Advanced determinations of flare plasma characteristics from X-ray observations

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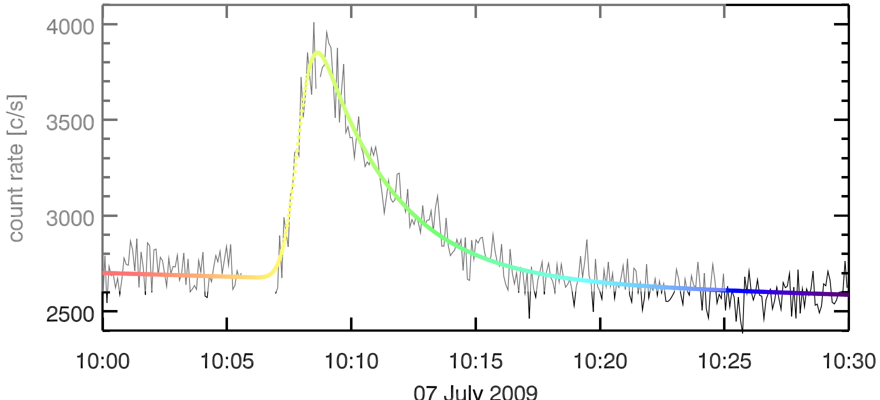
Goals & Motivation

Huge dataset of small solar flares observations by SphinX

Our goal is preparation of the catalogue of X-ray flare events parameters based on interpretation of SphinX observations

Because of statistical noise, data gaps and time-overlapped events, it is a challenge to obtain these properties in systematic and consistent way.



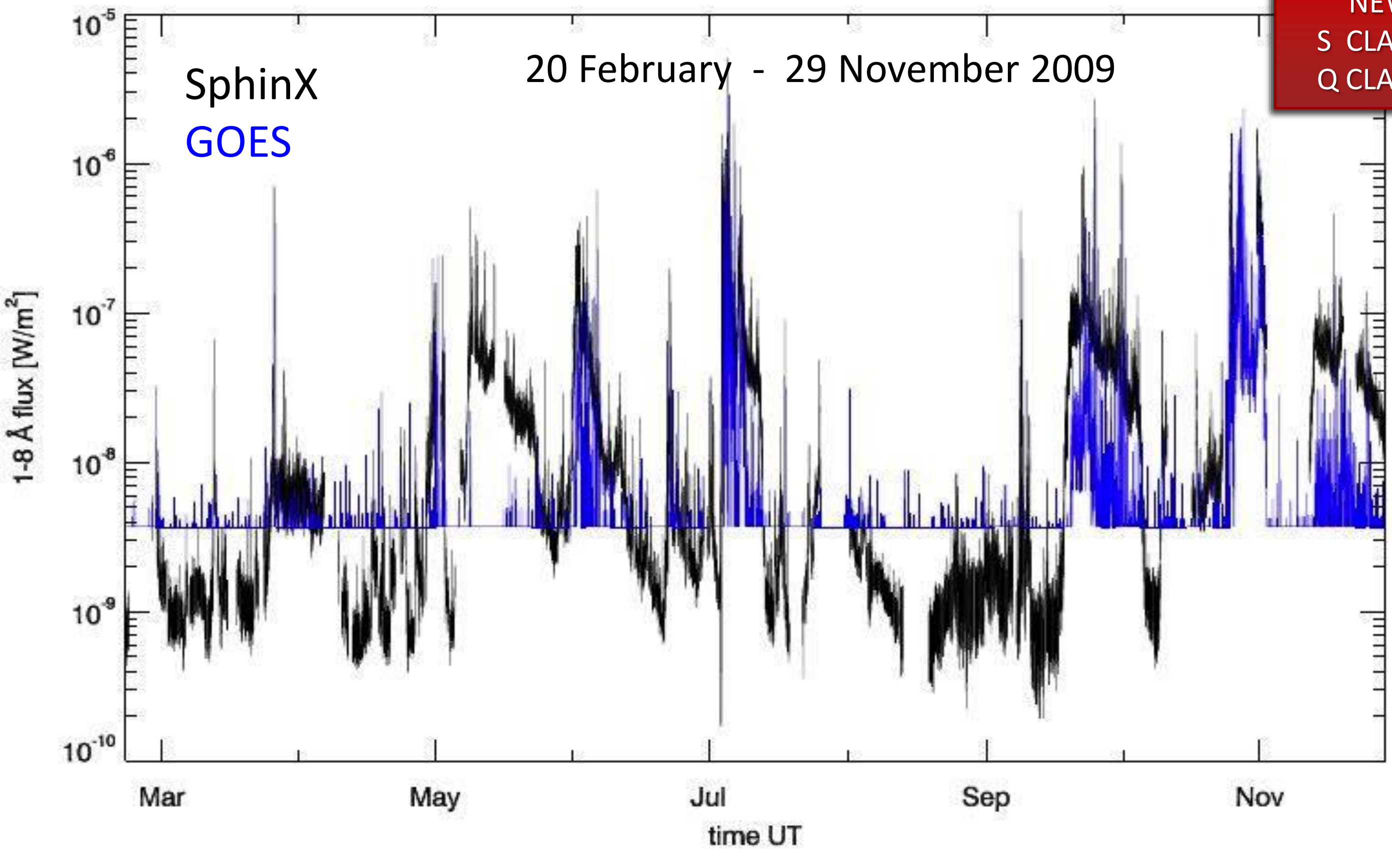
Solar Photometer in X-ray

SphinX BASIC INFORMATIONS	
LAUNCHED:	30 January 2009 at 13:30 UT from Plesetsk Cosmodrom
SATELLITE:	CORONAS – Photon
ORBITS PARAMETERS:	orbit duration- 96min altitude - 550km near polar orbit
MASS:	3.7 kg
POWER:	10 W
ENERGY RANGE:	1.2 keV - 15 keV in 256 energy bins
LIFESPAN OF THE MISSION:	20 February - 29 November 2009

SphinX Data

minimum of solar activity, 23rd / 24th Solar Cycles

NEW SXR FLARES CLASSES
S CLASS - S1 = 1. e-09 W/m²
Q CLASS - Q1 = 1. e-10 W/m²



GOES threshold 3.726e-9 W/m²

ARs & flares features

Figure 1. Solar fluxes in 1-8 Å energy band calculated from SphinX data (black colour) compared with those observed by GOES (blue colour). The characteristic features of ARs and flares can be seen. It is also apparent that due to lack of sensitivity GOES did not observe any X-ray flux variability below 3.73×10^{-9} $[W/m^2]$.

