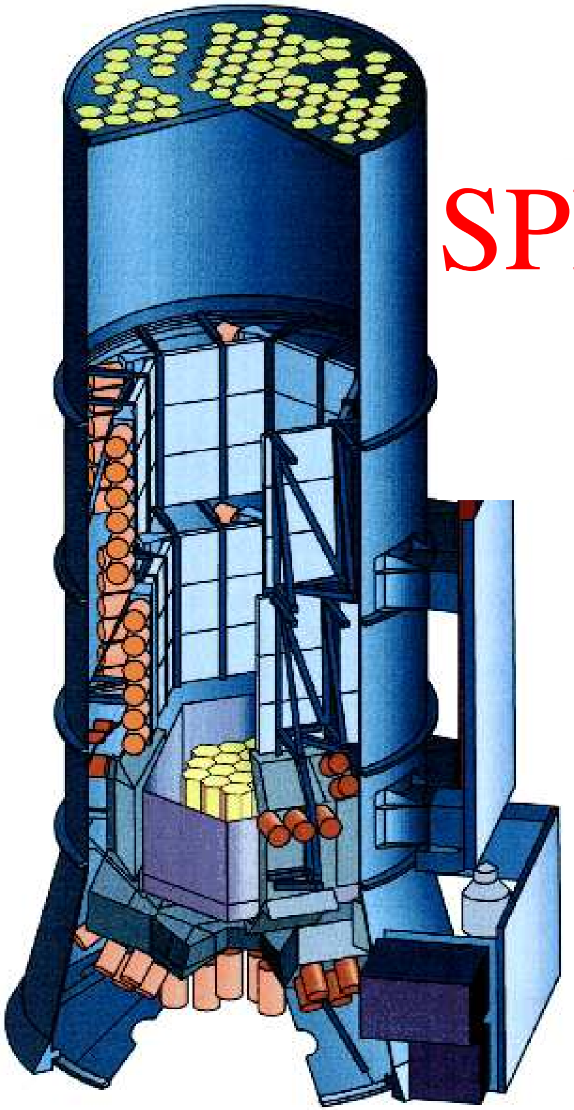
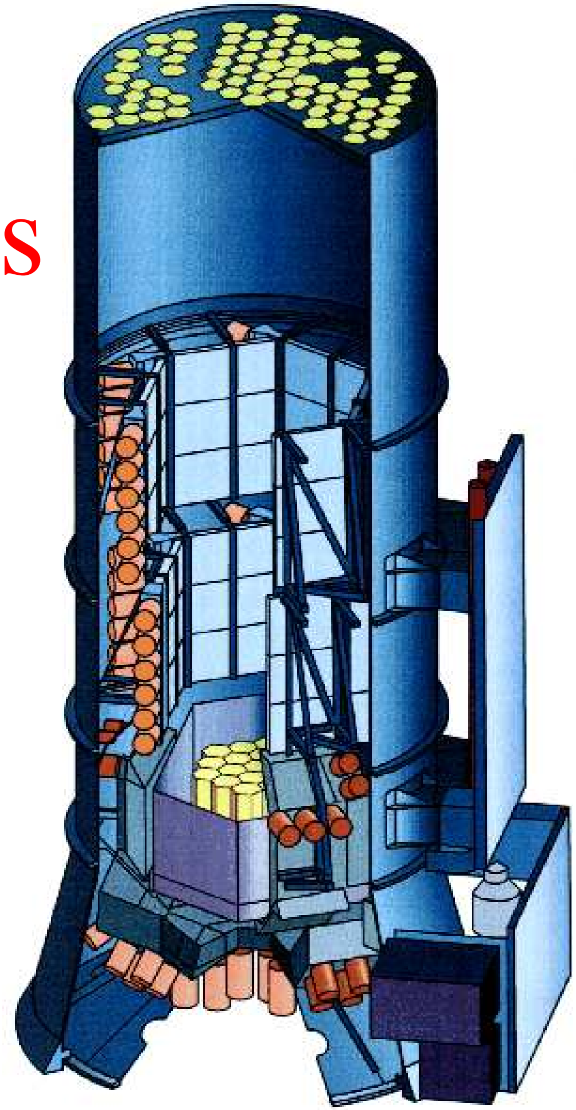


SPI Data Analysis



A. Strong
MPE

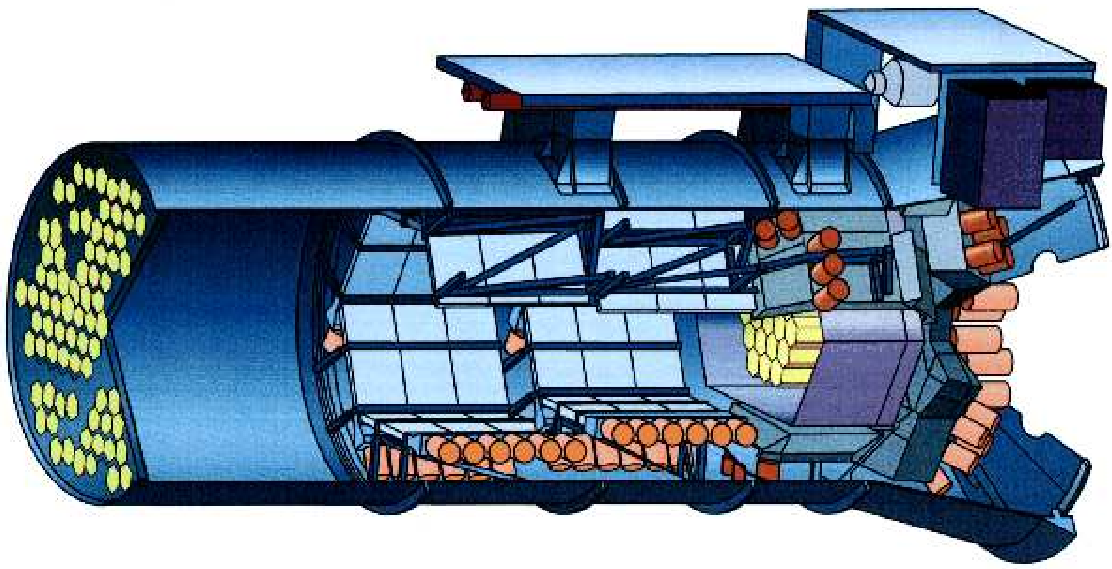
Moriond, Les Arcs 2002

SPI Data Analysis

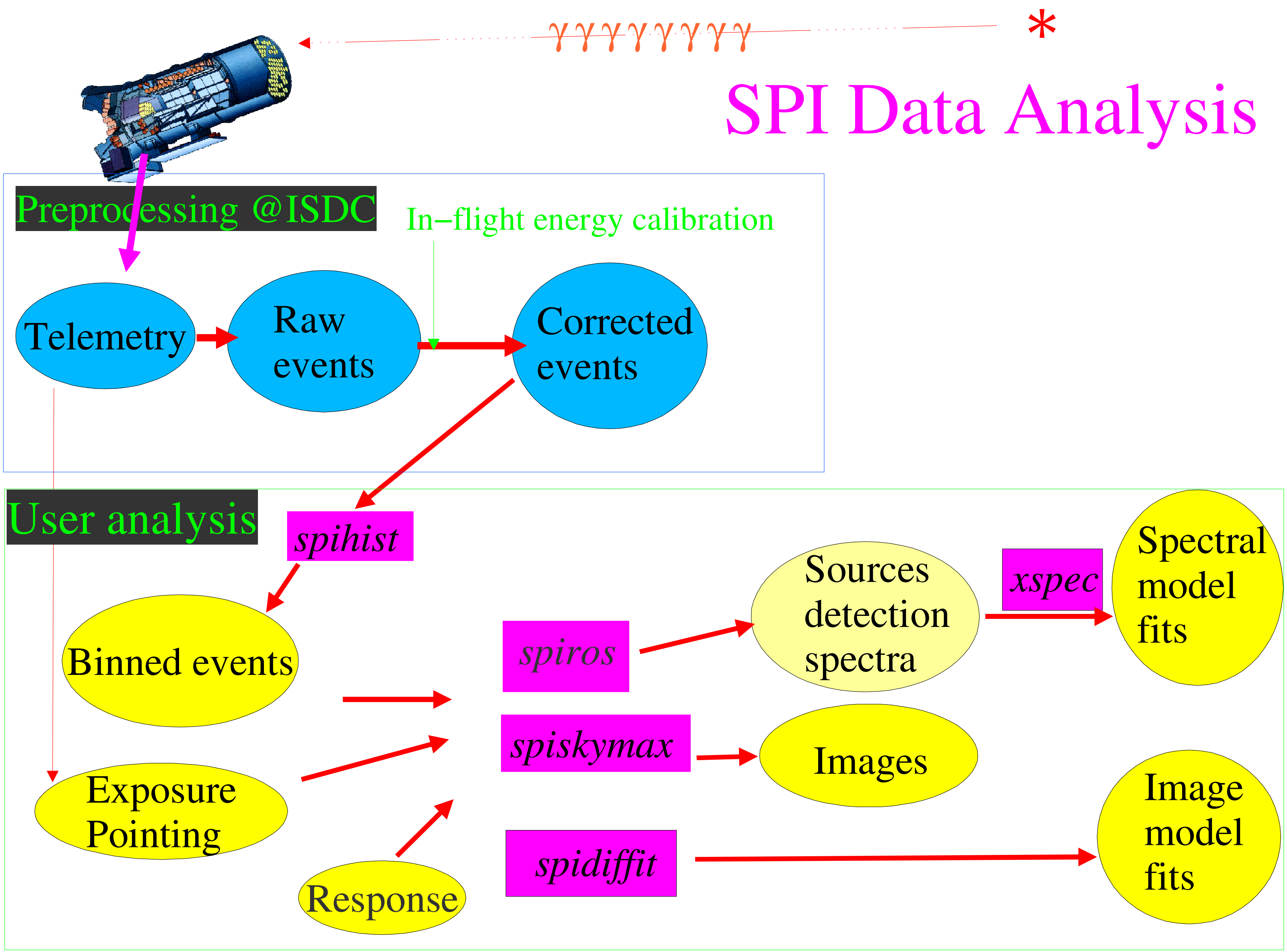
Data & response

Analysis methods

Examples from
* calibration
* simulations



SPI Data Analysis



SPI Response

(B. Teegarden et al. GSFC)

IRF = Instrument Response Function

f(θ, ϕ, detector, E_γ , E'_γ)

based on extensive GEANT simulations using SPI mass model

IRF *factorized* into components to make tractable:

mask * interaction * energy response

Also for given direction: energy response f(detector, E_γ , E'_γ)
(e.g. for use in *xspec*).

