

RHESSI and SphinX Common Observations of Solar Flares

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RHESSI SphinX

3-4 keV	3.03-4.03 keV
4-5 keV	4.03-5.03 keV
5-6 keV	5.03-5.98 keV

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.

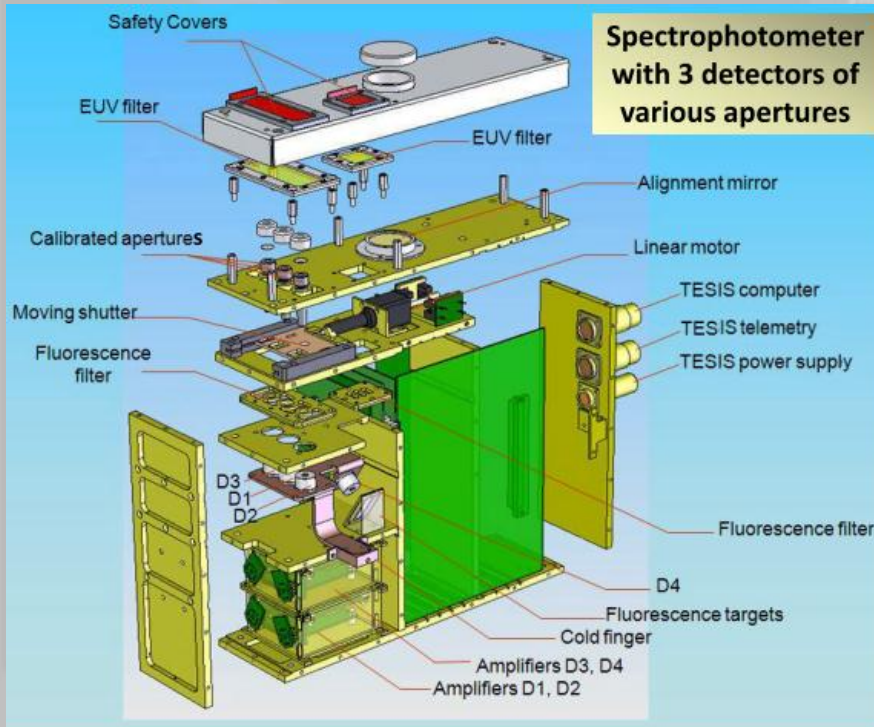
Aim: to compare data obtained by two (three) different instruments

SphinX - Polish concept, design & manufacture

Solar Photometer in X-rays (SphinX)

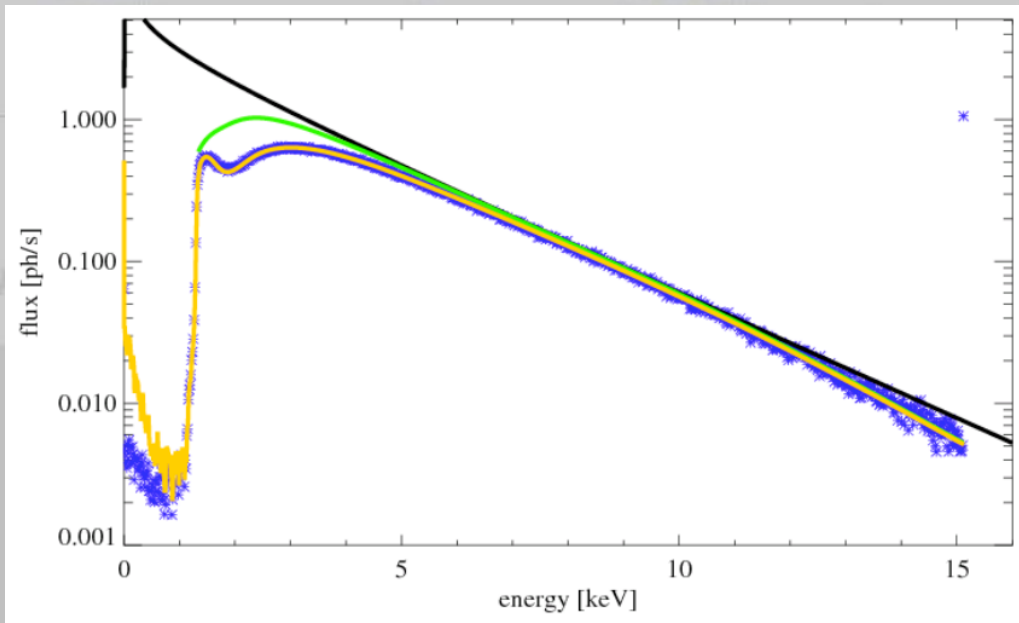
**Goal: to measure the X-ray emission of the Sun
in the ~1.2 – 15 keV band**

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

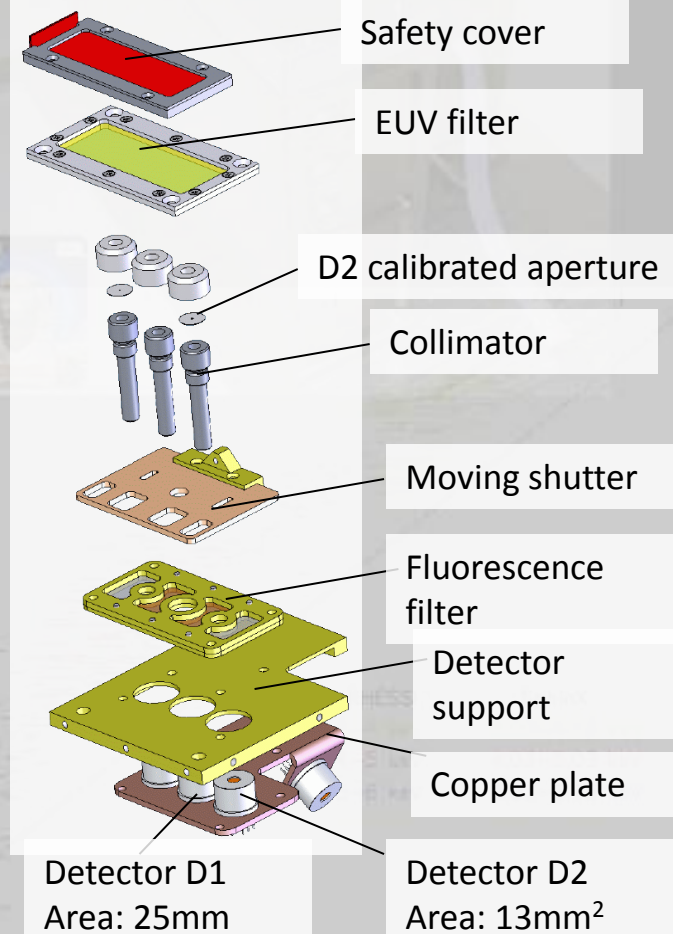


- energy range: 1.2 – 15 keV
- time resolution: ~0.00001 s
- sensitivity: 100x better than GOES XRM
- energy resolution: ~0.4 keV

SphinX - Polish concept, design & manufacture



SphinX optical entrance



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.

RHESSI (Ramaty High Energy Solar Spectroscopic Imager)

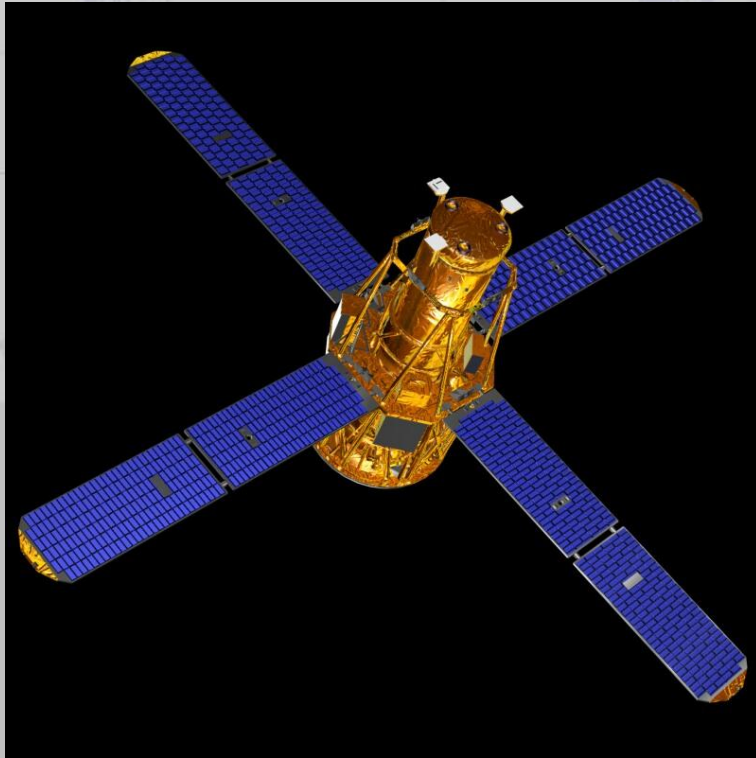


1942 - 2012



- 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

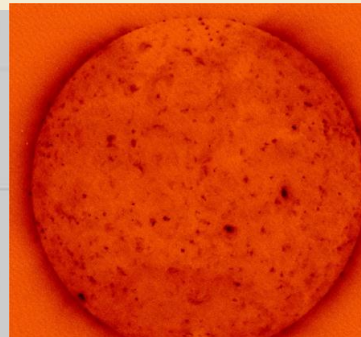
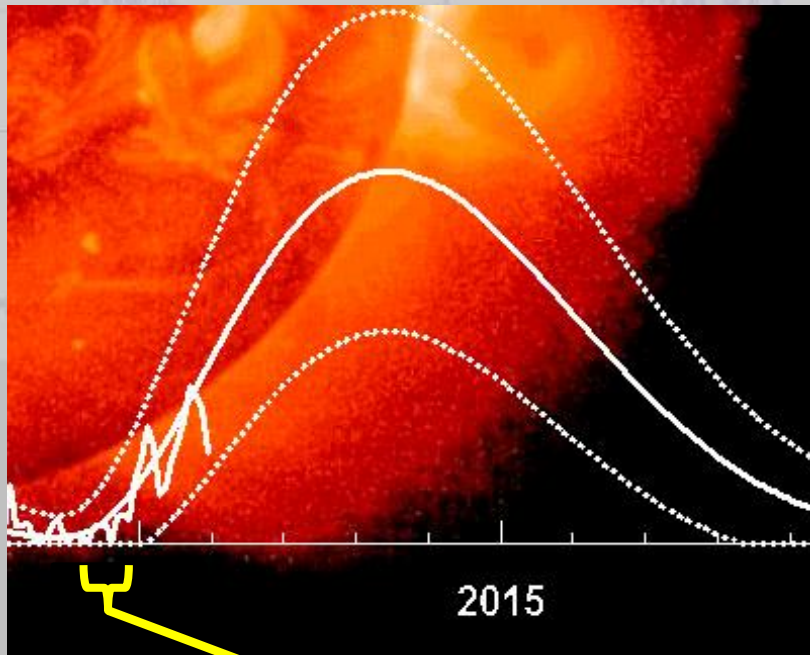