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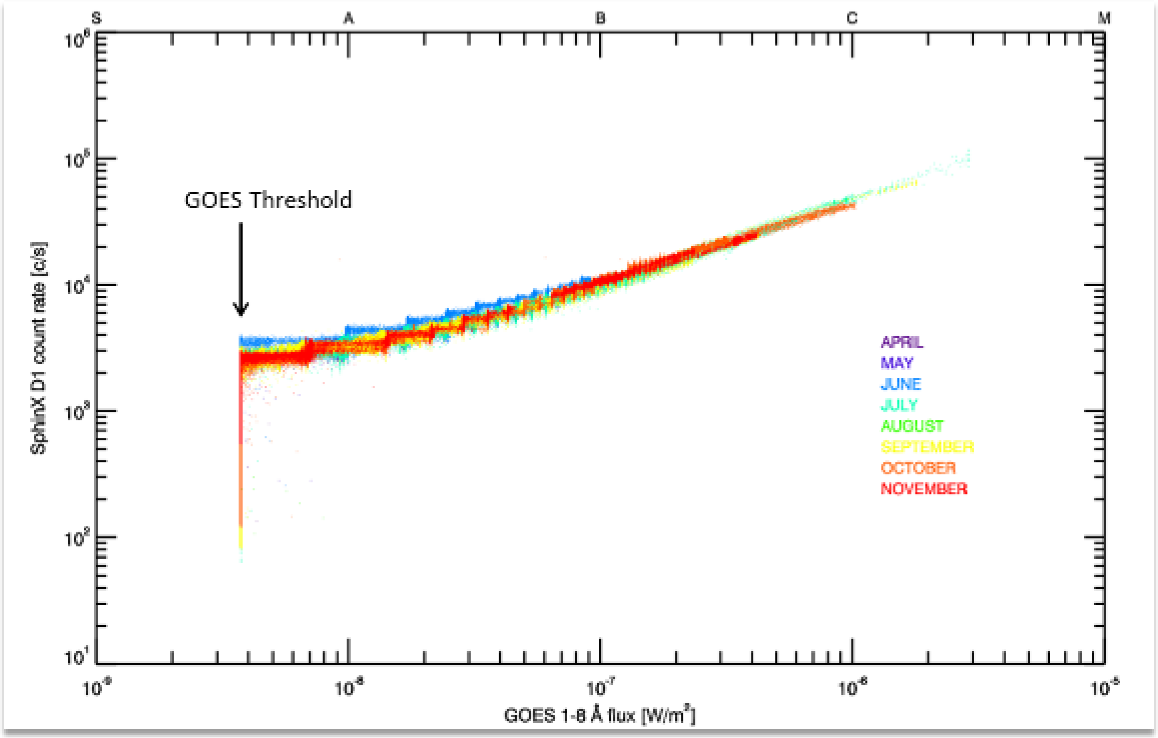


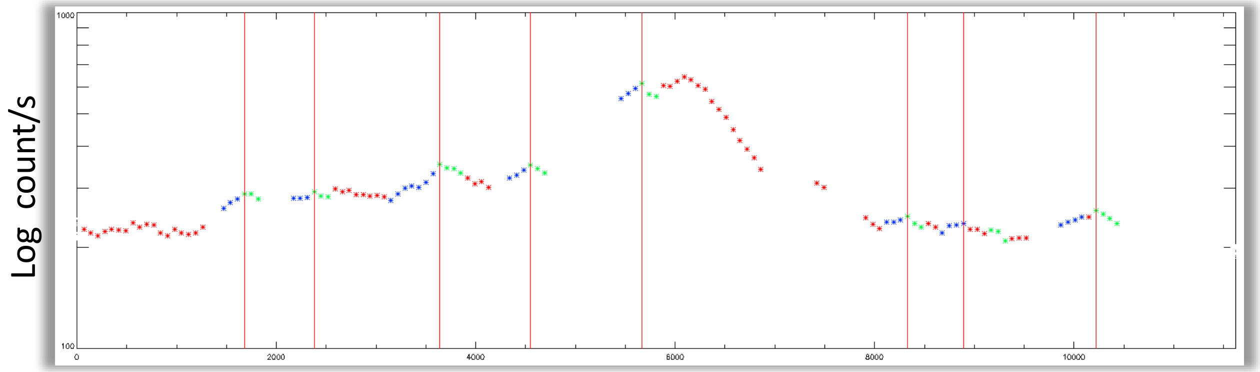
The largest SphinX flare
5th July 2009
C 2.7 GOESS class flare

GOES threshold = 3.726e-09 W/m^2 3.7 S
D1 minimum = ~2.e-10 W/m^2 2.0 Q

Flare Detection Algorithm

Semi-automated method
step by step:

- data preparation: averaging
- serching for 4 points of consecutive increase and 3 points of decrease after them
- maxima finding
- visual inspection and correction

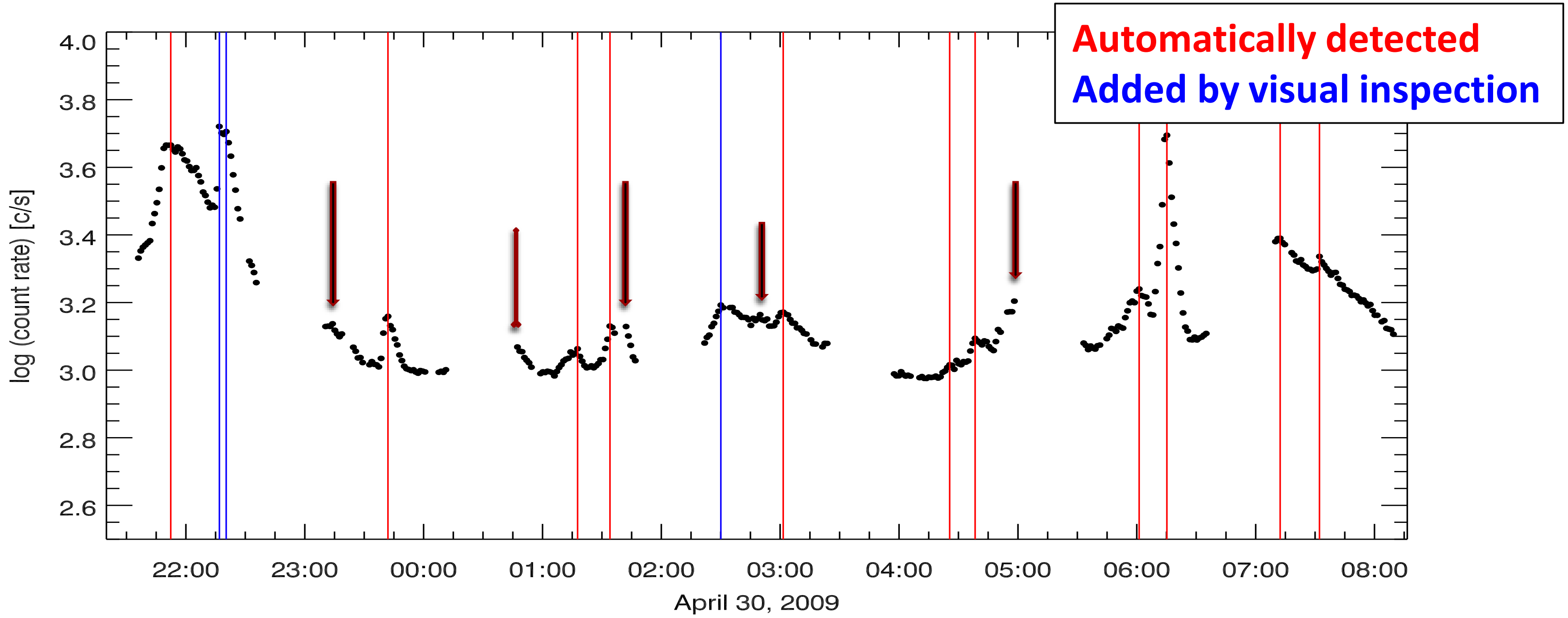


The algorithm is very sensitive but still omits some flares.

