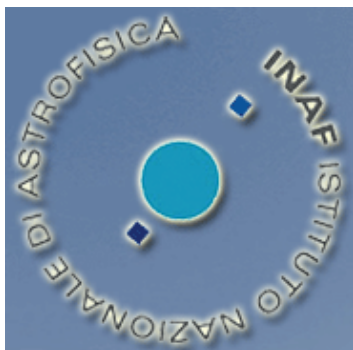




IBIS/PICsIT Data Analysis

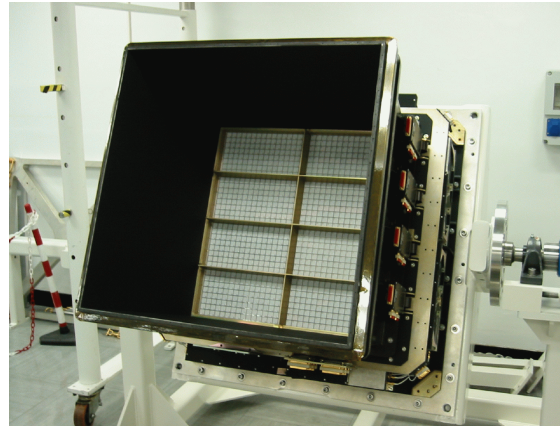
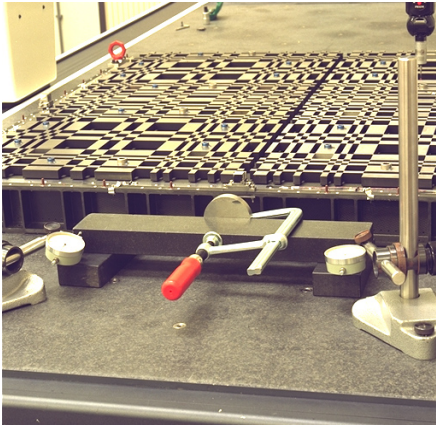
Luigi Foschini
INAF/IASF-Bologna (Italy)



INTEGRAL Data Analysis Workshop
ISDC, Geneva, 12-14 October 2005



IBIS (Imager on Board the Integral Satellite)



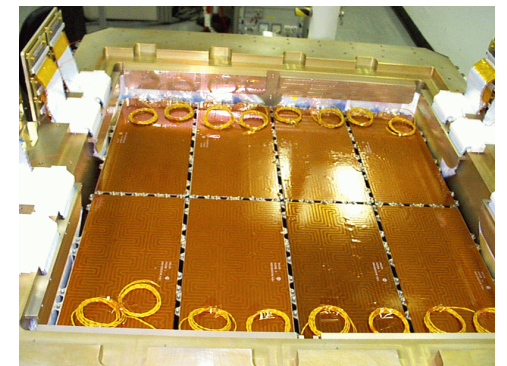
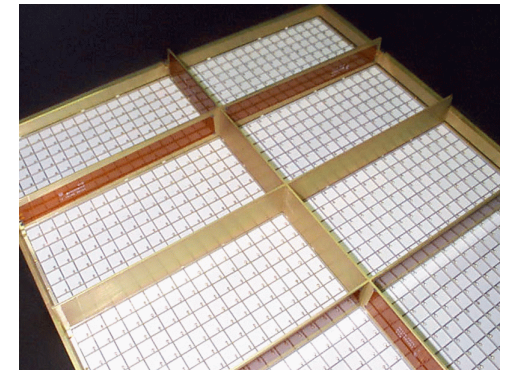
IBIS (Ubertini P., Lebrun F., Di Cocco G., et al, 2003, A&A 411, L131) is optimized for high-resolution (12'), wide FOV (29°x29°), point sources imaging and moderate energy resolution (8% @ 100 keV, 10% @ 1 MeV). It is composed of 2 detectors:



ISGRI, CdTe detector in the range 15 keV – 1 MeV; 128x128 pixels organized in 8 modules; 5' pixel (Lebrun et al., 2003, A&A 411, L141). See the talk by A. Goldwurm & A. Gros.



PICsIT, CsI detector in the range 175 keV – 10 MeV; 64x64 pixels organized in 8 modules; 10' pixels (Di Cocco et al., 2003, A&A 411, L189).





IBIS/PICsIT identity card
(*Pixellated Imaging Caesium Iodide Telescope*)

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
Time Resolution:	0.97-500 ms (spectral timing) 64 μs (photon-by-photon)

See Di Cocco et al. (2003) for more details.



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 \Rightarrow 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*.

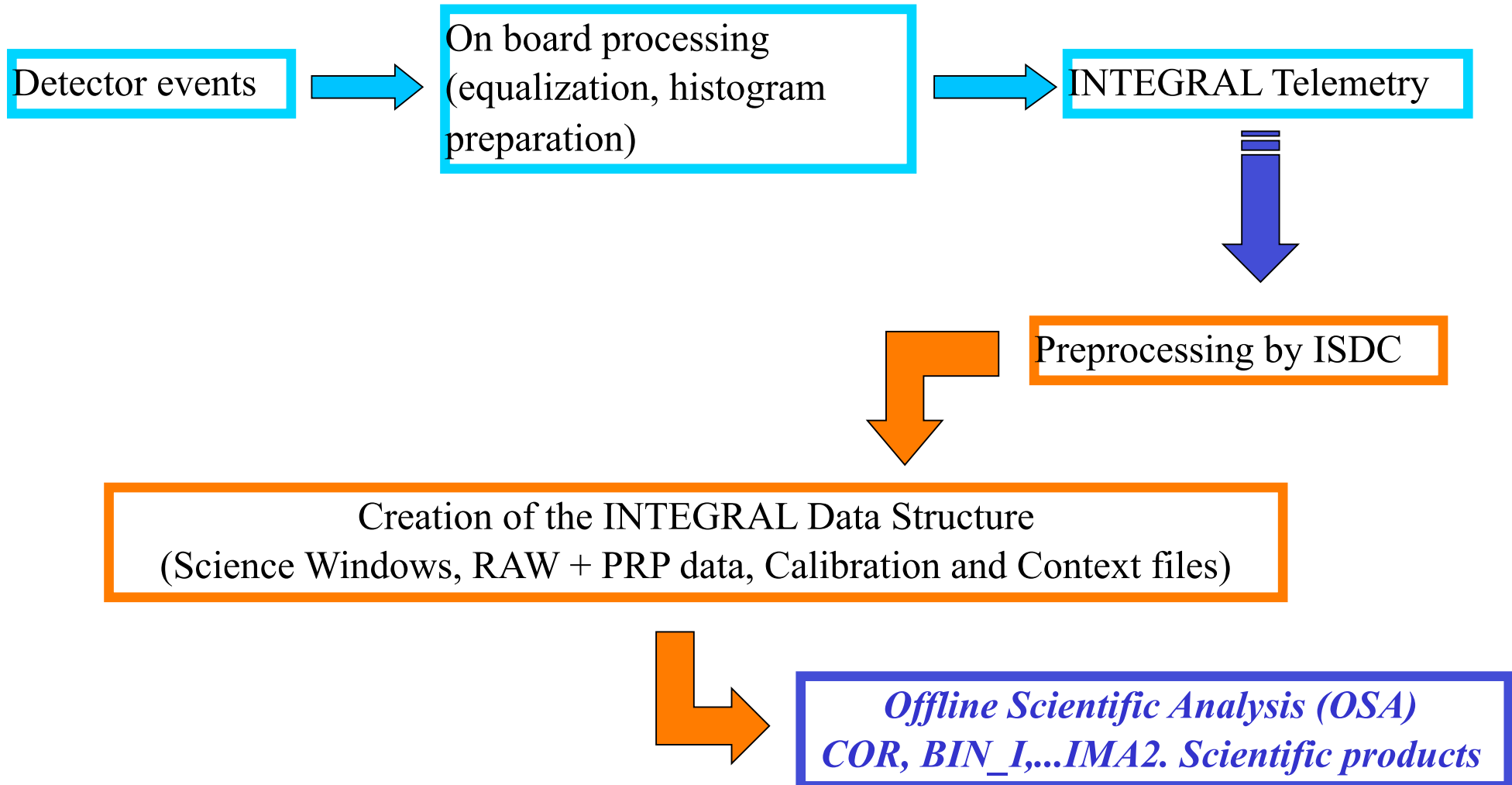
- *Single event*: a photon interacts with only 1 pixel;

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

▶ Events are equalized with onboard Look-up Tables (LUT), integrated according to binning tables (still into LUT), and transmitted to ground.



