IBIS/PICsIT Data Analysis

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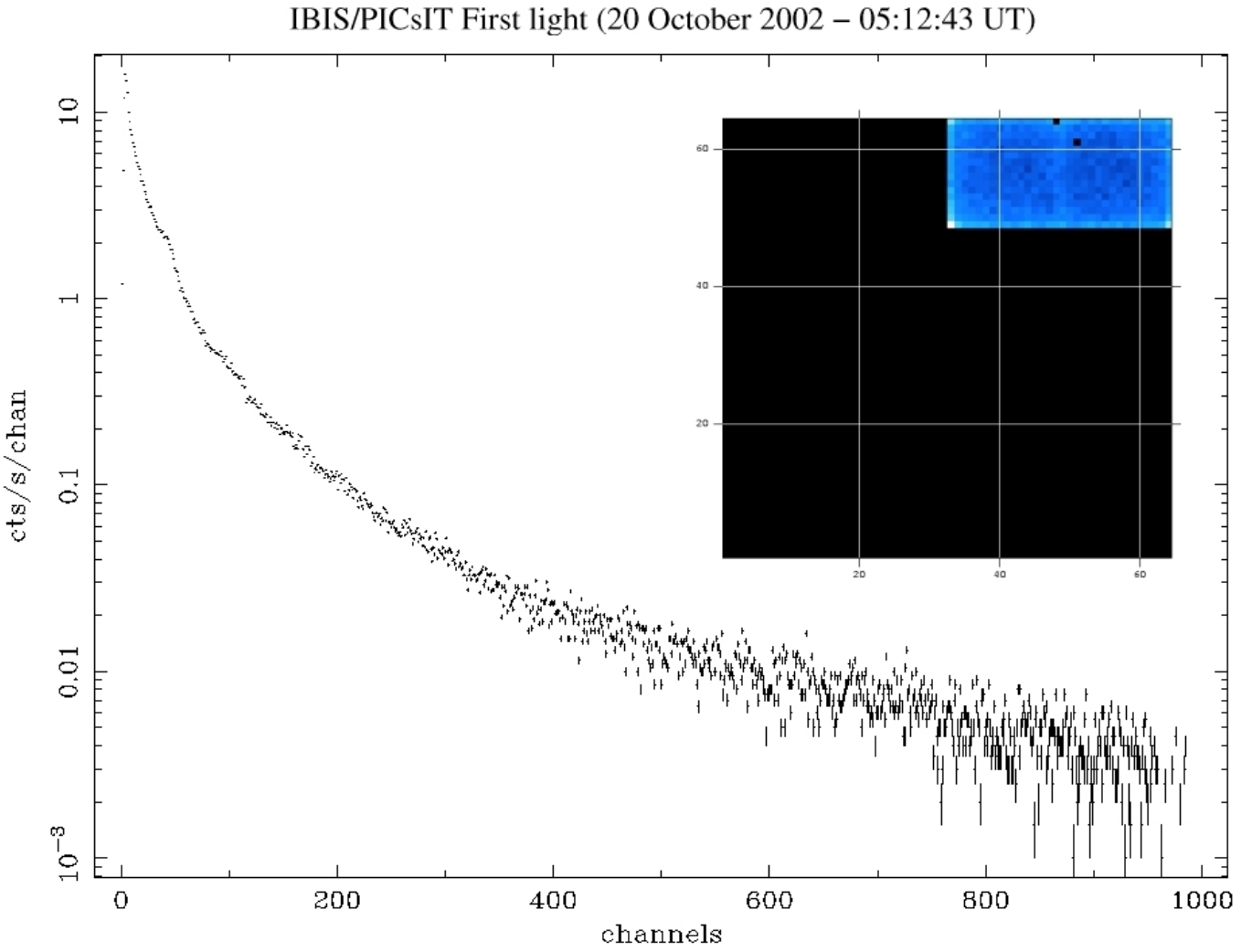
IBIS *(**I**mager on **B**oard the **I**ntegral **S**atellite)*

IBIS (Ubertini P., Lebrun F., Di Cocco G., et al, 2003, A&A 411, L131) is composed of 2 detectors:

ISGRI, CdTe detector in the range 15 keV – 1 MeV (Lebrun et al., 2003, A&A 411, L141).

PICsIT, CsI detector in the range 175 keV – 10 MeV (Di Cocco et al., 2003, A&A 411, L189).



IBIS/PICsIT identity card

*(**P**ixellated **I**maging **C**ae**s**ium **I**odide **T**elescope)*

The high-energy detector of IBIS aboard INTEGRAL

Energy range:	175 keV – 6.5 MeV (single events)
	350 keV – 13 MeV (multiple events)
Energy Resolution:	18% @ 511 keV - 9% @ 1.275 MeV
Pixels:	4096 (64×64) organized in 16 semimodules
Detector area:	2890 cm^2
Effective area:	~1400 cm^2 @ 500 keV / ~600 cm^2 @ 2 MeV
Angular resolution:	~12’
PSLA:	<5’
Field Of View (FOV):	9° × 9° Fully Coded - 19° × 19° Half Coded
Timing Resolution:	0.97-500 ms (spectral timing)
	>64 μs (photon-by-photon)

For more details see Di Cocco et al. (2003)

On board processing

Because of tight telemetry budget, it is not possible a complete (position, time, energy) transmission photon-by-photon (ppm) of all the PICsIT data need for onboard processing.

- Every event that is **not** in coincidence with ISGRI events (Compton events), calibration unit tags (calibration events), VETO strobes (background event), is considered a ***valid PICsIT event.***

- ***Single event:*** a photon interacts with only 1 pixel;
- ***Multiple event:*** a photon interacts with more than 1 pixel;

- Events are equalized with onboard **L**ook-**u**p **T**ables (LUT), integrated according to binning tables (still into LUT), and transmitted to ground.

General Flow Chart

Detector events

On board processing (equalization, histogram preparation)

INTEGRAL Telemetry

Preprocessing by ISDC

Creation of the INTEGRAL Data Structure
(Science Windows, RAW + PRP data, Calibration and Context files)

Offline Scientific Analysis (OSA)
COR... Scientific products

IBIS/PICsIT Modes of Operation

The ***Standard mode*** is composed of 2 complementary submodes:

Spectral Imaging + Spectral Timing

(On board integration of data to produce histograms due to telemetry limits)

Spectral Imaging (spi):

- 256 x 64 x 64 (Channel x Pixel x Pixel);
  loss of time resolution;
  reduction of energy resolution;
  time of integration ~2 ks (~ 1 Scw).

Spectral Timing (spt):

4(8) energy bands
loss of spatial and energy resolution
high time resolution (1-500 ms)

Photon-by-photon (ppm):

Generation of a list of photons, with their channel (max 1024!), time lag, detector position (y,z);

Require a huge telemetry budget, therefore can work for observations only in very particular cases (e.g. Calibration tests);

Normally operating only during slews (~120 s long).

Standard Mode OSA Pipeline

Images (spi histograms):

* Deadtime Calculation
* Shadowgram Build
* Background/Uniformity Correction
* Shadowgram integration (staring)
* Deconvolution, Source detection

--- (staring observation stops here)

* Mosaic, Source detection (dithering)

Spectra (spi histograms)

* Deadtime Calculation
* Shadowgram Build
* Background Correction
* Single source spectra extraction

In **ppm** is more or less the same, but it works for imaging only.

Lightcurves (spt histograms):

* Deadtime Calculation
* Lightcurve extraction for the whole FOV
* Barycenter correction

Algorithms for the deconvolution

Algorithms for the deconvolution explained in detail in Goldwurm et al. 2003, A&A 411, L223 (special issue dedicated to INTEGRAL).