Algorithm have detected 1604 FLARES from April 6th to November 30th

Flare Detection Algorithm

<u>1601 flares</u> **20 February - 29 November 2009**



51% PERCENTAGE OF SOLAR UNBIASED MEASUREMENTS WHEN THE INSTRUMENT WAS IN THE ON STATE

Elementary SXR flare time profile

$$F(t) = 0.5\ \sqrt{\pi}\ A\ C\ exp(D(B-t) + (C^2D^2)/4) \cdot$$
$$[erf((2B + C^2D)/2C) - erf((2(B-t) + C^2D)/2C)] +$$
$$+Et + F$$

Convolution of two functions

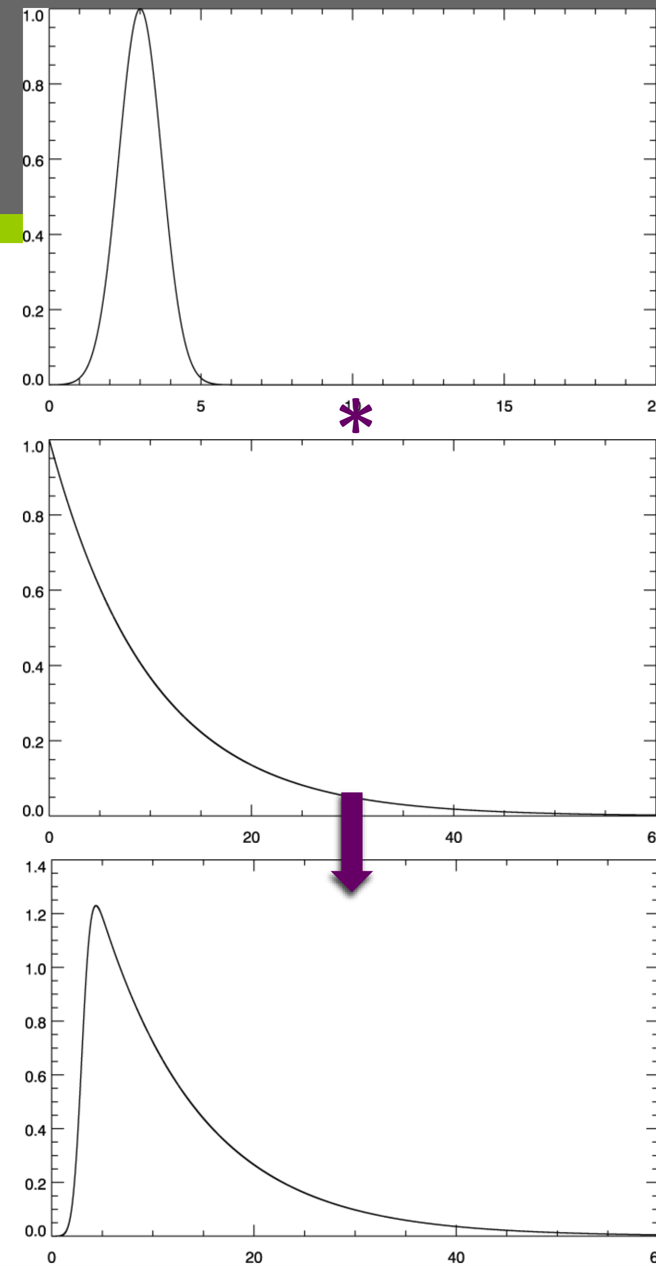
Gauss function: $f(t) = Ae^{(-(t-B)^2/C^2)}$

