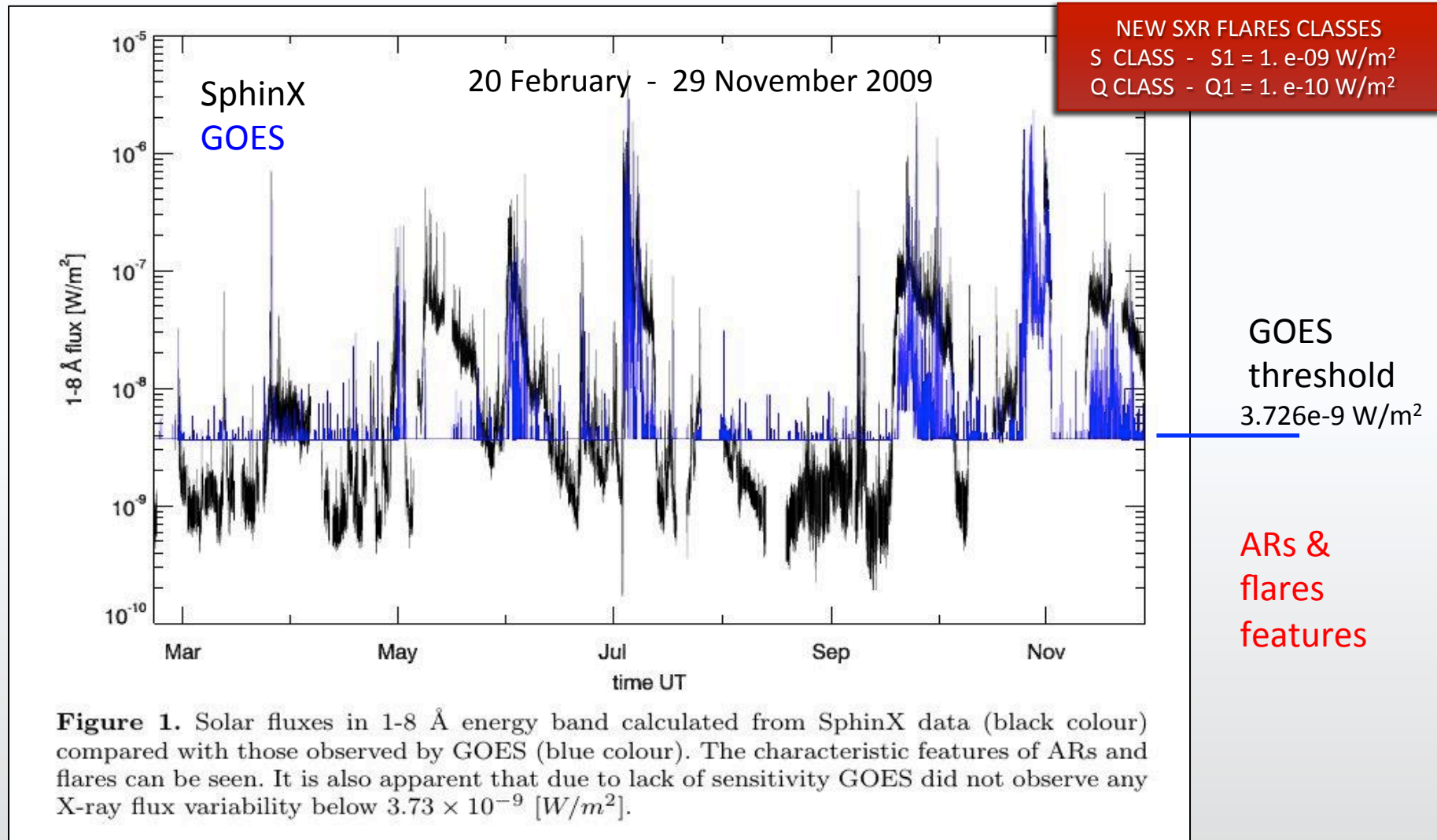


Analiza krzywych blasku uzyskanych za pomocą spektrofotometru SphinX

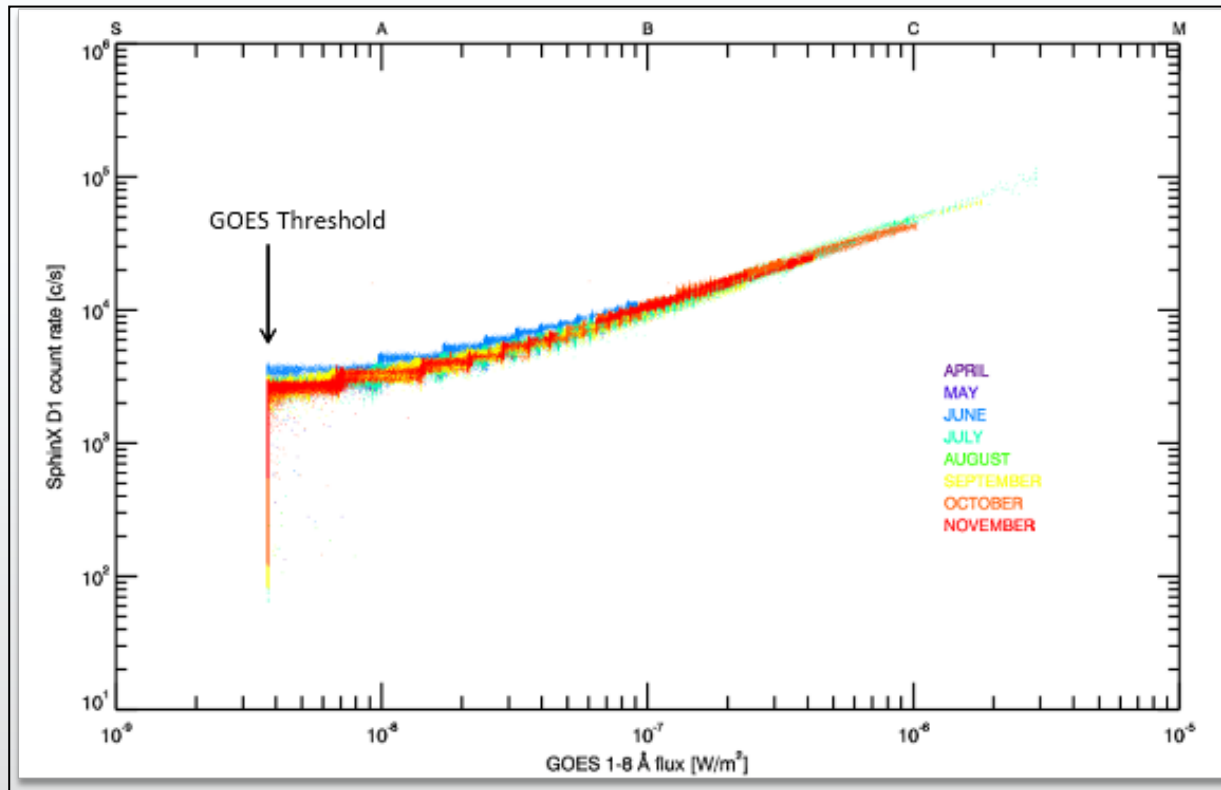
Magdalena Gryciuk
CBK PAN, ZFS



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



20 lutego - 29 listopada 2009



NEW SXR FLARES CLASSES
S CLASS - $S1 = 1. \cdot 10^{-9} \text{ W/m}^2$
Q CLASS - $Q1 = 1. \cdot 10^{-10} \text{ W/m}^2$

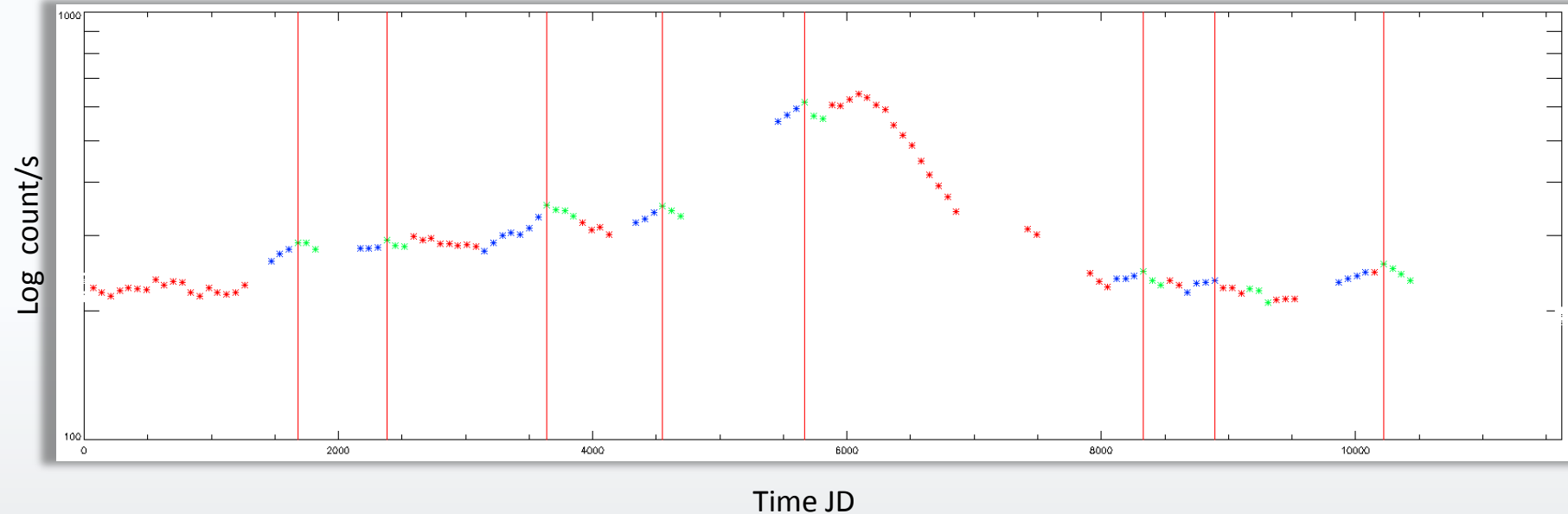
The largest SphinX flare
5th July 2009
C 2.7 GOESS class flare

GOES threshold = $3.726 \cdot 10^{-9} \text{ W/m}^2$ 3.7 S
D1 minimum = $\sim 2 \cdot 10^{-10} \text{ W/m}^2$ 2.0 Q

1604 rozbłysków 20 II - 29 XI 2009

Semi-automated method step by step:

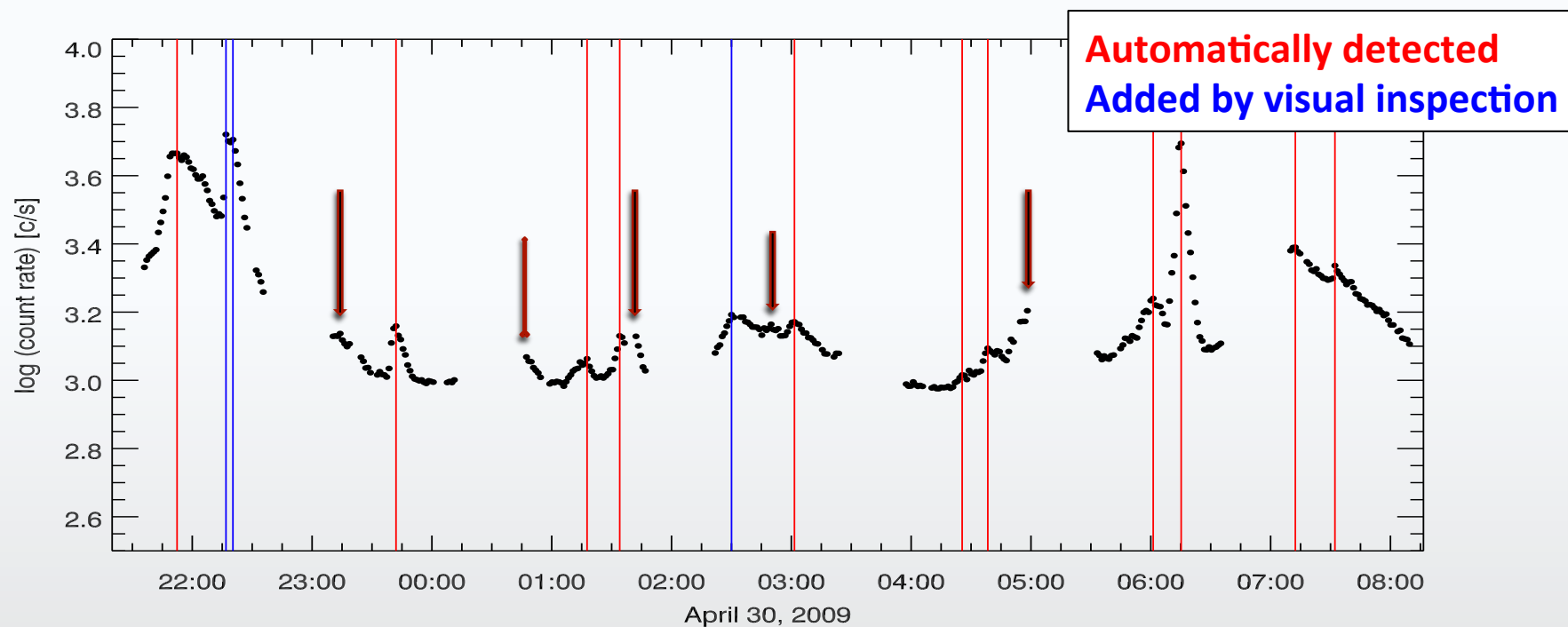
- data preparation: averaging
- searching for 4 points of consecutive increase and 3 points of decrease after them
- criterion: $x_1 < 1.03 * x_4$
- maxima finding
- visual inspection and correction



Algorytm czuły na zjawiska o szerokim zakresie amplitud.

Niekiedy znajduje bardzo małe maksima, które zostają usunięte podczas ręcznej korekty. Niekiedy także pomija 'ewidentne' silniejsze zjawiska.