A&A 411, L223–L229 (2003)
DOI: 10.1051/0004-6361:20031395

Astronomy & Astrophysics

The INTEGRAL/IBIS scientific data analysis⋆

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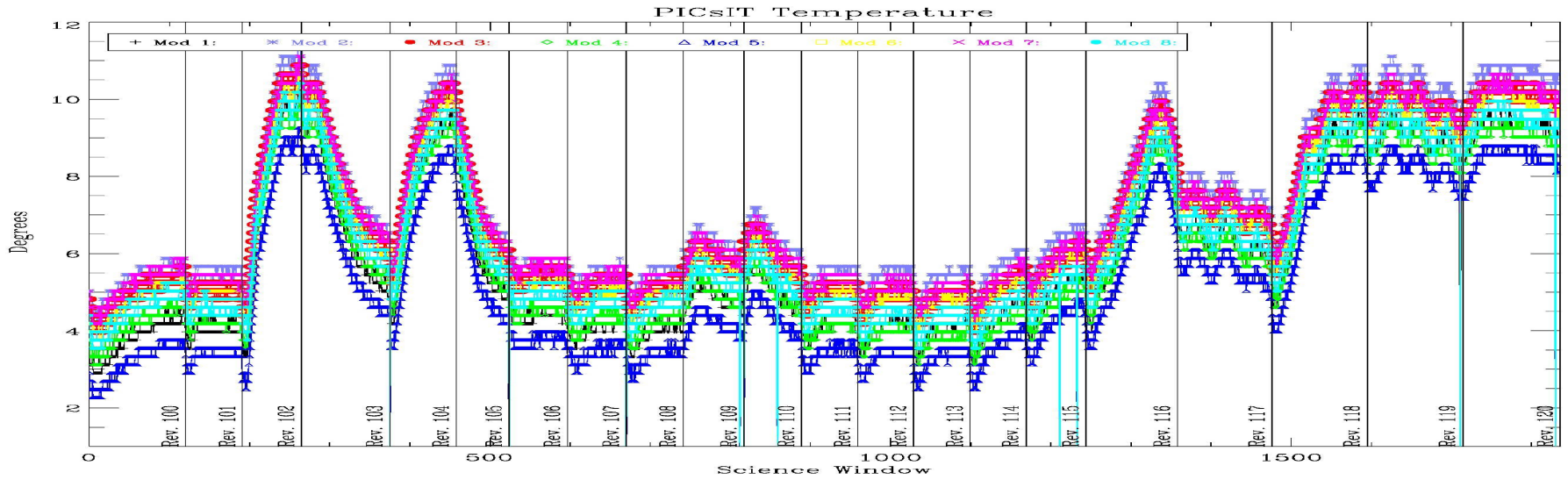
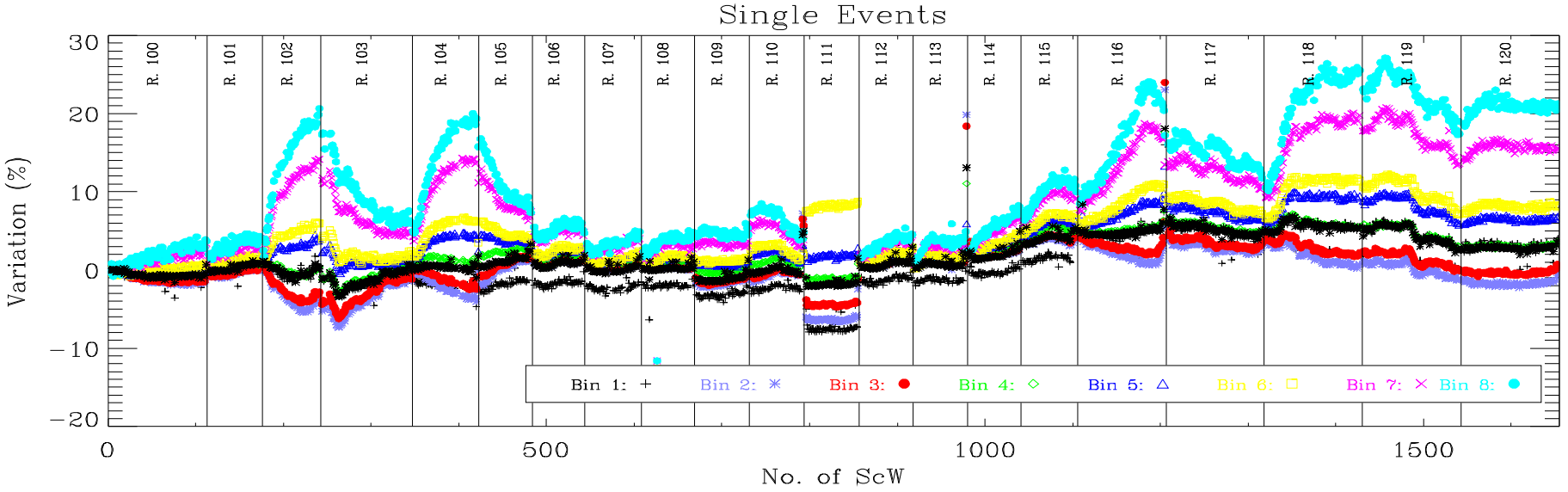
IBIS/PICsIT Background





IBIS/PICsIT Background: Cosmic Rays Induced Events

- After the launch, it resulted that PICsIT suffered for an additional background component due to cosmic-rays interaction with the satellite structure (Segreto et al. 2003);

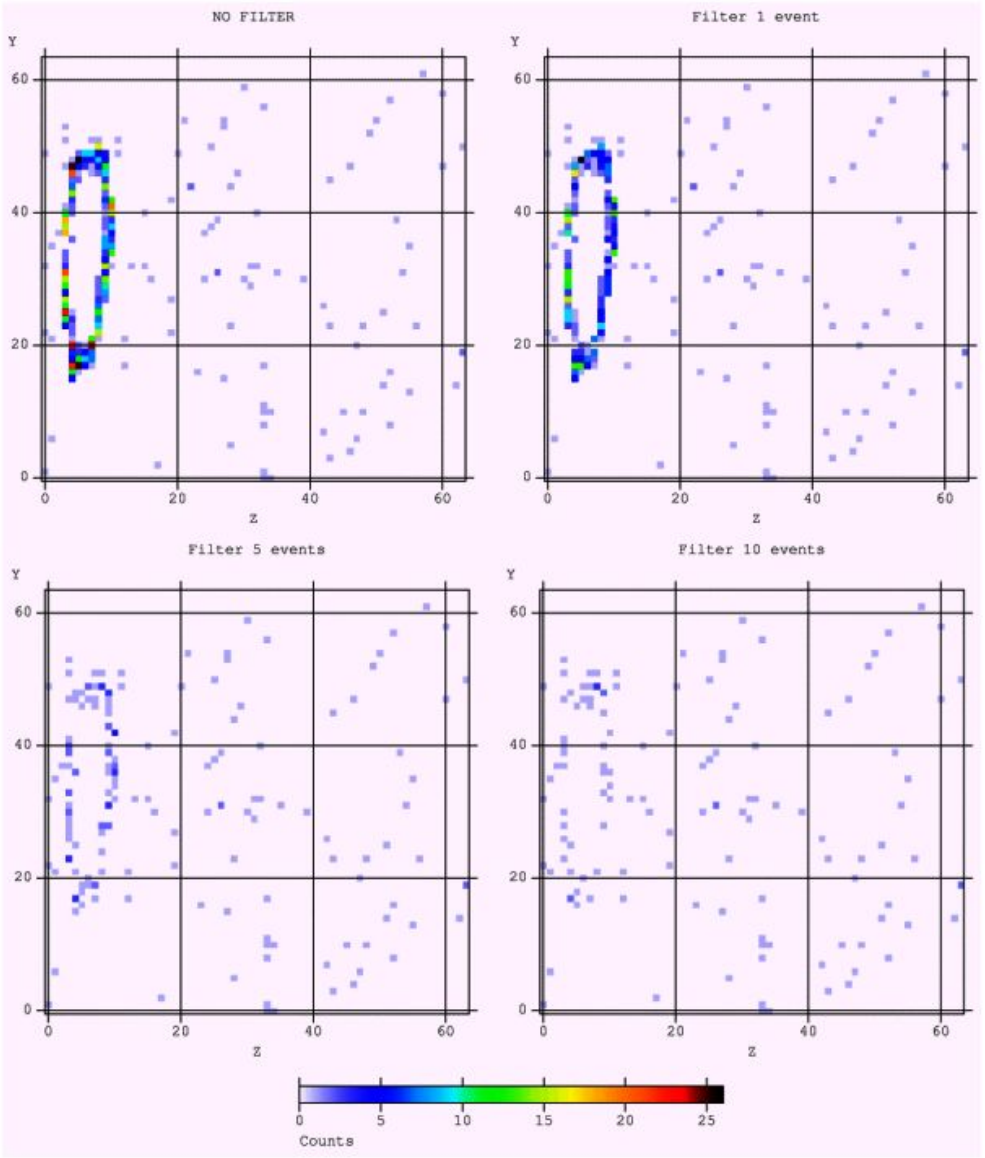
- Tests of PICsIT pixels at DA NE Beam Test Facility (INFN, Frascati) and simulations with GEANT 4.3 suggested that a pixel generates spikes when receiving E>4.6 GeV;

- Presently it is not possible to correct efficiently for this additional background component, since events are integrated on board (histogram mode);

- It is possible to clean data by changing the on board software; an algorithm has been proposed;

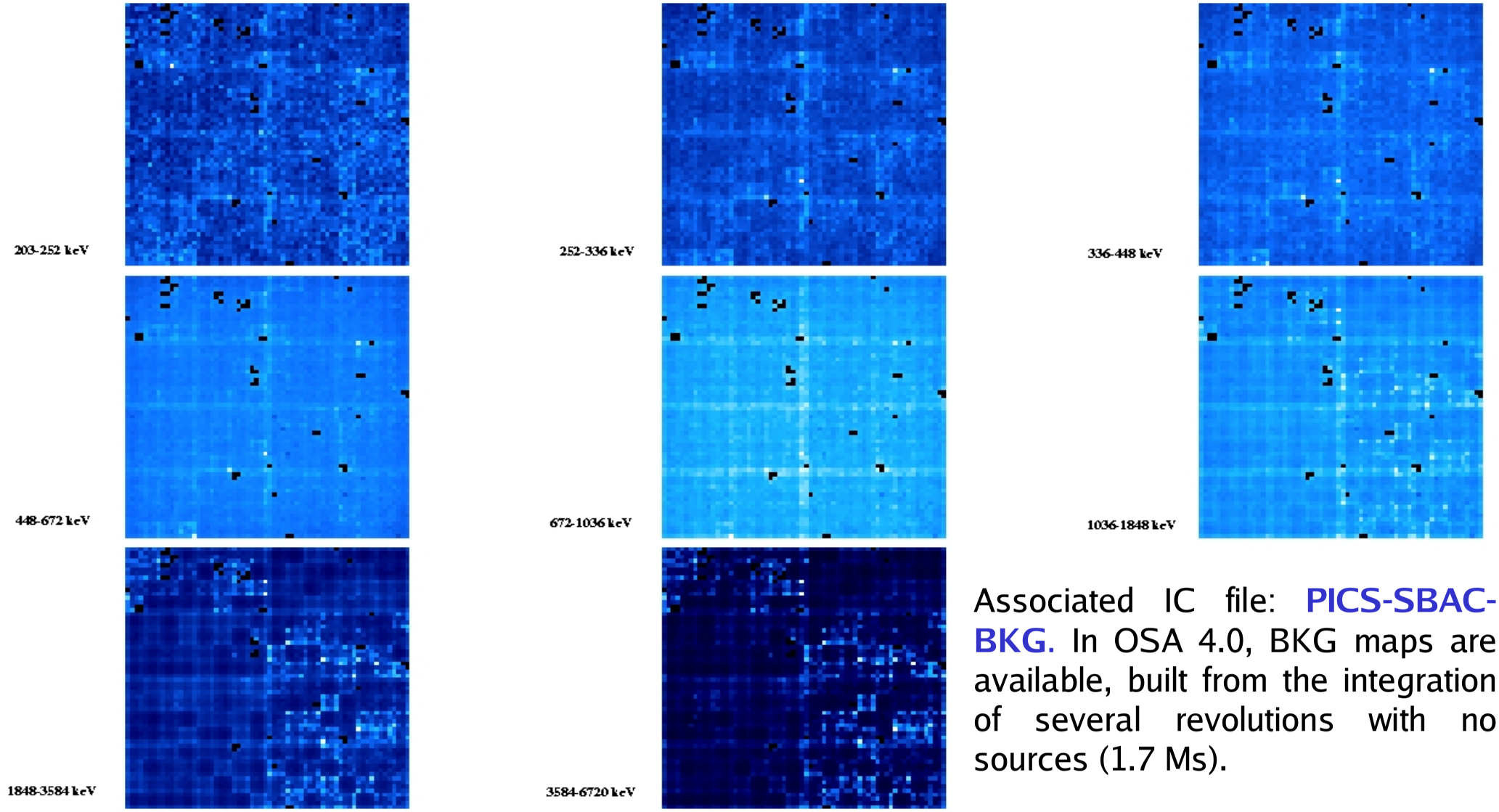
- A full detailed report will be soon available.

