
# IBIS/PICsIT Data Analysis

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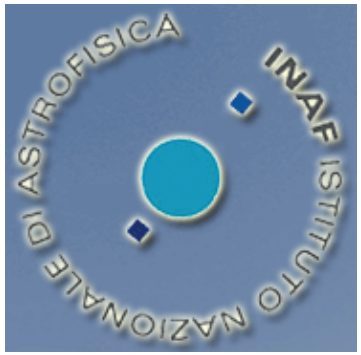
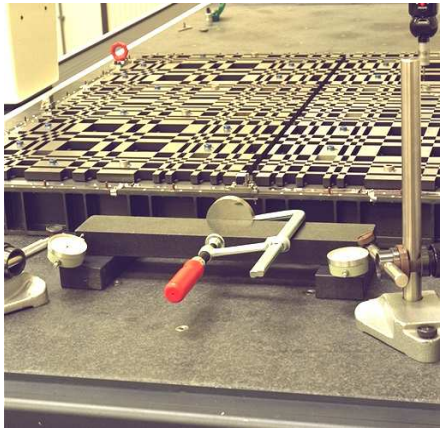
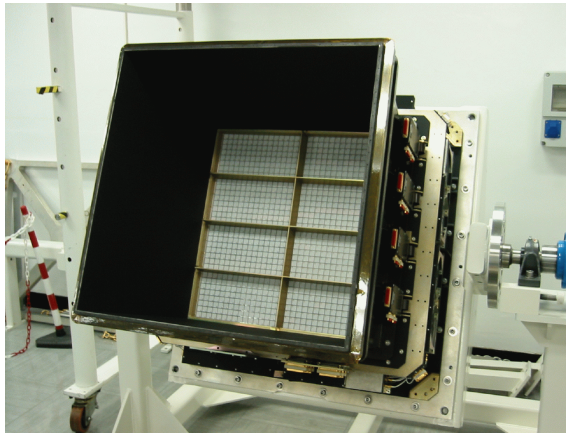


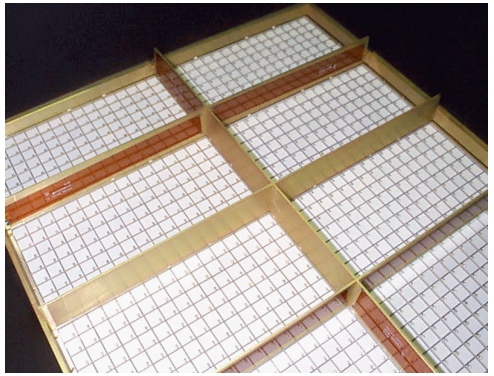

*INTEGRAL Data Analysis Workshop*
ISDC, Geneva, 12-14 October 2005

# **IBIS** (*Imager on Board the Integral Satellite*)

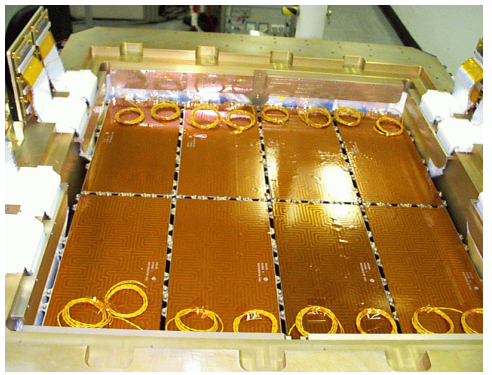




**IBIS** (Ubertini P., Lebrun F., Di Cocco G., et al, 2003, A&A 411, L131) is optimized for high-resolution (12′), wide FOV (29°x29°), point sources imaging and moderate energy resolution (8% @ 100 keV, 10% @ 1 MeV). It is composed of 2 detectors:



**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

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

| | |
|---|---|
| **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 ⇨ 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, BIN_I,...IMA2. 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: 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.

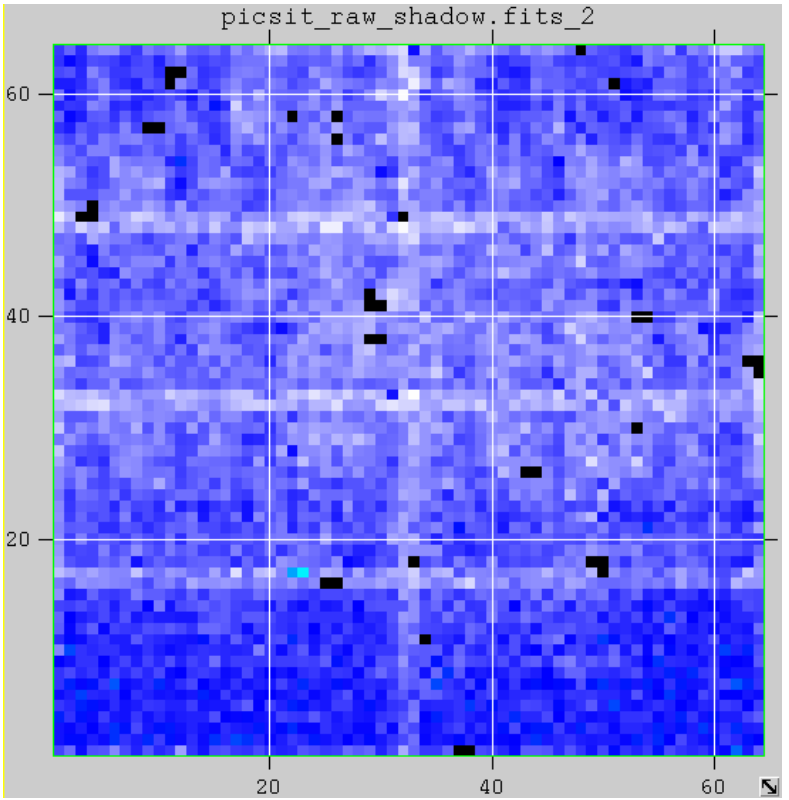
**DEAD: Intrinsic detector deadtime calculation:** it is calculated as complementary of the HK livetime counter. The livetime counter is calculated onboard taking into account VETO and calibration unit coincidences.

