XIIIth Hvar

Astrophysical Colloquium

Tiny flares properties based on SphinX observations

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OUTLINE

I. SphinX Instrument & Observations

II. Flares Detection Algorithm

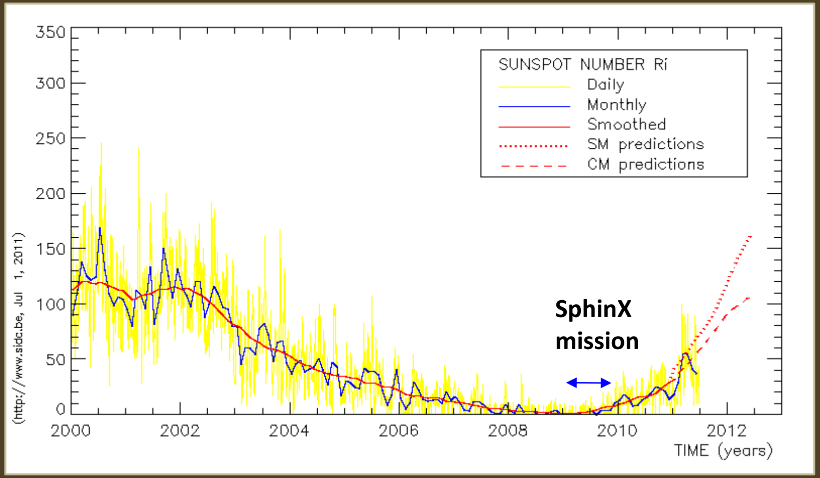
III. Elementary SXR Lightcurve Flare Profile

IV. Background subtracted plasma diagnostics

V. Detailed analysis of selected flare

VI. Conclusions & Plans

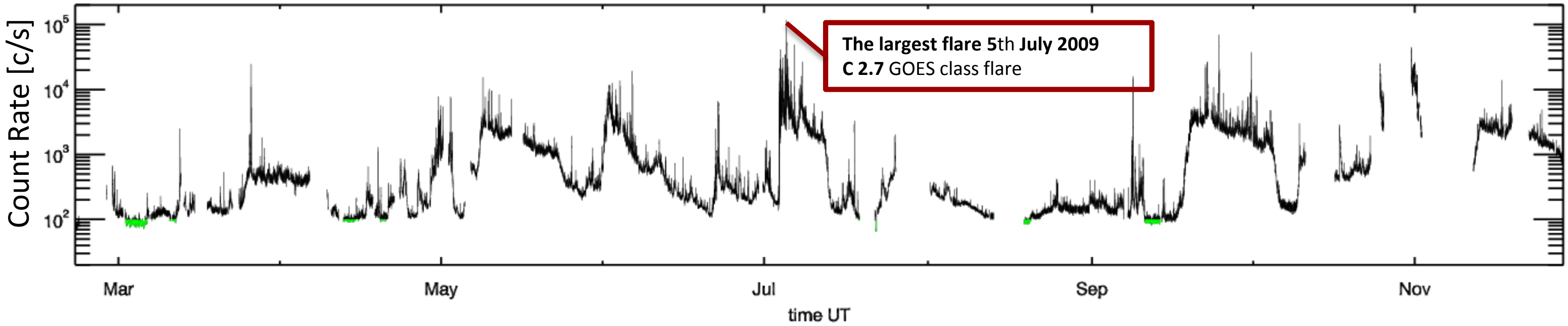
Solar Photometer in X-ray

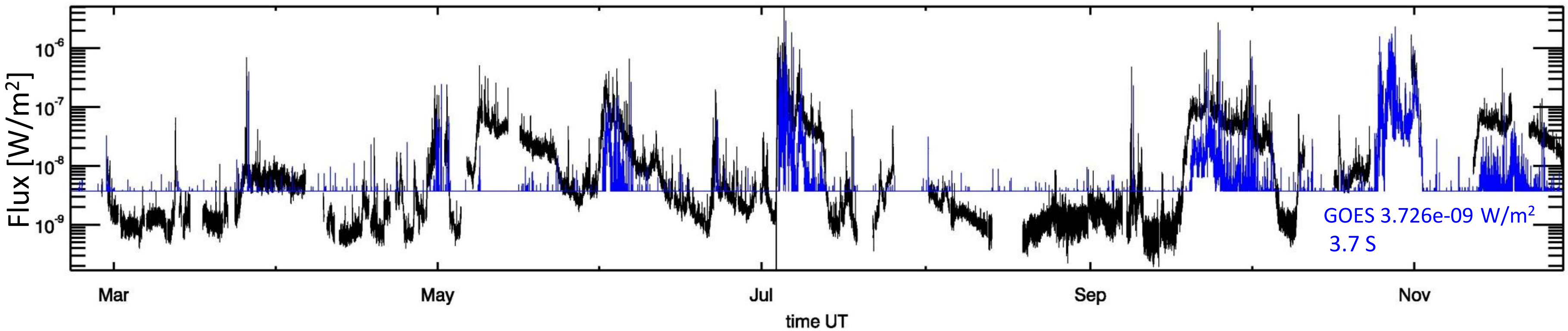


SphinX BASIC PARAMETERS	
LAUNCHED:	30 January 2009 at 13:30 UT from Plesetsk Cosmodrom
SATELLITE:	CORONAS – Photon
ORBITS PARAMETERS:	orbit duration- 96min altitude - 550km near polar orbit
MASS:	3.7 kg
POWER:	10 W
ENERGY RANGE:	1.2 keV - 15 keV in 256 energy bins
LIFESPAN OF THE MISSION:	20 February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

SphinX Mission Observations 2009

http://156.17.94.1/sphinx_l1_catalogue/SphinX_cat_main.html



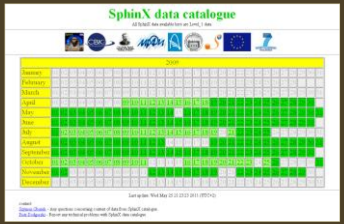


NEW SXR FLARES CLASSES

S CLASS - S1 = 1. e-09 W/m^2

Q CLASS - Q1 = 1. e-10 W/m^2

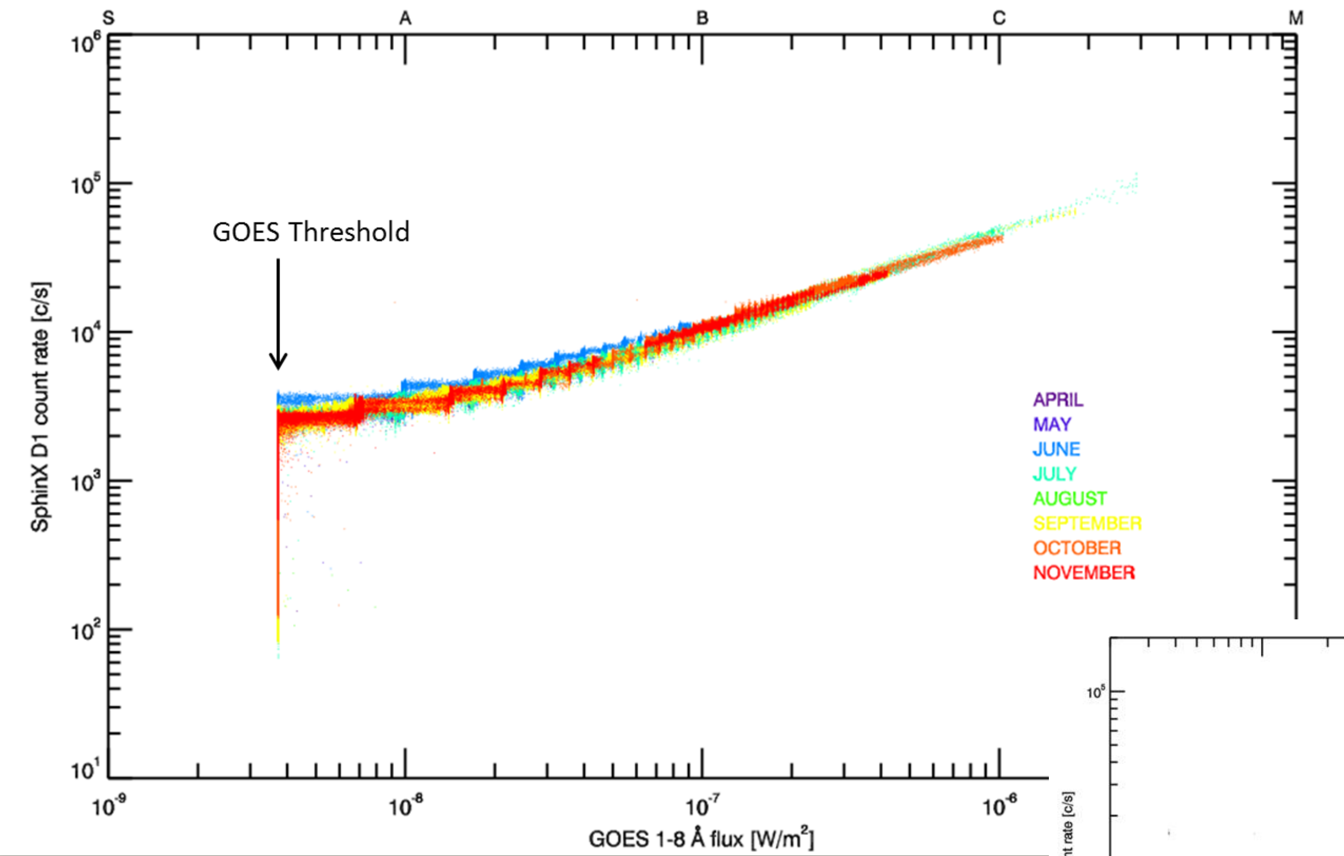
GOES threshold =	3.726e-09 W/m^2	3.7 S
D1 minimum =	~2.e-10 W/m^2	2.0 Q



SphinX level1 data catalogue

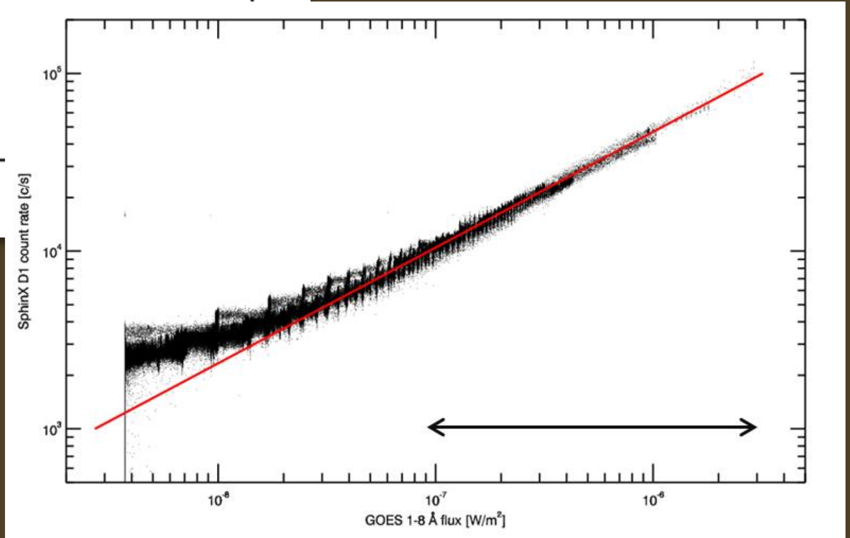
- The catalog contains data from D1 SphinX detector
- All available data files are stored in FITS format (OGIP-93/003 format)