Exponential function: $f(t) = e^{(-Dt)}$

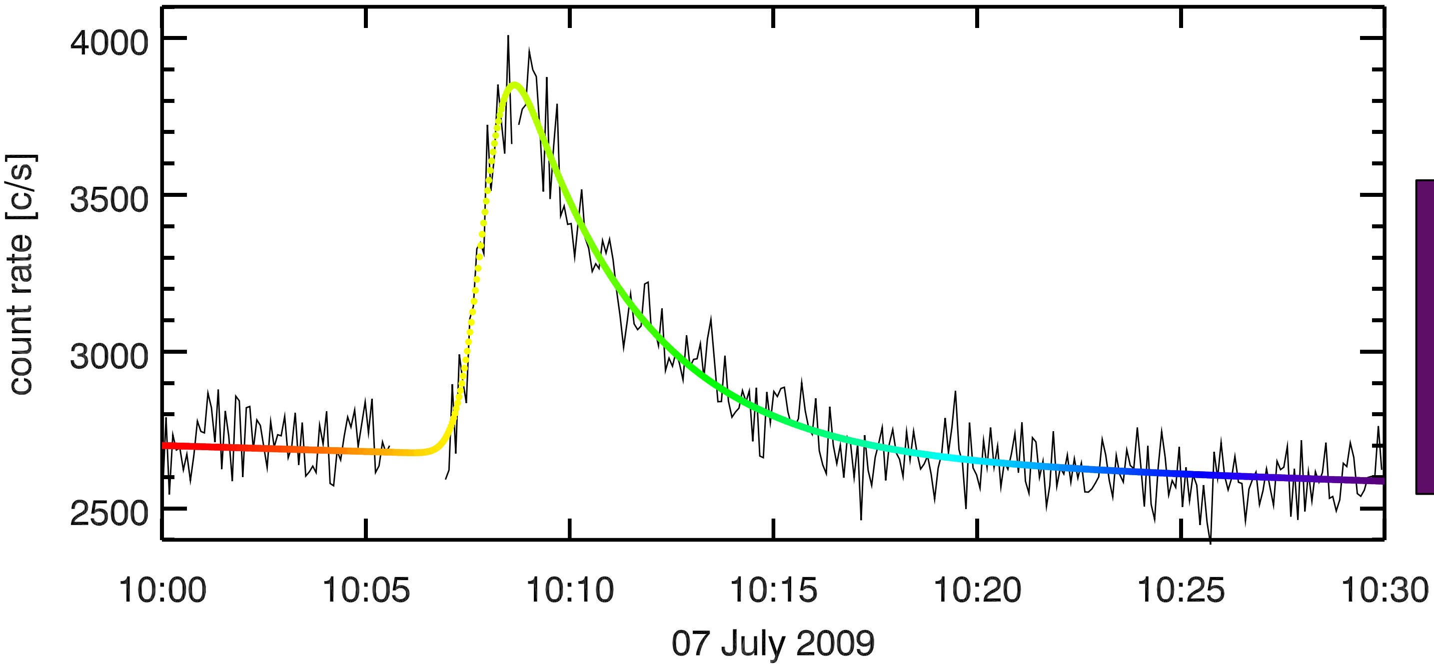
Linear background

$$f_{bg}(t) = Et + F$$

4 parameters (flare) +
2 parameters (linear background)
= 6 PARAMETERS

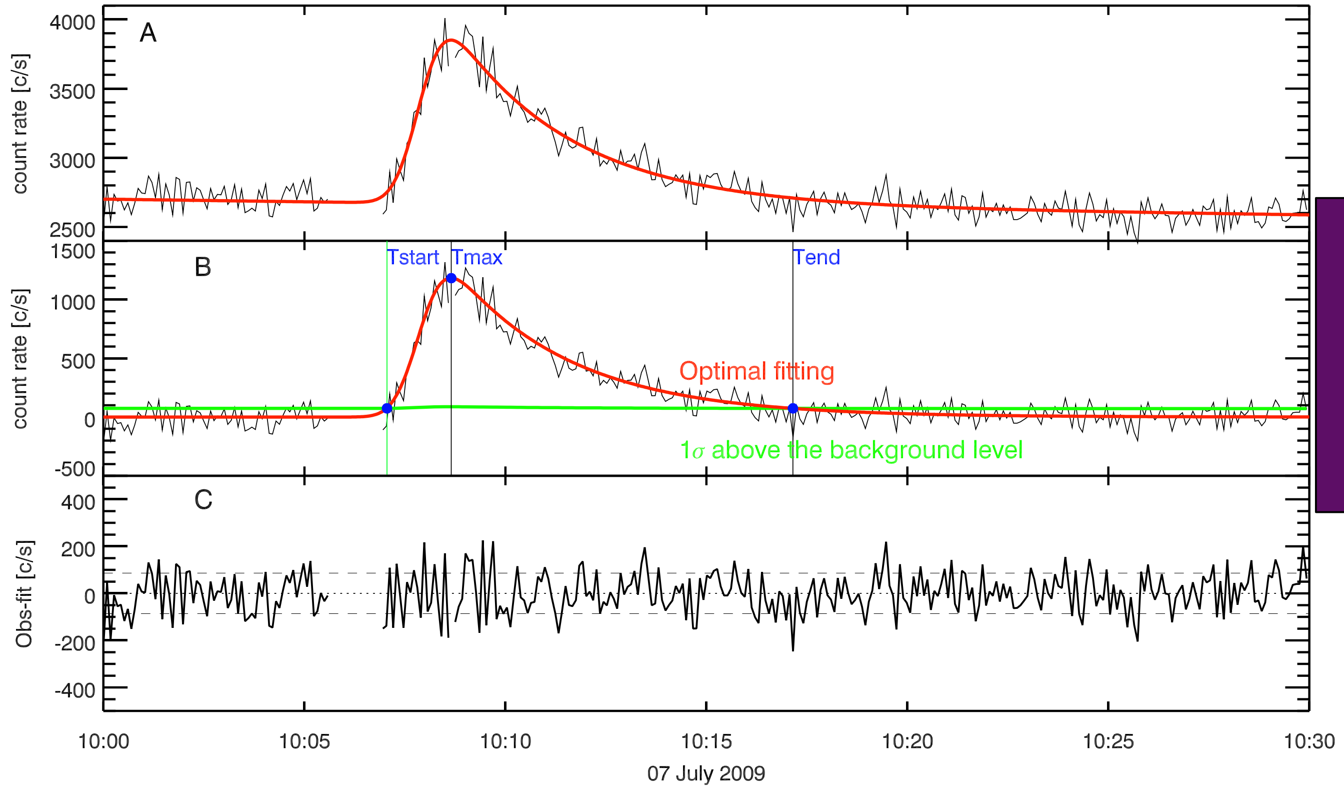


Flare Temporal Parameters



- TIME OF START
- TIME OF MAXIMUM
- TIME OF END
- AMPLITUDE (incremental class)