Motivation:

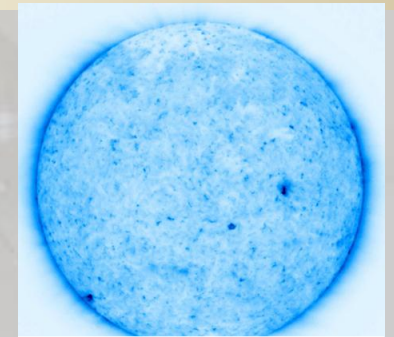
- observations overlap in the energy range 3-15 keV
- SphinX is absolutely calibrated, RHESSI is well explored due to 10 years of observations
- possibility for extending spectral fits to energy of the order of 1 keV – improvement of spectral fits in the lowest energies observed by RHESSI

RHESSI	SphinX
3-15 keV	0.03-15 keV
4-5 keV	0.03-0.03 keV
5-6 keV	0.03-0.03 keV

Observational period

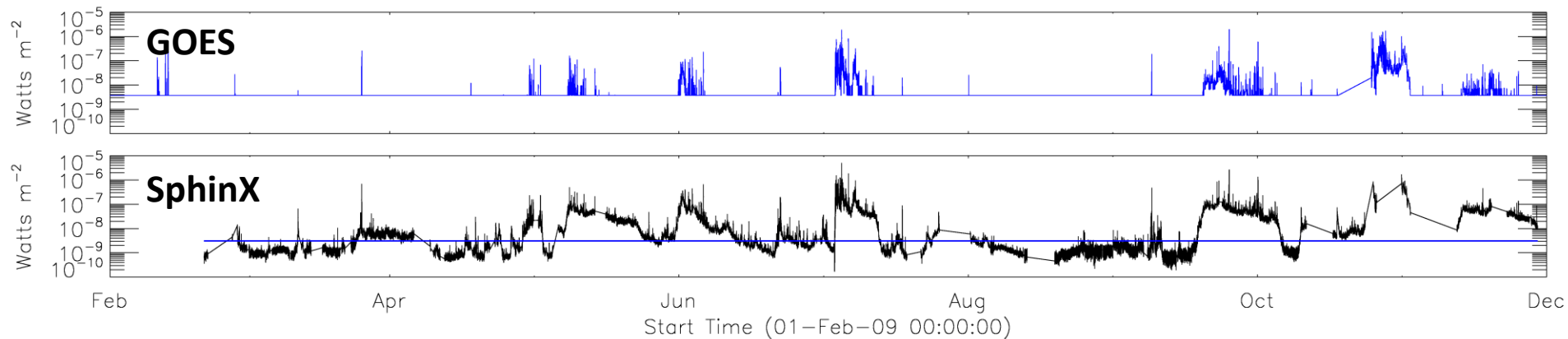


Hinode XRT Ti_{poly}
2009 Sept. 15 15:47:31



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

SphinX data catalogue

156.17.94.1/sphinx_ll_catalogue/Sphinx_cat_main.html

SphinX data catalogue

All SphinX data available here are Level_1 data.

[SphinX event catalogue](#)
[event catalogue description](#)

2009																														
January	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
February	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		
March	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
April	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
May	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
June	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
July	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
August	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
September	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
October	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
November	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
December	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

[Legend](#) [SphinX level-1 data description, calibration info and software](#)

Last update: Tue Jun 5 17:56:42 2012 (UTC+2)

Zakład Fizyki Słońca

www.cbk.pan.wroc.pl

Solar Physics Division

Grants Conferences Experiments Publications Presentations News

EXPERIMENTS

- SPHINX**
 - SphinX Home Page
 - Publications
 - SphinX Data Catalogue
 - SphinX Data Catalogue Level 1
- RESIK**
 - RESIK News
 - Publications
 - Data (Level 2)
 - RESIK Data Catalogue
- DIOGENESS**
 - Publications
- INTERBALL**
 - INTERBALL Home Page
 - Publications

- 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

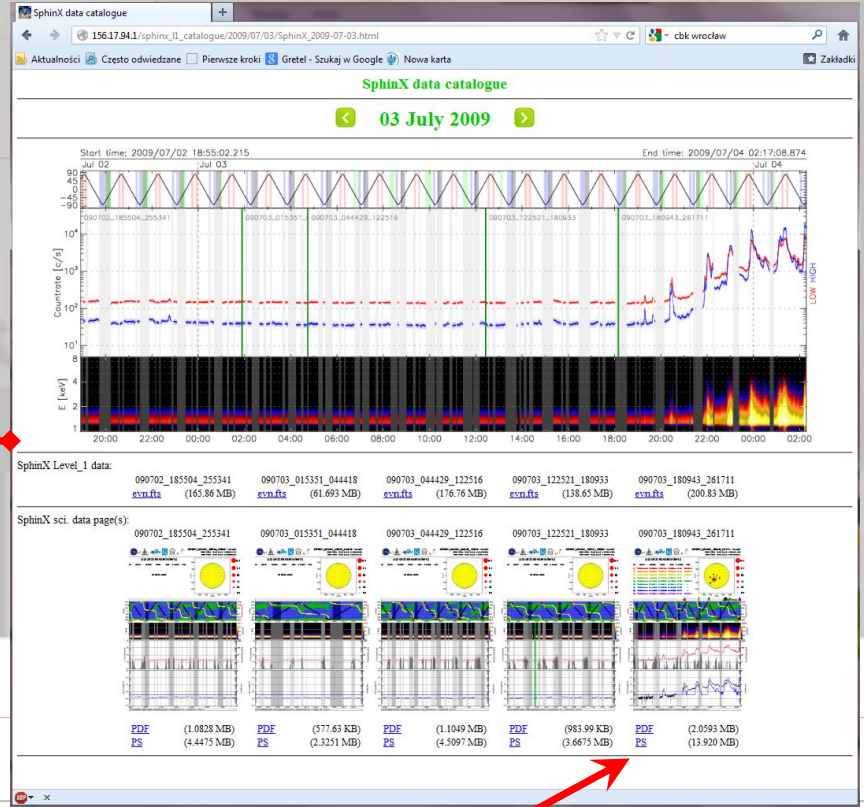
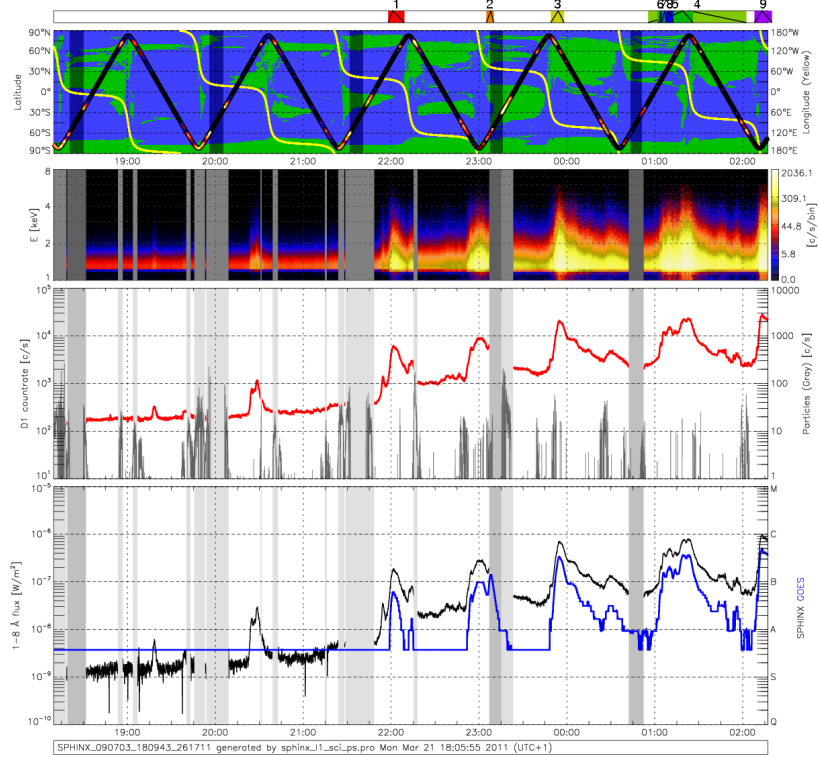
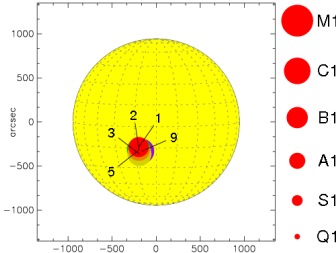


SPHINX_090703_180943_261711 - Level1

Start Time: 2009-07-03 18:09:41.428
End Time: 2009-07-04 02:17:08.874

LIST OF STRONGER EVENTS

ID	DATE	START	PEAK	END	CLASS	POS
1)	2009-07-03	21:58:00	22:01:00	22:09:00	A6.0	S24E13
2)	2009-07-03	23:05:00	23:08:00	23:10:00	B1.3	S26E13
3)	2009-07-03	23:49:00	23:54:00	23:58:00	B3.2	S29E13
4)	2009-07-04	00:55:27	01:23:27	02:02:27	A9.1	-
5)	2009-07-04	01:02:00	01:19:00	01:26:00	B3.6	S26E13
6)	2009-07-04	01:03:11	01:04:11	01:04:11	A2.4	-
7)	2009-07-04	01:04:45	01:08:45	01:07:45	A5.3	-
8)	2009-07-04	01:07:36	01:09:36	01:12:36	A6.2	-
9)	2009-07-04	02:08:00	02:13:00	02:20:00	B4.7	S27E11