General Flow Chart



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: 1 ScW (~2 ks).

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
- * 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) (already done in rev_2 data)

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.

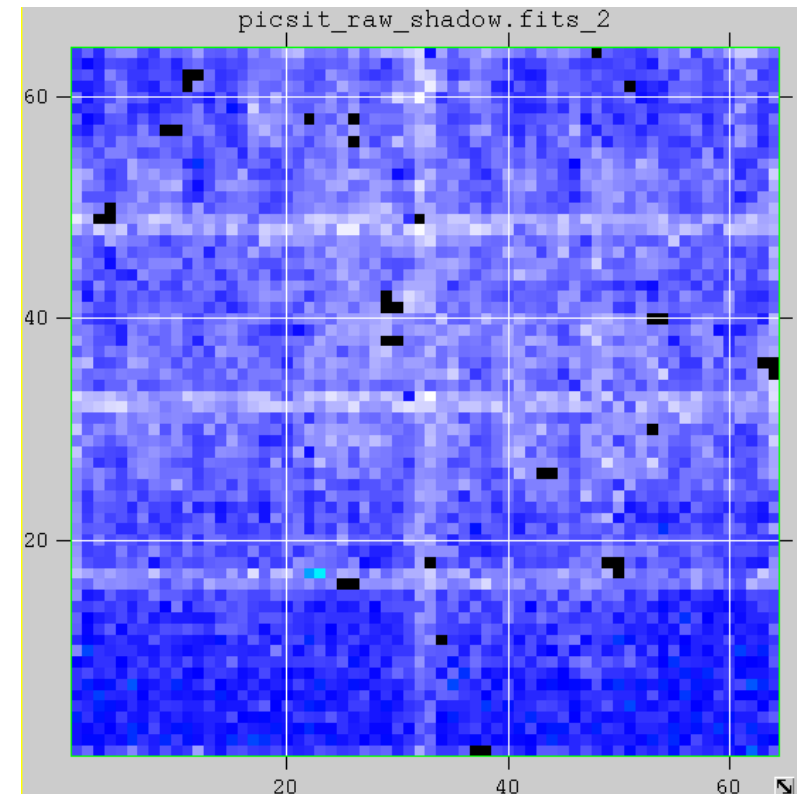
DEAD: Intrinsic detector deadtime calculation: it is calculated as complementary of the HK livetime counter. The livetime counter is calculated onboard taking into account VETO and calibration unit coincidences.

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.

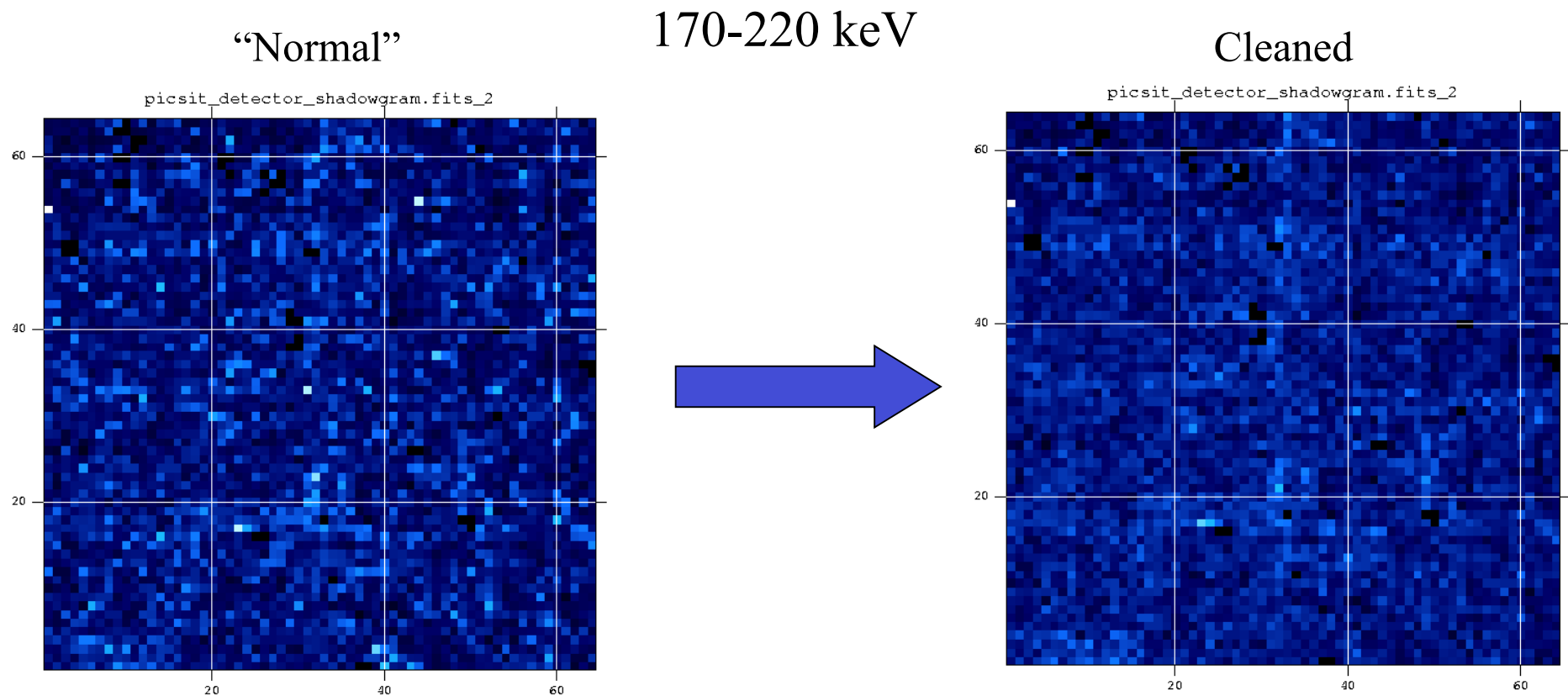
Partially downloaded histograms: it is possible to integrate also partially downloaded histograms; in this case, the missing pixels are considered as killed pixels (**IBIS_IPS_corrPDH=0**).



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 (Segreto et al. 2003). Set **SCW1_BIN_cleanTrk=1. Only in ppm!**



Step 3: Shadowgram correction (Levels BKG_I)



