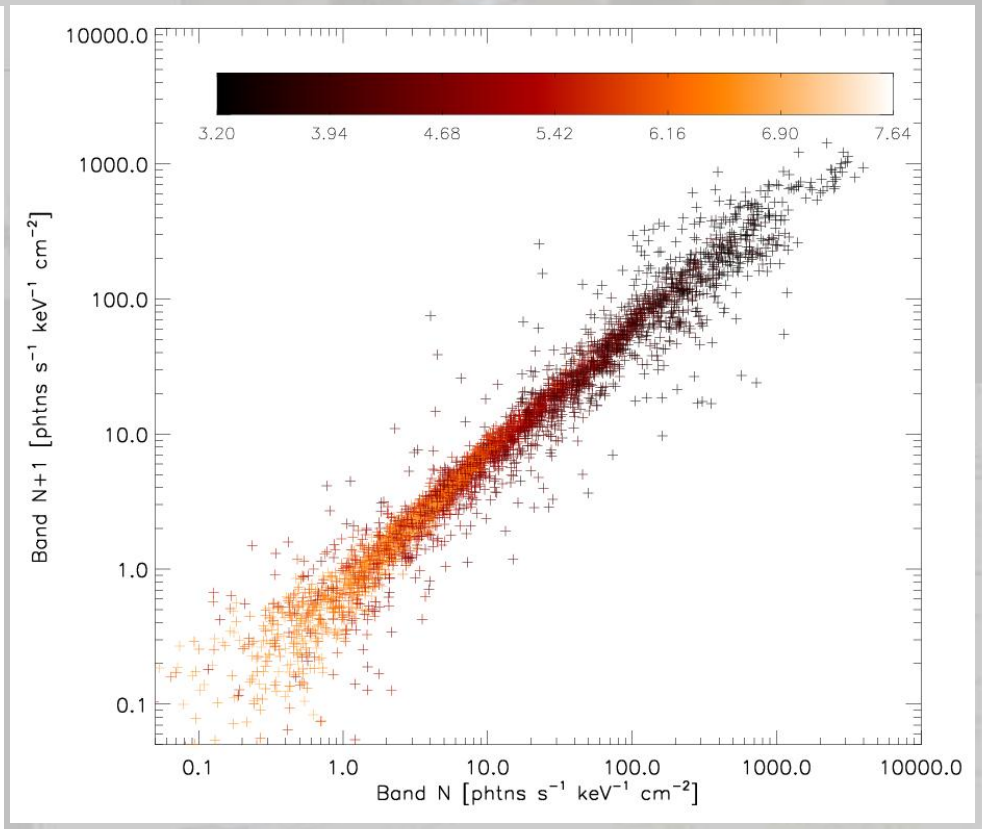
Fluxes in neighbouring energy bands were compared

400 spectra (EM: $10^{44}$–$10^{49}$cm$^{-3}$ ,T: 0.1–2 keV)