Large datasets, available at ISDC.

Access software interpolates in IRF to obtain
response for any angle, detector, energy.

Event binning

Corrected events

γγγγγ

spihist

Singles Det. 0–18

Multiples Det. >18
'pseudo–detectors' handled in same way as singles, response available.
Standard case: 85 pseudodetectors

Binned event spectra

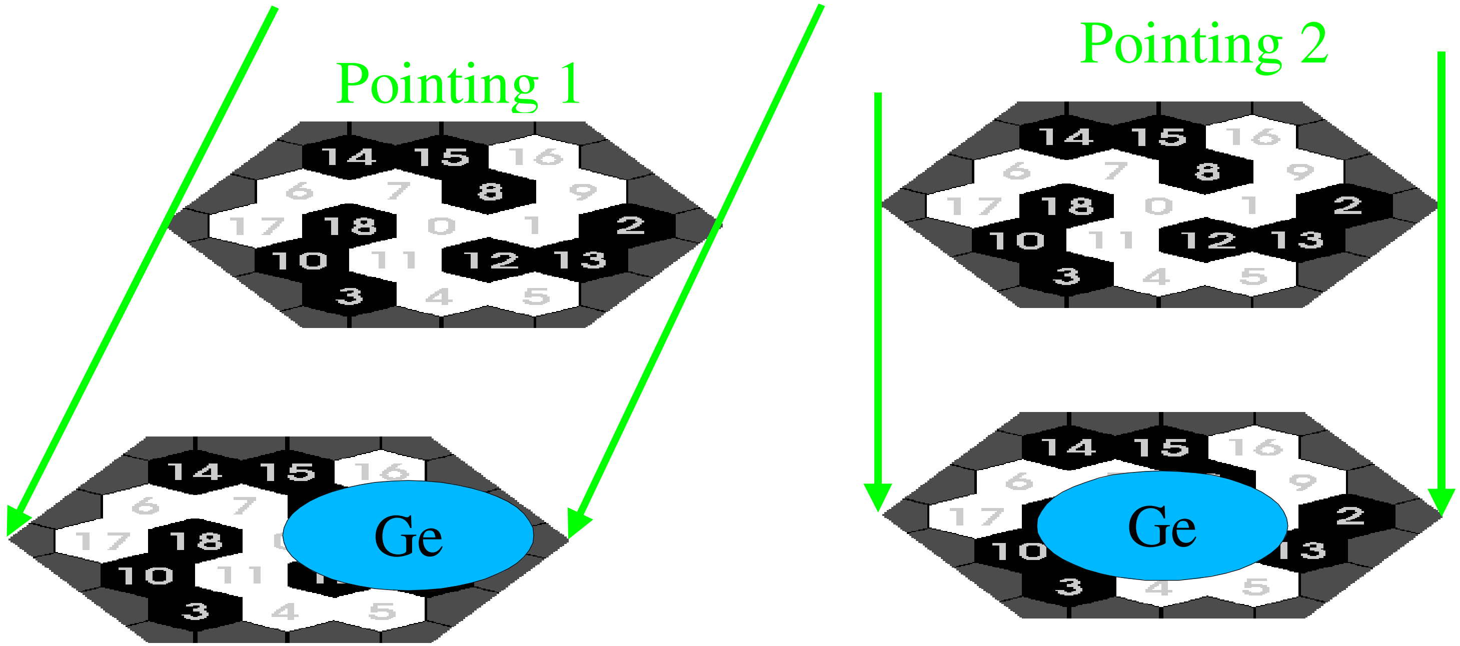
Pointing1 Counts spectra Detector 1 2 3 ... 85

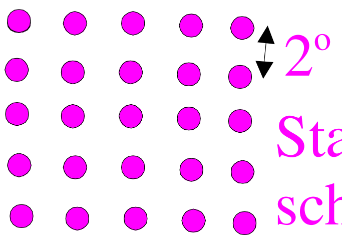
Pointing 2 ....

Pointing 3..................

General principle of SPI observing

Multiple pointings/observation:
–>covers mask pattern = better coding
–>determination of background





Standard 25 pointing scheme

Sample different parts of mask pattern

Analysis methods use *forward−folding*

data = image * response + background

Iterative methods: comparing predicted with observed data.

Correlation used only for fast initial source search in ***spiros***. Cf IBIS, JEM−X which use correlation only!

Background treatment

19 detectors, or 85 pseudo detectors each with its own background.
Have to solve for these along with sources/image!

Multiples: lower background, mult~single at high E

Series of pointings: background ~ constant while source mask pattern moves around –> can solve for background

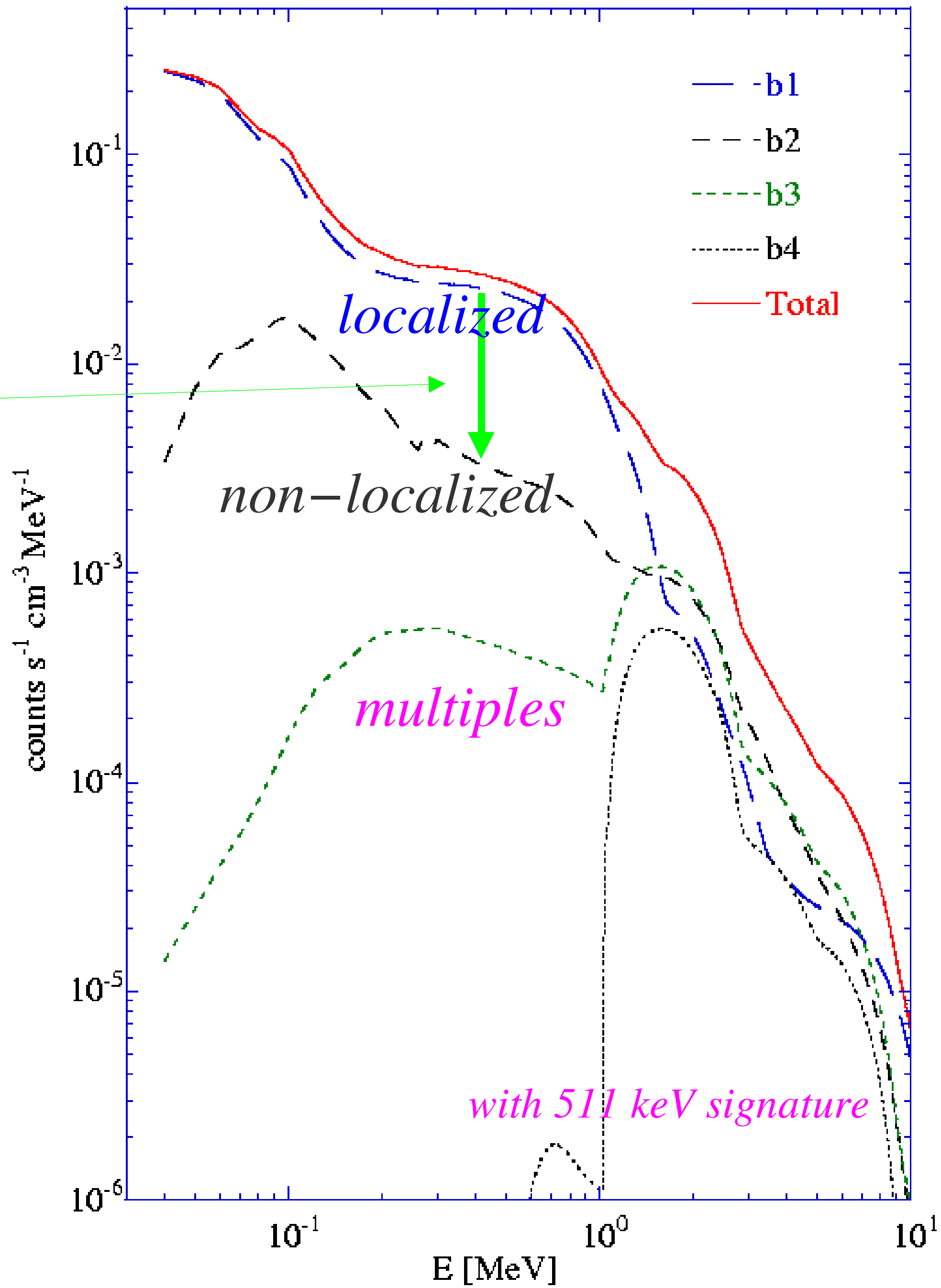
If background time–dependent, need *template* of time–dependence to fit to data: use *spiback*.