1604 rozbłysków 20 II - 29 XI 2009



37.5% PERCENTAGE OF SOLAR UNBIASED MEASUREMENTS
WHEN THE INSTRUMENT WAS IN THE ON STATE

Elementarny profil rozbłysku

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

Splot dwóch funkcji:

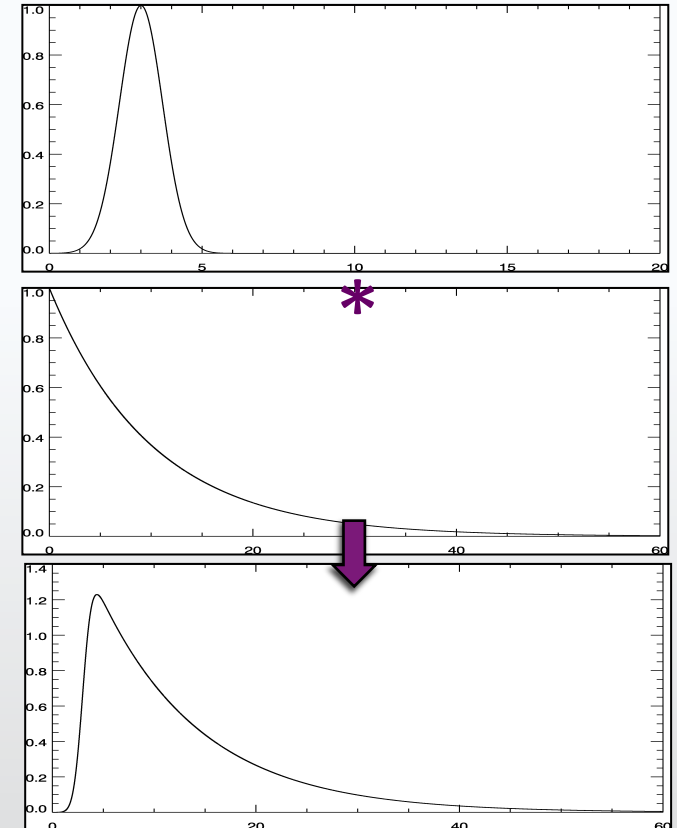
Funkcja Gaussa: $f(t) = Ae^{(-(t-B)^2/C^2)}$

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

Liniowe tło

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

4 parametry (rozbłysk) +
2 parametry (liniowe tło)
= 6 PARAMETRÓW



Metoda dopasowywania modelu do obserwowanych rozbłyków

Funkcja IDL **MPFITFUN** (Markwardt, 2009)

www.physics.wisc.edu/~craigm/idl/mpfittut.htm

(The MPFITFUN algorithm was translated from MINPACK-1 package (More 1977) for solving nonlinear equations and nonlinear least squares problems.)

final_parameters = MPFITFUN(,ProfileModel_expresion', Time, Obs_LC, errors, initial_parameters, PARINFO = pi, STATUS = status, PERROR = perror, ERRMSG = errmsg, BESTNORM = bestnorm, DOF = dof)

PARINFO – umożliwia ‘sztywne’ przypisanie wartości parametru

STATUS – informacja o przebiegu dopasowania

PERROR – 1 sigma error

ERRMSG – informacja o ewentualnym błędzie

BESTNORM - the value of the summed squared residuals for the returned parameter values

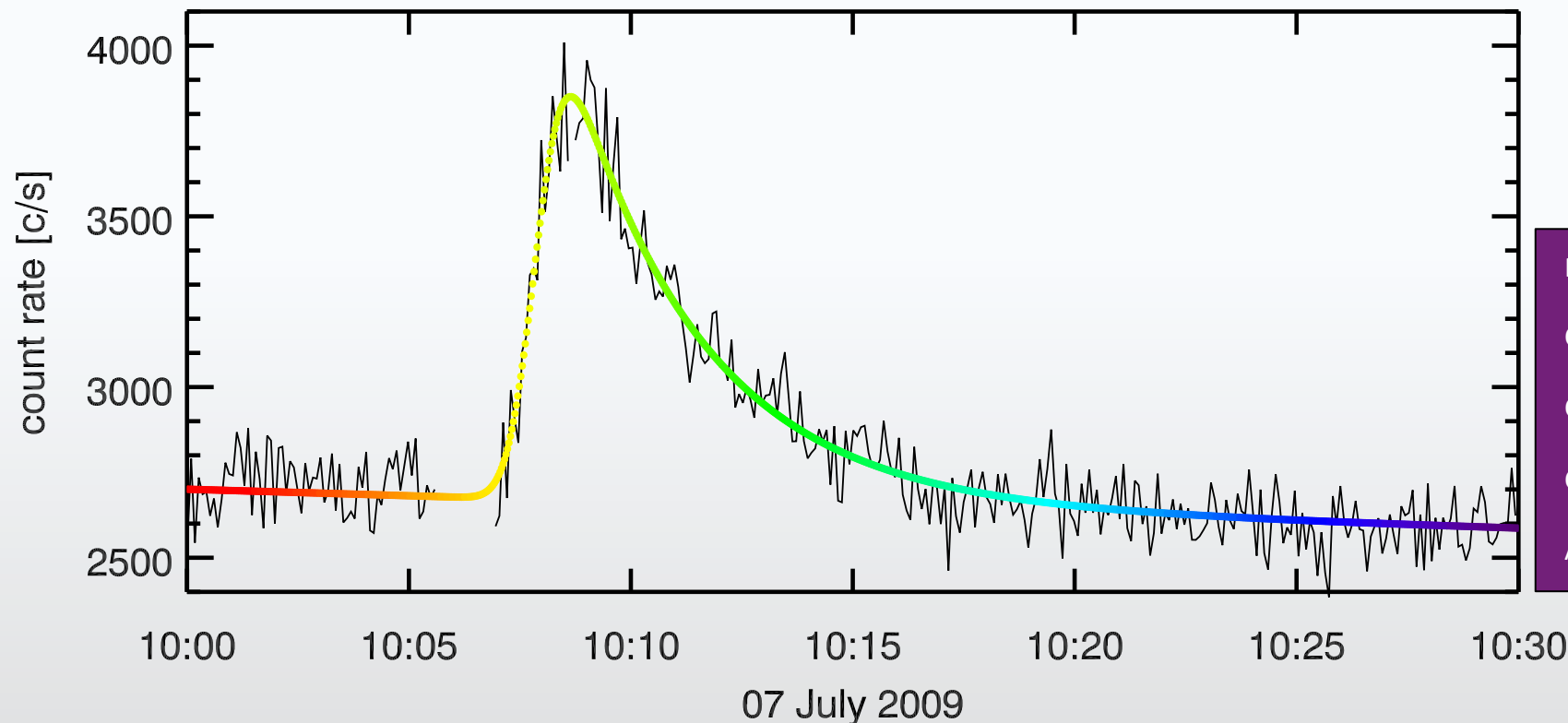
DOF - number of degrees of freedom, computed as $DOF = N_ELEMENTS(DEVIATES) - NFREE$

Dopasowanie Elementarnego Profilu Rozbłysku do obserwacji SphinX

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

$$[\operatorname{erf}((2B + C^2 D)/2C) - \operatorname{erf}((2(B - t) + C^2 D)/2C)] +$$

$$+ Et + F$$



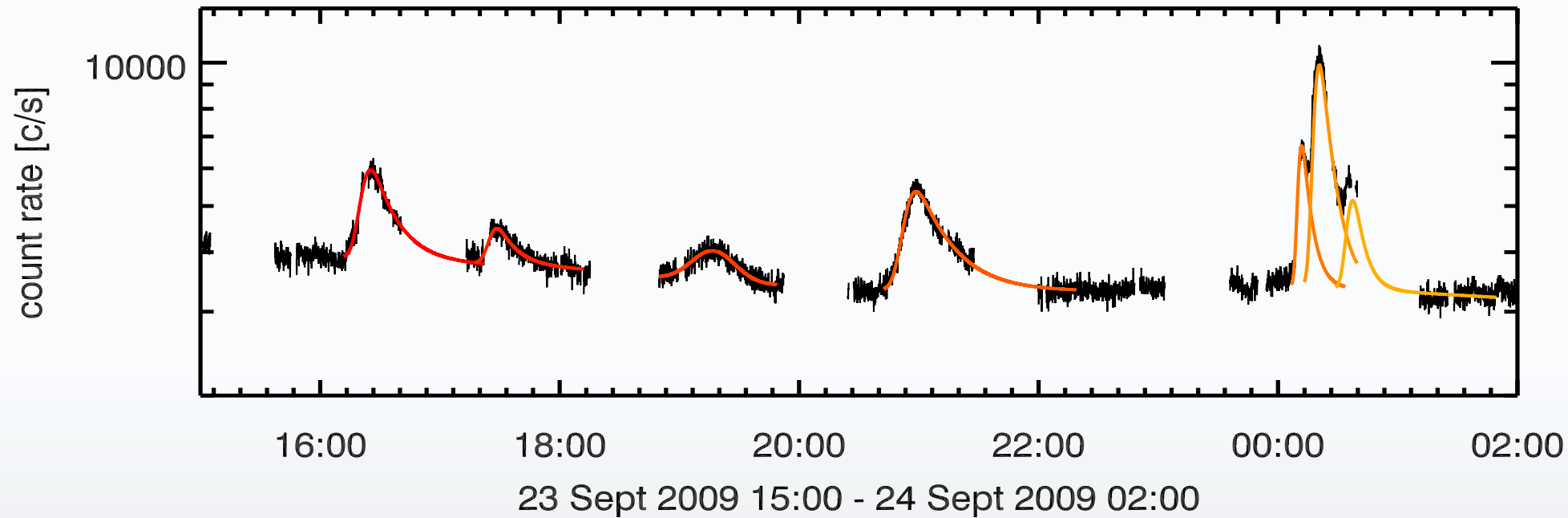
PARAMETRY:

Czas startu

Czas maksimum

Czas końca

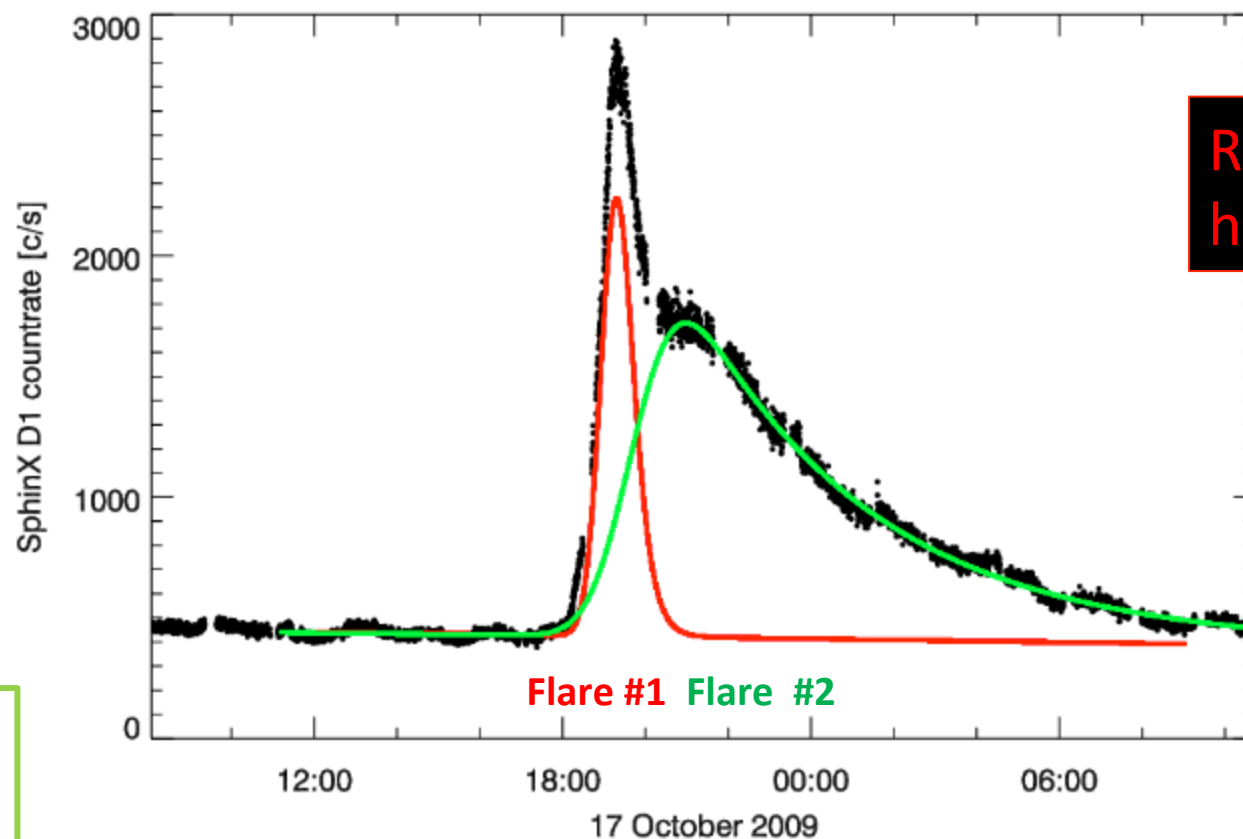
Amplituda (incremental class)



SphinX 1.2 - 15 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.