IBIS/PICsIT Background: Cosmic Rays Induced Events



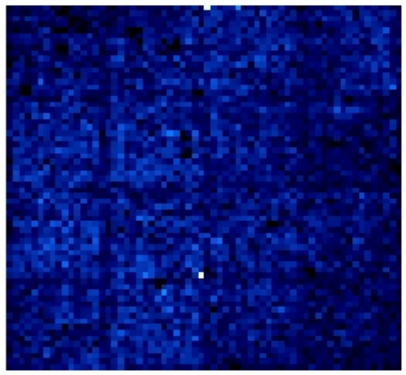
Example of filtering a shower of cosmic-rays induced events

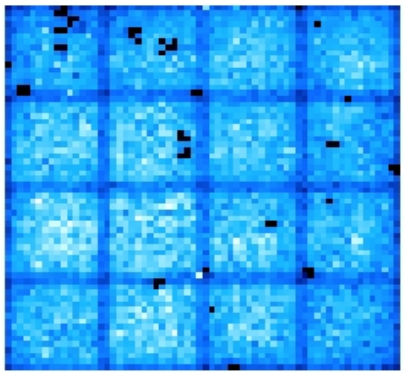
Background maps – Single Events

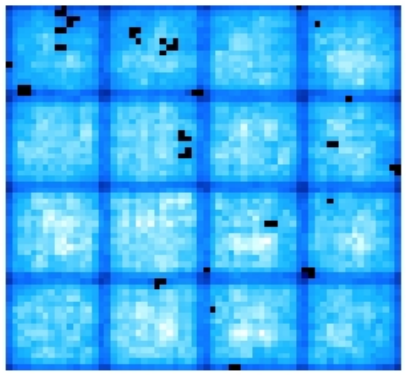


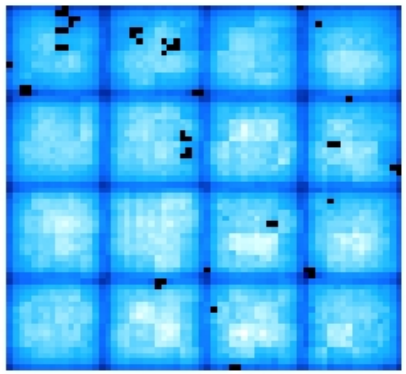
Associated IC file: **PICS-SBAC-BKG.** In OSA 4.0, BKG maps are available, built from the integration of several revolutions with no sources (1.7 Ms).

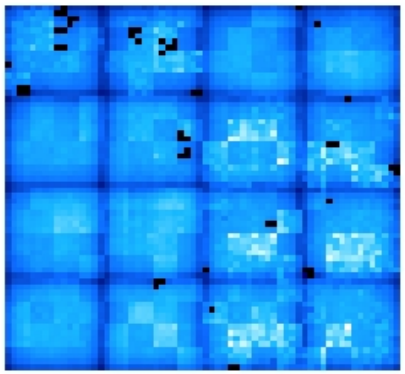
Background maps – Multiple events

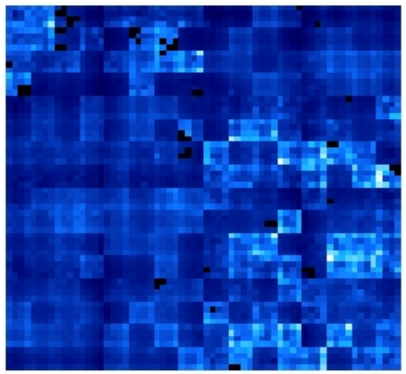


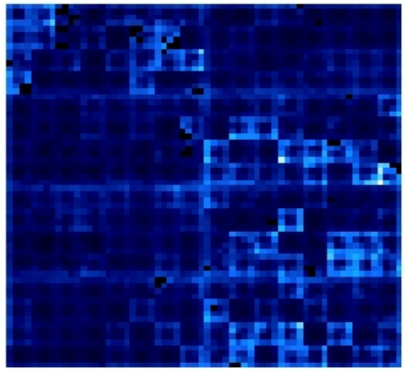


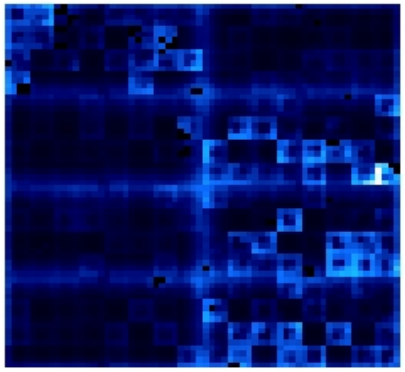












Associated IC file: **PICS-MBAC-BKG.**

IBIS/PICsIT Observation of the Crab (February 2003)

Summary:

- Analysis of almost all the pointings performed Feb. 2003;
- Revolutions 39, 42, 43, 44, 45
- Only standard mode;
- Staring, Hexagonal and 5x5 dither patterns;
- On axis and off axis up to 7°;
- Only complete histograms;
- Total Elapsed time: 807 ks;
- Total Exposure: 556 ks;
- Single and Multiple events.

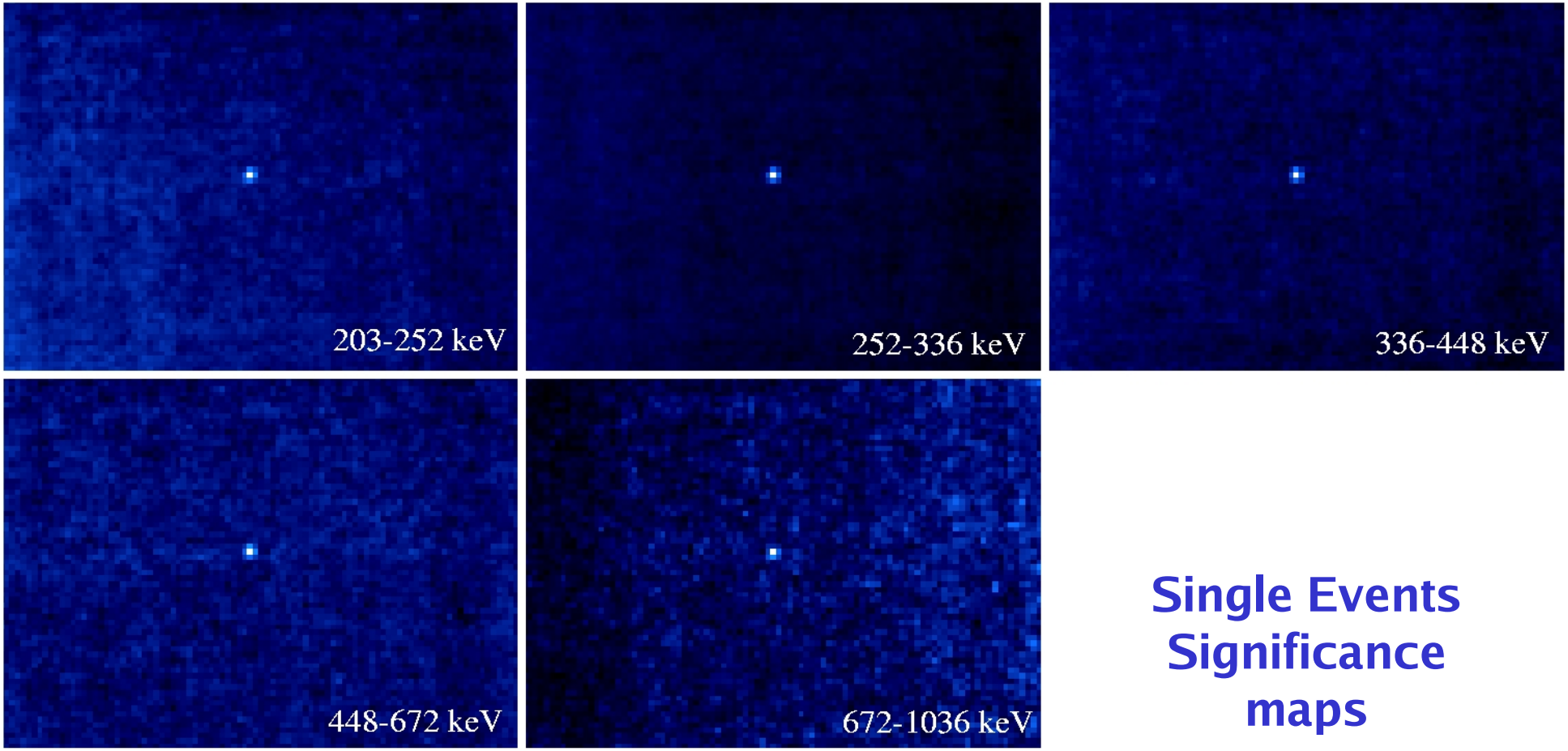
Crab observation Feb 2003

Exposures: 556 ks for singles; 545 for multiples.

