PICsIT data analysis

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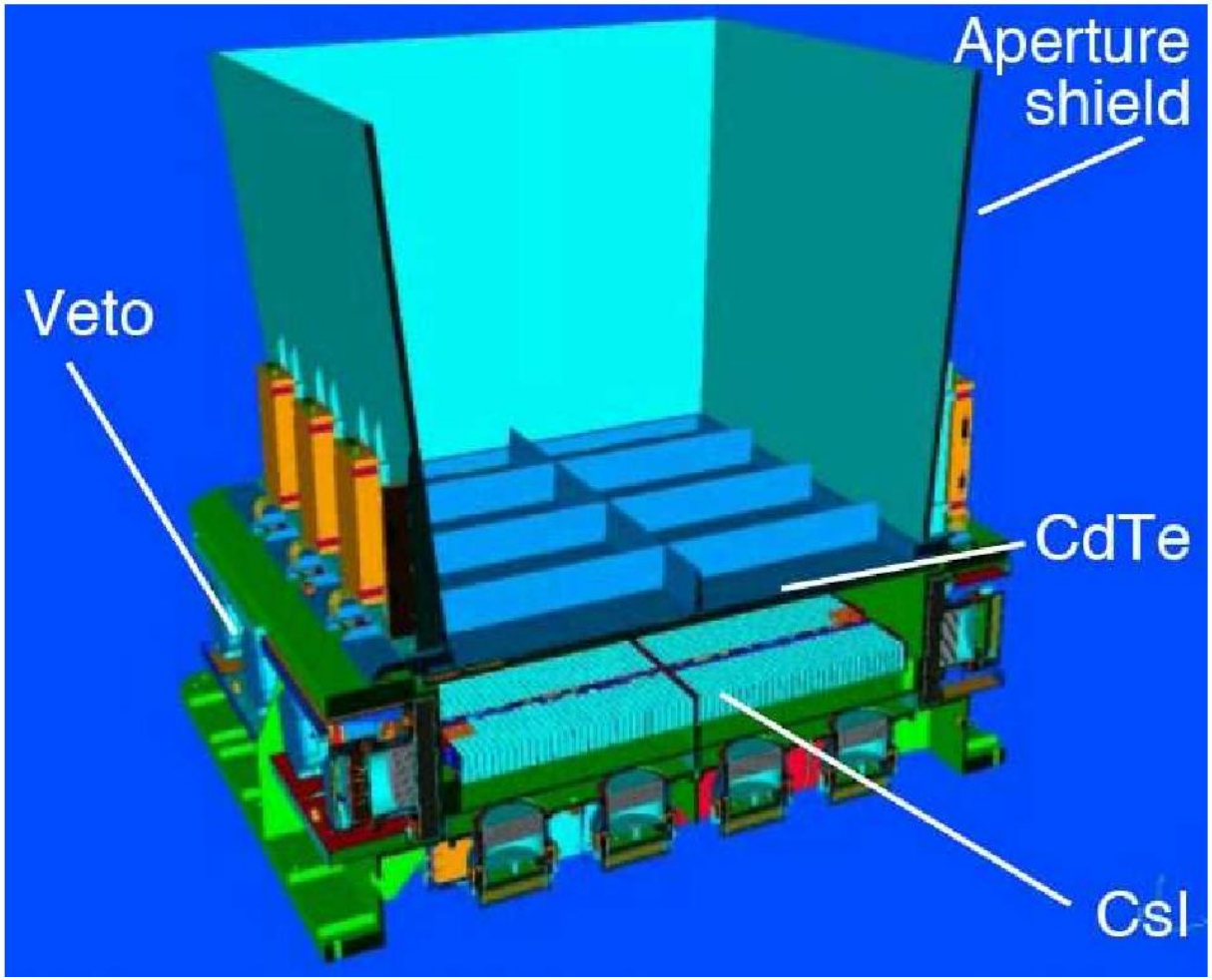
PICsIT
PIxellated Caesium Iodide Telescope



Instrument properties

- array of 64x64 pixels, 8.55x8.55x30 mm
- 16 submodules
- energy range: 175 keV - 6.5 MeV (single)
- energy range: 350 keV - 13 MeV (multiple)
- field of view: 9°x9° fully coded
- field of view: 46°x46° total
- angular resolution: 12’

Types of events

- single: single pixel
- multiple: several pixels in submodule
- Compton single: single pixels in ISGRI and PICsIT
- Compton multiple: single pixel in ISGRI, several pixels in PICsIT submodule

Observing modes

- photon-by-photon: 64x64 pixels, 1024 energy chan., 64 μs
- spectral-imaging: 64x64 pixels, 256 energy chan., $\geq$ 30 min
- spectral-timing: entire detector, 2-8 energy chan., 1-500 ms

Default SPTI settings: 4 ms, 260-364 keV, 364-676 keV, 676-1196 keV, 1196-2600 keV

Image deconvolution, dithering observation

```
ibis_science_analysis
ogDOL="./og_ibis.fits[1]"
startLevel="BIN_I"
endLevel="IMA2"
OBS1_ScwType="ANY"
CAT_refCat="$ISDC_REF_CAT"
SWITCH_disablePICsIT="NO"
SWITCH_disableIsgri="YES"
IBIS_IPS_ChanNum=0
SCW1_BKG_P_method=1
PICSIT_inCorVar=0
PICSIT_outVarian=0
SCW1_BKG_picsSUnifDOL="-"
SCW1_BKG_picsMUnifDOL="-"
```