SphinX Level_1 data:

090702_185504_255341 evt.fits (165.86 MB)	090703_015351_044418 evt.fits (61.693 MB)	090703_044429_122516 evt.fits (176.76 MB)	090703_122521_180953 evt.fits (138.65 MB)	090703_180943_261711 evt.fits (200.83 MB)
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SphinX sci. data page(s):

090702_185504_255341 PDF (1.0828 MB) PS (4.4475 MB)	090703_015351_044418 PDF (577.63 KB) PS (2.3251 MB)	090703_044429_122516 PDF (1.1049 MB) PS (4.5097 MB)	090703_122521_180953 PDF (983.99 KB) PS (3.6675 MB)	090703_180943_261711 PDF (2.0593 MB) PS (13.920 MB)
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2009																																
January	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
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Flares selection

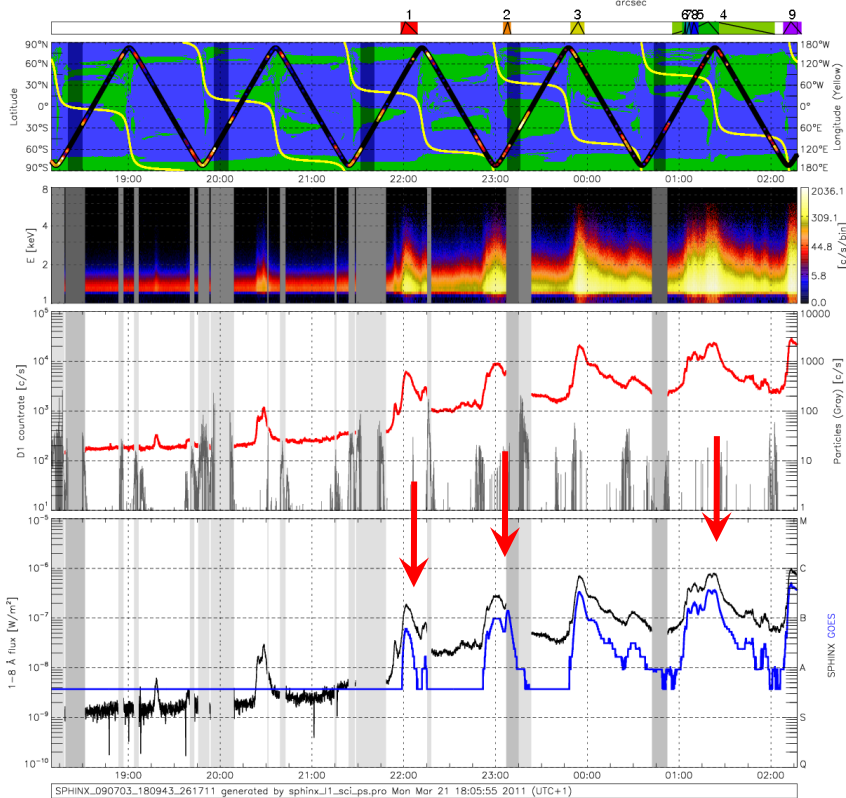
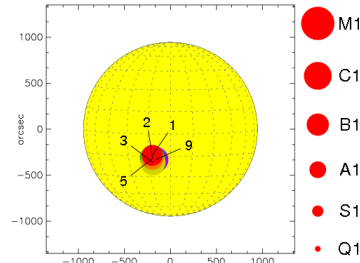


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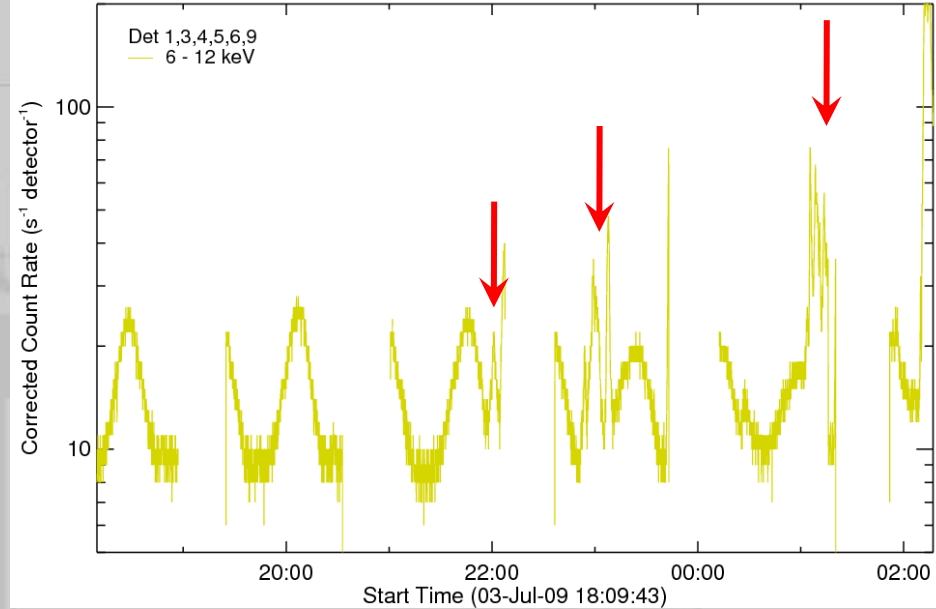
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4)	2009-07-04	00:55:27	01:23:27	02:02:27	A9.1	-
5)	2009-07-04	01:02:00	01:19:00	01:26:00	B3.6	S26E13
6)	2009-07-04	01:03:11	01:04:11	01:04:11	A2.4	-
7)	2009-07-04	01:04:45	01:06:45	01:07:45	A5.3	-
8)	2009-07-04	01:07:36	01:09:36	01:12:36	A6.2	-
9)	2009-07-04	02:08:00	02:13:00	02:20:00	B4.7	S27E11



SPHINX_090703_180943_261711 generated by sphinx_j1_sci_ps.pro Mon Mar 21 18:05:55 2011 (UTC+1)

HESSI Observing Summary Count Rates, Corrected



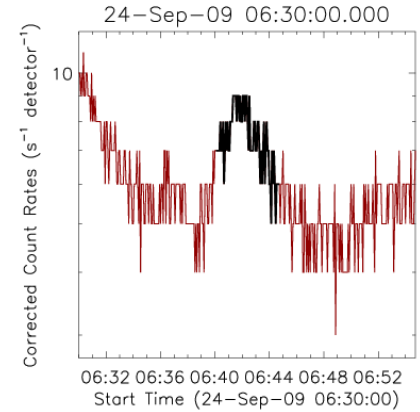
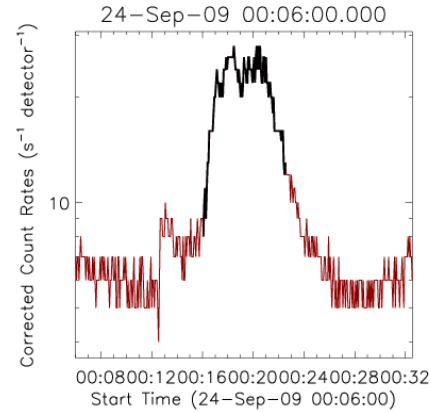
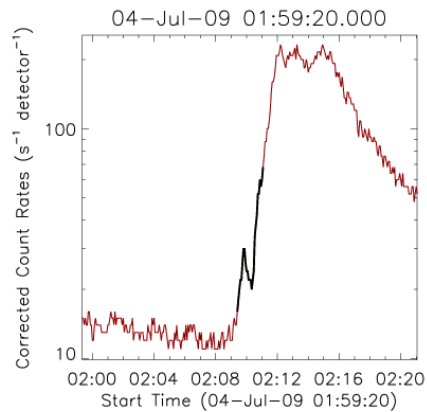
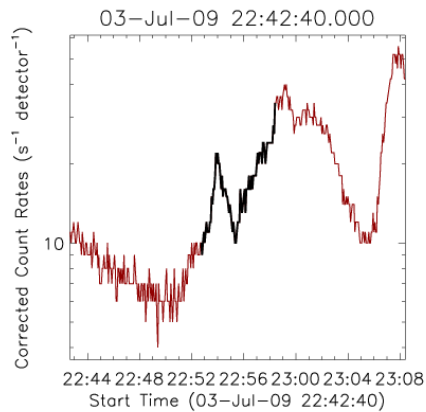
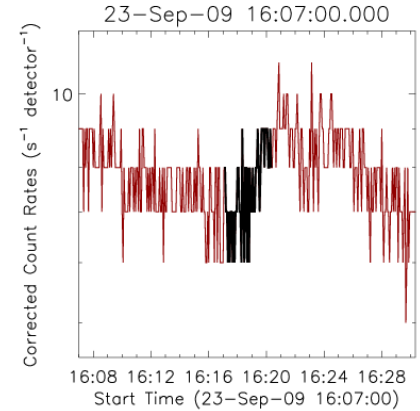
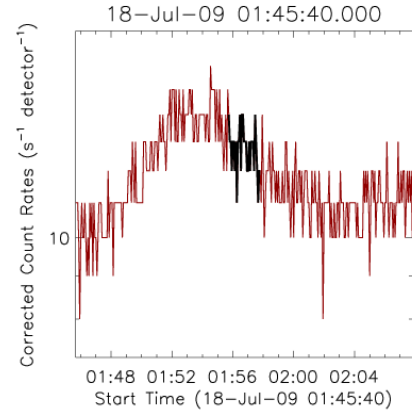
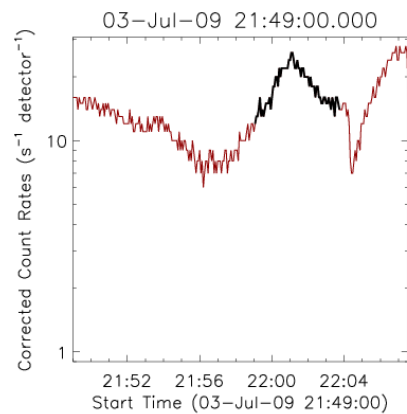
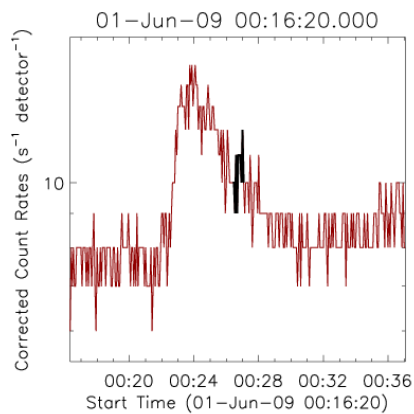
Flares were chosen by the inspection of RHESSI and SphinX data catalogues