Both *spiros* and *spiskymax* methods solve for background including time–dependent template. [However if background steady, all the better].

Time–dependence: can be based on e.g. anticoincidence shield rates.

Hard to test before real data available !

SPI in−orbit background estimate (P.Jean)



Backgound reduction by PSD >200 keV

Used for observation simulations

spiros

SPI Iterative Removal of Sources
(Paul Connell, U. Birmingam, UK)

Finds and locates sources, generates spectra
Constrained linear method using likelihood function
(+ initial rough seach using correlation).

1. correlation search to find sources, with iterative removal
2. simultaneous fitting to find source positions
3. spectral fitting for all sources
4. also features imaging via splines, temporal variations

Output (counts/source) can also be input to *xspec* for spectral model fitting.

spiskymax

Maximum Entropy Imaging

method: Bayesian parameter estimation
parameters = image pixels + background

application: extended emission, but also sources

output: skymaps, profiles, source fluxes with error estimates

spidiffit

diffuse lines, continuum
INTEGRAL large–scale surveys,
Core Program GCDE + GPS
[+ commission phase + all public data]
typically few 1000 pointings.

skymaps generated in line energy, continuum bands by *spiskymax*

but for spectra and quantitive analysis best to use model–fitting
since fewer parameters *cf* skymapping and specific questions addressed

eg ^{26}Al fit to free–free 90 Ghz map
continuum fit to HI+CO+inverse Compton+unresolved sources
spidiffit
Bayesian method
parameters probability distributions
flexible : error estimates on function of parameters

SPI Calibration

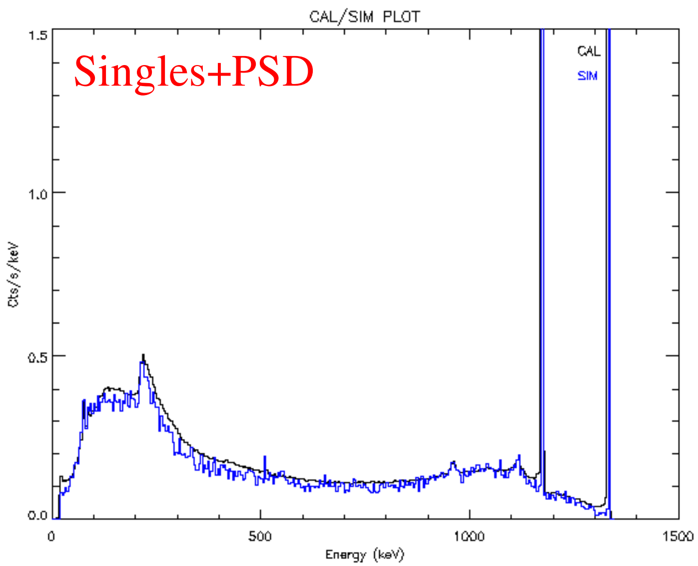
Bruyeres–le–Chatel, April 2001

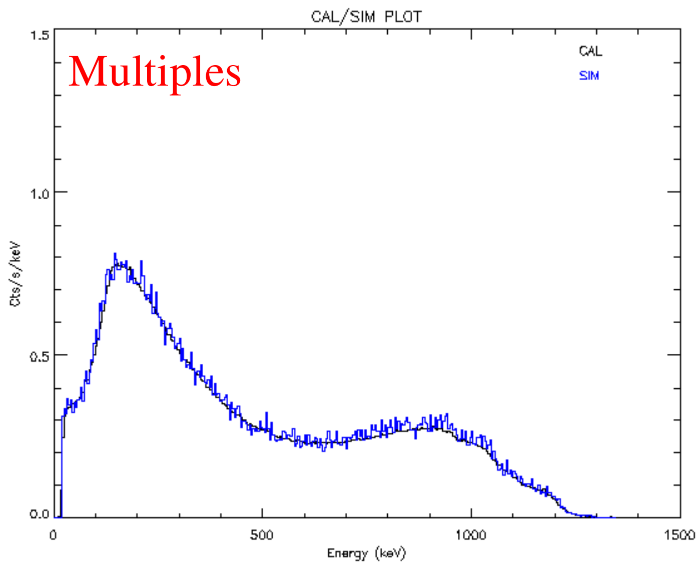
Spectral and imaging properties of SPI

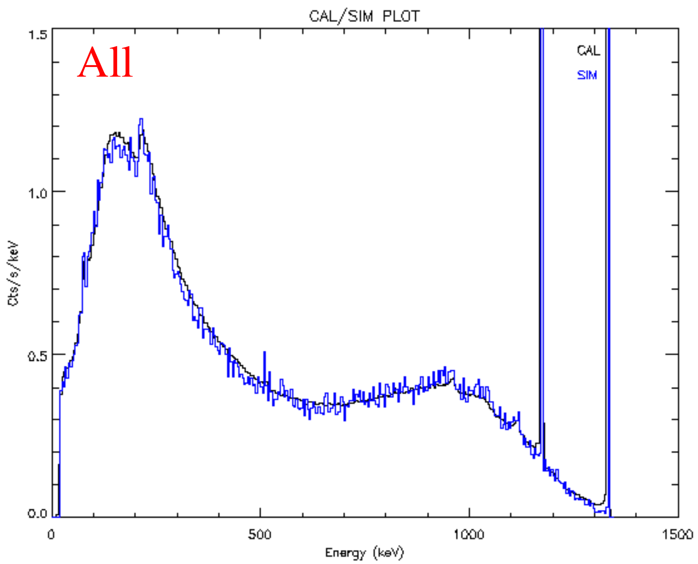
Comparison of response with model.

Imaging: sources at 125m distance (‘parallel beam’)