Image deconvolution, staring observation

```
ibis_science_analysis
ogDOL="./og_ibis.fits[1]"
startLevel="BIN_I"
endLevel="IMA2"
OBS1_ScwType="ANY"
CAT_refCat="$ISDC_REF_CAT"
SWITCH_disablePICsIT="NO"
SWITCH_disableIsgri="YES"
IBIS_IPS_ChanNum=0
SCW1_BKG_P_method=1
PICSIT_inCorVar=0
PICSIT_outVarian=0
SCW1_BKG_picsSUnifDOL="-"
SCW1_BKG_picsMUnifDOL="-"
staring=yes
tolerance=0.1
```

Mosaic image, OSA tool ip_skymosaic

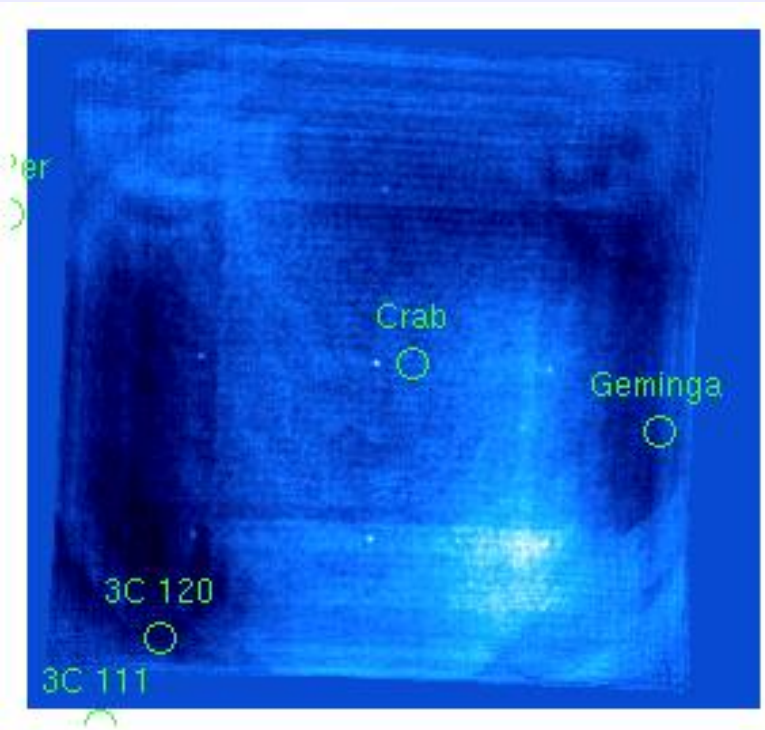
```
ip_skymosaic
inOG=""
idxScw=""
outOG="./og_ibis.fits[1]"
outMosaic="./pics_mosa_ima2.fits(PICS-MOSA-IMA-IDX.tpl)"
outPicsitCat="./pics_mosa_res2.fits(PICS-MOSA-RES-IDX.tpl)"
inCat="./isgri_catalog.fits[1]"
detThr=3.0
imgSel="EVT_TYPE==’SINGLE’ && E_MIN==252 && E_MAX==336"
projSel="-TAN"
```

Mosaic image, HEASOFT tool varmosaic

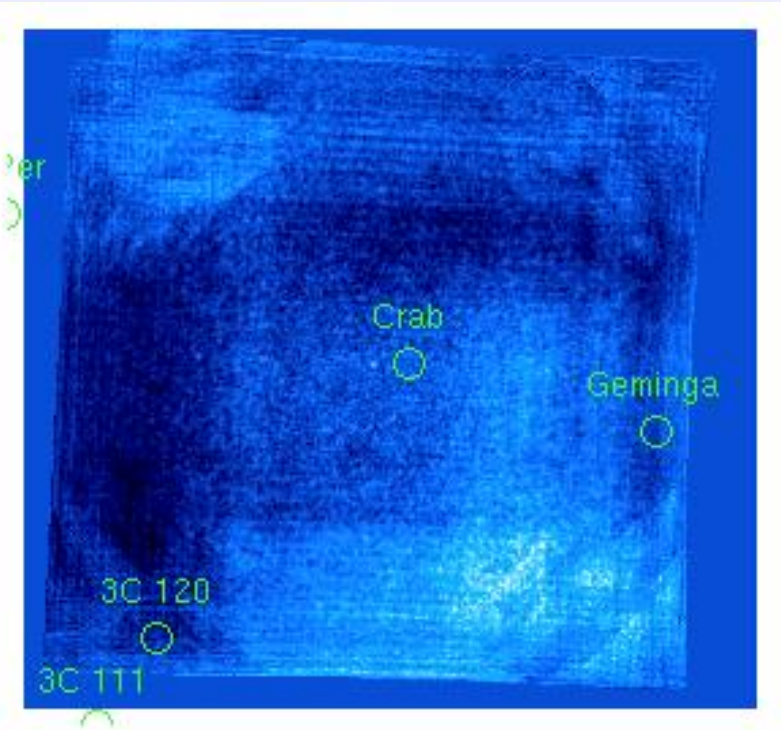
ls scw/*/picsit_ima.fits > name.list
varmosaic name.list name.fits