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

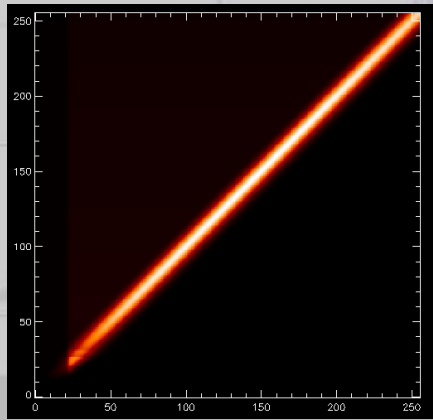


Red – RHESSI data, Black – SphinX observations

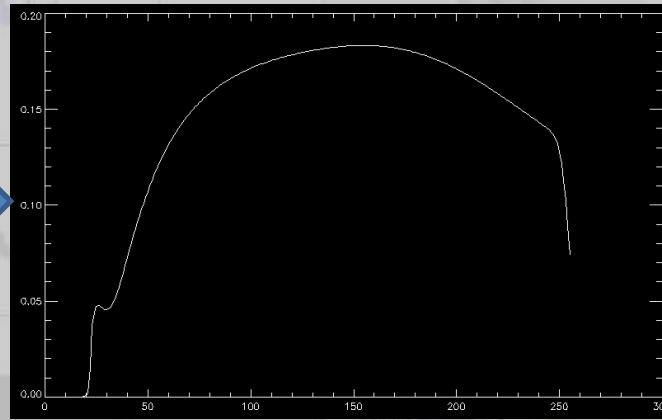
- 12 flares well observed by RHESSI (far from SAA, outside radiation belts)
- 12 s time intervals (244 intervals)
- energy range: 3-8 keV (16 energy bands, $\Delta E=0.3$ keV)

Fluxes comparison

cnts s⁻¹



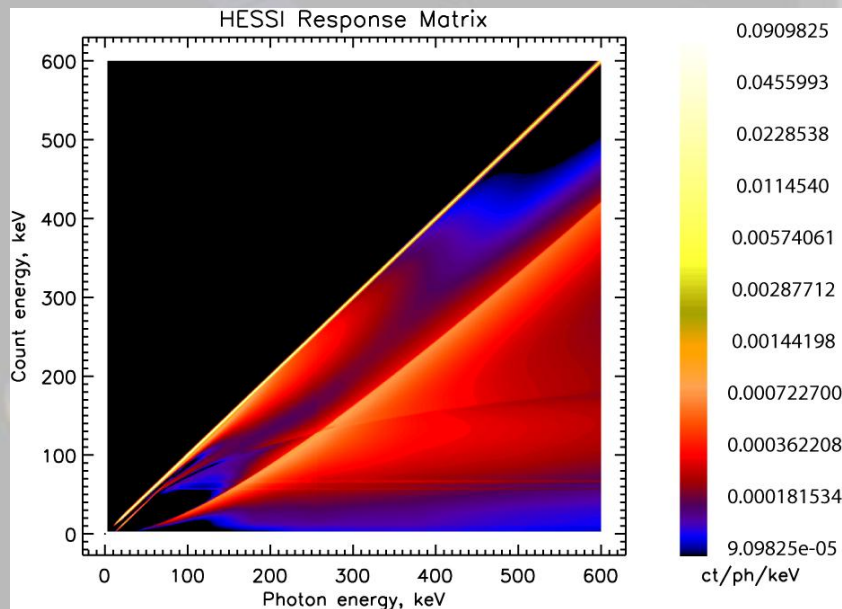
SphinX DRM



conversion factors



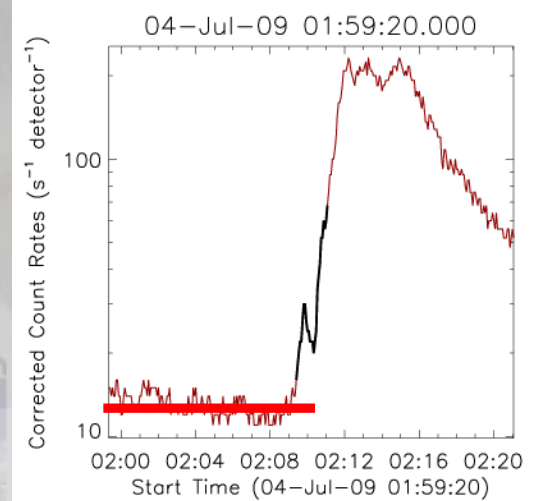
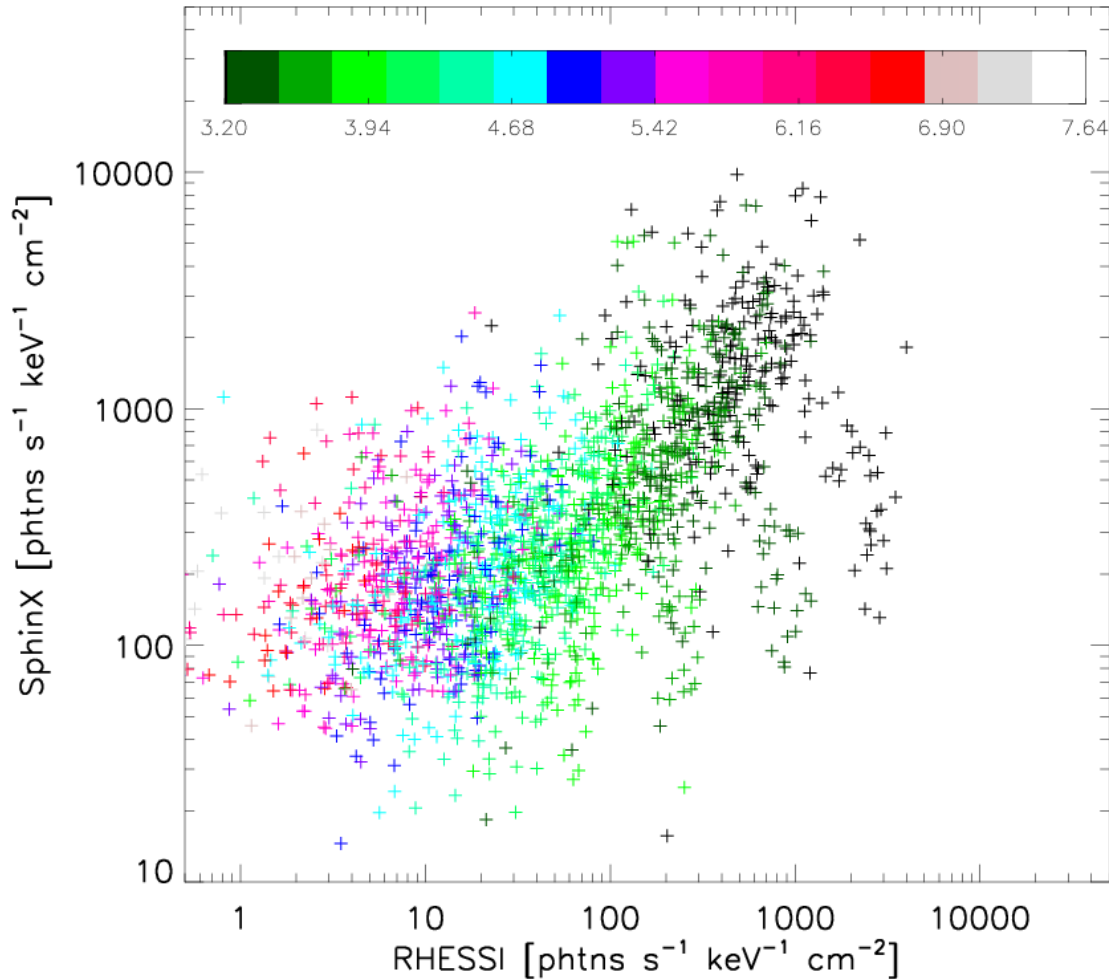
phtns s⁻¹ keV⁻¹ cm⁻²



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

RHESSI	SphinX
1-4 keV	3.03-4.03 keV
4-5 keV	4.03-5.03 keV
5-6 keV	5.03-6.03 keV

Fluxes comparison



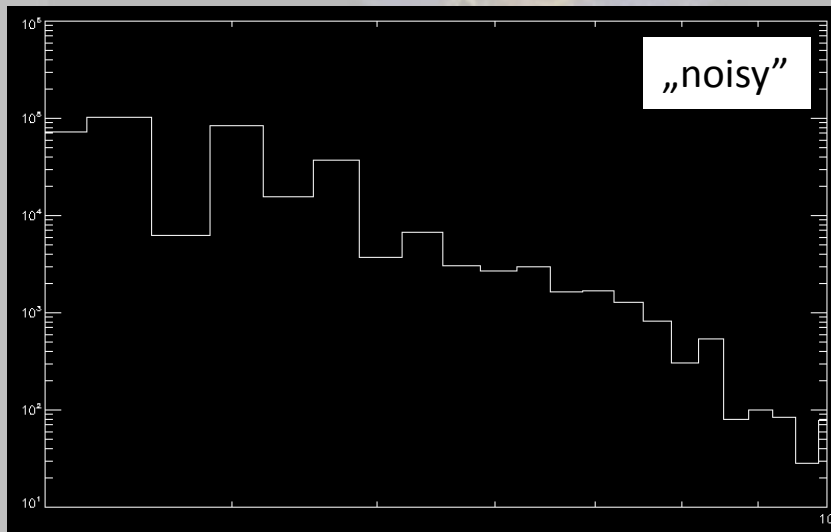
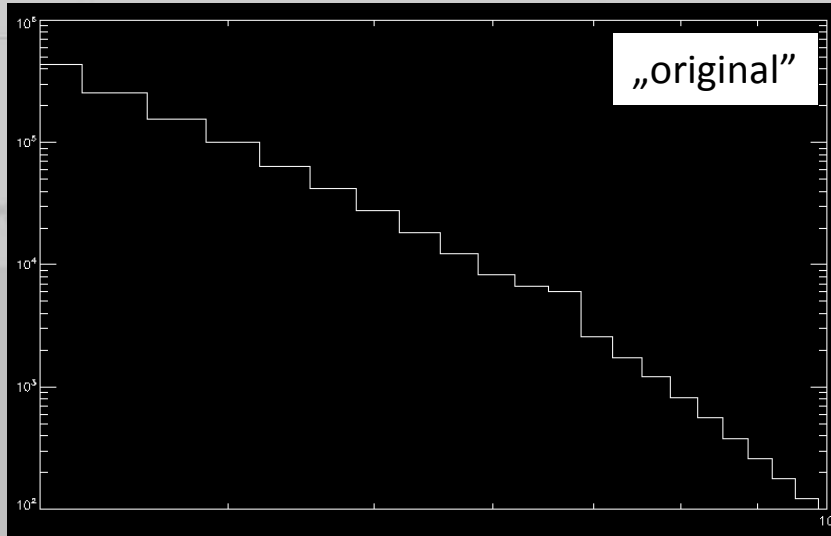
background subtracted fluxes
for all time intervals