Latest Simulation Results – ^{60}Co, 8 Meters,no mask



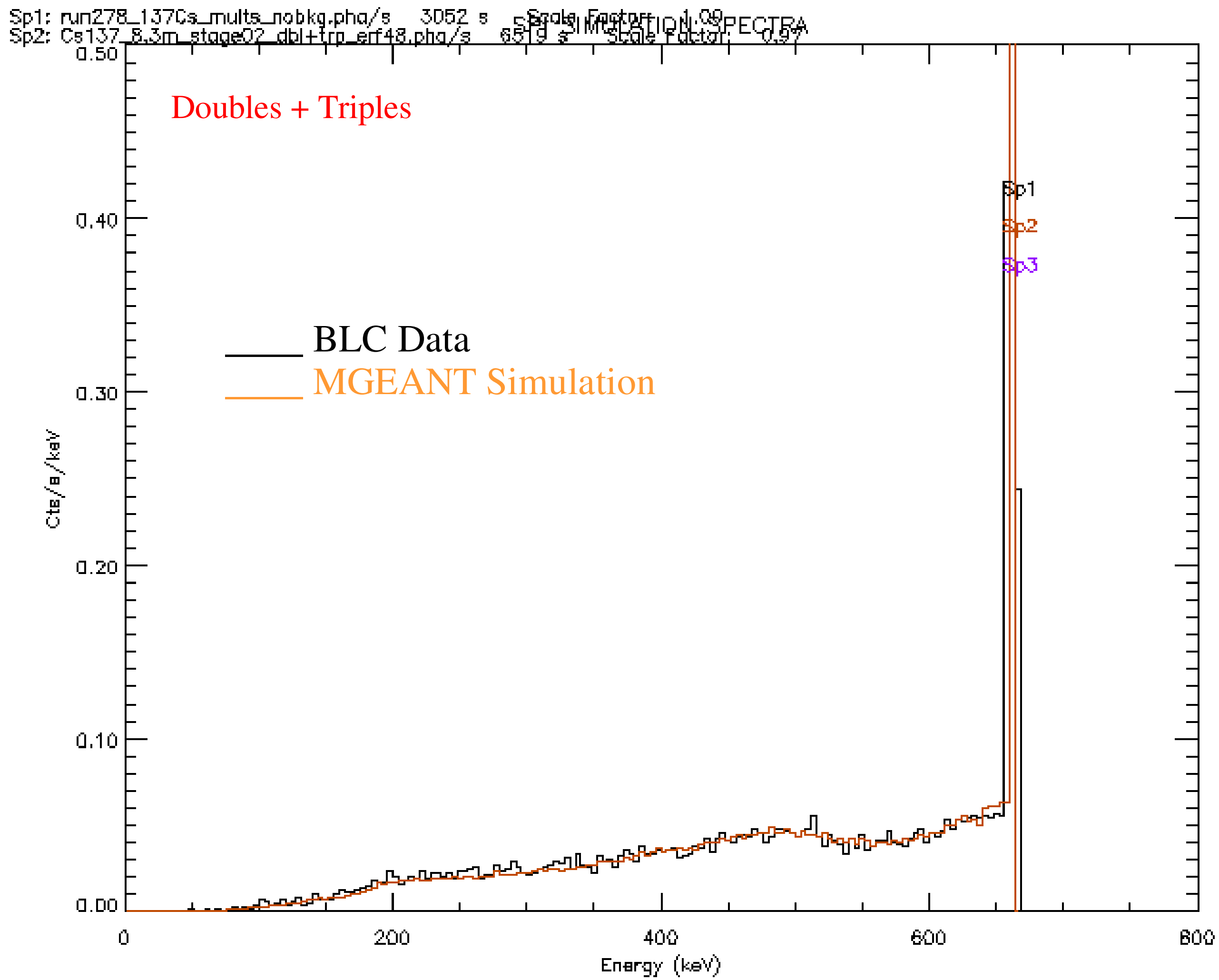




____ BLC Data
____ MGEANT Simulations

- 3% dead time applied to simulations

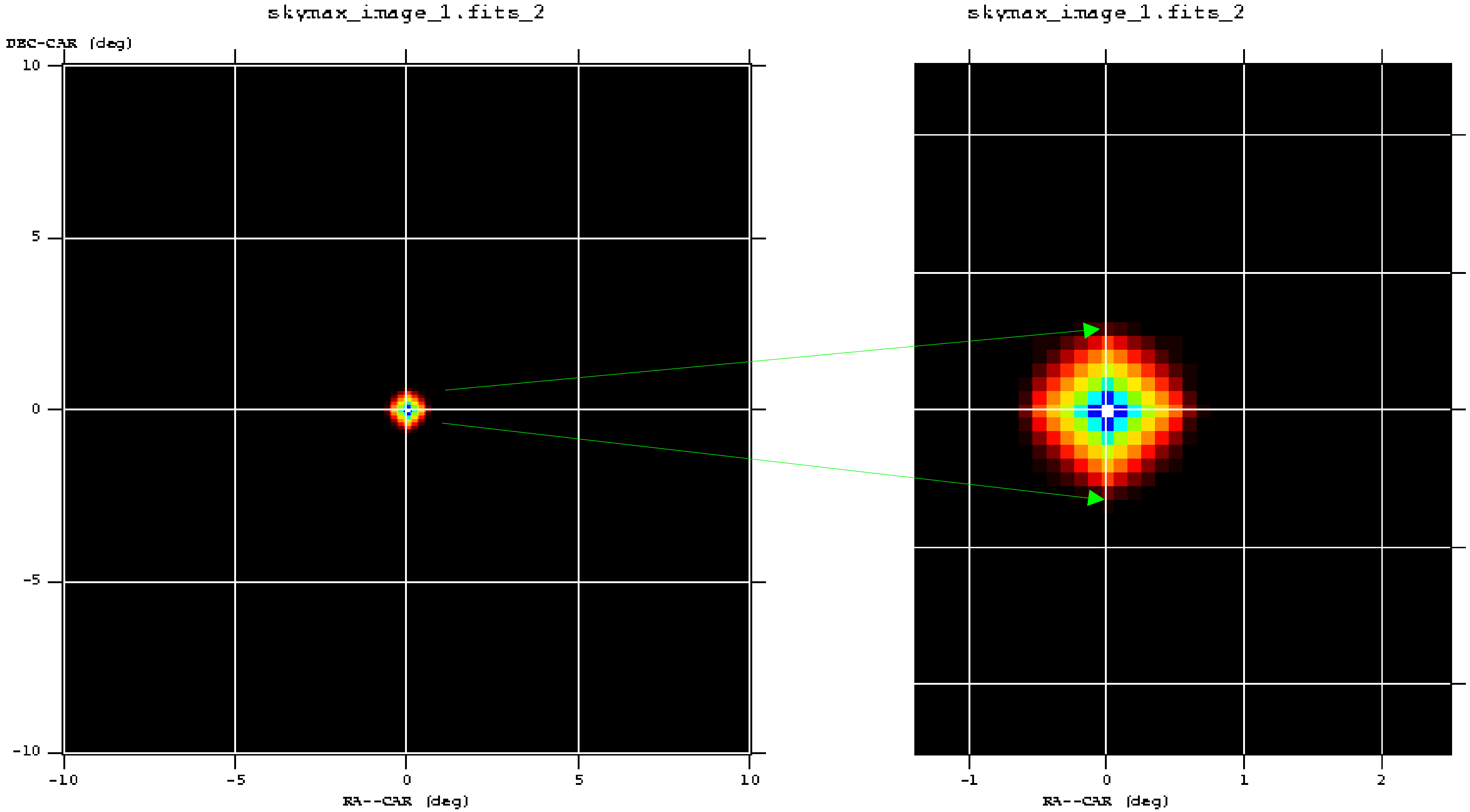
Latest Simulation Results – ^{137}Cs, 8.3 m, ISDC Processing, Mask



