SphinX

CORONAS

X-ray solar luminosity and spectra seen by SphinX during low activity period

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for the SphinX team

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Wrocław, Poland

SOTERIA

SEVENTH FRAMEWORK PROGRAMME

Coronas-Photon Project Scientist:

Prof. Yury Kotov *MEPhi*, Moscow

↓The SphinX Team ↓

- Solar Physics Division SRC PAS Wrocław
  - Mirek Kowalinski, Szymon Gburek, Marek Siarkowski, Jarek Bakala, Zbigniew Kordylewski, Piotr Podgórski, Barbara Sylwester, Magdalena Gryciuk, Anna Kępa, Witold Trzebiński, Tomek Mrozek

- P.N. Lebedev Physical Institute, Moscow

  Sergey Kuzin-TESIS PI, Andrei Pertsov, Sergey Bogachev

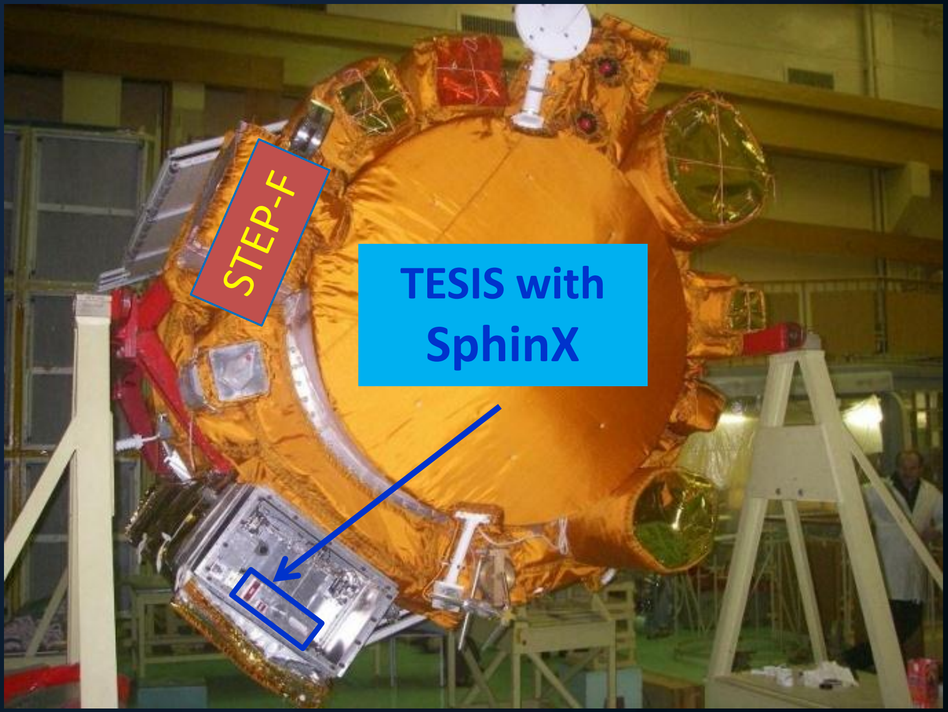
- Astronomical Institute, Ondrejov
  - Frantisek Farnik
- Astronomical Observatory, Palermo
  - Fabio Reale, Alfonso Collura
- University College, London
  - Ken Phillips

SphinX: Solar Photometer in X-rays, PI: SRC-PAS

Mass ~2500 kg,
8.2 GB/day

Pointing
Semi-Three axis stabilised
http://www.tesis.lebedev.ru/

Launched
30 Jan. 2009 at 13:30 UT
from Plesetsk Cosmodrome
aboard *CORONAS-Photon*



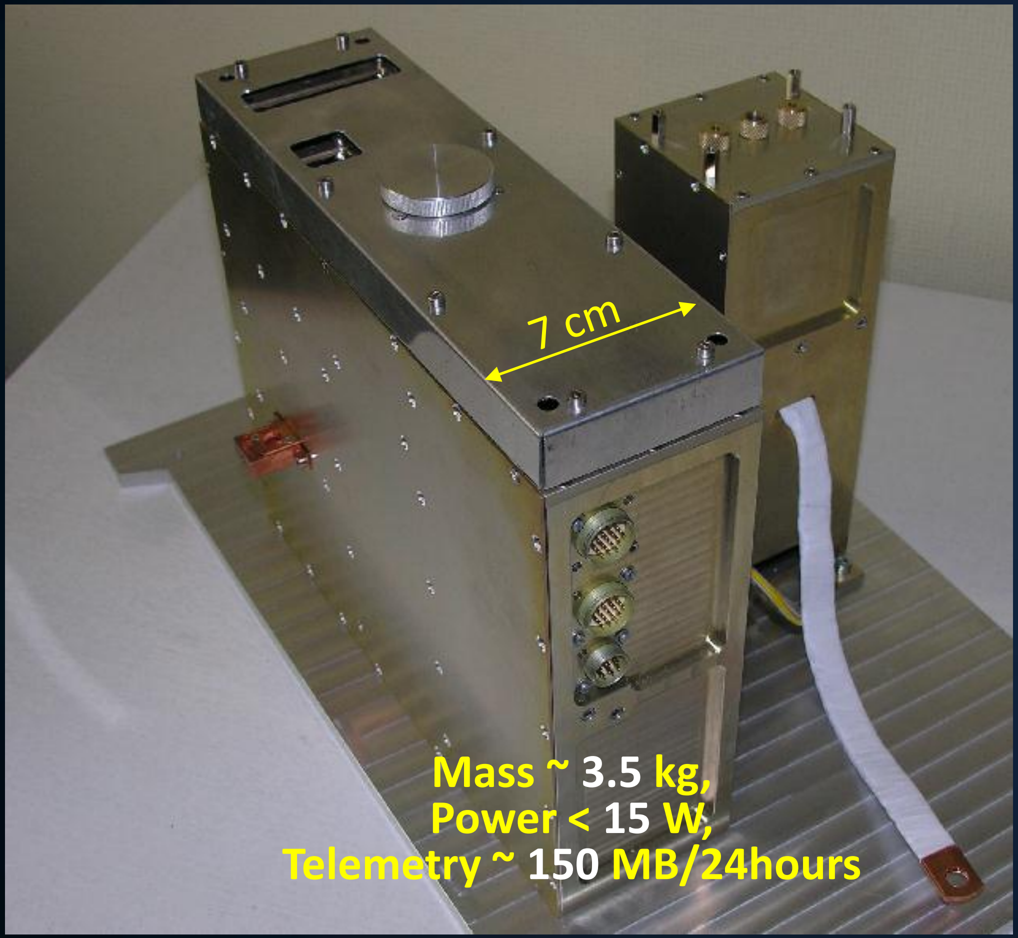
J. Astrophys. Astr. (2008) **29,** 1–5

http://www.cbk.pan.wroc.pl/body/publikacje/2008/SphinX.pdf

SphinX: A Fast Solar Photometer in X-rays

J. Sylwester[1,*], S. Kuzin[2], Yu. D. Kotov[3], F. Farnik[4] & F. Reale[5]

SphinX
Polish concept, design & manufacture



GOALS: to measure the X-ray emission of the Sun

in the ~0.8 – 15 keV band with <u>*unprecedented*</u>

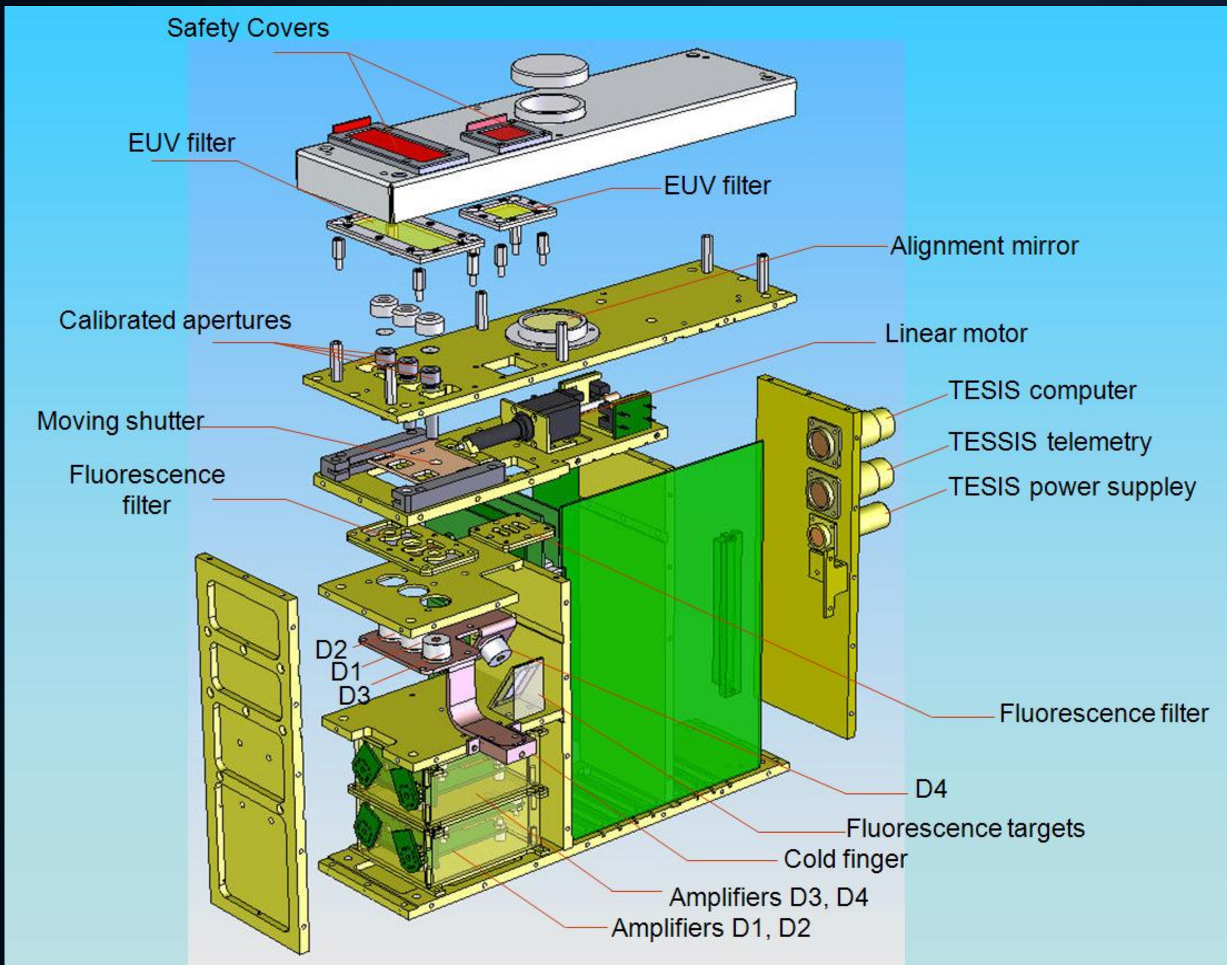
- Time resolution ~0.00001 s
- Sensitivity

  100 x exceeding that of *GOES* (NOAA) XRM
- Energy resolution

  3x RHESSI (NASA)

Aimed to see the **weekest** levels of solar coronal emission

SphinX construction



- EUV filters (doubly aluminized Mylar)
- Photometer
  - Collimators (+-2.5 deg)
  - Three apertures
  - D1, D2, D3
- Electronics
  - Front end Amptek
  - Digital „our"
- Computer/Controller
  - Software
  - reprogramming
- Heat sink

Total cost of the project ~ 1 mln Euro, Polish KBN T12 grant

Amptek (Bedford, US) detectors used

256 energy bins between 0 - 15 keV

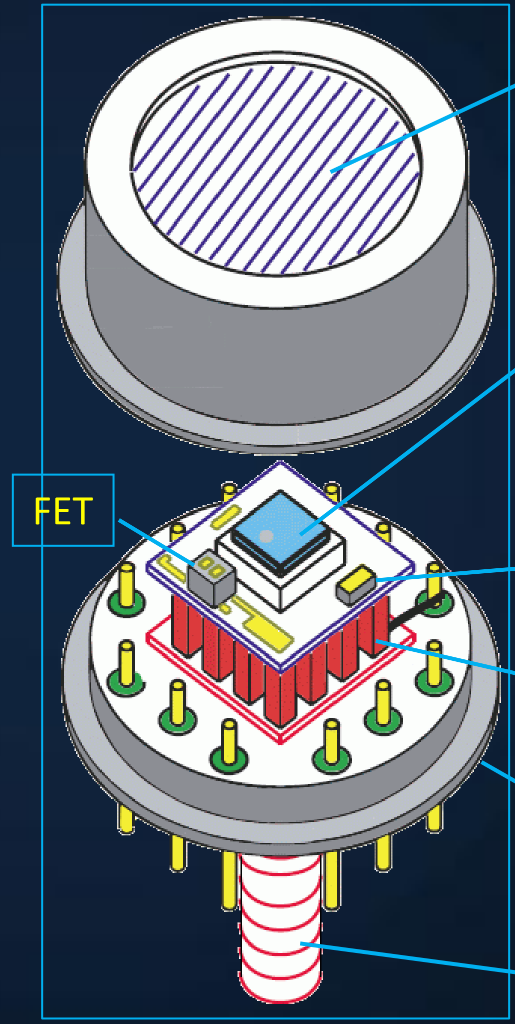
The count rate in the highest energy bin depends on:

- Particles population

- Photons flux > 15 keV

(detector efficiency decreases significantly with photon energies due to small thickness)

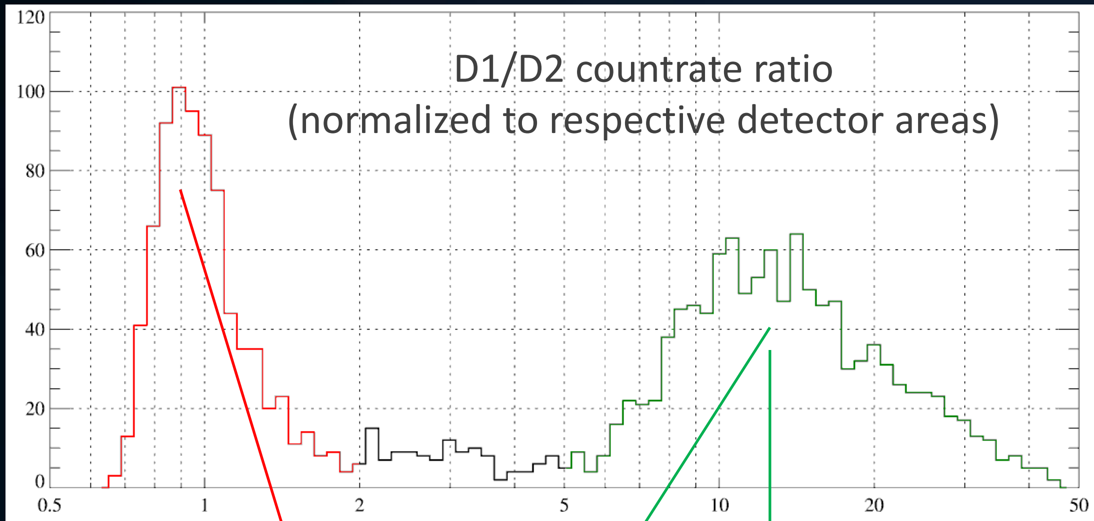
Detector D1 is more sensitive to the particles than other detectors mainly due to larger physical dimensions of silicon crystal.