# 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`)**.

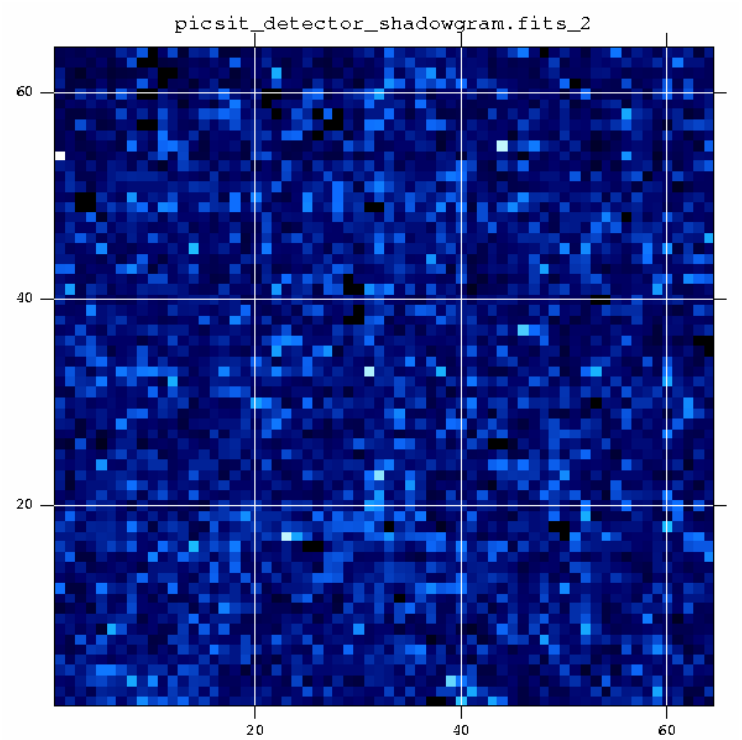


# Step 2: Shadowgram building (Levels BIN_I/BIN_S)

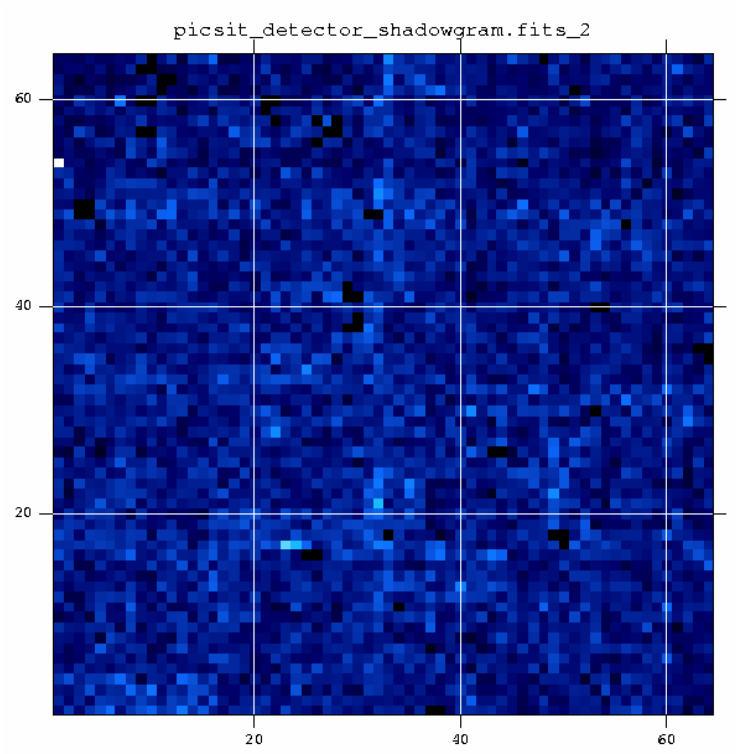
**BIN_I: shadowgram building for imaging in ppm**: the GTI are taken into account; it is possible at this stage to clean for cosmic-rays induced events (Segreto et al. 2003). Set **`SCW1_BIN_cleanTrk=1`**. **Only in ppm!**

170-220 keV

"Normal"




Cleaned



# Step 3: Shadowgram correction (Levels BKG_I)

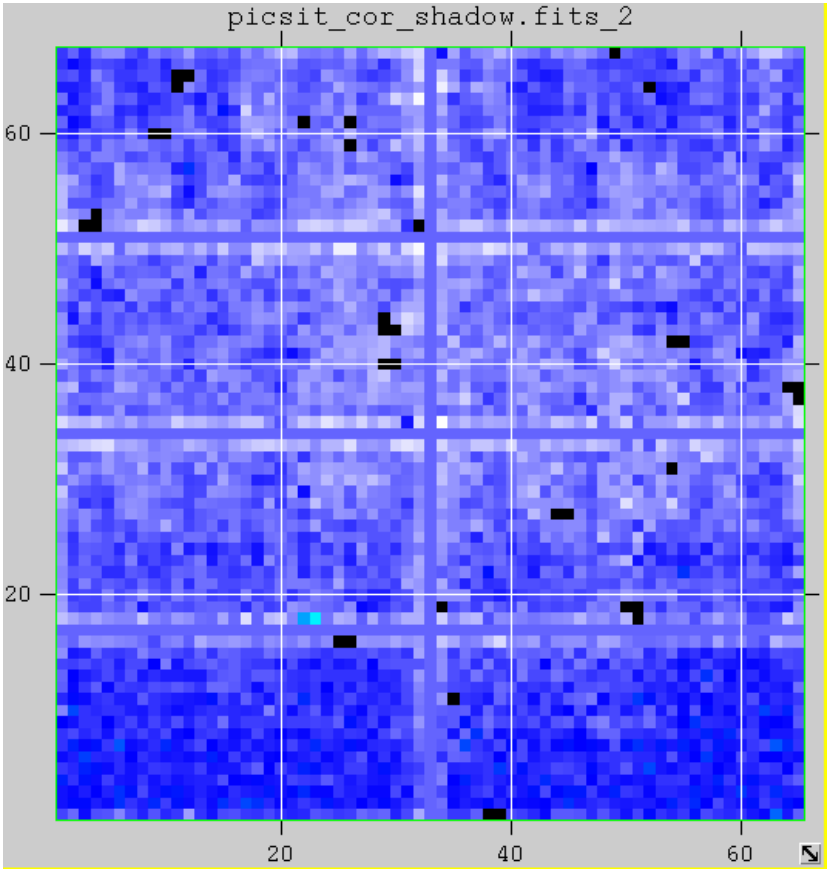
**BKG_I: shadowgram correction and expansion:** perform the correction for efficiency, background subtraction, non-uniformity correction, and shadowgram expansion from 64x64 to 65x67.

**`CorShd=(RawShd-k*Bkg)/Uni`**

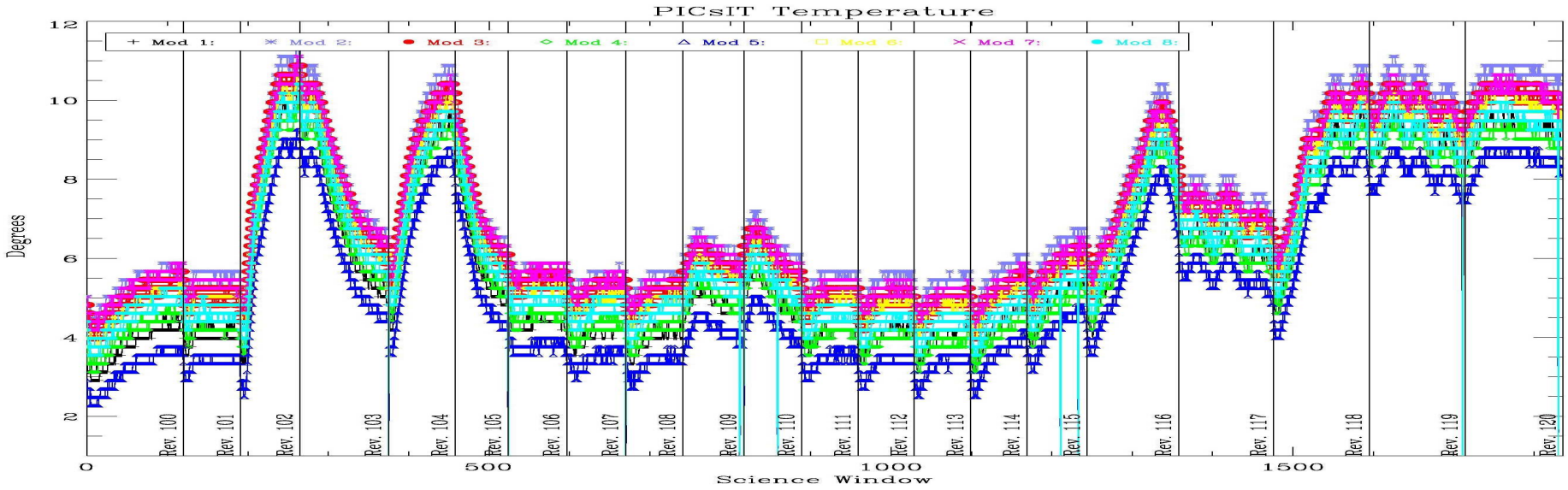
**k:** normalization constant, calculated in 2 ways: by equalizing the mean map count averaged over the whole detector or the exposures.