Crab, Rev. 0239, ip_skymosaic mocaics

336-448 keV



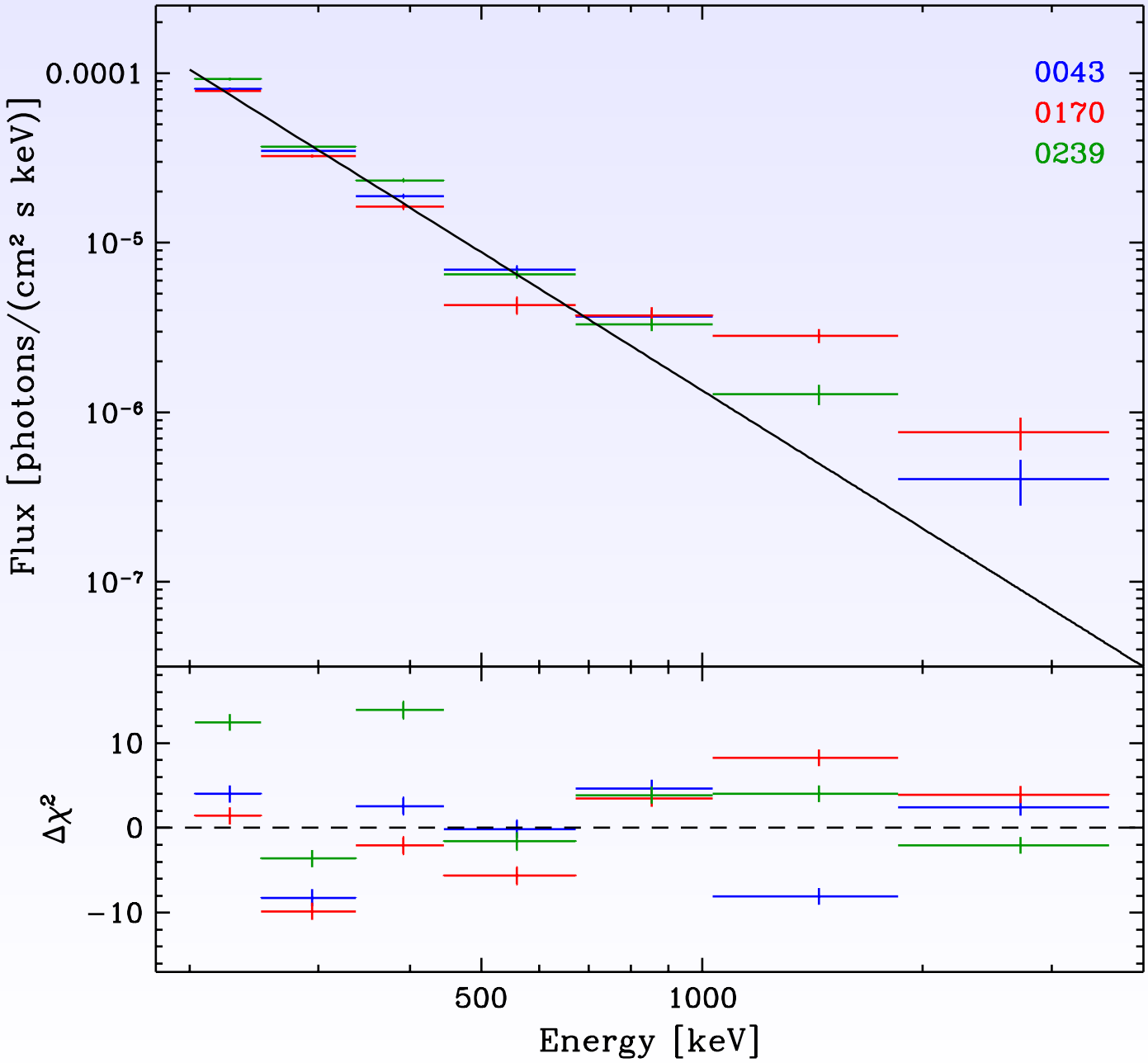
672-1036 keV



Spectral extraction software is still not ready

Spectra can be made using the fluxes from mosaic images
or
from set of individual sky images with the script spextract_pics
(http://isdc.unige.ch/index.cgi?Soft+scripts)