SphinX and GOES observations - comparison



NEW SXR FLARES CLASSES
S CLASS - S1 = 1. e-09 W/m^2
Q CLASS - Q1 = 1. e-10 W/m^2

The largest SphinX flare:
5th July 2009
C 2.7 GOES class flare



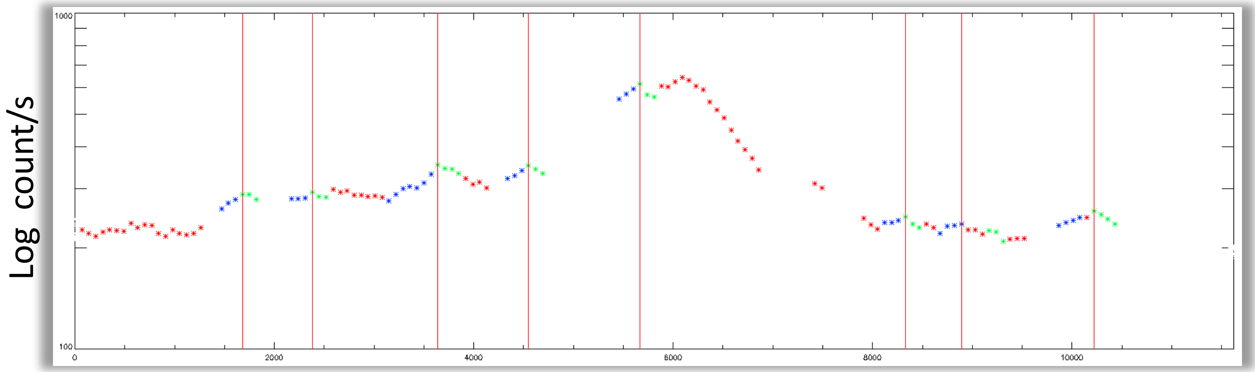
Estimation GOES 1-8 Å flux based on SphinX D1 count rate

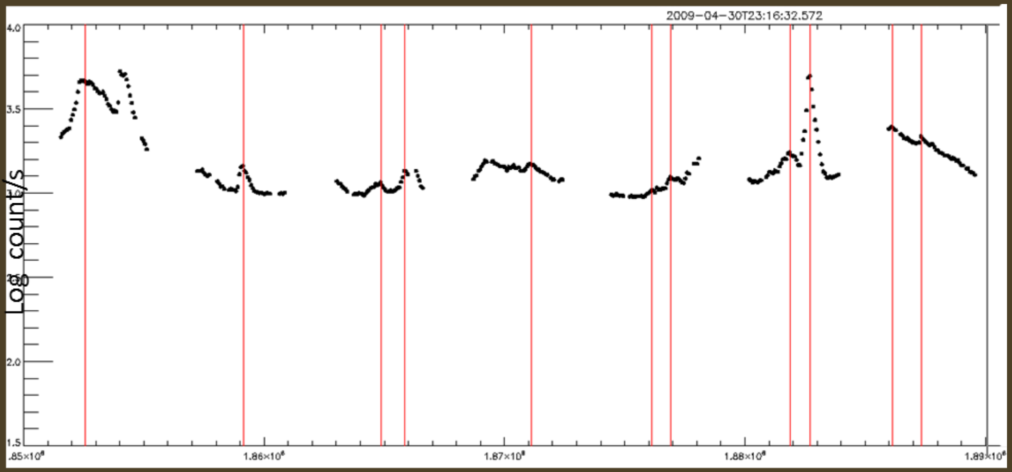
regression line for GOES data ≥ B class

SphinX Events List - flares 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 1431 FLARES from April 6th to November 30th

ELEMENTARY SOFT X-RAY FLARE PROFILE

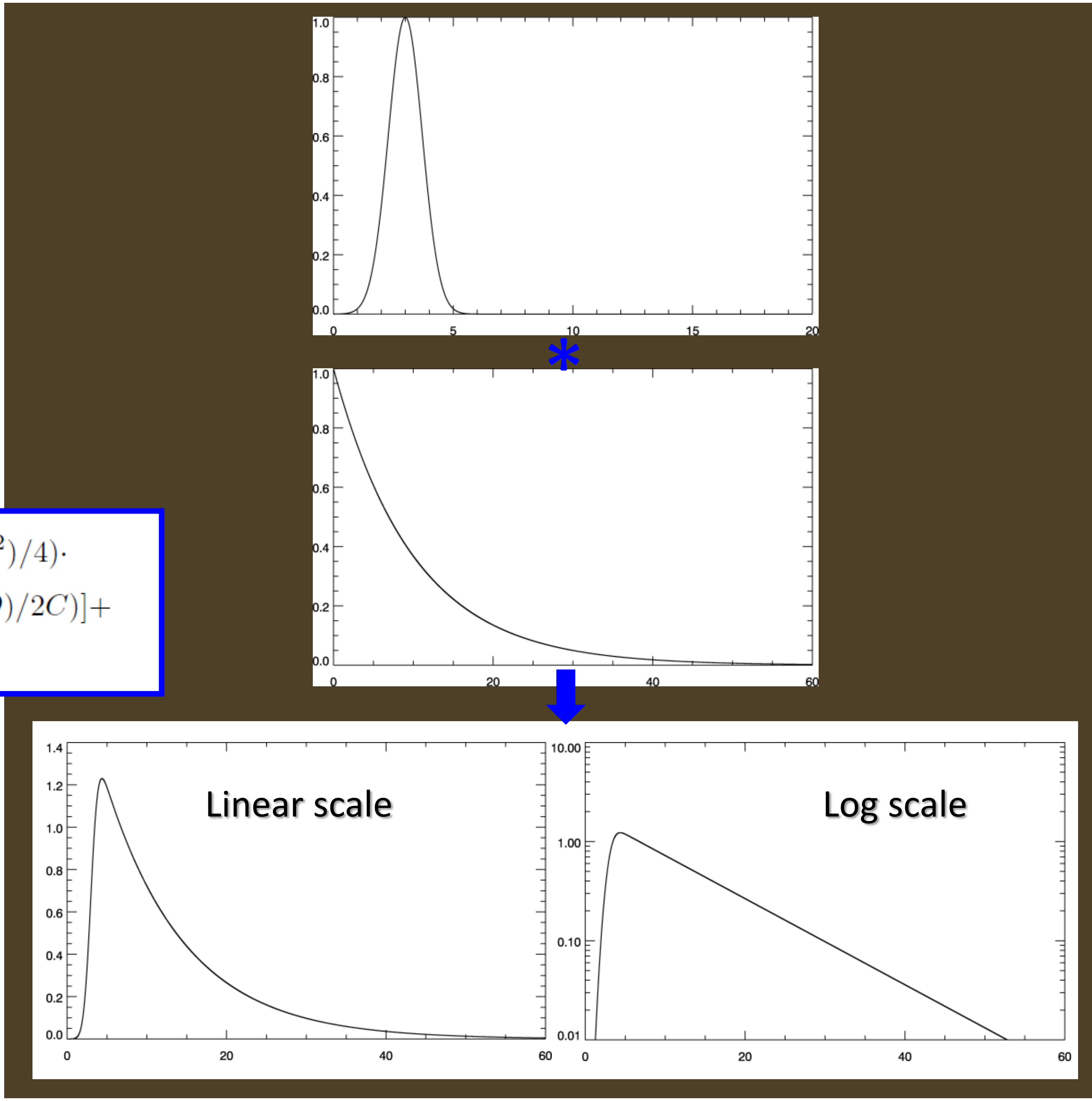
Convolution of two functions

Gauss function:

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

Exponential function:

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



FLARE PROFILE FORMULA:

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

Linear background

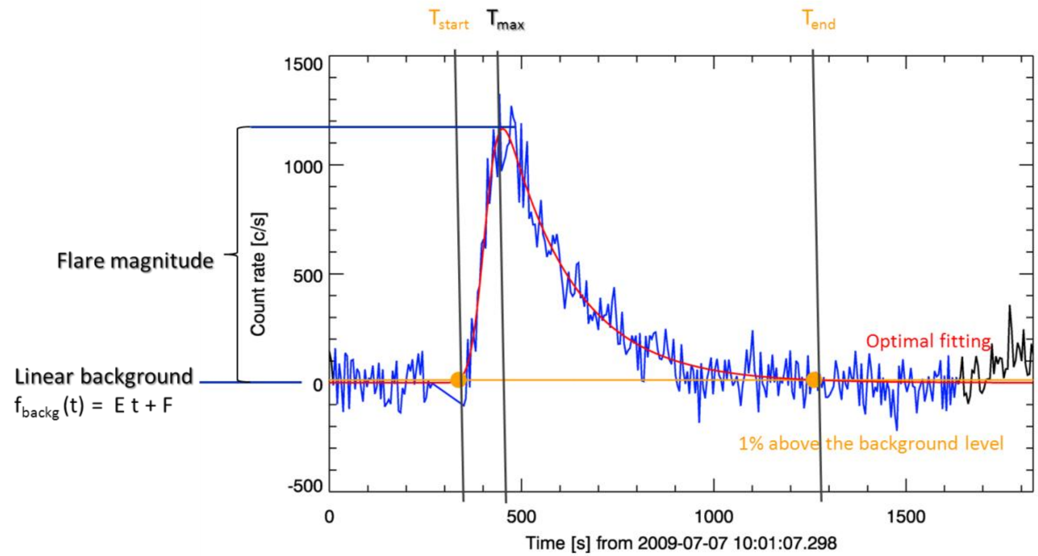
$$f_{bg}(t) = Et + F$$

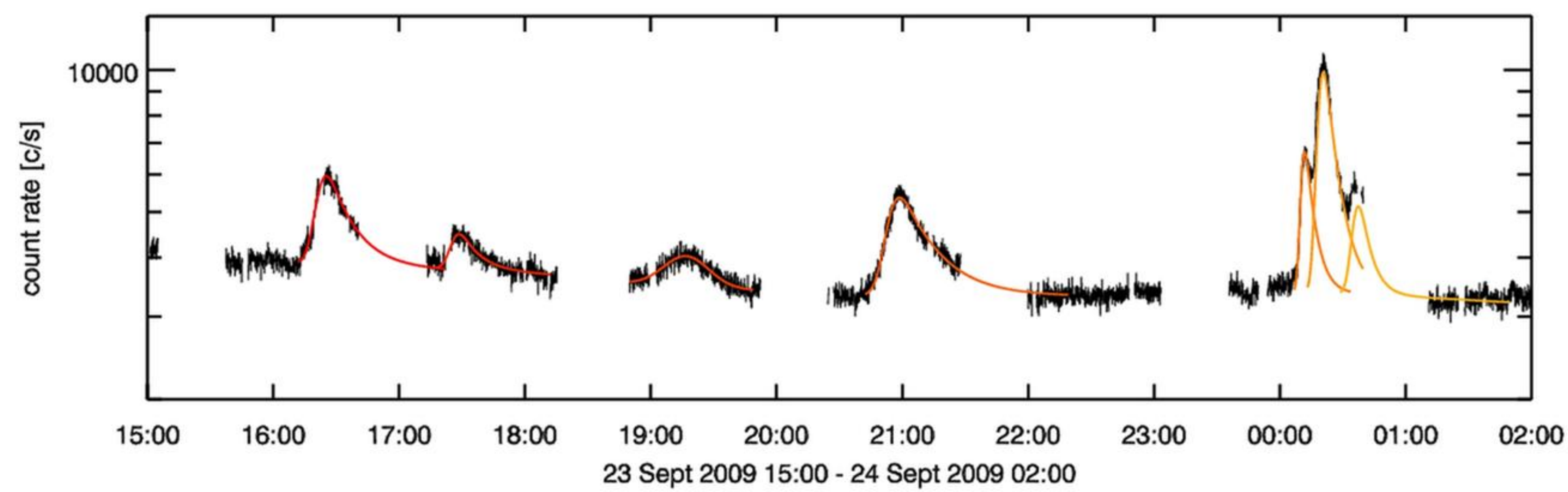
4 parameters (flare) +
2 parameters (linear background-attributable) = 6 PARAMETERS

SphinX Events Catalogue – time parameters

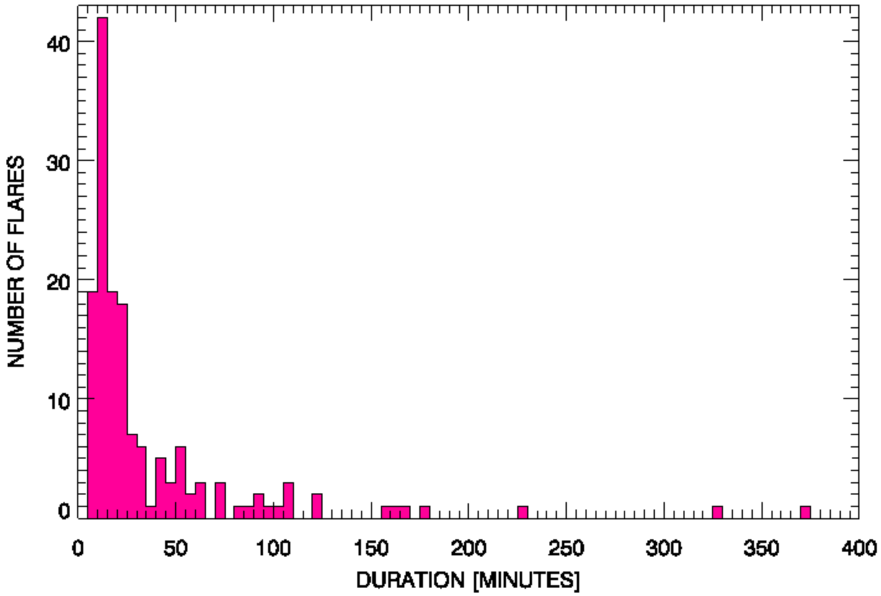
FLARE AFTER BACKGROUND SUBTRACTION

PARAMETERS:
T_{start} time of start
T_{end} time of end
T_{max} time of maximum
Flare magnitude



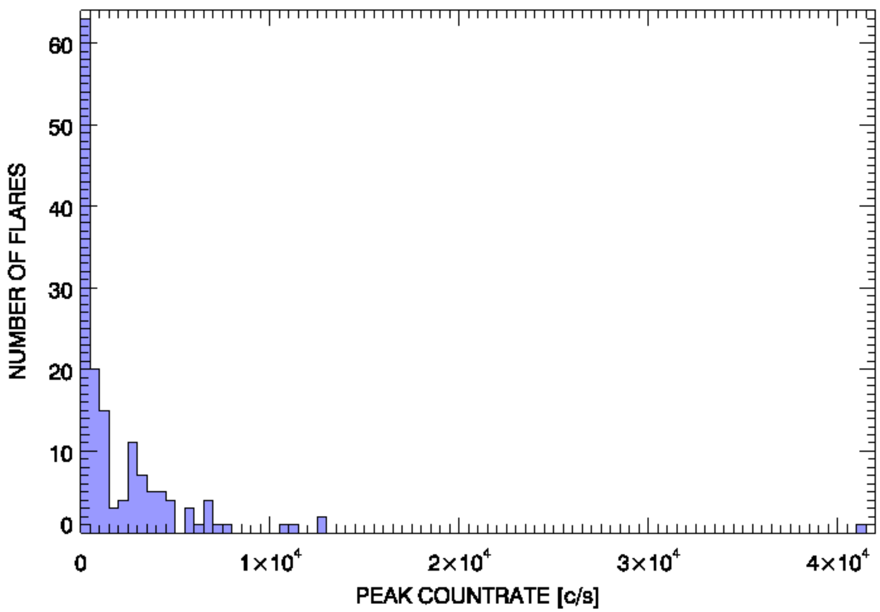


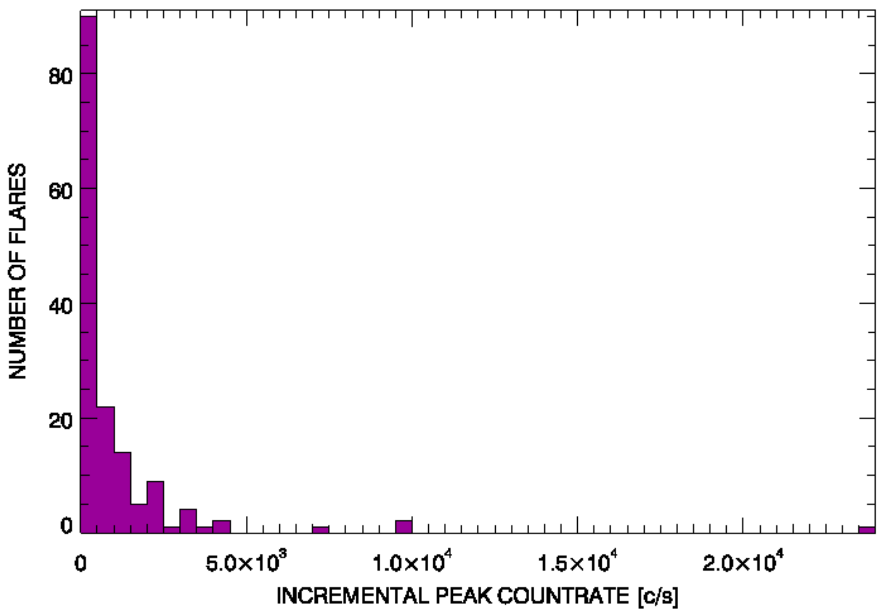
Flare parameters statistics



PROBE OF 153 EVENTS

Flares duration [min]
Maximal countrate [c/s]
Incremental maximal countrate [c/s]
(= above background level)

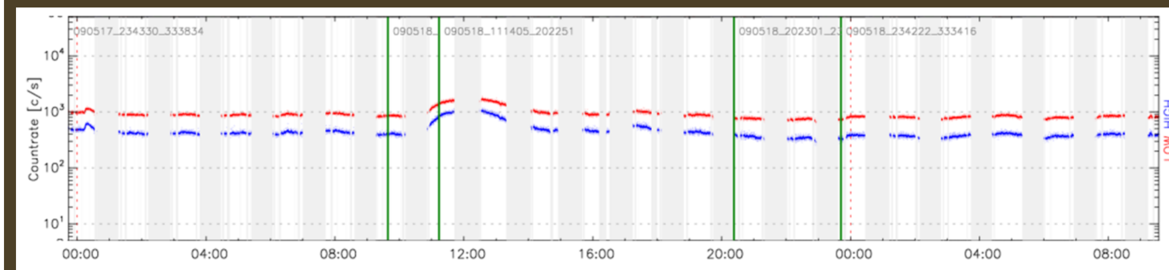


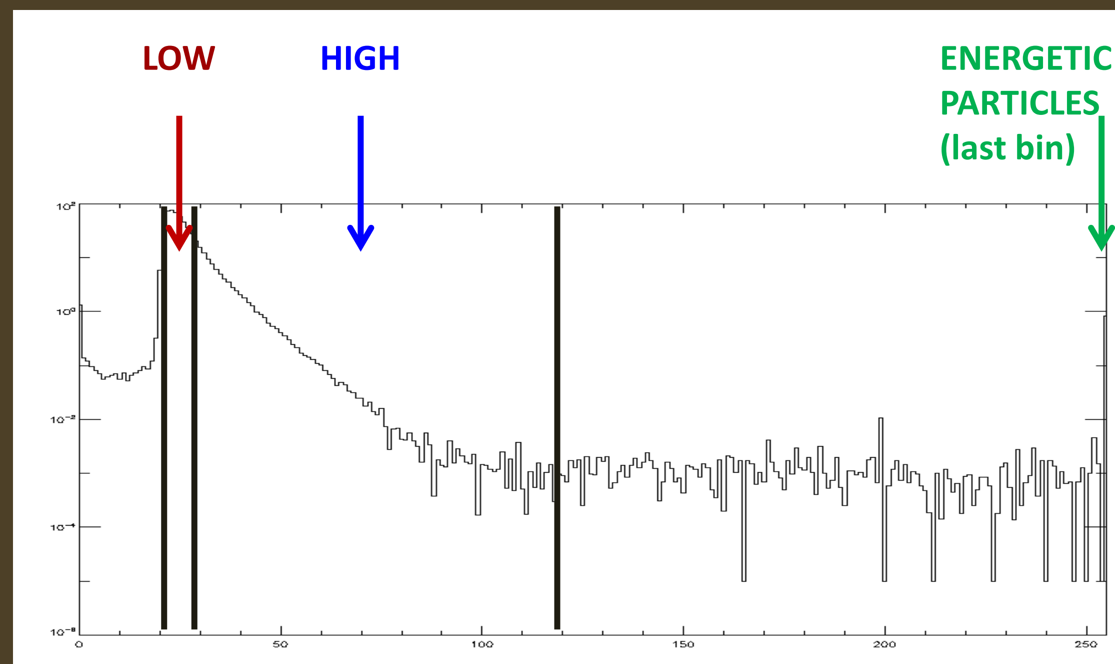


SphinX data – plasma diagnostics

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.



