IBIS/PICsIT Data Analysis

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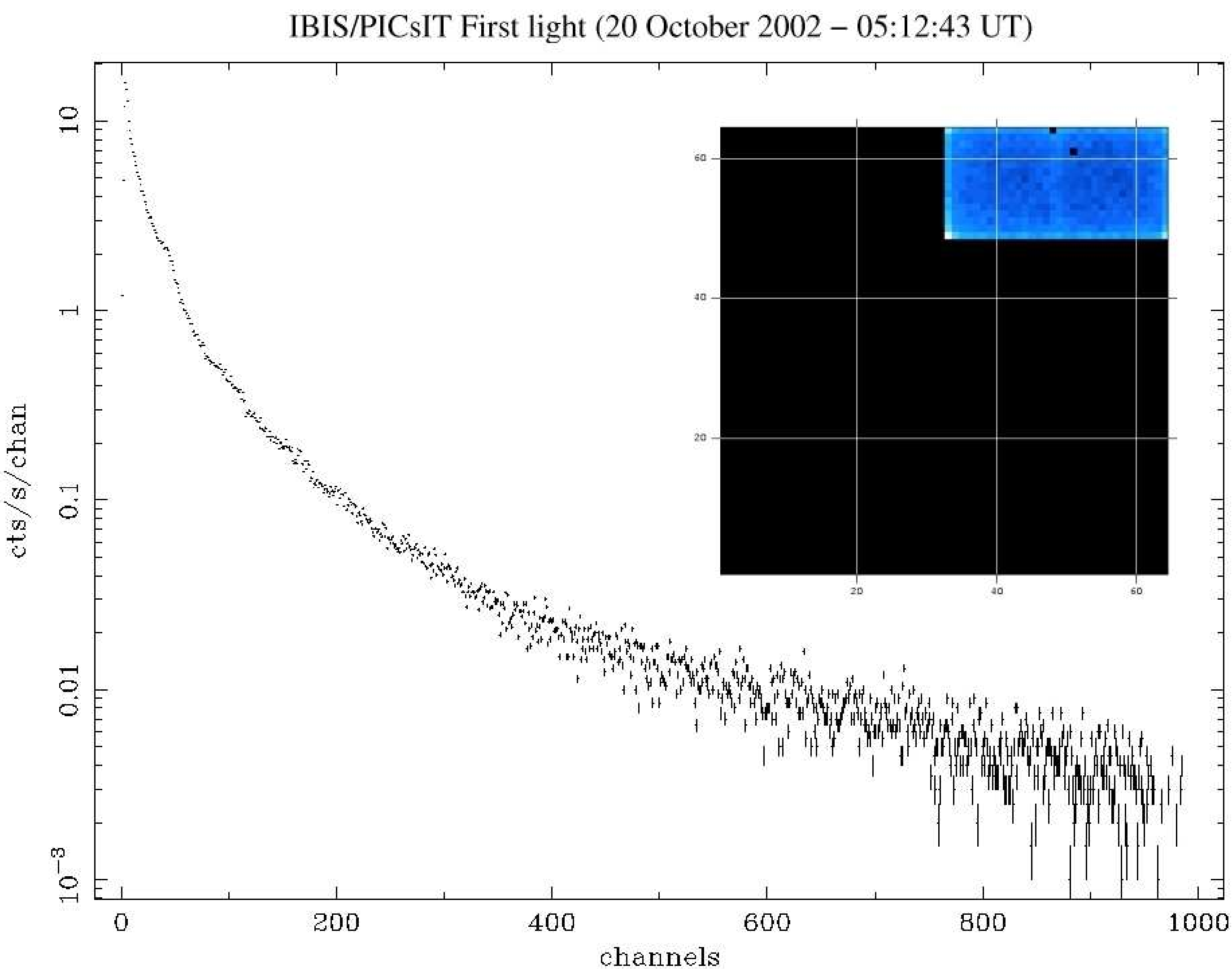
IBIS *(<u>I</u>mager on <u>B</u>oard the <u>I</u>ntegral <u>S</u>atellite)*

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 - I

(Pixellated Imaging Caesium Iodide Telescope)

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

IBIS/PICsIT identity card - II

(<u>P</u>ixellated <u>I</u>maging <u>C</u>ae<u>s</u>ium <u>I</u>odide <u>T</u>elescope)

The high-energy detector of IBIS aboard INTEGRAL

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) [in OSA 4.2]:

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

Lightcurves (spt histograms):

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

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

Step 1: Data preparation
(Levels COR, GTI, DEAD)

COR: Event correction (for ppm only): applied if there are substantial deviations from on board LUT.
Associated IC file: **PICS-ENER-MOD**, deviation of gain/offset with respect to the onboard values. At present, it is filled with 1.0 for gain and 0.0 for offset (i.e. no deviation from onboard LUT). See Malaguti et al. 2003, A&A 411, L173 for more details on gain/offset calibration.

GTI: Good Time Intervals (for ppm only): creation of GTI by taking into account HK limits and telemetry gaps.

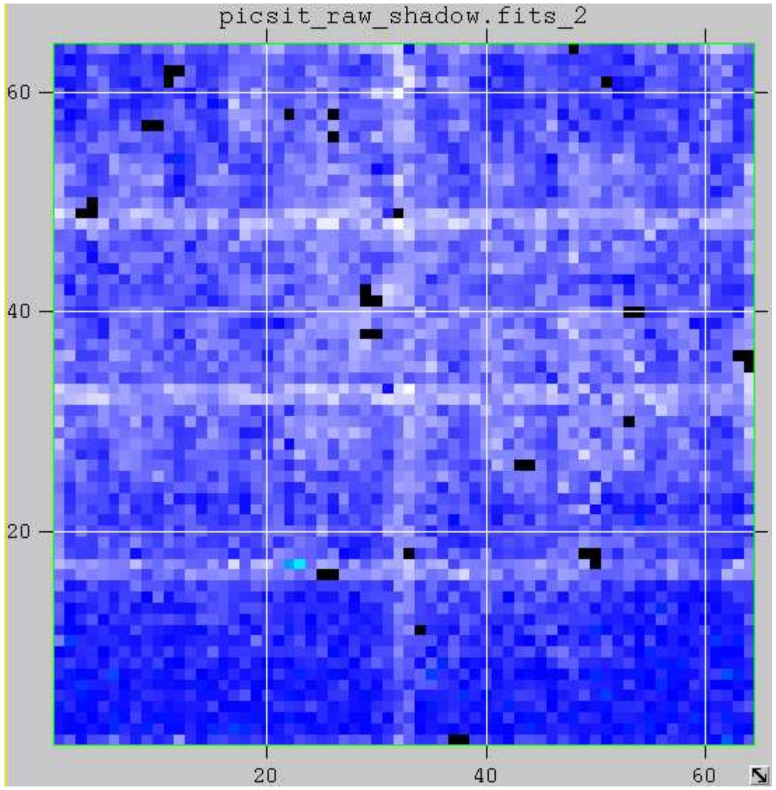
DEAD: Intrinsic detector deadtime calculation: it is calculated as complementary of the HK livetime counter. The livetime counter is calculated onboard taking into account VETO and calibration unit coincidences.

Step 2: Shadowgram building
(Levels BIN_I/BIN_S)

BIN_I: shadowgram building for imaging: it prepares the shadowgrams in the energy bands selected by the user and the efficiency map (killed pixels and deadtime). Associated IC file: **PICS-BINT-CFG** the onboard binning tables.

BIN_S: shadowgram building for spectra: in addition to the above mentioned characteristics, it is possible to read the energy bands directly from the RMF matrix.

Partially downloaded histograms: it is possible to integrate also partially downloaded histograms; in this case, the missing pixels are considered as killed pixels (IBIS_IPS_corrPDH=0).

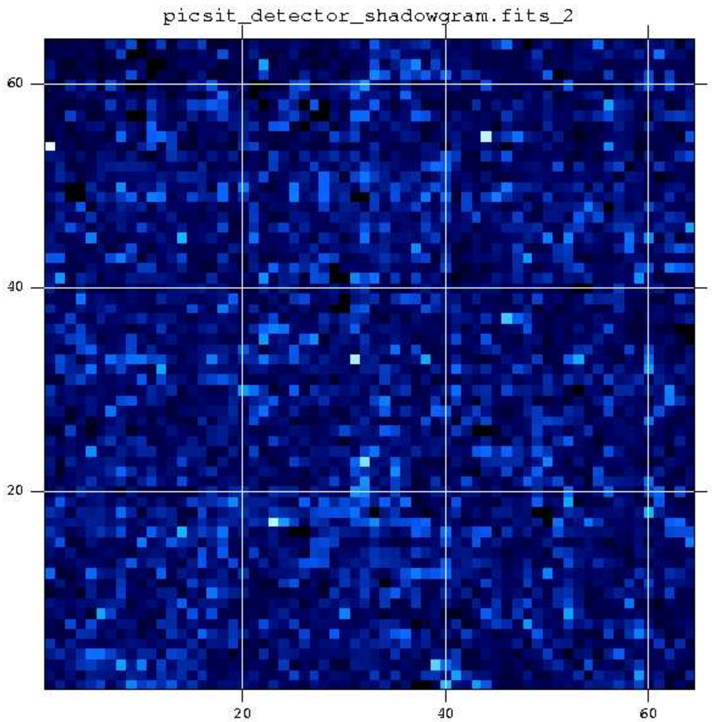


Step 2: Shadowgram building
(Levels BIN_I/BIN_S)