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

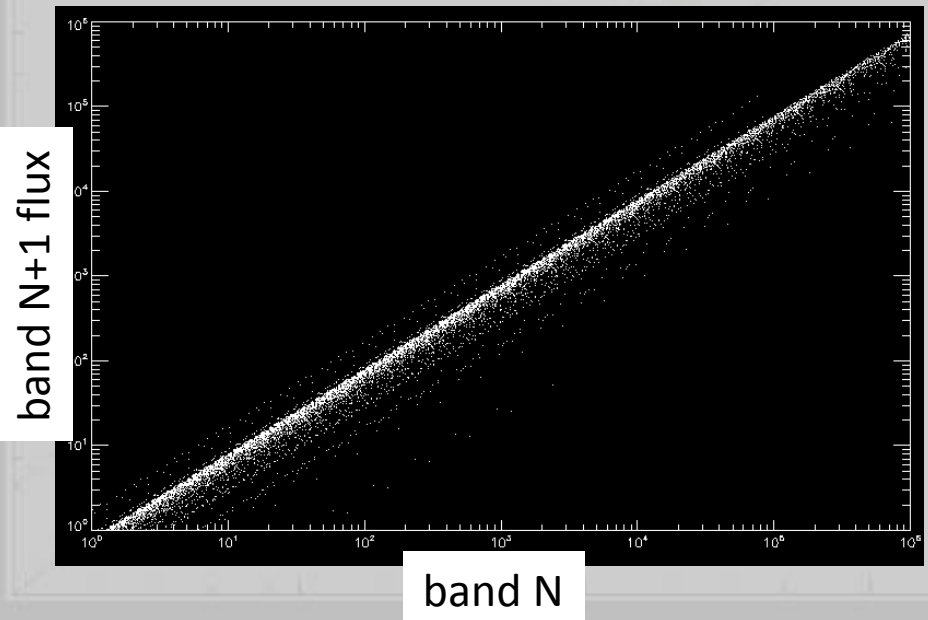
$dE=0.3\text{keV}$, $EM=10^{49}\text{cm}^{-3}$, $T=1\text{keV}$



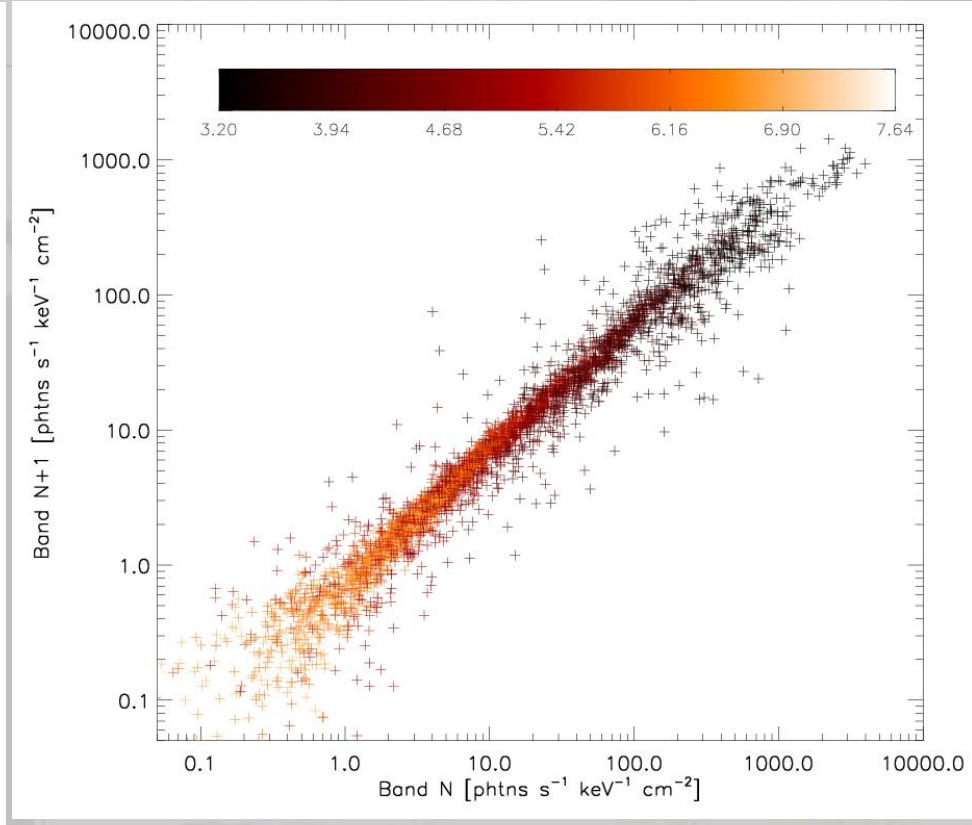
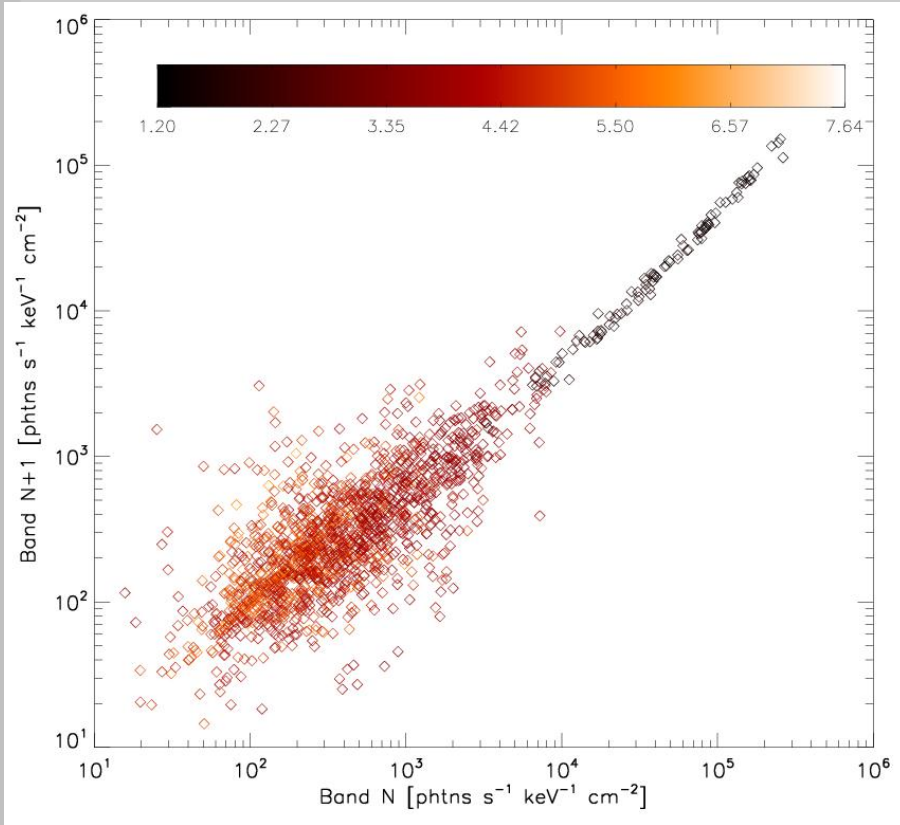
Where is located the end of real SphinX measurements?