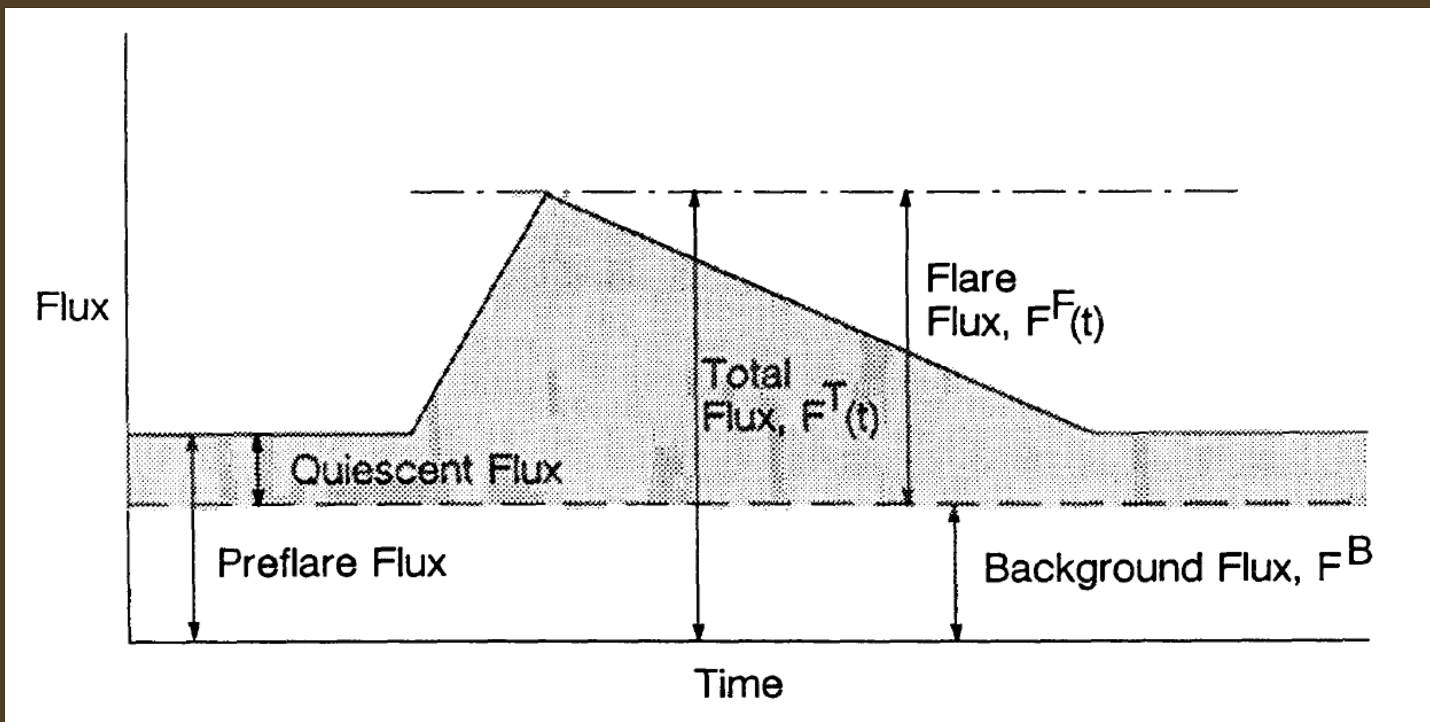


ISOTHERMAL APPROXIMATION USED FOR PLASMA TEMPERATURE AND EMISSION MEASURE CALCULATIONS

Low/high = f (T, EM)

Flares Background determination

BACKGROUND LEVEL SUBTRACTION ESPECIALLY CRITICAL FOR SMALL EVENTS!

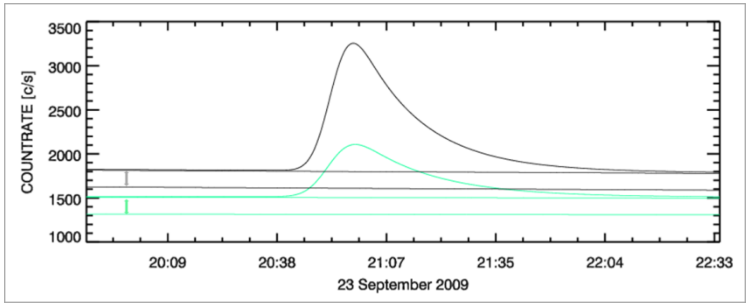


Bornmann, P. L. 1990, ApJ, 356, 733

BACKGROUND LEVEL DEFINITION PROBLEM

FLARING PLASMA EMISSION

SphinX catalogue – plasma diagnostics

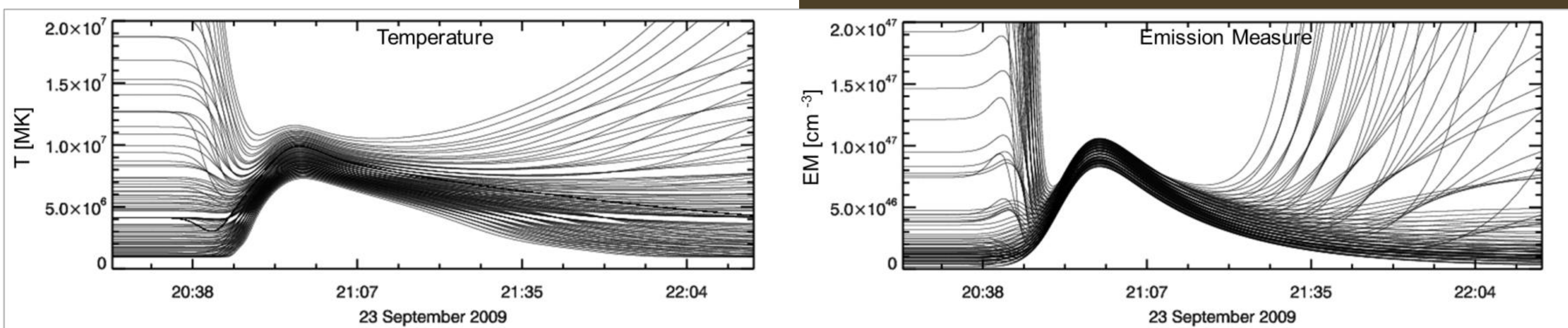


Background estimation

100 different background levels analysed

-> generation 100 different T and EM

T, EM CALCULATIONS



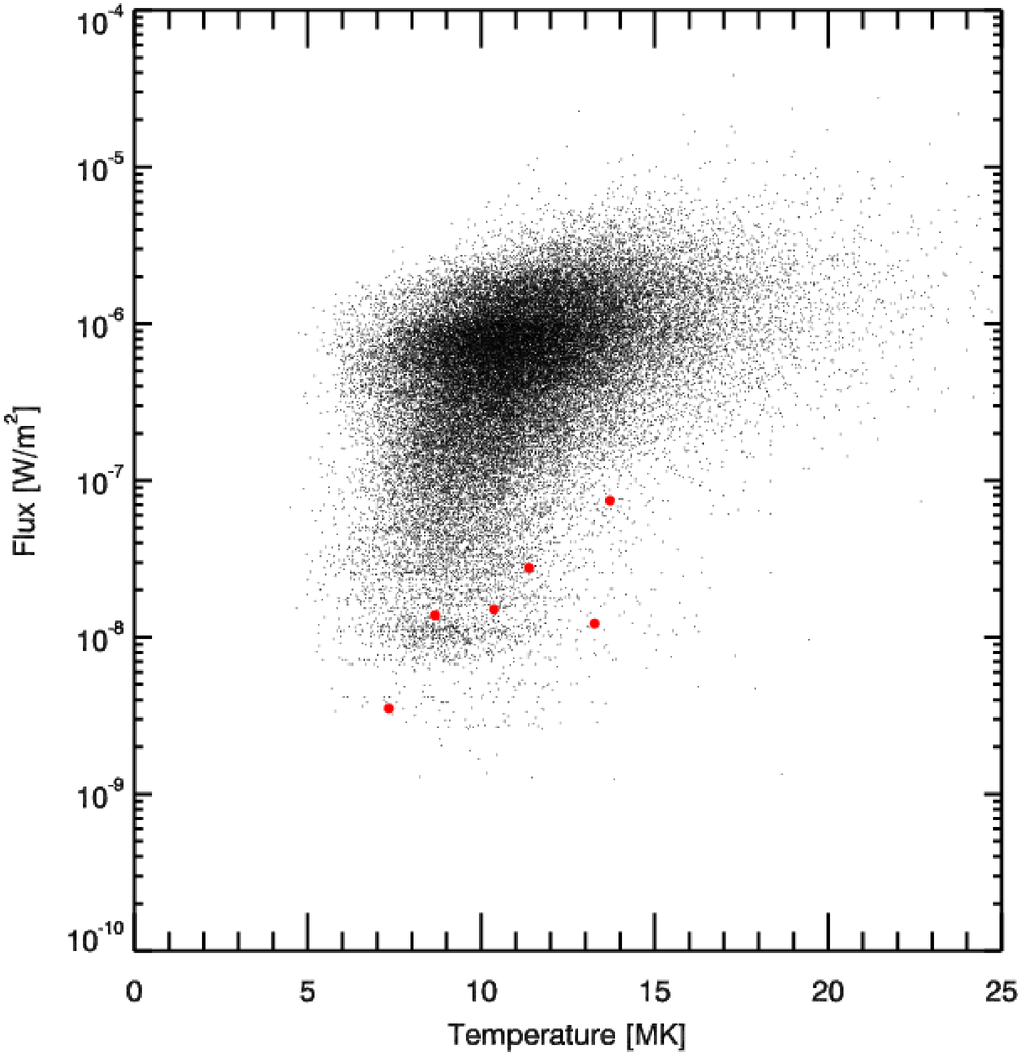
The set of one hundred *T* and *EM* estimations for tested levels of backgrounds.

The physical-like T end EM estimations acceptable are selected as optimal set. The final T and EM are calculated as mean value.