Flare Temporal Parameters



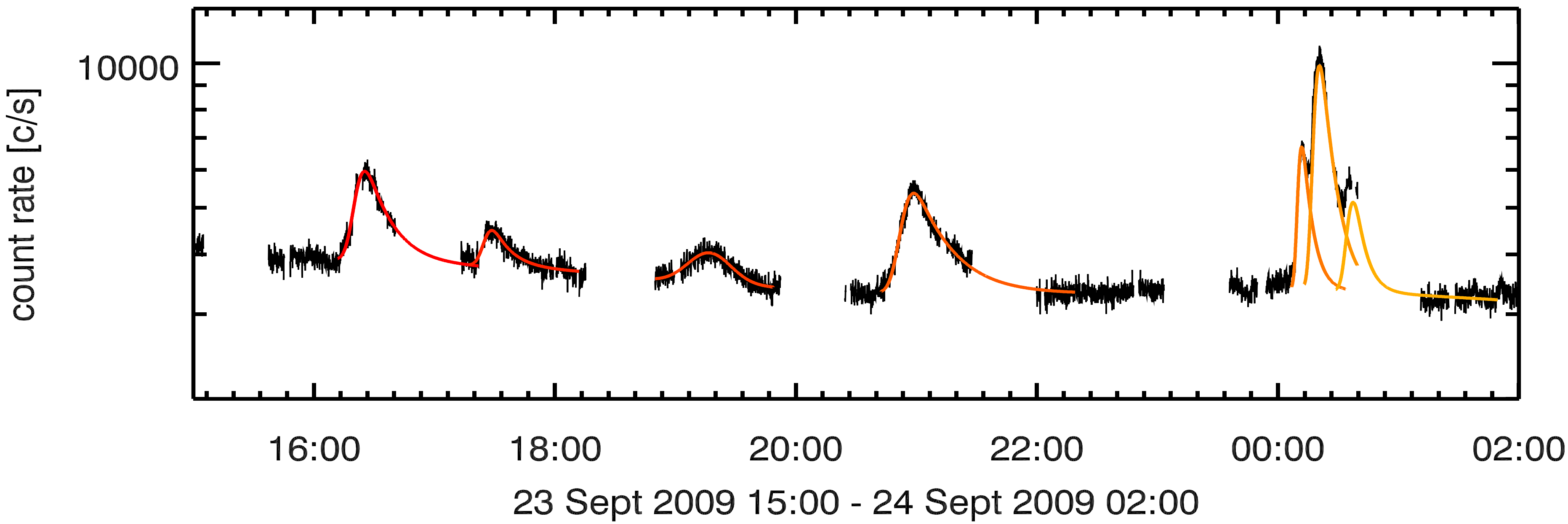
TIME OF START

TIME OF MAXIMUM

TIME OF END

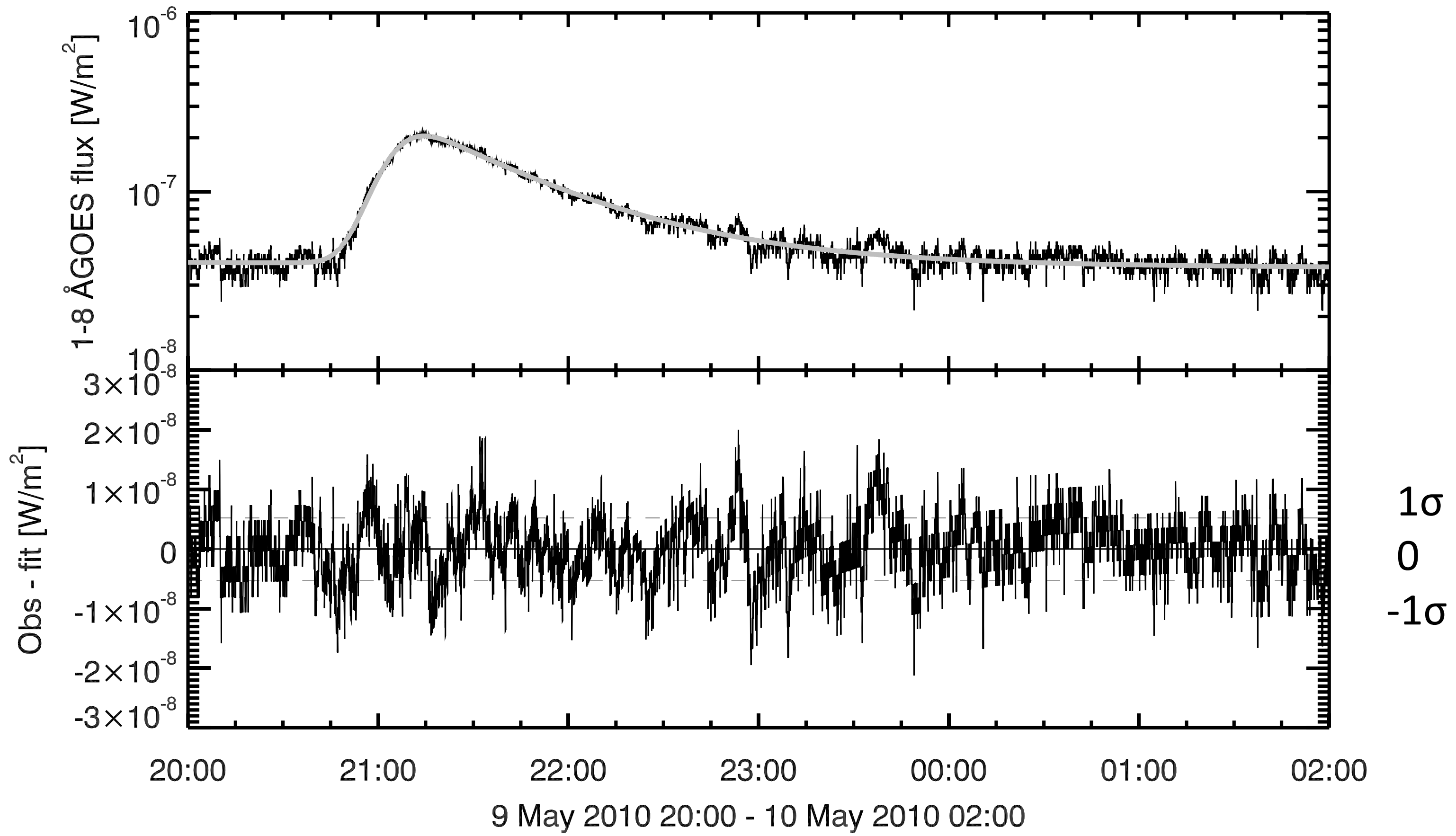
AMPLITUDE (incremental class)

Fitted SphinX profiles



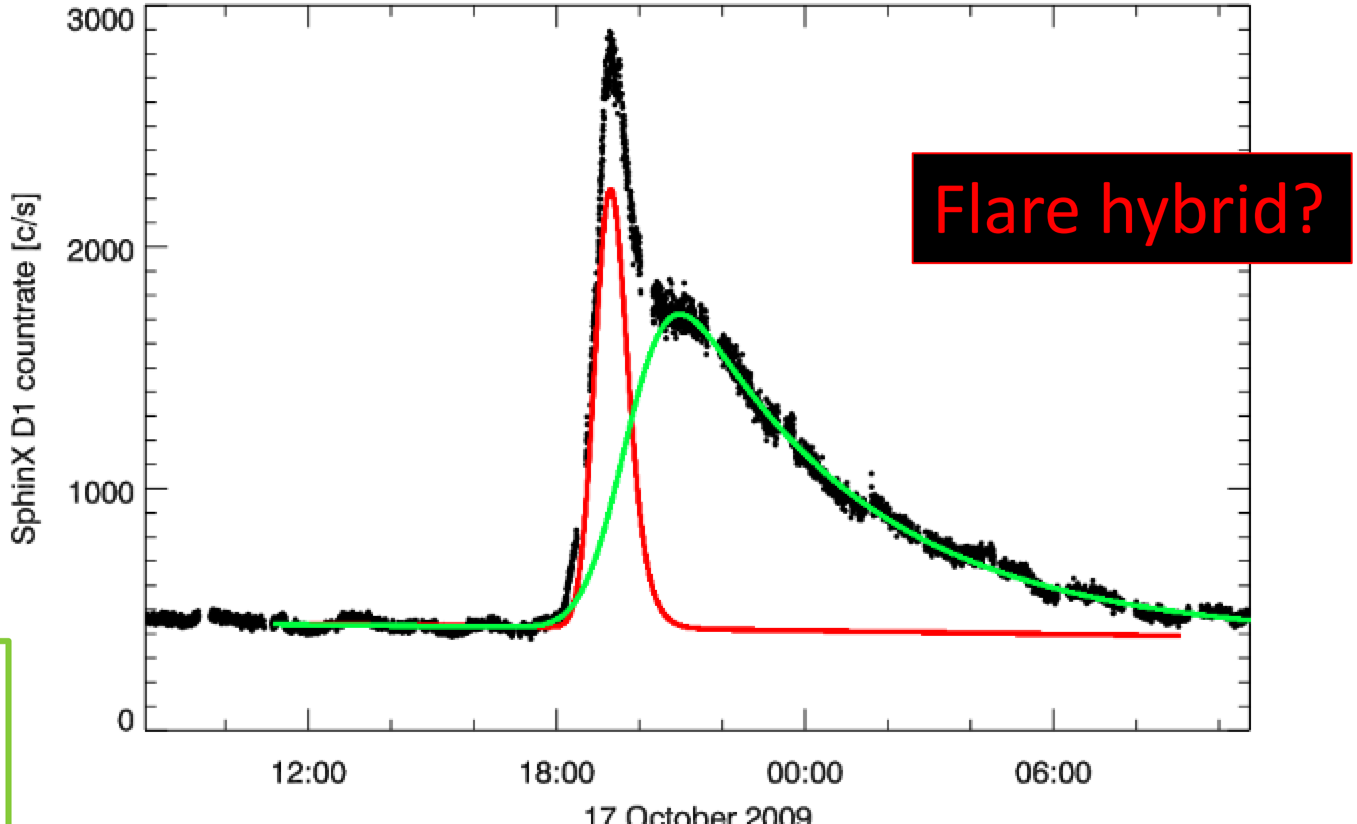
SphinX 1.2 - 10 keV lightcurve with optimal fit of elementary flares.
The last three events in the plot are examples of overlapped flare profiles. The coloured lines represent the best quality fits to the individual flares. The fitted profiles are plotted from the start to the end time of respective flares.