Fluxes in neighbouring energy bands were compared

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



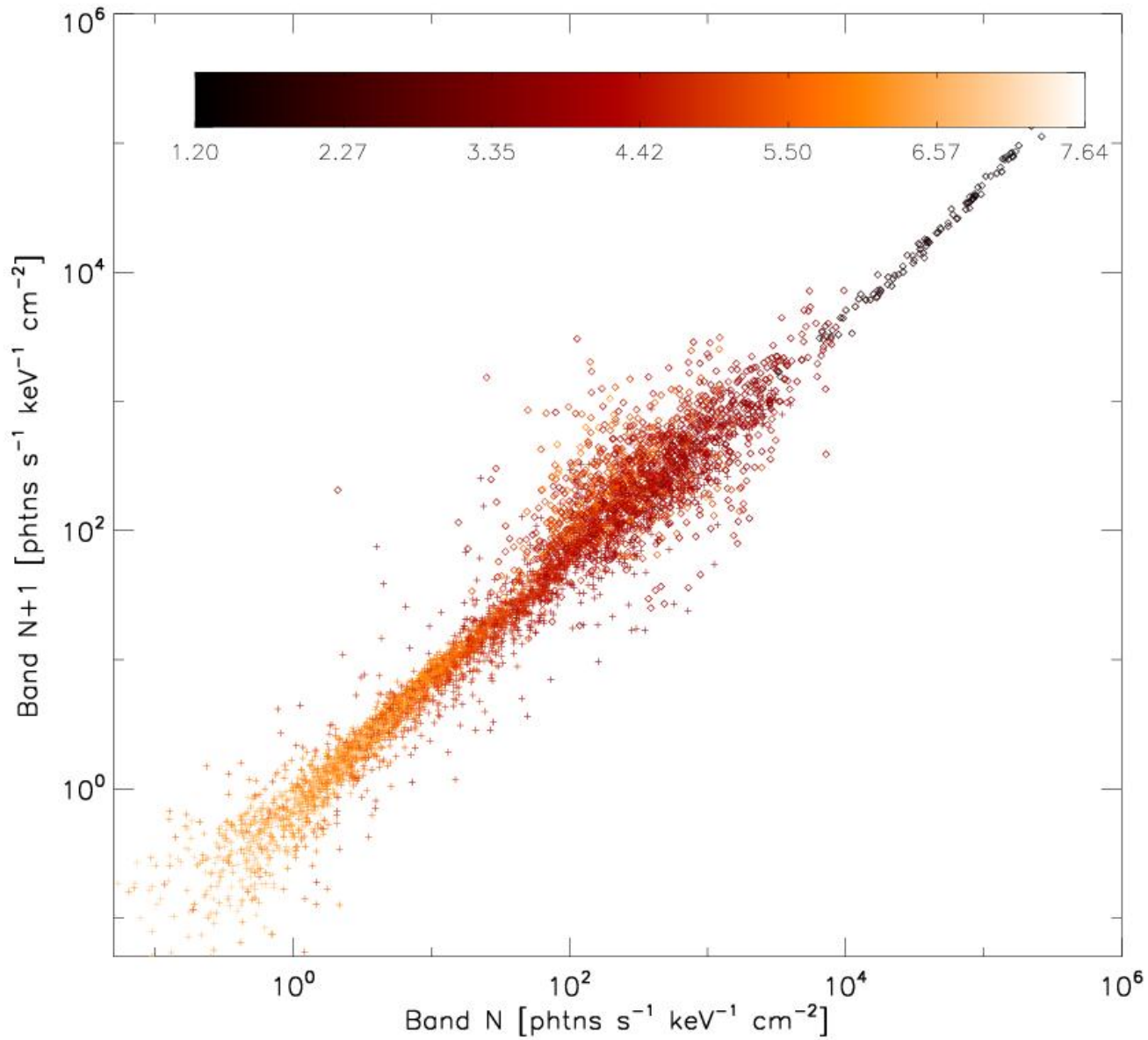
Data self-consistency



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

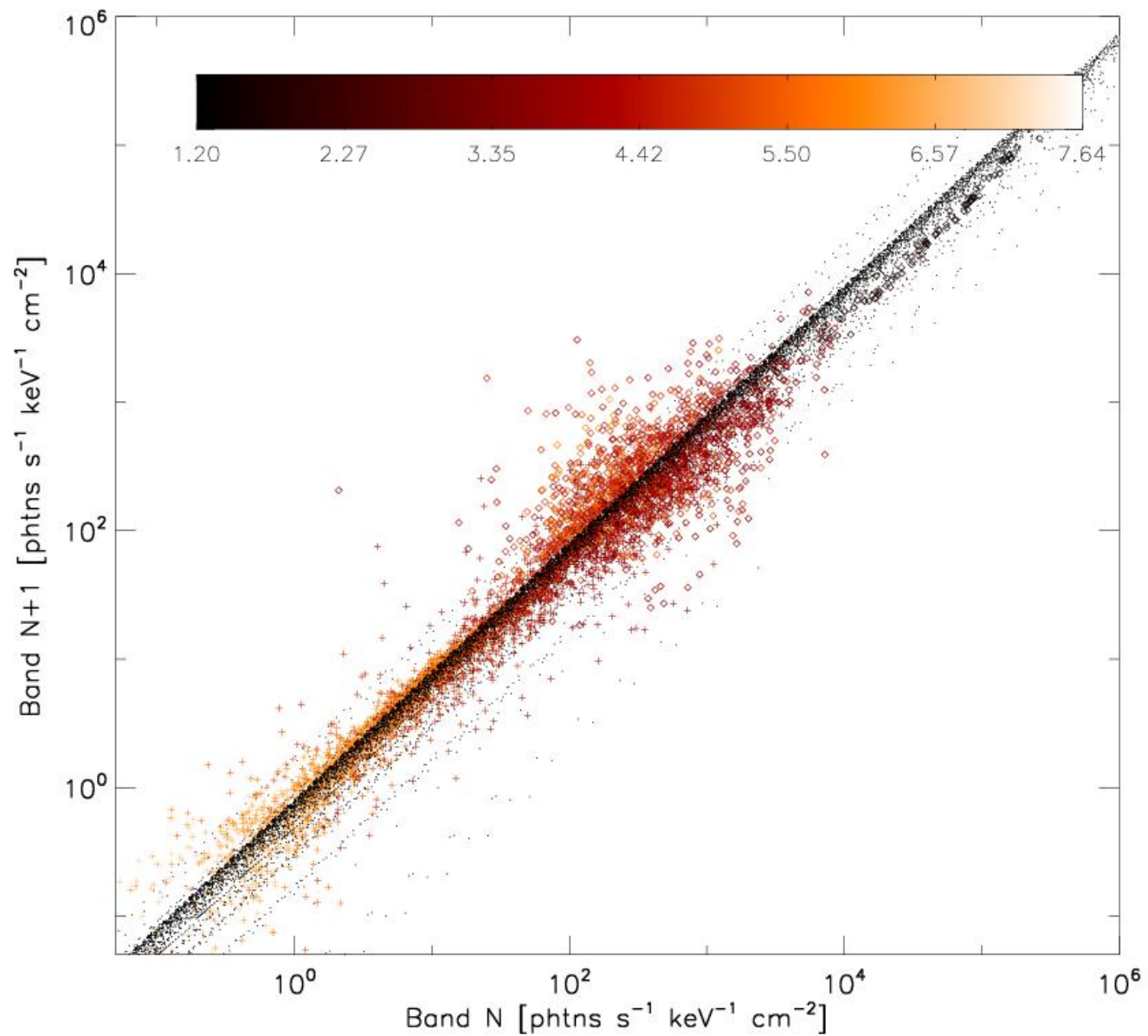
RHESSI – more noisy in whole energy range (below 4 keV – drop in sensitivity, above 7 keV – poor statistics)

Data self-consistency



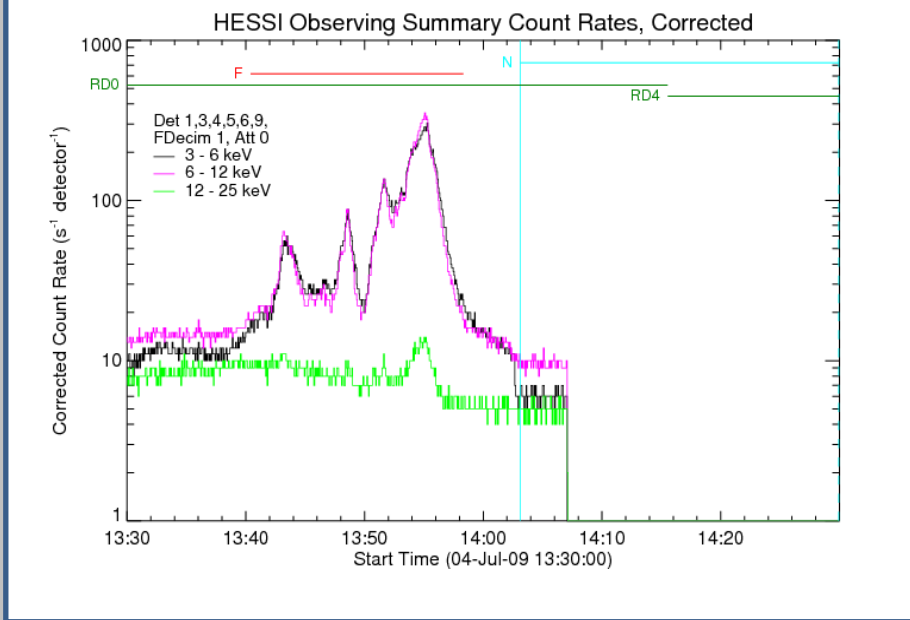
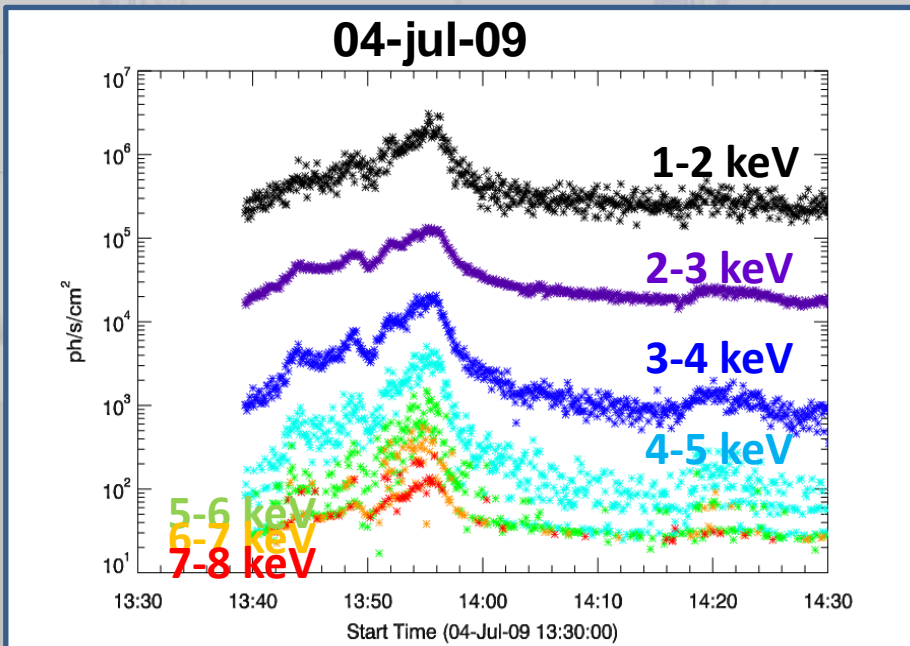
SI: EphiX
N: 3.03-4.03 keV
N+1: 4.03-5.03 keV
N+2: 5.03-6.03 keV