Adopted method proposed by Bornmann and improved by Ryan et al. 2012

SphinX – TEBBS catalogue

TEBBS – The Temperature and Emission measure-Based Background Subtraction



TEBBS data

> 50 000 flares
(1980 - 2007)

SphinX data

background (with slope) subtracted estimations

TEBBS REFERENCES:
Ryan, D.F. et al. 2012, The Astrophysical Journal Supplement, 202, 11, 15

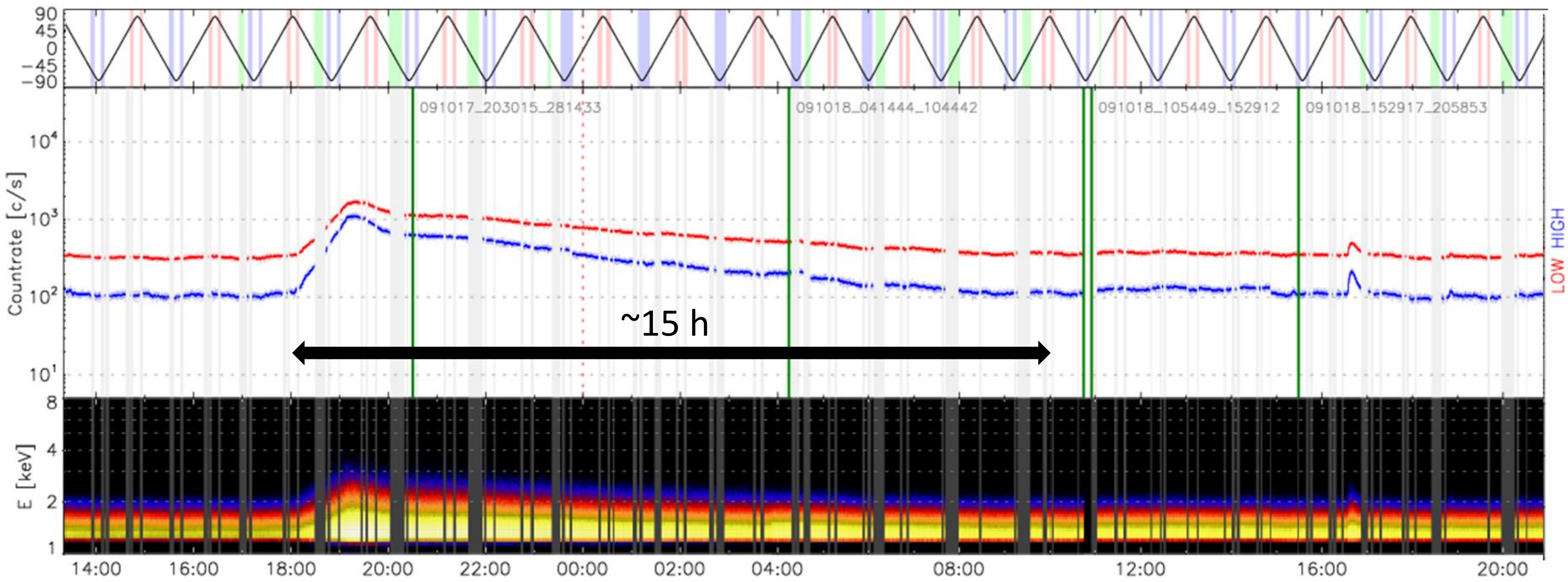
Conclusions and Future Plans

- ✓ The wide database of flare events – statistical methods
- ✓ Low activity Sun still produce many flares
- ✓ Analysis of nature of tiny flares
- ✓ Flares decomposition - the method allow us to analyse individual components of composite events
- ✓ Improved background determination

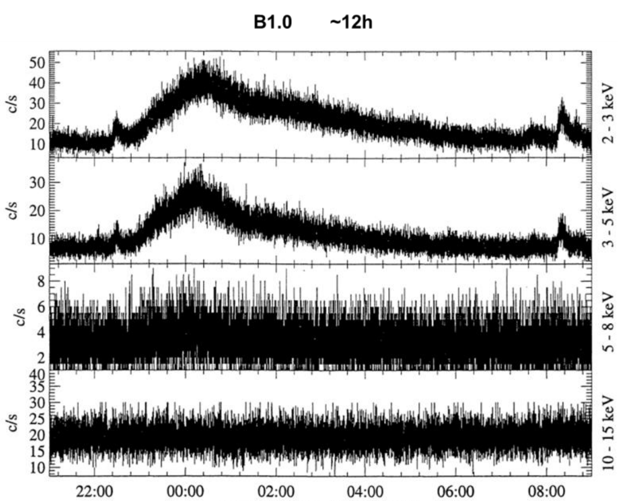
PLANS:

- ✓ Extension of the SphinX Events Catalogue
- ✓ Morfology analysis (based on data from other solar space instruments)
- ✓ Correlations analysis of obtained parameters