# *Data self-consistency*

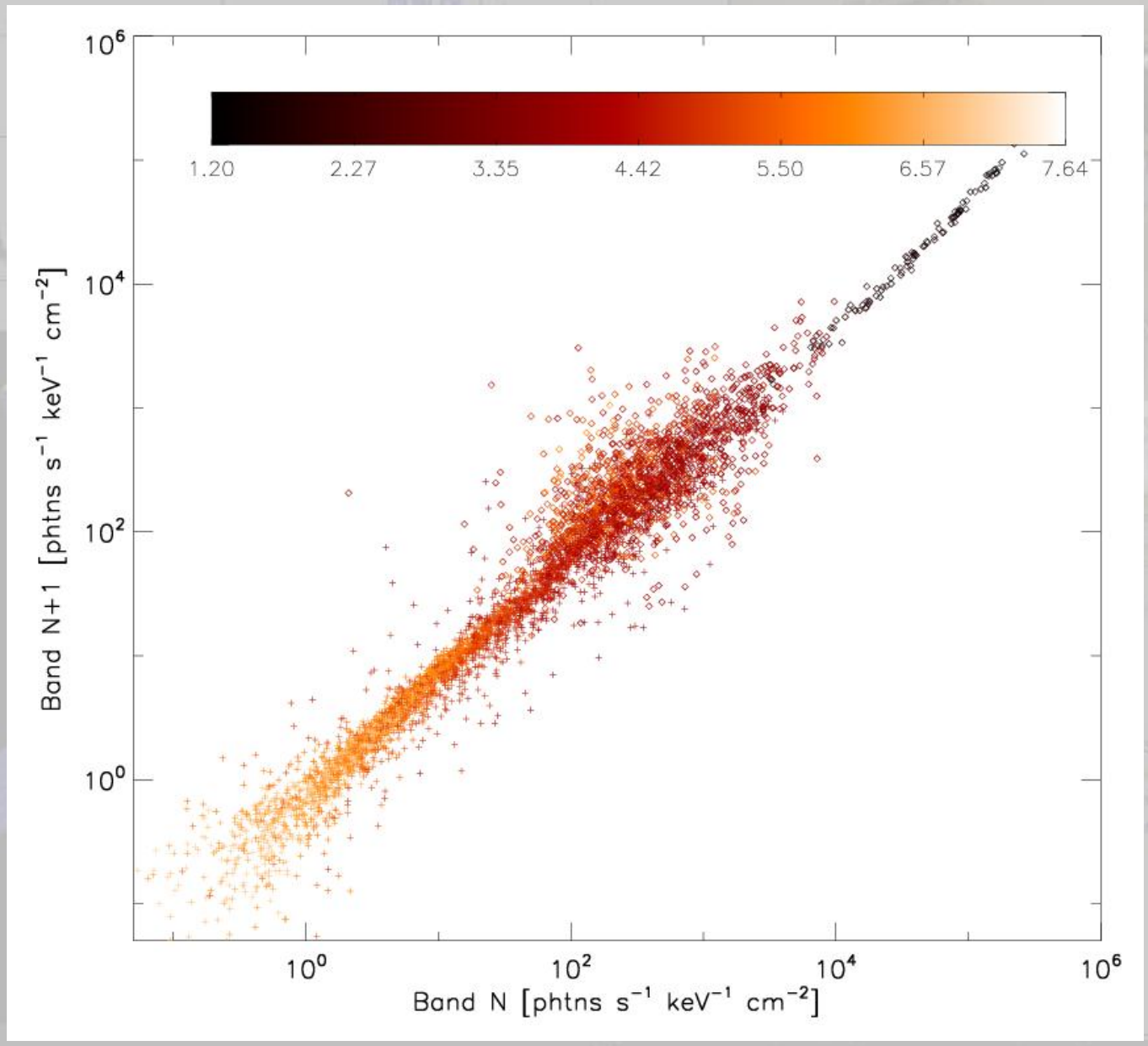


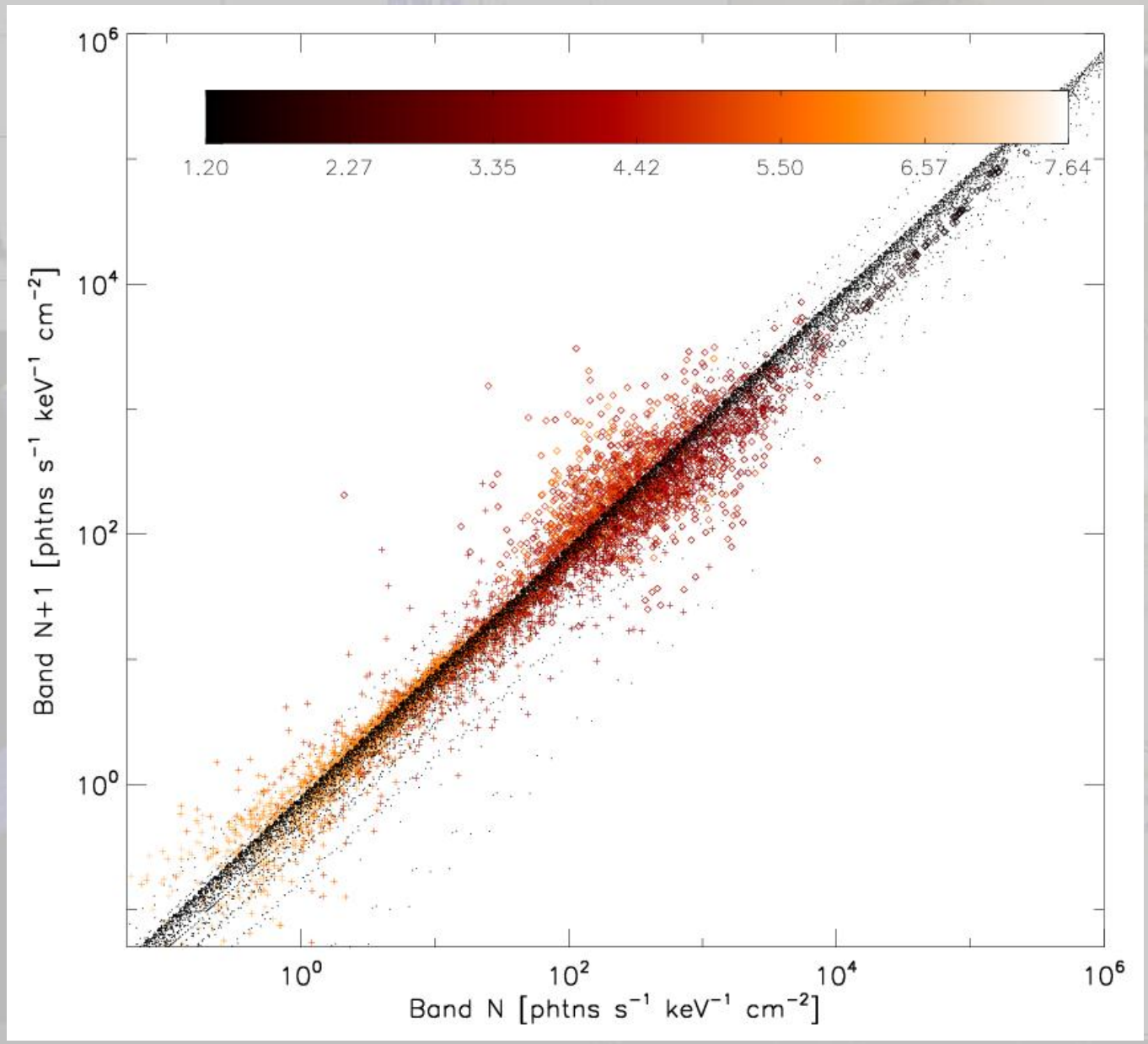

SphinX – large spread above 4-5 keV, but there is still information

RHESSI – more noisy in whole energy range (below 4 keV – drop in sensitivity, above 7 keV – poor statistics)