Si-PIN Detector
Si Thickness: 500 μm
Area: D1: 21.5 mm^2
D2: 13 → 0.5 mm^2
D3: 13 → 0.01 mm^2

Amptek XR-100CR silicon PIN detector:

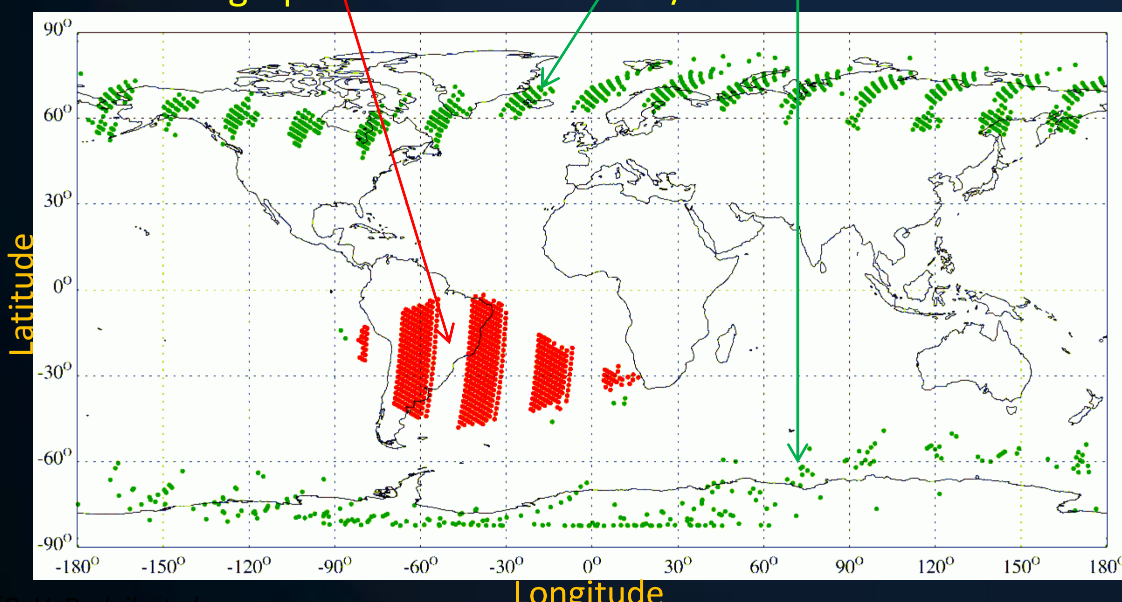
SphinX sensitivity to particles



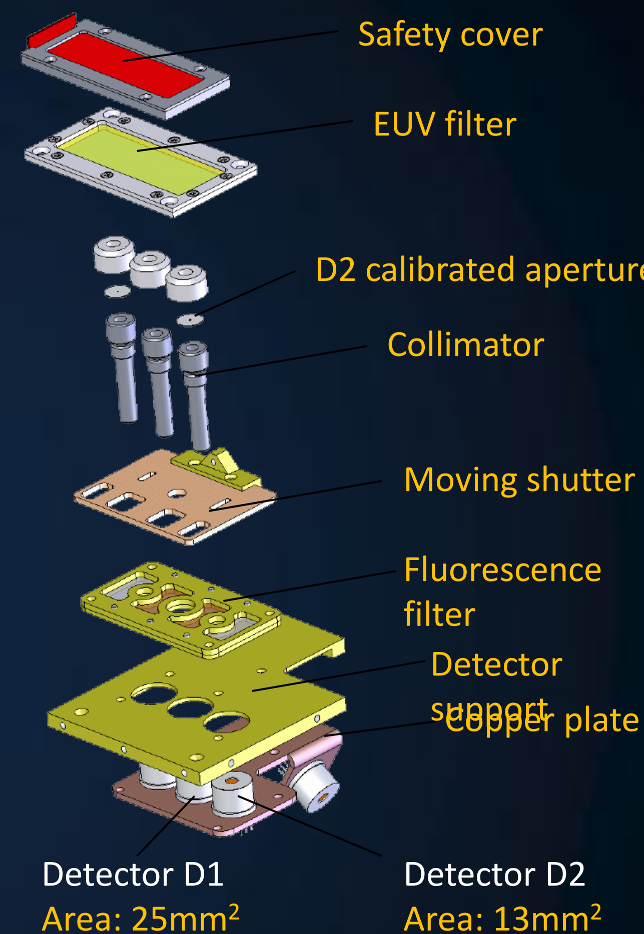
SAA

RB

Geographic coordinates of D1/D2 countrate ratio



SphinX optical entrance

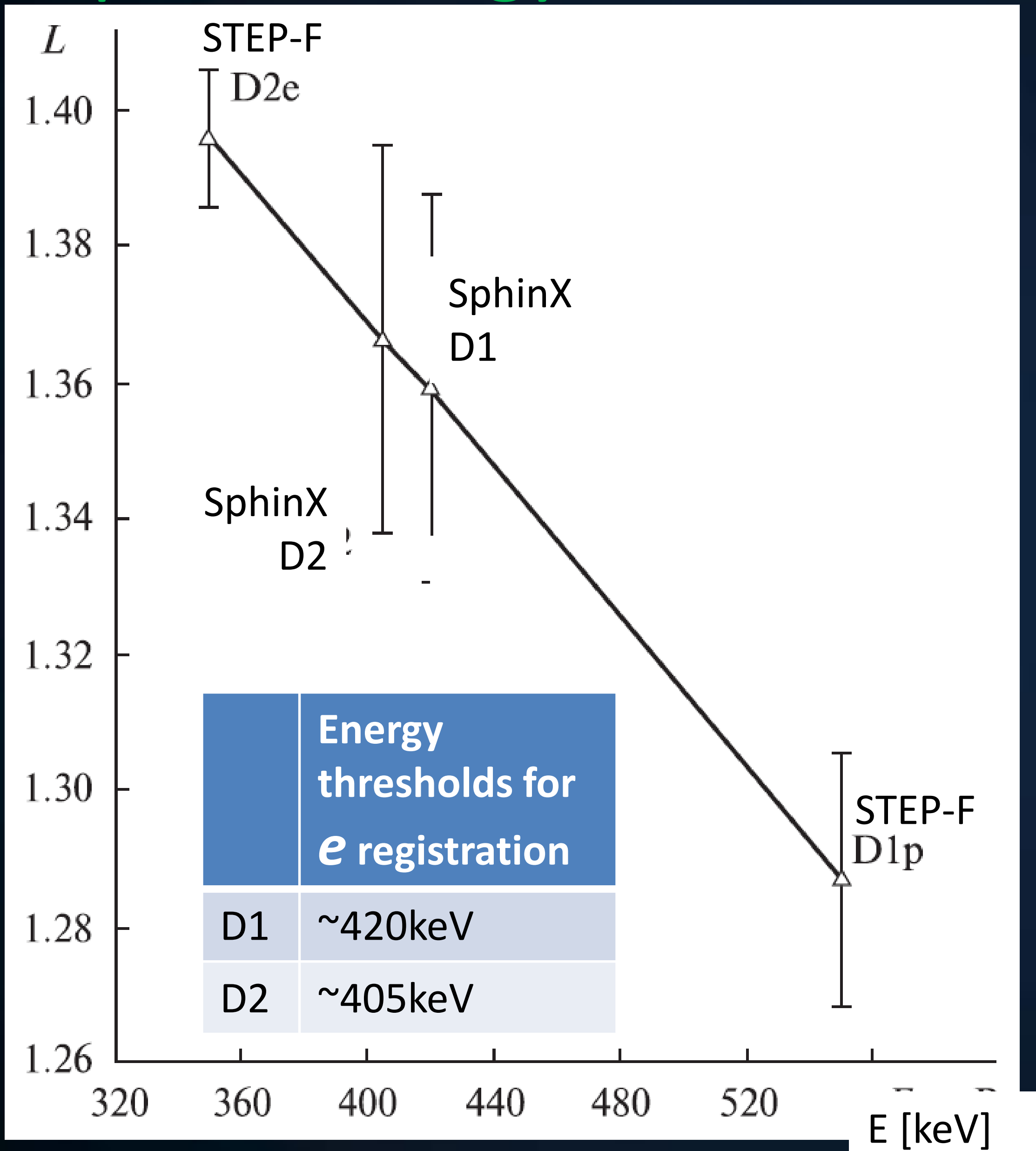


Detector differences

	D1	D2
Area	25mm²	13mm²
External aperture	-	+

[O. V. Dudnik et al.
X-RAY SPECTROPHOTOMETER SPHINX AND PARTICLE SPECTROMETER STEP-F OF THE SATELLITE EXPERIMENT CORONAS-PHOTON – PRELIMINARY RESULTS OF JOINT DATA ANALYSIS, Solar System Research (in press 2011)]

SphinX energy thresholds for partilcles

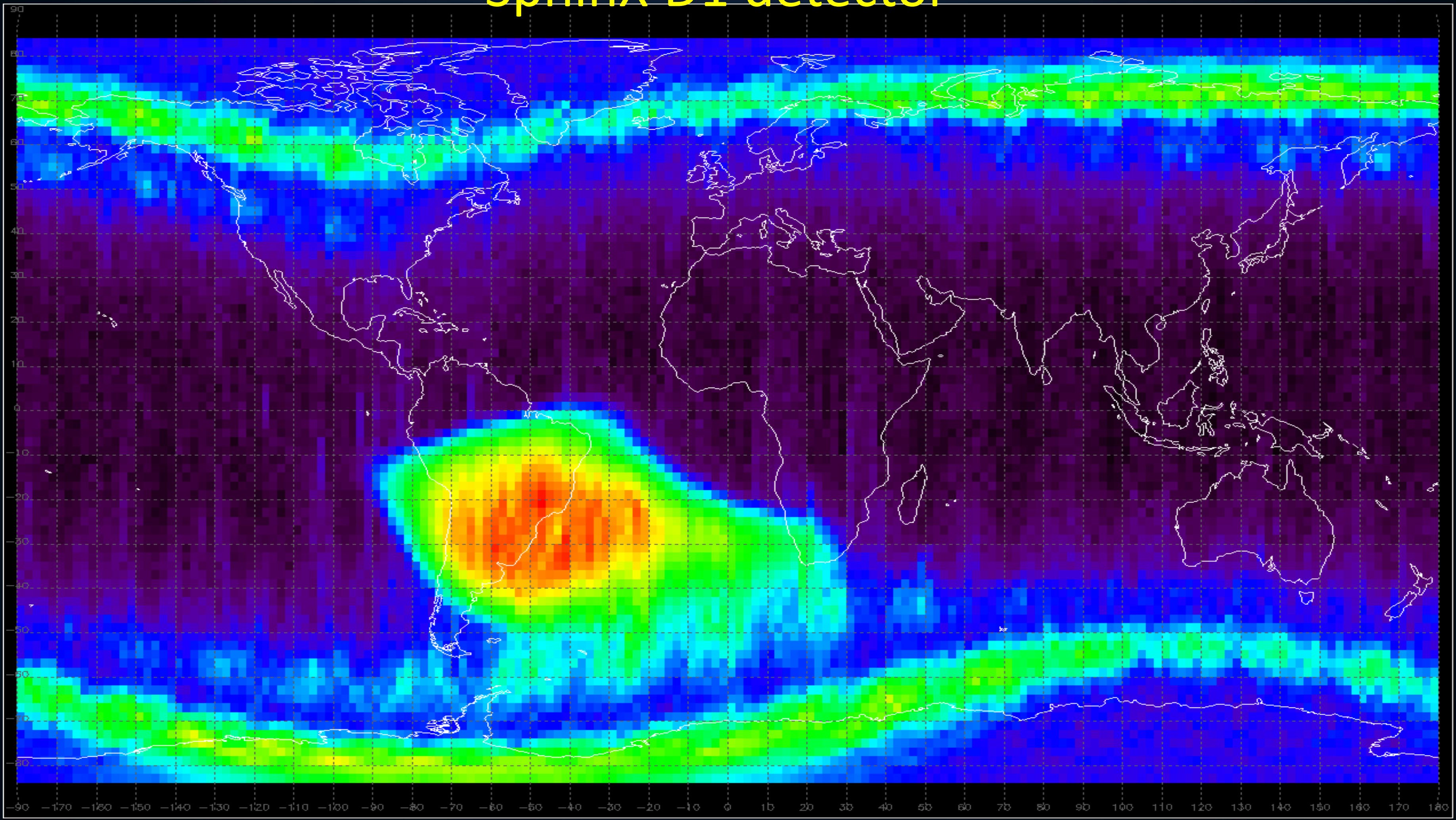


	Energy thresholds for *e* registration
D1	~420keV
D2	~405keV

L-shell position of maximum particle signal within SAA in dependency on energy threshold. The L positions were taken from each 4th ascending node of Coronas-Photon orbit and were averaged for time period from 1st to 14th May, 2009.