17 October 2009 flares   A7 class



http://156.17.94.1/sphinx_l1_catalogue/SphinX_cat_main.html



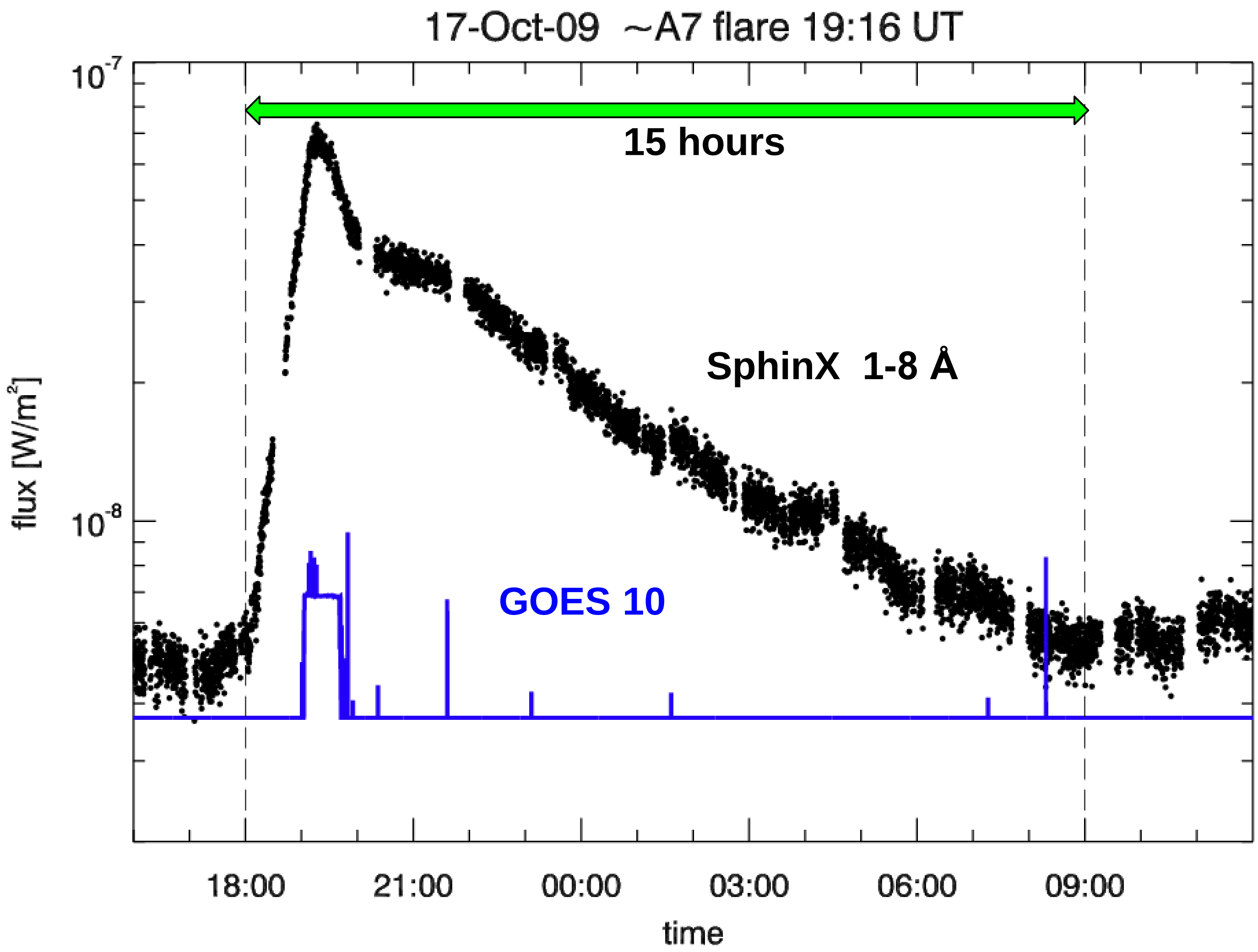
LONG DURATION EVENT

LDE, Hybrid flare ?
Svestka, Solar Phys. 1989, 121, 399

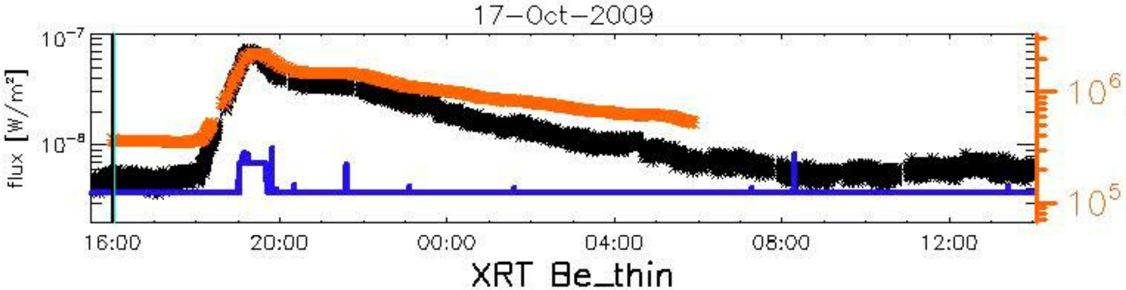
Interball RF15I
11-Jan-96 LDE

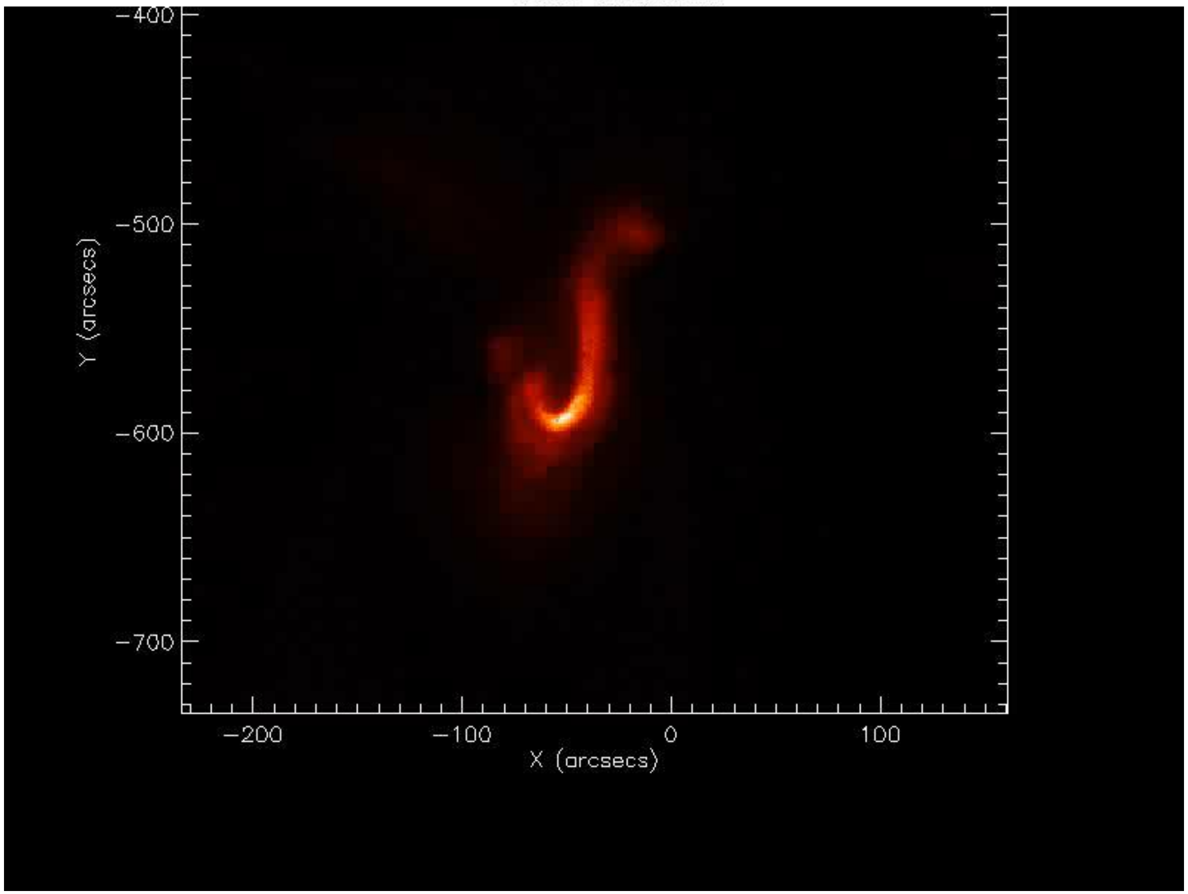
17 October 2009 flares A7 class

SphinX & GOES Observations

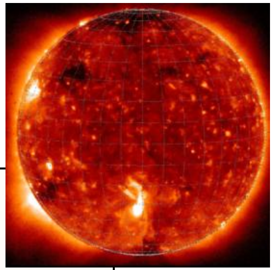


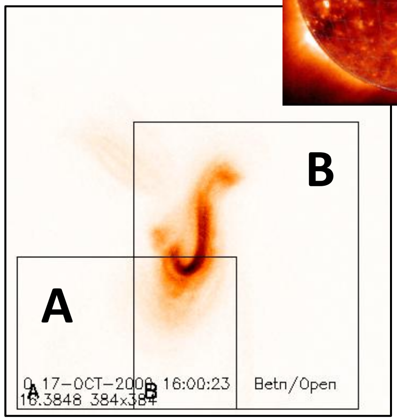
17 October 2009 flares

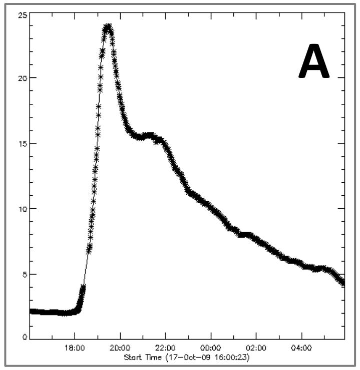


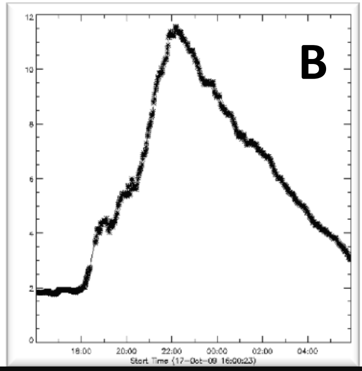