GOES flares time profile shape



EXAMPLE 17 October 2009 flares

Elementary flare time profile optimal fits



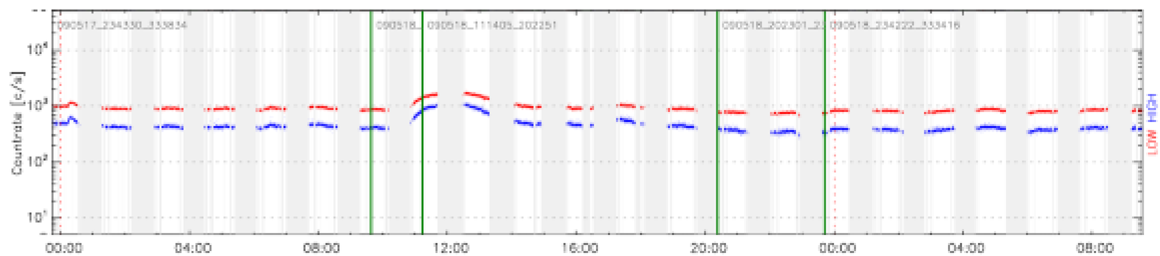
Flare #1 Flare #2

DIAGNOSTIC RESULTS:
max T 5.48 [MK]
max EM 1.23×10^{47} [cm^{-3}]
max T 4.57 [MK]
max EM 1.17×10^{47} [cm^{-3}]

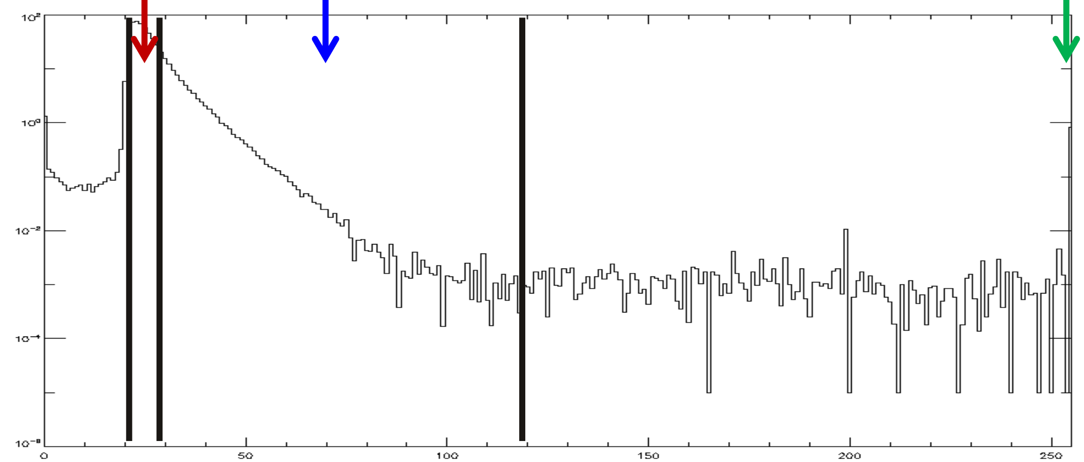
Plasma diagnostics

SphinX lightcurves in two channels:

Low (red curve): countrates of photons within energy range 1.16 - 1.5 keV.
High (blue curve): countrates of photons within energy range 1.5 - 15.07 keV.



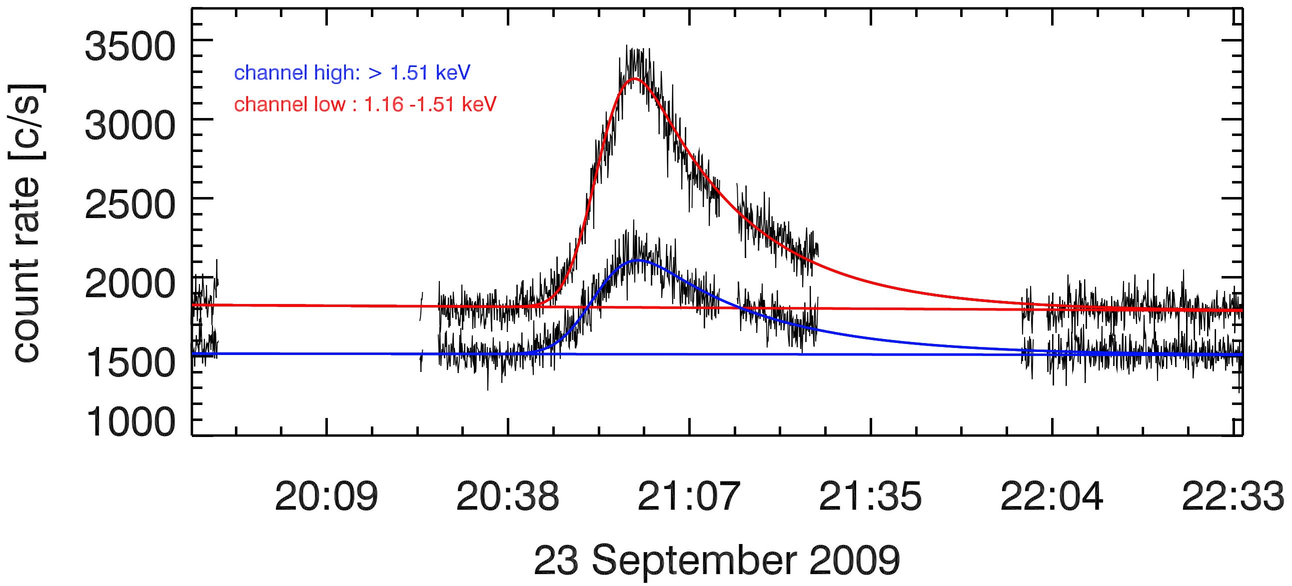
LOW HIGH ENERGETIC PARTICLES (last bin)



ISOTHERMAL APPROXIMATION USED FOR PLASMA TEMPERATURE AND EMISSION MEASURE CALCULATIONS

Low/high = f (T, EM)