Rozbłysk A7 17 X 2009 SphinX

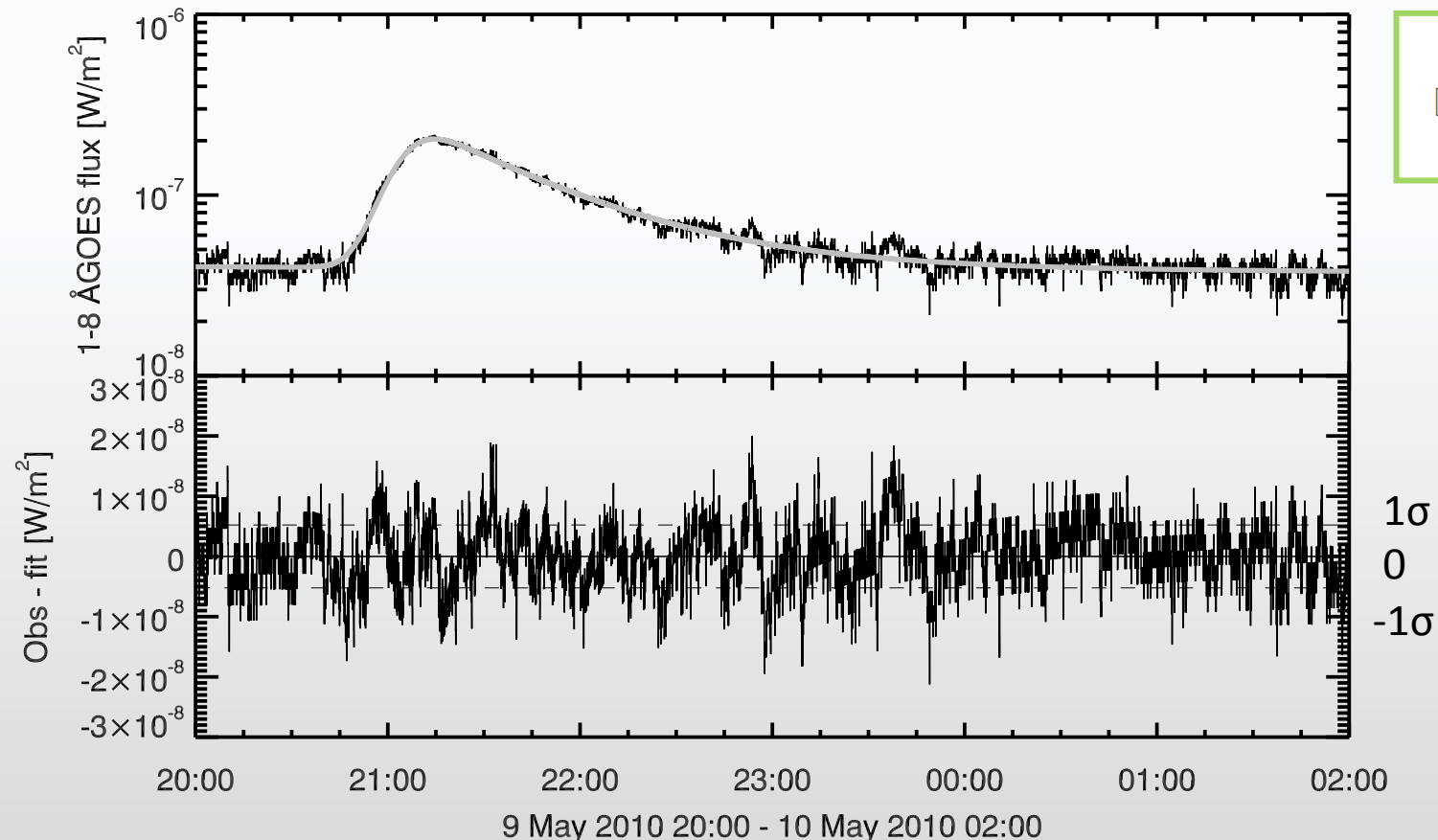


Rozbłysk
hybrydowy?

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]

GOES 1-8 Å – przykład dopasowania elementarnego profilu

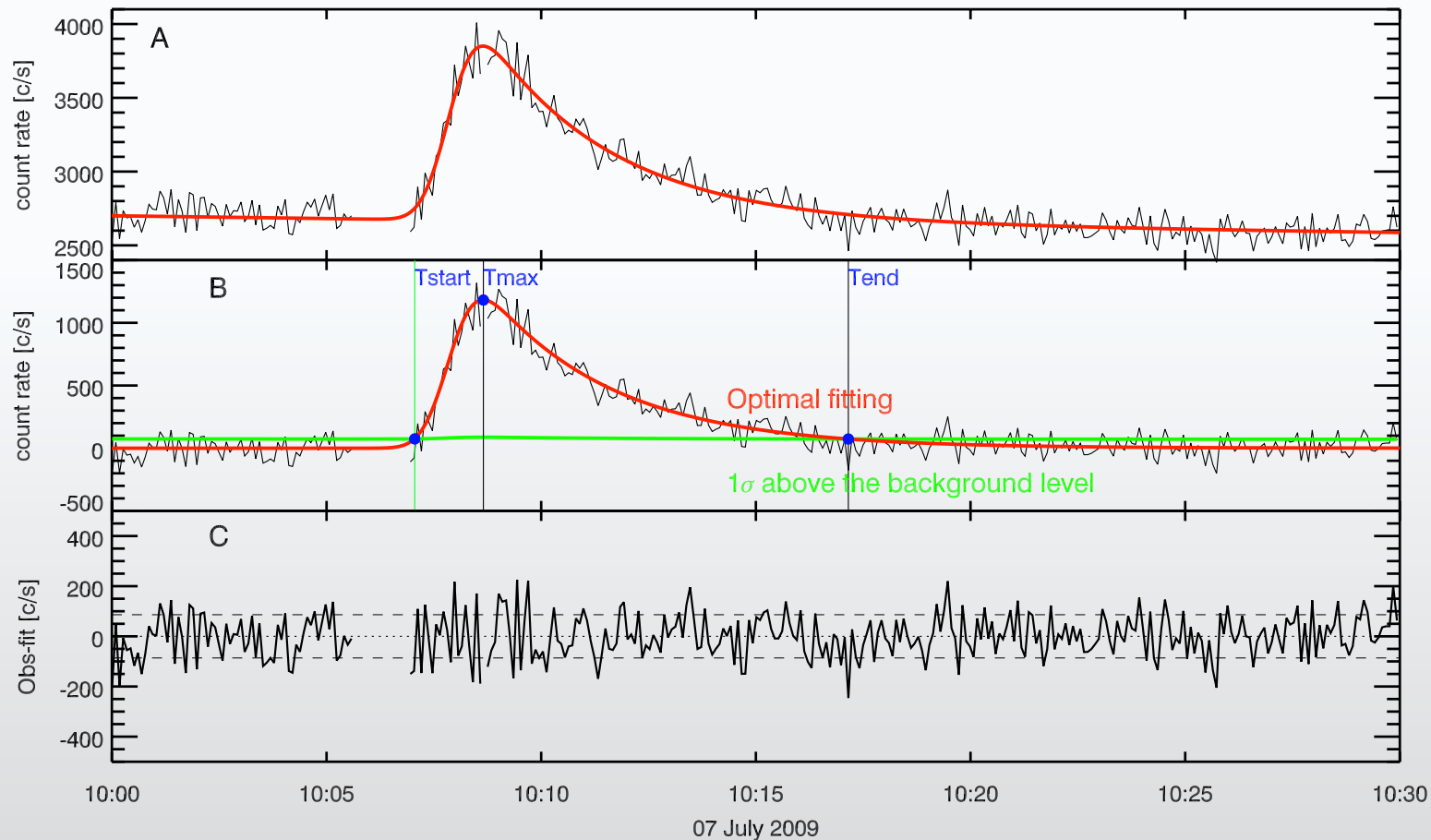


$$F(t) = 0.5 \sqrt{\pi} A C \exp(D(B - t) + (C^2 D^2)/4) \cdot$$

$$[\operatorname{erf}((2B + C^2 D)/2C) - \operatorname{erf}((2(B - t) + C^2 D)/2C)] +$$

$$+ Et + F$$

Parametry czasowe rozbłysku



PARAMETRY:

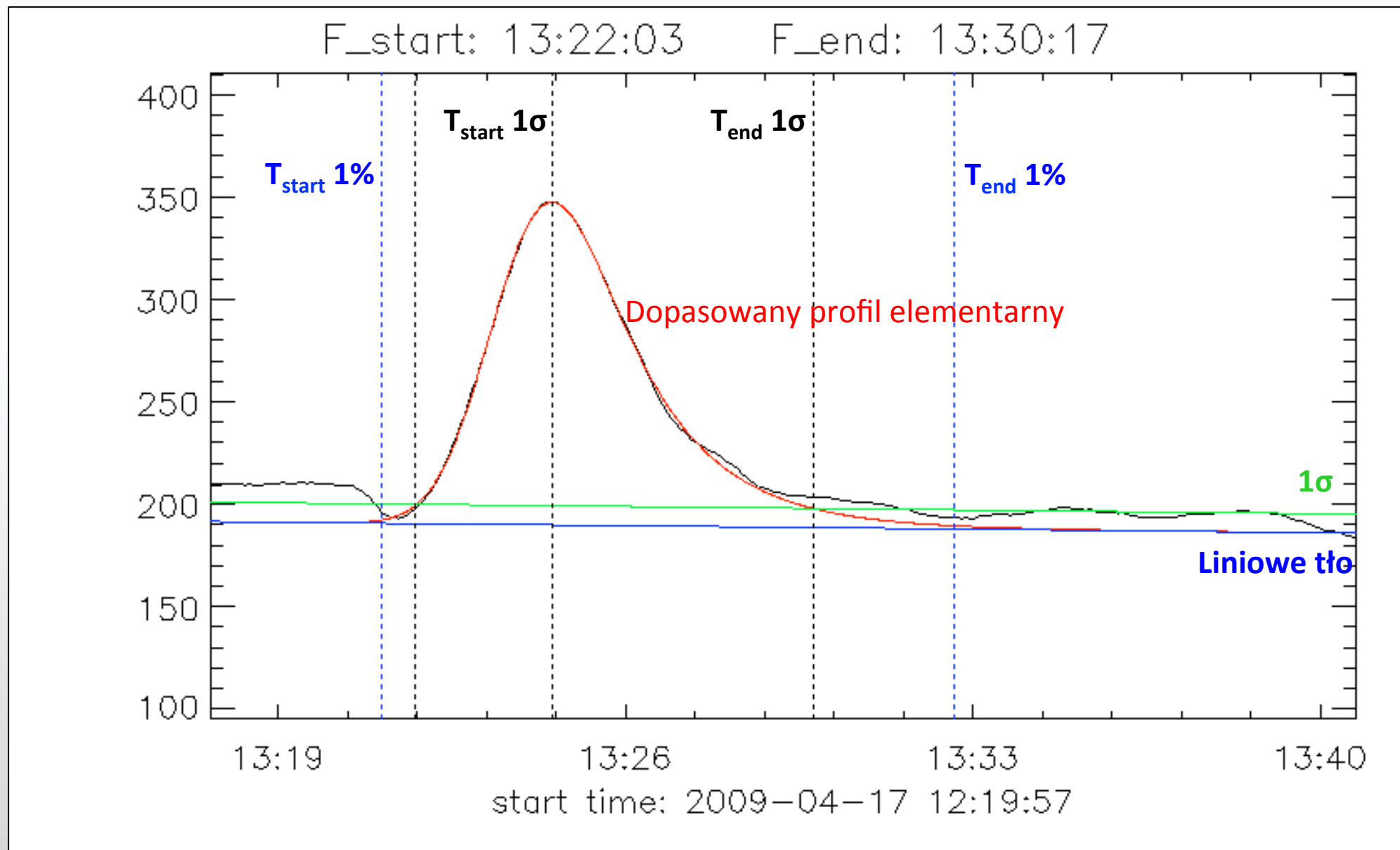
Czas startu

Czas maksimum

Czas końca

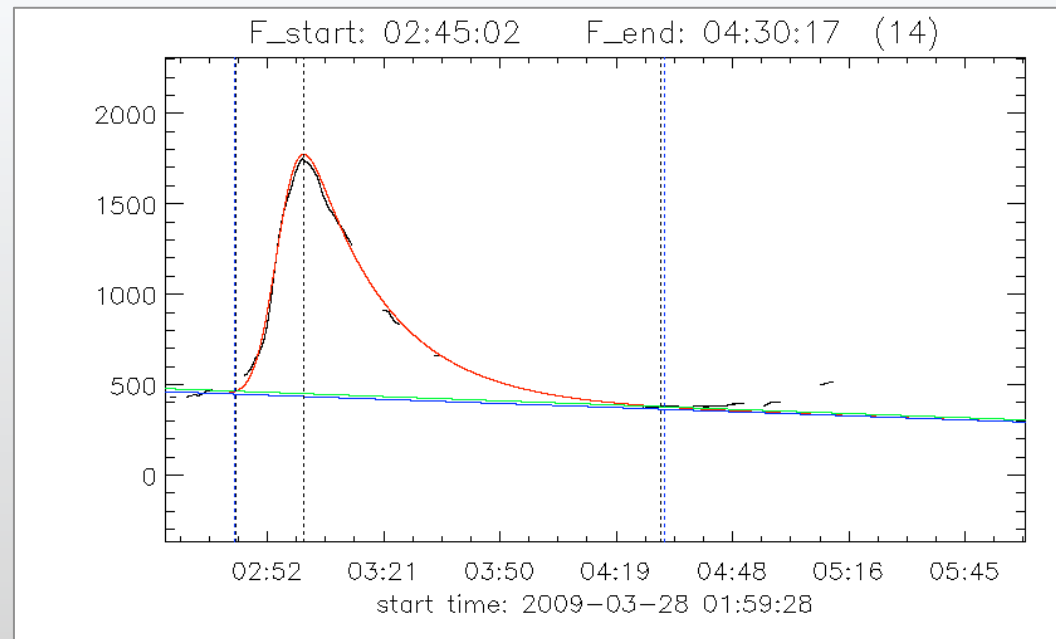
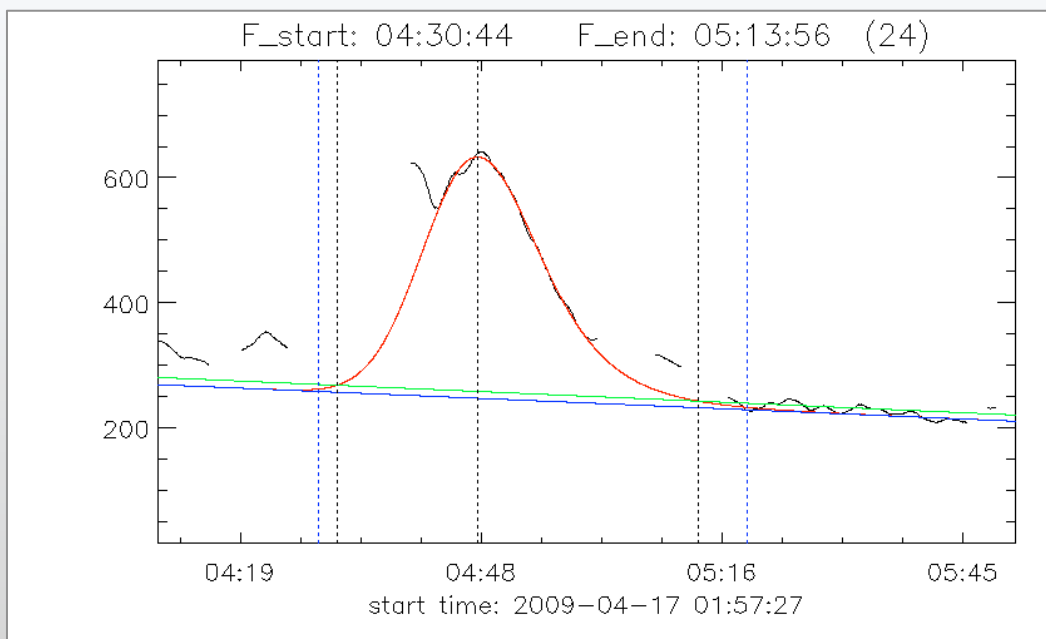
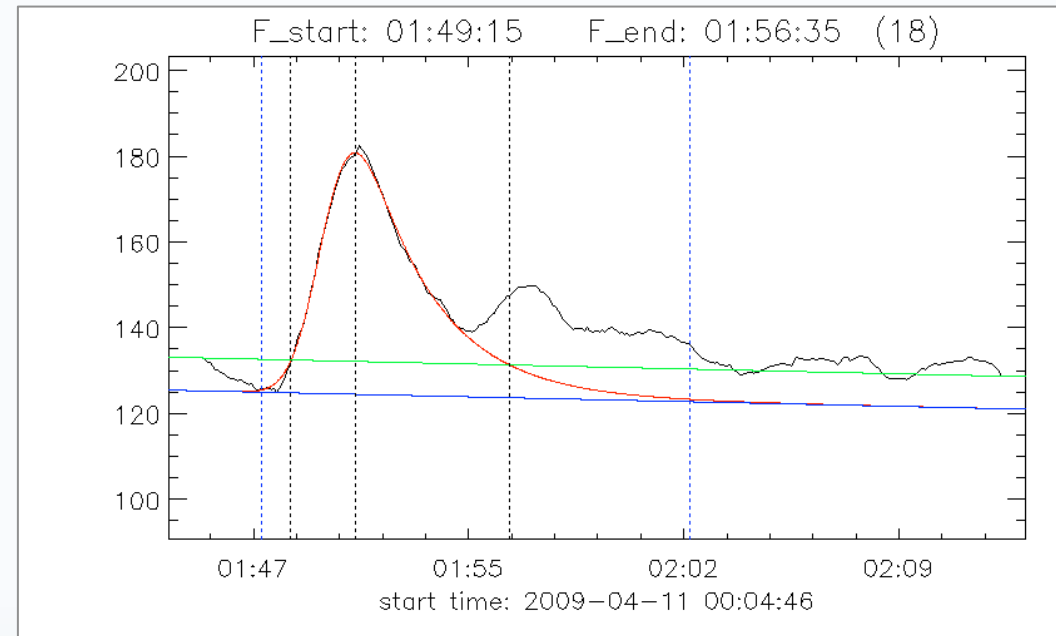
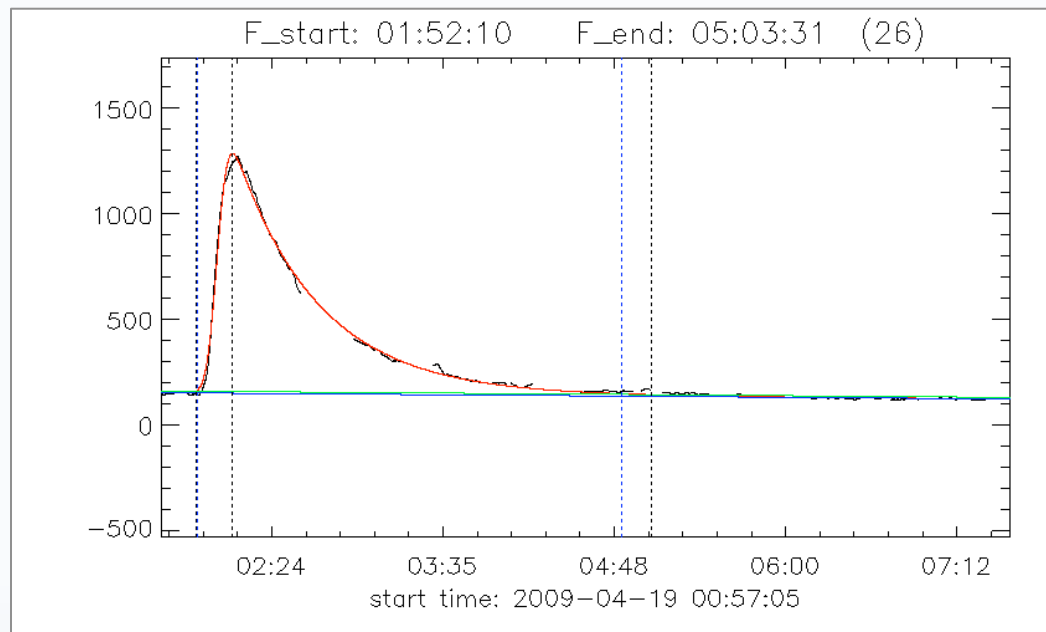
Amplituda (incremental class)

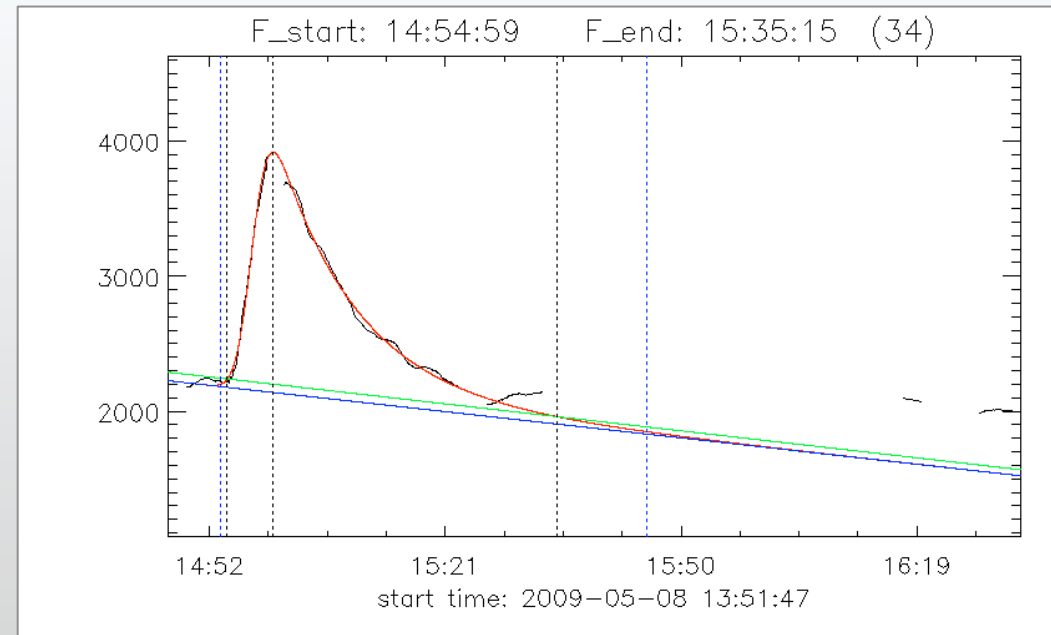
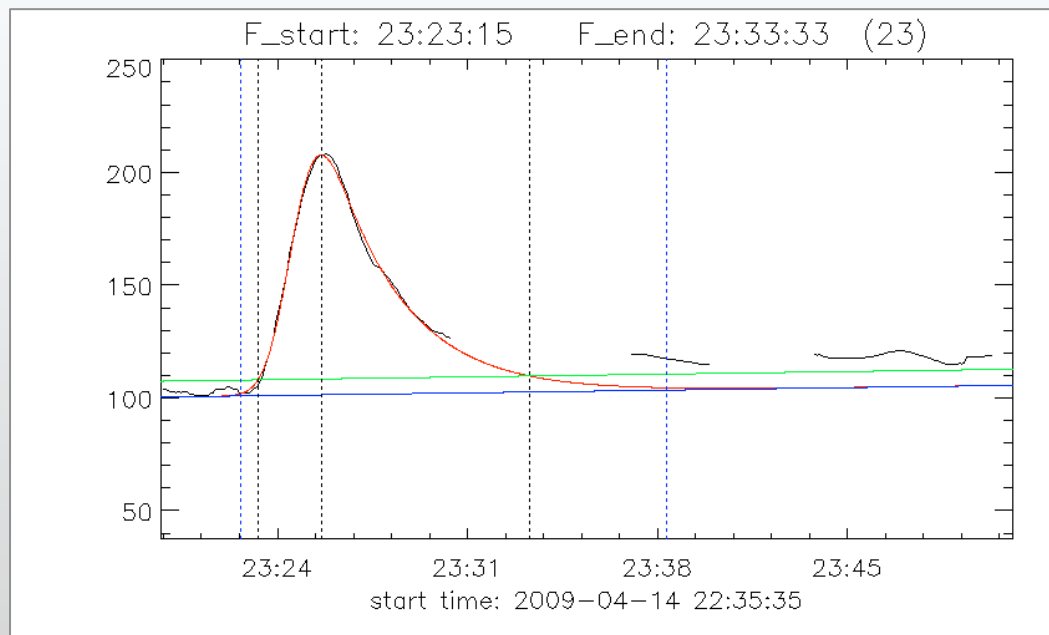
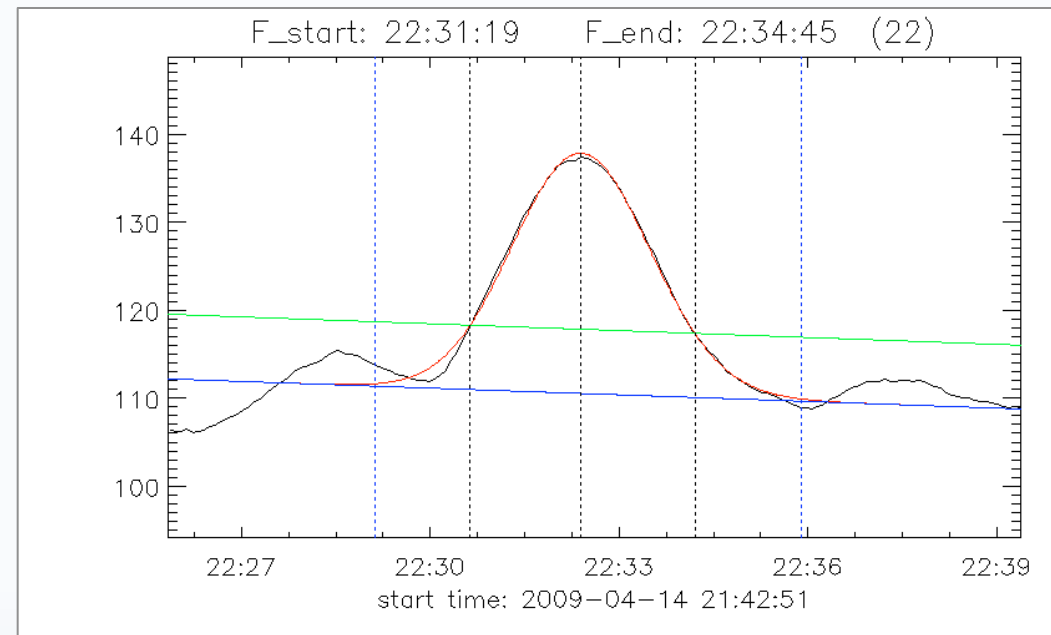
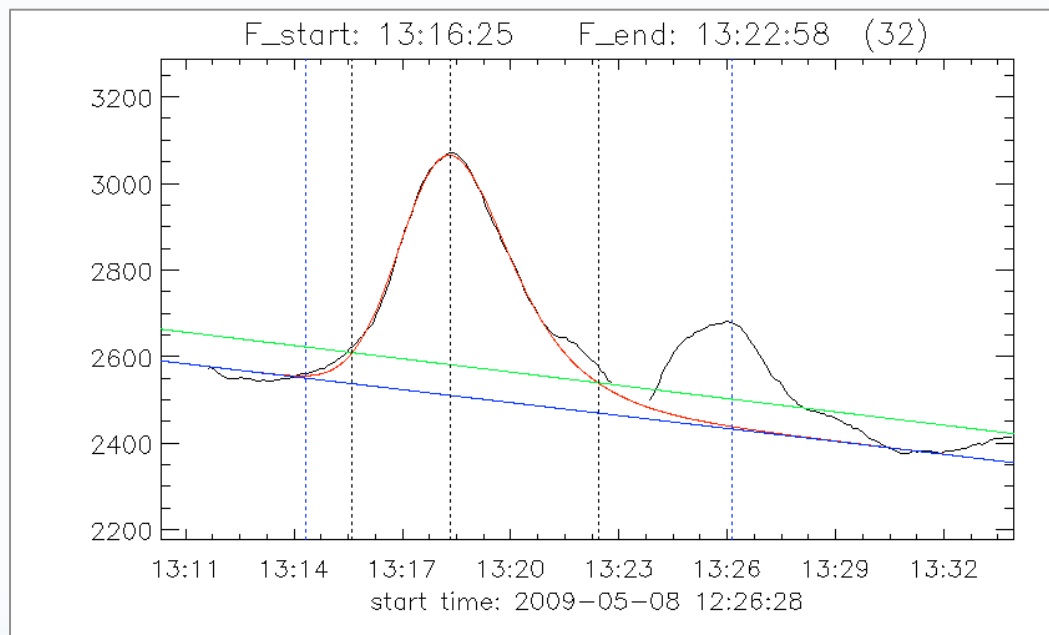
Parametry czasowe