Data self-consistency



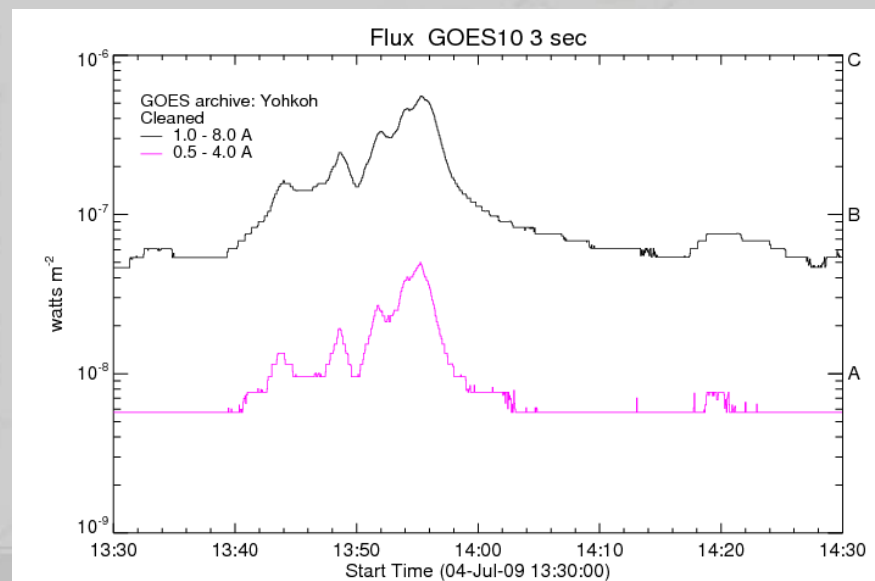
SI: EphiX
E: 3.03-5.03 keV
W: 0.03-0.03 keV
R: 5.03-5.98 keV

Case study: July 4th



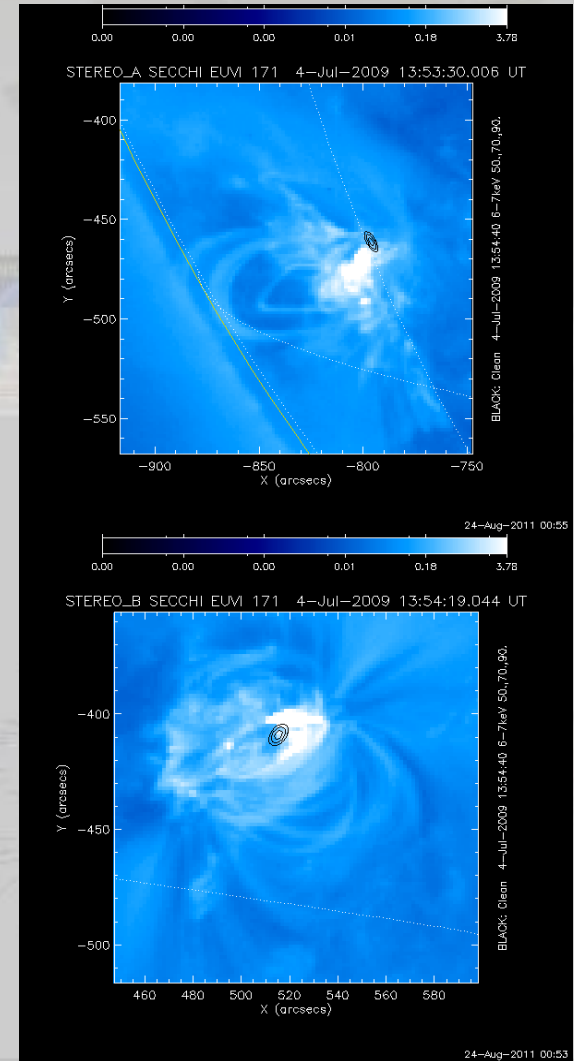
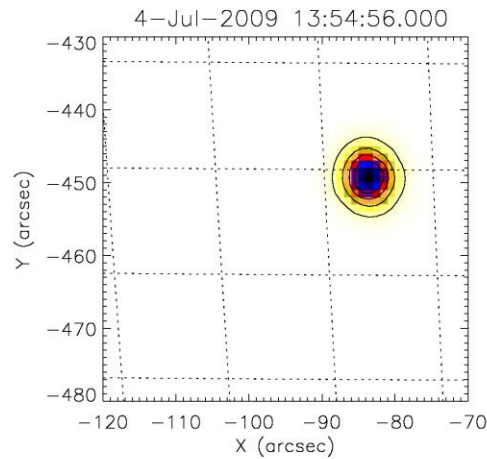
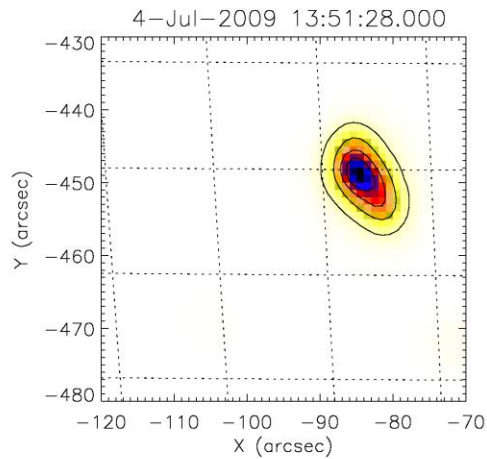
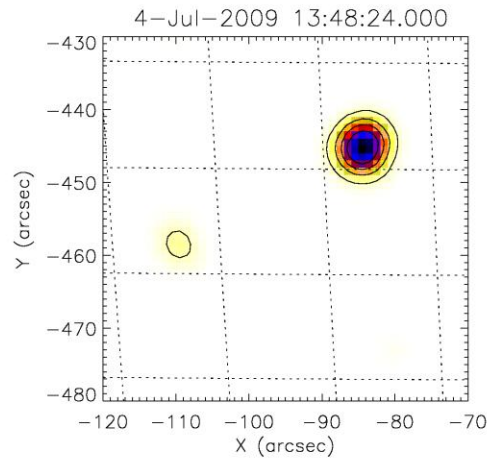
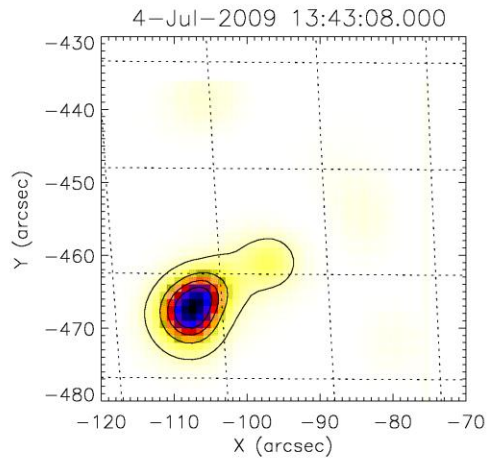
Date	SphinX max [UT]	RHESSI max [UT]	GOES class
4.07.2009	13:44	13:43	B1.6
	13:48	13:48	B2.4
	13:54	13:52	B4.6
	13:55	13:55	B5.3