Crab, spectra from Revs. 0043, 0170, 0239

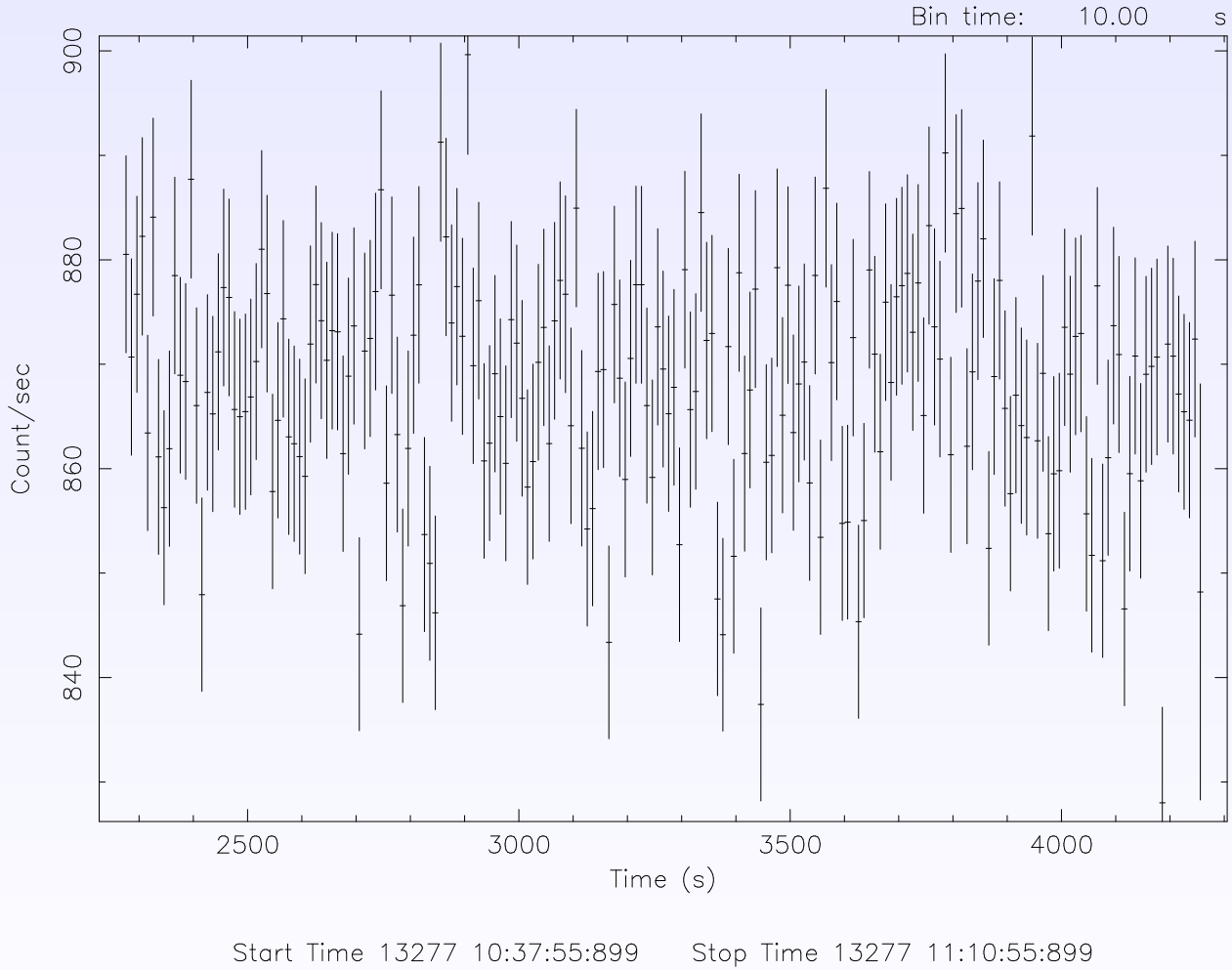


Detector light curve (SPTI data)

```
ibis_science_analysis
ogDOL="./og_ibis.fits[1]"
startLevel="LCR"
endLevel="LCR"
OBS1_ScwType="ANY"
CAT_refCat="$ISDC_REF_CAT"
SWITCH_disablePICsIT="NO"
SWITCH_disableIsgri="YES"
```

Resulting scw/*/picsit_lcr.fits files can be analysed with tools like lcurve

Crab, light curve from ScW 023900770010

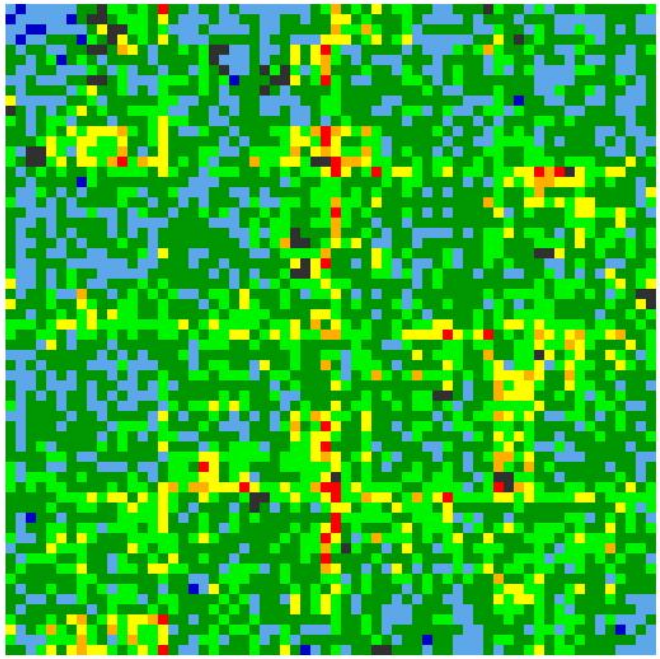


Start Time 13277 10:37:55:899 Stop Time 13277 11:10:55:899

More details on the standard software analysis can be found in:

http://www.iasf-bologna.inaf.it/∼foschini/OSAP/picsit_data_analysis.html

LIMITATIONS, count rate extraction method



2 ks shadowgram, 252-336 keV:
$\approx 1.2 \times 10^6$ background counts
≈ 1000 counts from source (over ≈ 2000 pixels)
about 0.5 counts per pixel