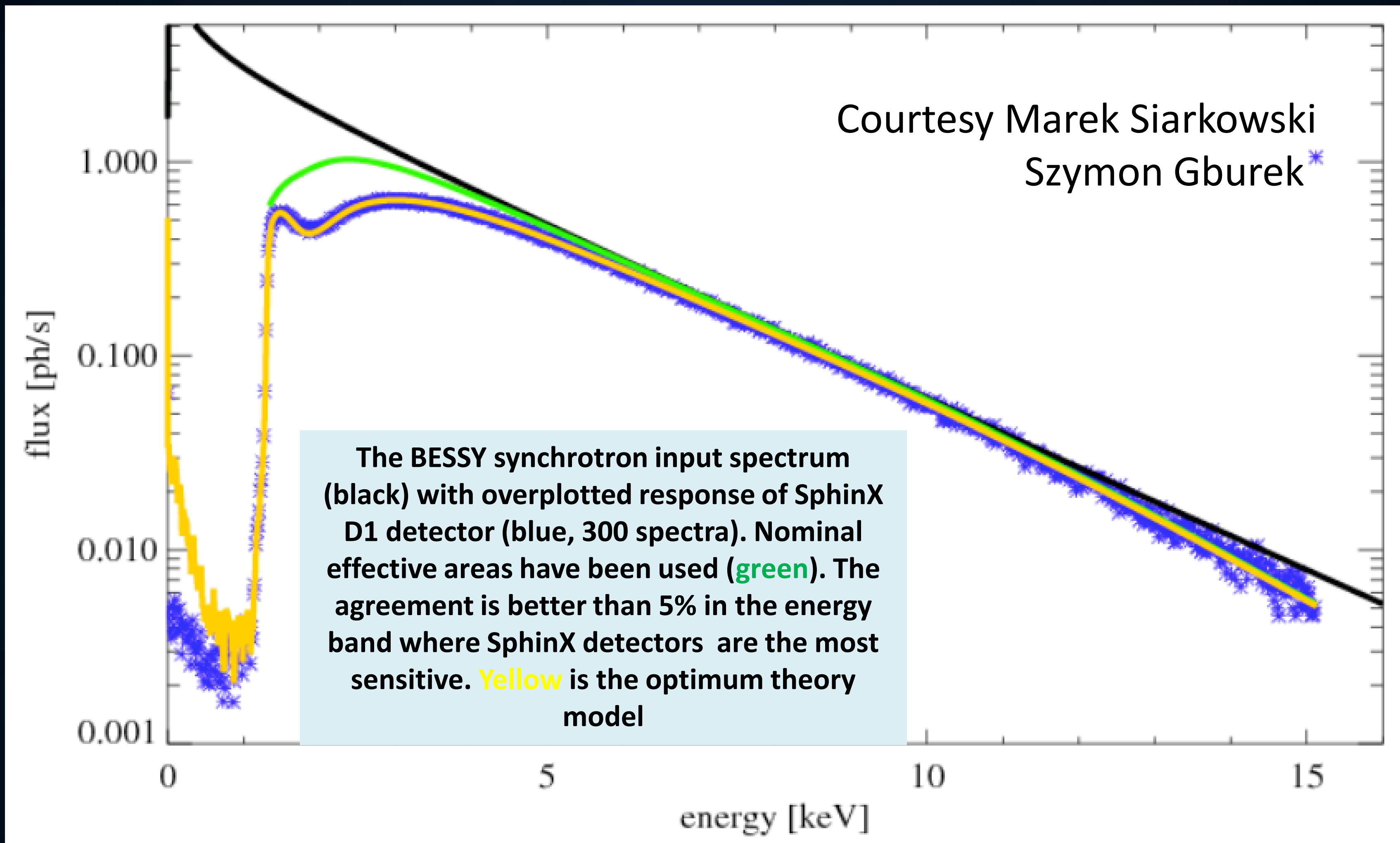
[O. V. Dudnik et al.
INVESTIGATION OF ELECTRON BELTS IN THE EARTH'S MAGNETOSPHERE WITH THE HELP OF X-RAY SPECTROPHOTOMETER SPHINX AND SATELLITE TELESCOPE OF ELECTRONS AND PROTONS STEP-F: PRELIMINARY RESULTS
Space Science and Technology (in press 2011)]

Reconstruction of Earth's particle environment from SphinX D1 detector



Courtesy: Piotr Podgórski

How detector performance looks from the ground tests



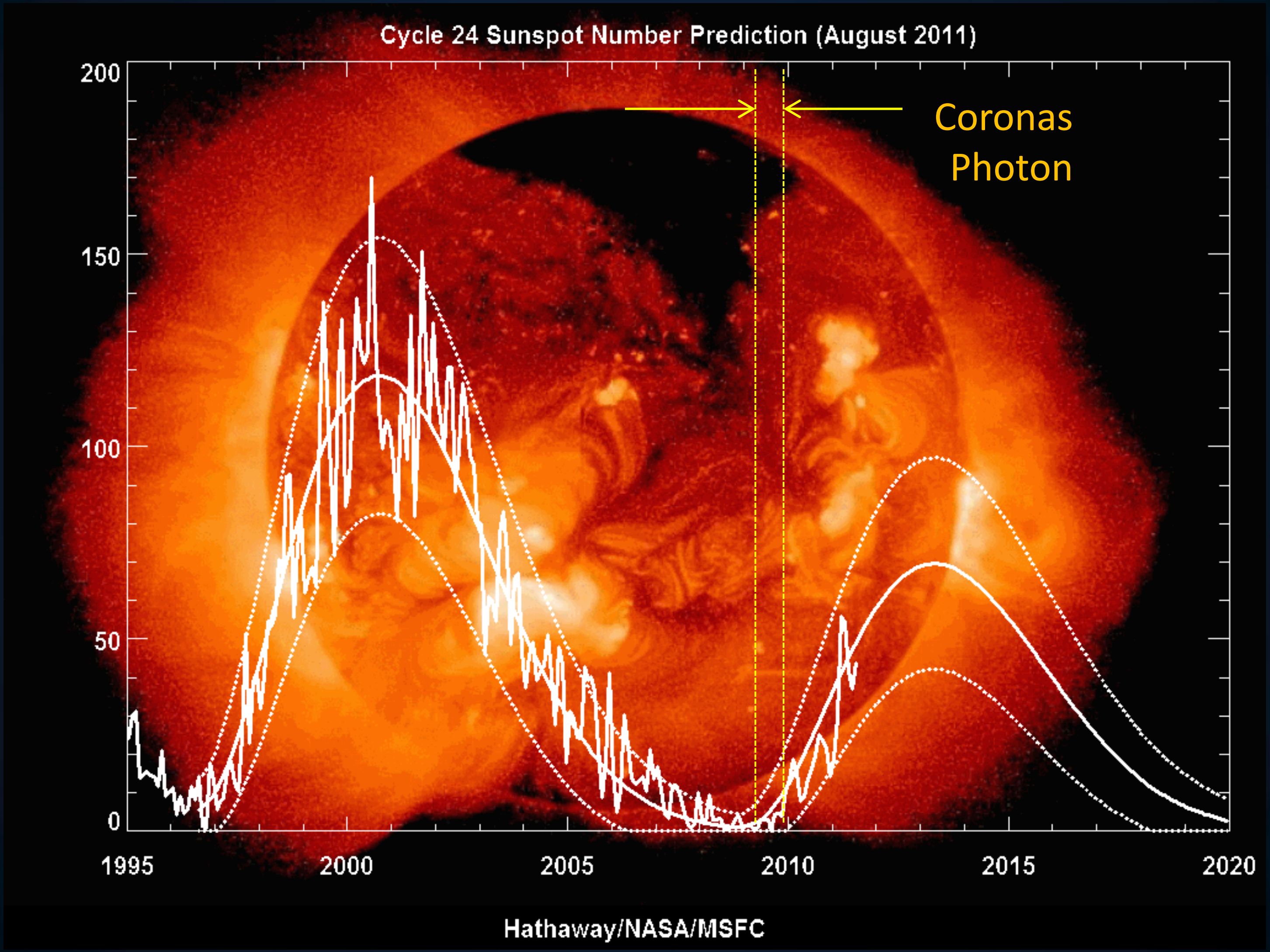
BESSY II Berlin Synchrotron calibrations:

-All detectors' l gain is inear (0.1%) over 0.8-14.5 keV; & dynamic range 10^4. - pile-up matrices known as measured from X-ray 4 crystal monochromator spectra – **still not accounted** for in reduction

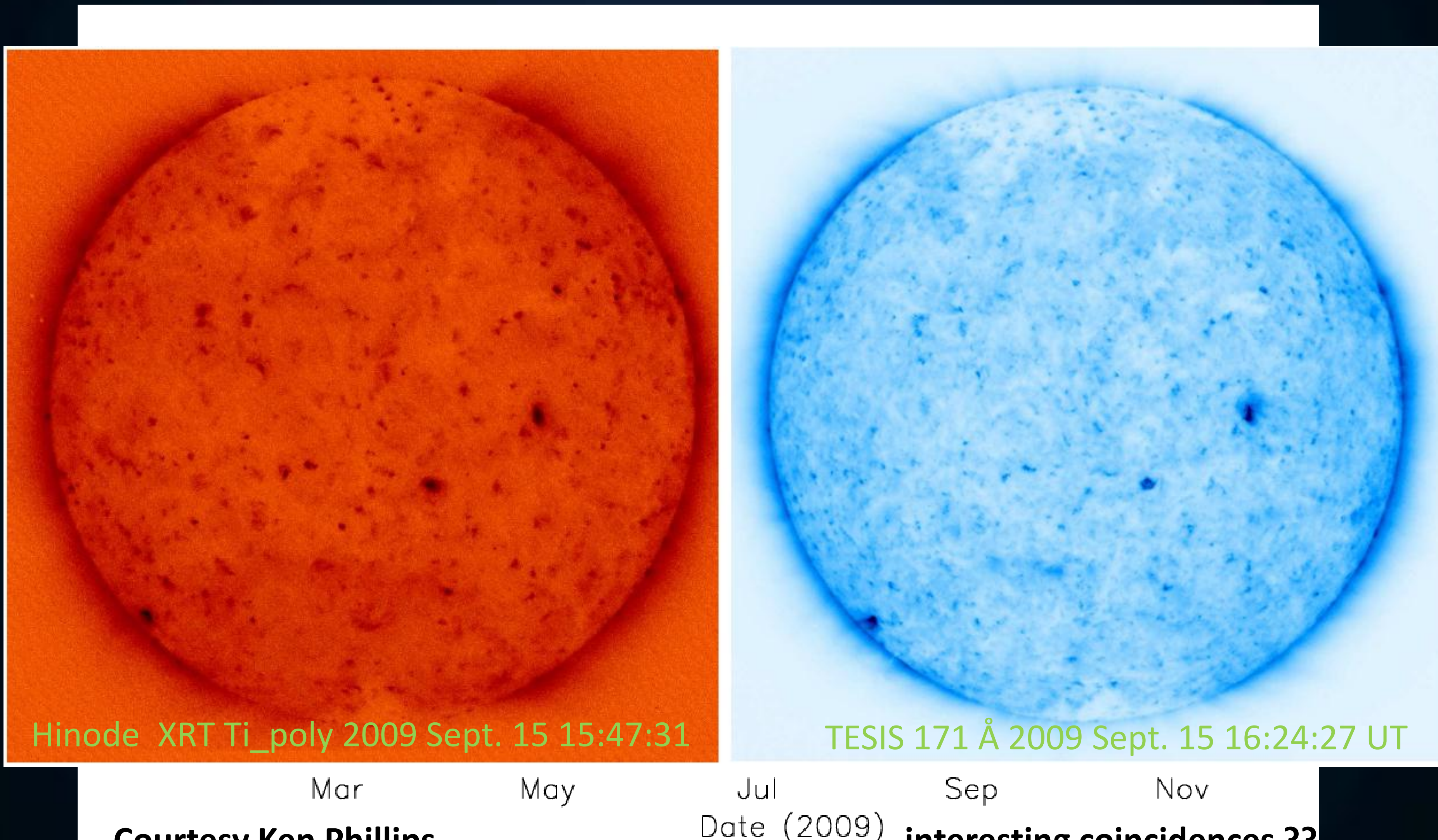
Overview of the talk

- Low activity spectra and coronal luminosity
- Isolated AR history and plasma characteristics
- Unexpected importance of SphinX measurements for WIMPs
- Further steps in data analysis
  - Isothermal approach has a limited applicability (flares)
  - Importance of assumed abundance model
- Existing collaborations on data analysis