Two energy channels



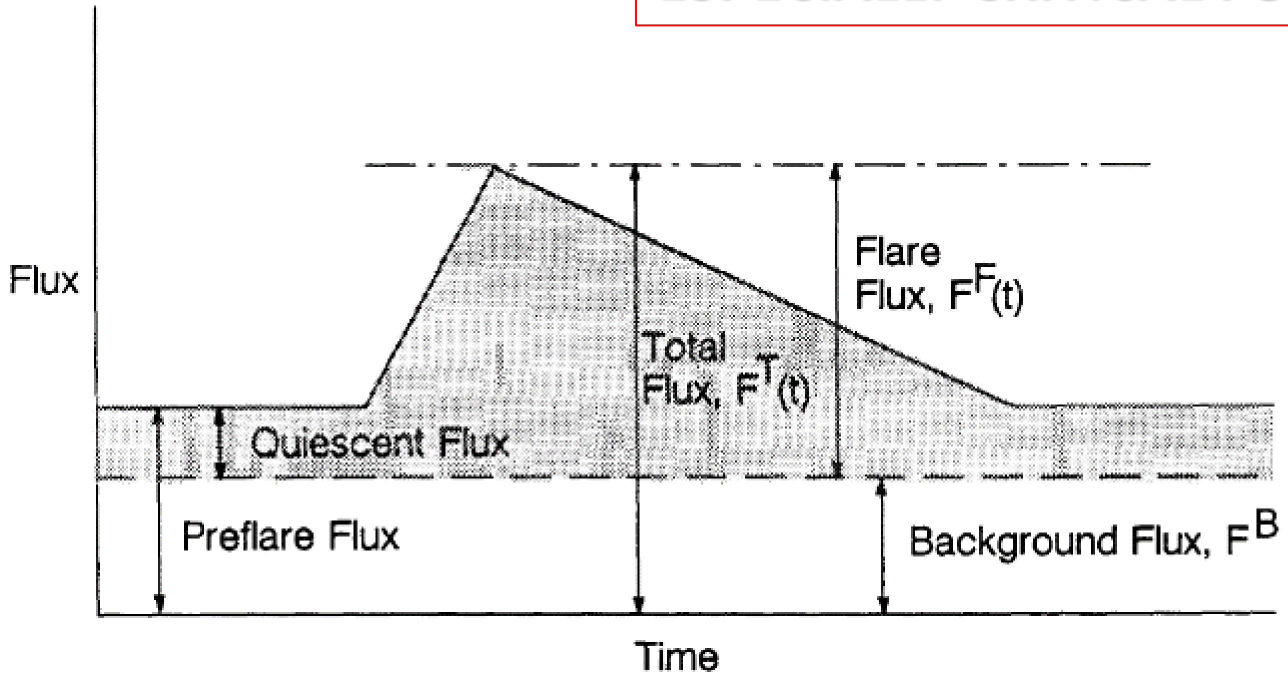
CHANNELS energy ranges:

LOW 1.16 – 1.5 keV

HIGH 1.5 – 15.7 keV

Flare background determination

BACKGROUND LEVEL SUBTRACTION ESPECIALLY CRITICAL FOR SMALL EVENTS!

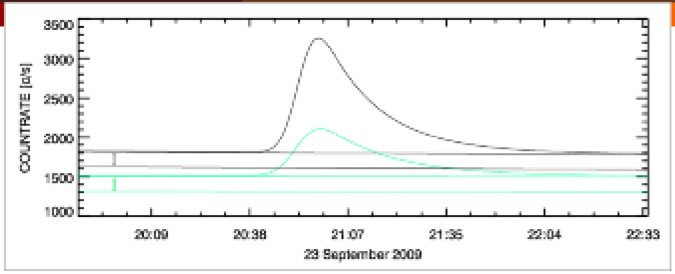


Bornmann, P. L. 1990, ApJ, 356, 733

BACKGROUND LEVEL DEFINITION PROBLEM

FLARING PLASMA EMISSION

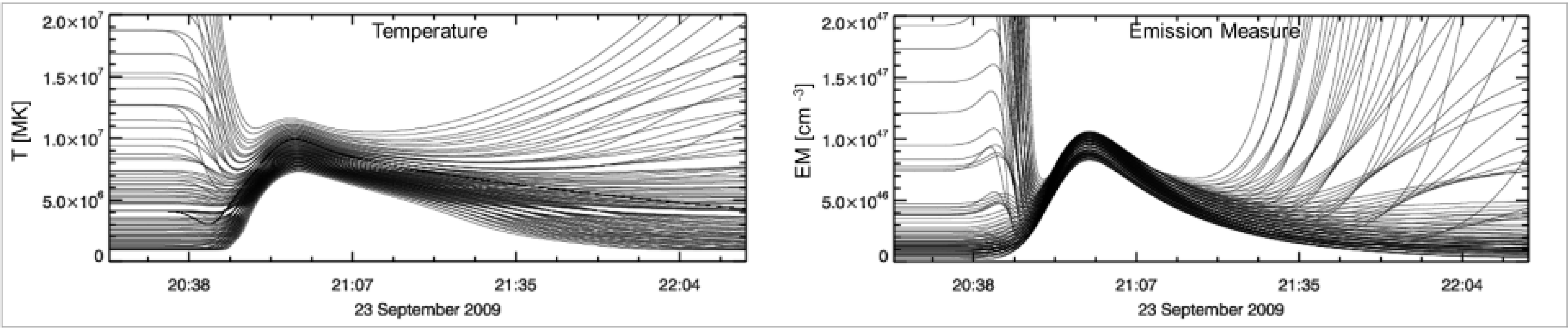
Plasma diagnostics



Background estimation

different background levels analysed

-> different *T* and *EM* time profiles



The set of one hundred *T* and *EM* estimations
for tested levels of backgrounds.

The physical-like T end EM estimations acceptable are selected as optimal set. The final bkg are taken for mean value of temperature.