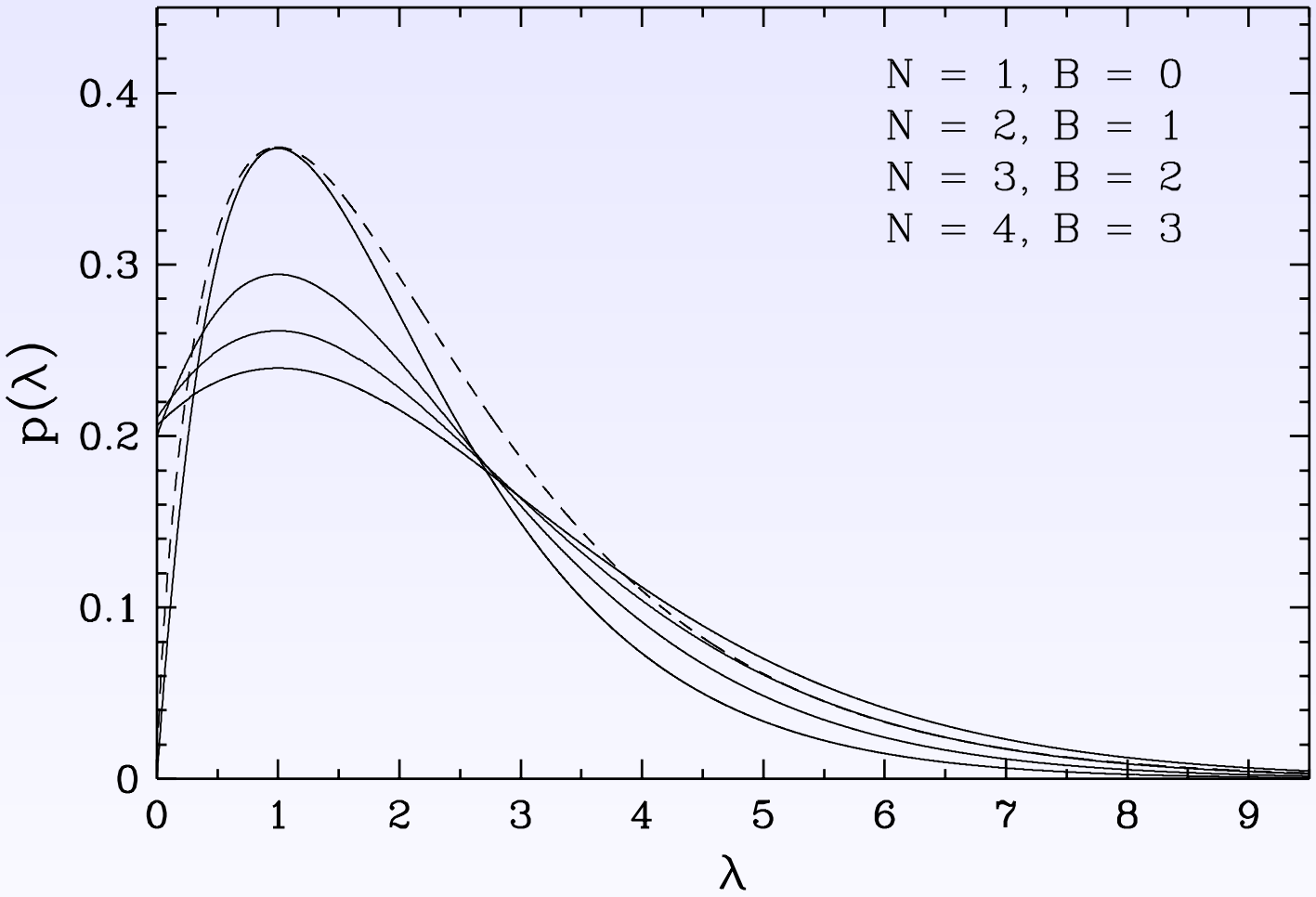
standard approximation of Gaussian type data will not work

Poisson distribution

Poisson probability density distribution, unknown net source counts λ, measured source+background counts N and background counts B

$$p(\lambda) = C \frac{e^{-(\lambda+B)}(\lambda+B)^N}{\Gamma(N+1)} \tag{1}$$

Poisson distribution is not defined for negative count rates !



Probability density distributions for low number of counts

Sum of two Poisson distributions is also Poisson distributed, with $\lambda = \lambda_1 + \lambda_2$

Difference of two Poisson distributions is not Poisson distributed !