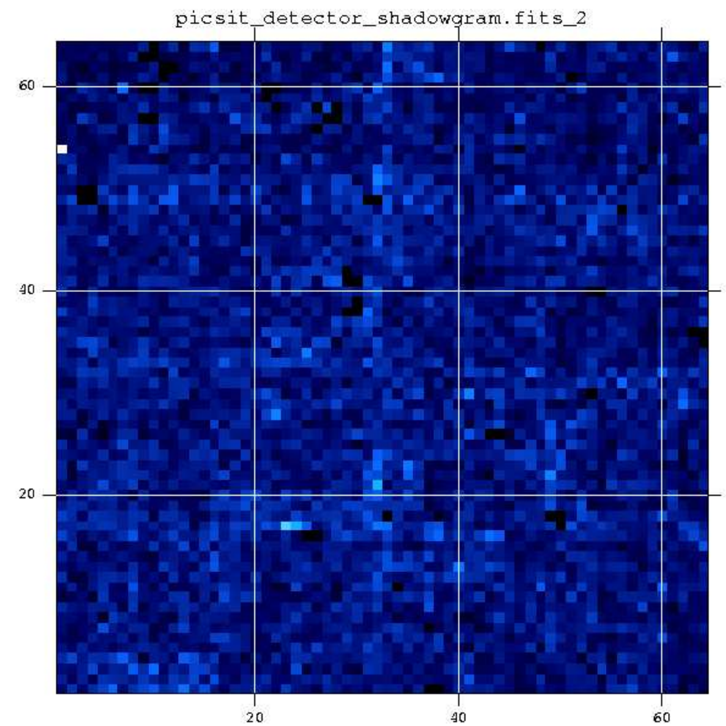
BIN_I: shadowgram building for imaging: in ppm, the GTI are taken into account; it is possible at this stage to clean for cosmic-rays induced events (**SCW1_BIN_cleanTrk=1**). See Segreto et al. (2003). **Only in ppm!**

170-220 keV

“Normal”



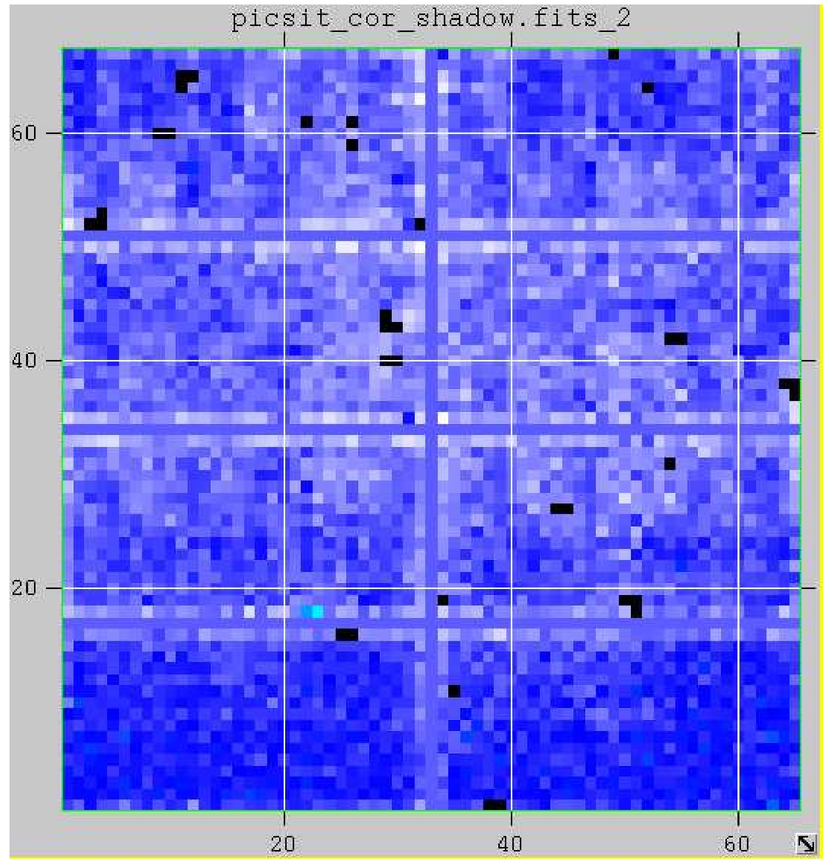
Cleaned



Step 3: Shadowgram correction
(Levels BKG_I)

BKG_I: shadowgram correction and expansion: perform the correction for efficiency, background subtraction, non-uniformity correction, and shadowgram expansion from 64x64 to 65x67.

CorShd=(RawShd-k*Bkg)/Uni

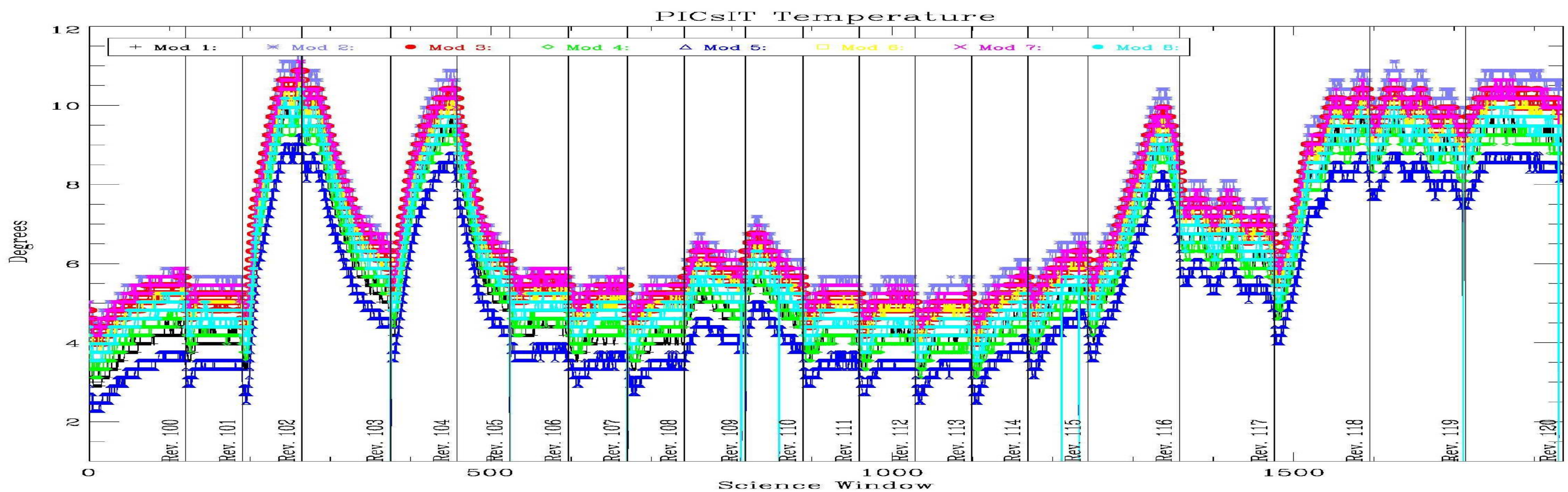


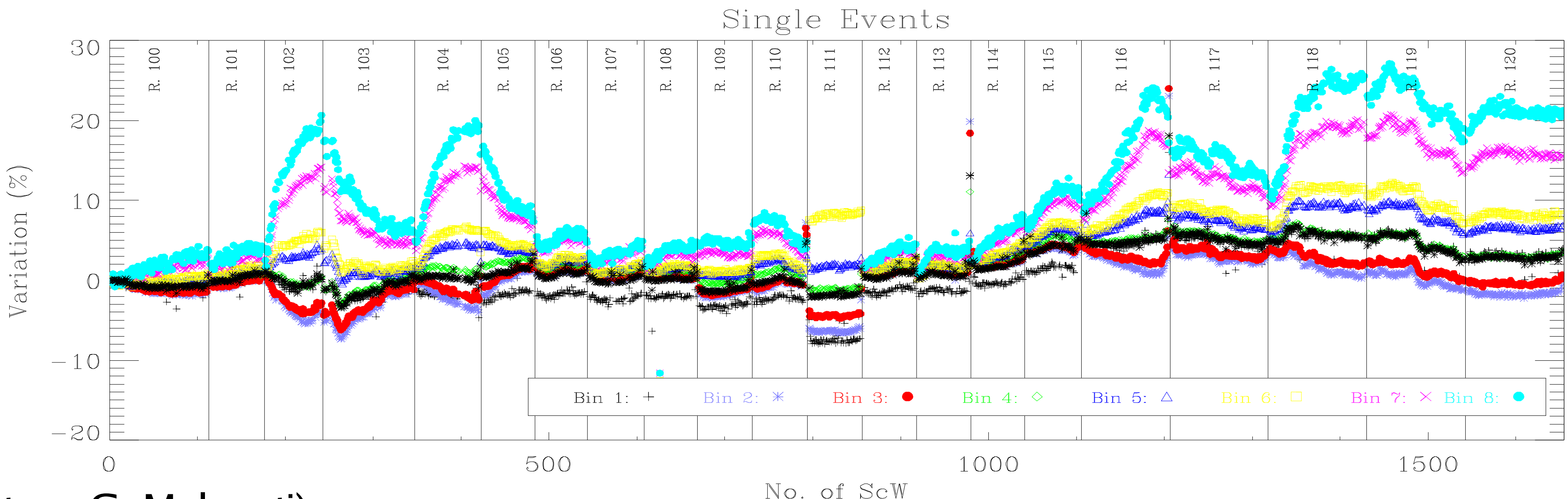
k: normalization constant, calculated in 2 ways: by equalizing the mean map count averaged over the whole detector or the exposures.

Presently, only background maps are present. No uniformity maps are yet available.

The gaps between modules are filled with the mean value averaged over the whole detector.