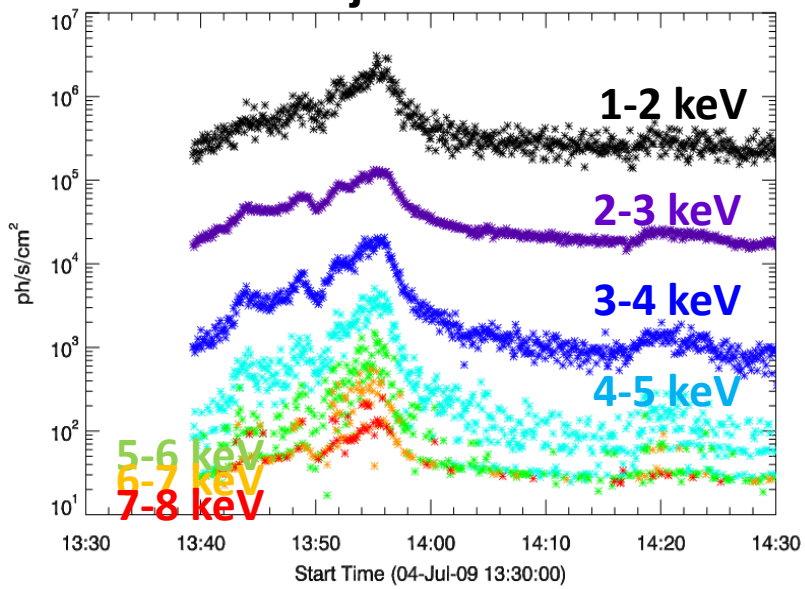
# *Data self-consistency*

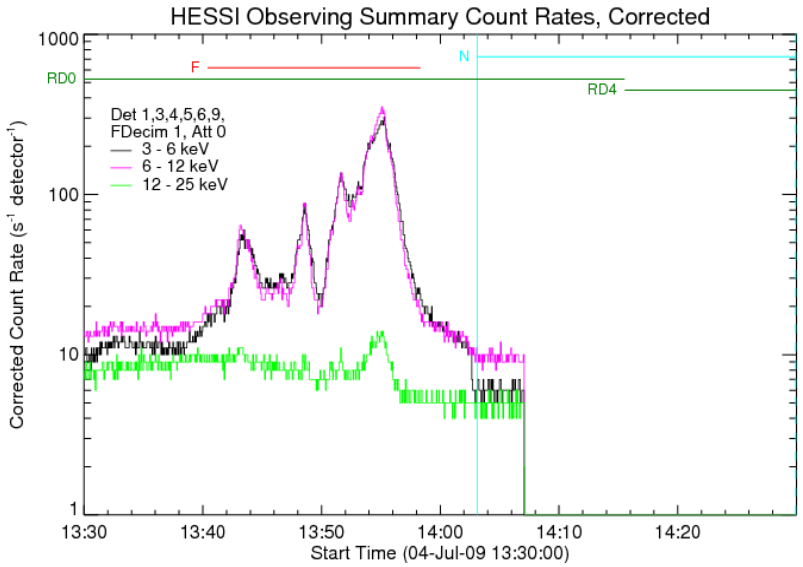


# *Data self-consistency*



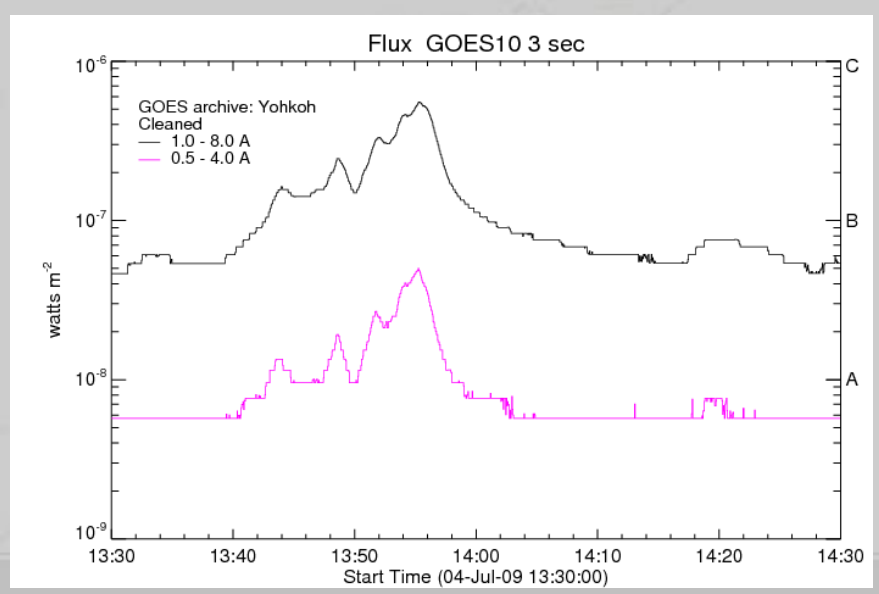
# *Case study: July 4th*



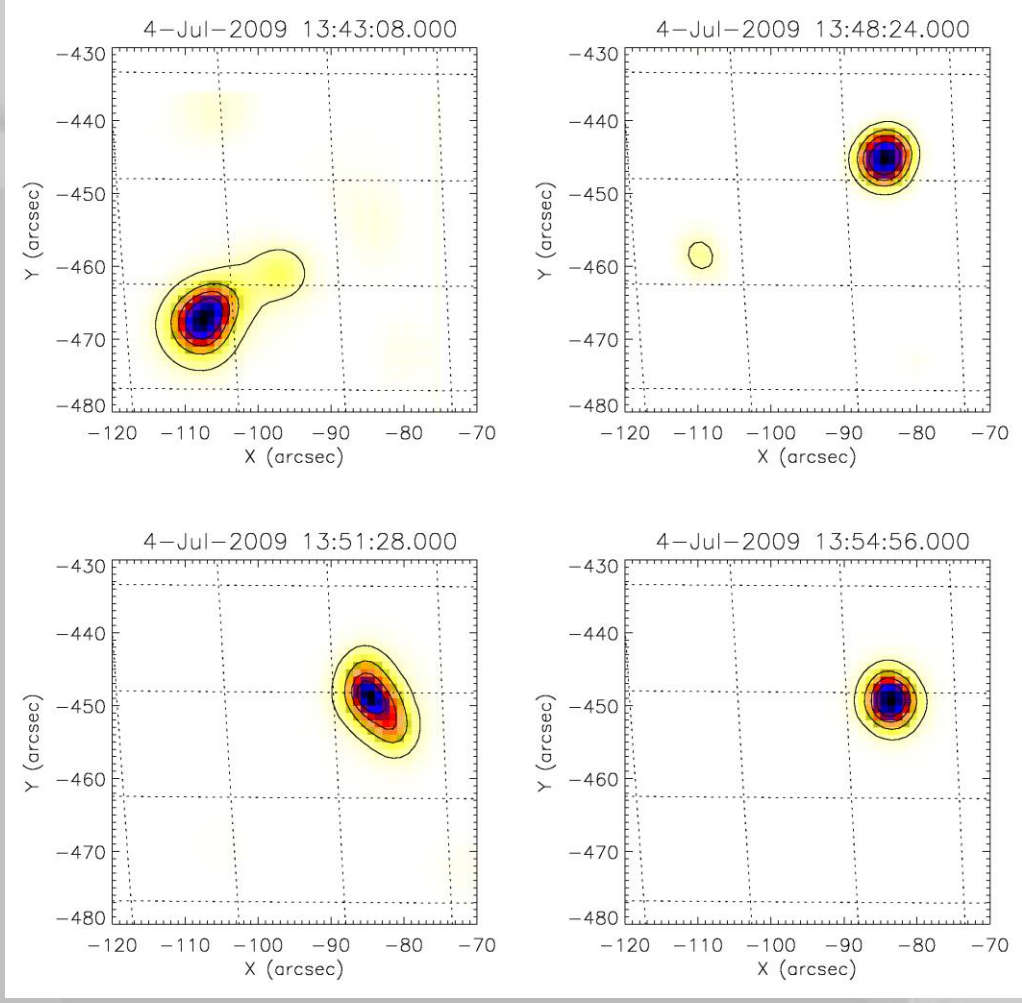