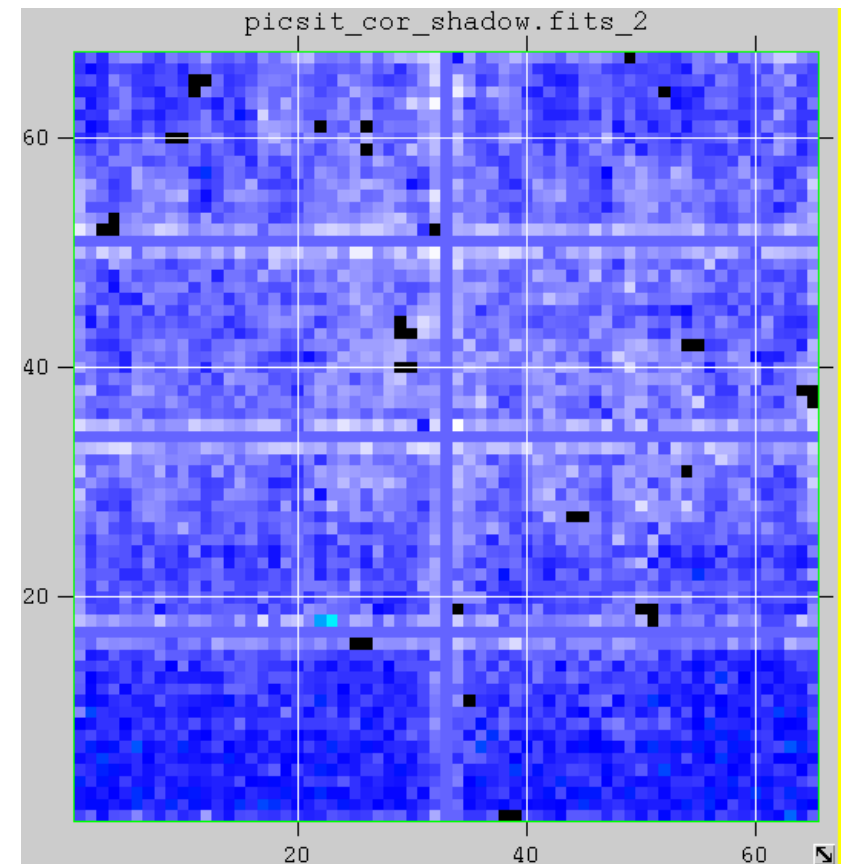
BKG_I: shadowgram correction and expansion: perform the correction for efficiency, background subtraction, non-uniformity correction, and shadowgram expansion from 64x64 to 65x67.

$$\text{CorShd} = (\text{RawShd} - k * \text{Bkg}) / \text{Uni}$$

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

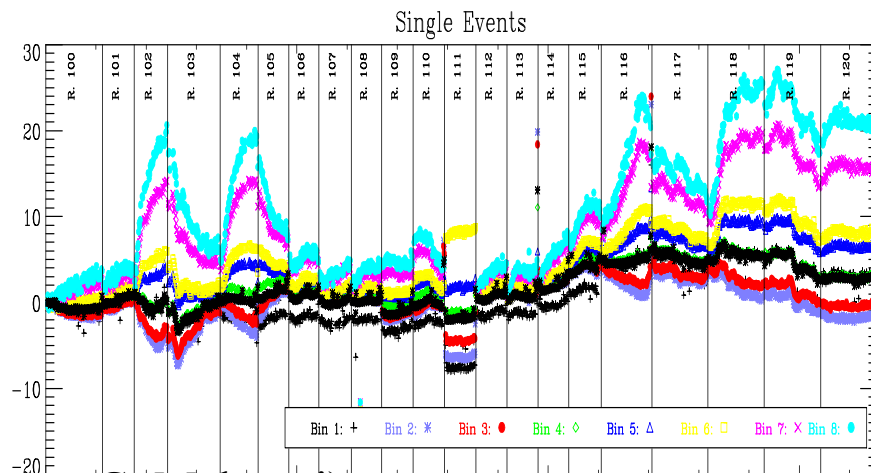
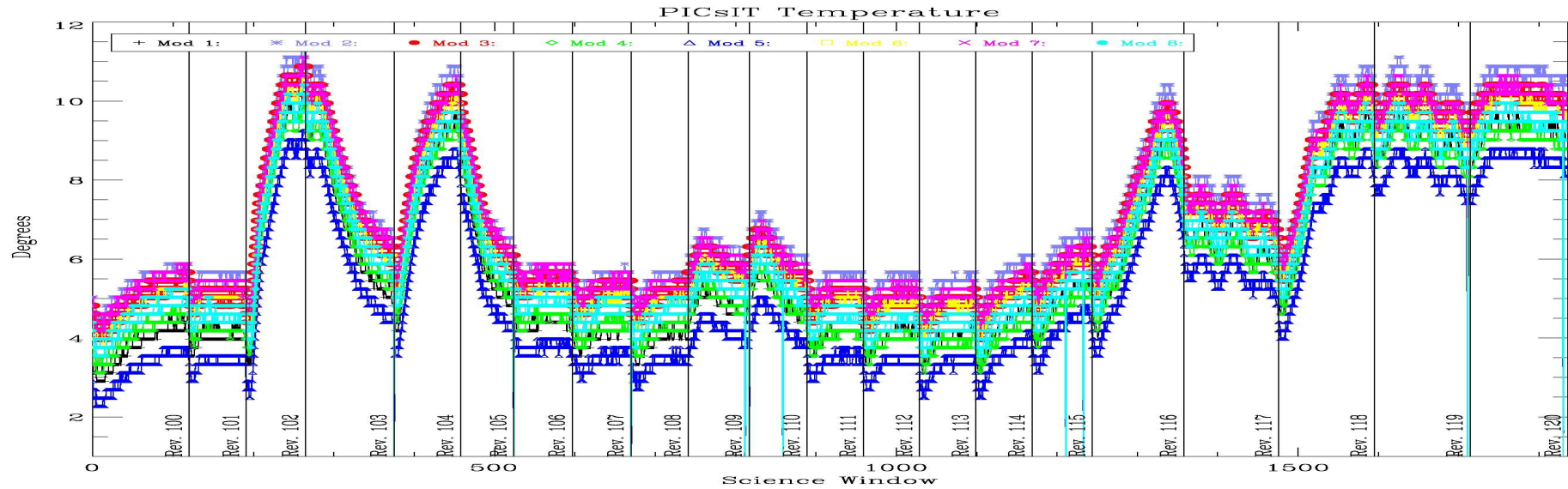
Presently, only background maps are present. No uniformity maps are yet available.

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



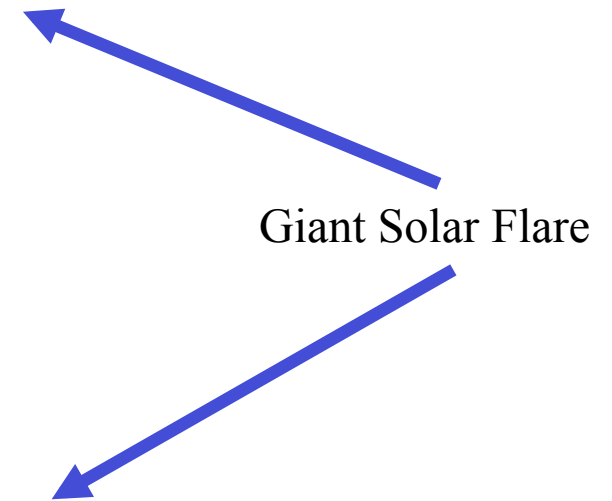
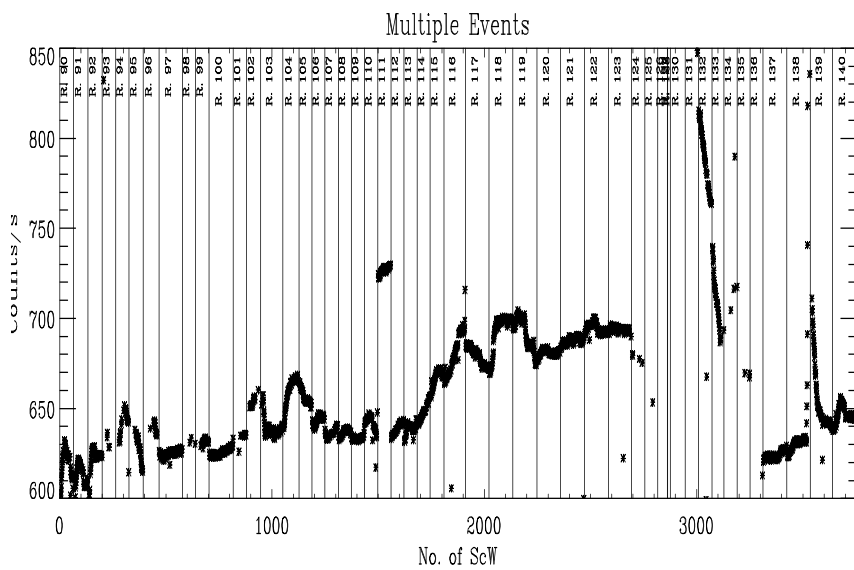
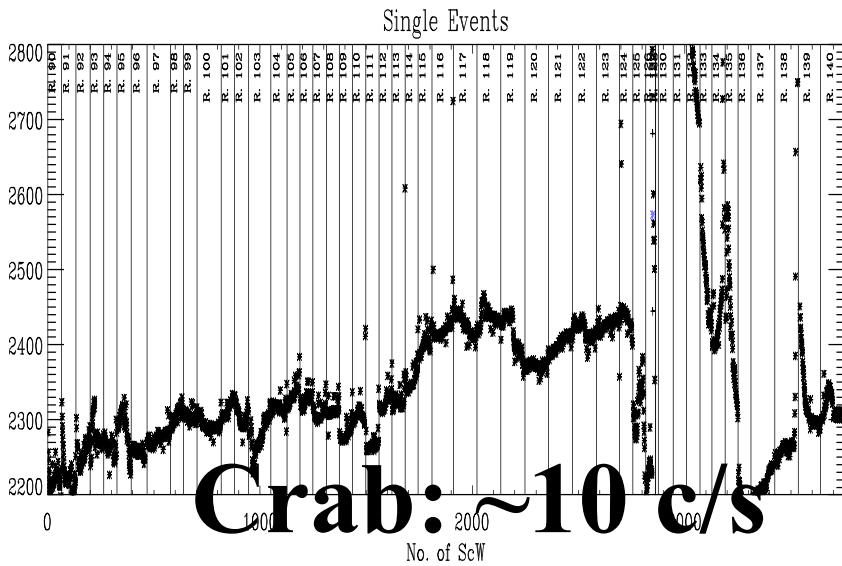