Background and source have to be fitted together

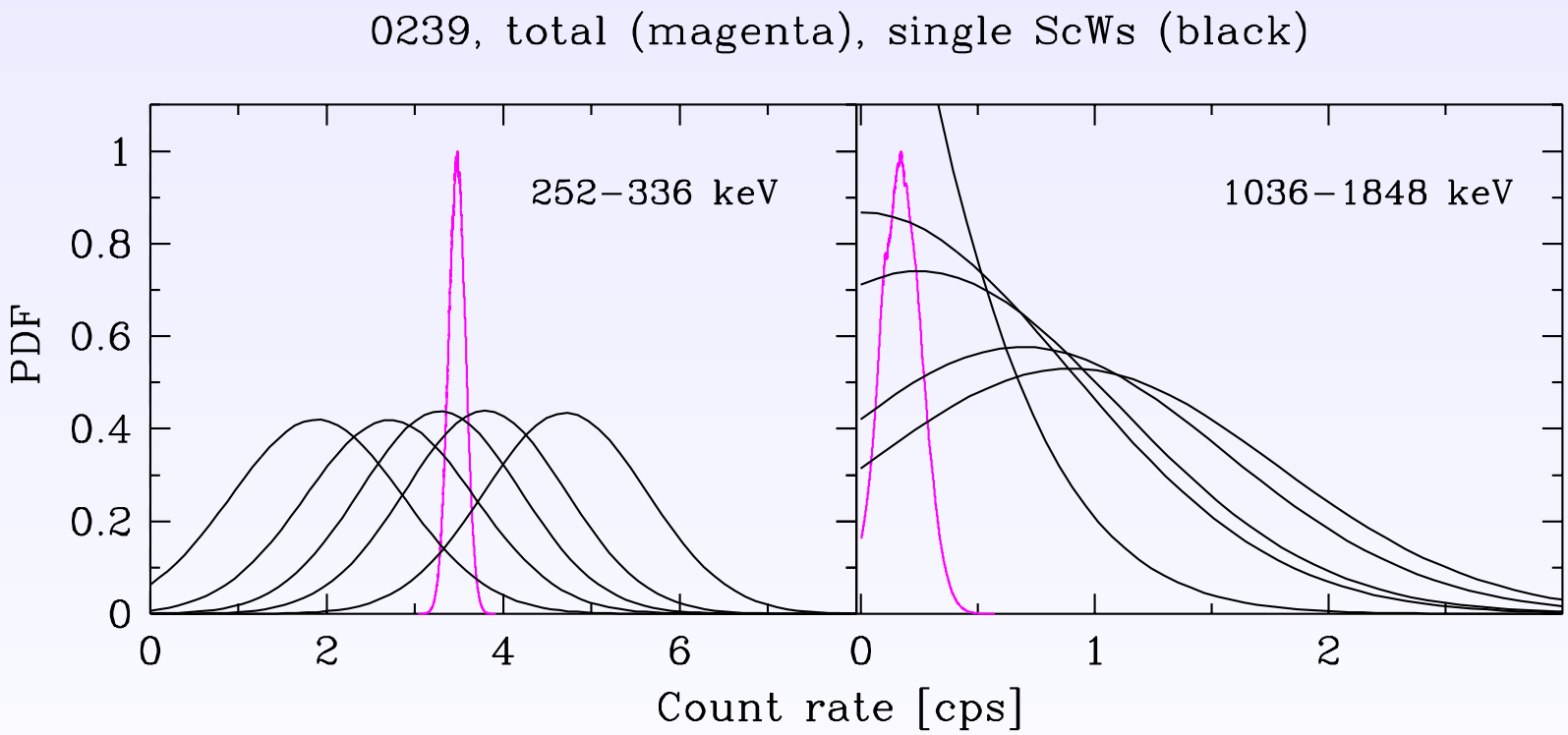
PDF method

Joint probability density determined as a product of distributions associated with each datum

$$P(\lambda) = \prod_{i=1}^{n} p_i(\lambda) \tag{2}$$

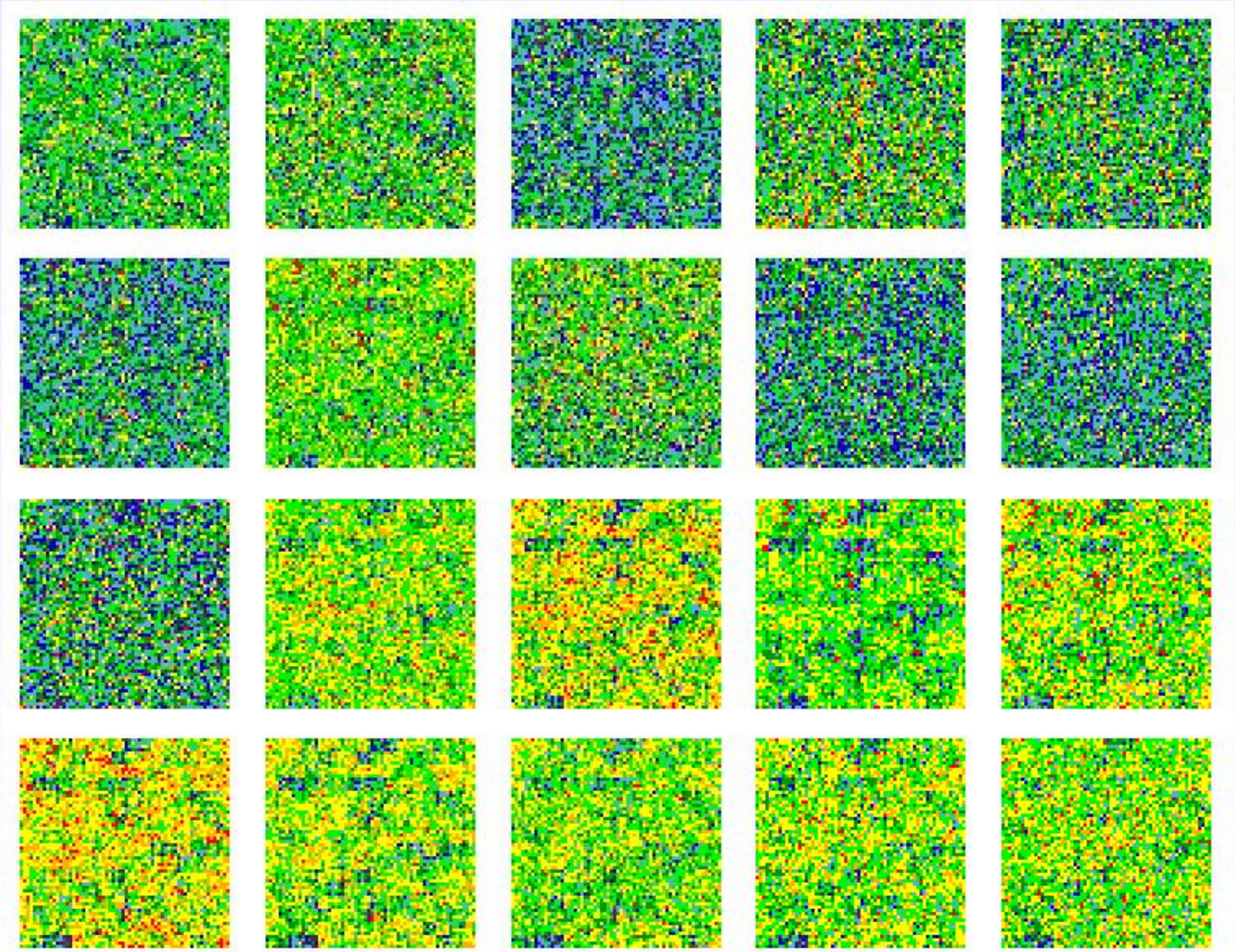
PDFs for source count rate and background map normalization extracted through the marginalization: integration over a nuisance parameter