Be_thin filter

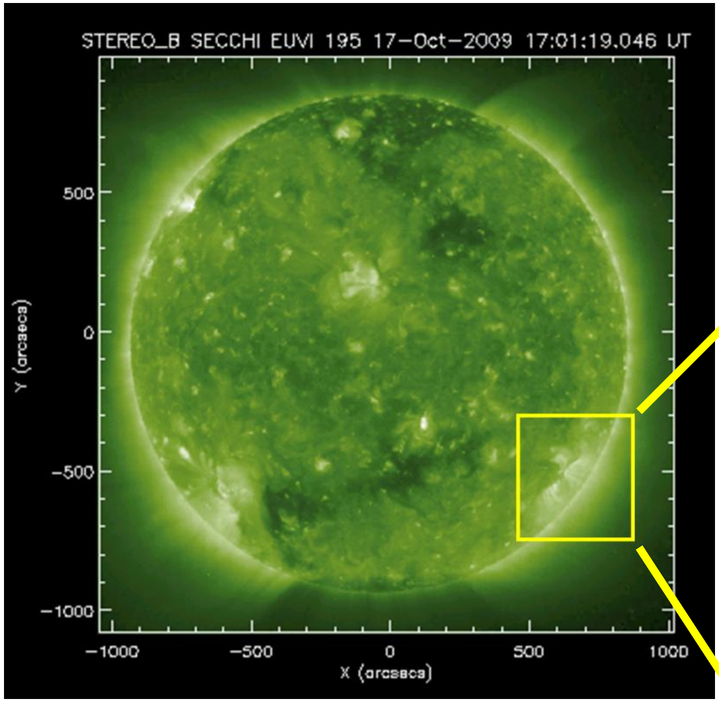


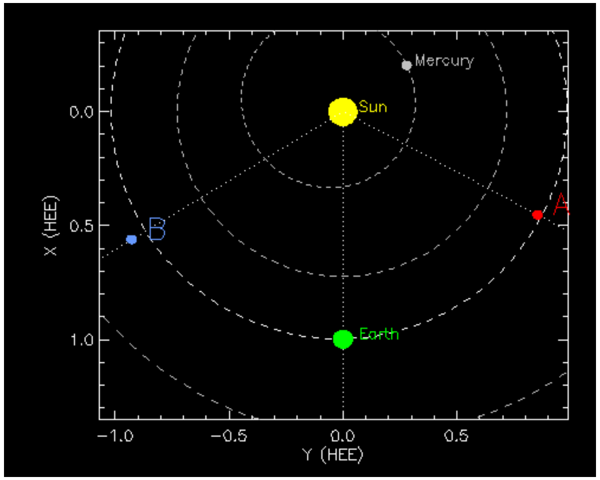


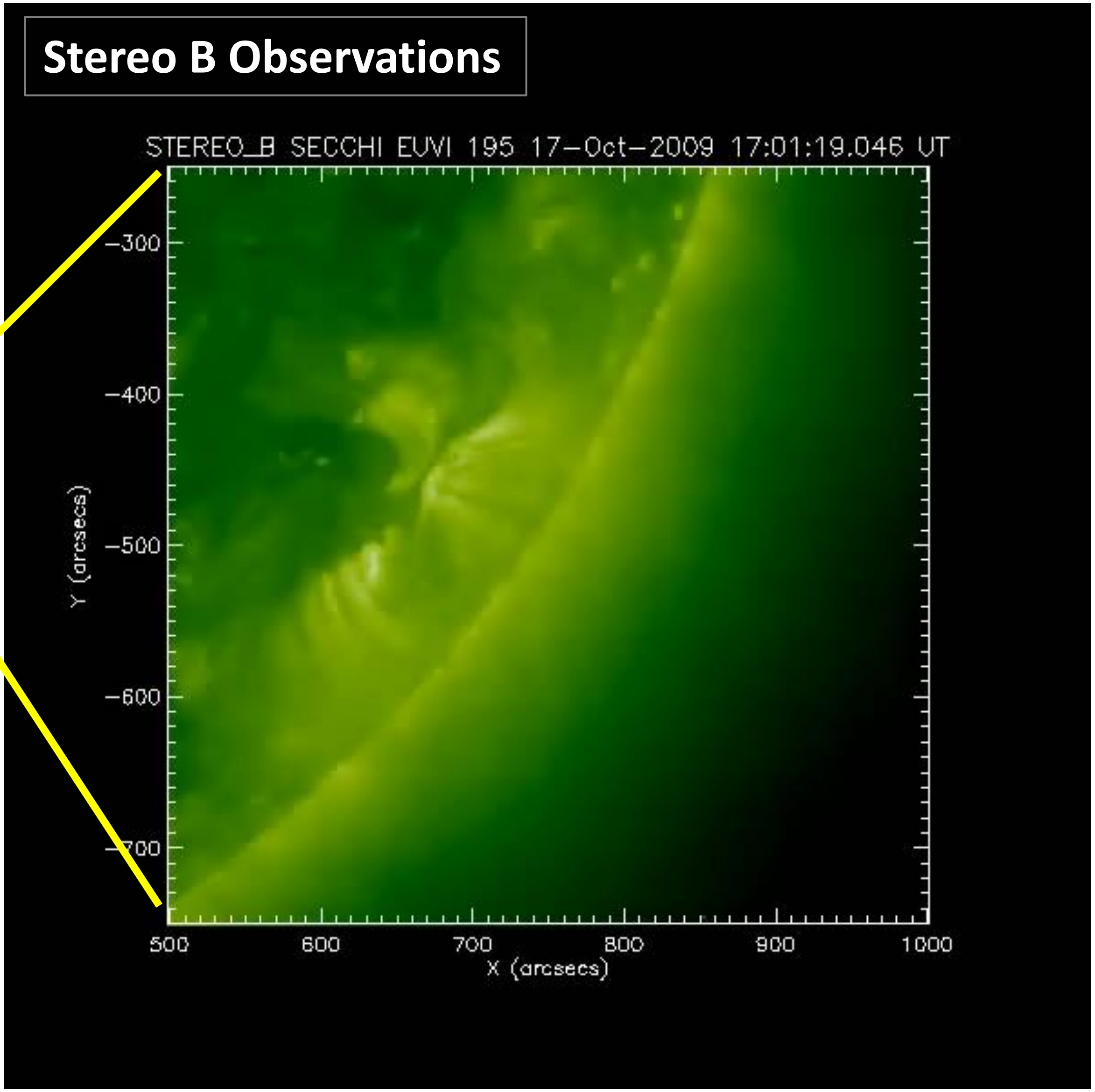




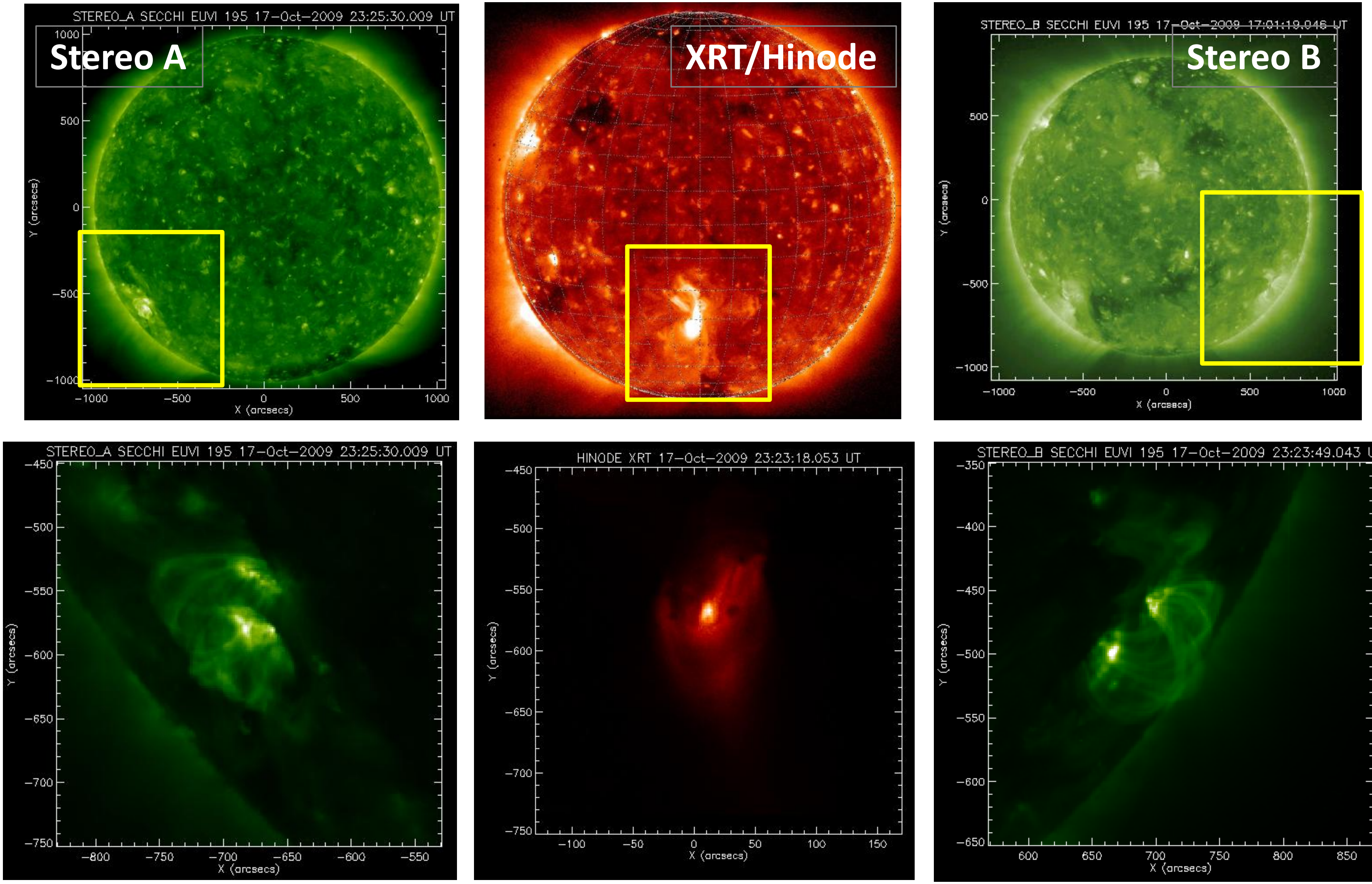
17 October 2009 flares





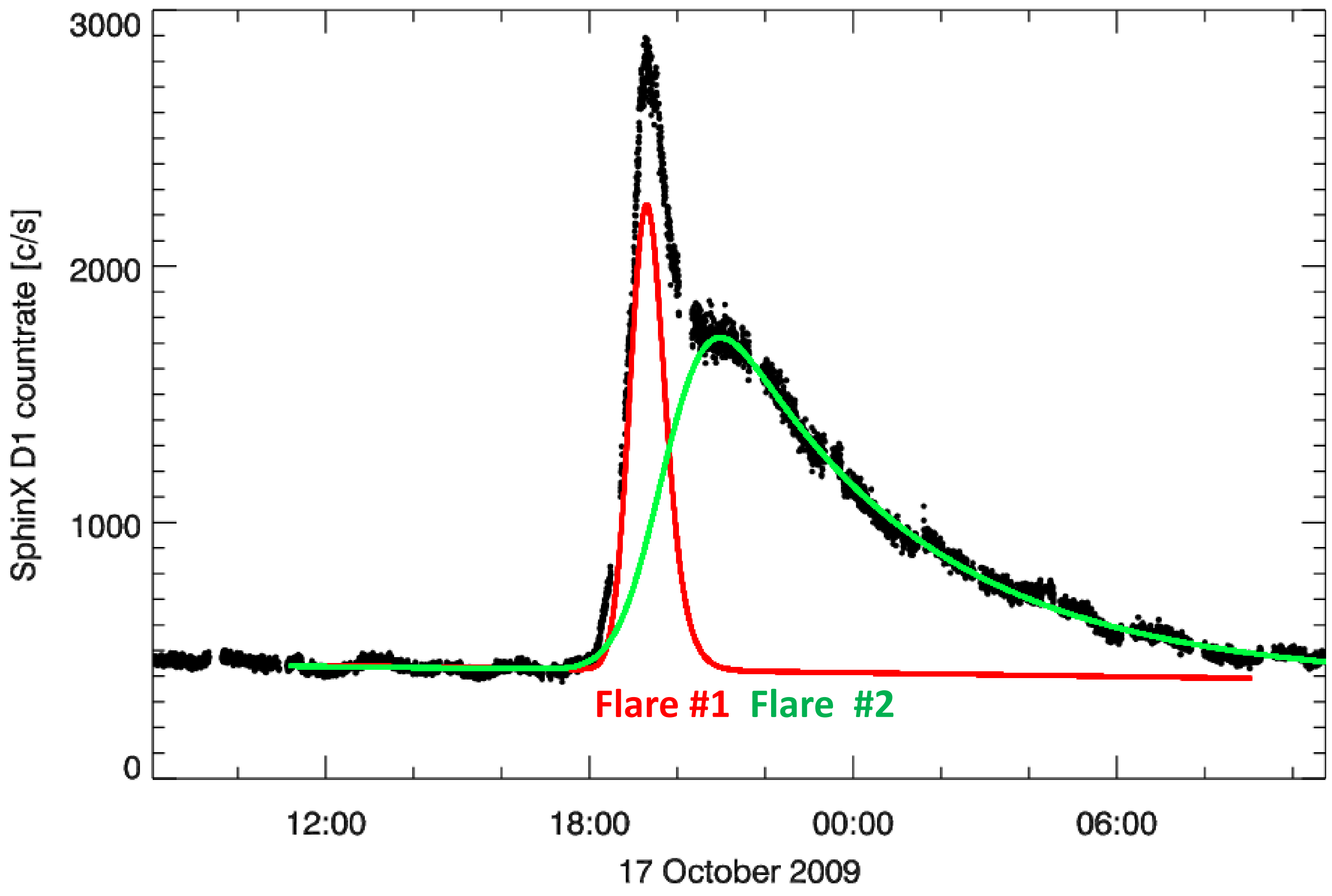


17 October 2009 flares – complex view



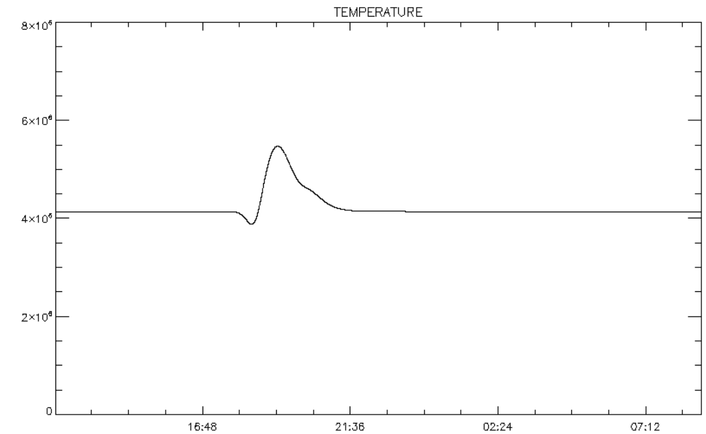
17 October 2009 flares

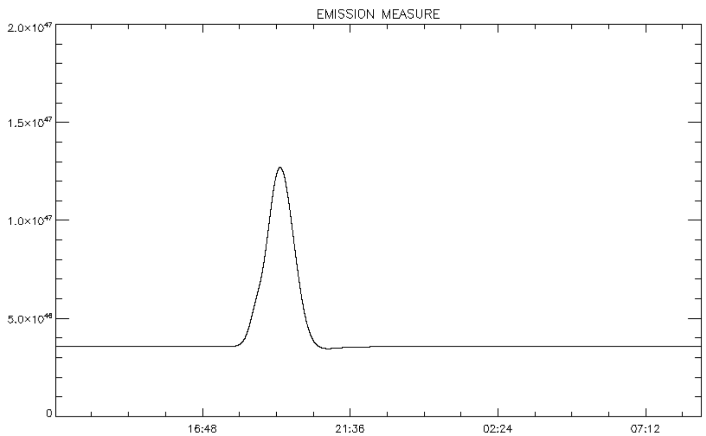
Elementary flare time profile optimal fits



17 October 2009 flares

Flare #1

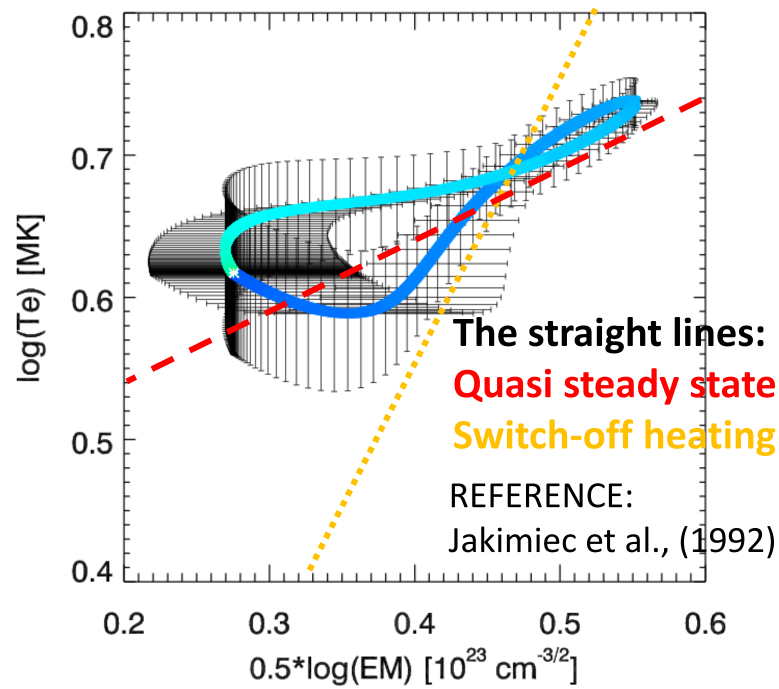


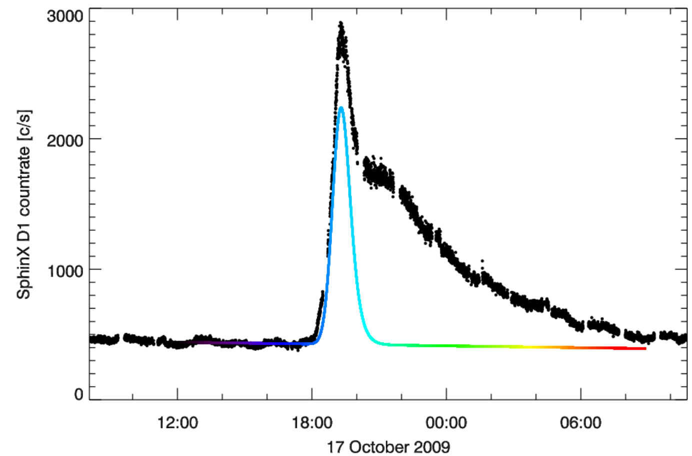


RESULTS:

max T 5.48 [MK]