	Single Events		Multiple Events	
Energy Band [keV]	**Rate [c/s]**	**SNR [σ]**	**Rate [c/s]**	**SNR [σ]**
203-252	3.31	57.1	-	-
252-336	2.86	57.0	-	-
336-448	1.33	32.9	0.07(*)	5.0(*)
448-672	0.84	19.3	0.18	6.8
672-1036	0.28	8.3	0.20	7.6
1036-3584	-	-	0.12(*)	4.7(*)

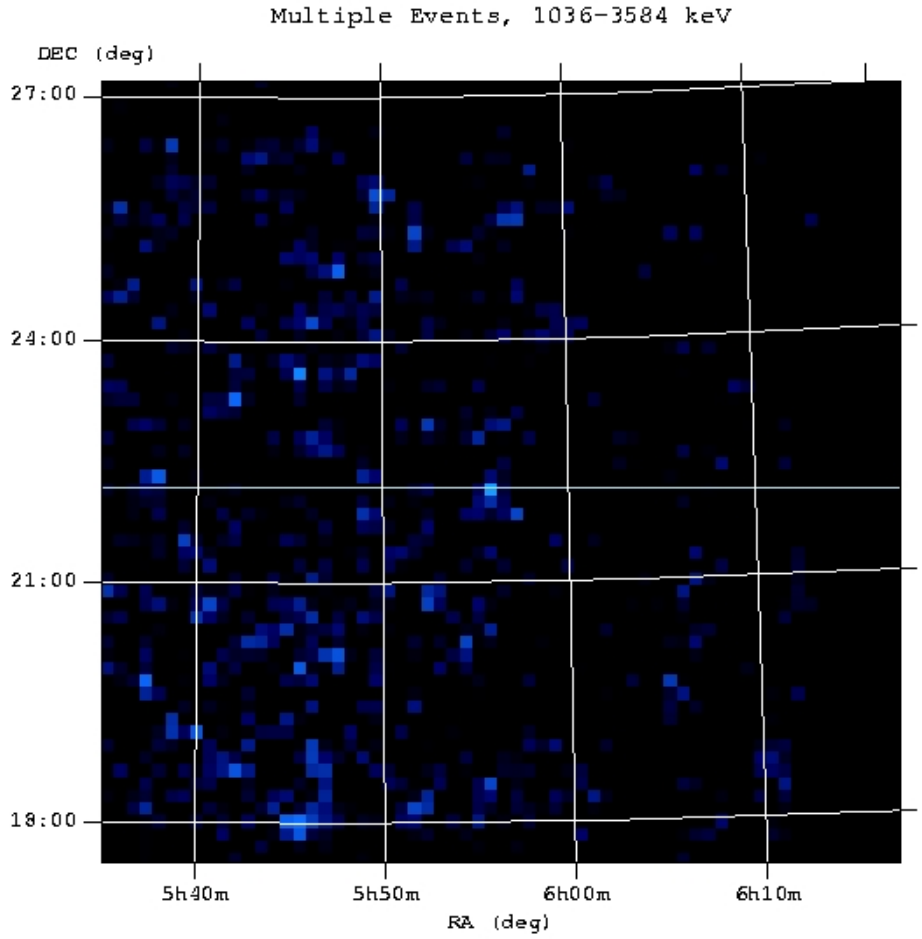
(*) Faint detection with still strong background residuals. Doubtful, but hopeful.

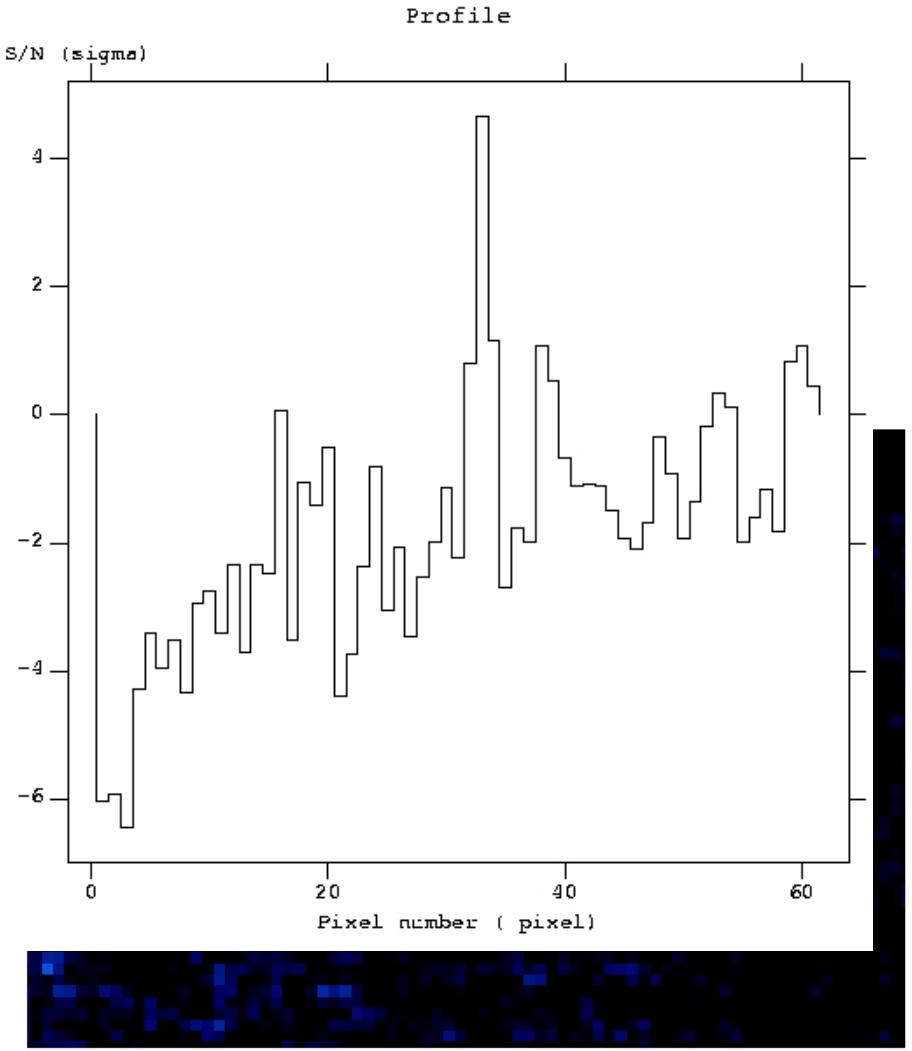
Crab observation Feb 2003



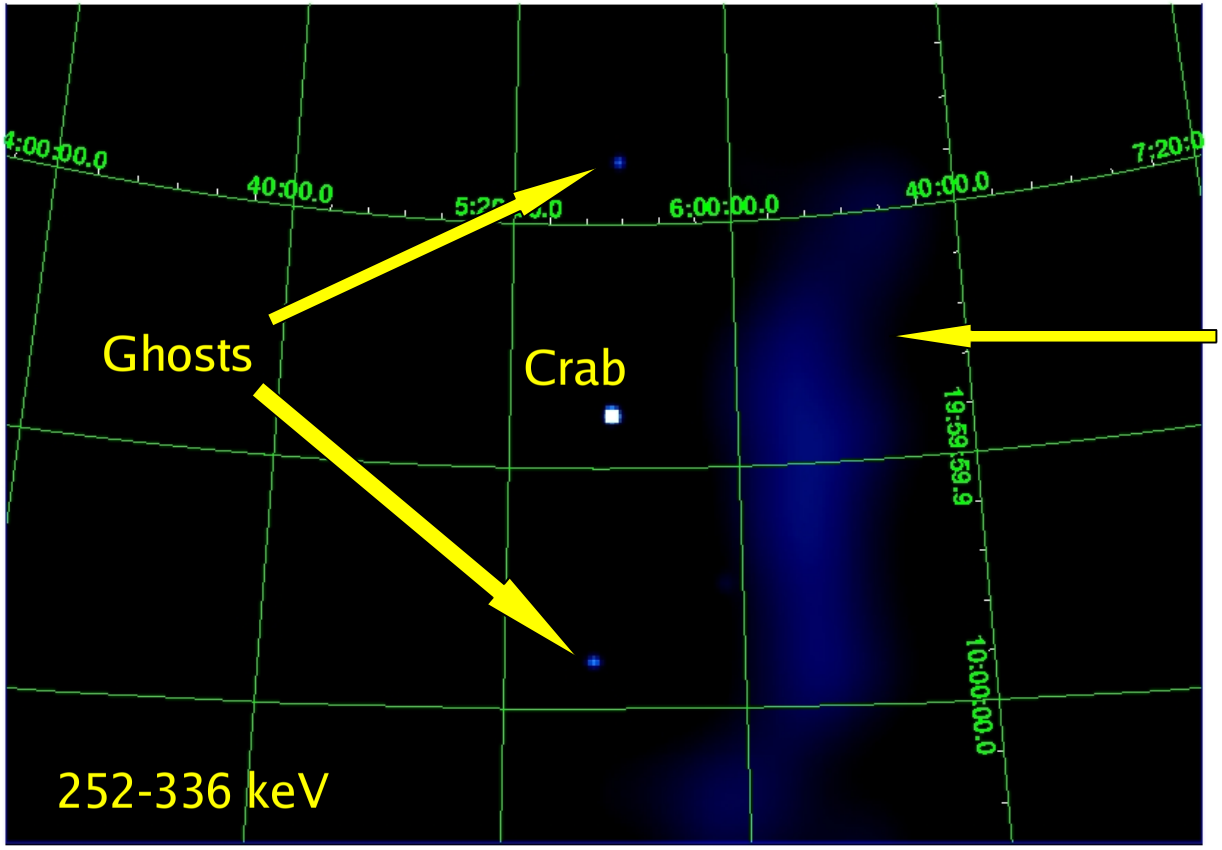
Single Events Significance maps

Crab: multiple events (545 ks)