IBIS/PICsIT Background



(courtesy G. Malaguti)

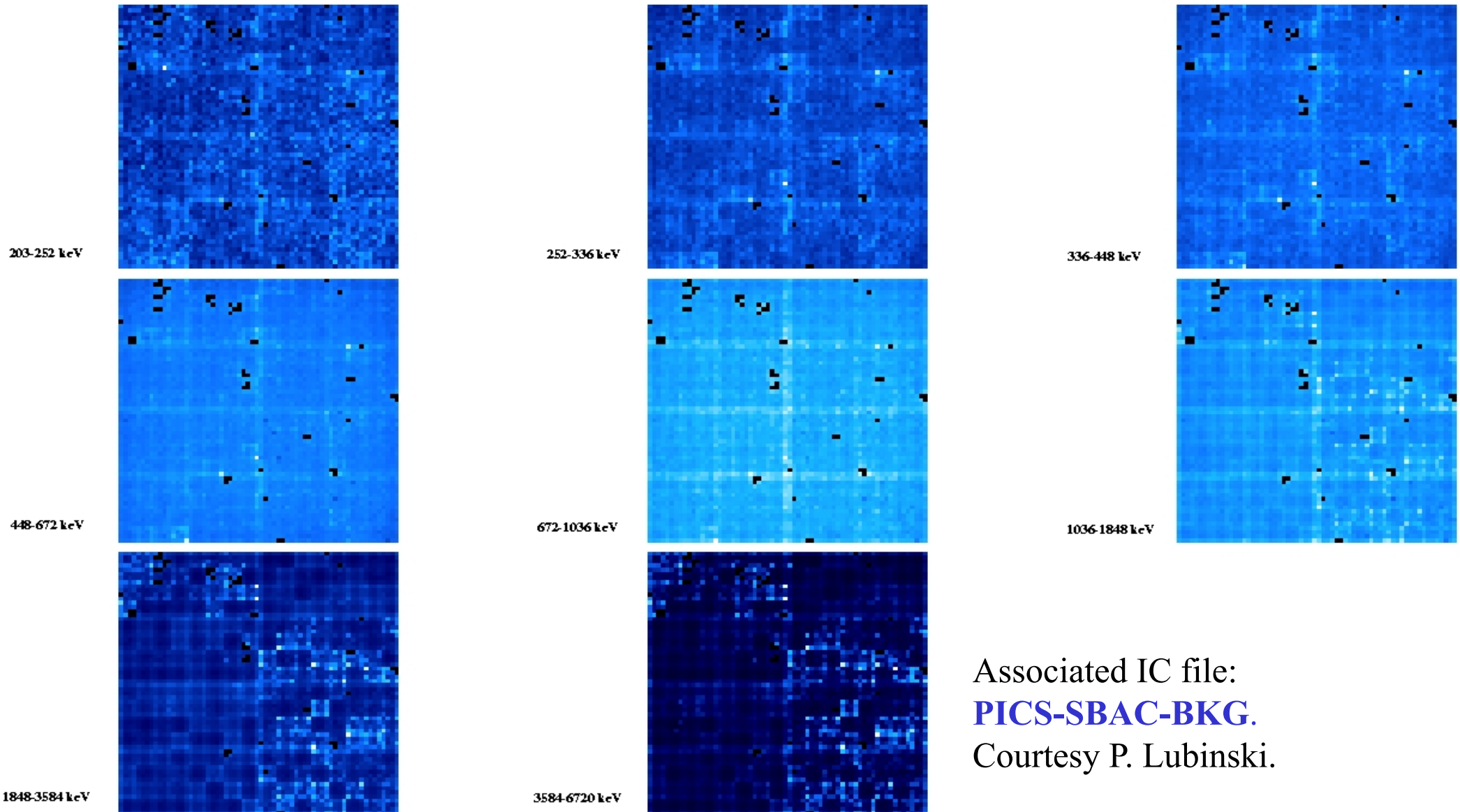
Background Count Rate (Rev 90-140)



(courtesy G. Malaguti)

Background maps – Single Events

Starting from OSA 4.0, BKG maps are available, built from the integration of several orbits with no sources.

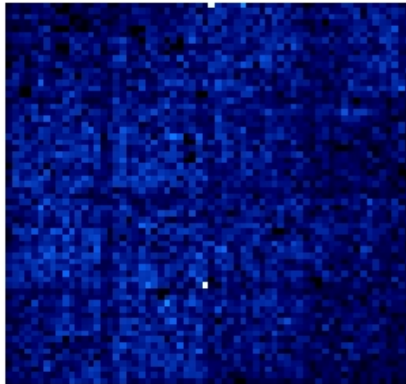


Associated IC file:
PICS-SBAC-BKG.
Courtesy P. Lubinski.