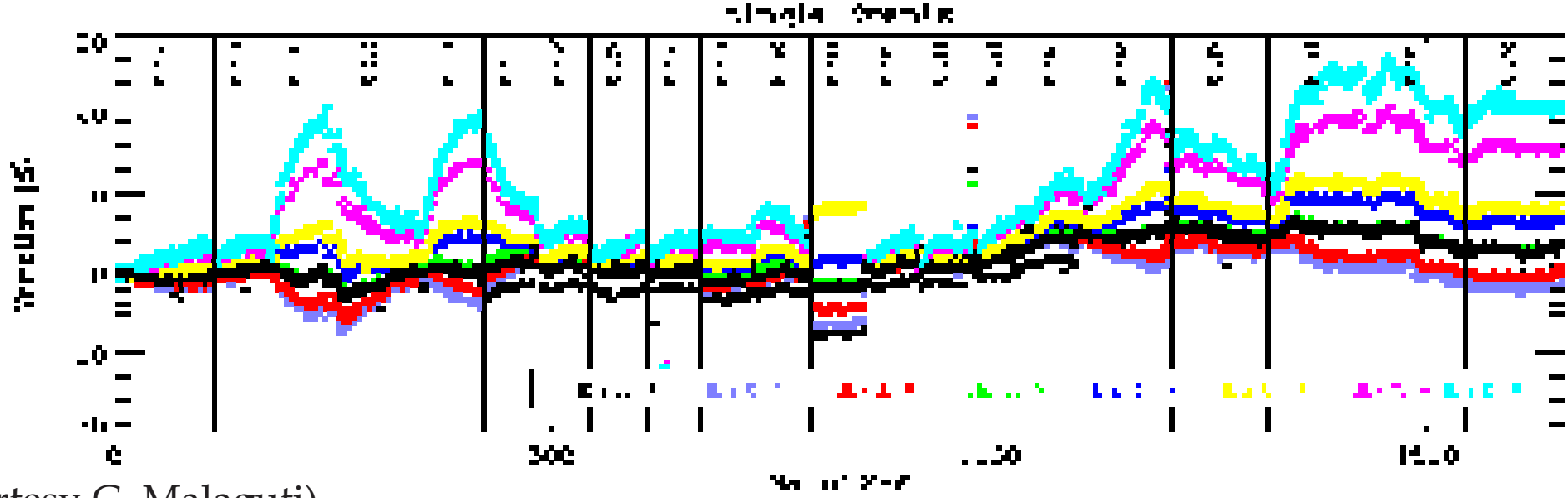
Presently, only background maps are present. No uniformity maps are yet available.

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



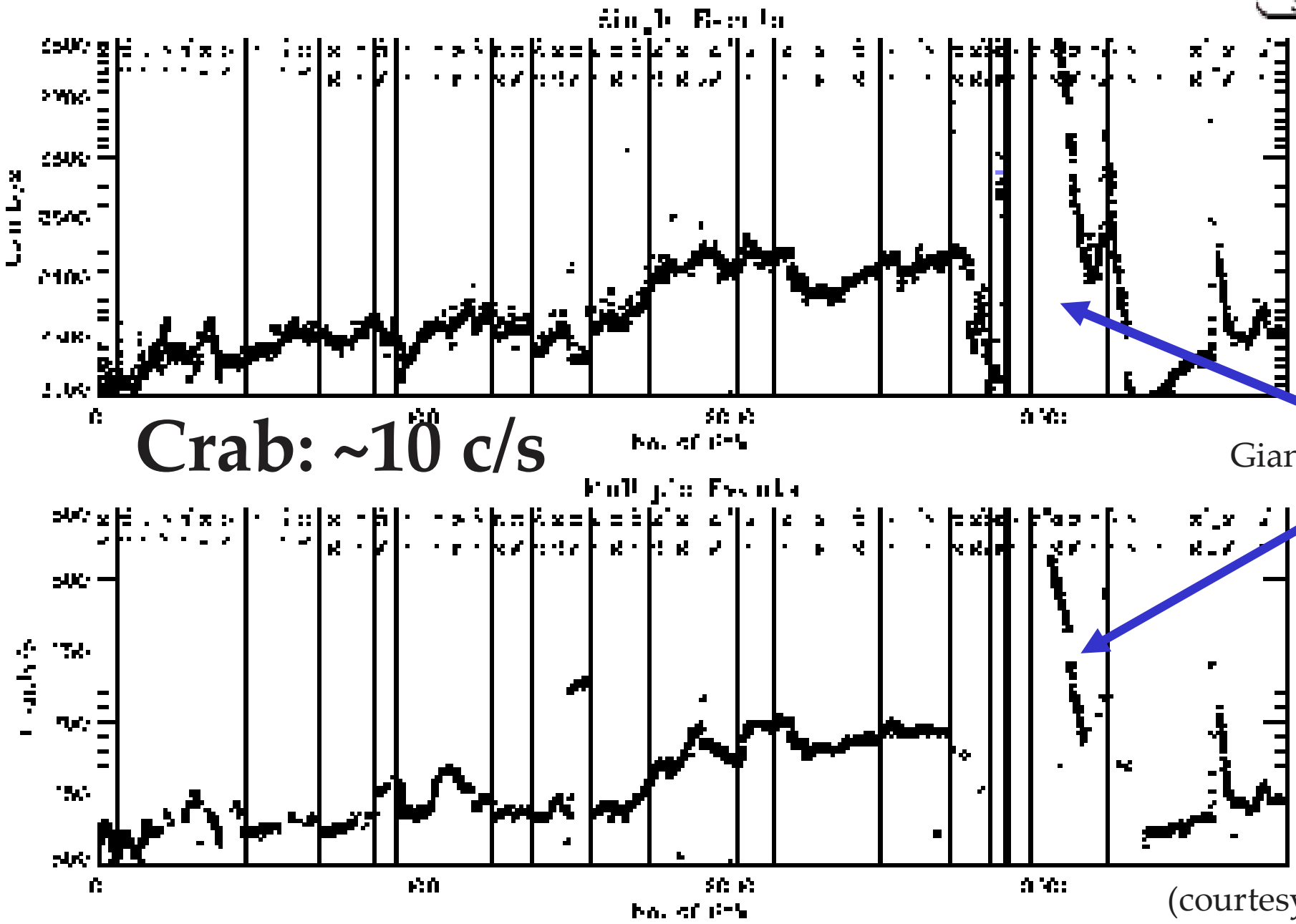
# *IBIS/PICsIT Background*



(courtesy G. Malaguti)