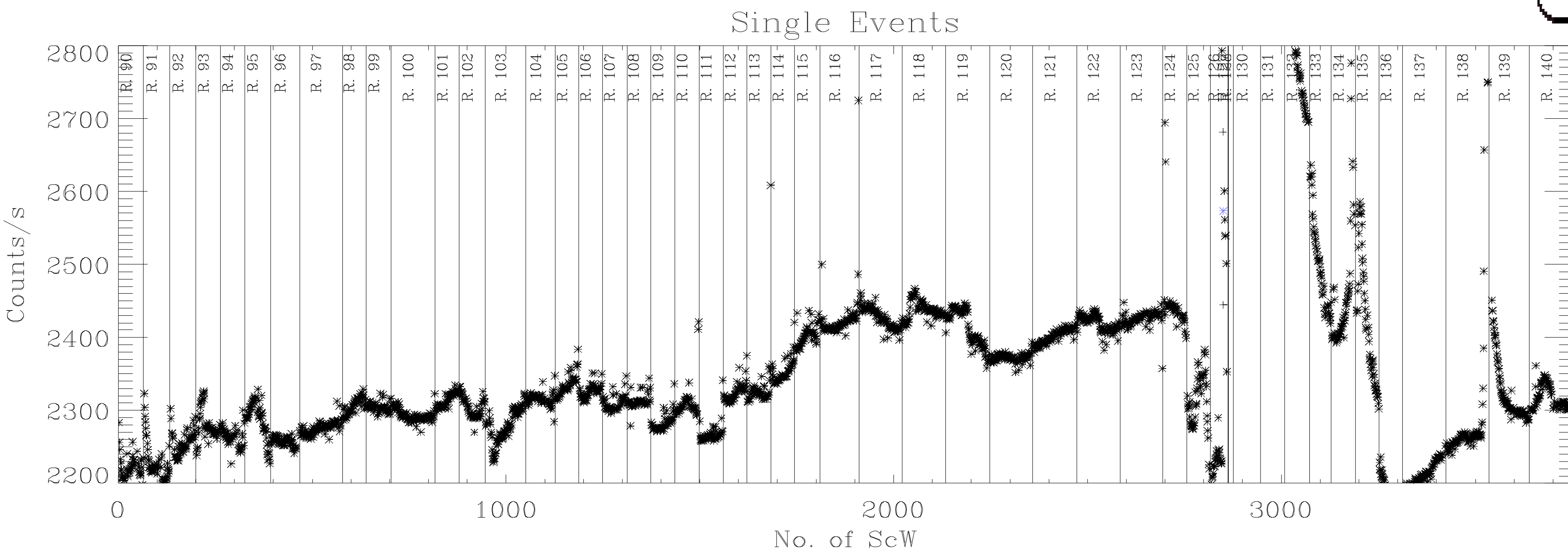
IBIS/PICsIT Background

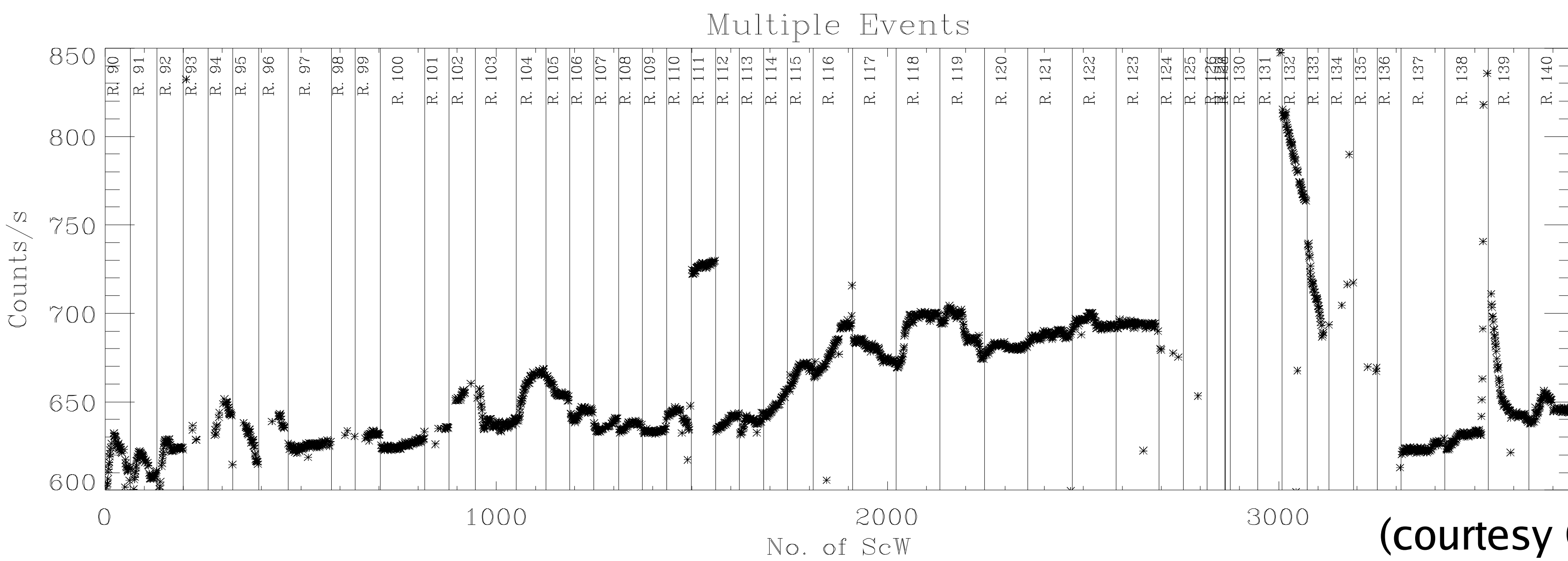




(courtesy G. Malaguti)

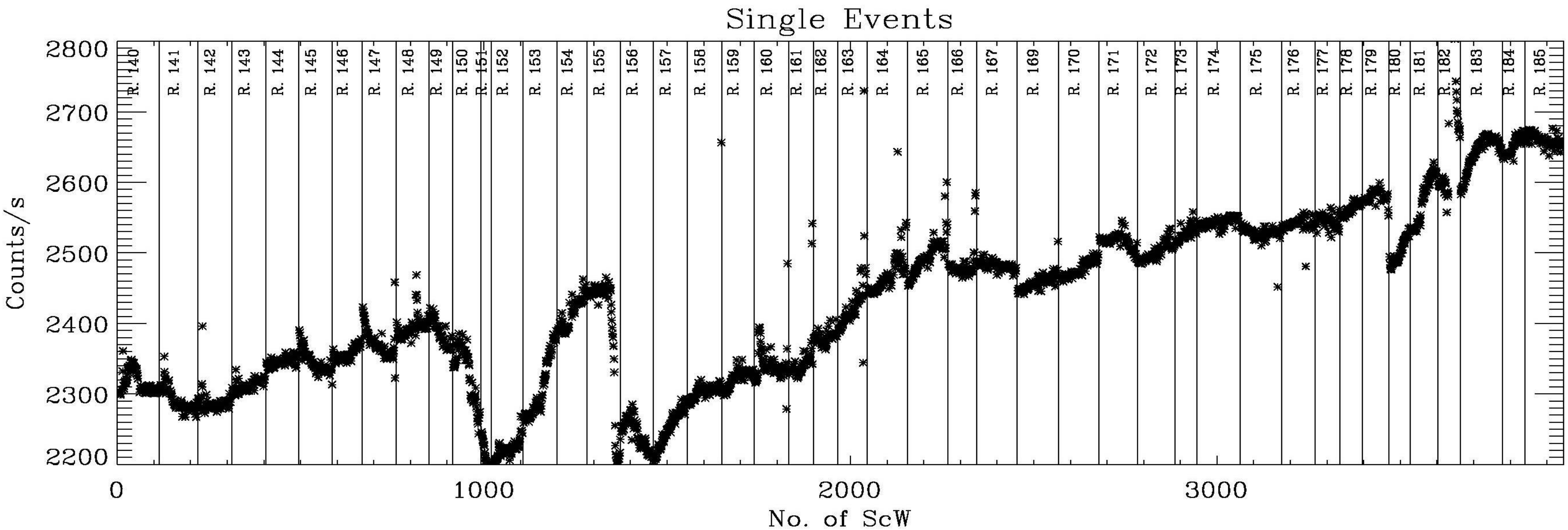
Background Count Rate (Rev 90-140)