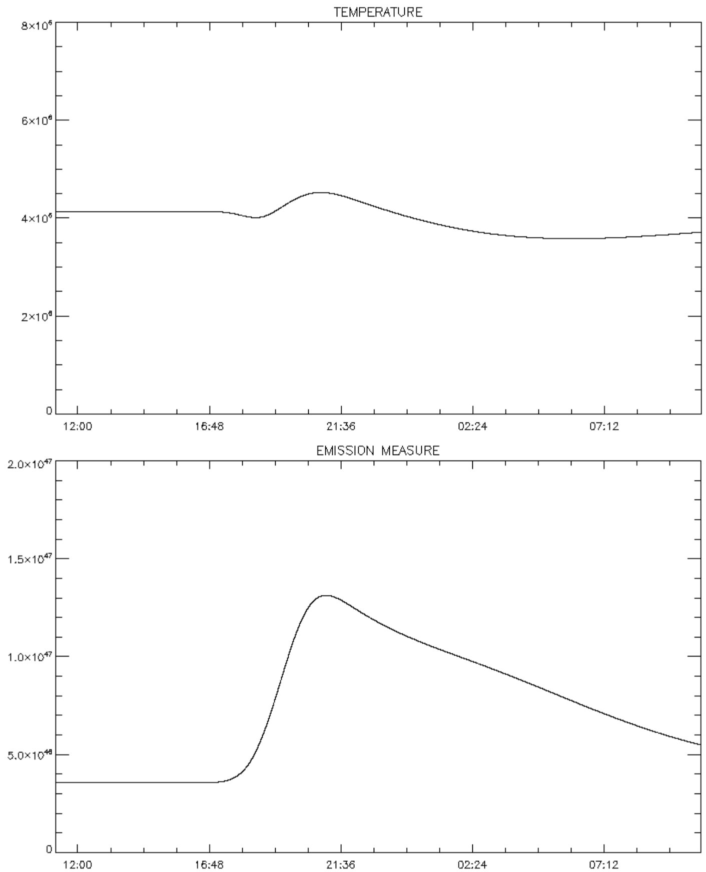
max EM 1.23×10^{47} [cm^{-3}]

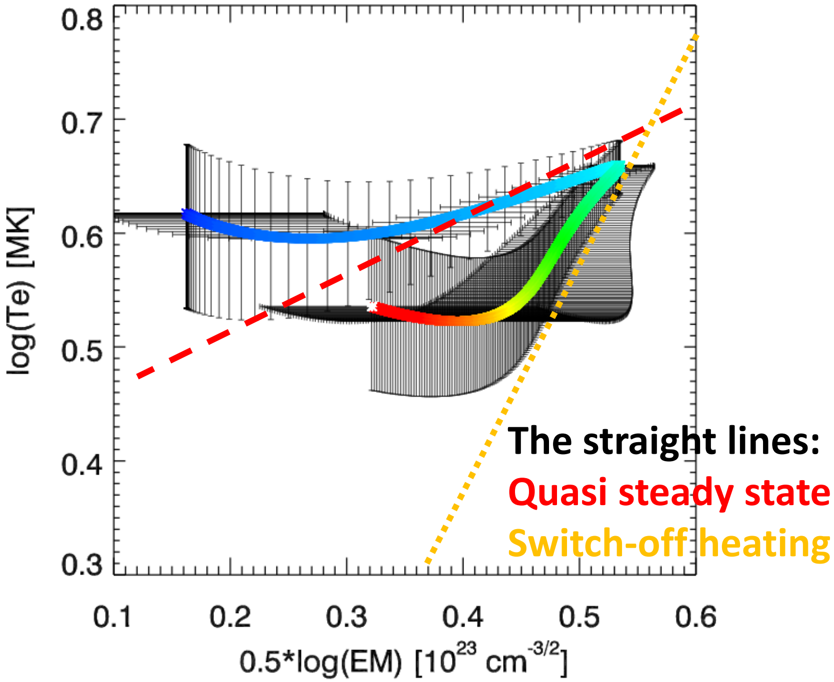


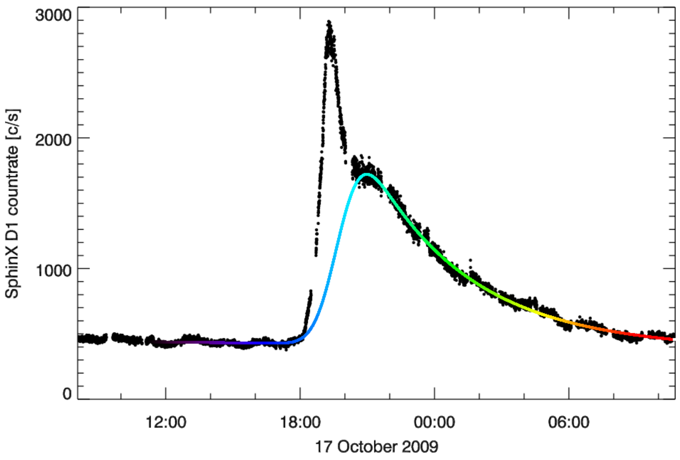


17 October 2009 flares

Flare #2







RESULTS:

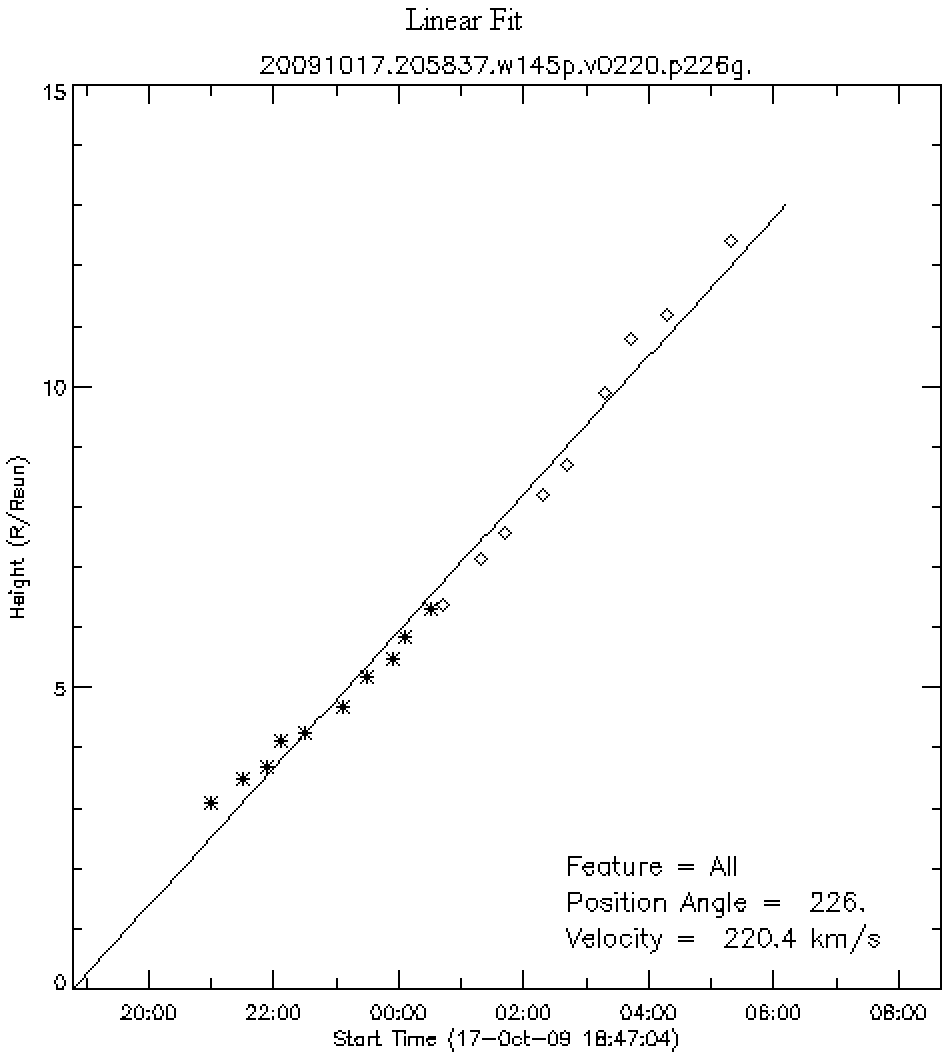
max T **4.57 [MK]**

max EM **1.17×10^{47} [cm^{-3}]**

17 October 2009 flares & CME asocciated with

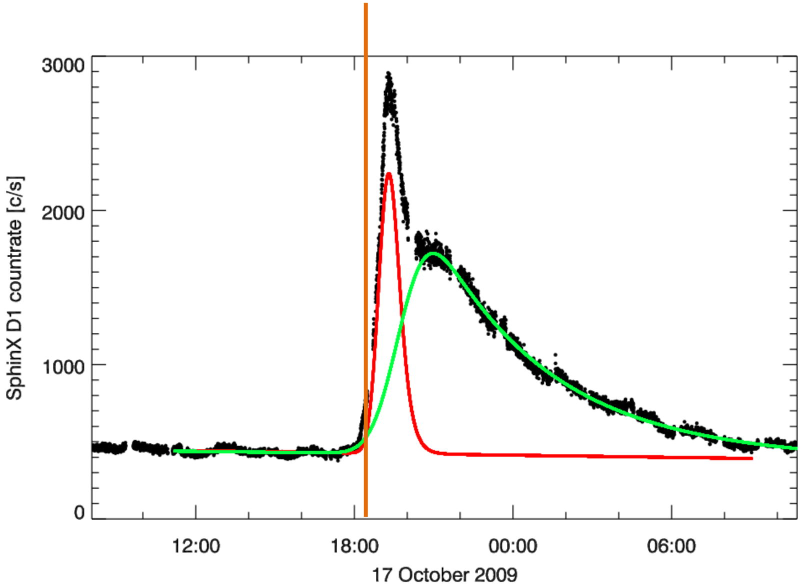
CME event

'Very Poor Event; Partial Halo' (SOHO LASCO CME CATALOGUE)



Determinations based on **LASCO data**

~ 18:47



Conclusions

- Small flares differ from large ones only on scales (of size, Te, EM etc.)
- Morphology of small flare can be as complicated as larger ones
- Even small flares can be associated with ejection phenomena (CME) - flares lightcurves deconvolution allow for determination of exact start and end times of event

The End

THANK YOU

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