Singles+PSD+doubles+triples BLC run 31

^{60}Co 1173 keV 125m   on−axis

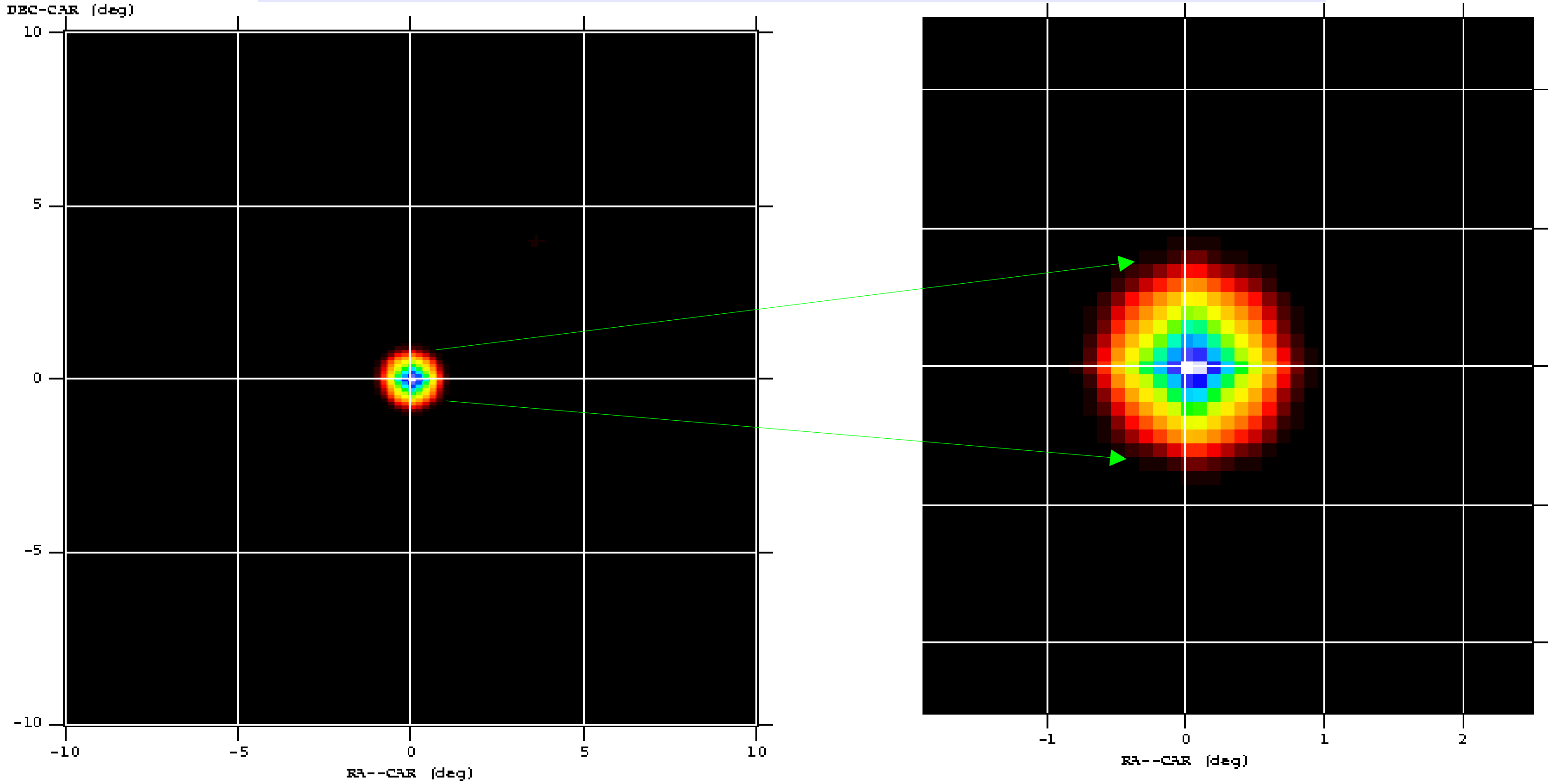
spiskymax   IRF from GSFC



Multidetectors: Singles+PSD + doubles +triples

^{60}Co 125m 11 pointings

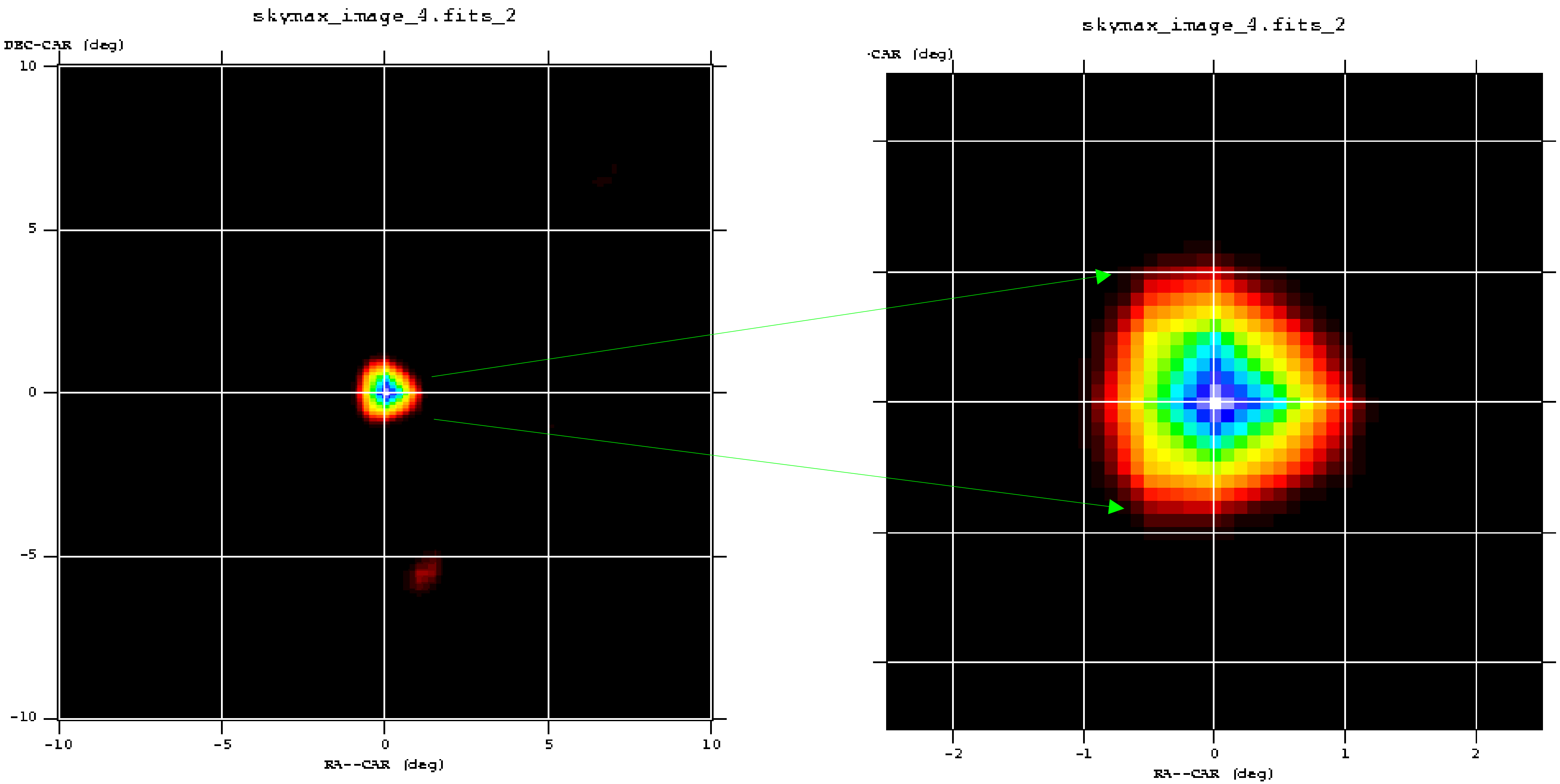
spiskymax IRF from GSFC



Multidetectors: doubles + triples ONLY

^{60}Co 125m 1 pointing, on–axis, BLC run 31

spiskymax IRF from GSFC

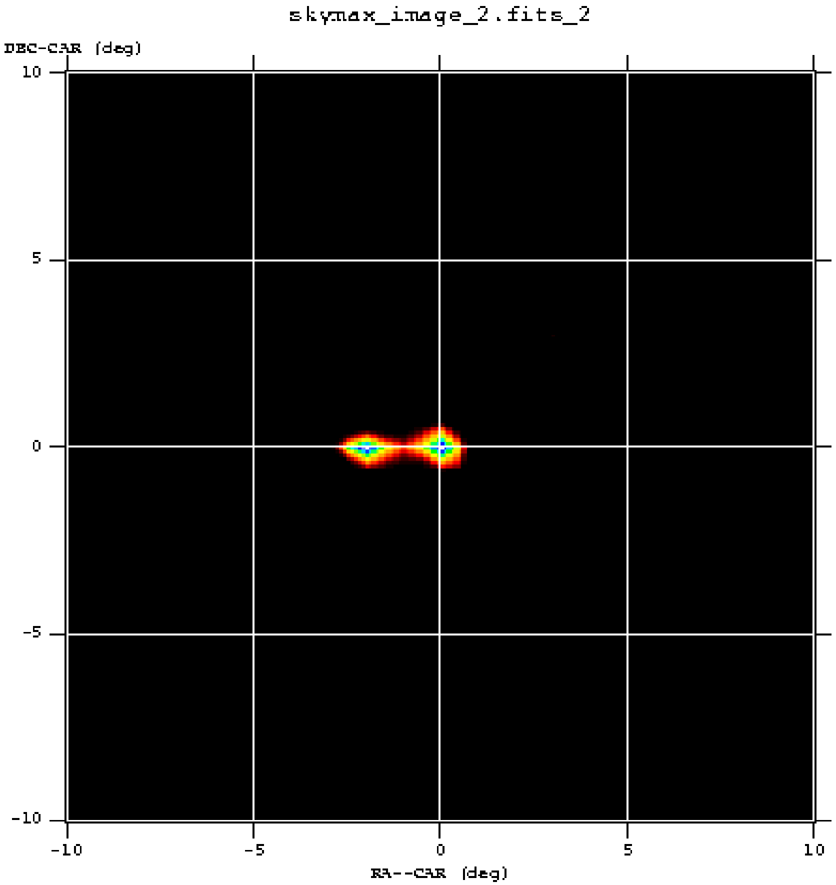


Synthesize dithered observation of 2 sources separated by 2^{o}

^{60}Co 125m singles + PSD +doubles+triples

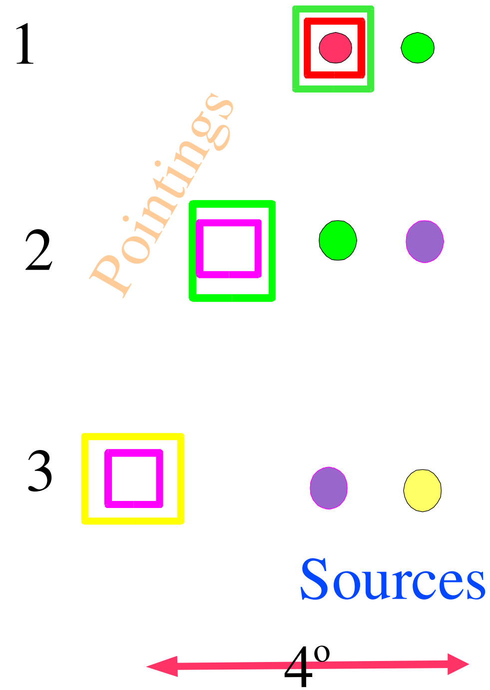
5 pointings, *spisumhist* to synthesize data