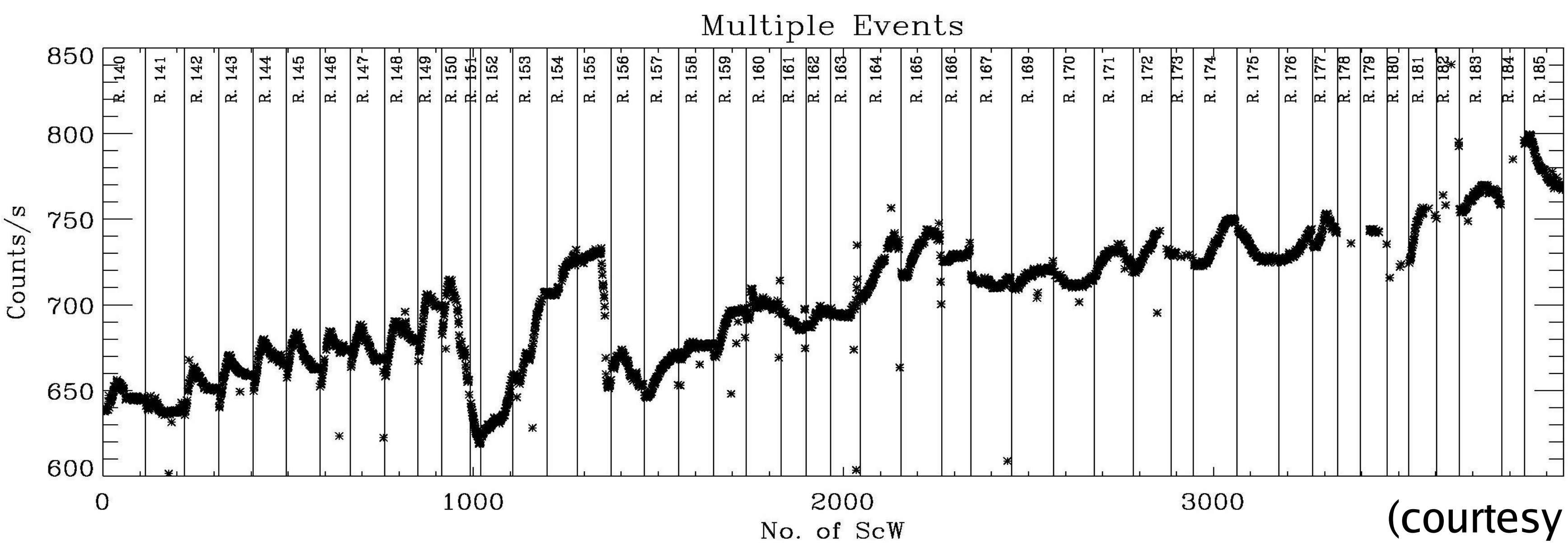




(courtesy G. Malaguti)

Background Count Rate (Rev 140-185)

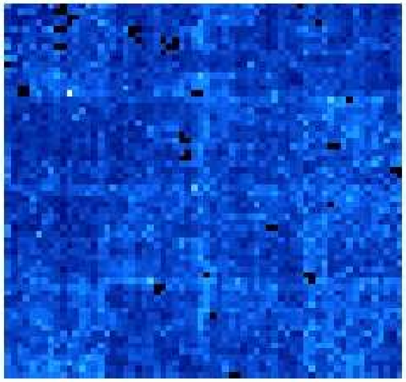




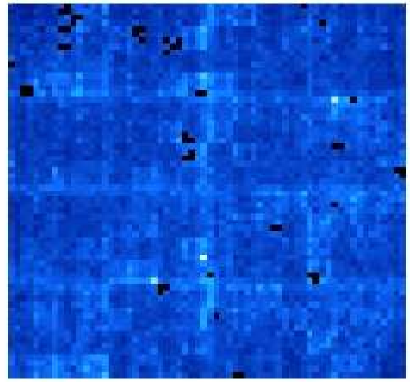
(courtesy G. Malaguti)

Background maps – Single Events

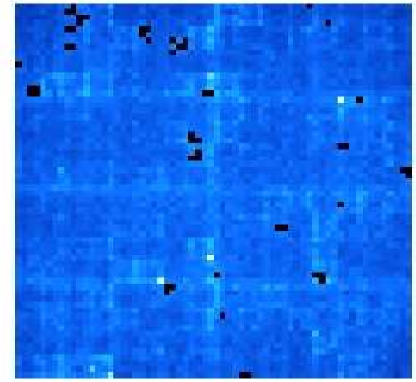
203-252 keV



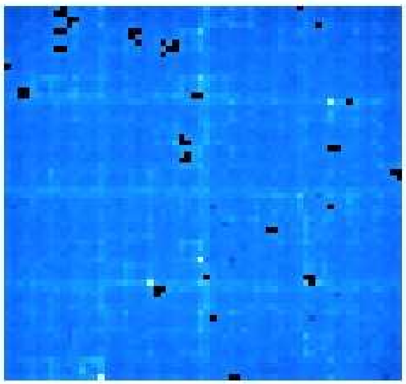
252-336 keV



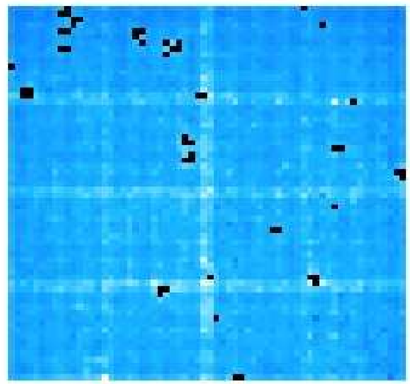
336-448 keV



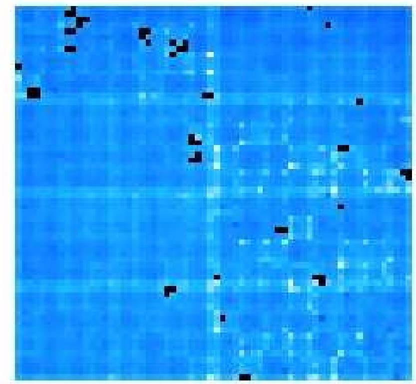
448-672 keV



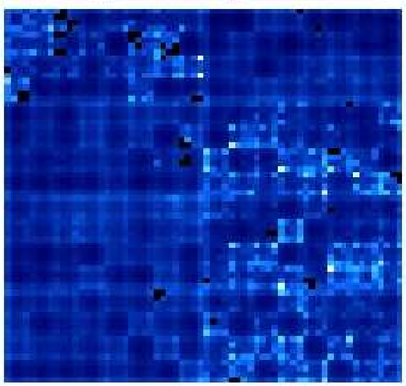
672-1036 keV



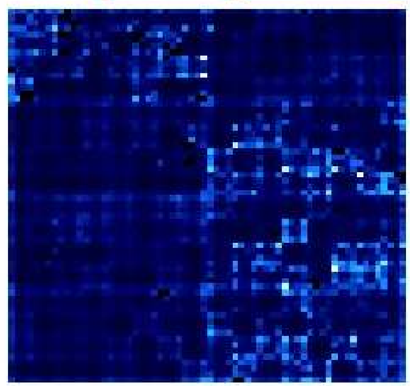
1036-1848 keV



1848-3584 keV



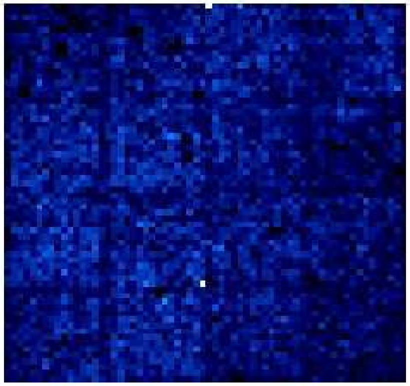
3584-6720 keV



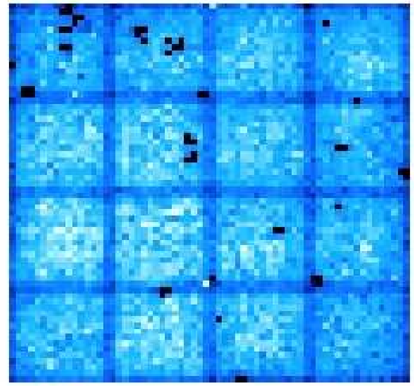
Associated IC file: **PICS-SBAC-BKG.** In OSA 4.0, BKG maps are available, built from the integration of several revolutions with no sources (1.7 Ms). Courtesy P. Lubinski.