# Background Count Rate (Rev 90-140)



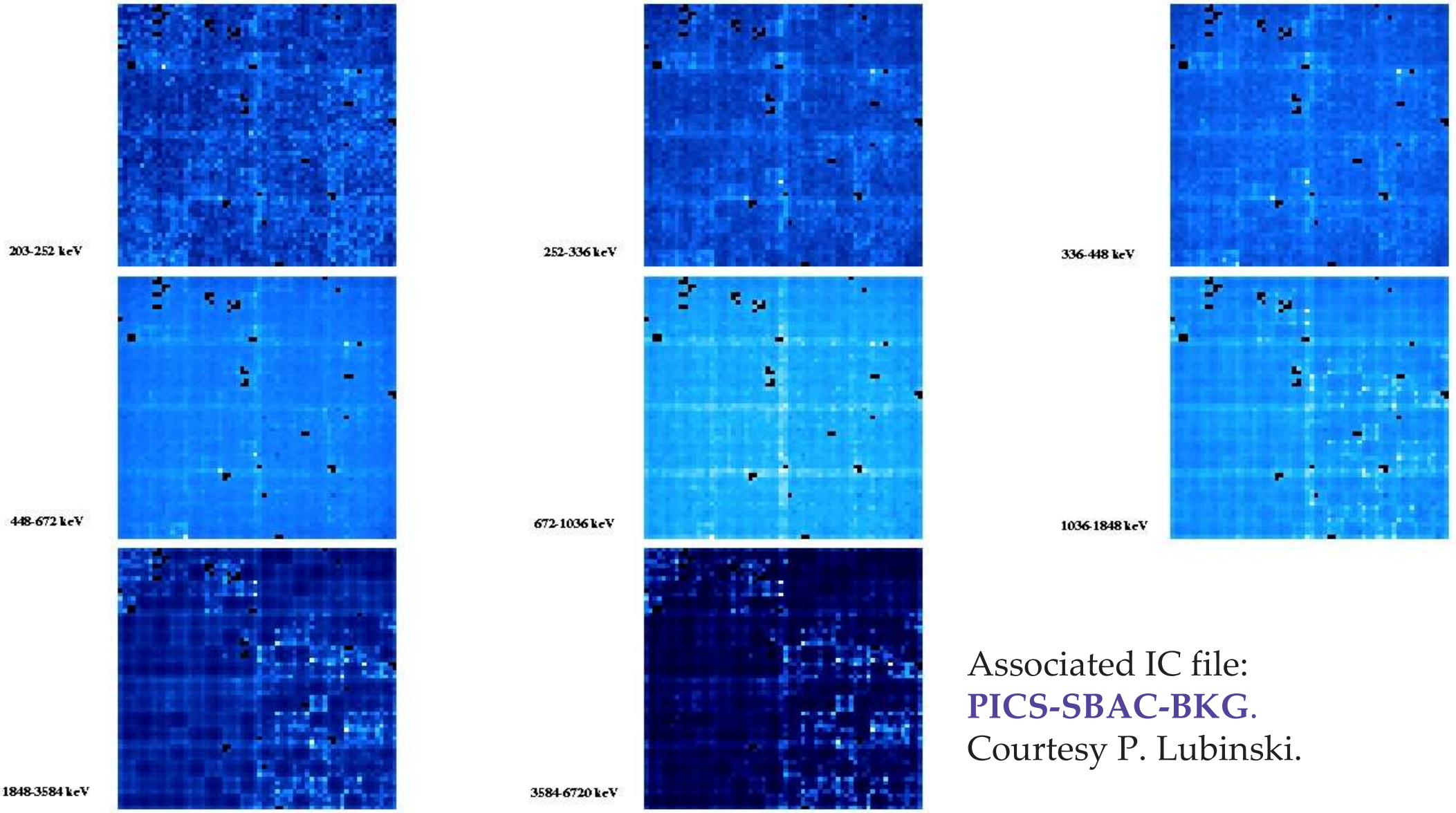
**Crab: ~10 c/s**

Giant Solar Flare

(courtesy G. Malaguti)