| Date | SphinX max [UT] | RHESSI max [UT] | GOES class |
|---|---|---|---|
| 4.07.2009 | 13:44 | 13:43 | B1.6 |
| | 13:48 | 13:48 | B2.4 |
| | 13:54 | 13:52 | B4.6 |
| | 13:55 | 13:55 | B5.3 |

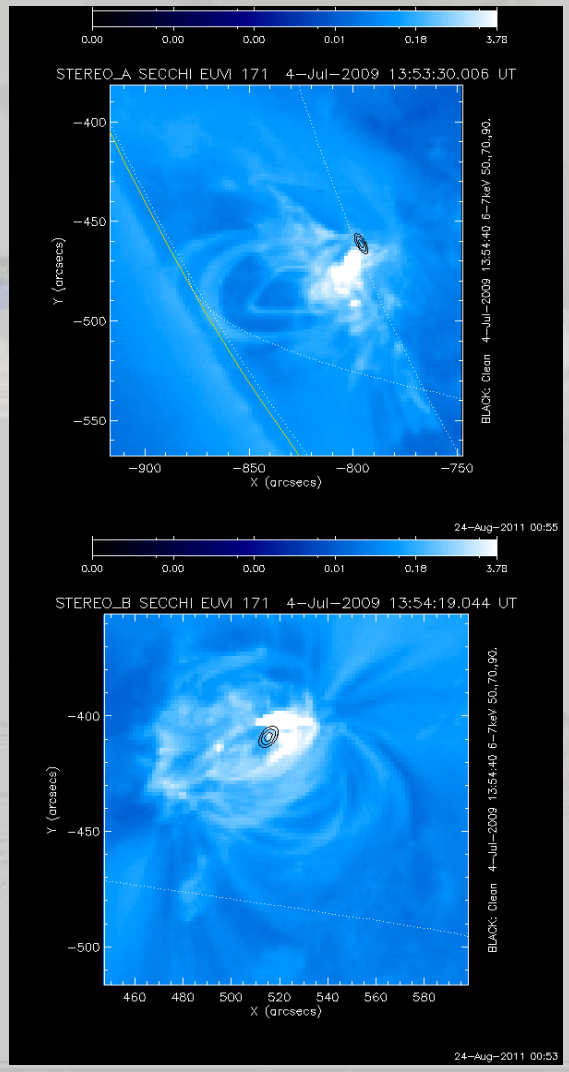
**All four peaks were observed by SphinX, RHESSI and GOES**