Shows how dithering improves imaging by sampling full source pattern



Higher iteration

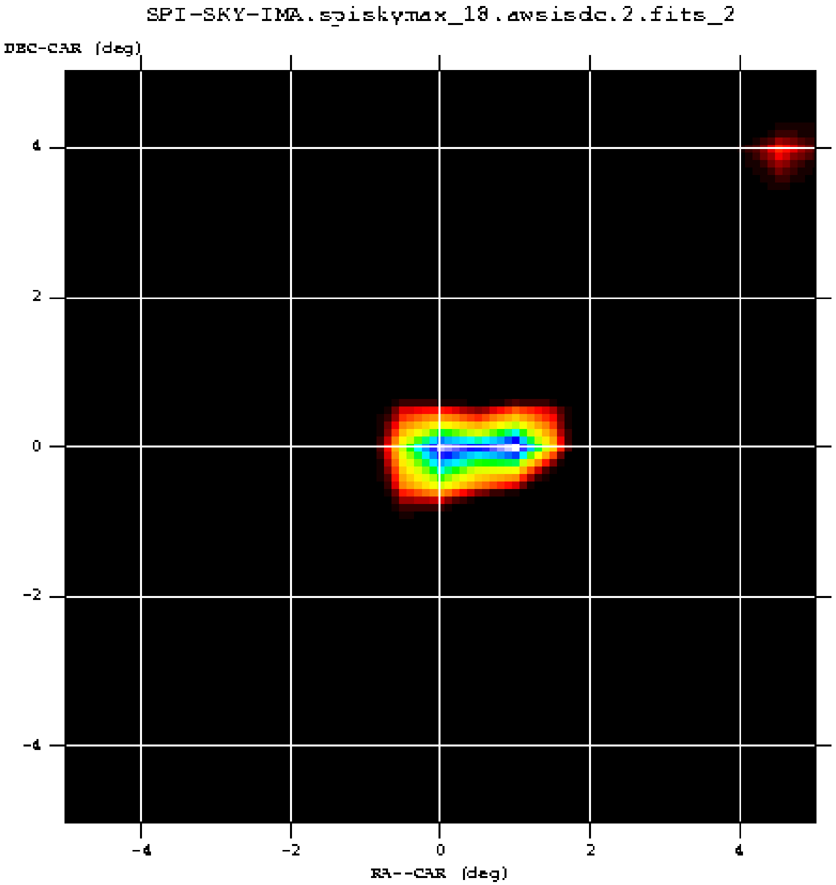
Synthetic pointing

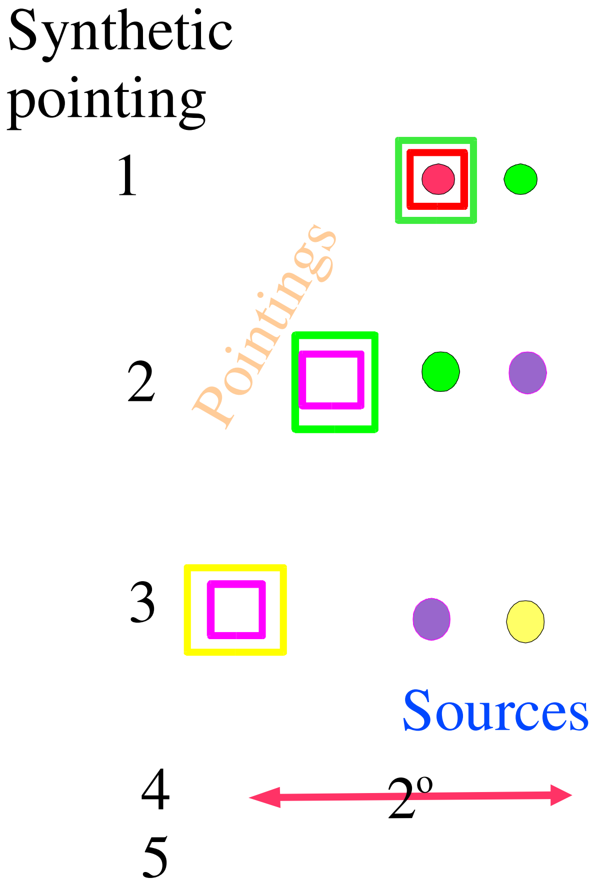


Synthesize dithered observation of 2 sources separated by 1°

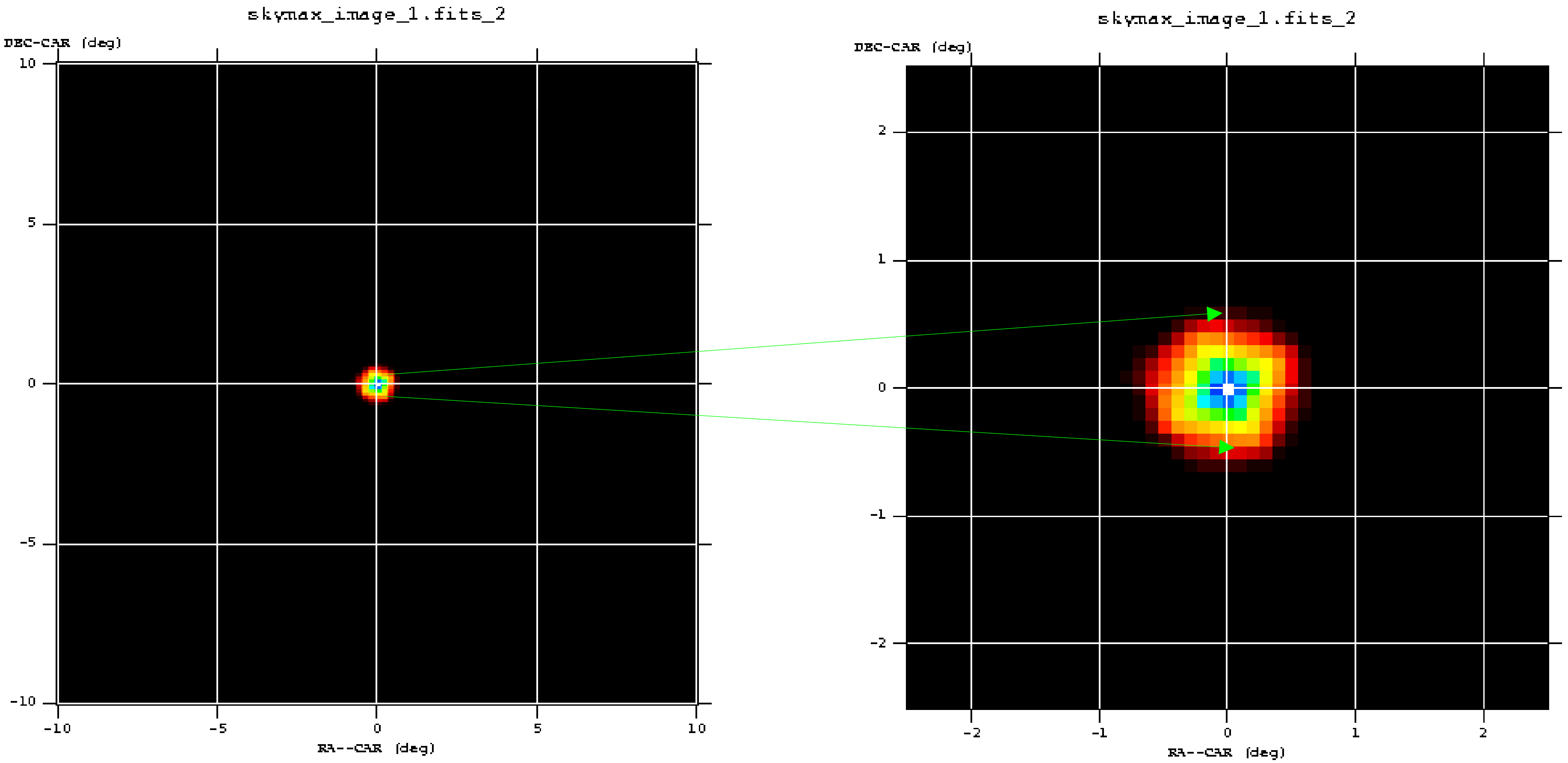
^{60}Co 125m singles + PSD +doubles+triples

5 effective pointings, *spisumhist* to synthesize data





Singles+doubles+triples   BLC run 329
^{24}Na 2754 keV 125m 0°
spiskymax   IRF from GSFC