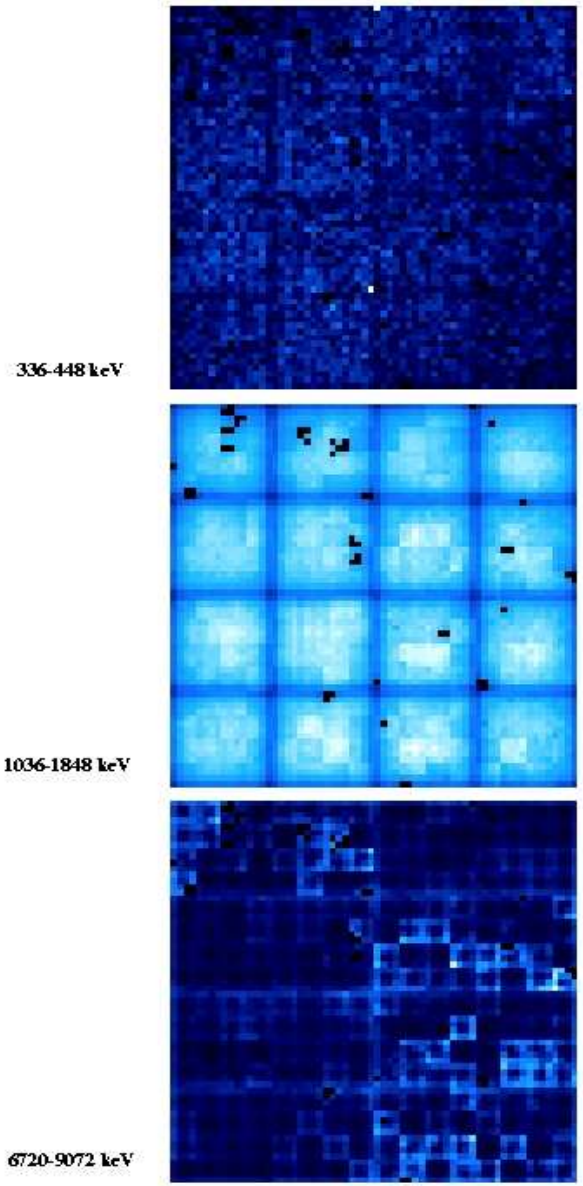
# *Background maps – Single Events*

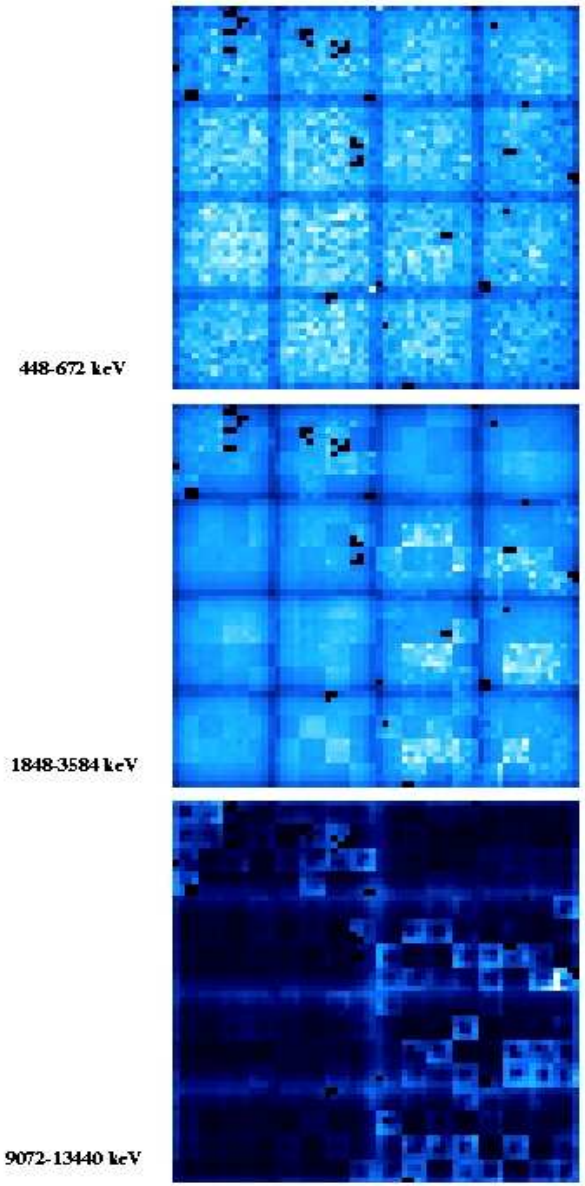
Starting from OSA 4.0, BKG maps are available, built from the integration of several orbits with no sources.

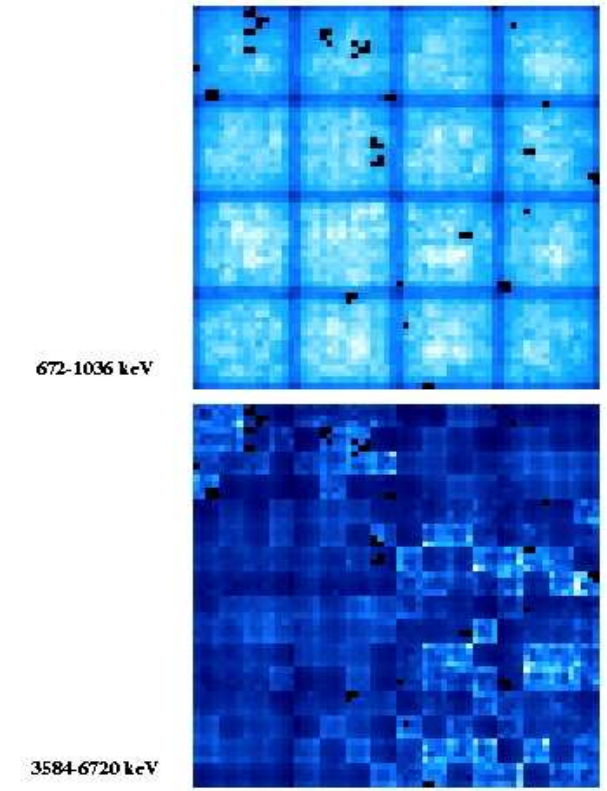



Associated IC file:
**PICS-SBAC-BKG**.
Courtesy P. Lubinski.

# *Background maps – Multiple events*



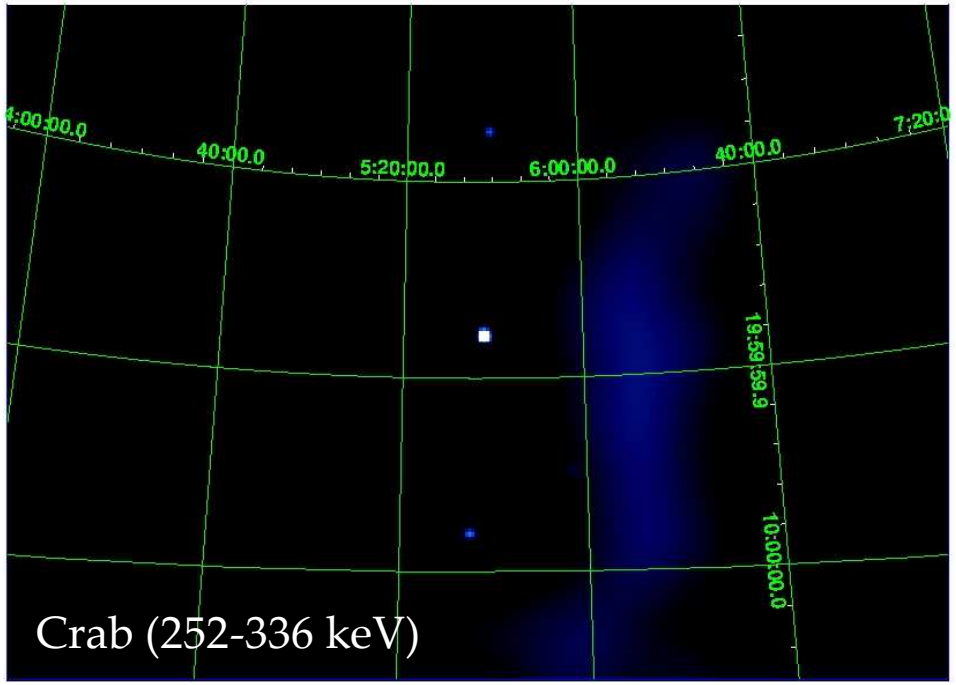



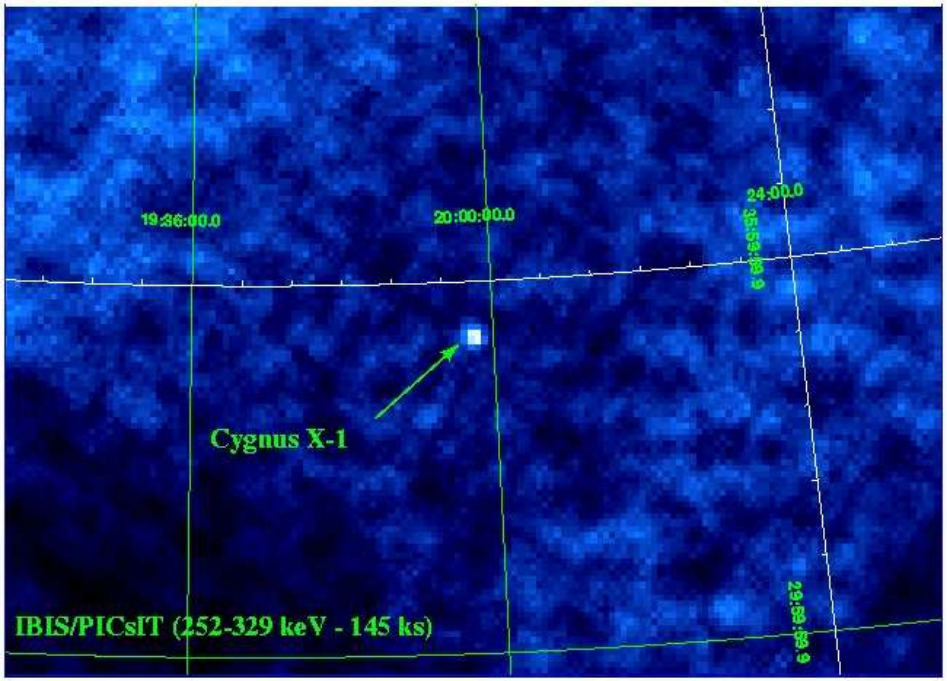




Associated IC file:
**PICS-MBAC-BKG**.
Courtesy P. Lubinski.