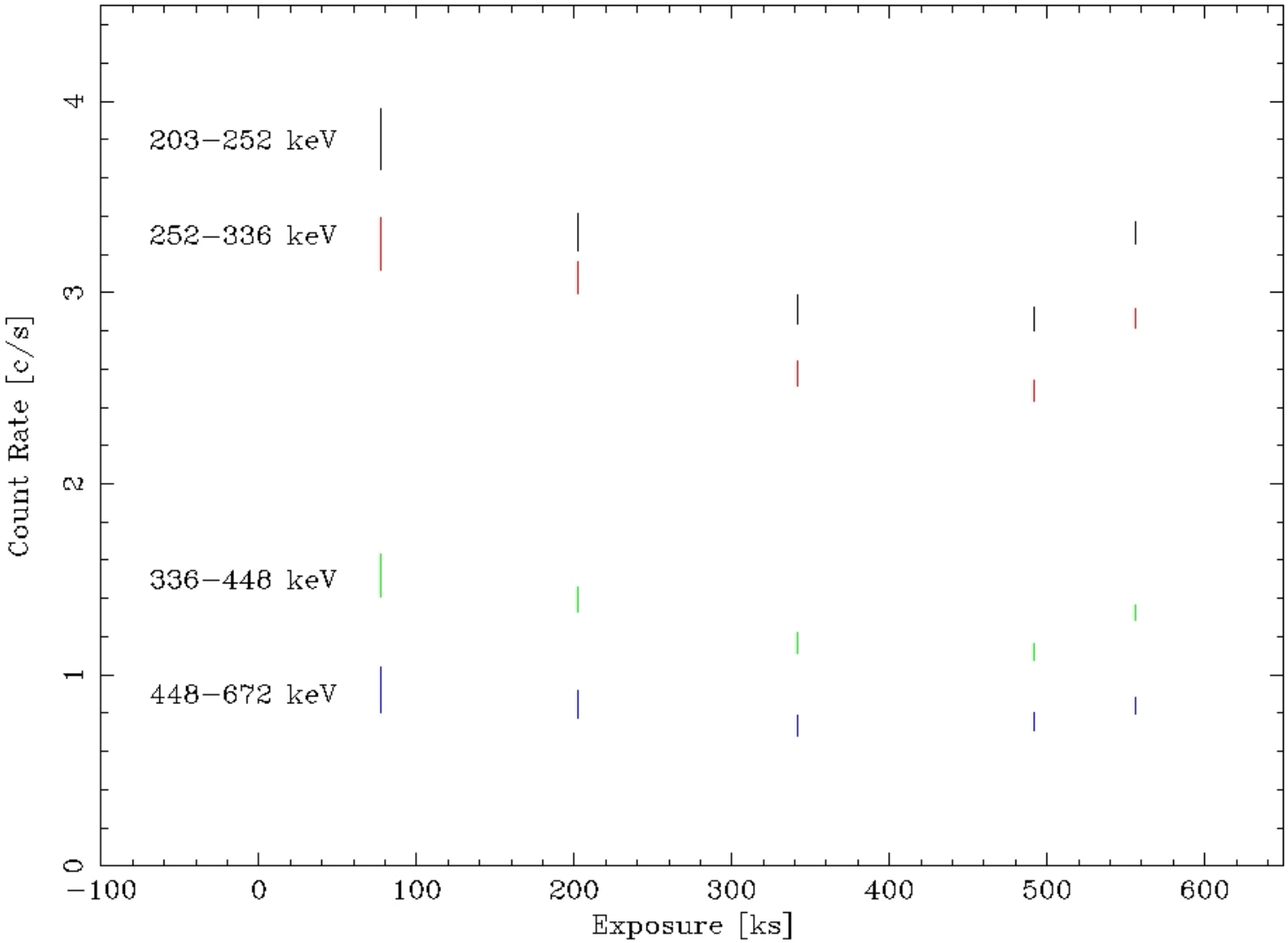
Improving PICsIT images with smoothing



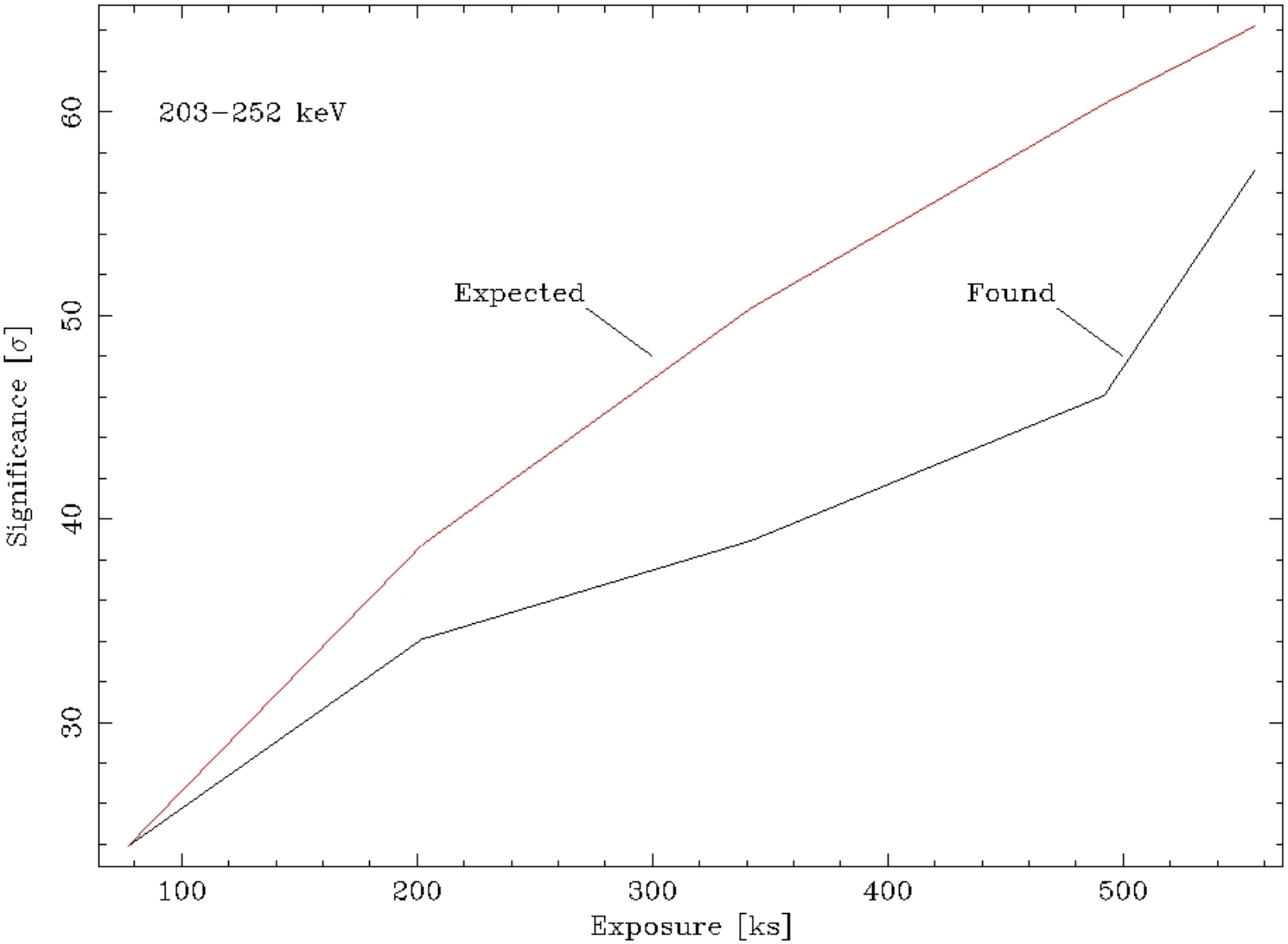
Residual background structures

Image obtained with the output of OSA as input of Chandra CIAO's tool **`csmooth`**.