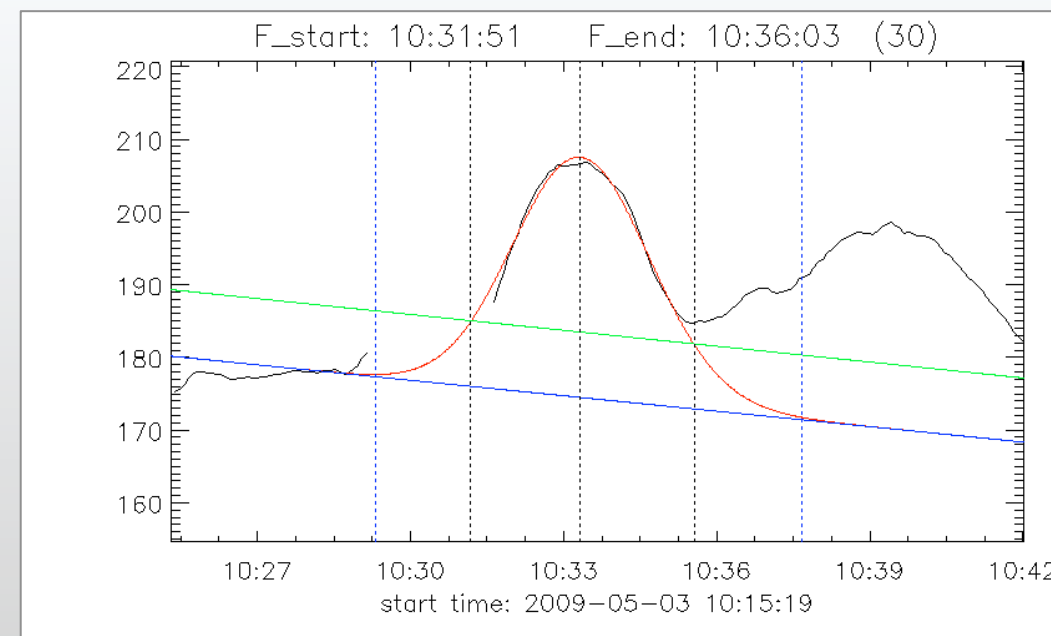
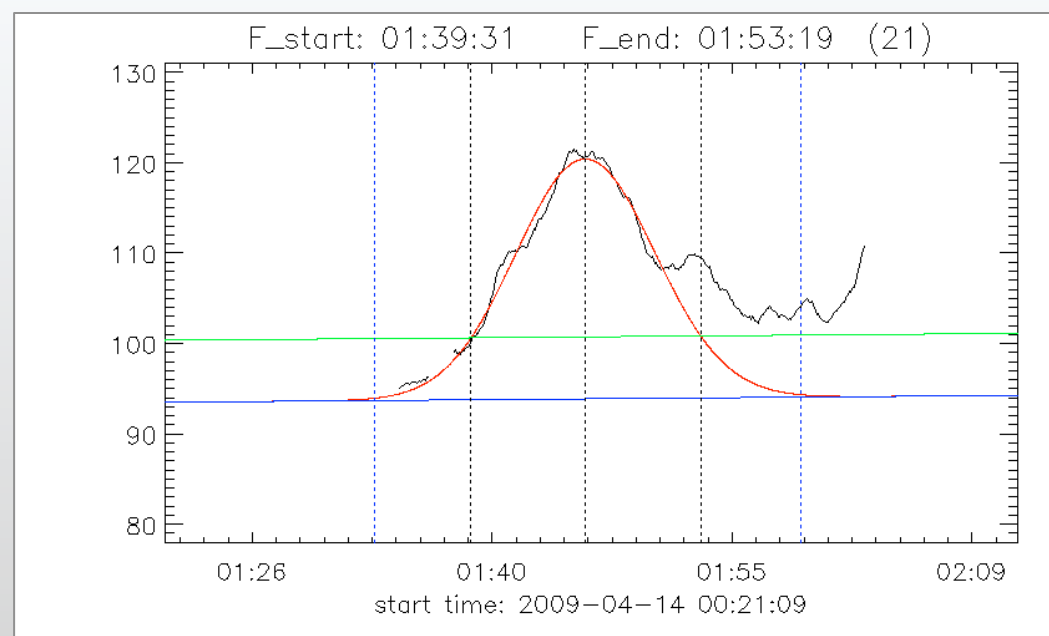
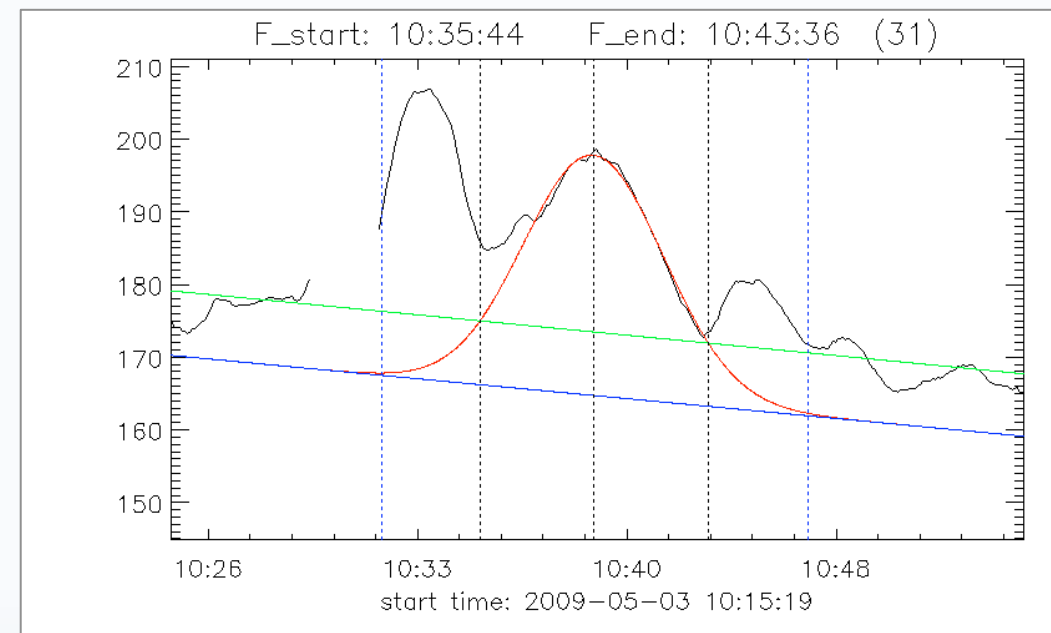
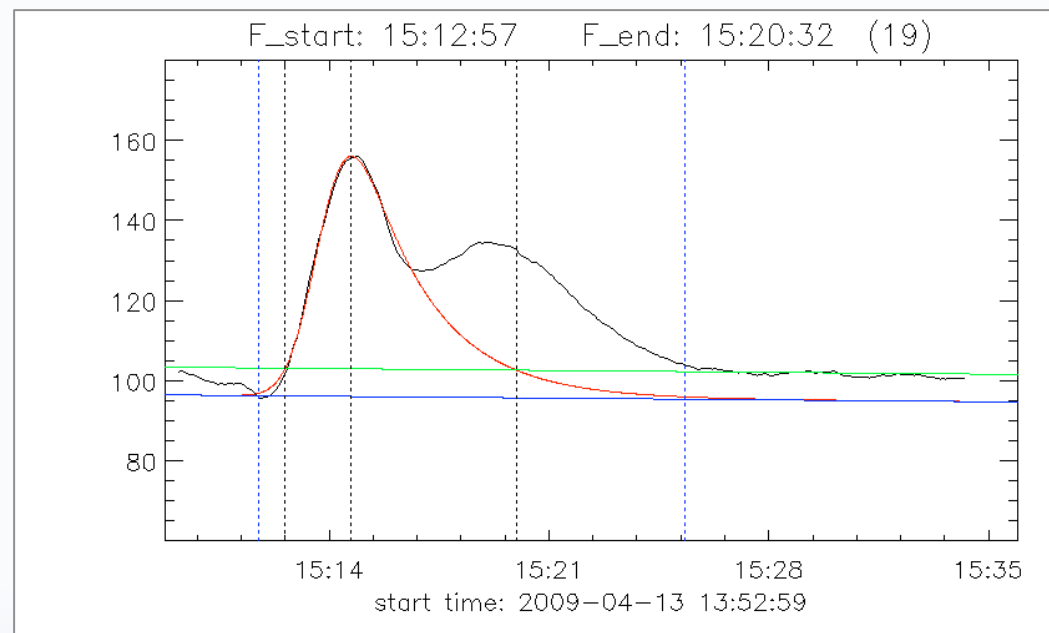


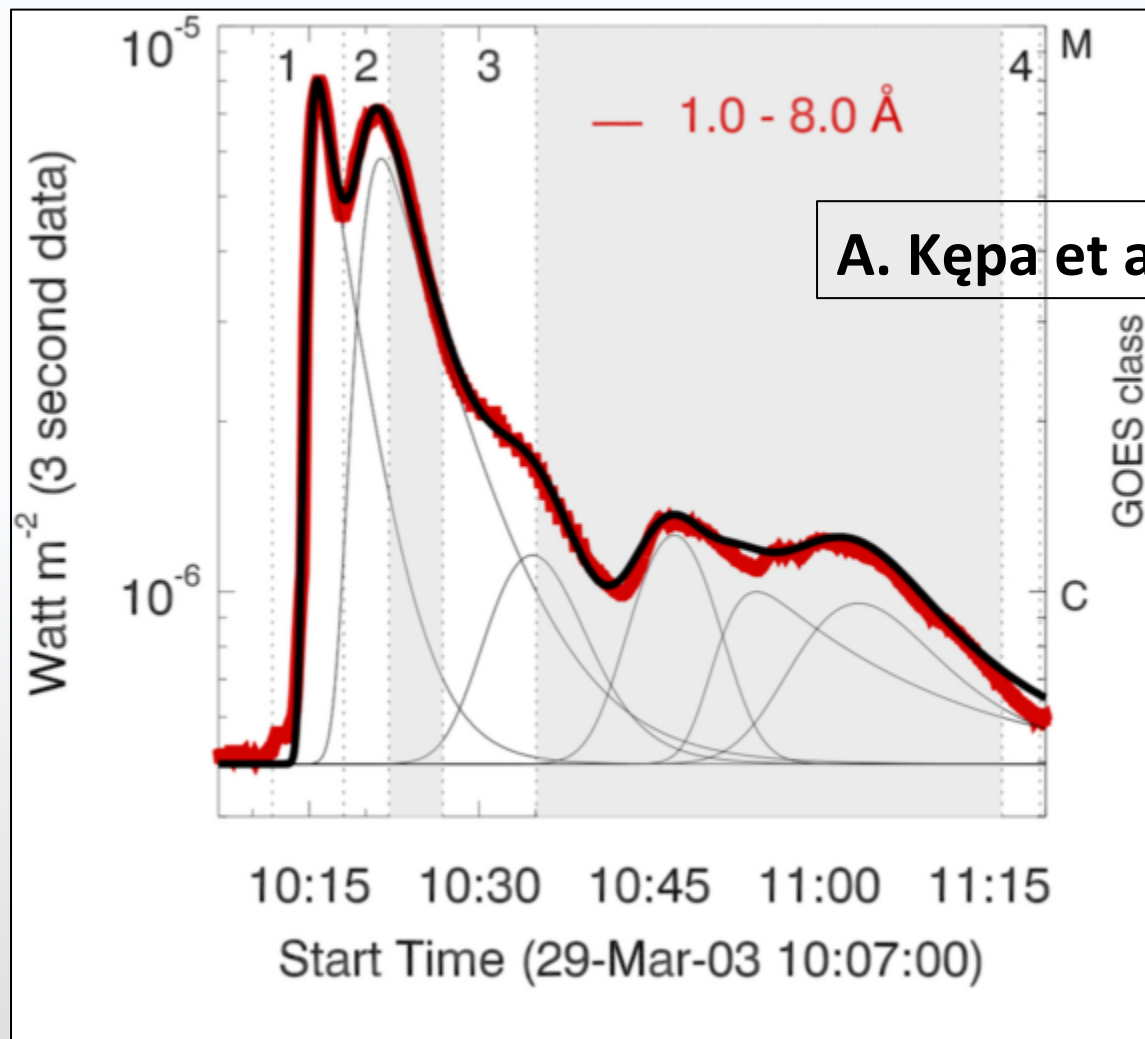
**DWA KRYTERIA
WYBORU CZASU
STARTU I KOŃCA
ZJAWISKA:**

- 1% AMPLITUDY,
- 1σ z obserwacji powyżej liniowego tła przyjętego z najlepszego dopasowania