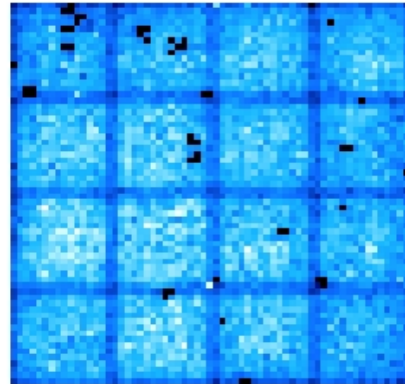
Background maps – Multiple events



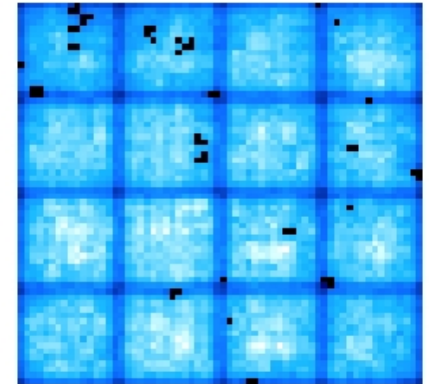
336-448 keV



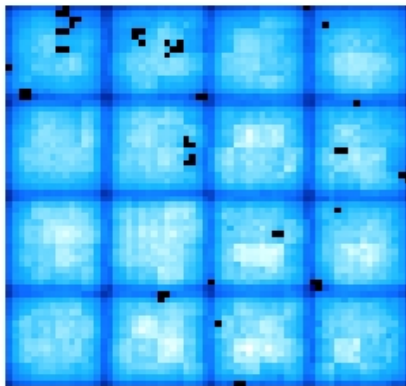
448-672 keV



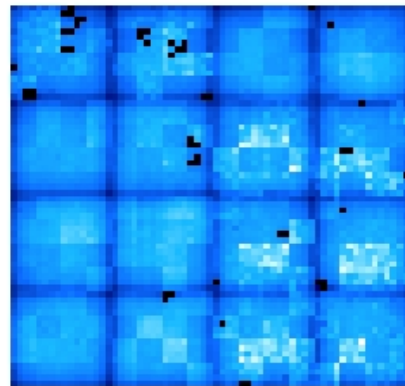
672-1036 keV



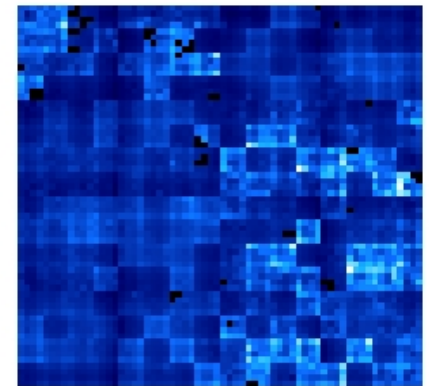
1036-1848 keV



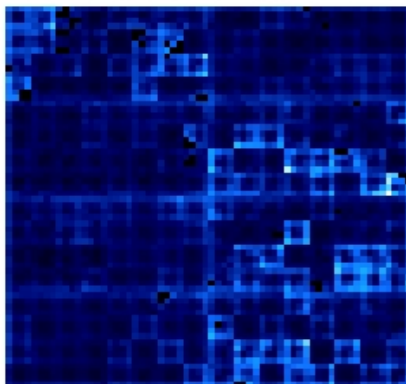
1848-3584 keV



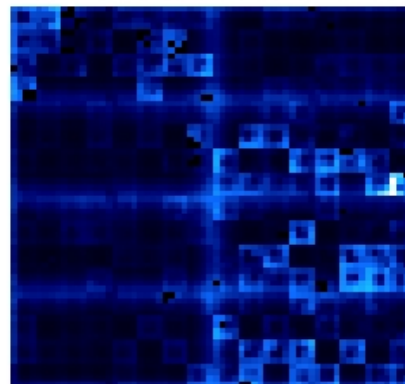
3584-6720 keV



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)

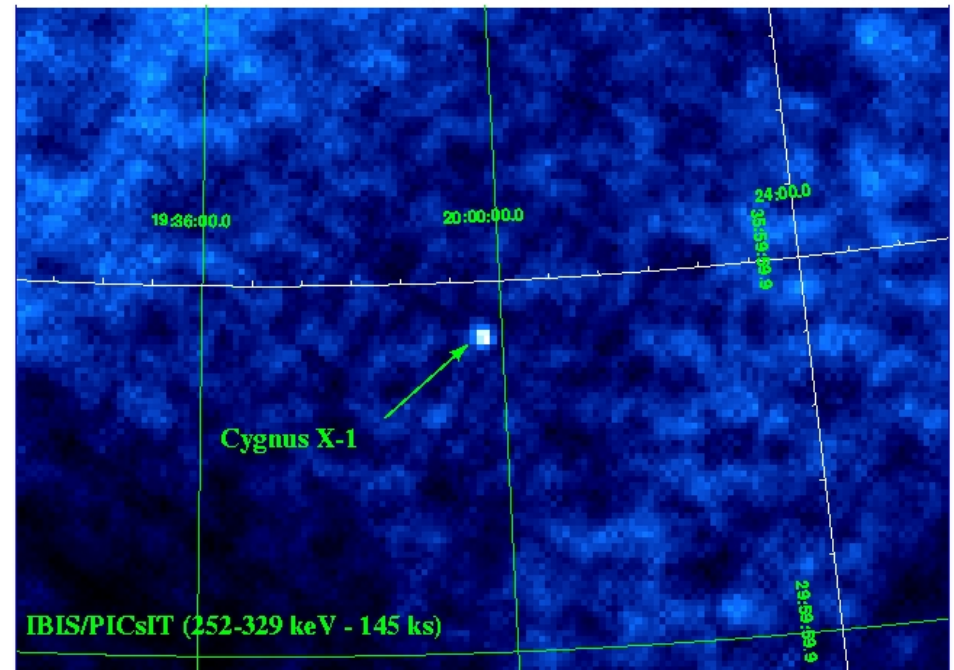
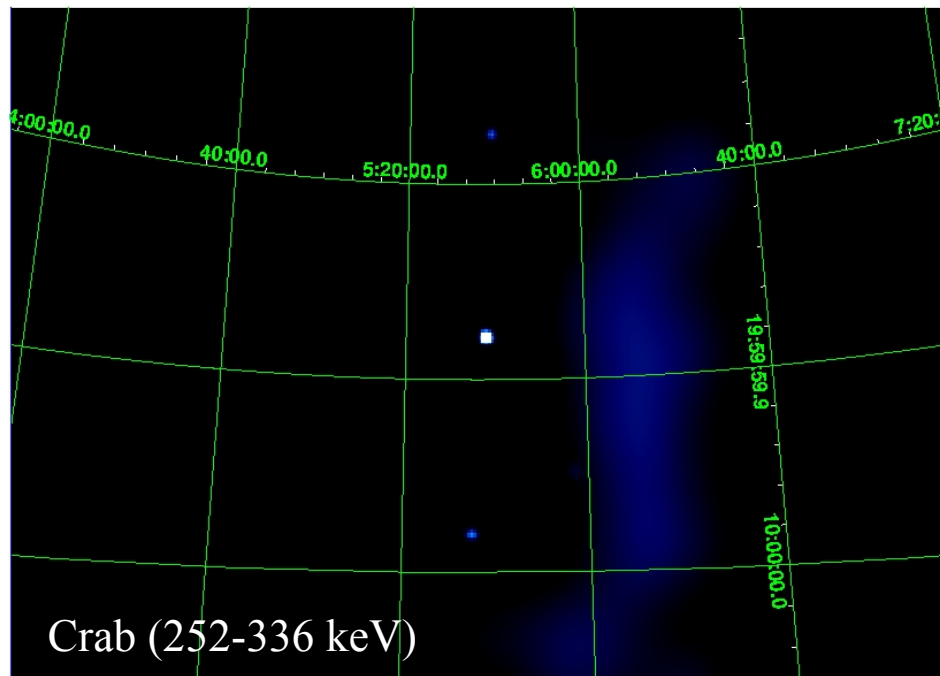


CAT_I: extraction, from the general catalog, of the sources in the FOV.

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**).



Algorithms for the deconvolution explained in detail in Goldwurm et al. 2003, A&A 411, L223.



See also the talk by A. Goldwurm / A. Gros (IBIS/ISGRI).

See also the talk by G. Skinner for coded-mask instruments (ISDC Data Analysis WS 2004).