2009: the year of low solar activity

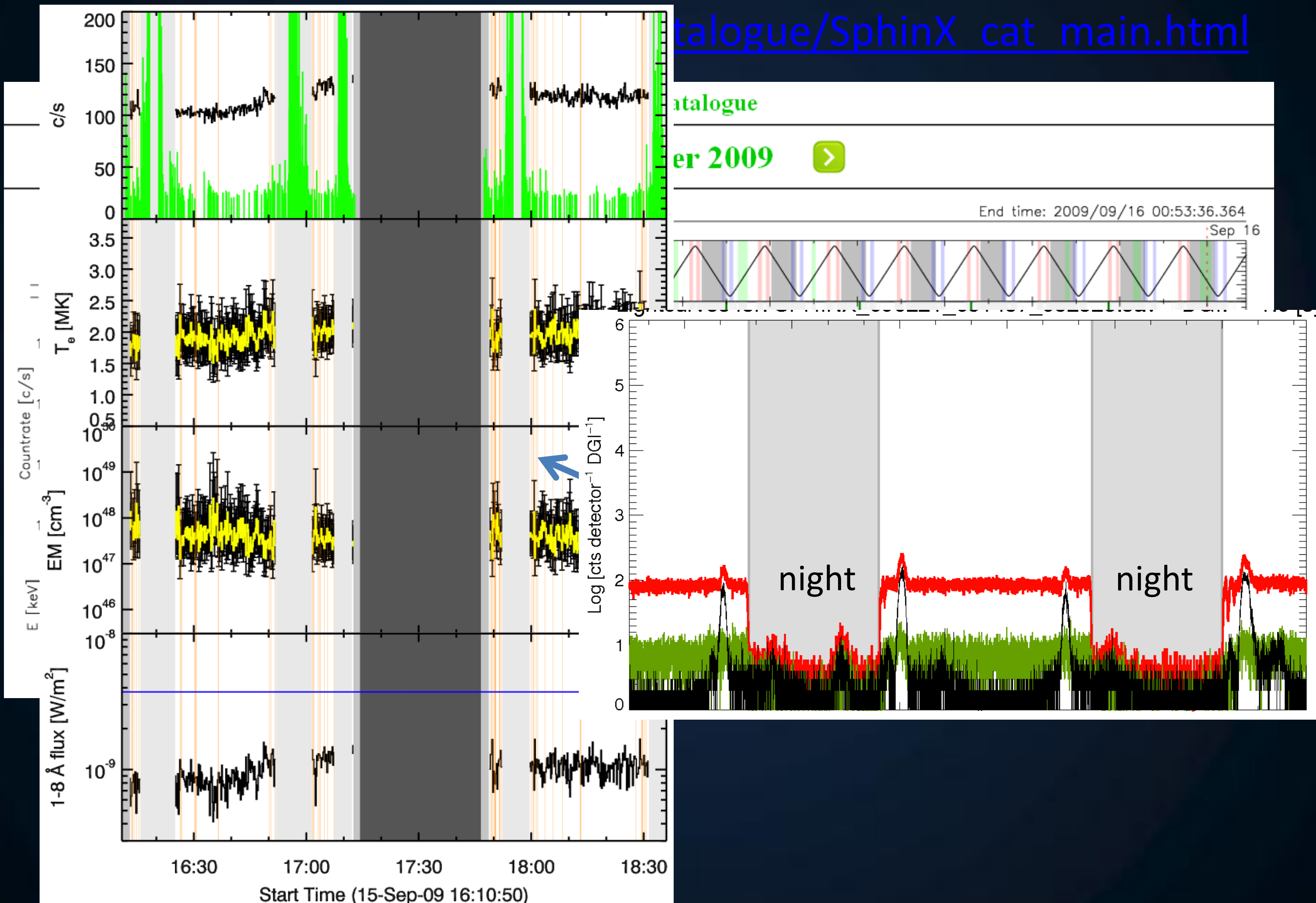


2009: the year of low activity

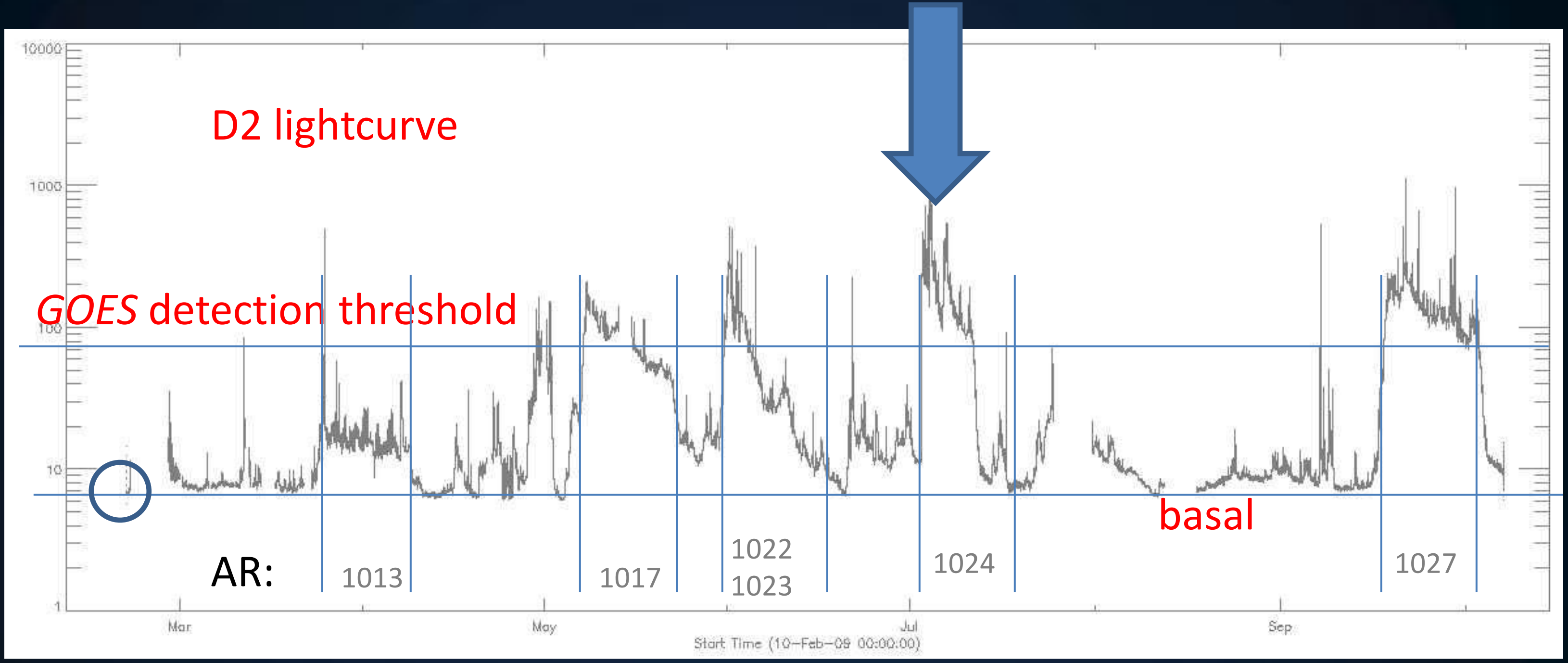


Courtesy Ken Phillips **interesting coincidences ??**

Spectral variability



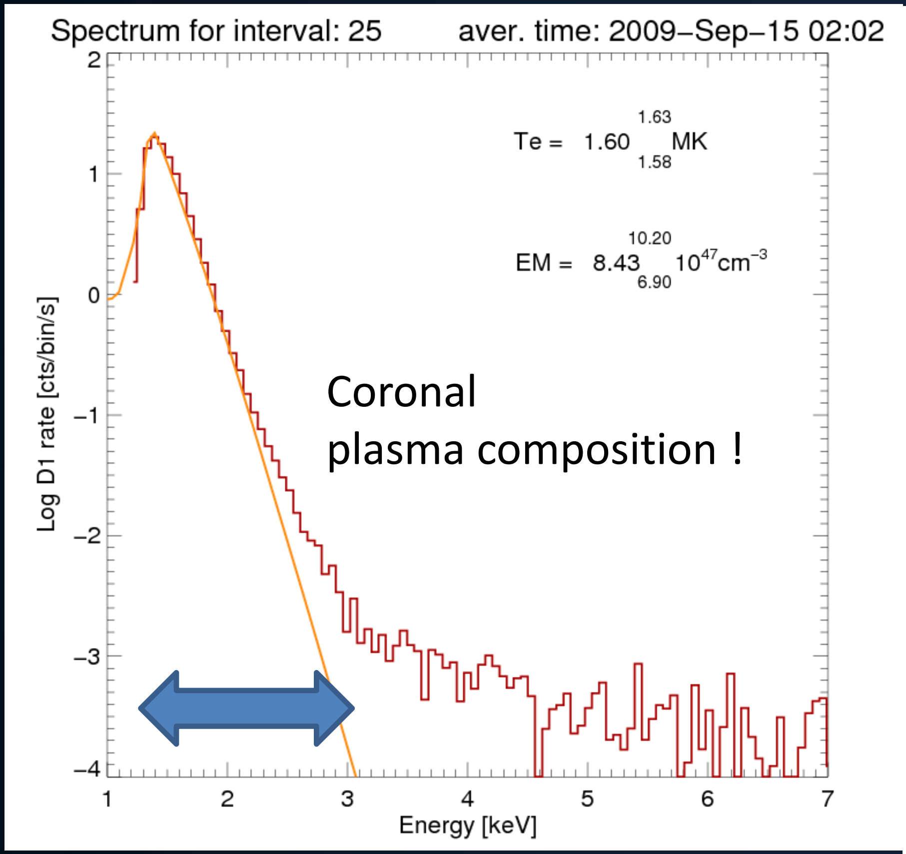
Long-term variability

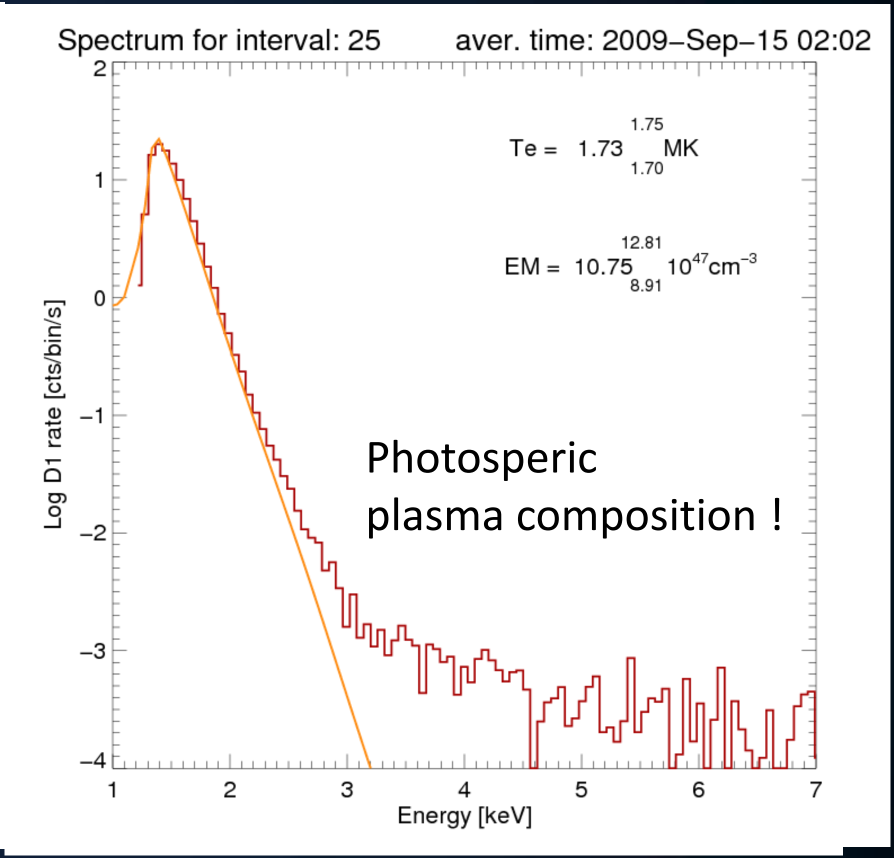


Courtesy Szymon Gburek et al. 2009

- Passages/ development/decay of AR clearly seen
- Presence of basal non-AR coronal emission measurable, 20 x below GOES detection threshold
- Level of basal flux pretty constant at 80 cts/s in D1 & 6.5 cts/s in D2

Characteristics of coronal plasma when NO AR was present (27 intervals)





Substantial emission observed below 3 keV

Minimum solar soft X-ray luminosity

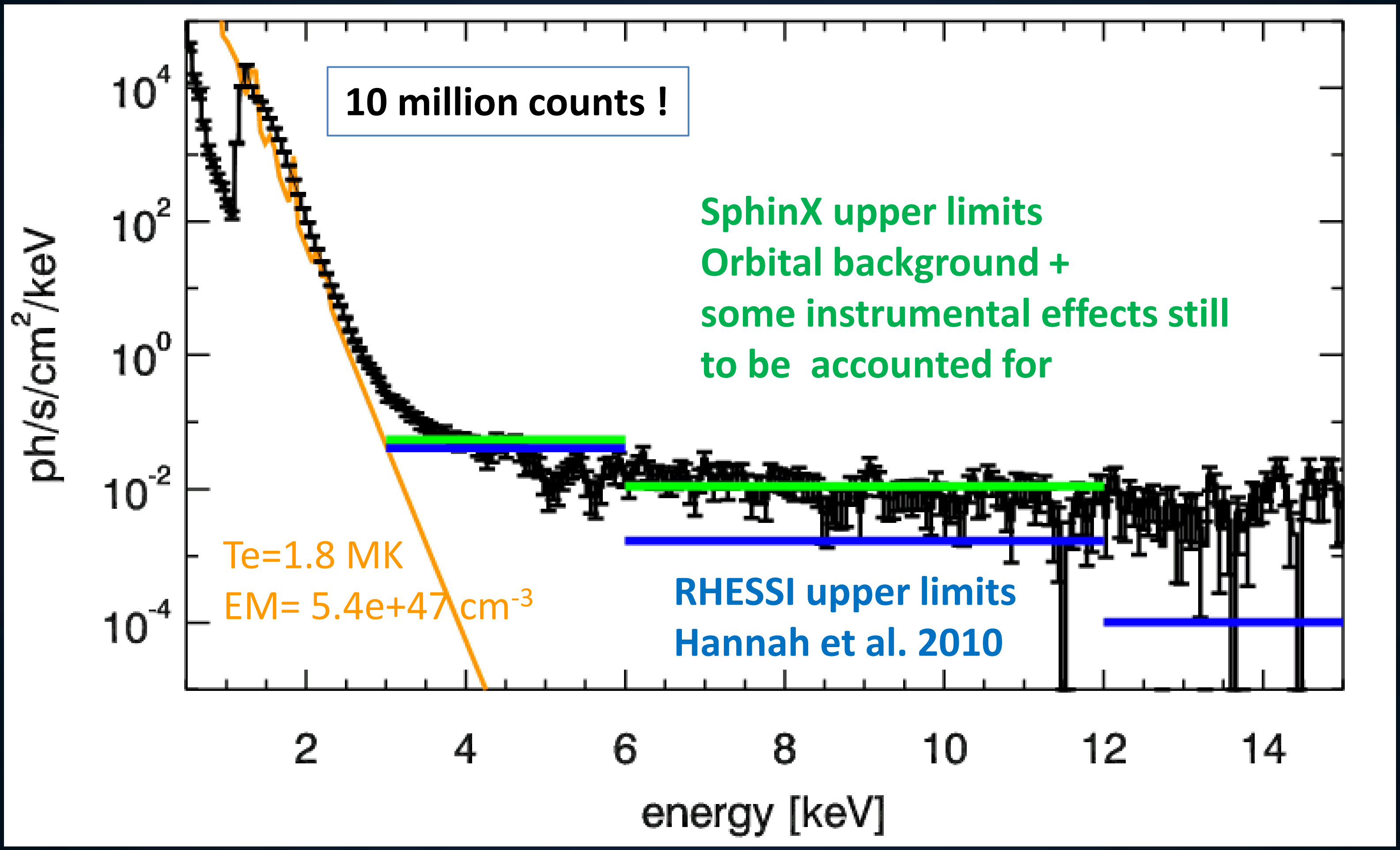
Conclusions:

- Minimum level of emission ~constant at the level of 70-100 cts/s (D1) → T ~ 1.6 ÷ 1.75 MK

  log EM~ 47.8 ÷ 48.2 cm^{-3}
- 1-15 keV Sun's X-ray minimum luminosity

  (4.4 ÷ 7.3) 10^{22} erg/s
- Fluctuations larger than statistically expected takes place however, within time scales of minutes (bright-point flaring: see the poster by Magdalena Gryciuk)
- Presence of AR causes basal flux increses by 2-3 orders of magnitude

SphinX quiet Sun spectrum
Integrated over few days in September 2009



Average Sphinx (black and green) and RHESSI (blue) quiet-Sun photon flux spectrum during 11-17 September 2009.