All four peaks were observed by SphinX, RHESSI and GOES

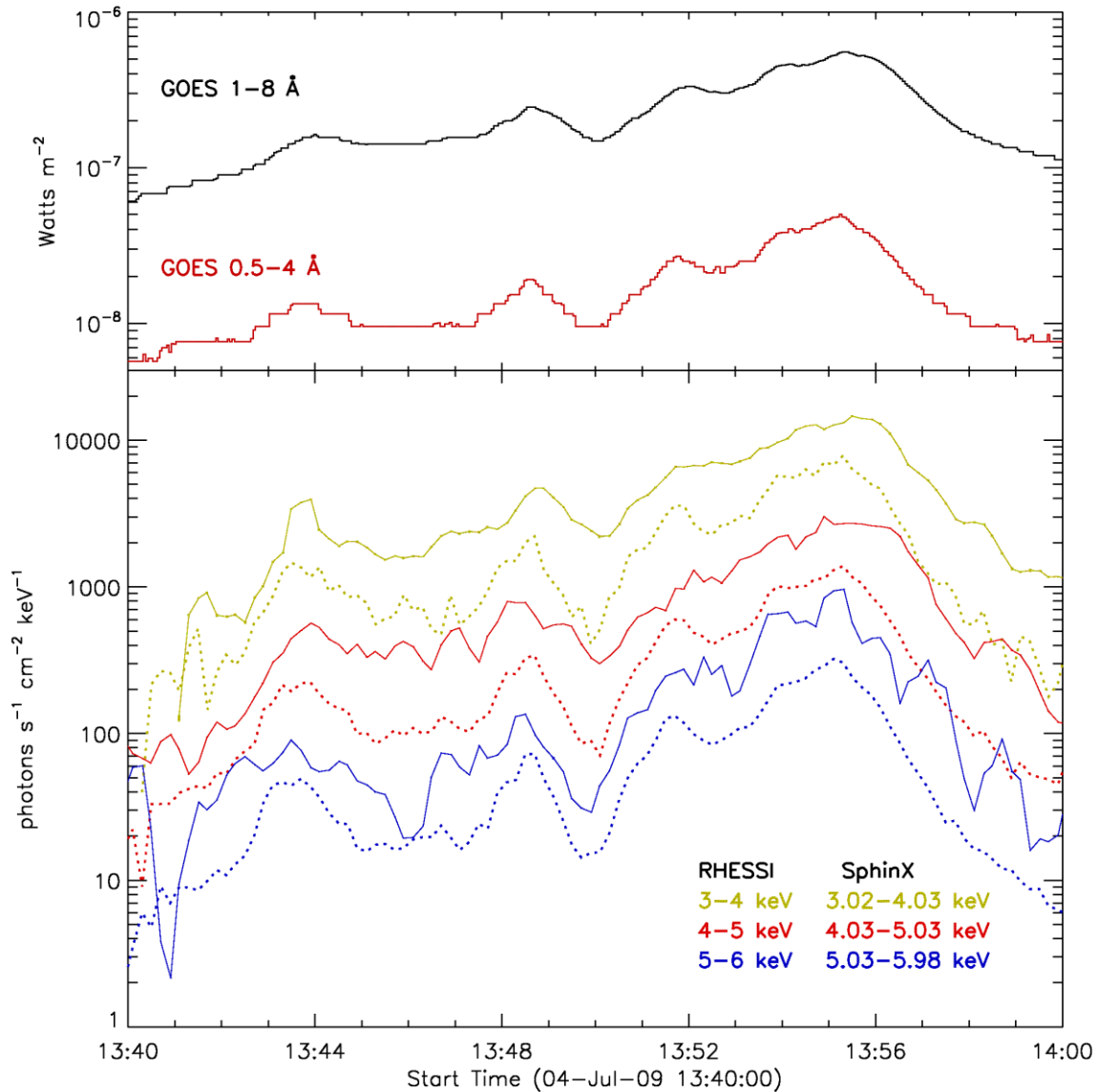


Case study: July 4th

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



Case study: July 4th

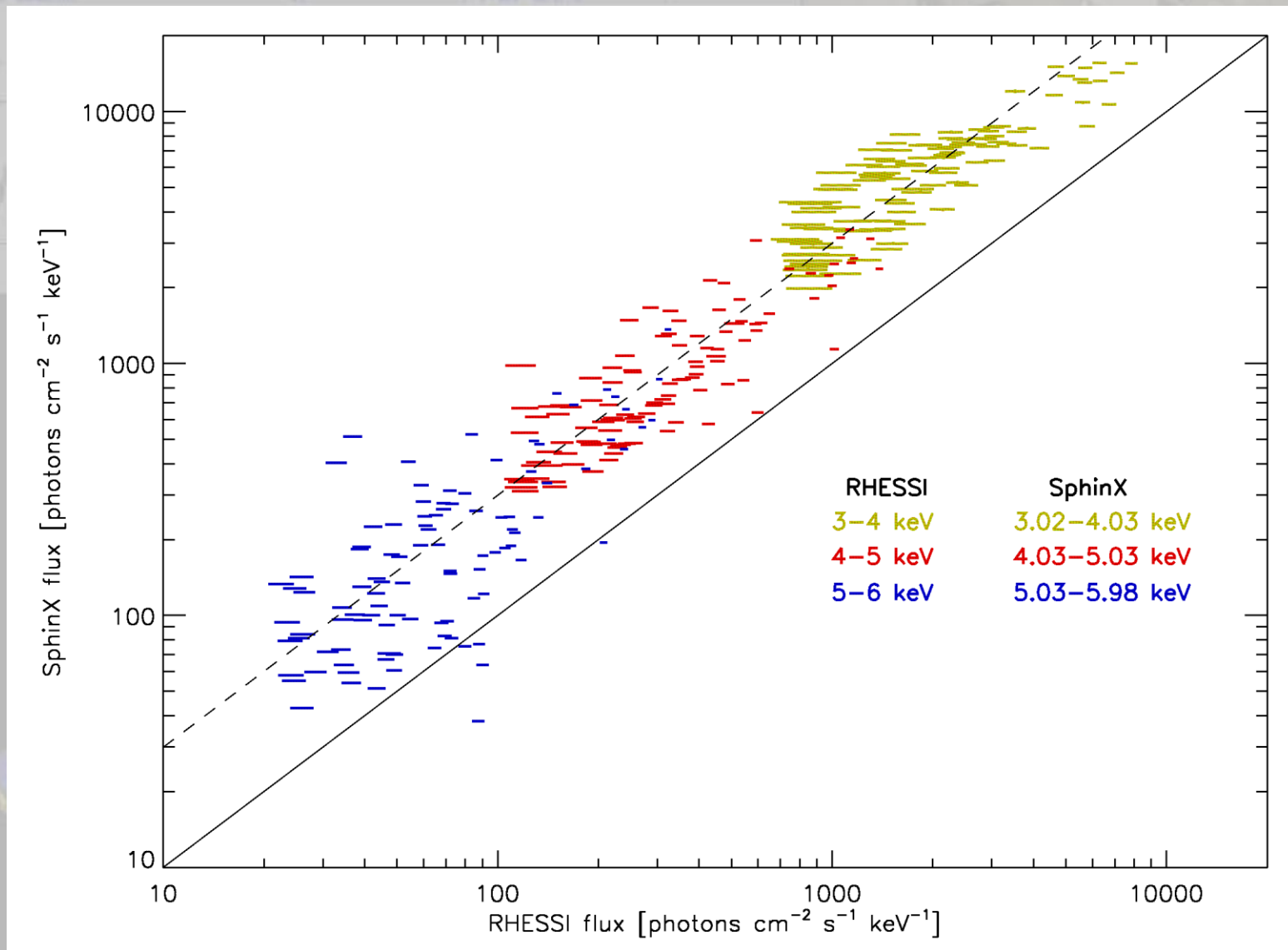


Time evolution is similar for all three instruments.

There is a difference in fluxes (factor ~ 3)

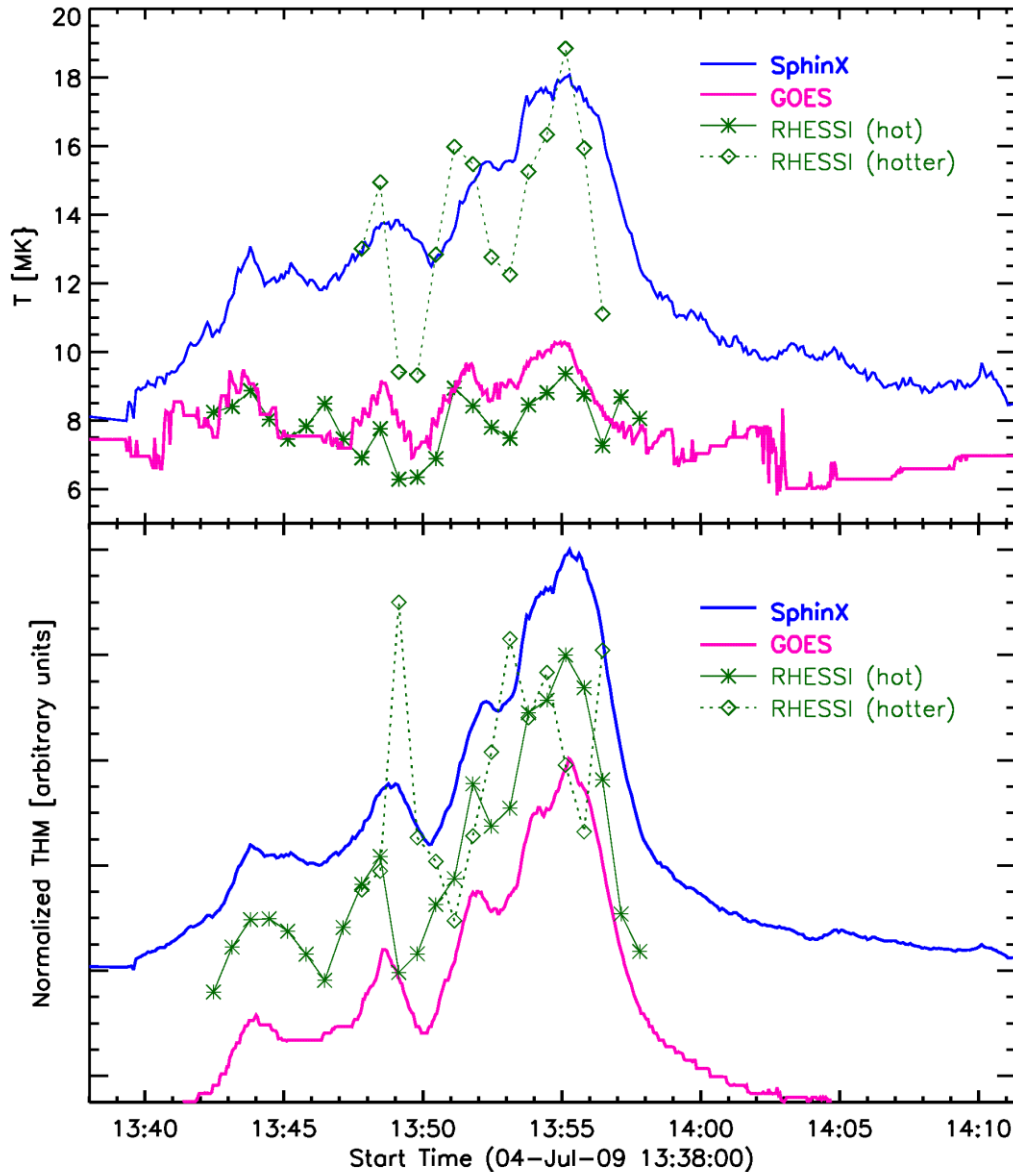
line – SphinX
dots – RHESSI

Case study: July 4th



SphinX
3.02-4.03 keV
4.03-5.03 keV
5.03-5.98 keV

Case study: July 4th



SphinX – flaring component (subtracted active region background)

RHESSI – two temperature fit

GOES – filter ratio method

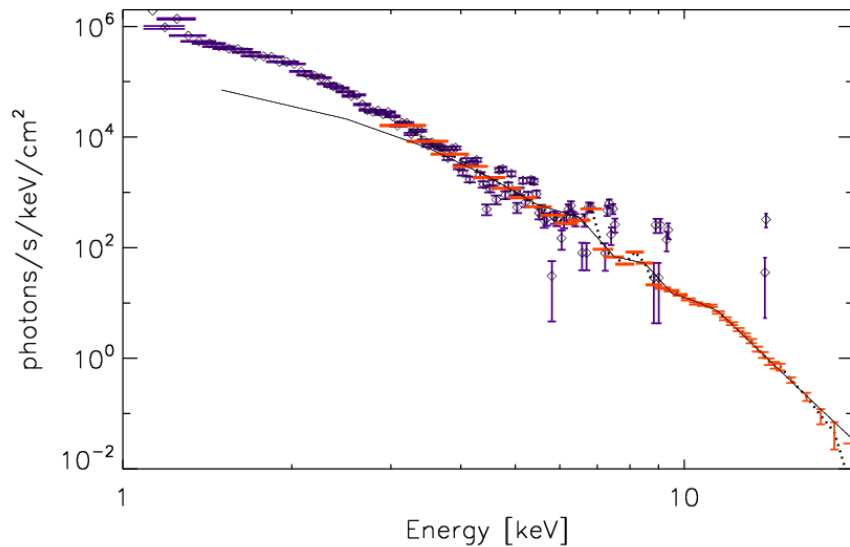
The thermodynamic measure represents volume-unrelated part of the E_{th} :

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

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.