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

**Astronomy
&
Astrophysics**

The INTEGRAL/IBIS scientific data analysis[★]

A. Goldwurm¹, P. David¹, L. Foschini², A. Gros¹, P. Laurent¹, A. Sauvageon¹,
A. J. Bird³, L. Lerusse⁴, and N. Produit⁴

¹ CEA Saclay, DSM/DAPNIA/SAP, 91191 Gif-sur-Yvette Cedex, France

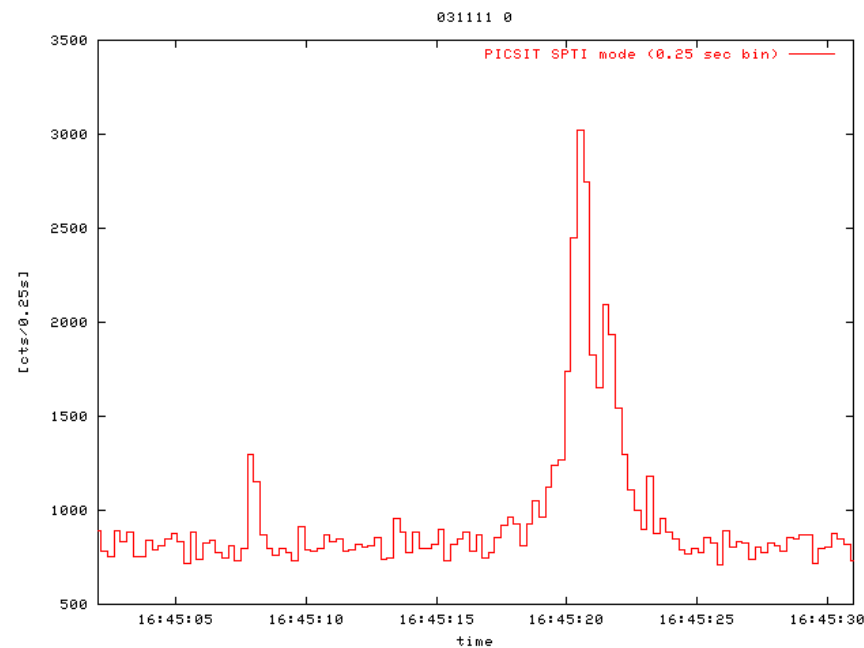
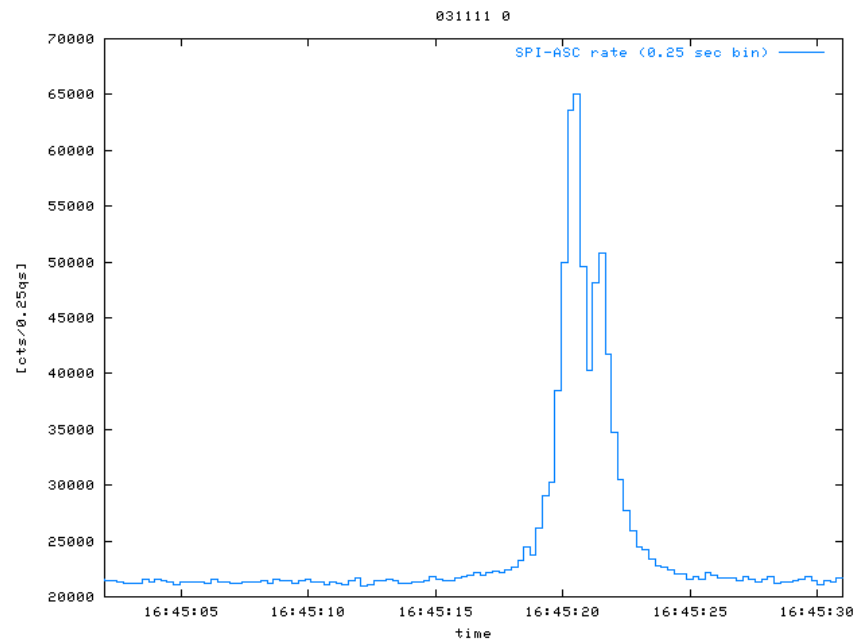
² IASF/CNR, sezione di Bologna, via Gobetti 101, 40129 Bologna, Italy

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

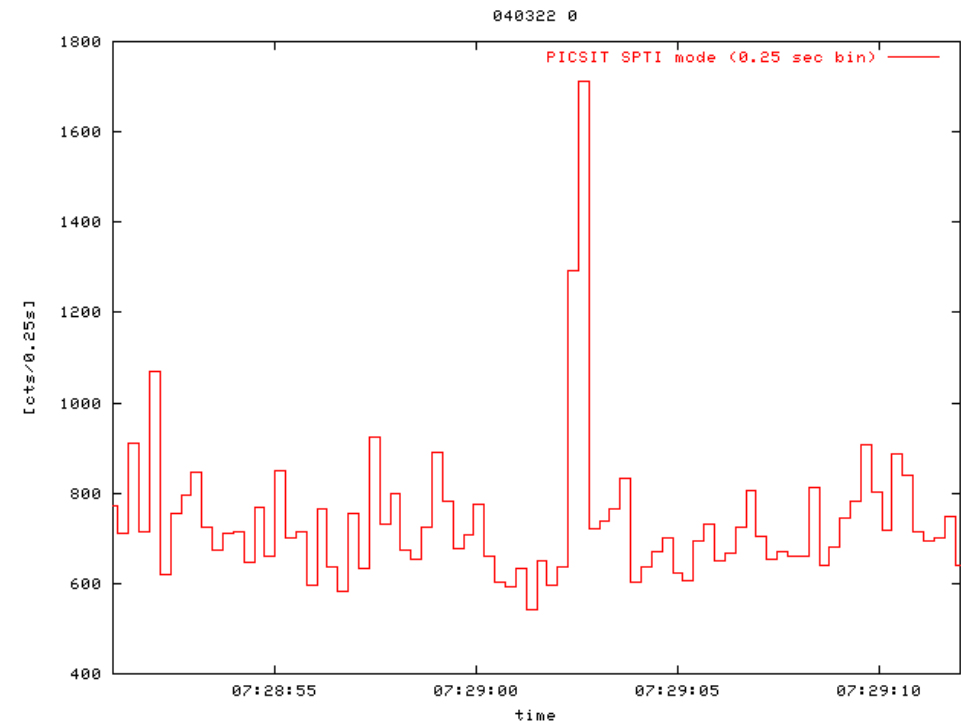
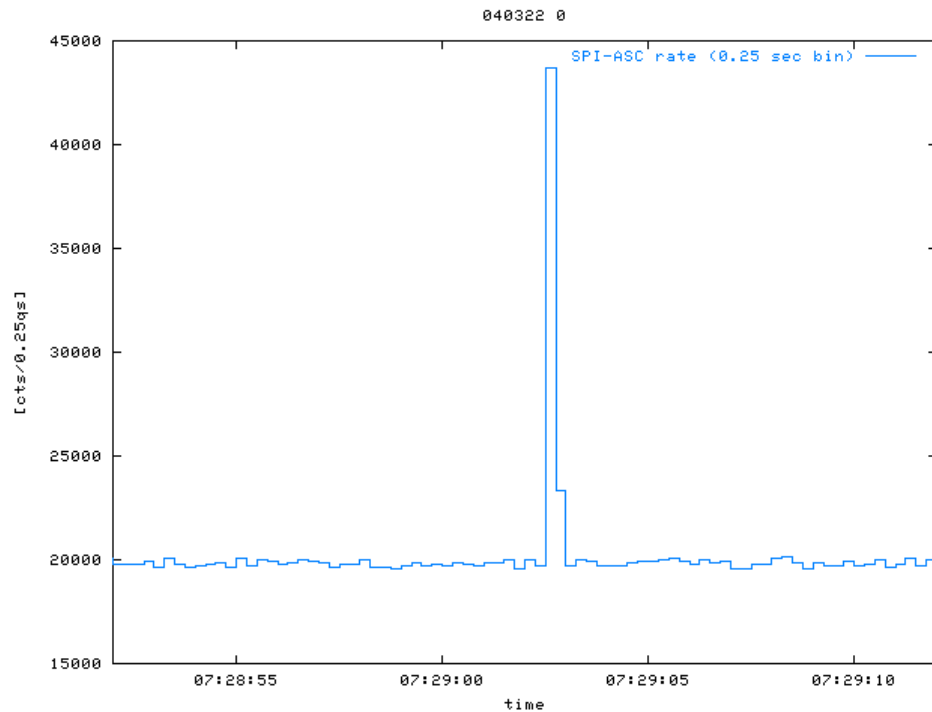
Step 5: Lightcurve extraction (Level LCR)

LCR: from spectral timing data we have count rates of the whole detector in 4 energy bands (260-364, 364-676, 676-1196, 1196-2600 keV) and 4 ms of time resolution (default values). Useful for GRB! IBIS/PICsIT is the only flying instrument exploring the MeV energy range.