PDF method, examples of the final result



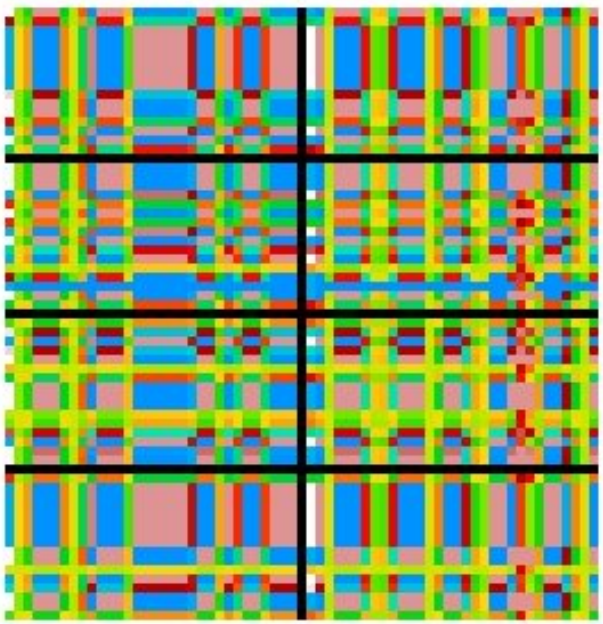
LIMITATIONS, adequate background maps

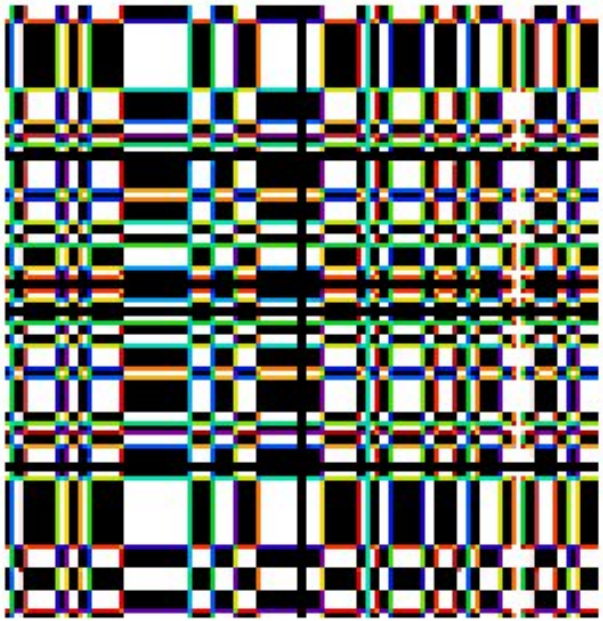
Difference between shadowgram from Rev. 0079 and shadowgrams from Revs. 0070 - 0090



LIMITATIONS, mask model

Mask transparency - PIF is energy dependent





LIMITATIONS, detection reliability

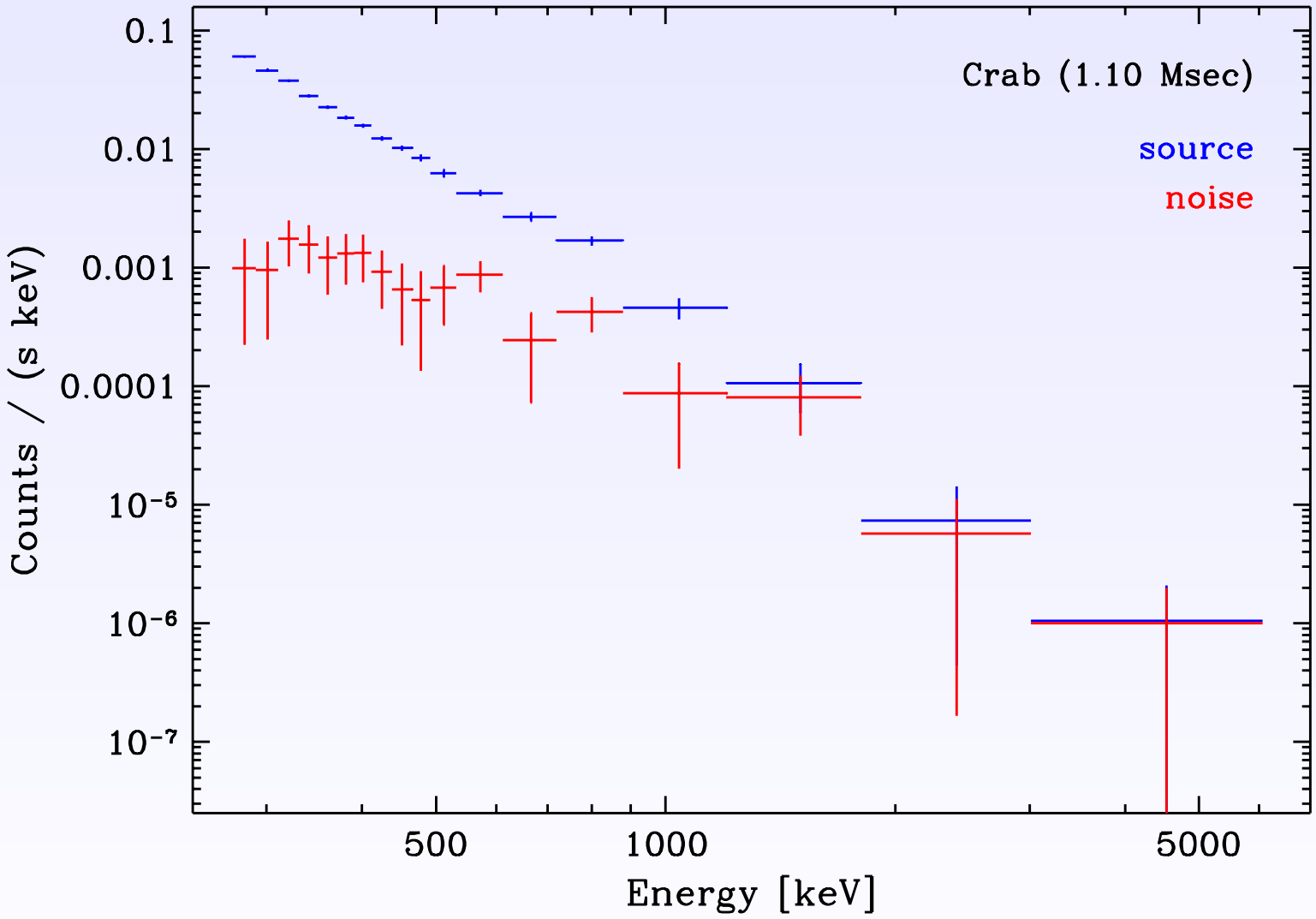
Simple 3 or 5 σ criterion works when the variance corresponds to the entire uncertainty, including all systematic effects