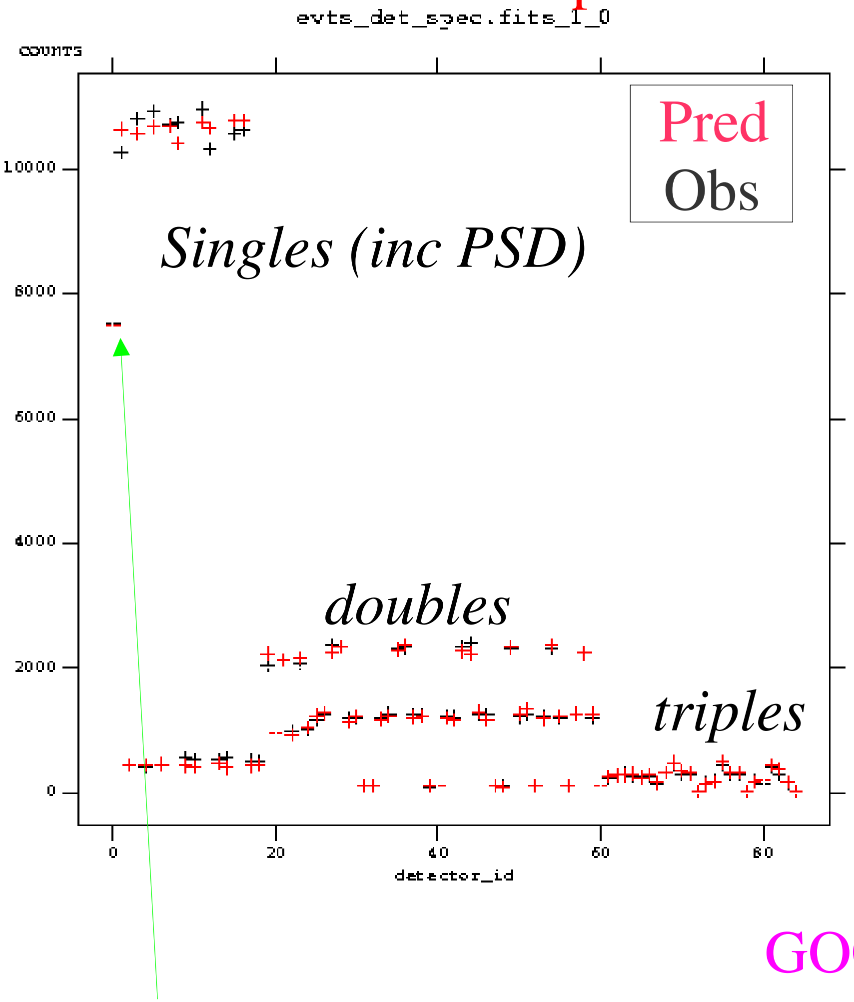


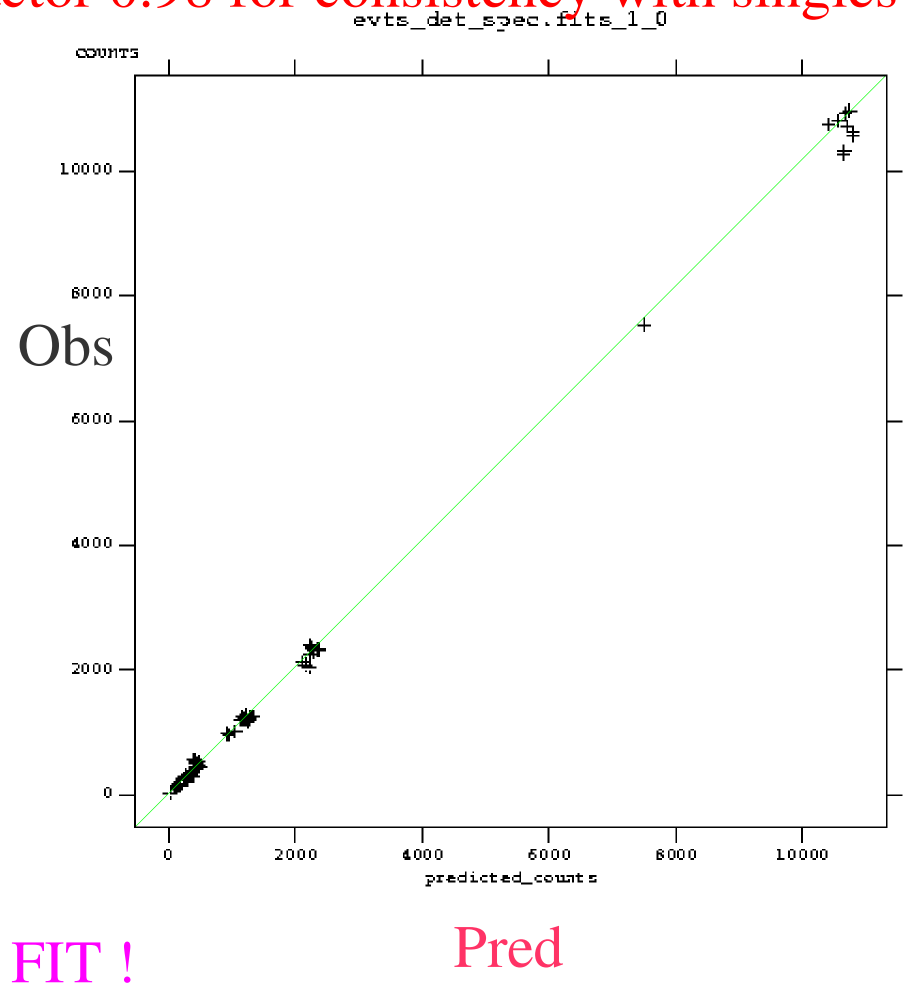
Comparison of observed and predicted counts

^{60}Co 125m using new GSFC IRFs.

BLC Run 31 on–axis, spihist 2.1.2

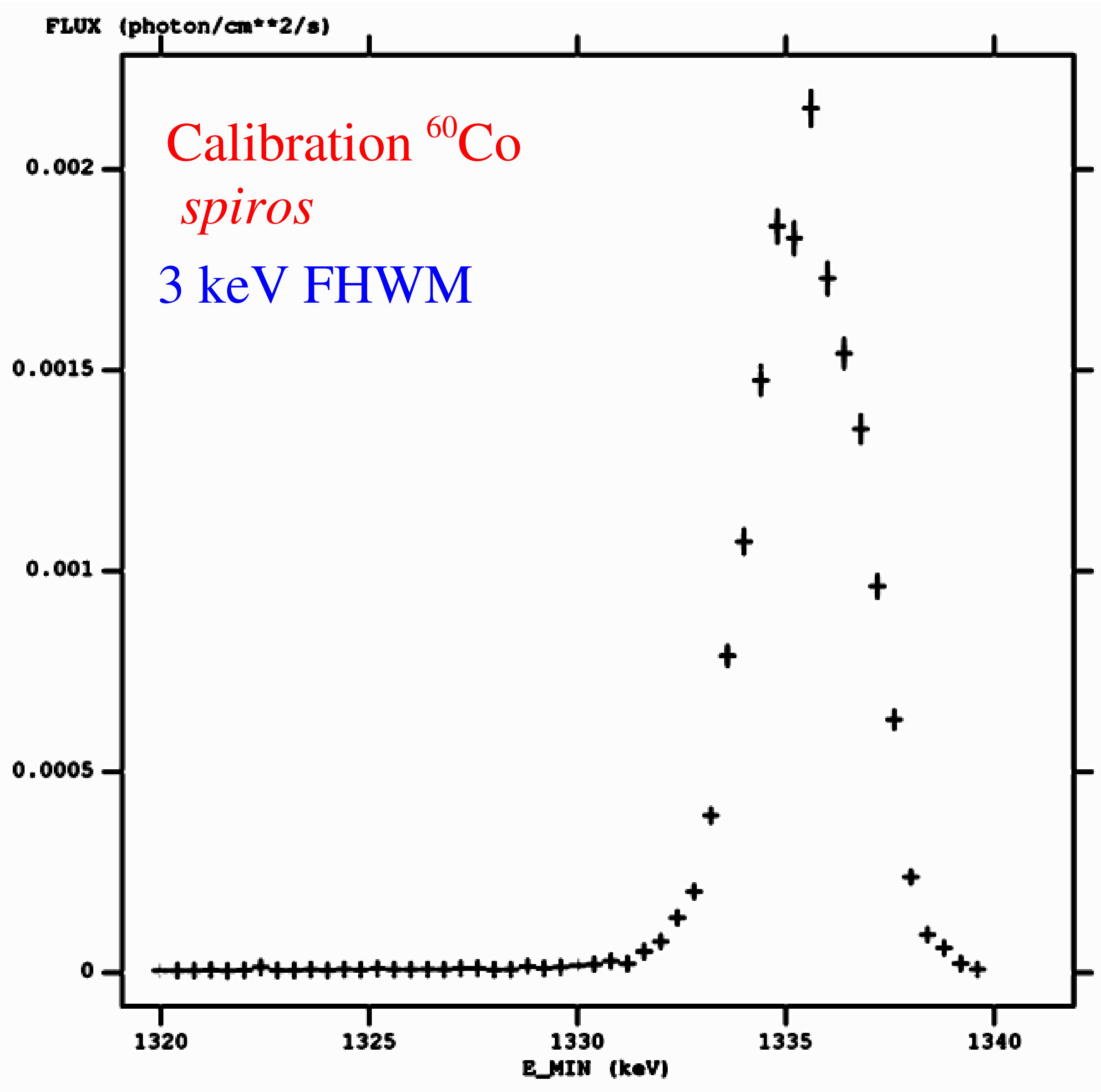
multiples livetime factor 0.98 for consistency with singles





GOOD FIT !

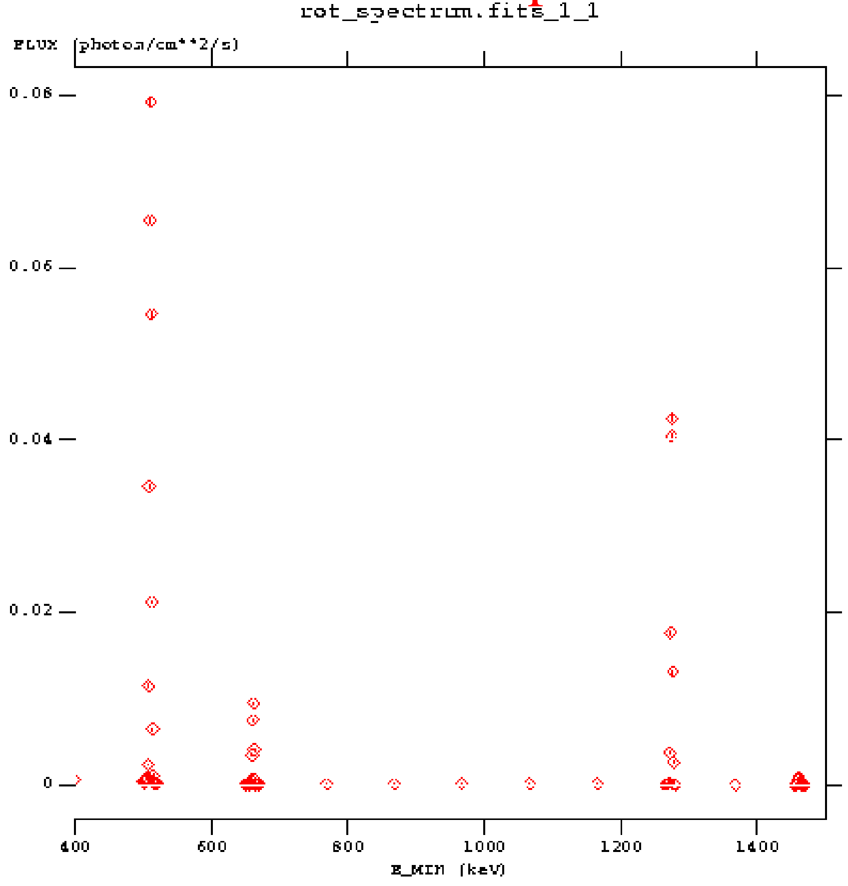
Central obscurer well modelled

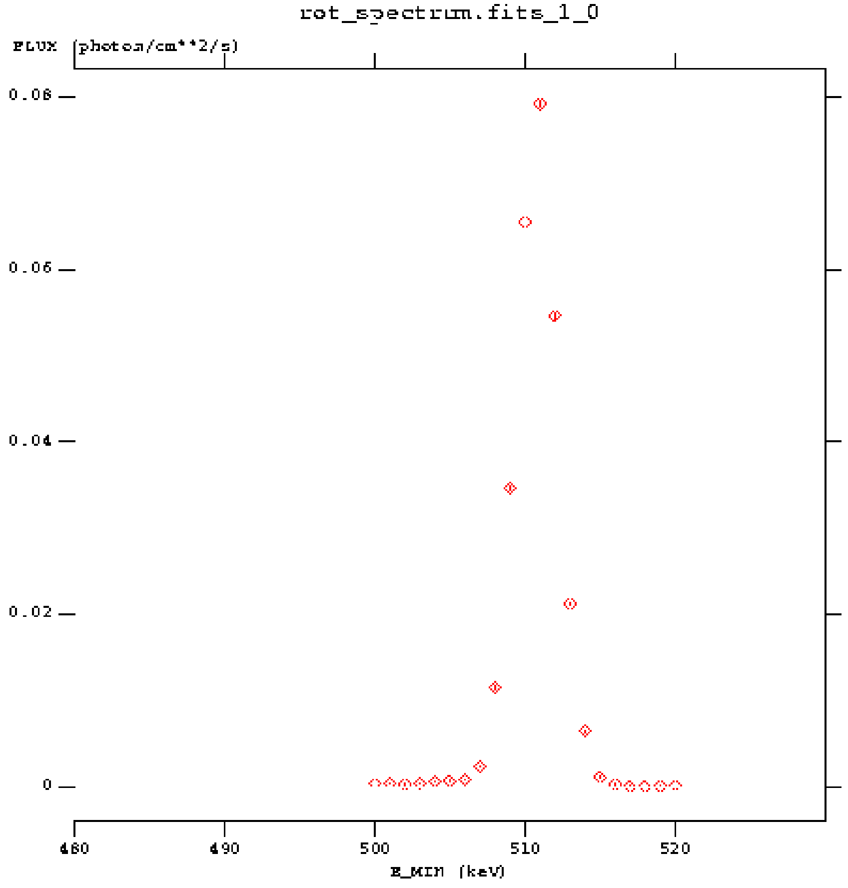

FLUX (photon/cm**2/s)
Calibration ^{60}Co
spiros
3 keV FHWM
0.002
0.0015
0.001
0.0005
0
1320
1325
1330
1335
1340
E_MIN (keV)