# 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


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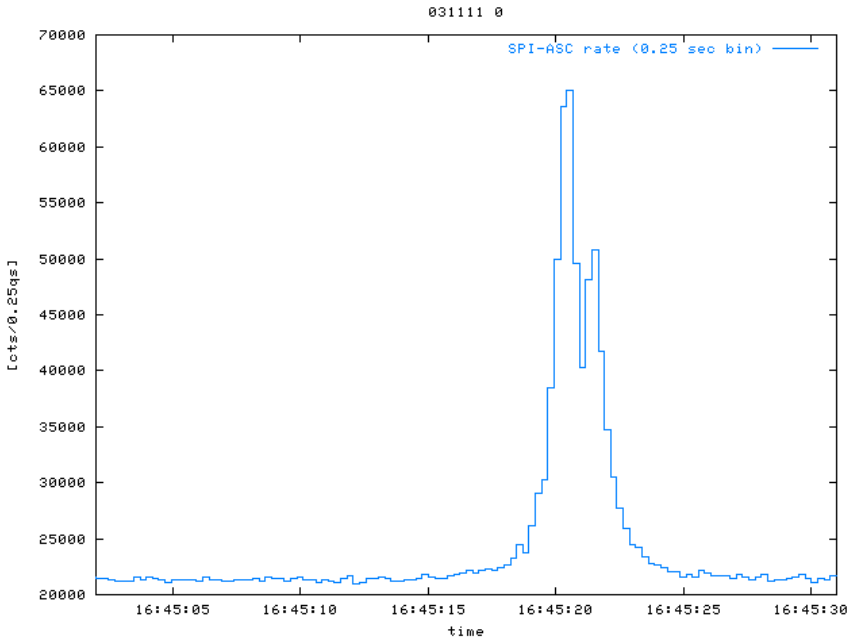
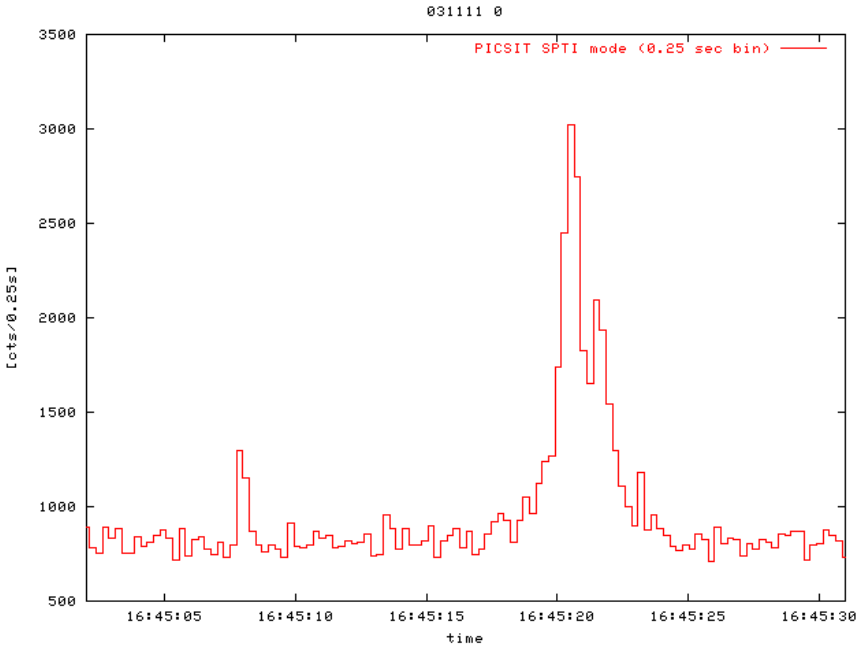
[2] IASF/CNR, sezione di Bologna, via Gobetti 101, 40129 Bologna, Italy
[3] School of Physics and Astronomy, University of Southampton, Highfield, SO17 1BJ, UK
[4] Integral Science Data Center, Chemin d'Écogia, 16, 1290 Versoix, Switzerland

# Step 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).

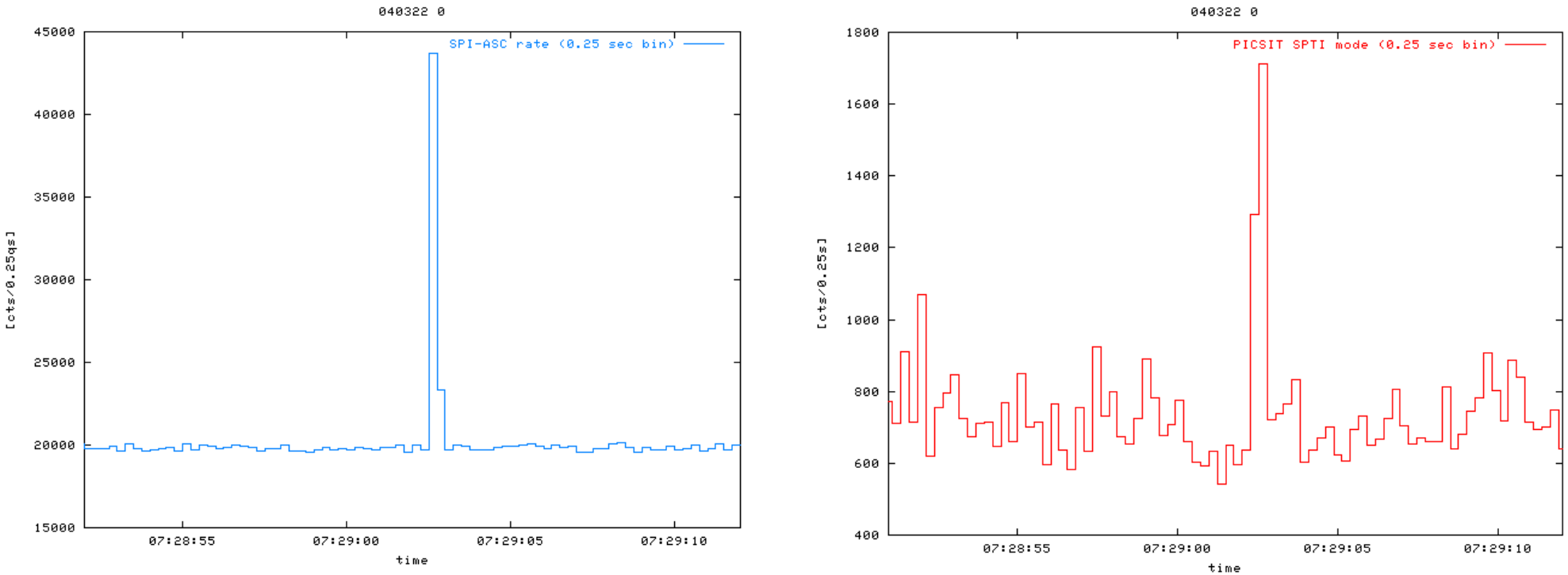
Useful for GRB! IBIS/PICsIT is the only flying instrument exploring the MeV energy range.