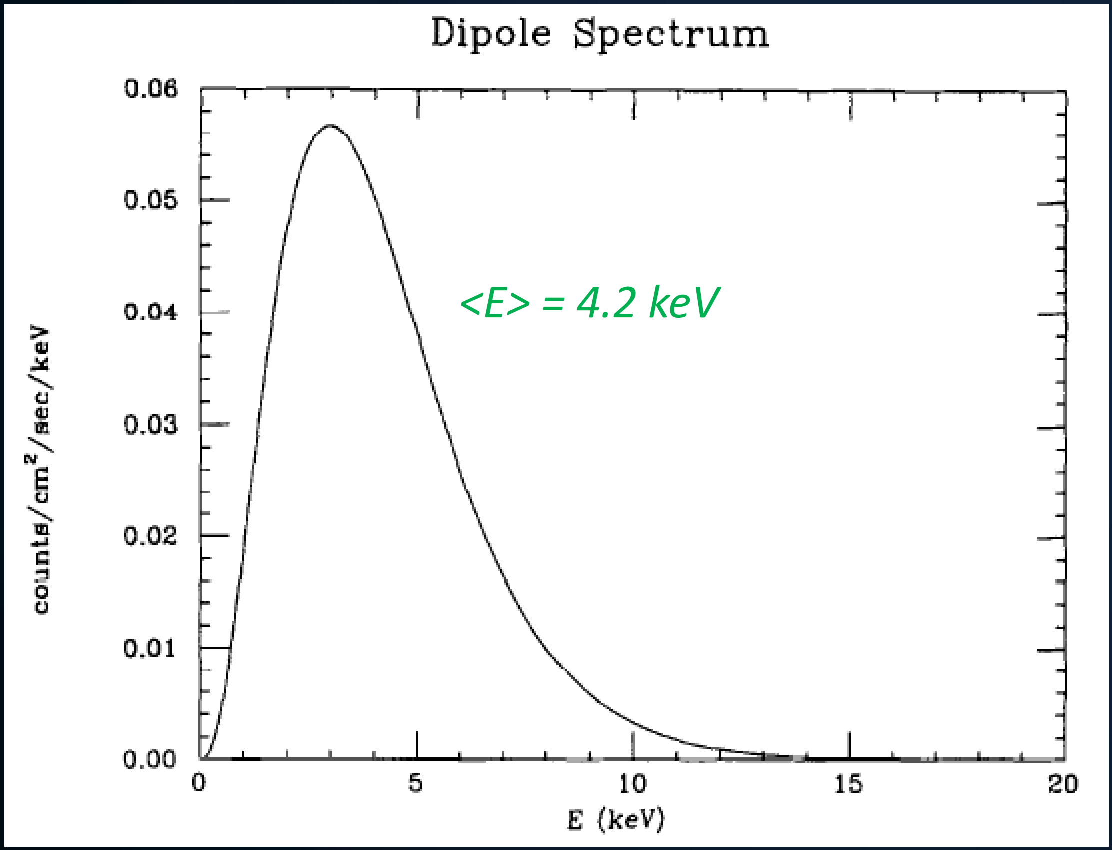
Conversion of axion to X-rays in coronal magnetic field

(by the inverse Primakoff effect)

Konstantin Zioutas
CERN

Szymon Gburek
Ken Phillips
SphinX Team

The flux of solar axions has a mean energy of 4.2 keV



The probability of conversion to X-ray photons is proportional to <gBL>^{2} where g is the coupling constant, B the magnetic field strength, and L a length scale.

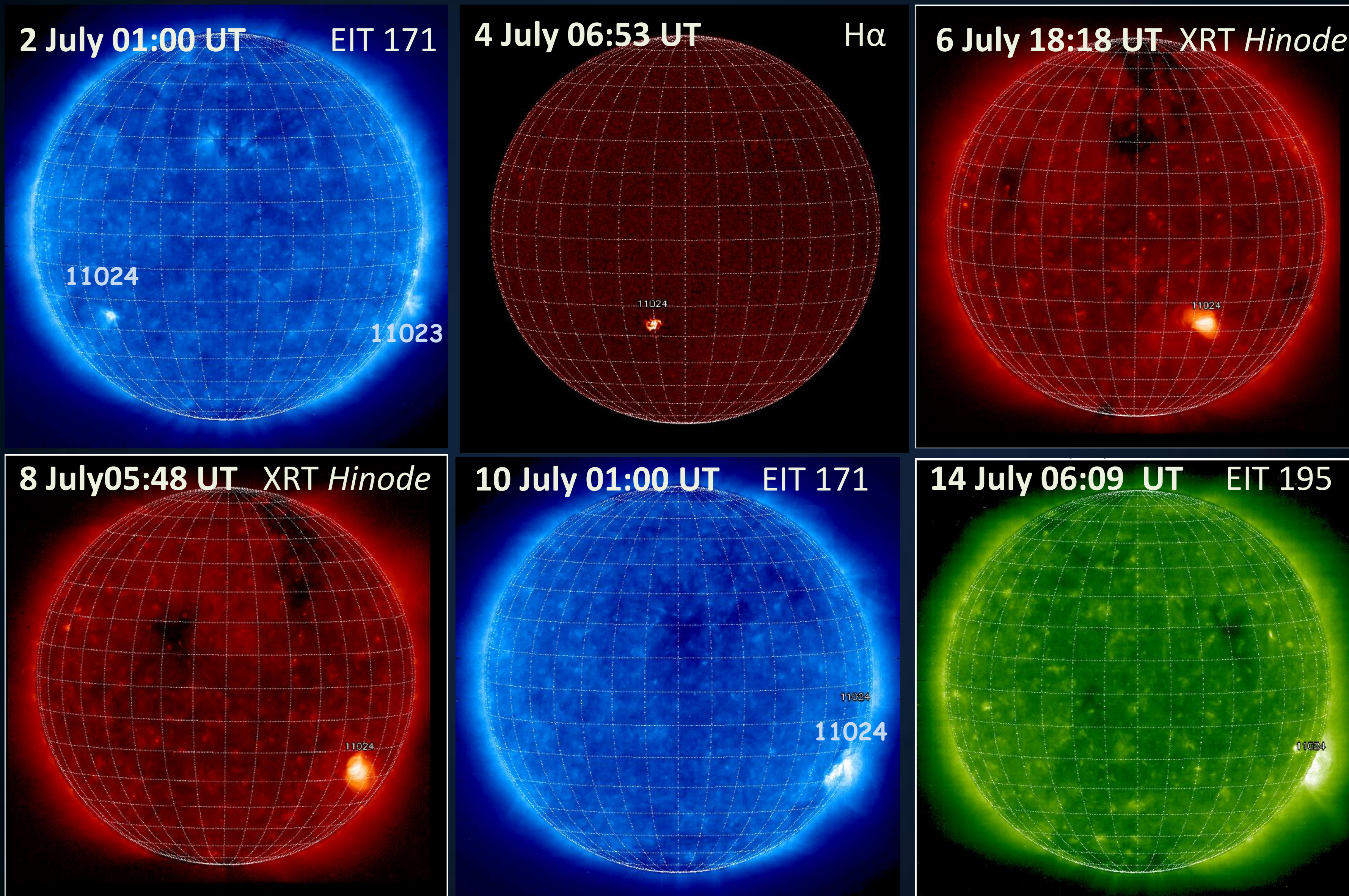
$$P \propto g^2 |\mathbf{D}(x,y)|^2$$

$$\mathbf{D}(x,y) = \int_0^L \mathbf{B}_\perp(x,y,z) e^{i\theta(z)} \mathrm{d}z$$

$$\theta(z) = \int_0^z \left(\frac{2\pi\alpha n_\mathrm{e}(z')}{m_\mathrm{e} E} - \frac{m^2}{2E} \right) \mathrm{d}z'$$

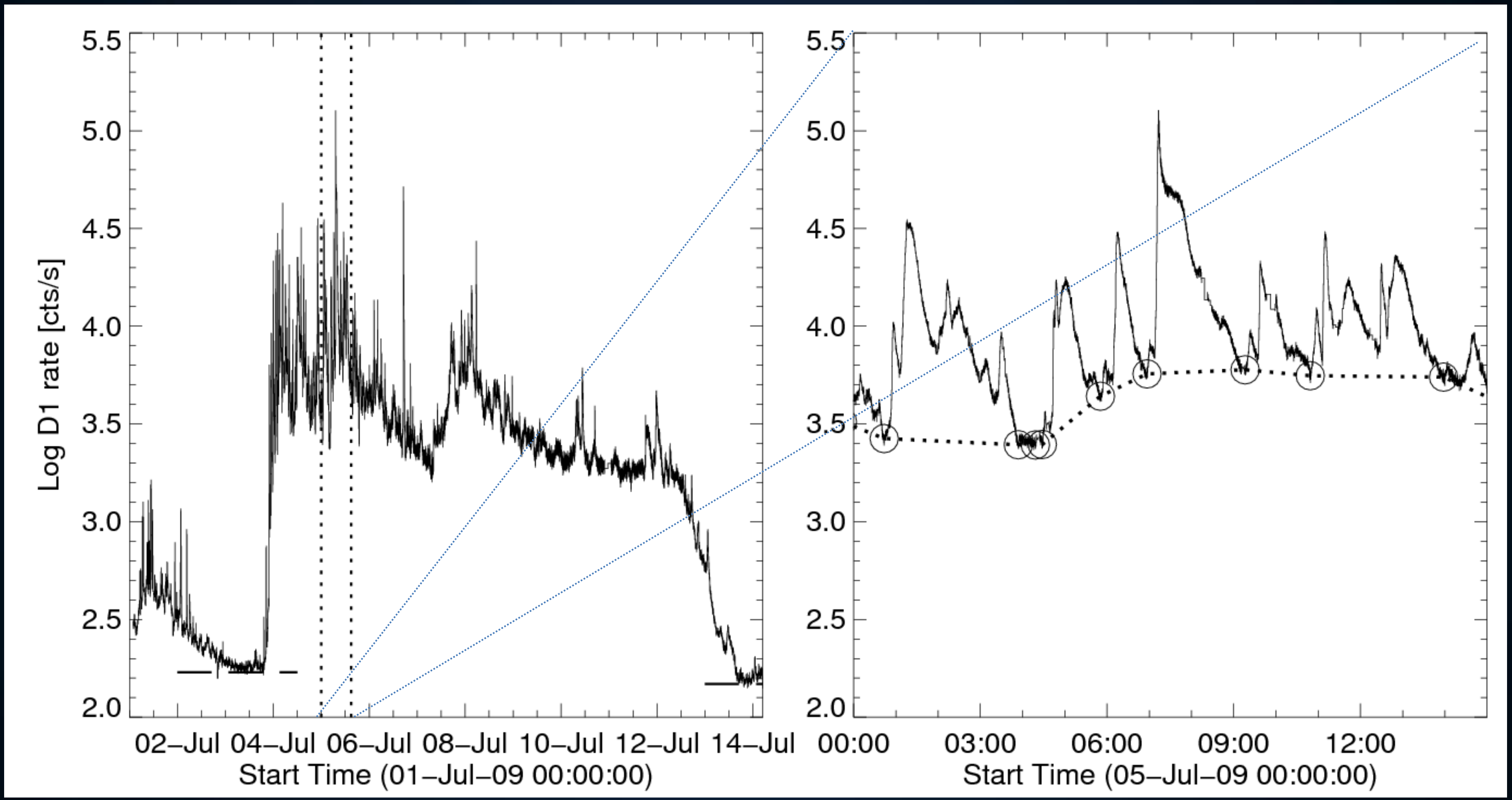
Carlson & Tseng_Physics Letters B 365 (1996) 193-201