Adopted method proposed by

Bornmann and improved by Ryan et al. 2012

Plasma diagnostics

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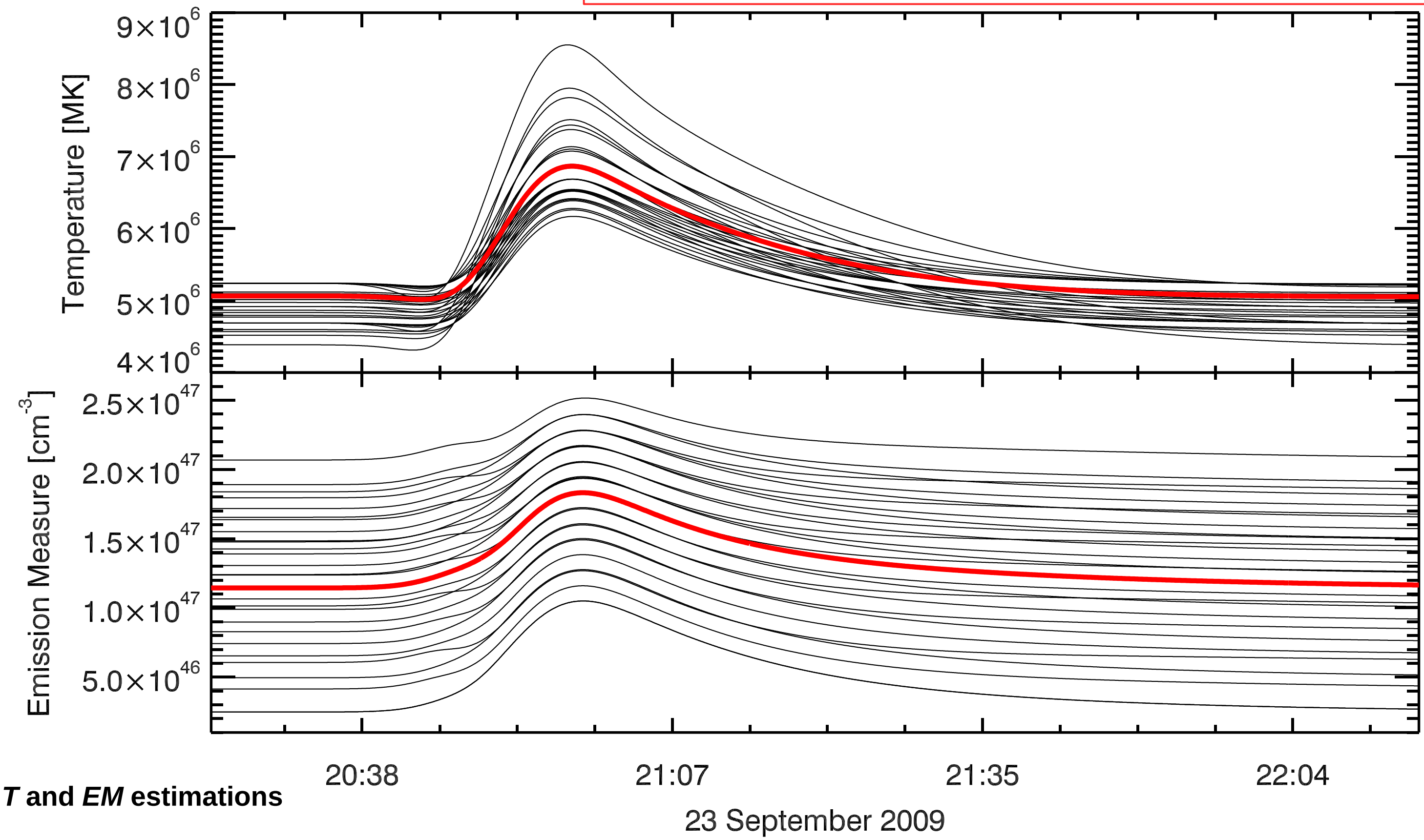


The set of 27 *T* and *EM* estimations

Concluding remarks I

- In order to gain a deeper understanding of the nature of smll SXR solar flares more precise estimations of properties are needed
- SphinX provide large data base of flares and brightenings observed during very deep solar minimum of activity
- In spite of the fact that SphinX was in operation during the period of very low solar activity there were many events overlapped in time
- We have proposed a model of time flare profile, which is usefull tool for SXR flares parameters analaysis

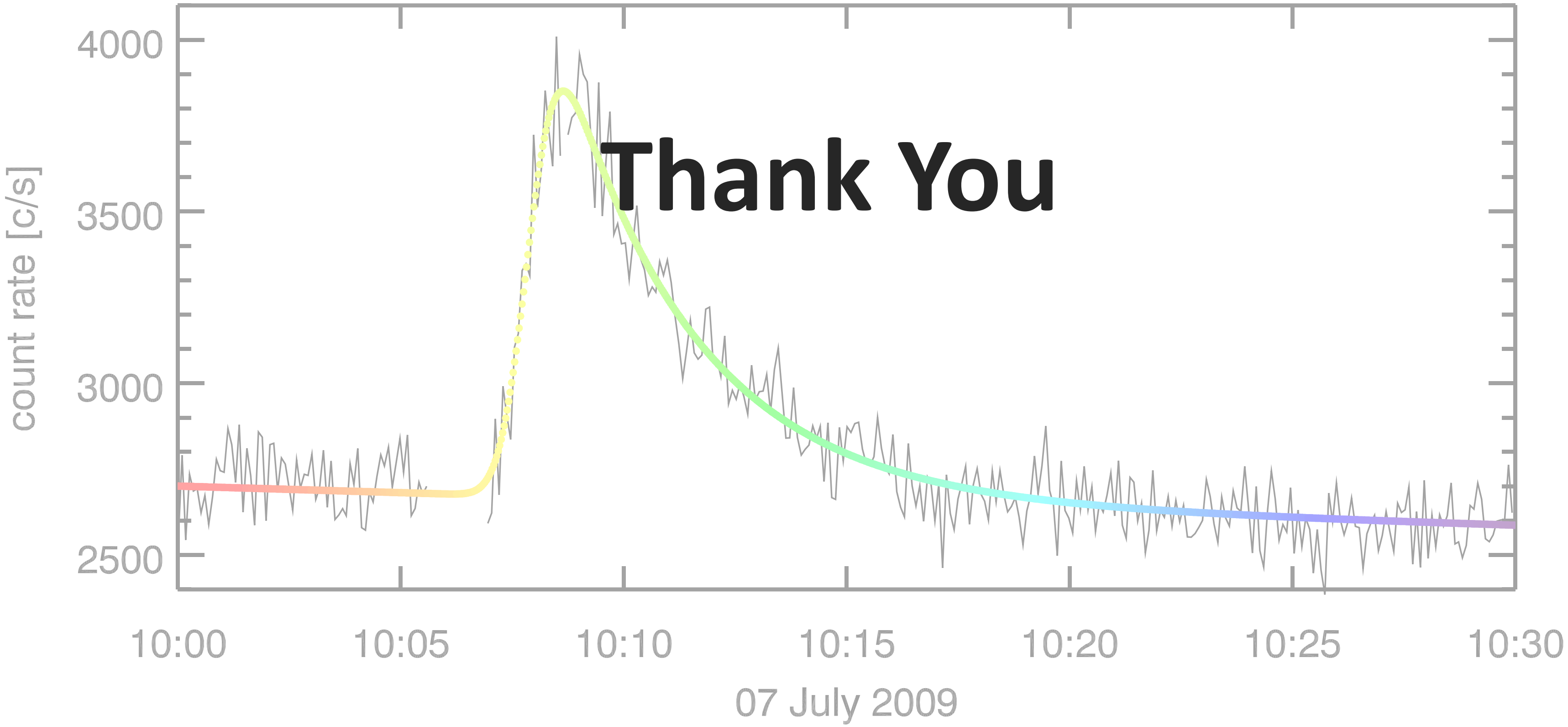
Concluding remarks II

- More precise and homogeneous method of time parameters estimations
- Analysis of multi-picked flares (time covered events)
- Linear background determination
- Method can be apply with other SXR data as well

- Parameters catalogue as plenteous material of statistical analysis

- Removed background emission itself will be used for the
  analysis of active regions thermal mean parameters and their evolution.

SphinX data are available on the webpage of Solar Physics Division, Space Research Centre Polish Academy of Sciences (SRC PAS): http://156.17.94.1/sphinx l1 catalogue/ SphinX cat main.html


4000
3500
3000
2500
count rate [c/s]
10:00
10:05
10:10
10:15
10:20
10:25
10:30
07 July 2009

Thank You