Background maps – Multiple events

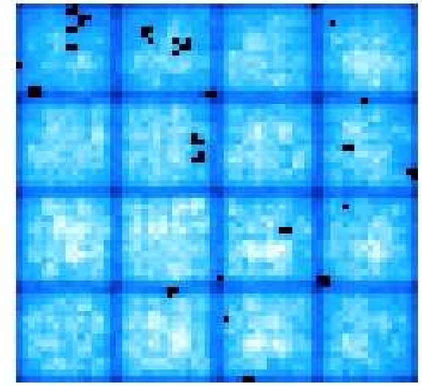
336-448 keV



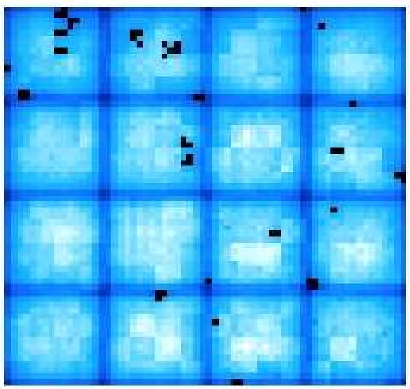
448-672 keV



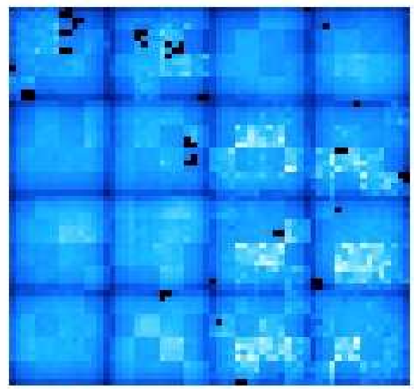
672-1036 keV



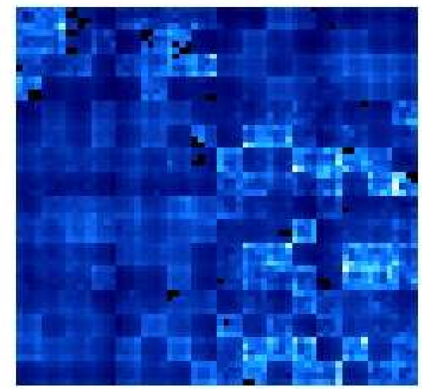
1036-1848 keV



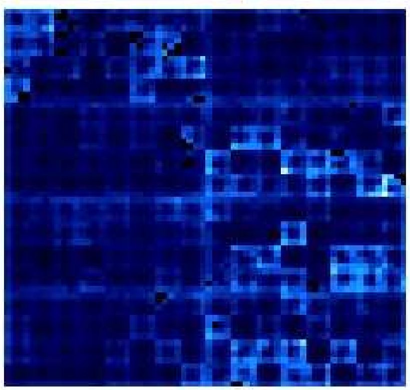
1848-3584 keV



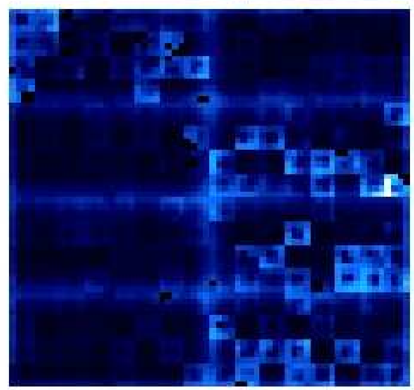
3584-6720 keV



6720-9072 keV



9072-13440 keV

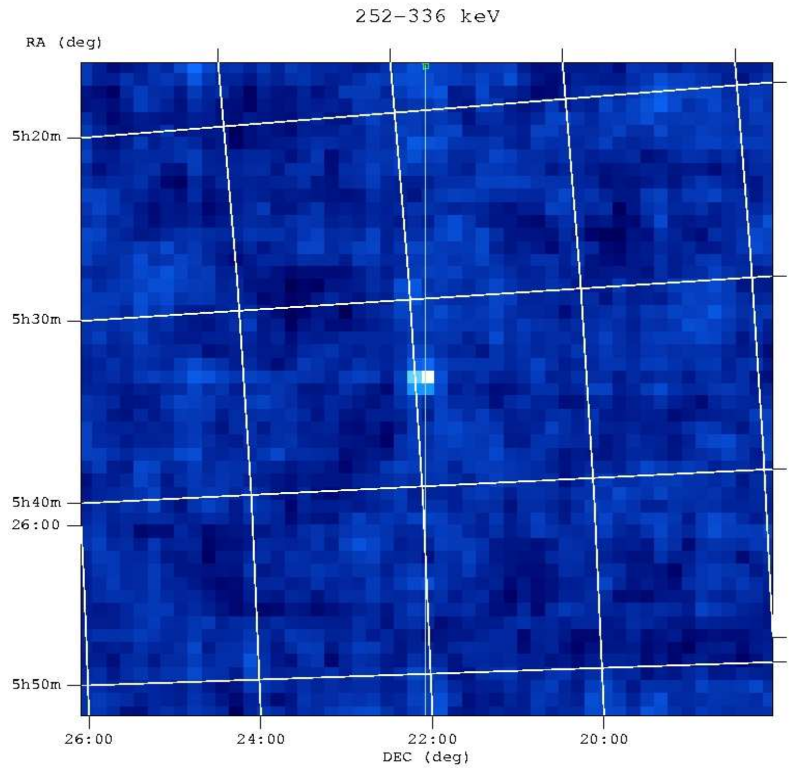


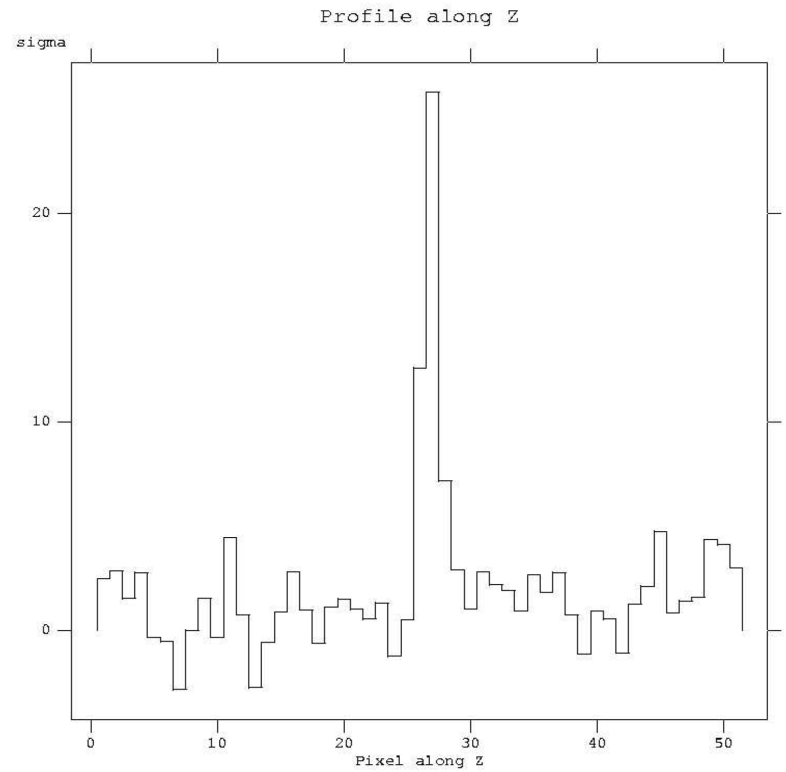
Associated IC file: PICS-MBAC-BKG. Courtesy P. Lubinski.

Step 4: Sky image generation
(Levels CAT_I, IMA2, CLEAN)

CAT_I: extraction, from the general catalog, of the sources in the FOV.
Sumhist: for **staring observation only** there is the possibility to integrate the shadowgram **before** the deconvolution.
IMA2: shadowgram deconvolution, sky image generation, and source detection (per Scw).
CLEAN: integration of the Scw sky images **after** the deconvolution (mosaic) and source detection (for **dithering**).

Crab
Rev 39
77 ks
252-336 keV





Step 4: Sky image generation
(Levels CAT_I, IMA2, CLEAN)

Algorithms for the deconvolution explained in detail in Goldwurm et al. 2003, A&A 411, L223. See also the talk by A. Goldwurm. See also the talk by G. Skinner for coded-mask instruments.

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

Astronomy & Astrophysics

The INTEGRAL/IBIS scientific data analysis*

A. Goldwurm[1], P. David[1], L. Foschini[2], A. Gros[1], P. Laurent[1], A. Sauvageon[1], A. J. Bird[3], L. Lerusse[4], and N. Produit[4]

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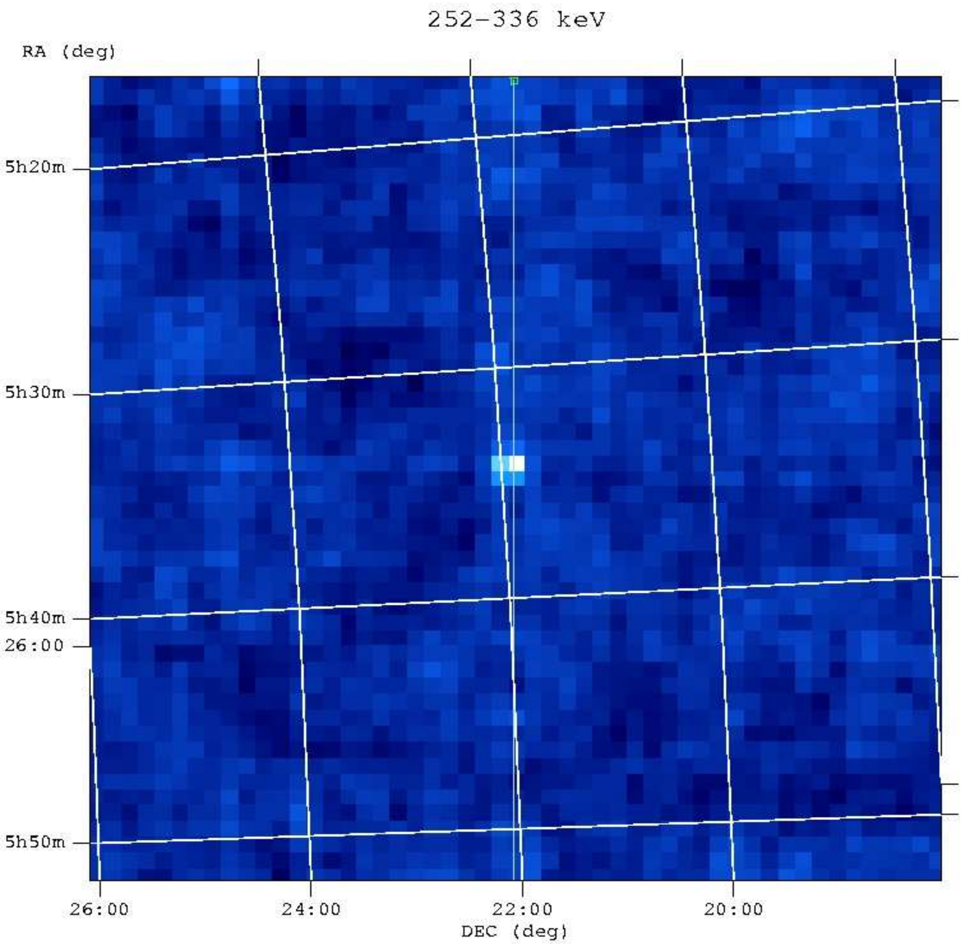
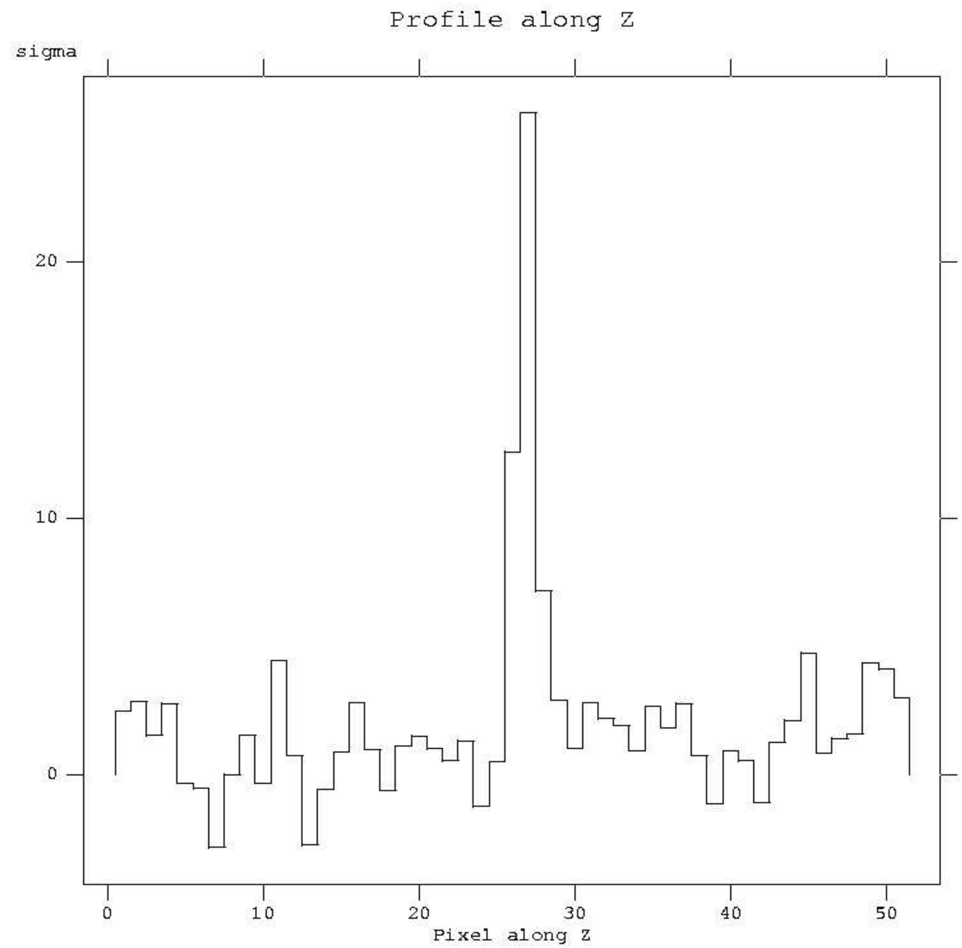
[2] IASF/CNR, sezione di Bologna, via Gobetti 101, 40129 Bologna, Italy
[3] School of Physics and Astronomy, University of Southampton, Highfield, SO17 1BJ, UK
[4] Integral Science Data Center, Chemin d'Écogia, 16, 1290 Versoix, Switzerland