# *Case study: July 4th*

**Small structure observed in the energy band 6-8 keV (RHESSI data, PIXON algorithm)**



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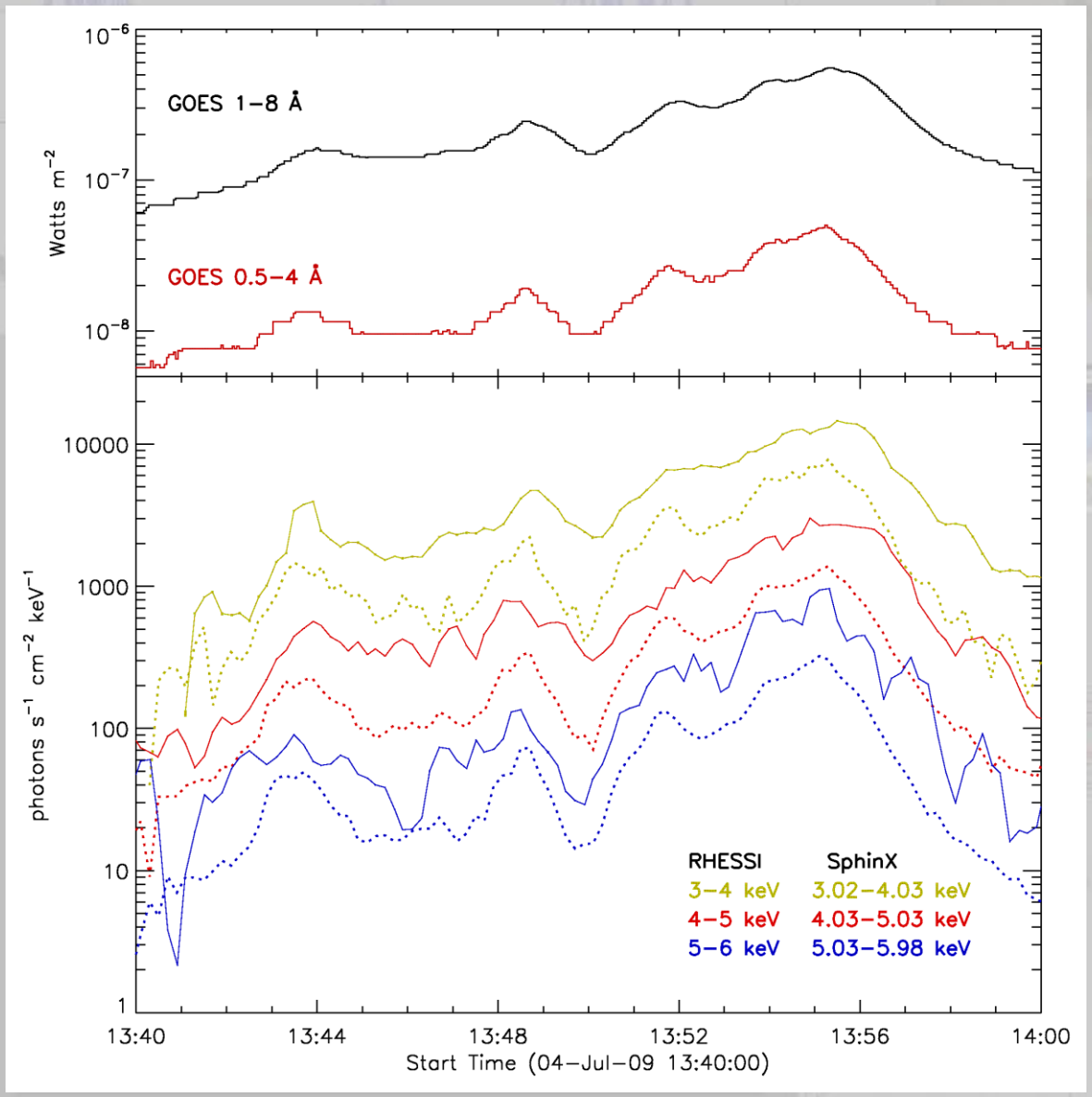
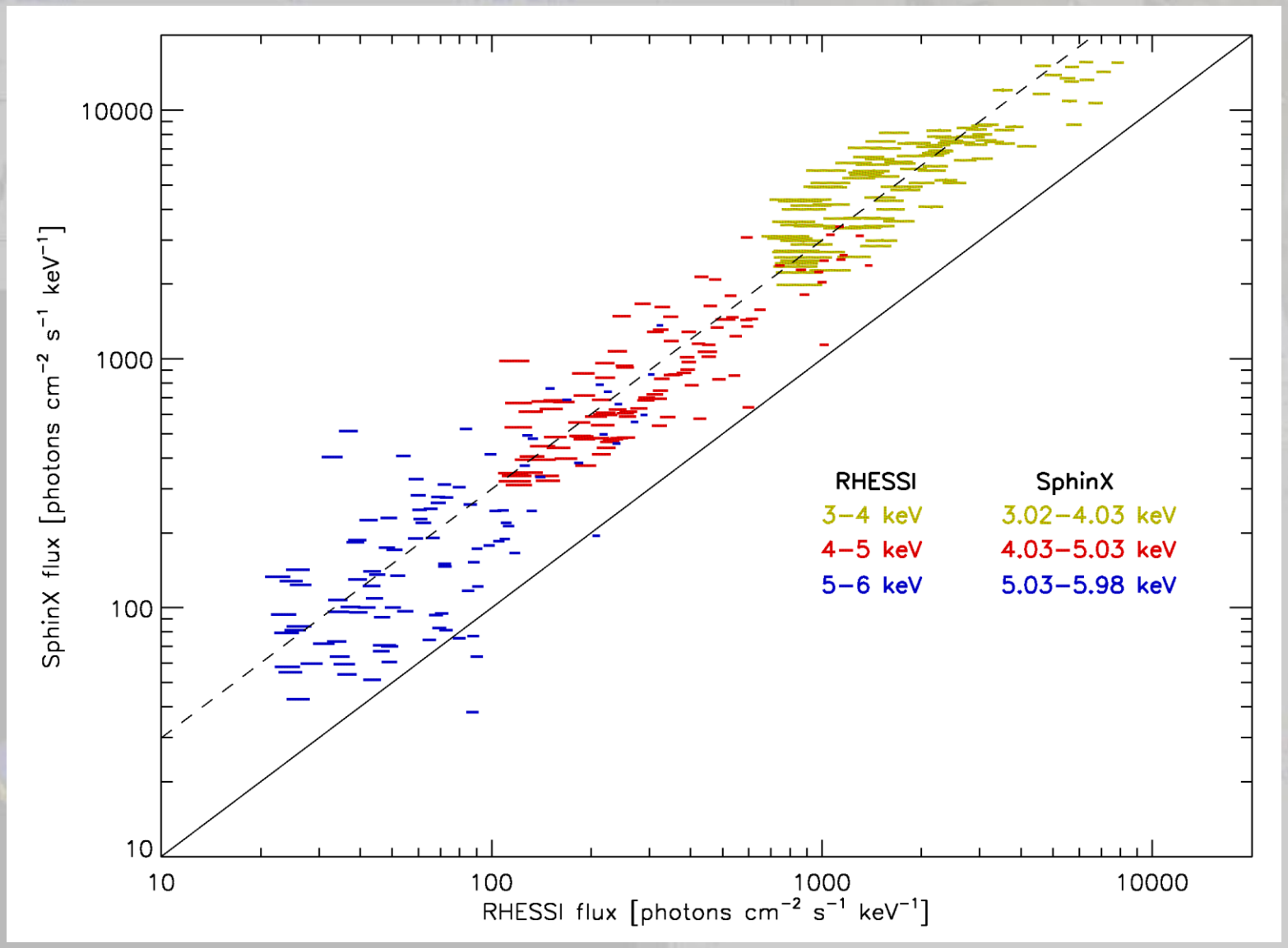