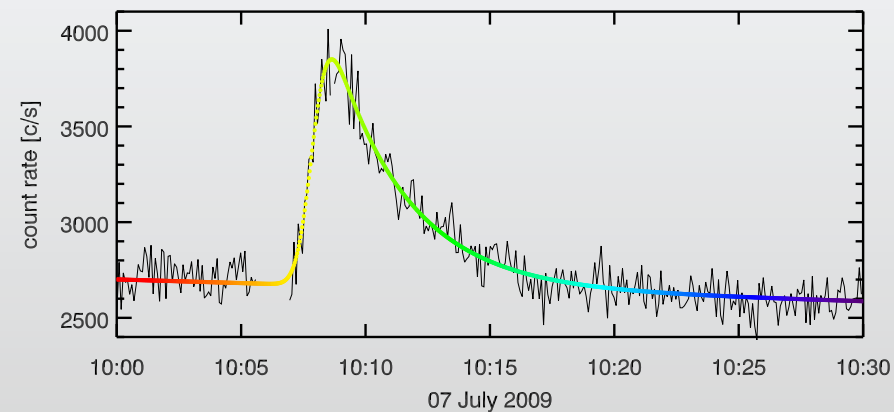




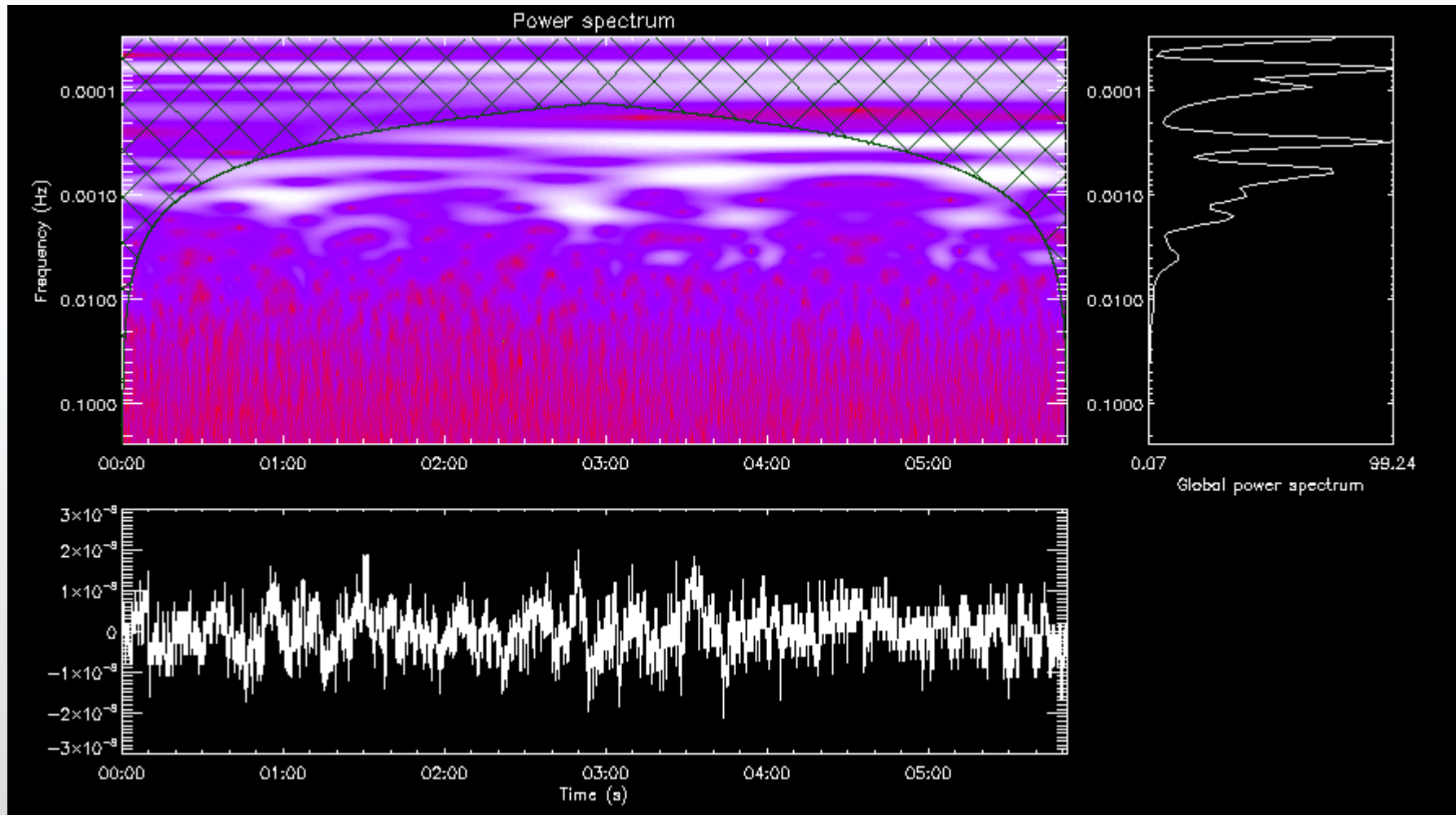


GOES kanał 1-8 Å

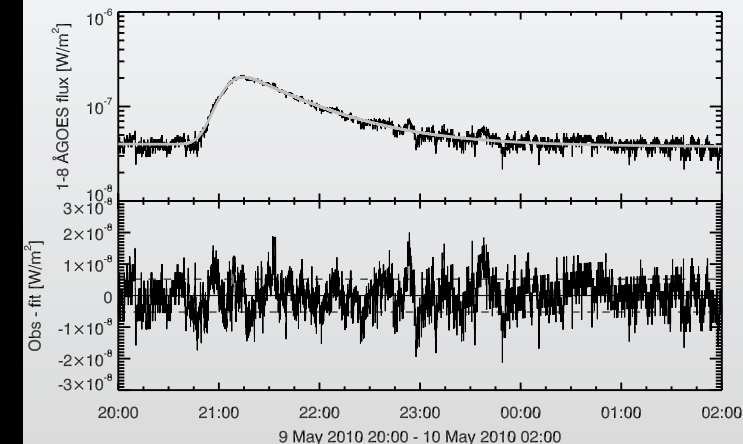
N = 6 rozbłysków



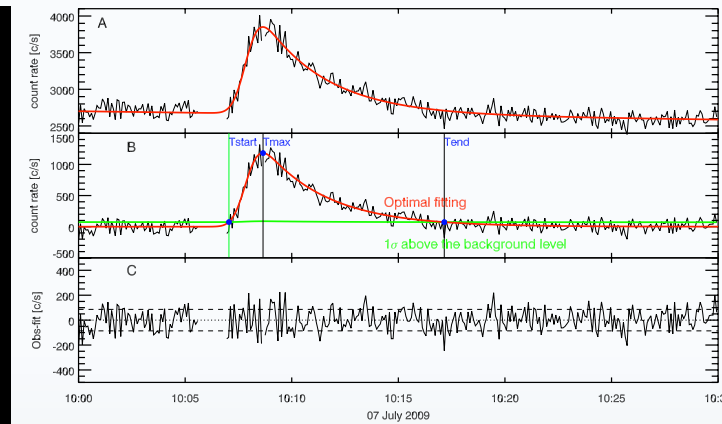
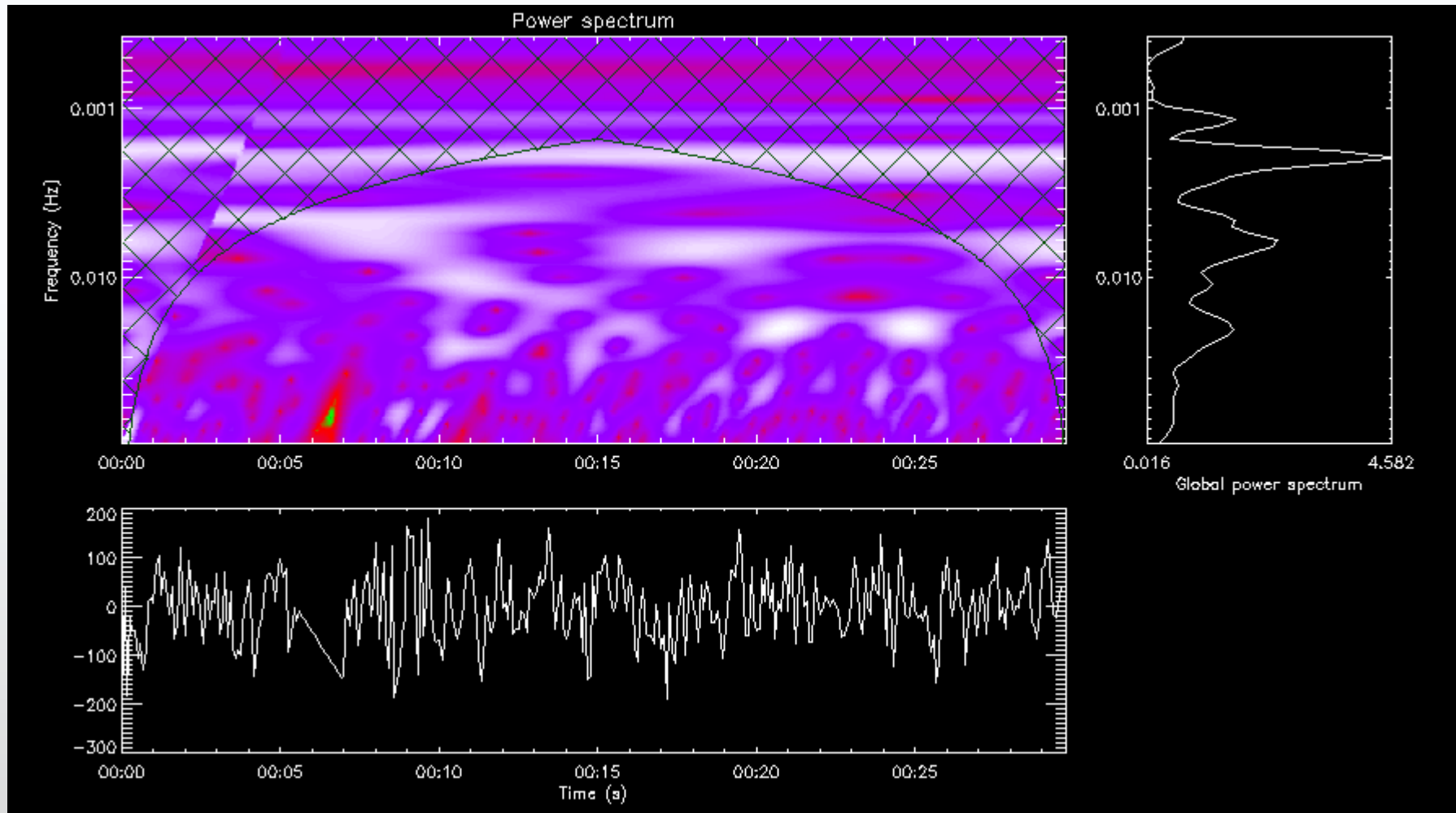
Obserwacje po odjęciu dopasowanego modelu profilu



Przekształcenie falkowe
dla falki Morleta



Obserwacje po odjęciu dopasowanego modelu profilu



Przekształcenie falkowe
dla falki Morleta

Częstość występowania rozbłysków

Minimum aktywności 2009 (na przełomie cykli 23/24)

Obserwacje prowadzone przez 9 miesięcy (II – XI 2009)

SphinX Duty Cycle: 37.5%

FLAGI: satelita w cieniu Ziemi, przejście przez pasy radiacji, wyłączenia instrumentu, 'inne flag'

LICZBA ROZBŁYSKÓW: 1604

ŚREDNI CZAS POMIĘDZY ROZBŁYSKAMI WYZNACZONY Z OBSERWACJI SphinX:

1.58 h ($\approx$ 15 flares/day)

Częstość występowania rozbłysków – klasa GOES

Klasa GOES	Liczba N	Procent z wszystkich rozbłysków (1604)
C	11	0.686%
B	332	20.70%
A	560	34.91%
S	647	40.33%
<u>Q</u>	<u>54</u>	<u>3.37%</u>

The standard classification of X-ray Solar Flares (traditionally used for GOES):

X1 - 10^{-4} [W/m²]

M1 - 10^{-5} [W/m²]

C1 - 10^{-6} [W/m²]

B1 - 10^{-7} [W/m²]

A1 - 10^{-8} [W/m²]

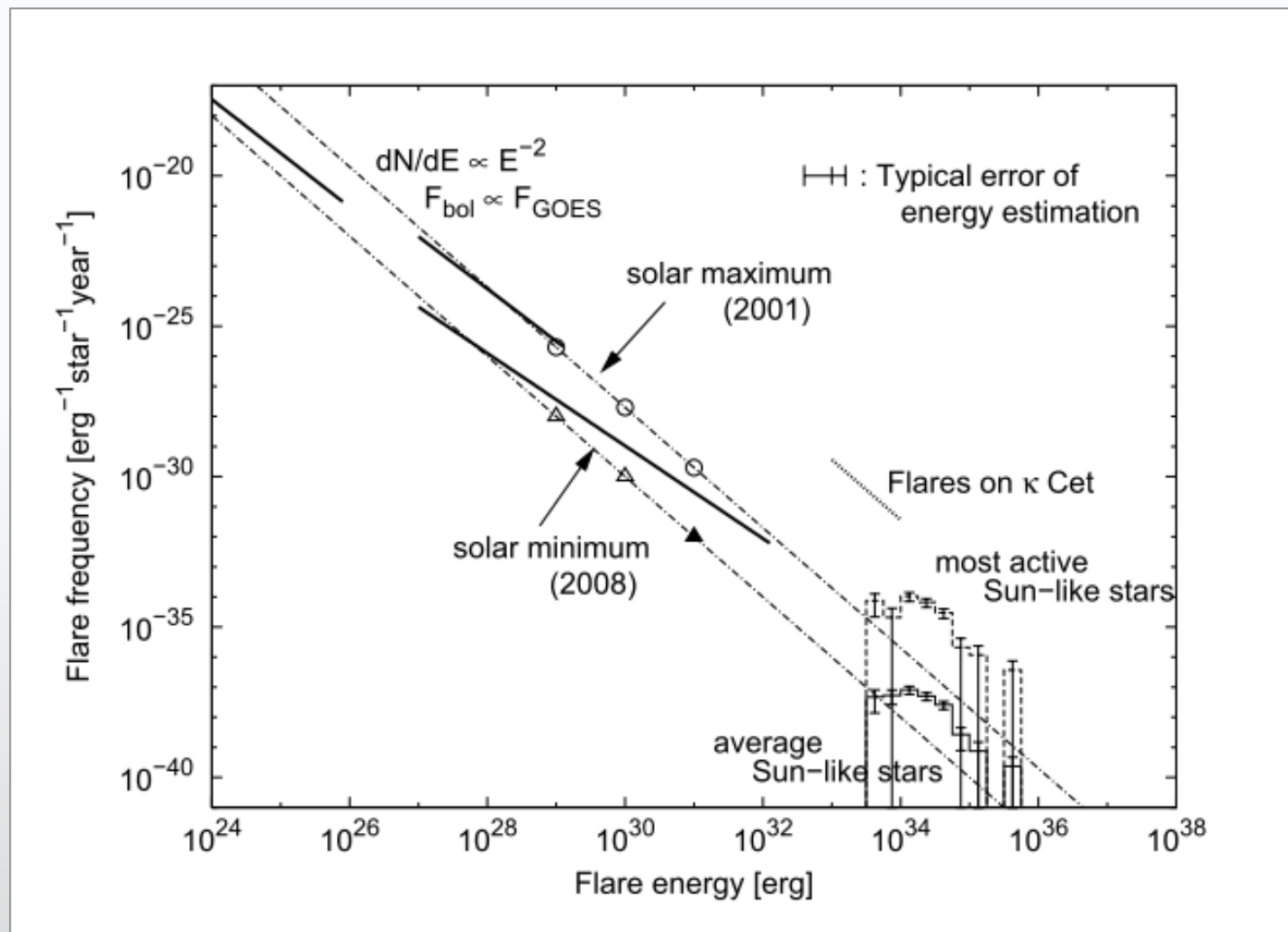
Two new flare classes introduced by SphinX Team:

S1 - 10^{-9} [W/m²]

Q1 - 10^{-10} [W/m²]

Estymacja strumienia bolometrycznego wg Kretzschmara

Fig. 10.— Flare occurrence frequency as a function of the flare energy in light on the stellar activity cycle. Solid lines correspond to power-law distributions of solar flares, which are the same lines as in Figure 9. Distribution histograms represent the flare occurrence frequency of superflares on all Sun-like stars (solid curve), and on Sun-like stars with more than one superflare (dashed curve). The bar at the upper right of this figure shows a typical error of our energy estimate. Dash-dotted lines correspond to power-law distributions estimated from numbers of solar flares observed by GOES. The flux in bolometric flux of flare (F_{bol}) is estimated to be in proportion to the GOES X-ray Flux (F_{GOES}). We show the case of $F_{\text{bol}} \propto F_{\text{GOES}}^{0.65}$ in Figure 13. Open circles show the occurrence frequency of C, M, X class solar flares during the solar maximum, while frequency during the solar minimum is shown by triangles. No X class solar flare was observed in the solar minimum (2008). We estimated the occurrence frequency of X class flare in the solar minimum, and the estimated frequency is shown by the closed triangle.