Noise (background fluctuations) level estimation

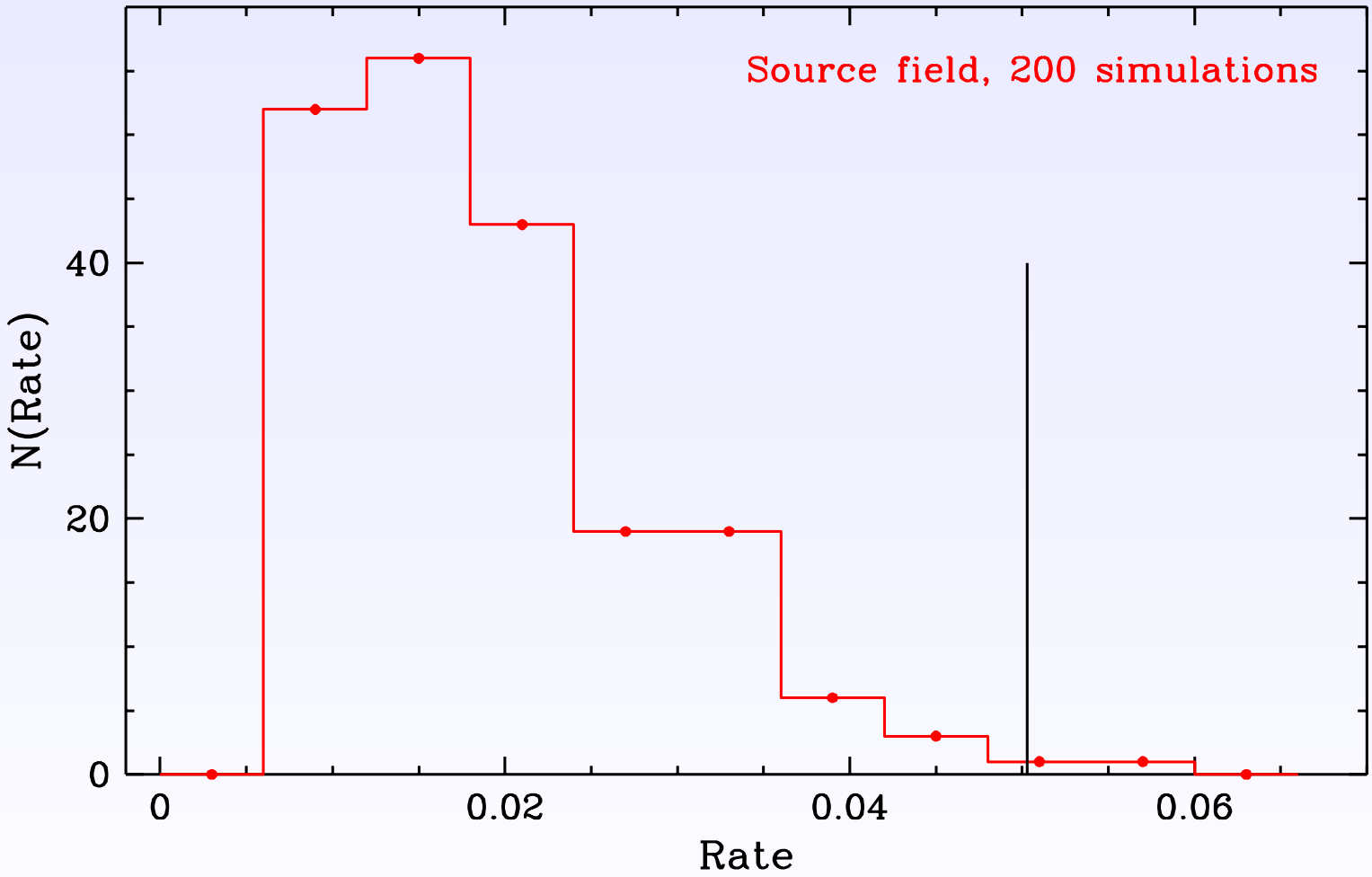
source PIF applied to empty field observations

or

source rate extraction done with randomized PIF for source field (equivalent to fitting a source with null rate)



Noise estimation histogram



CONCLUSIONS

- The only instrument on orbit in $\sim$ 1 MeV range with a high angular resolution
- Currently PICsIT can be used only for very strong sources
  - Crab
  - Cyg X-1
  - sources in outburst
  - strong, long GRBs
- Standard OSA software has limitations
  - rate extraction method
  - background maps
  - mask model/PIF energy dependence
- Advanced method with better instrument model should make it possible to detect about 20 persistent sources provided enough exposure