Present on the disc all the time, became pronounced between 2 - 14 July 2009



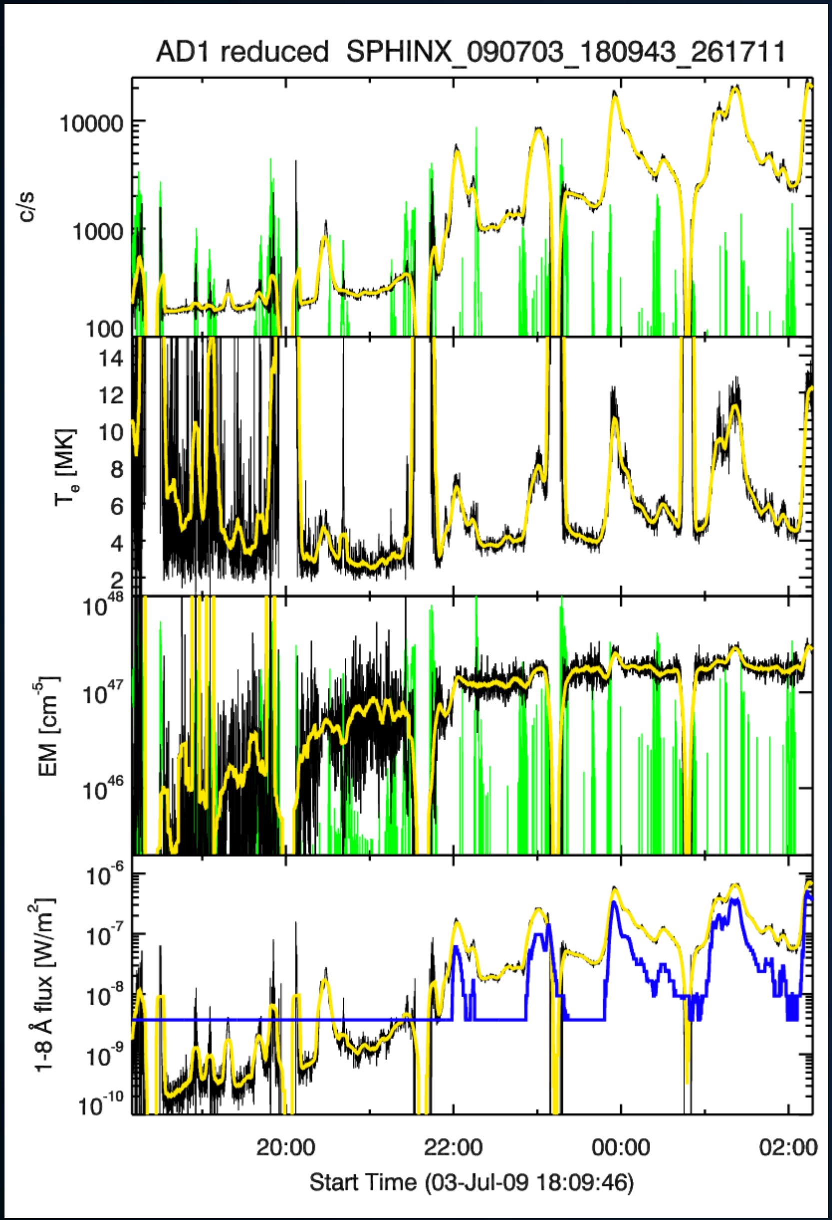
AR 11024 evolution

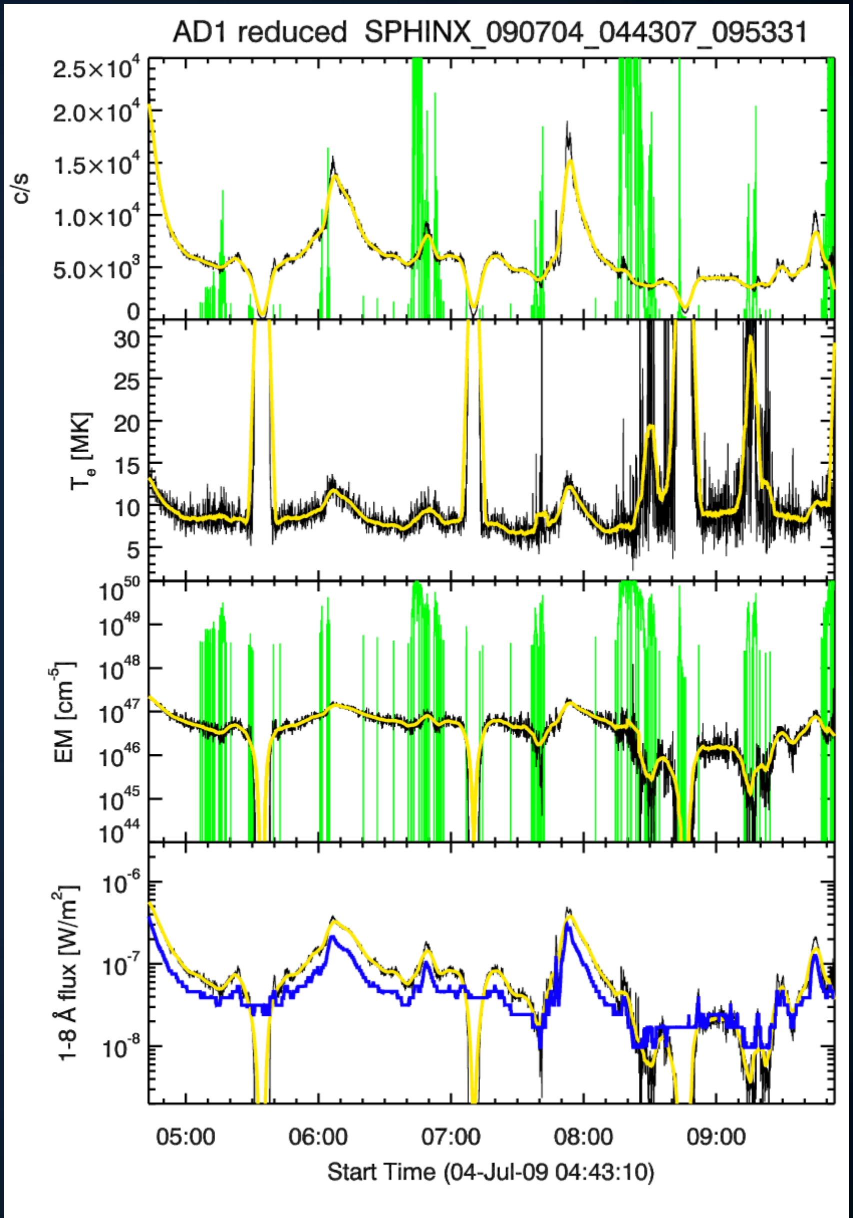
B. Sylwester et al., Cent. Eur. Astrophys. Bull. vol (2010) 1, 1



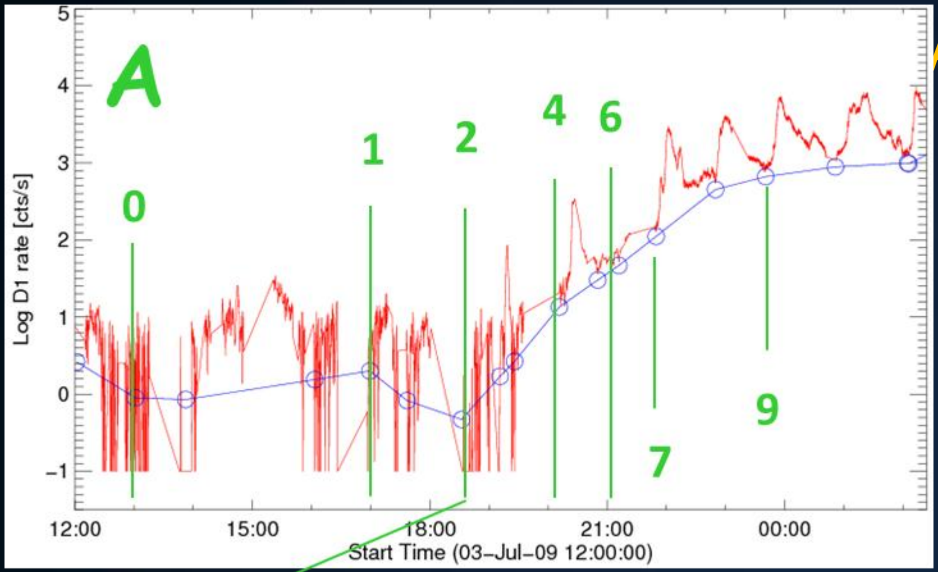
Nearly continuous measurements available from SphinX supported by 10 000 HXT images taken each minute in Be_medium and Ti_thin filters Alec Engel HS & Sergey Kuzin FIAN