Time evolution is similar for all three instruments.

There is a difference in fluxes (factor ~3)

line – SphinX
dots – RHESSI

# *Case study: July 4th*



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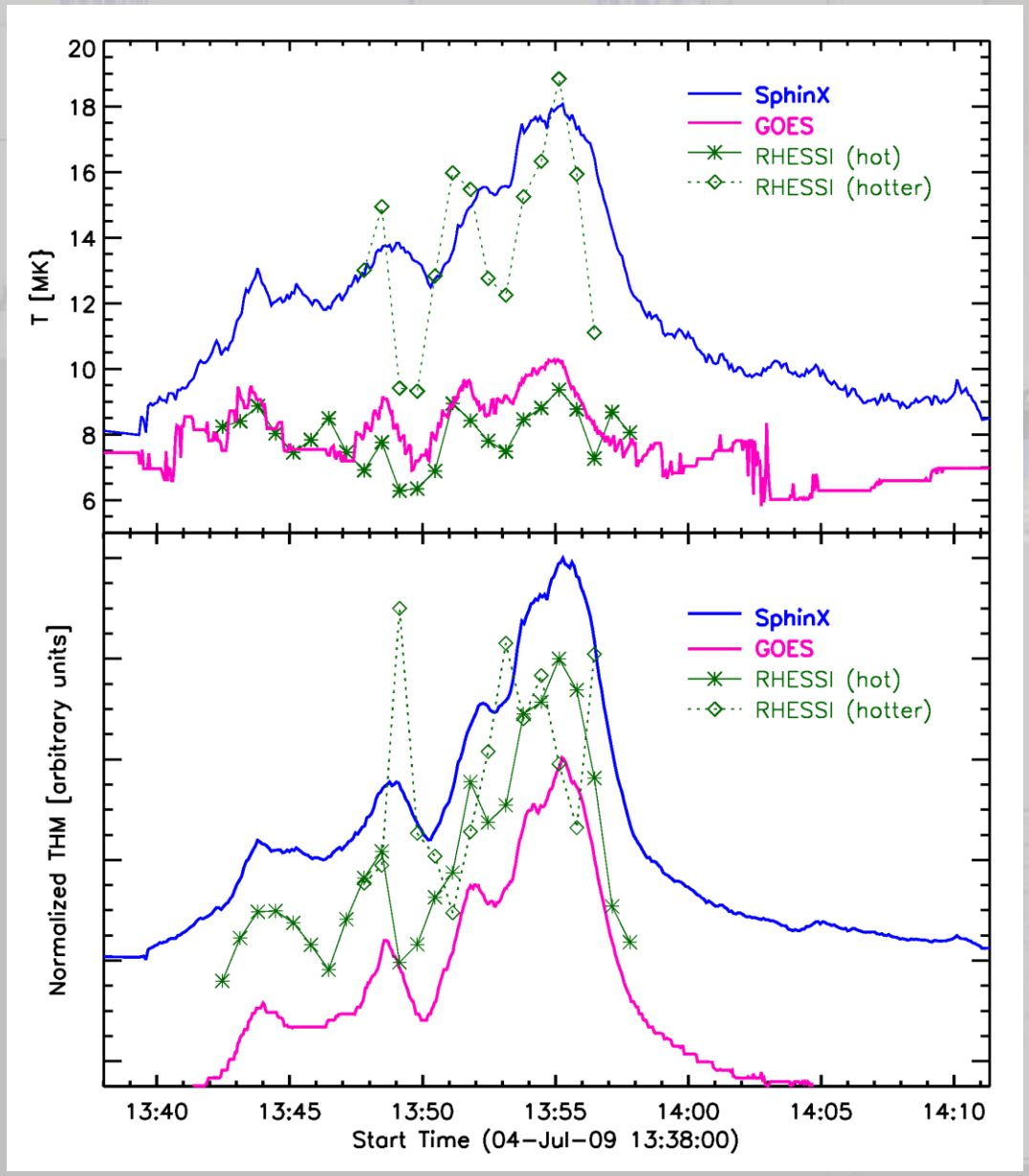