Superflares on Solar Type Stars Observed with Kepler I. Statistical Properties of Superflares

Takuya Shibayama¹, Hiroyuki Maehara^{2,3}, Shota Notsu¹, Yuta Notsu¹, Takashi Nagao¹,
Satoshi Honda^{2,4}, Takako T. Ishii², Daisaku Nogami², Kazunari Shibata²

shibayama@kwasan.kyoto-u.ac.jp

Estymacja strumienia bolometrycznego

B. Estimating total flare energy from GOES X-ray flux based on Kretzschmar's relation

Kretzschmar (2011) derived the empirical relation between the bolometric flux of flare and GOES X-ray flux as

$$F_{bol} = 2.4 \times 10^{12} F_{GOES}^{0.65}.$$

If we use this relation to derive the total flare energy from GOES X-ray flux assuming the total energy of X10 class flare is 10^{32} erg, then the total energy of X-class, M-class, C-class flares become $10^{31.4}$ erg, $10^{30.7}$ erg, $10^{30.1}$ erg, respectively. Figure 13 is the same as Figure 10 but for the case of the flare energy estimate using Kretzschmar's relation. In this case, we clearly see disagreement between the observed frequency of nanoflares and those based on Kretzschmar's relation.

Superflares on Solar Type Stars Observed with Kepler
I. Statistical Properties of Superflares

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Rozkład występowania rozbłysków Estymacja strumienia bolometrycznego

Superflares on Solar Type Stars Observed with Kepler I. Statistical Properties of Superflares

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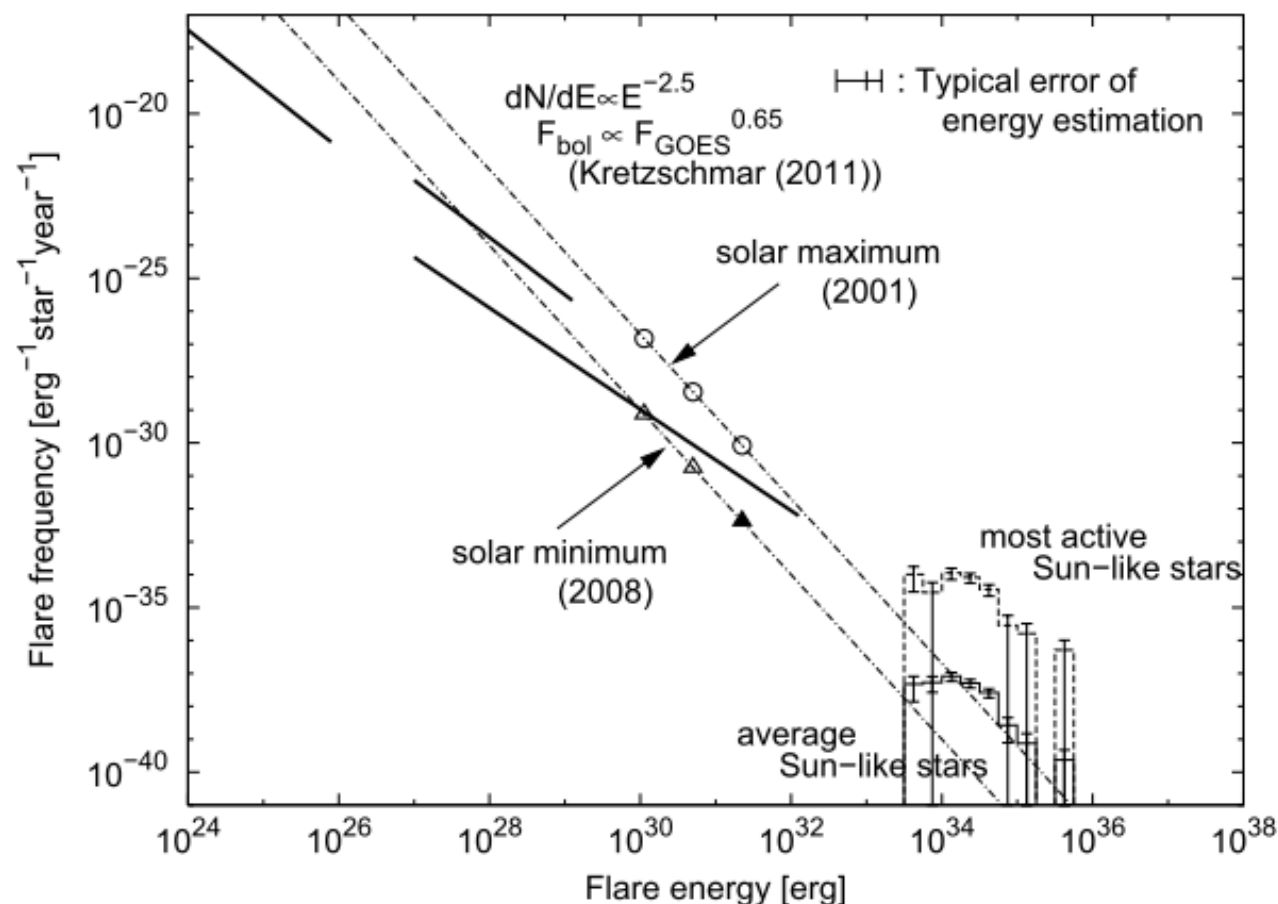
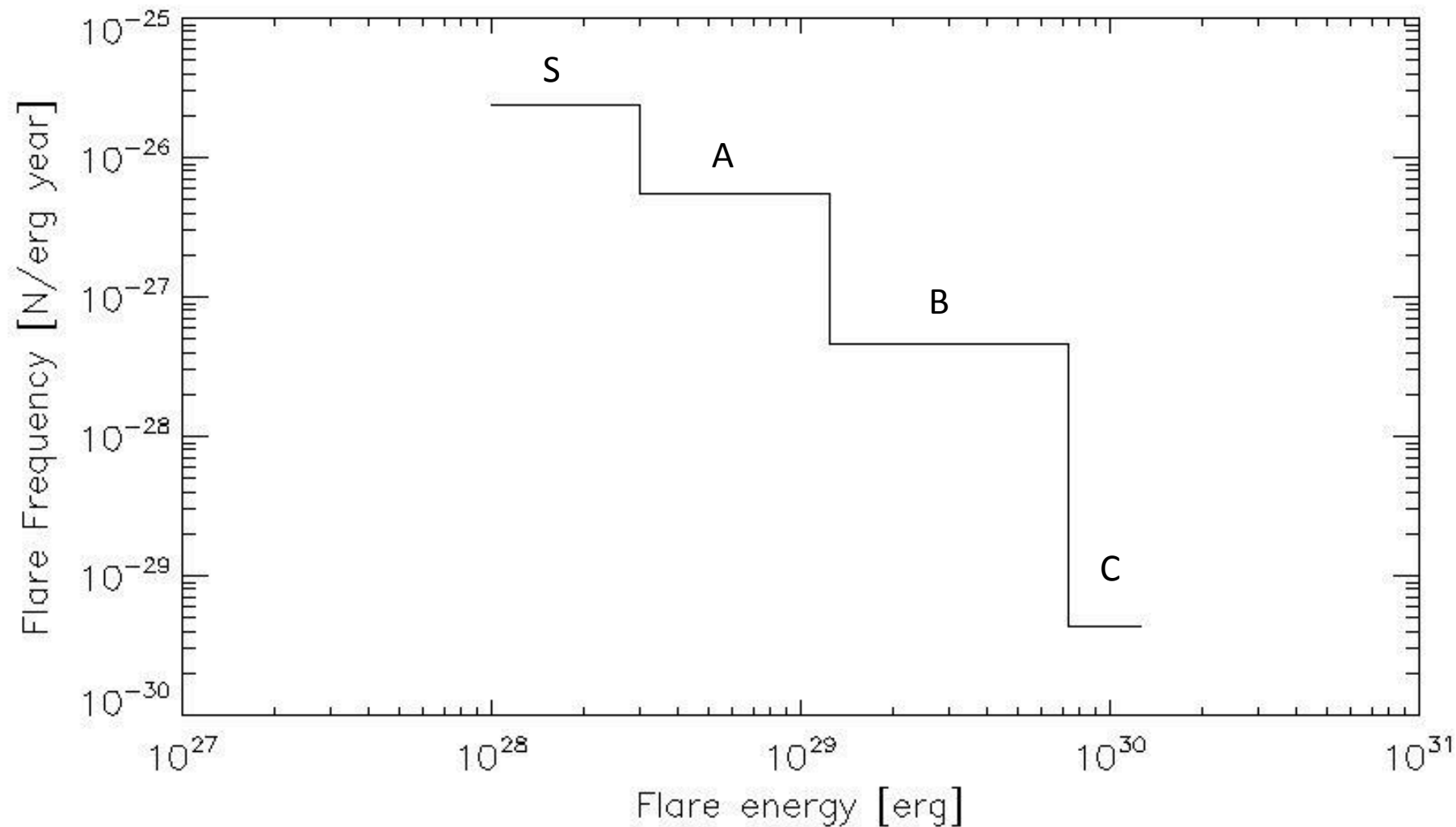
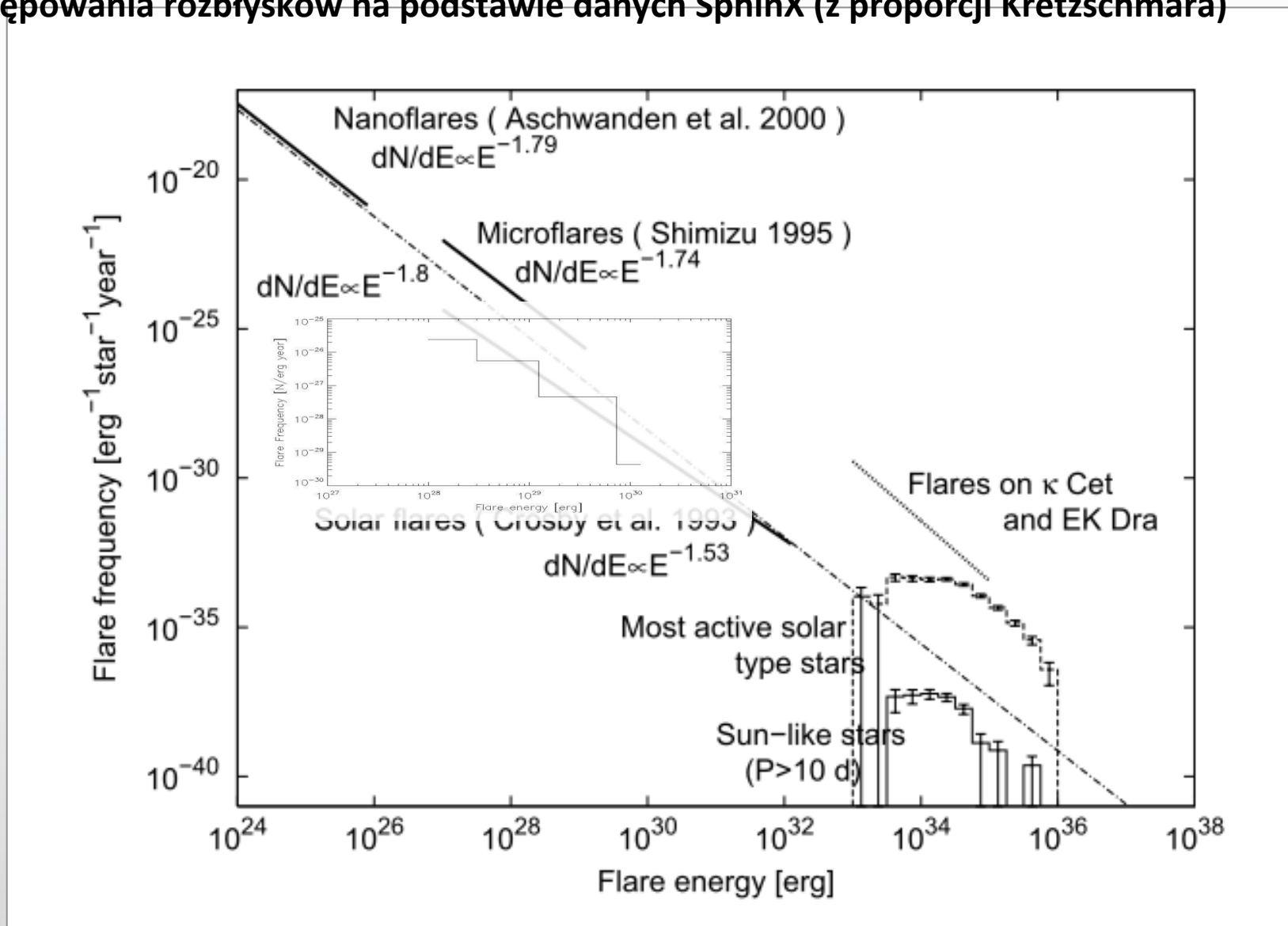


Fig. 13.— Same as Figure 10, but the total solar irradiance is estimated to be in proportion to the GOES X-ray Flux to the power of 0.65 (Kretzschmar 2011).

Fig. 13.— Same as Figure 10, but the total solar irradiance is estimated to be in proportion to the GOES X-ray Flux to the power of 0.65 (Kretzschmar 2011).