Step 4: Sky image generation
(Levels CAT_I, IMA2, CLEAN)

Crab, Rev 39, 77 ks, 252-336 keV





Crab observations of calibration

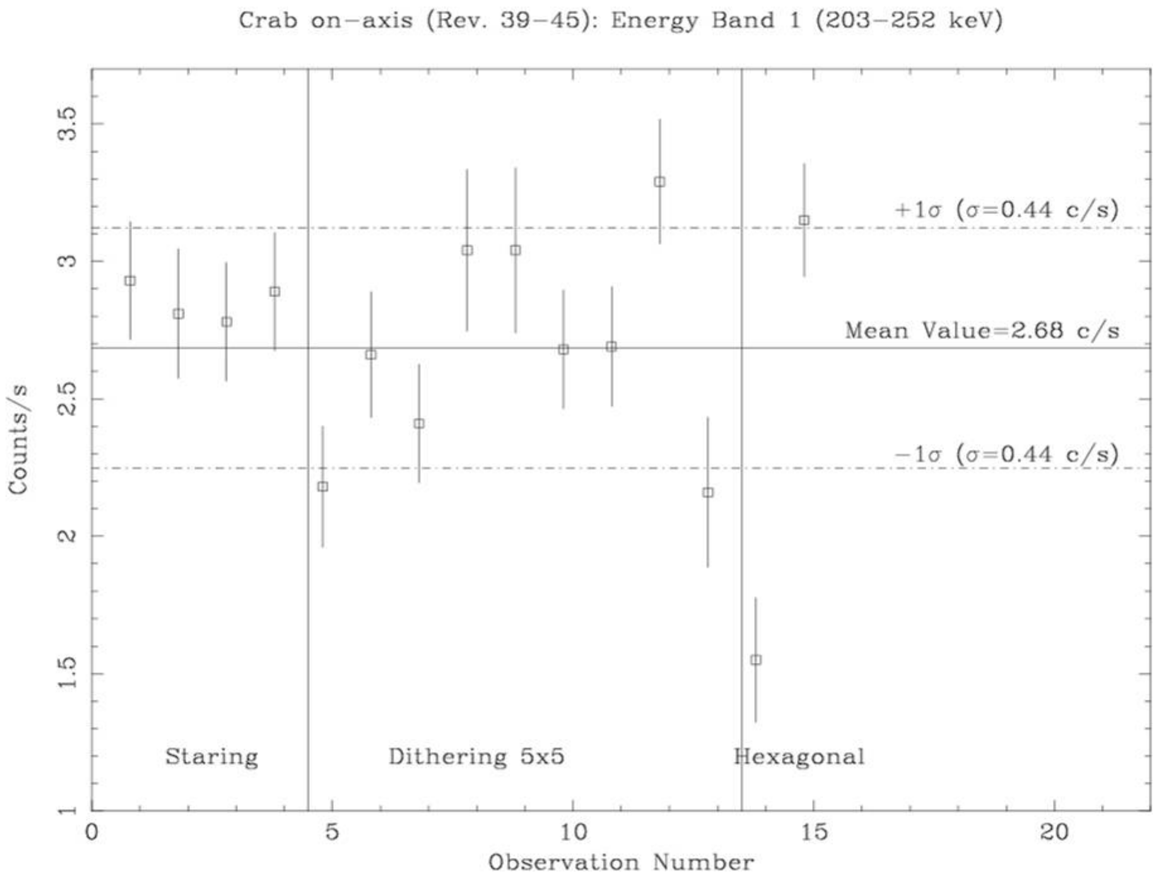
Rev 39 (02/2003)

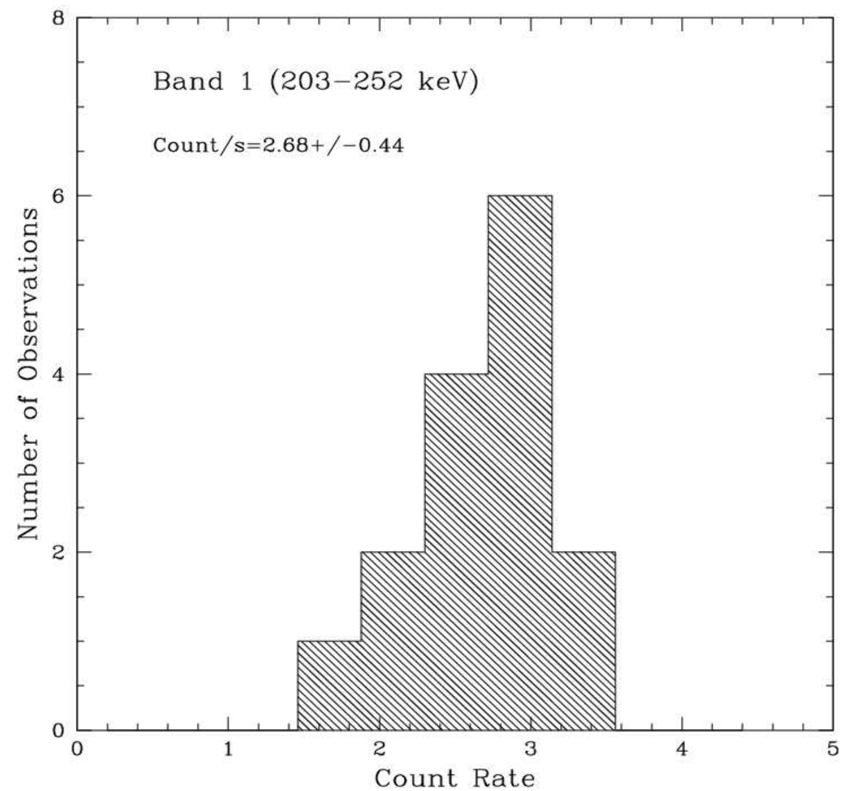
100 ks, staring, Exposure 77 ks

	OSA3* (staring=yes)		**OSA4** (staring=yes)		**OSA4** (staring=no, i.e. ip_skymosaic)	
Energy Band [keV]	**Rate [c/s]**	**SNR [▯]**	**Rate [c/s]**	**SNR [▯]**	**Rate [c/s]**	**SNR [▯]**
203-252	2.5	7.4	3.0	23.9	3.0	23.9
252-336	2.2	11.0	2.5	23.6	2.5	23.6
336-448	1.3	7.1	1.2	13.7	1.2	13.7
448-672	0.7	4.4	0.7	7.6	0.7	7.6
672-1036			0.3	4.2	0.3	4.2

* OSA3 had slightly different energy bands.