SphinX – flaring component (subtracted active region background)

RHESSI – two temperature fit

GOES – filter ratio method

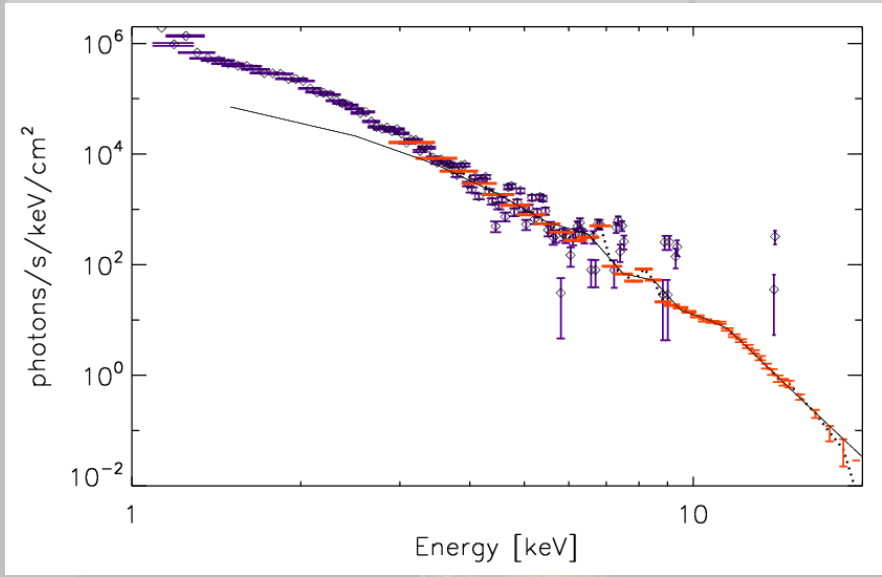
The thermodynamic measure represents volume-unrelated part of the $E_{th}$:

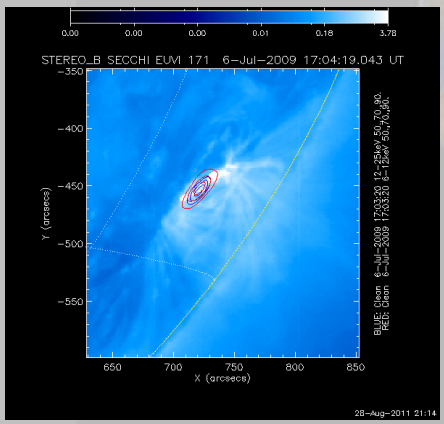
$$\eta = 3kT\sqrt{EM}$$

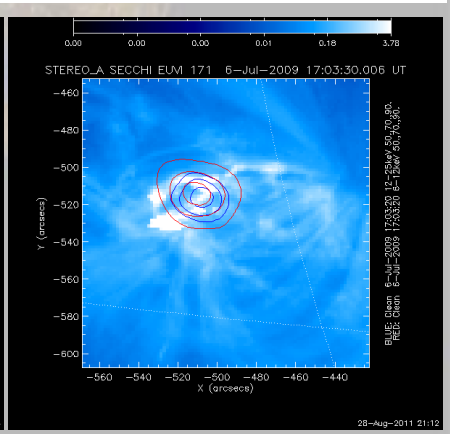
Assuming that there is no significant changes of volume during the flare, thermodynamic measure represents the change of the plasma thermal energy.

# Summary

**06-Jul-2009 (C1.0)**




**SphinX and RHESSI data are complementary**

**There is a systematical shift, of the order of 3, between spectra. Sometimes the shift is 0.**

**Nice agreement between light curves, time characteristics.**

**Temperatures agrees very well. Emission measure or thermodynamic measure differ due to differences between spectra.**

**For A or B class flares SphinX data are „real” up to 4-5 keV. Above these energies they became noisy, but there is still information to get.**