Rozkład częstości występowania rozbłysków na podstawie danych SphinX (z proporcji Kretzschmara)

Rozkład częstości występowania rozbłysków na podstawie danych SphinX (z proporcji Kretzschmara)



Podsumowanie

- >1.5 k rozbłysków zidentyfikowanych na podstawie interpretacji krzywych blasku SphinX
- Elementarny profil rozbłysku (EPR) – narzędzie pozwalające wyznaczyć parametry czasowe rozbłysków SXR oraz umożliwiające rozdzielenie zjawisk nakładających się w czasie
- EPR może być używany w analizie innych obserwacji SXR niż zarejestrowanych za pomocą SphinX
- Liniowy model tła zamiast stałego poziomu wyznaczonego na podstawie emisji przed rozbłyskiem
- Średnie tempo ‘generacji’ rozbłysków w czasie misji SphinX 15 zjawisk/dzień

Plany

- Analiza statystyczna wyznaczonych parametrów
- Diagnostyka temperaturowa plazmy rozbłyskowej
- Analiza obserwacji zarejestrowanych przez GOES oraz inne rentgenowskie obserwatoria satelitarne
- Klasyfikacja rozbłysków ze względu na cechy profili krzywych blasku (z użyciem sieci neuronowych Kohonena)

Sieci neuronowe Kohonena

Sieci neuronowe Kohonena (samoorganizujące się mapy Kohonena)

T. Kohonen „Self-Organized Formation of Topologically Correct Feature Maps”, 1982

Sieci neuronowe bez nauczyciela (*unsupervised learning; self-organizing*)

Zastosowanie algorytmu do klasyfikacji krzywych blasku:

Mon. Not. R. Astron. Soc. 000, 000–000 (0000) Printed 31 July 2013 (MN $\LaTeX$ style file v2.2)

The automated classification of astronomical lightcurves using Kohonen self-organising maps

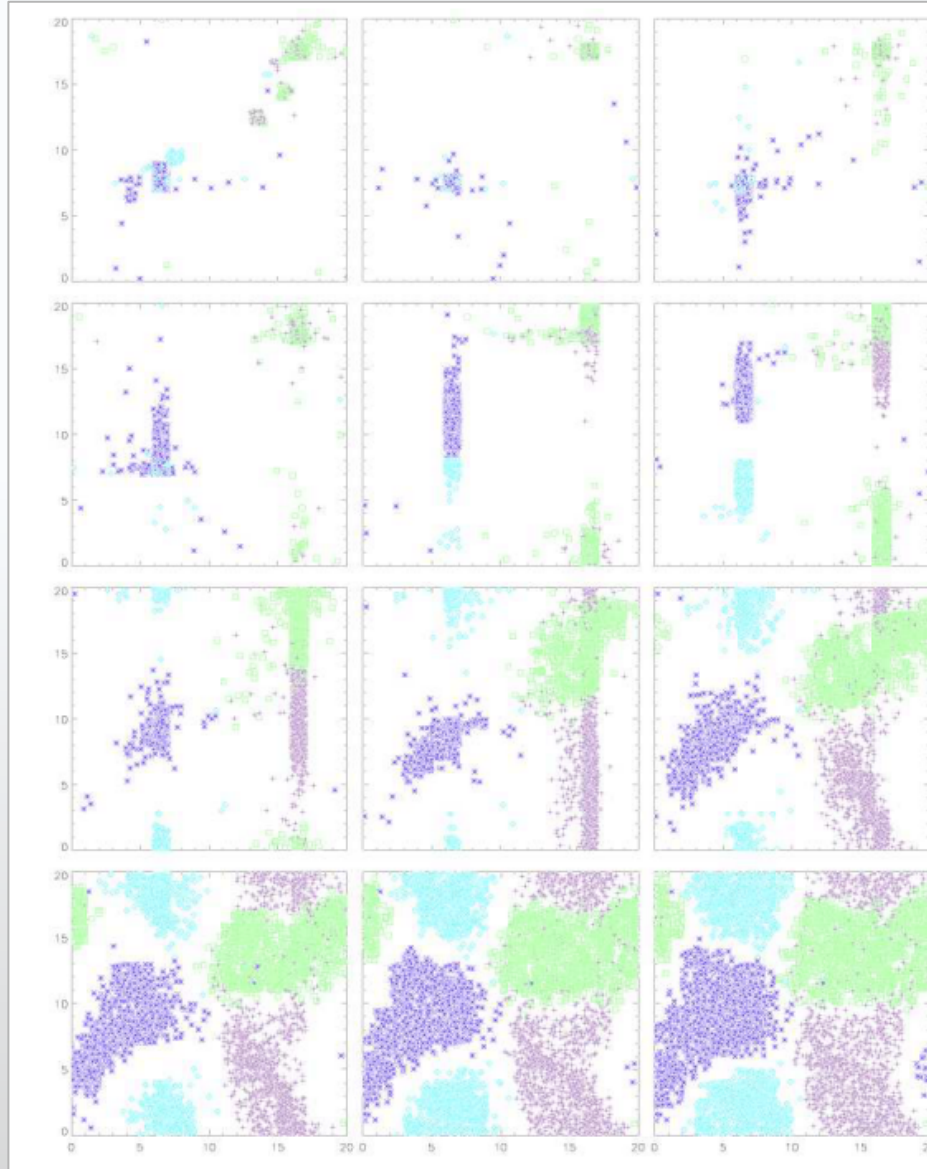
David R. Brett, Richard G. West^{*} and Peter J. Wheatley

Department of Physics & Astronomy, University of Leicester, University Road, Leicester LE1 7RH

31 July 2013

Sieci neuronowe Kohonena – zastosowanie metody do klasyfikacji krzywych blasku

Przykład zastosowania algorytmu dla sztucznych danych



We simulate lightcurves with the following basic shapes (see Figure 1):

- (i) a single skewed Gaussian peak (representing stars of the RR Lyrae ab-type family);
- (ii) a single symmetric Gaussian peak (representing stars of the RR Lyrae c-type, δ Scuti and Cepheid families);
- (iii) constant brightness with two broad Gaussian dips of equal width but differing depth (representing eclipsing close binary stars);
- (iv) as (iii) but with narrower dips (representing well-separated eclipsing binaries).

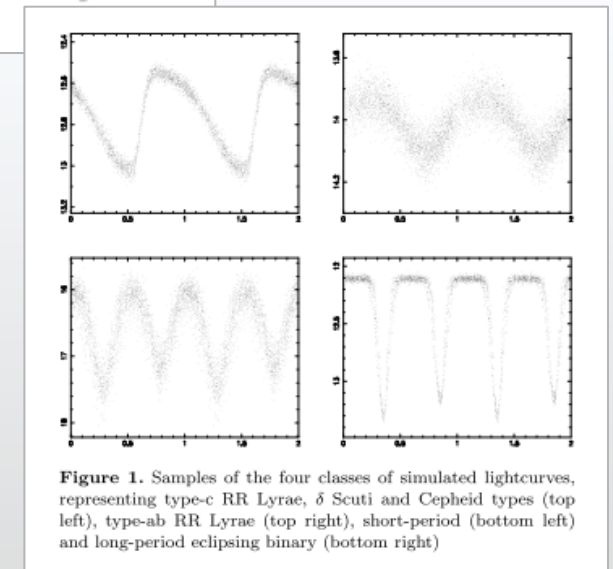


Figure 1. Samples of the four classes of simulated lightcurves, representing type-c RR Lyrae, δ Scuti and Cepheid types (top left), type-ab RR Lyrae (top right), short-period (bottom left) and long-period eclipsing binary (bottom right)

Figure 3. Evolution of a network trained with our synthetic data and with $\alpha(t) = \alpha_0 = 0.01$. Panels show (from left to right, top to bottom), iterations 1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34. The four classes of synthetic lightcurve (described in Section 1.2.1) are denoted by (i) squares, (ii) crosses, (iii) diamonds and (iv) stars. Note that, for the purposes of visualisation, the positions of all lightcurves have been randomised within their host neurons.

Sieci neuronowe Kohonena – zastosowanie metody do klasyfikacji krzywych blasku

Wynik zastosowania algorytmu dla danych z instrumentu ROTSE

1206 krzywych blasku

Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 31 July 2013 (MN $\LaTeX$ style file v2.2)

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31 July 2013

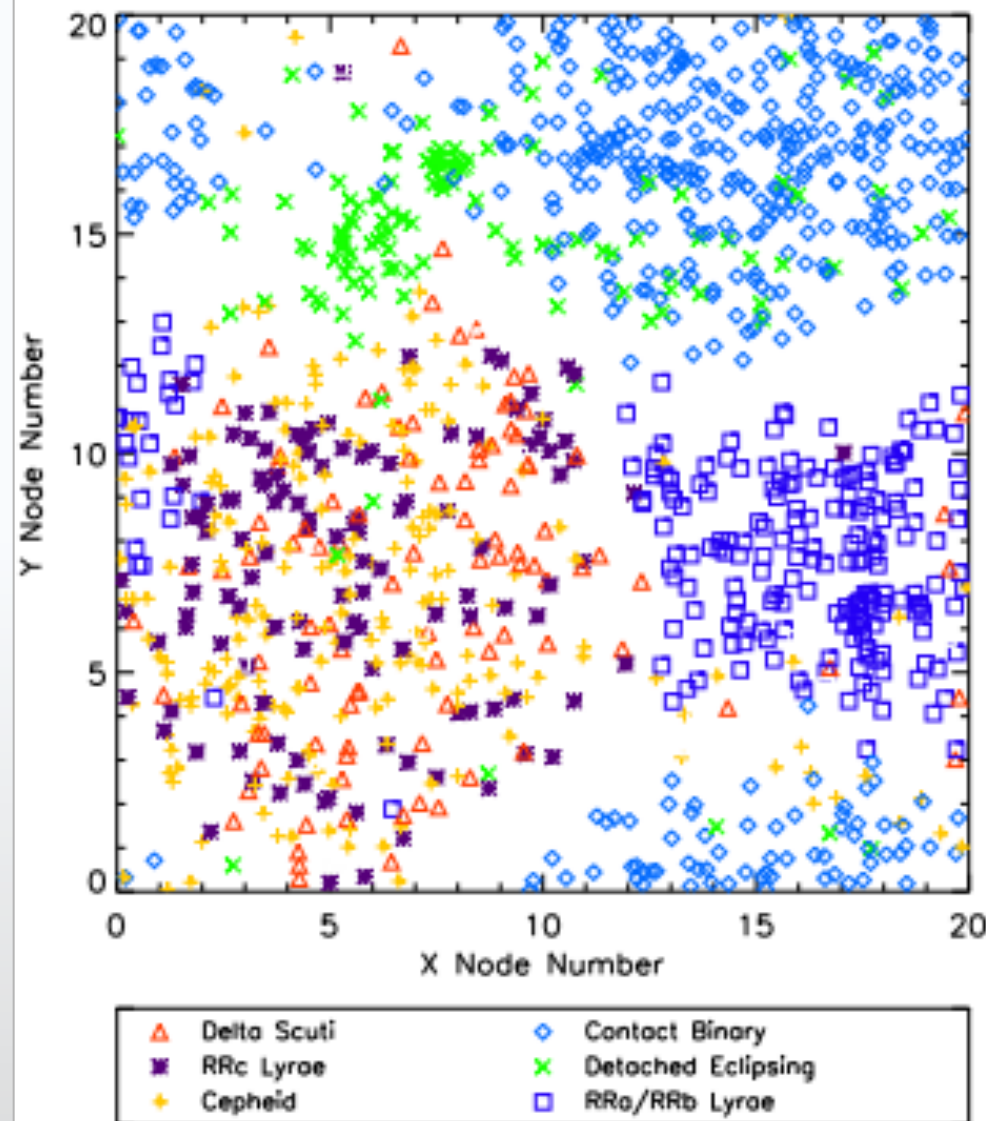
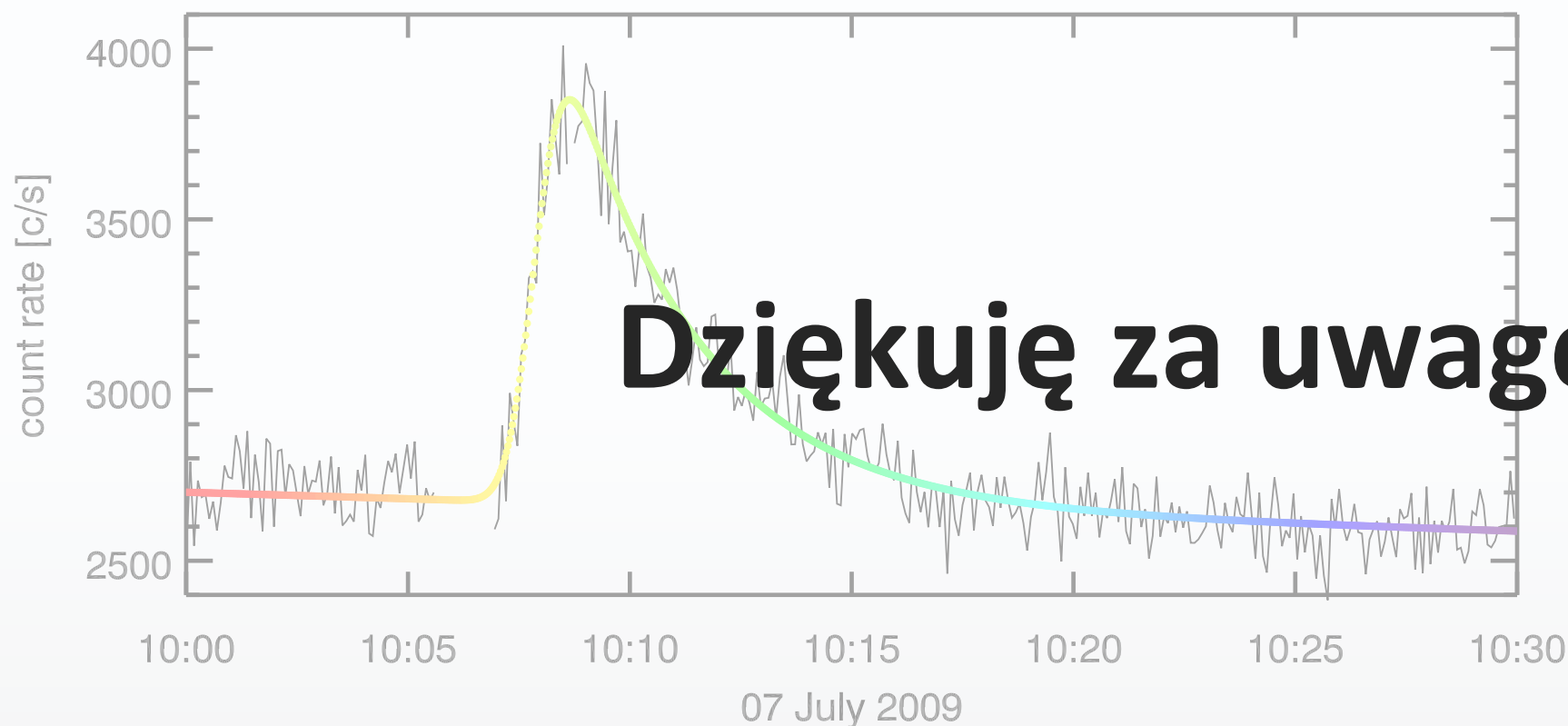


Figure 7. The final structure of a network trained using 1206 pre-classified ROTSE lightcurves.



LITERATURA:

D. R. Brett, R. G. West, P. J. Wheatley, 2013, Mon. Not. R. Astron. Soc.

T. Shibayama , H. Maehara , S. Notsu , Y. Notsu, T. Nagao, S. Honda, T. T. Ishii , D. Nogami , K. Shibata, 2013