GOES vs SphinX courtesy Marek Siarkowski

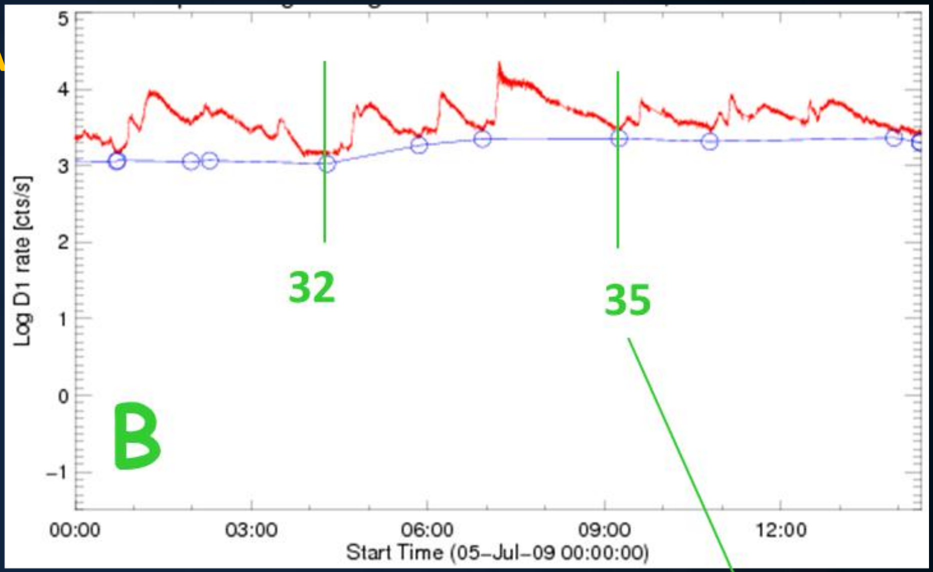


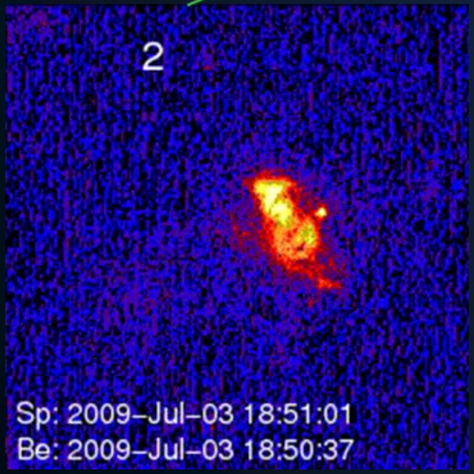


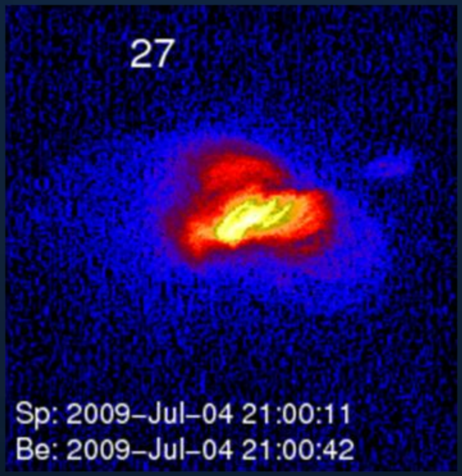
AR 11024 evolution flares removed

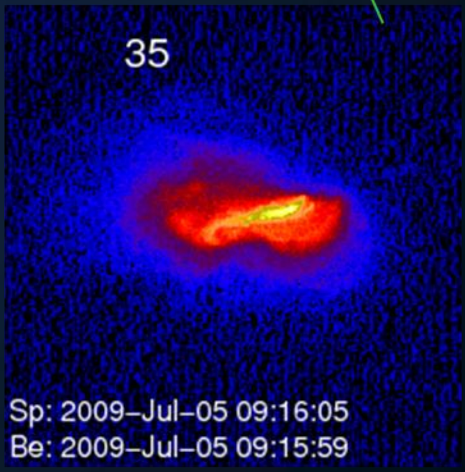


A





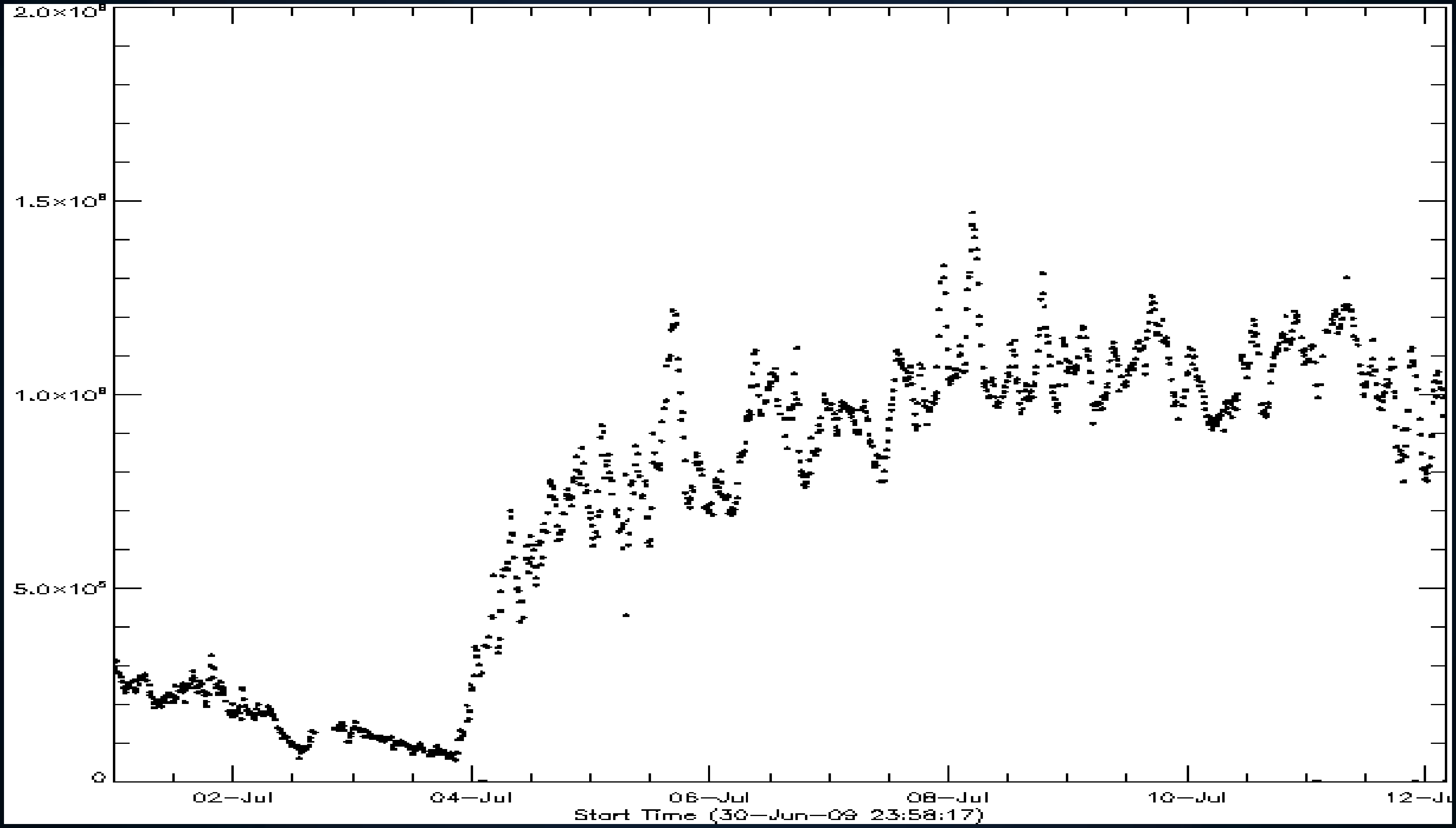




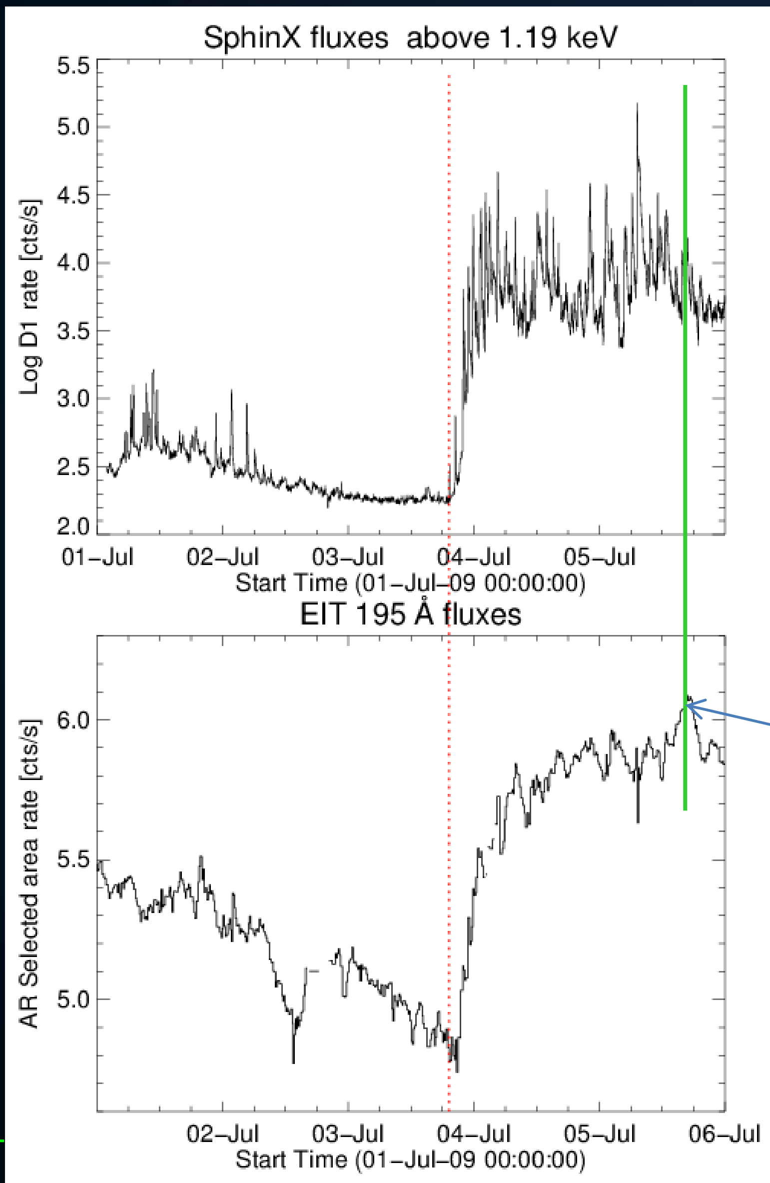
Non-flaring component of the AR studied. Fast morphology changes observed early-on

From Be_medium images areas determined where ½ of the AR flux is formed → V estimate

EIT 195 Å flux from AR 11024

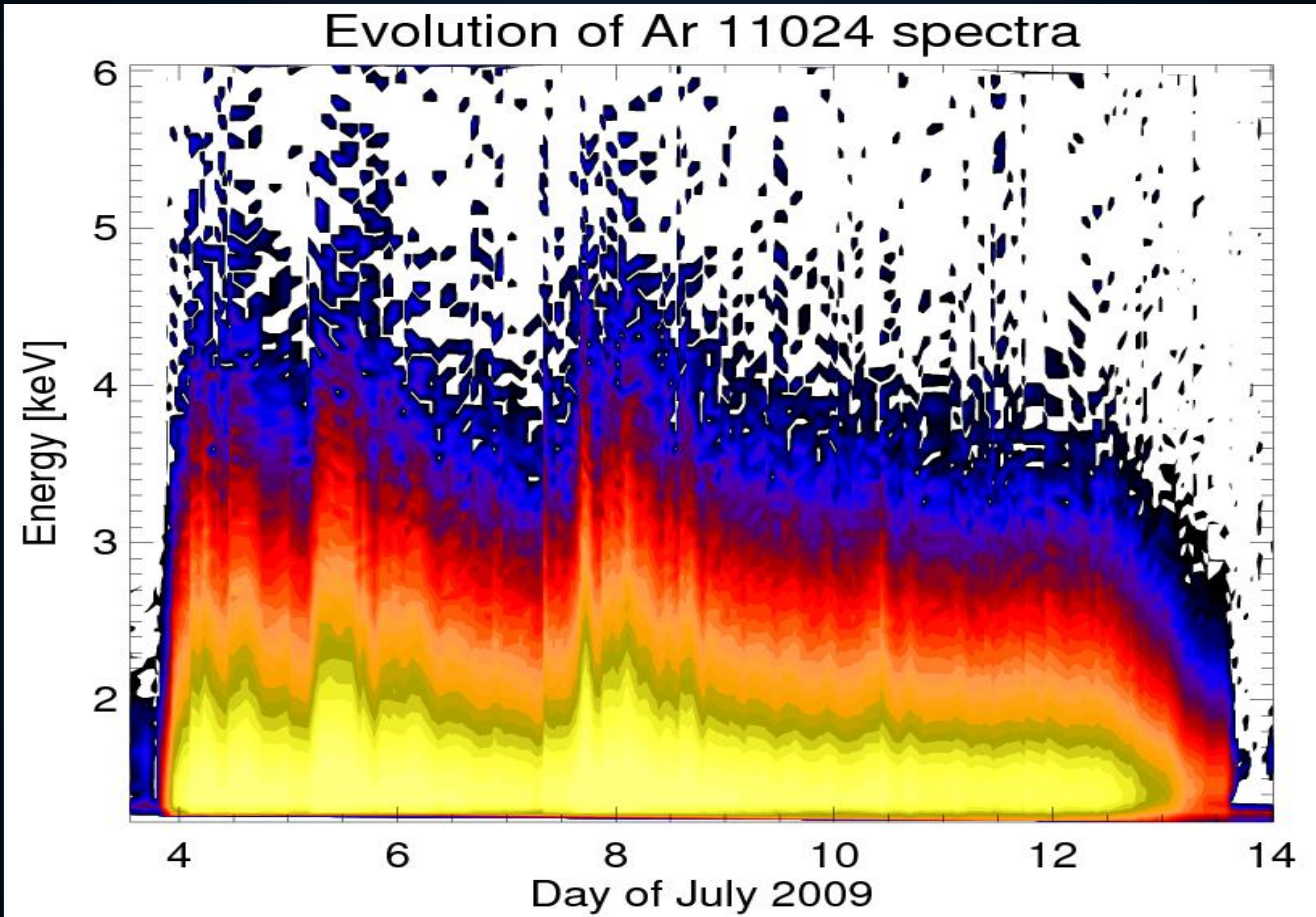


EIT & SphinX flux variability

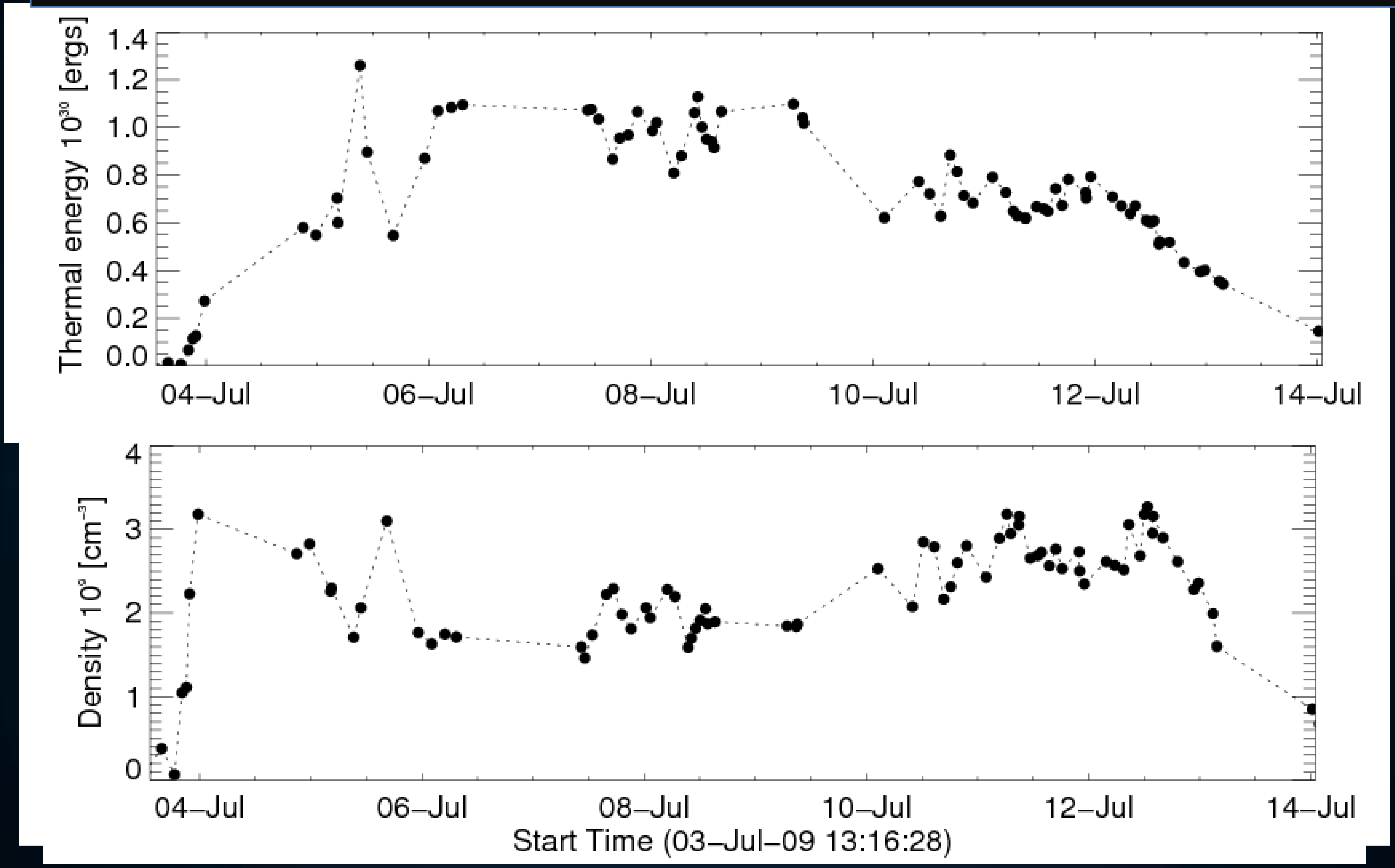


The SphinX soft X-ray radiation starts to rise ~2 hours earlier than the EUV radiation and its evolution is more dynamic than the EUV emission.

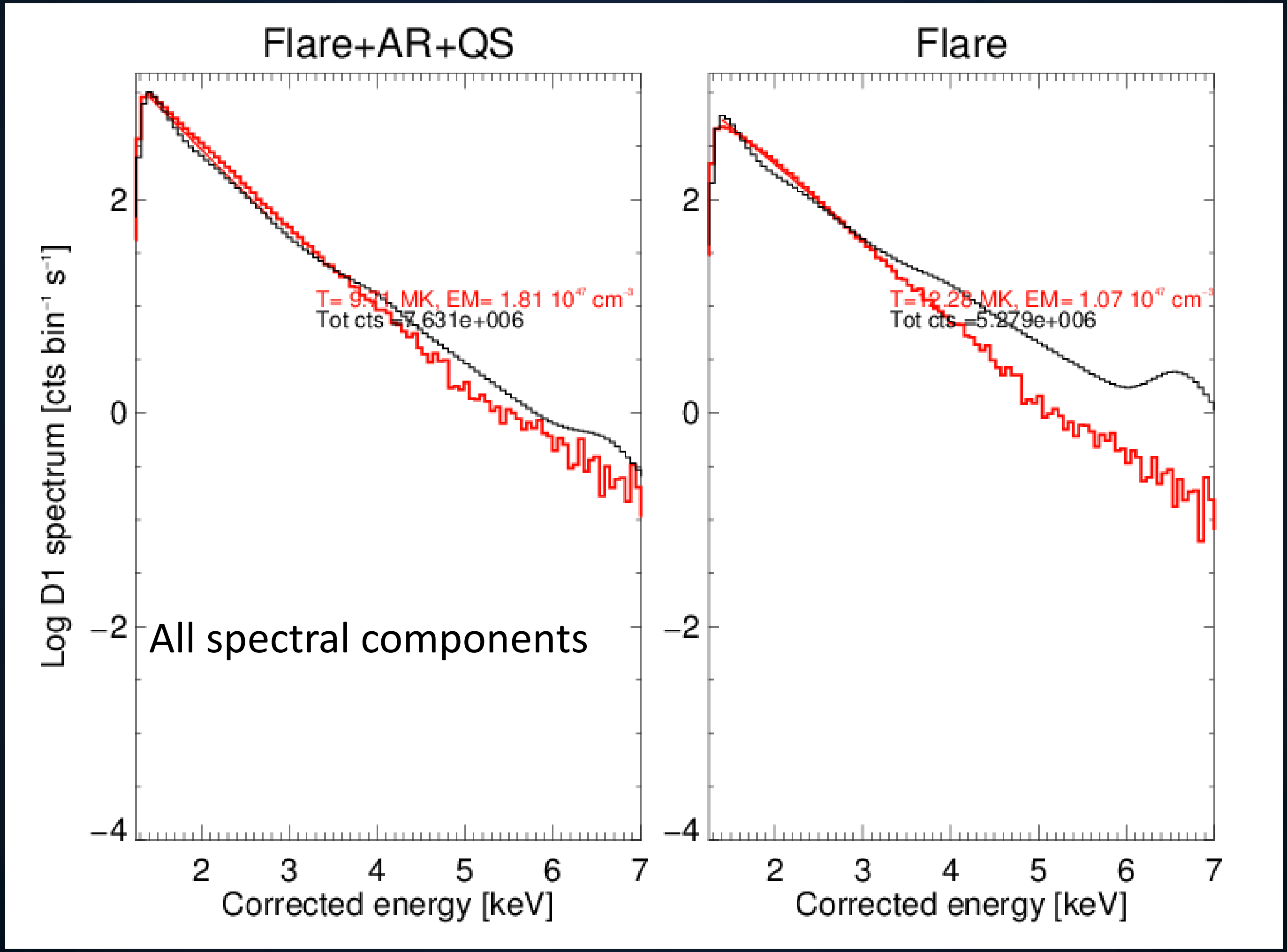
The most intense EUV spikes are NOT necessarily the most intense in X-ray radiation.