(Courtesy M. Denis)

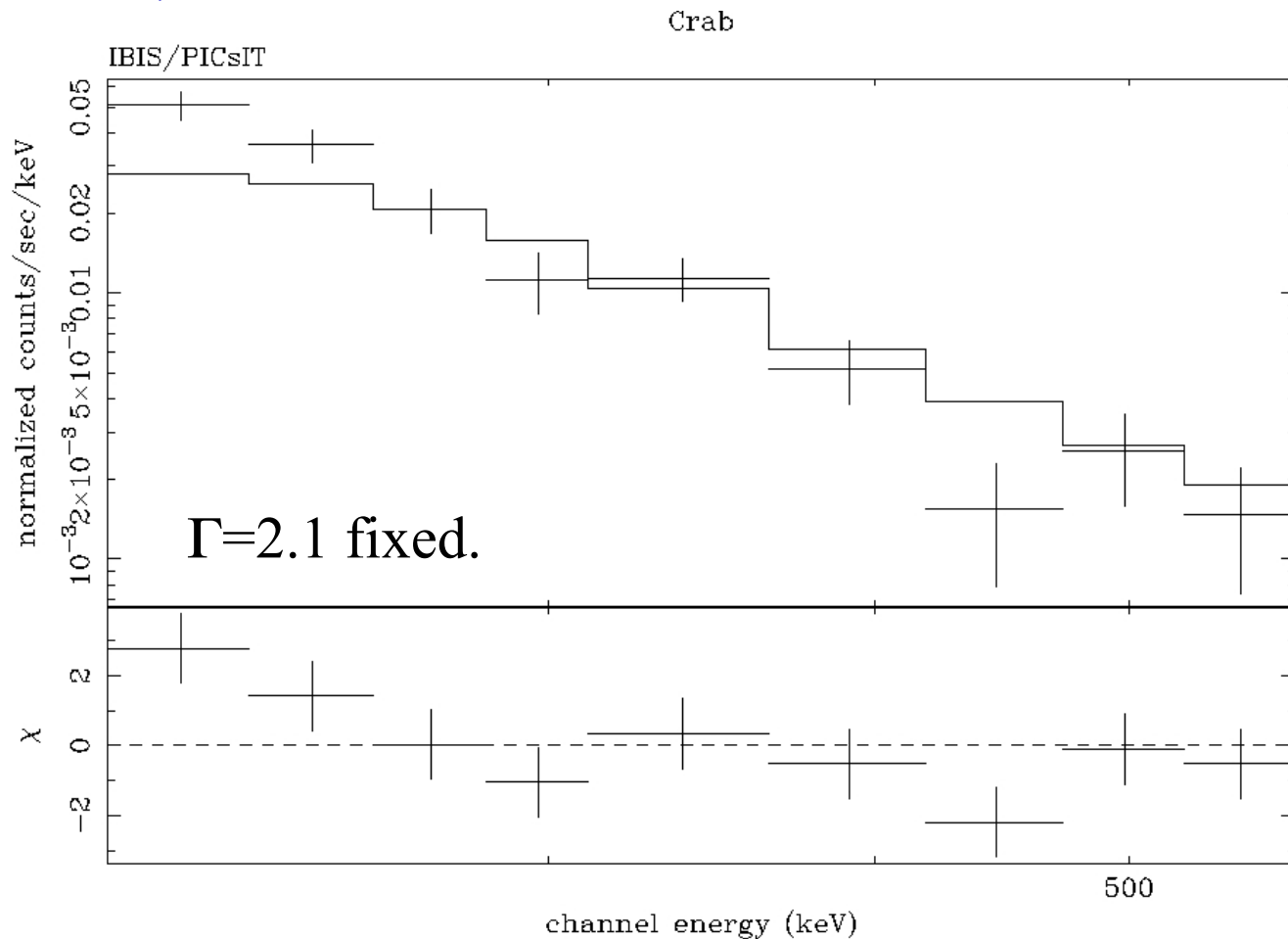
Step 5: Lightcurve extraction (Level LCR)



(Courtesy M. Denis)

See two works by R. Marcinkowski et al., *Proceedings "Astrophysical sources of high-energy particles and radiation"*, Torun (Poland), 20-24 June 2005.

Step 6: Spectra extraction (with PIF) (Level SPE)



foschini 9-Jun-2005 16:46

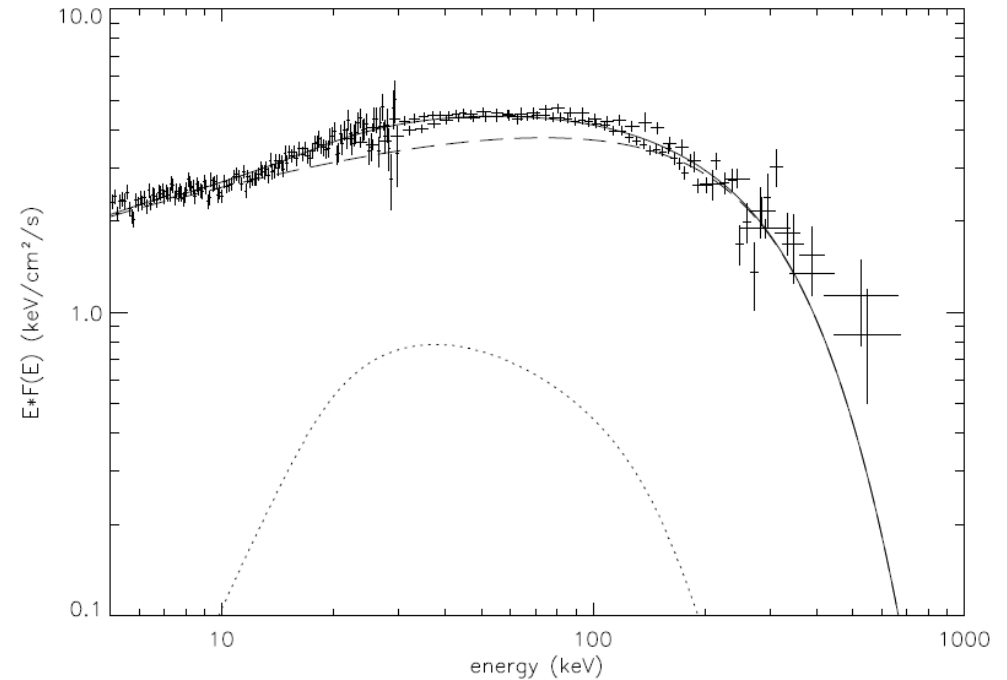
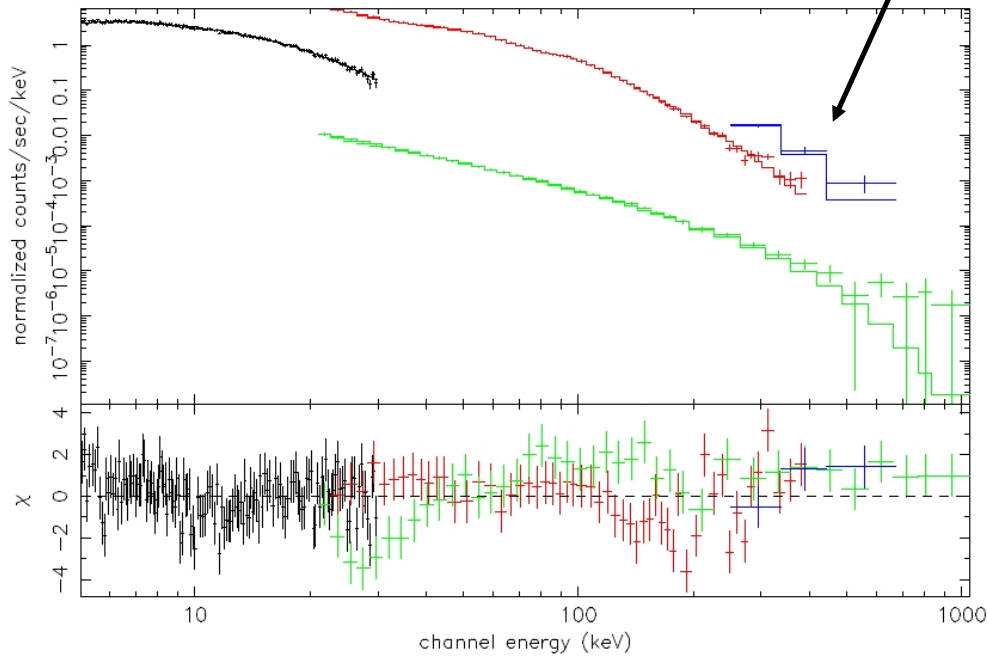
The image shows the deviations from the Crab standard spectrum.
Better to use the extraction of rates and errors from images...