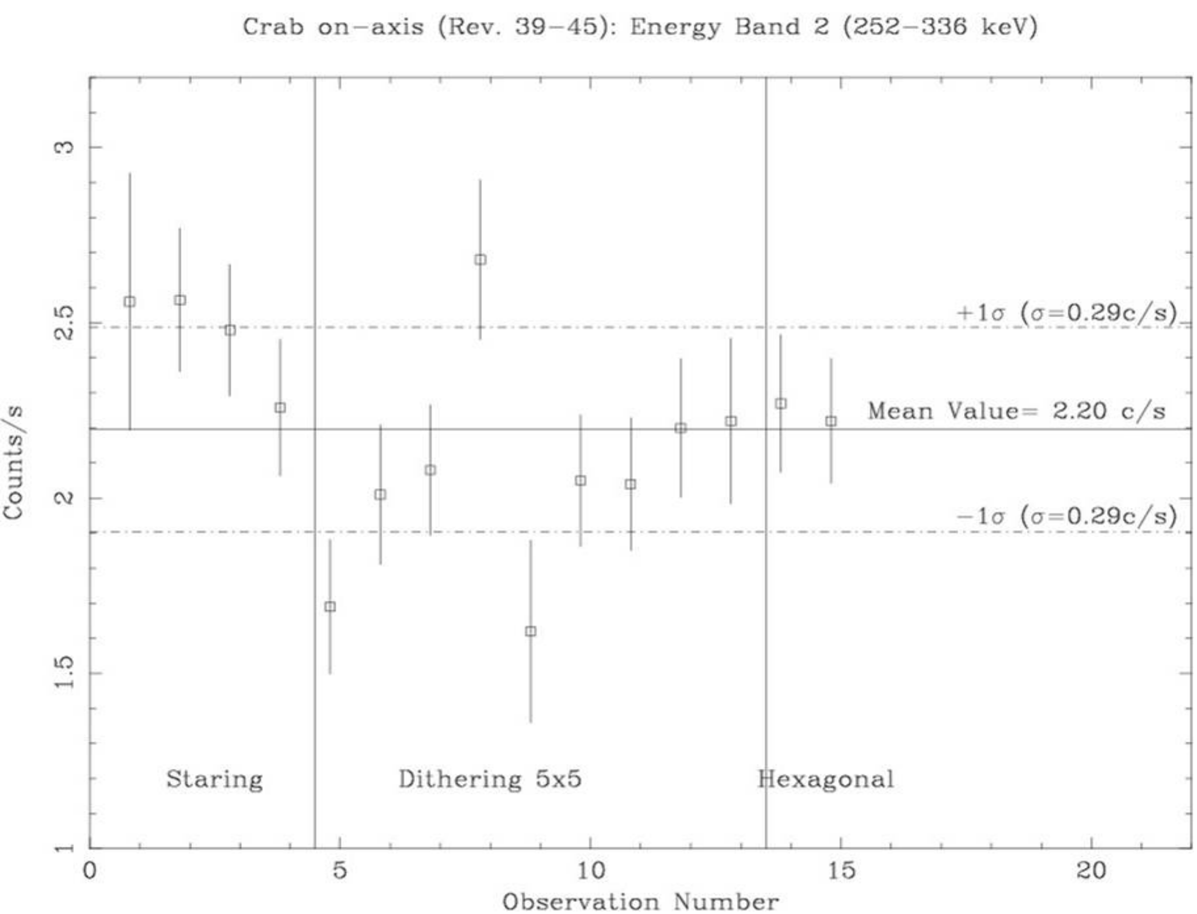
Crab count rate with different observing pattern (203-252 keV)

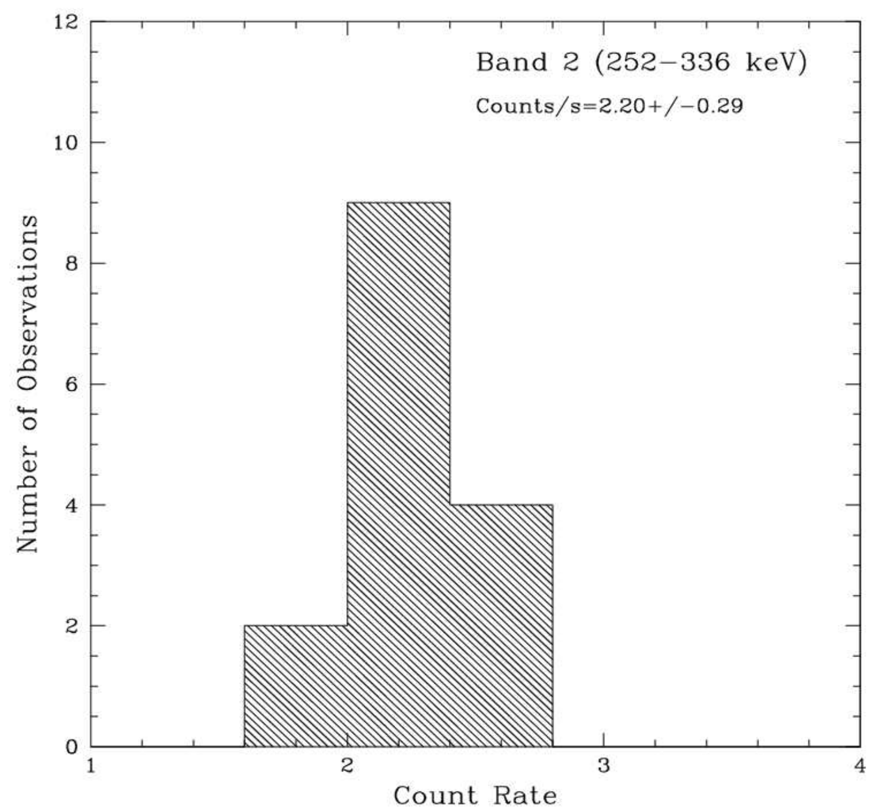




(courtesy M. Dadina)

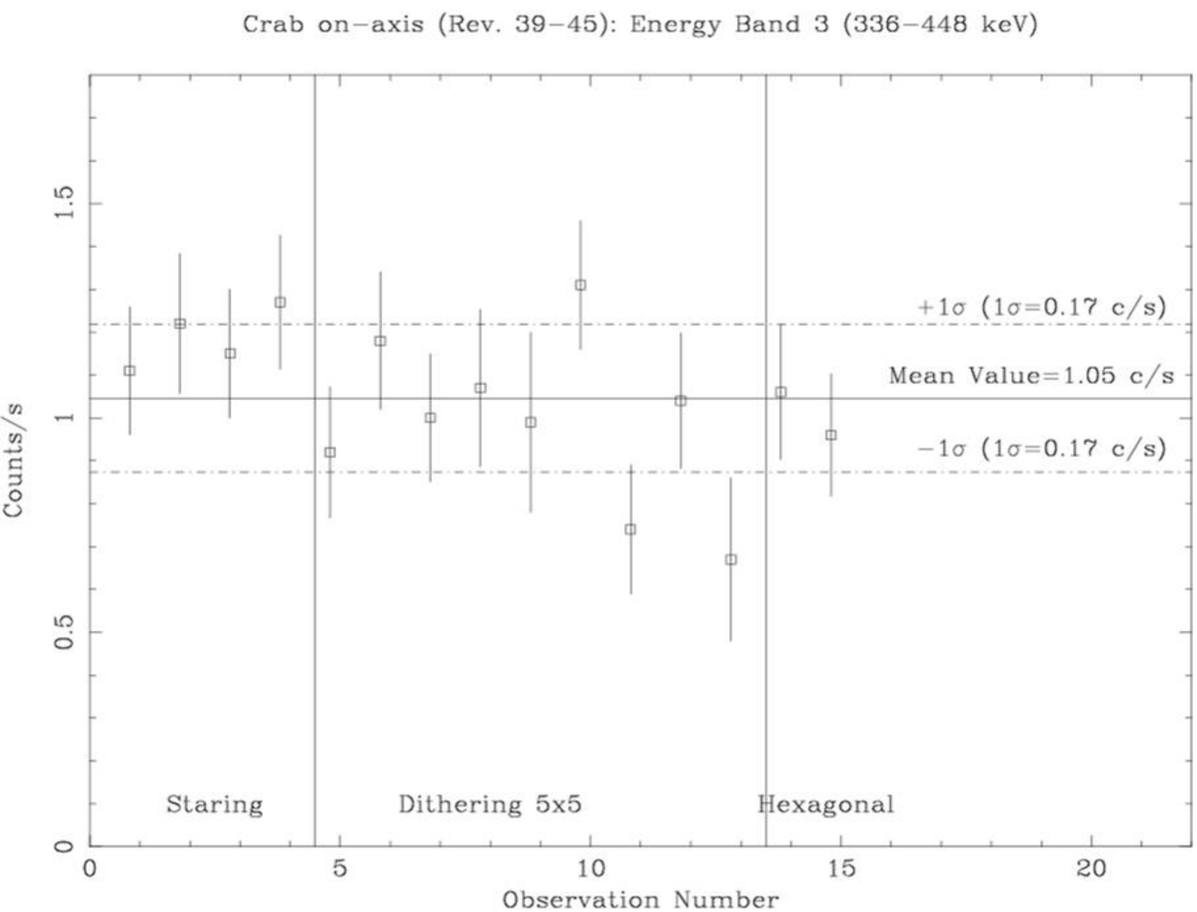
Crab count rate with different observing pattern (252-336 keV)