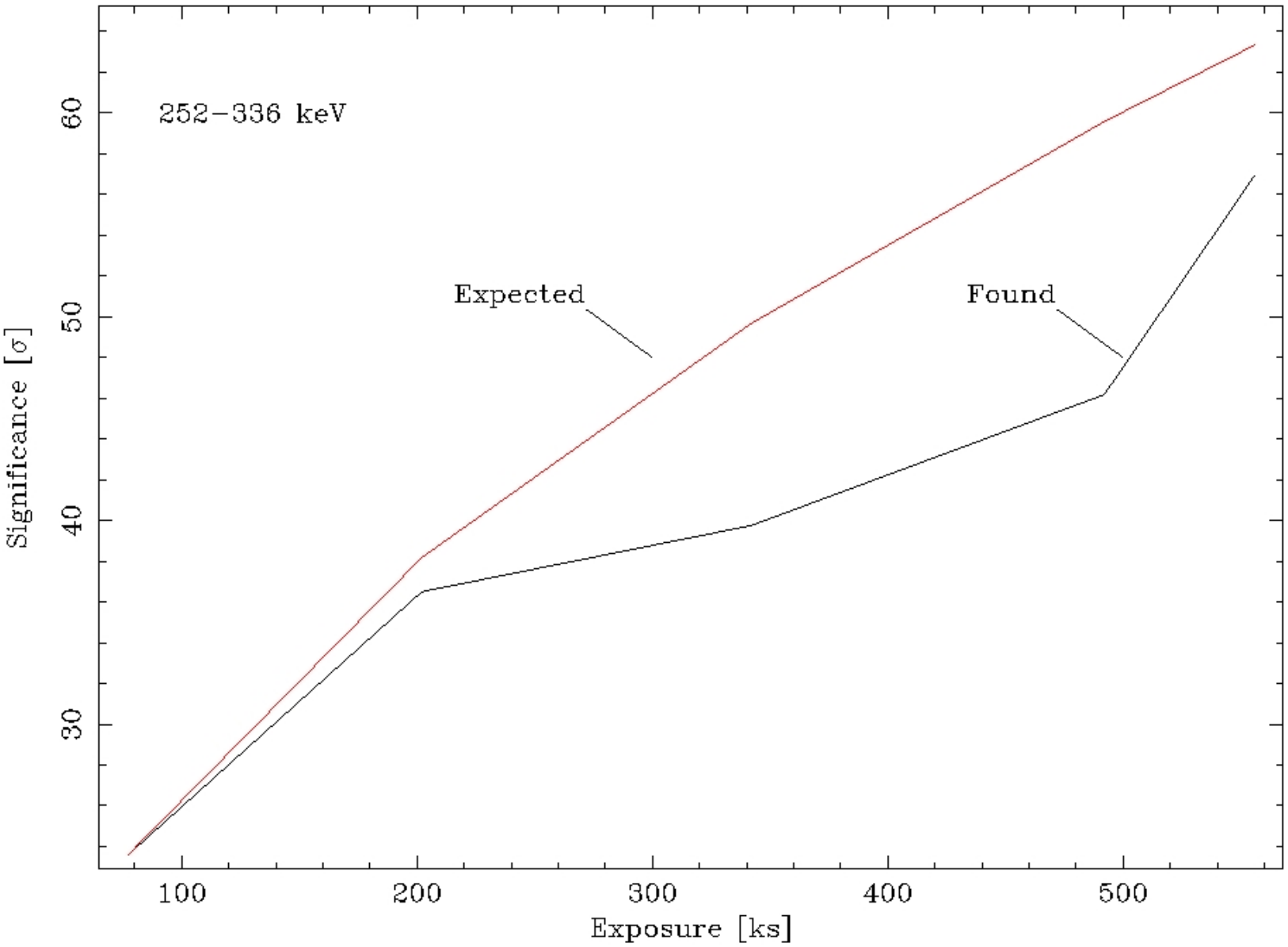
Crab count rate vs exposure



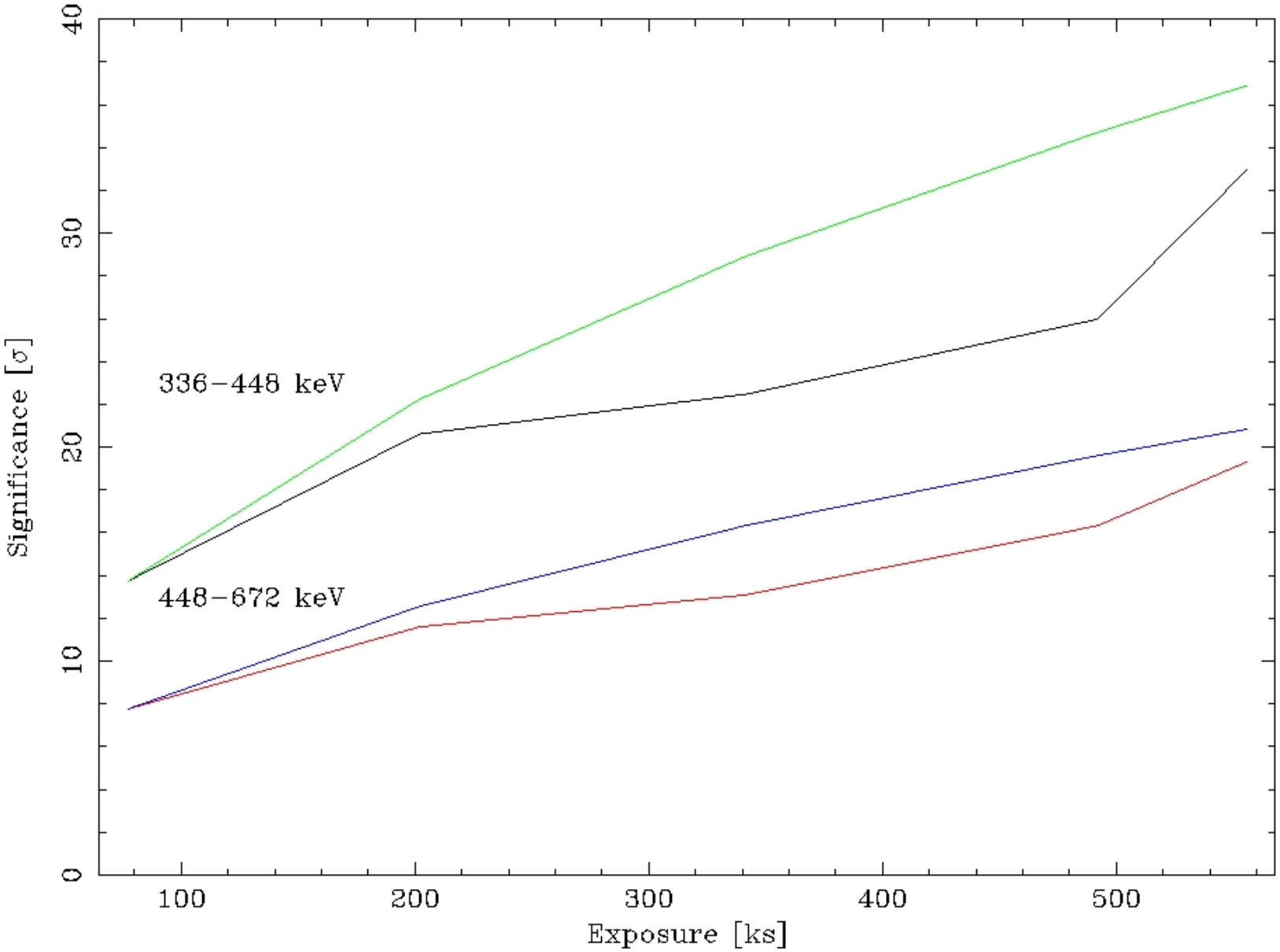
Crab S/N vs exposure



Crab S/N vs exposure



Crab S/N vs exposure



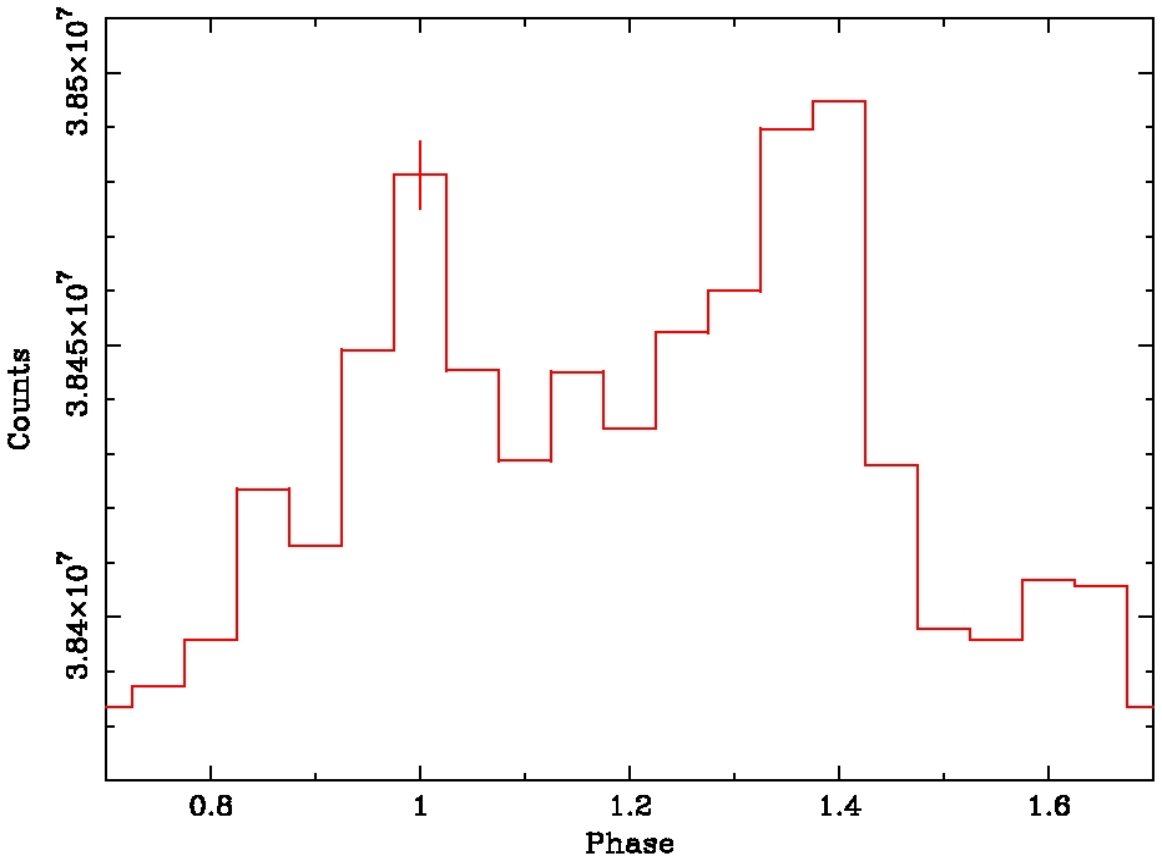
Source variability analysis

LCR: from spectral timing data we have count rates of the whole detector in 4 energy bands (156-208, 208-260, 260-364, 364-676 keV) and 4 ms of time resolution (default values).