(Courtesy M. Denis)

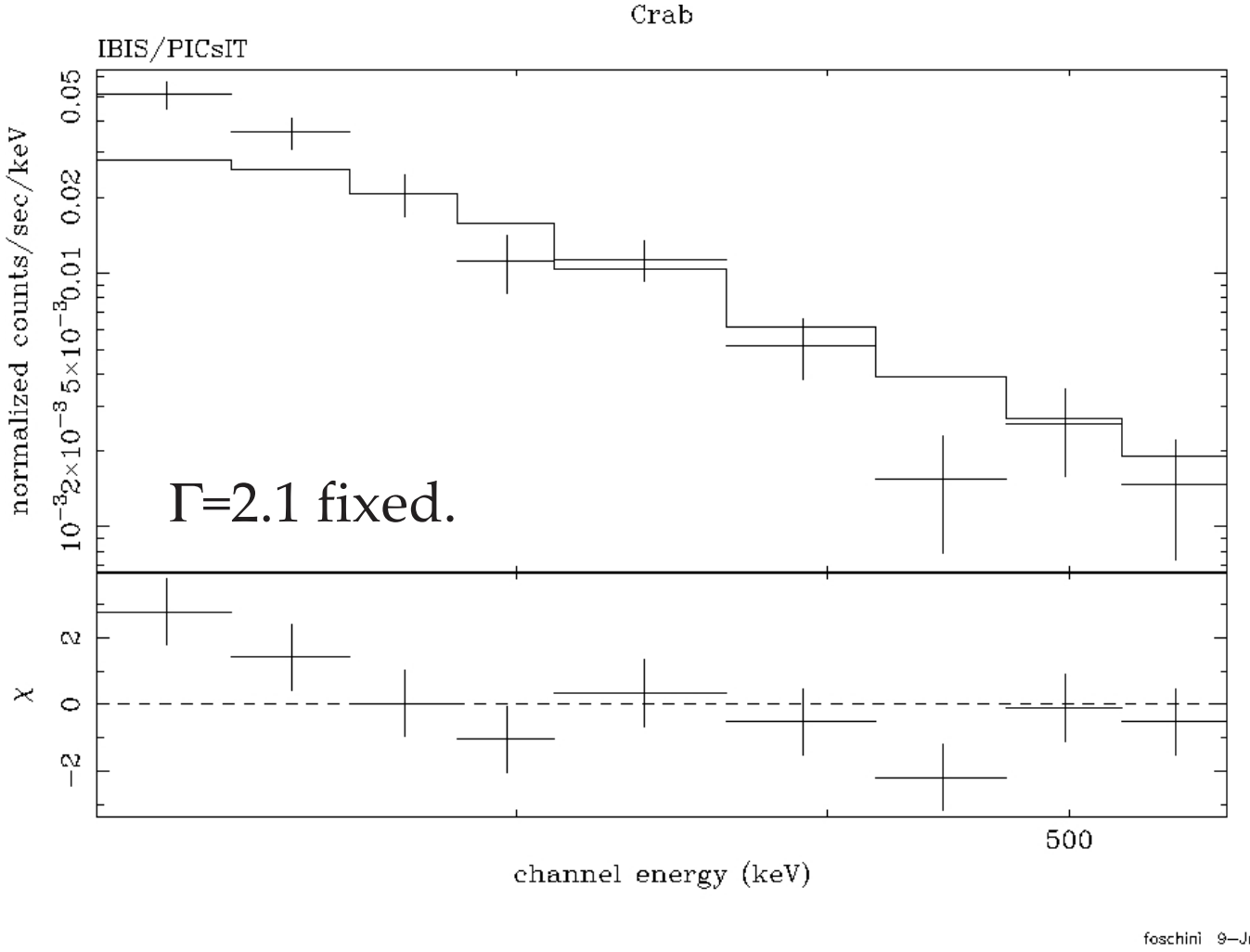
# Step 5: Lightcurve extraction (Level LCR)




(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.

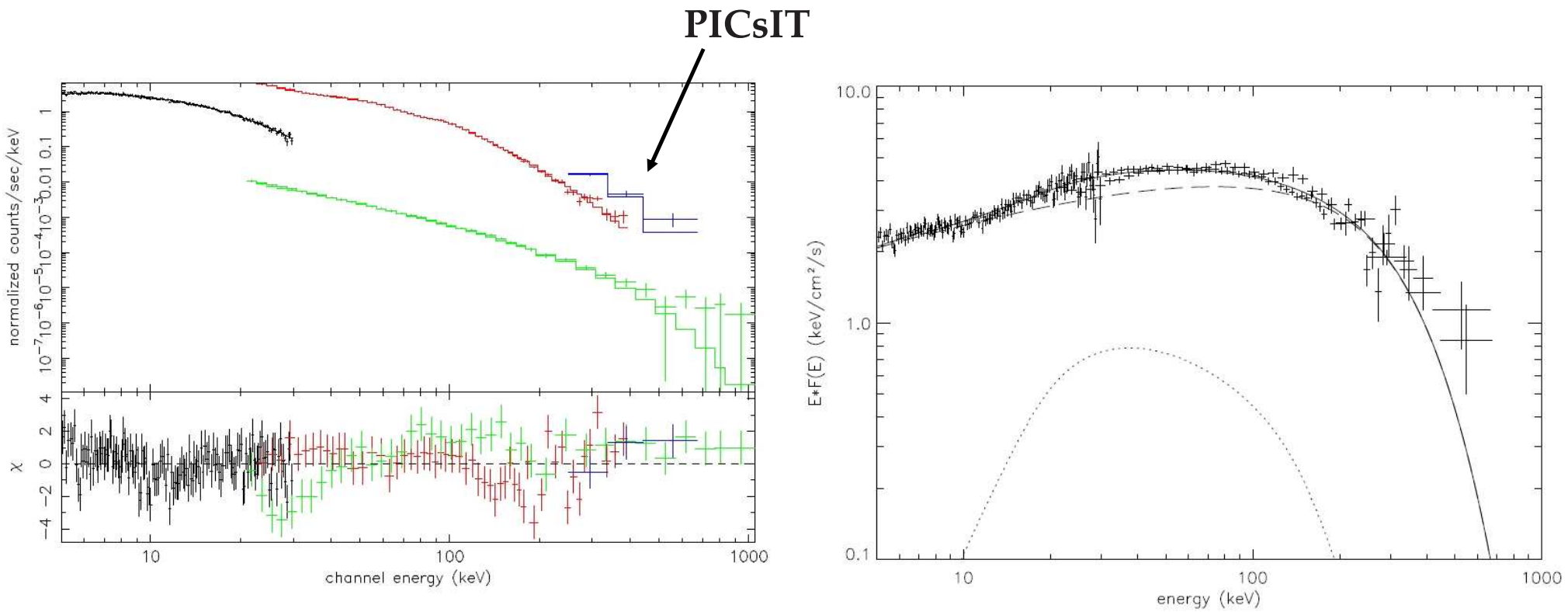
# Step 6: Spectra extraction (with PIF) (Level SPE)