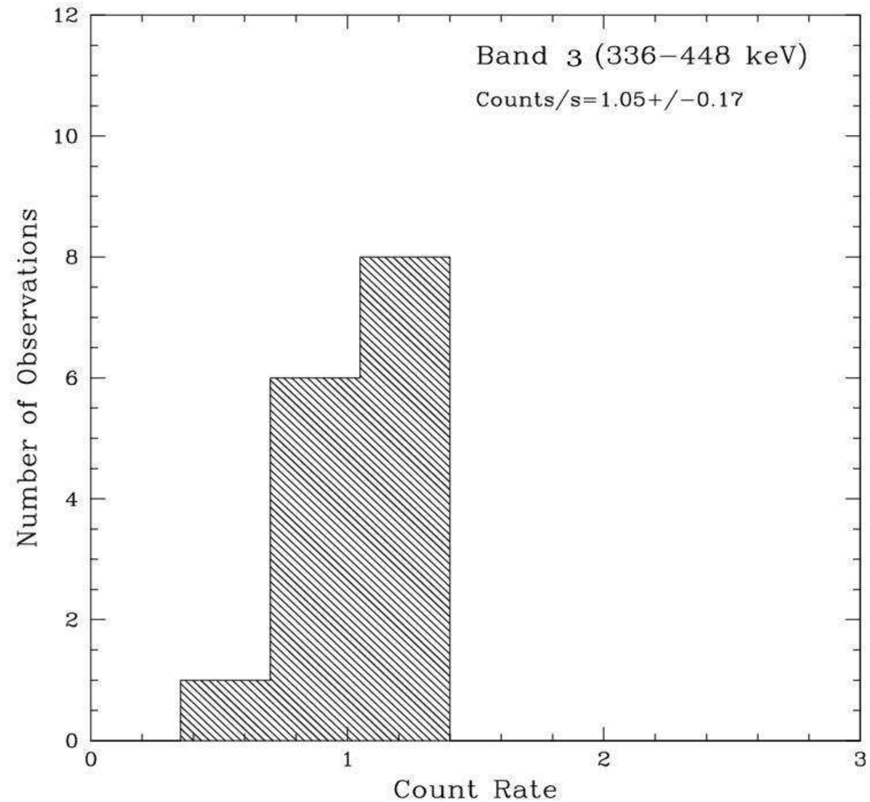




(courtesy M. Dadina)

Crab count rate with different observing pattern (336-448 keV)





(courtesy M. Dadina)

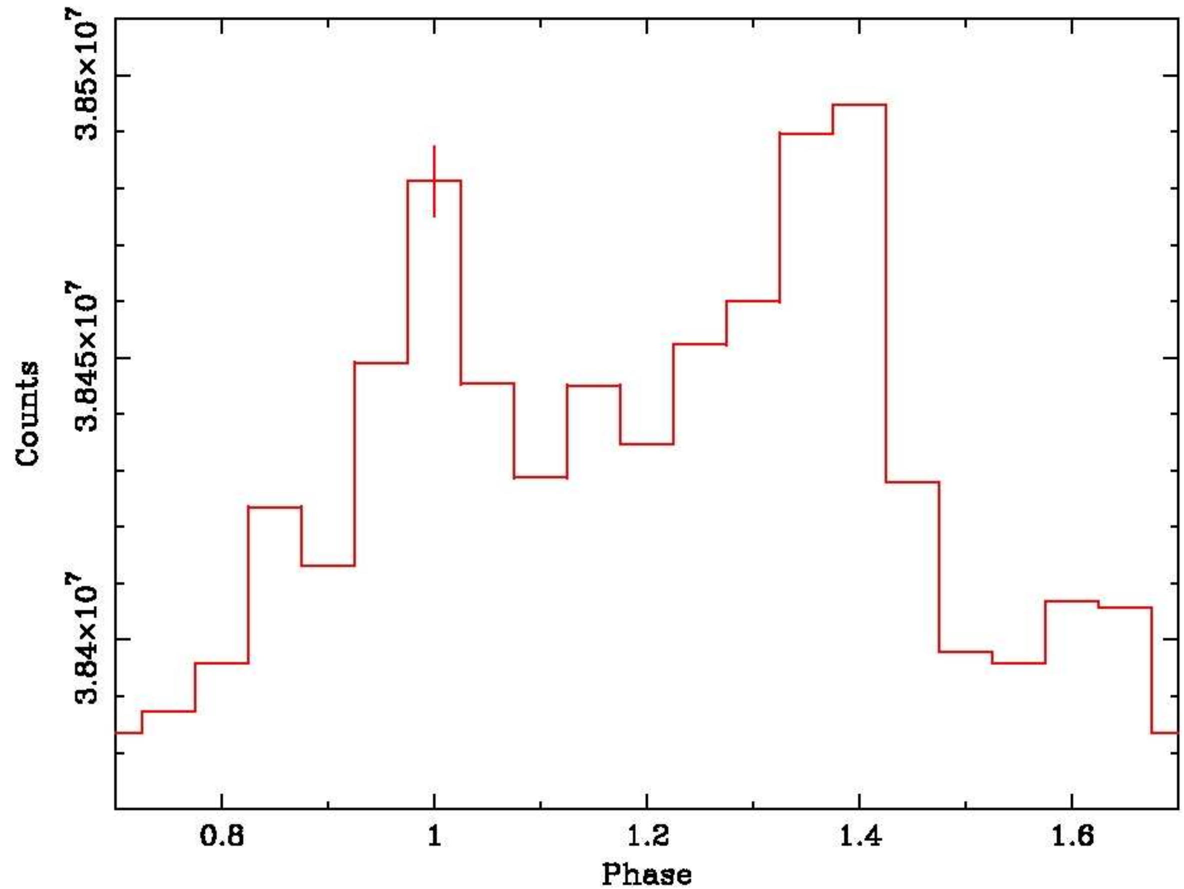
Step 5: Lightcurve extraction
(Levels LCR)

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).

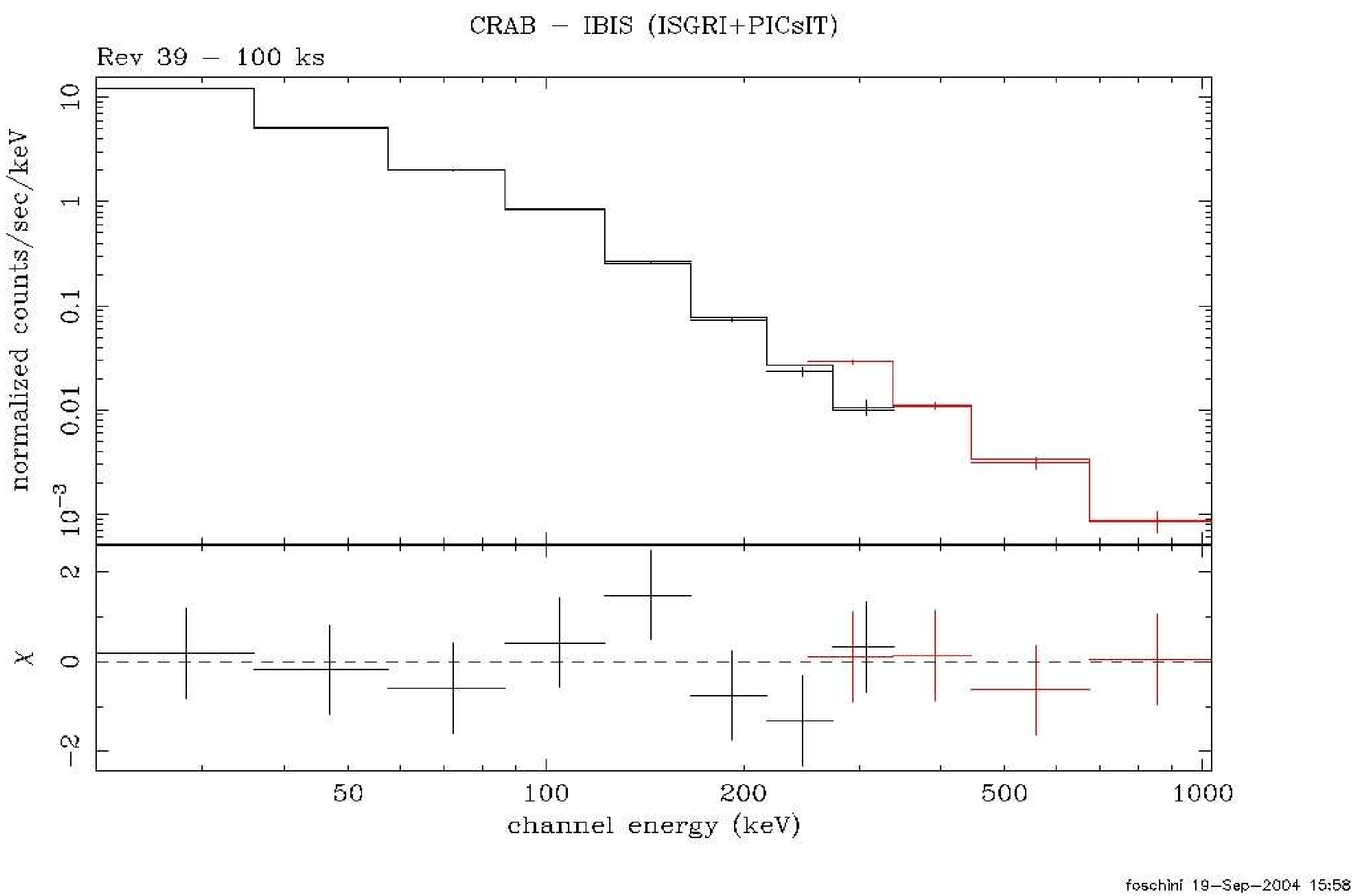
Example: Crab in Revolutions 40-41 (Feb 2003), with spectral timing mode (1 ms); total exposure: 310 ks.

(Courtesy T. Mineo)

Folded lightcurve (260-364 keV)



Spectra extraction [foreseen in OSA 4.2]



Crab with IBIS (ISGRI+PICsIT):

Γ=2.17±0.02; A=20±2; 0% Sys Err; Red. χ^2=0.63

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 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 Gallery