INTEGRAL observation of Cyg X-1

Cadolle-Bel et al., 2005, A&A, accepted
(astro-ph/0509851)



PICsIT



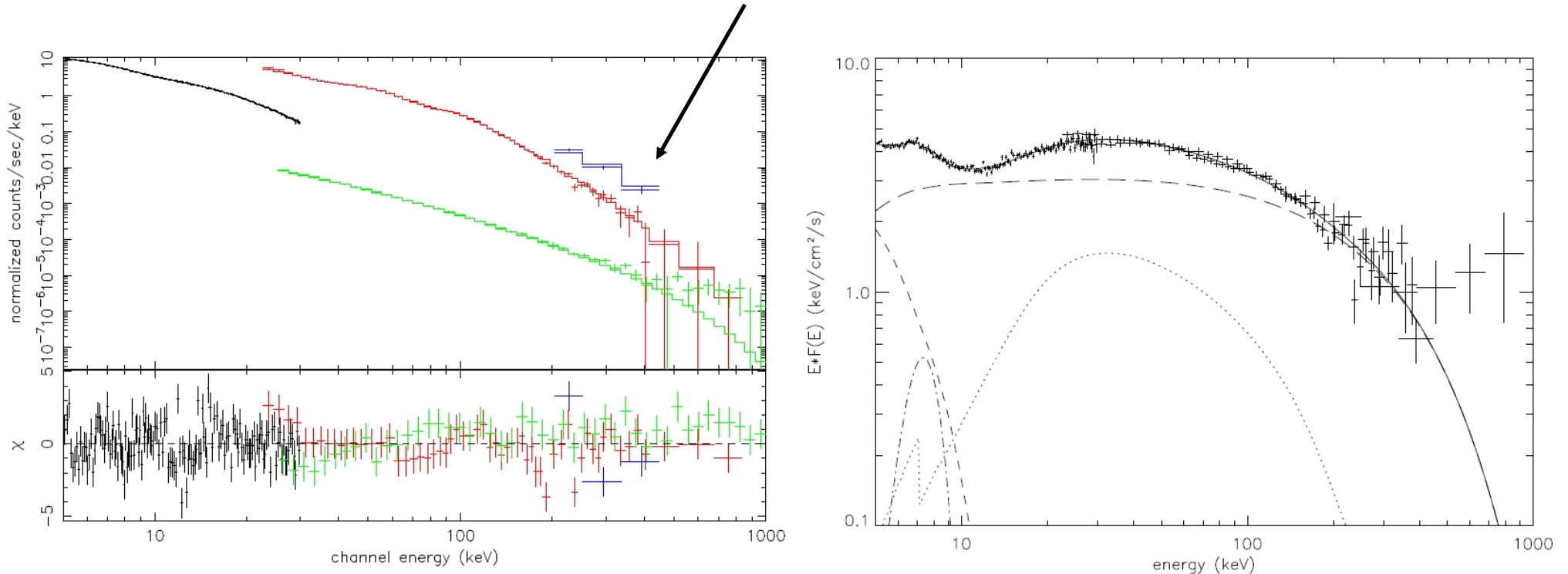
Epoch 1: 9-11 December 2002
Cygnus X-1 in hard state (thermal Comptonization + reflection)

INTEGRAL observation of Cyg X-1

Cadolle-Bel et al., 2005, A&A, accepted
(astro-ph/0509851)



PICsIT



Epoch 2: 7-11 June 2003

Transition to soft state (intermediate state):
accretion disk, emission line, thermal Comptonization, reflection

IBIS/PICsIT Source Catalog (Web)

<http://www.bo.iasf.cnr.it/Research/INTEGRAL>



The screenshot displays two browser windows. The left window shows the main website interface with a navigation menu. The right window shows a detailed table of Gamma-Ray Bursts (GRB) data.

IBIS/PICsIT Source Catalog

The list of sources is ordered according to the time of the event.

GRB	Coordinates (RA, Dec, J2000)	First GCN	Notes on PICsIT detection(*)
021125	19 47 57, +28 23 35	1706	IBIS FOV, ppm ; Malaguti et al. (2003)
021206	16 00 43, -09 43 24	1727	Spt, (M. Denis, personal communication)
021223	Annulus only	1778	Spt, (M. Denis, personal communication)
021226	02 54 58, +15 55 30	1779	Spt, (M. Denis, personal communication)
030102	12 07 41, +37 36 07	1786	Spt, (M. Denis, personal communication)
030204	00 03 20, +32 43 36	1854	Spt, (M. Denis, personal communication)
030218	23 24 43, -41 49 34	1874	Spt, (M. Denis, personal communication)
030228	23 10 30, -42 07 01	1918	Spt, (M. Denis, personal communication)
030307	23 01 14, -42 08 31	1937	Spt, (M. Denis, personal communication)
030320A	17 51 36, -25 18 52	1941	IBIS FOV, Spt
030320B	10 43 41, +41 49 08	1944	Spt, (M. Denis, personal communication)
030326	19 31 52, -11 43 13	1967	Spt, (M. Denis, personal communication)
030329	10 44 49, +21 31 23	1985	Spt, (M. Denis, personal communication)
030405	16 33 06, -24 09 09	2126	Spt, (M. Denis, personal communication)
030406	19 01 43, -68 04 39	2127	Spt, (M. Denis, personal communication)
030422A	Two error boxes	2162	Spt, (M. Denis, personal communication)
030501	19 05 33, +06 15 57	2181	IBIS FOV, Spt, (M. Denis, personal communication)
030509A	05 26 24, +07 08 48	2221	Spt, (M. Denis, personal communication)
030509B	22 08 21, -36 23 46	2226	Spt, (M. Denis, personal communication)
030518B	22 07 15, -35 14 38	2231	Spt, (M. Denis, personal communication)
030519	10 06 37, +35 07 26	2234	Spt, (M. Denis, personal communication)
030523	22 07 09, -34 29 02	2248	Spt, (M. Denis, personal communication)
030601	10 07 58, +33 12 18	2266	Spt, (M. Denis, personal communication)
030605	10 07 57, +32 48 18	2272	Spt, (M. Denis, personal communication)
030704	unknown	not confirmed	Spt, (M. Denis, personal communication)
030711	22 46 15, -13 14 06	2296	Spt, (M. Denis, personal communication)
030804	unknown	not confirmed	Spt, (M. Denis, personal communication)

The left window shows a navigation menu with the following items:

- [IBIS/PICsIT](#)
- [Scientific Results](#)
- [INTEGRAL Publications](#)
- [Links](#)

The footer of the left window reads: "The INTEGRAL Team at Bologna is co..."



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., 2005, v. 5.0 available at:

<http://isdc.unige.ch/index.cgi?Documents+docrep>