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)**

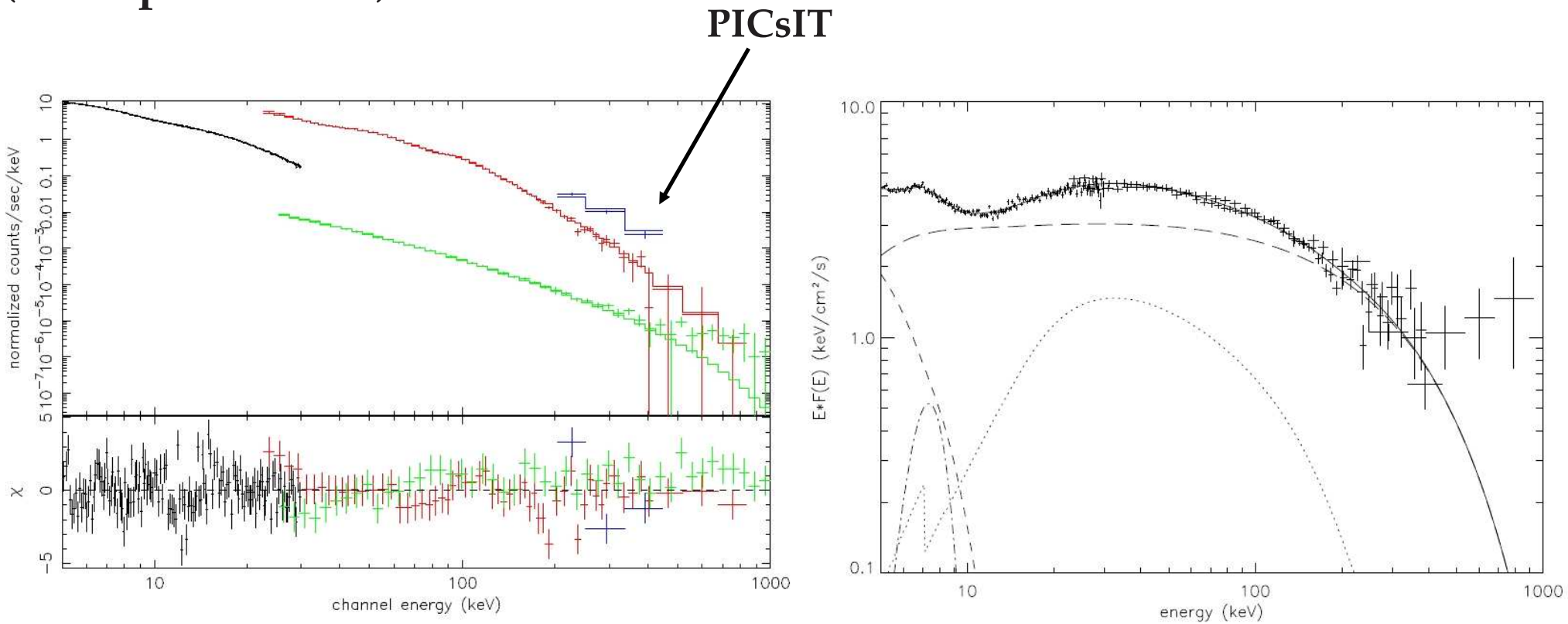



Epoch 1: 9-11 December 2002

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)**



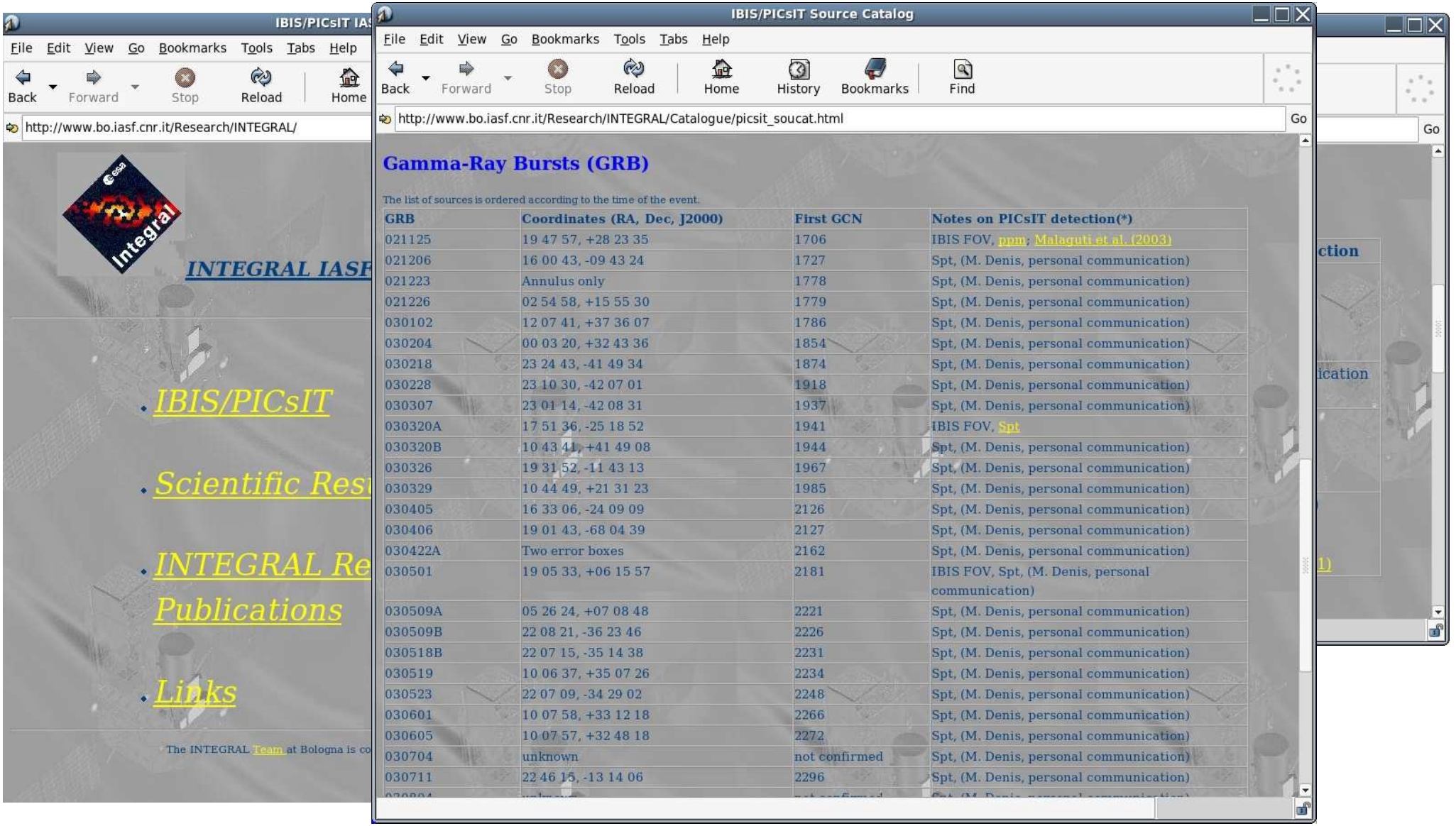

Epoch 2: 7-11 June 2003

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



# 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`**