Example: **Crab** in Revolutions 40-41 (Feb 2003), with spectral timing mode (1 ms); total exposure: 310 ks.

(Courtesy T. Mineo)

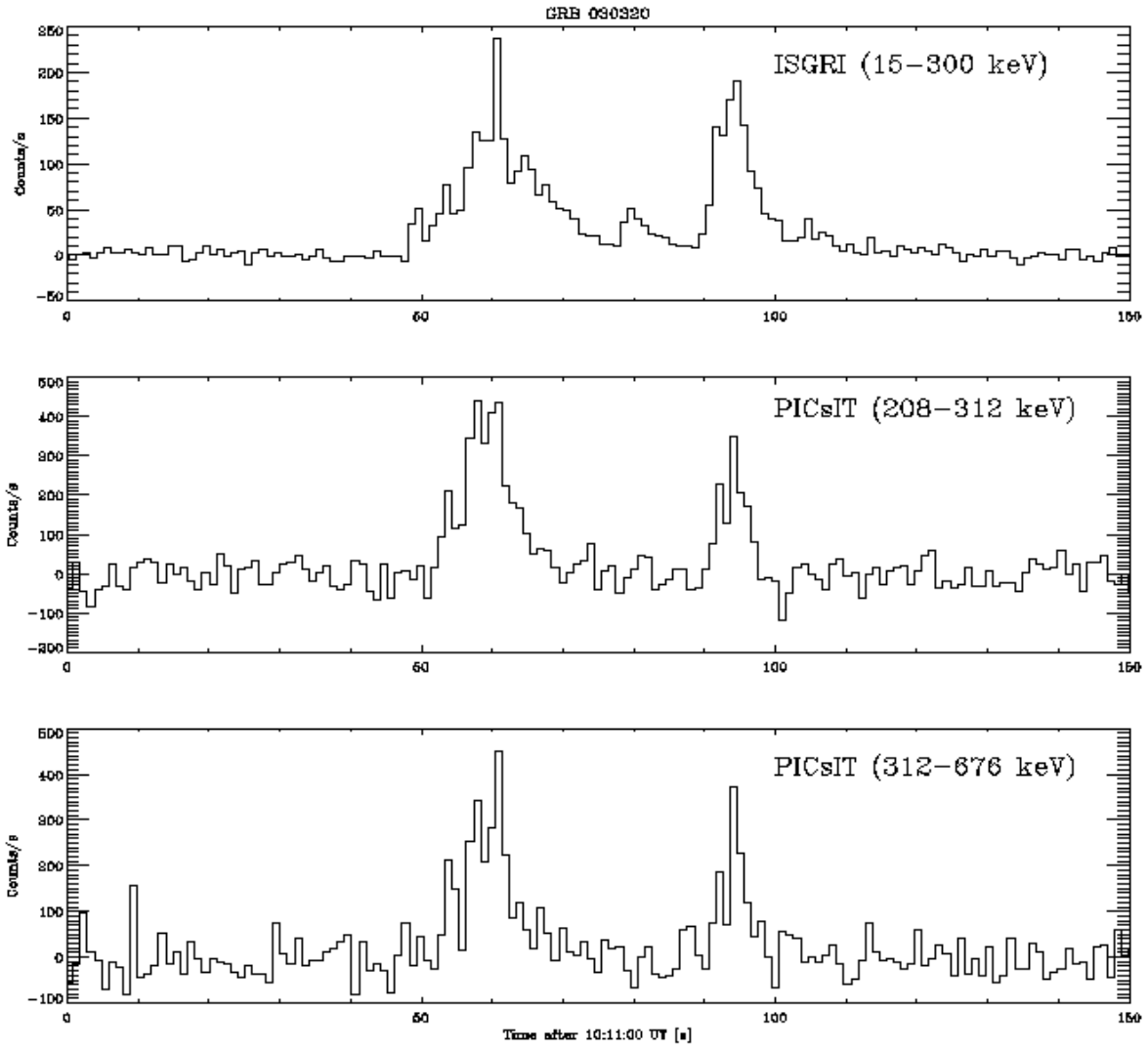
Folded lightcurve (260-364 keV)



Source variability analysis

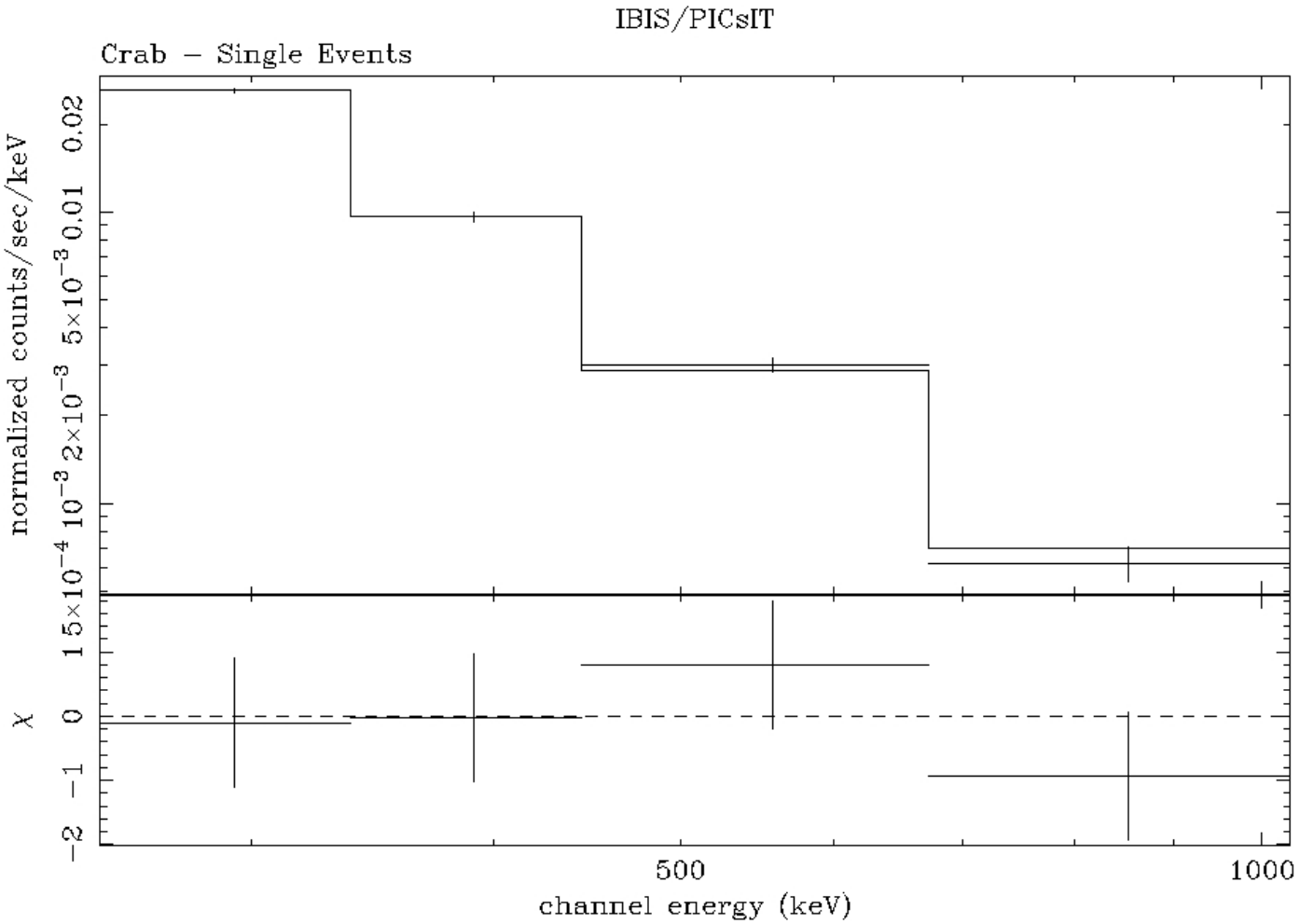
Example: **GRB030320** with spectral timing set in 2 energy bands (208-312 and 312-676 keV) with 62.5 ms of time resolution.

ISGRI lightcurve is also shown for comparison.