Evolution of Ar 11024 spectra
Energy [keV]
6
5
4
3
2
4
6
8
10
12
14
Day of July 2009

Flares of AR 11024: B. Sylwester this Thursday



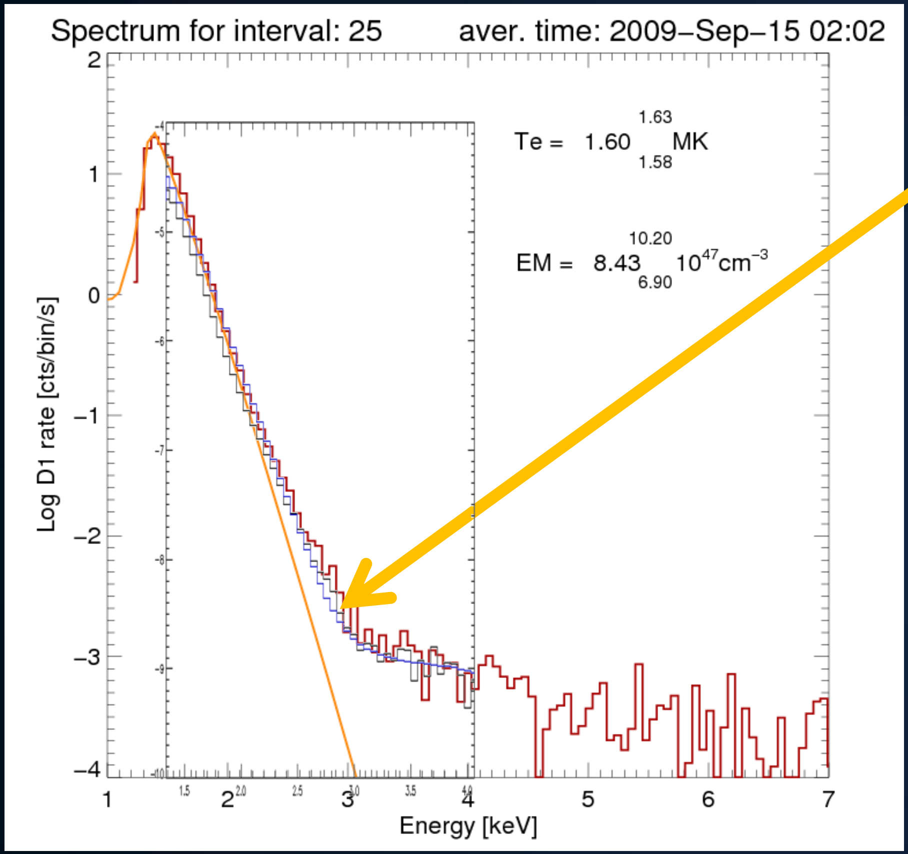
Not so good fits for flares however will be explained in Barbara's talk



Present directions in the interpretation of SphinX measurements

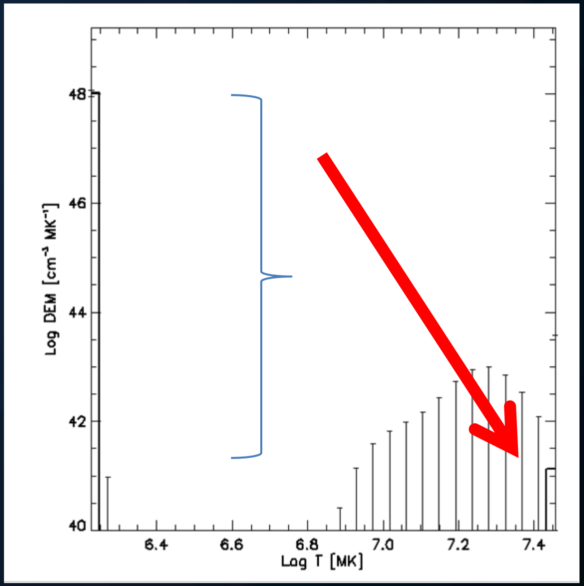
- **Theory**:
  - Extending the analysis to multitemperature plasmas where necessary
  - Study dependence of fit quality on plasma composition (playing with abundances)
  - Study effects on presence of time-dependent non-thermal electron populations
- **Quiet times**:
  - Periodicities in the time series of flux and/or T
  - Special events like eclipses
- **Active regions**:
  - Other good examples AR 11017 → see Szymon poster
- **Flares:**
  - Evolution of DEM with time
  - Studies of energy balance
  - Counting of flares (wait time analysis), hundreds of flares from each AR

Multitemperaure approach to spectral fitting



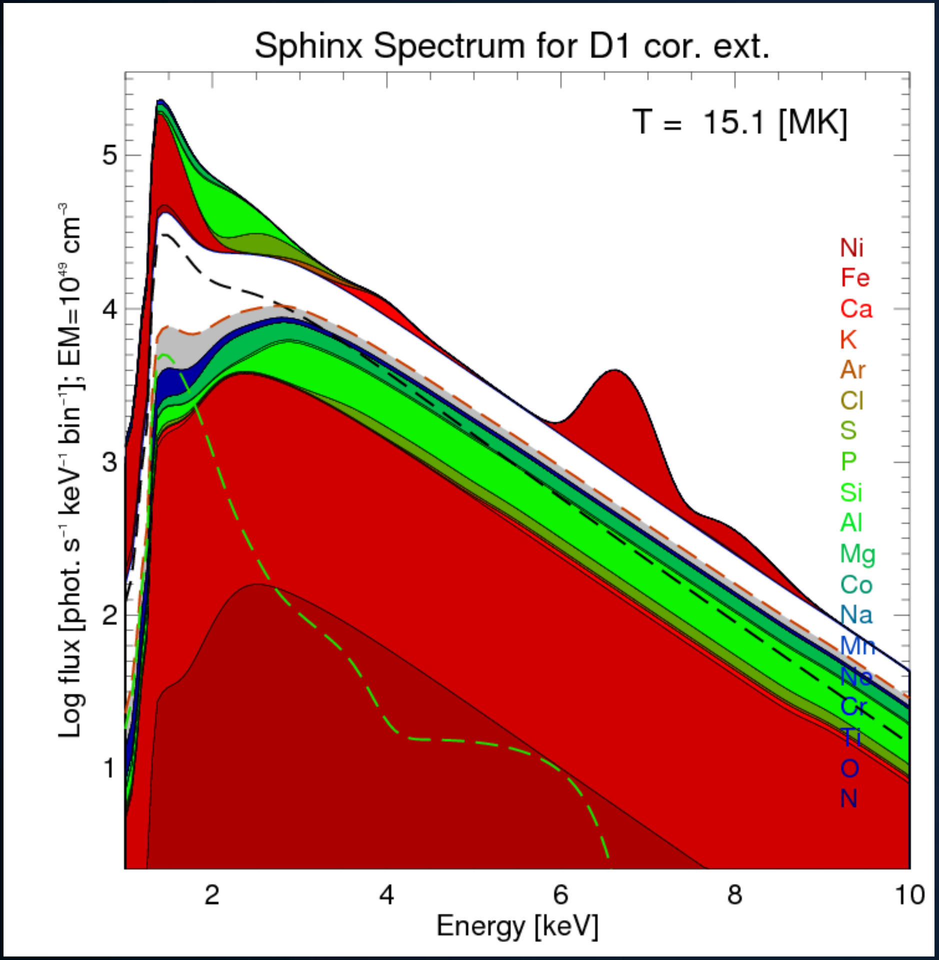
Quiet, NON-AR spectrum cannot Be accomodated in the isothermal approach at energies E> 2.5 kes

We have used maximum likelihood Bayesian iterative method to solve for unknown DEM to accomodate the shape of observed spectrum



How this works for flare spectra will be shown by Barbara this Thursday

Which processes and elements contrubute at most to SphinX spectra?



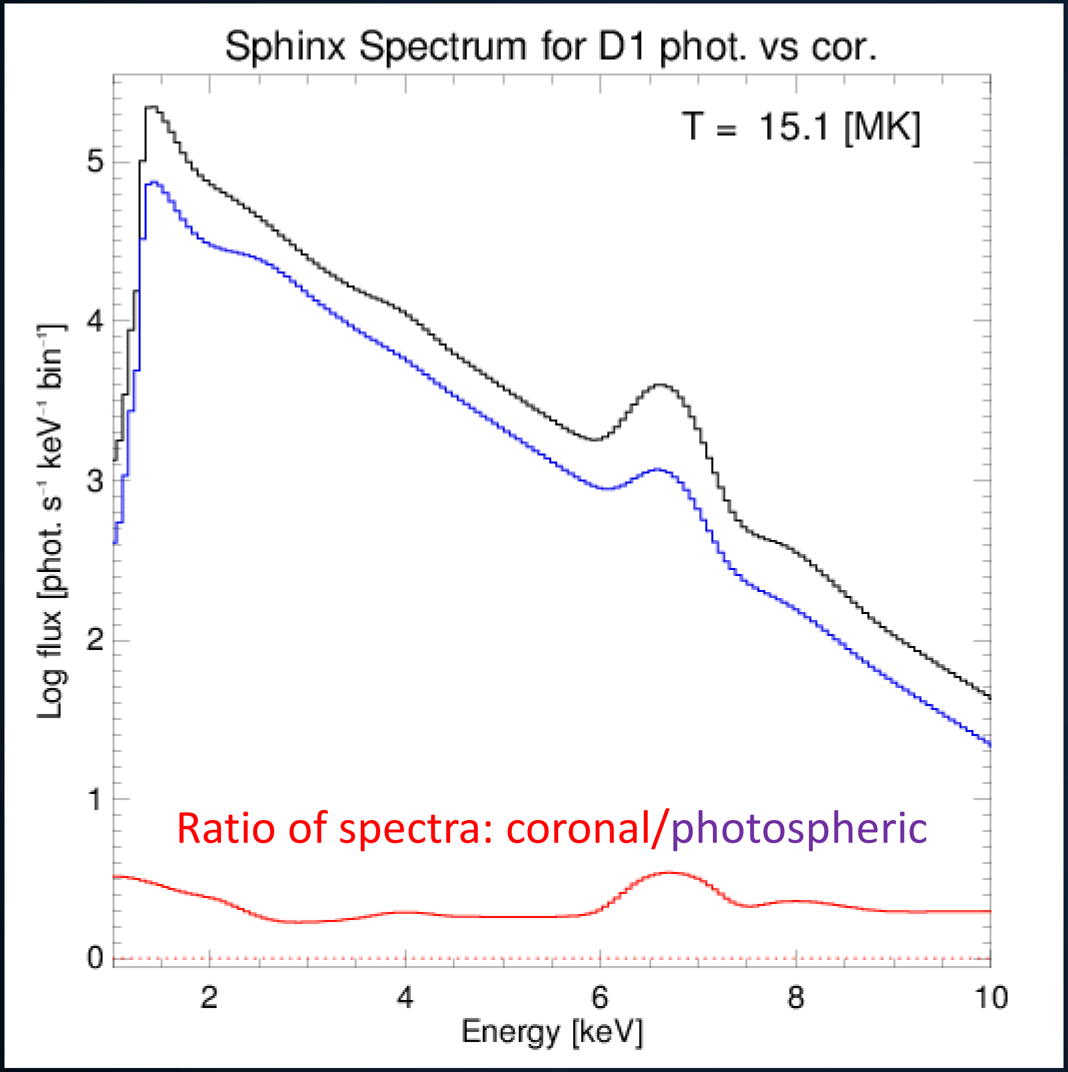
- Free-free emision
- Free-bound & 2phot
- Lines

The most important contributor: Fe

Also S, Si

around 2 keV

Coronal vs. Photosperic spectra



Corona:

- Low FIP elements' abundance increased by factor ~4 relative to photospere
- Details in Prof. Phillips lecture this afternoon

SphinX data access now is public

see Szymon's Poster

http://156.17.94.1/sphinx_l1_catalogue/SphinX_cat_main.htm

- All data reformatted and converted to Level_1
  - Time interval 20 February – 29 November 2009
  - Most instrumental problems resolved(Magdalena & Szymon)
  - Diagonal part of detector matrix used for now
  - CHIANTI 6.1 used to model the synthetic spectra
  - Isothermal assumption applied to derive prompt characteristics of observed plasma emission (filter ratio, but more advanced are being incorporated see the following talks)

SphinX collaborations

- Haward Smithsonian CfA (AR 11024 studies)
  - Alec Engell, Mark Weber
- MSSL (atomic processes)
  - Ken Phillips
- Palermo Observatory (calibration, high-T component)
  - Fabio Reale
  - Alfonso Collura
- FIAN (multiple subjects)
  - Sergey Kuzin
  - Sergey Bogachev
- SOTERIA 7FP and starting eHEROES
  - Kharkiv University: Oleksiy Dudnik

Thank you