(Courtesy D. Gotz)

Crab spectrum with PICsIT



Γ=2.2±0.1;

A=10^{+9}_{-5};

0% Sys Err;

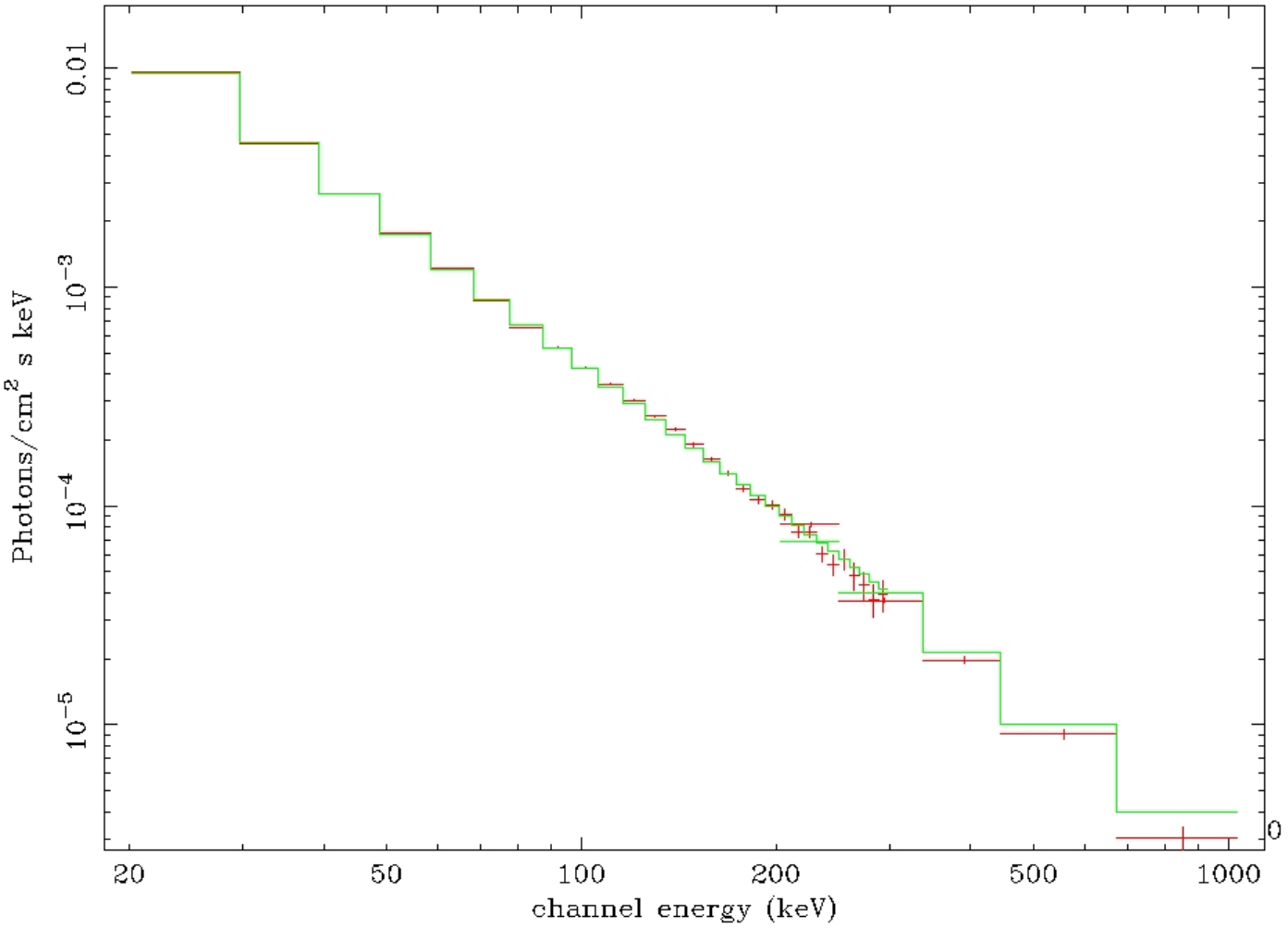
χ^2=1.5

dof=2

Red. χ^2=0.75

Prob.=0.471

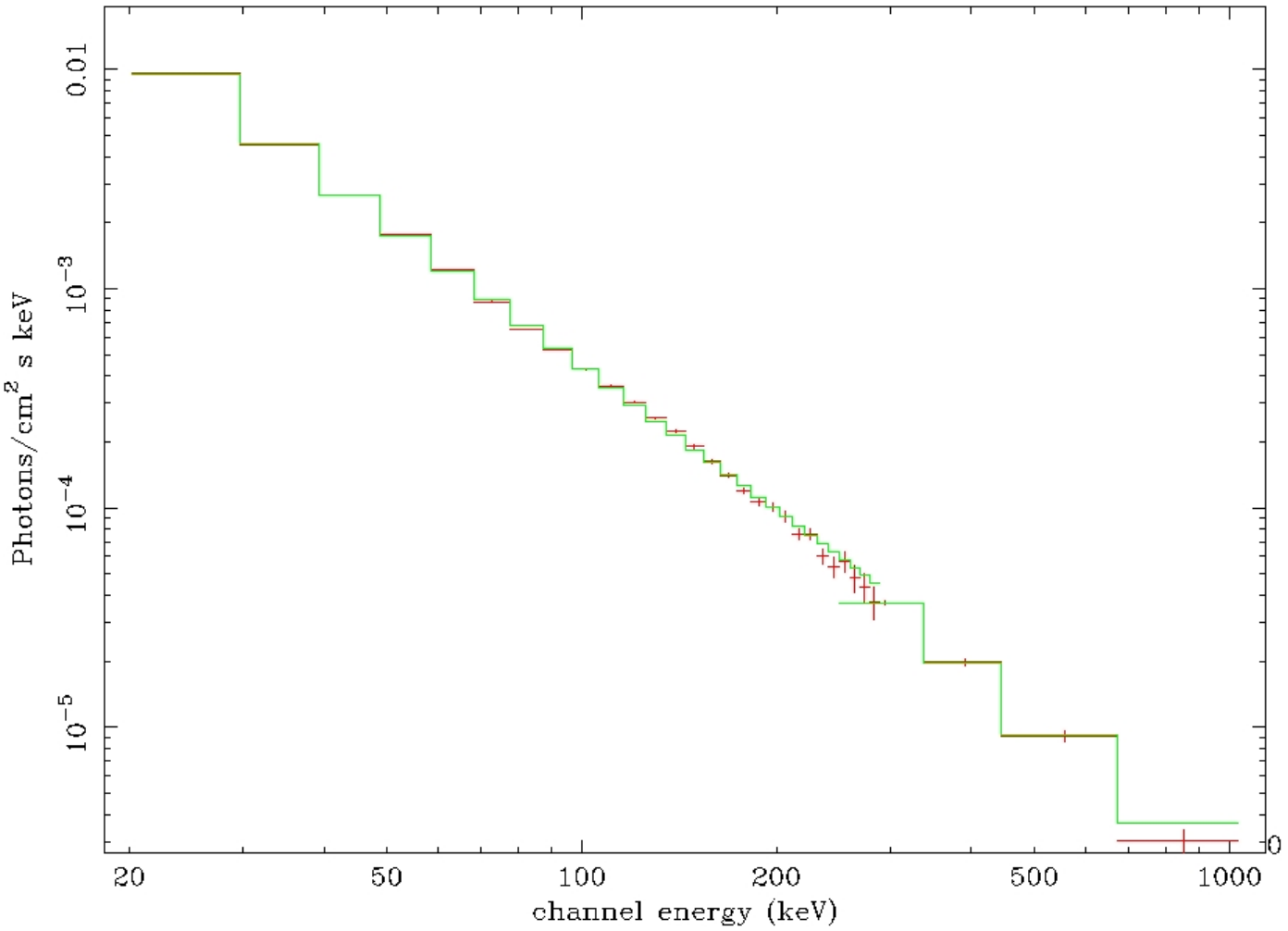
Crab spectrum with IBIS



Γ= 2.19±0.01;
A= 10.4±0.5;
C= 0.93±0.01
5% Sys Err;
χ^2= 34.7
dof= 31
Red. χ^2= 1.12
Prob. = 0.295

Flux[20-1000 keV] = 3.5 ×10^{-8} erg cm^{-2} s^{-1}
Flux[expected] = 3.7 ×10^{-8} erg cm^{-2} s^{-1}

Crab spectrum with IBIS



Γ=2.18±0.01;
A=10.1±0.3;
C=0.84±0.03
2% Sys Err;
χ^2 = 33.9
dof = 29
Red. χ^2 = 1.17
Prob. = 0.242

Without the first PICsIT channel.

References and further readings

Instrument IBIS/PICsIT:
Ubertini P., Lebrun F., Di Cocco G., et al., 2003, A&A 411, L131.
Di Cocco G., Caroli E., Celesti E., et al., 2003, A&A 411, L189.

In-flight calibrations:
Malaguti G., Bazzano A., Bird A.J., et al., 2003, A&A 411, L173.

Algorithms of the software:
Goldwurm A., David P., Foschini L., et al., 2003, A&A 411, L223.

IBIS/OSA User Manual:
prepared by M. Chernyakova, it is available in the OSA release.

Report on the scientific validation of the software:
Foschini L., 2004, v. 4.0 available at:
`http://isdc.unige.ch/index.cgi?Documents+docrep`

IBIS/PICsIT "Catalog"

Sources detected to date

Galactic Black Holes:

- Cygnus X-1 (see talk by M. Cadolle-Bel)
- XTE J1550-564 (see talk by M. Revnivtsev)

Pulsars and PWN:

- Crab

Gamma-ray Bursts:

- GRB021125
- GRB030320
- GRB041219 NEW