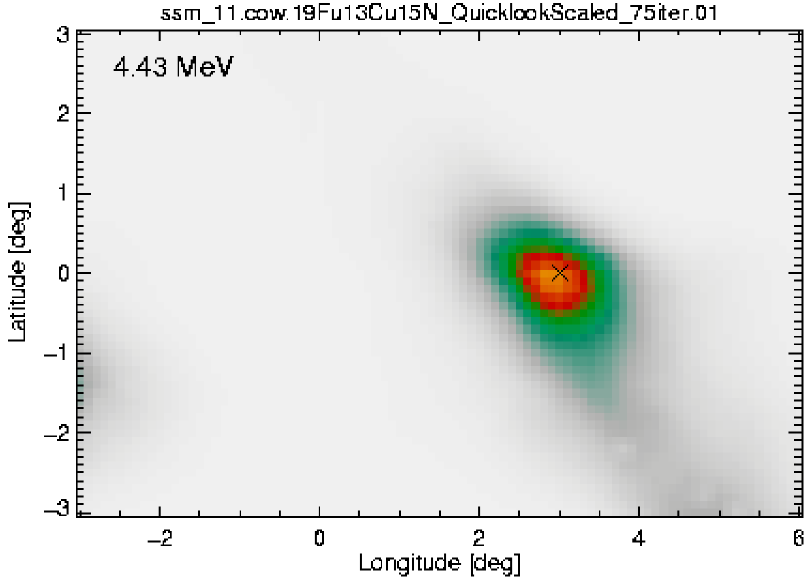
ESTEC Reference Orbit Test

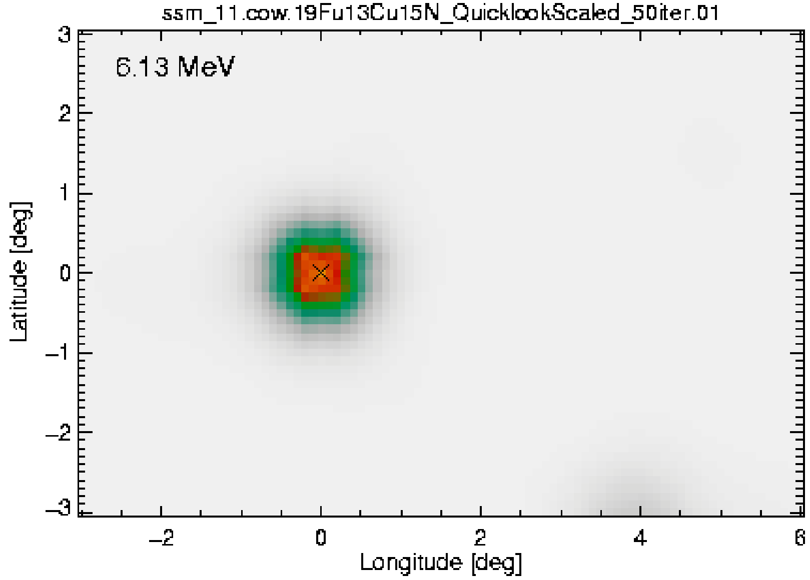
^{22}Na, ^{137}Cs 4 science windows

spiros



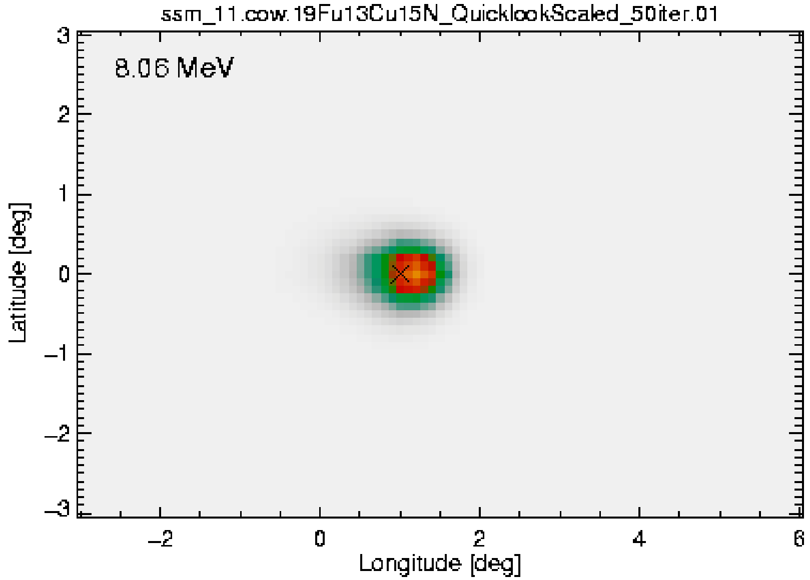






SPI Test Setup: C. Wunderer, MPE. Accelerator U. Stuttgart

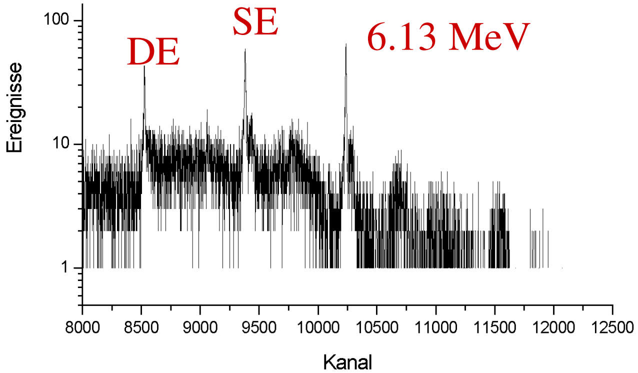
Maximum Entropy Images

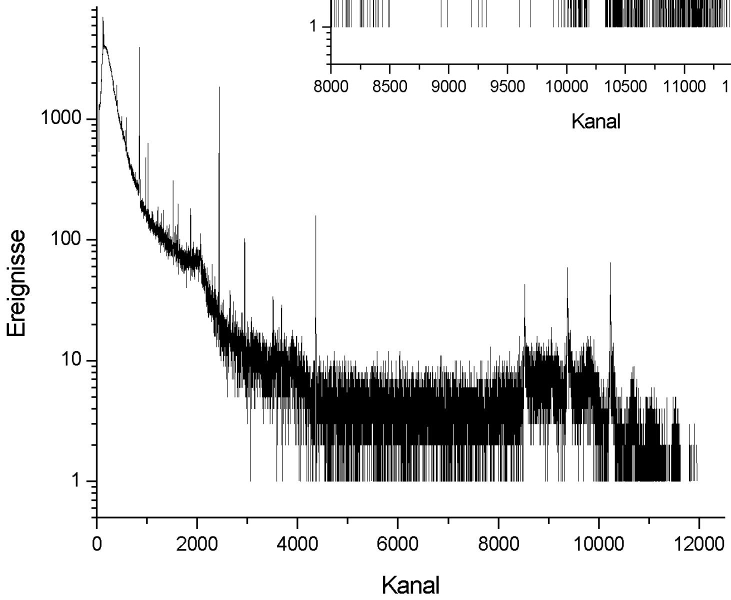


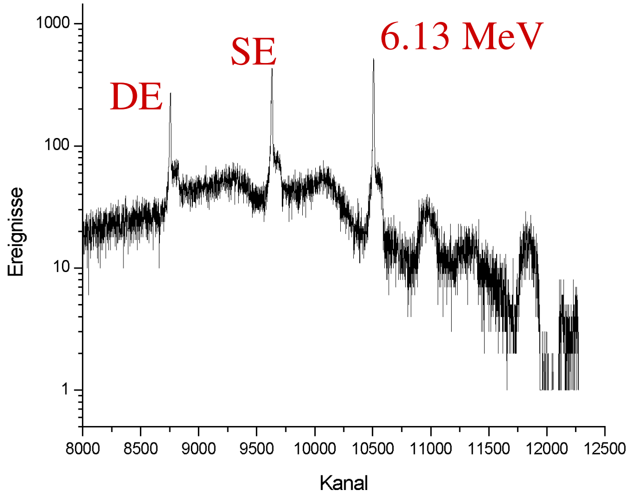
SPITS at IfS

$^{19}F\ (p,\alpha\gamma)\ ^{16}O$ – Spectra from 2 Detector positions

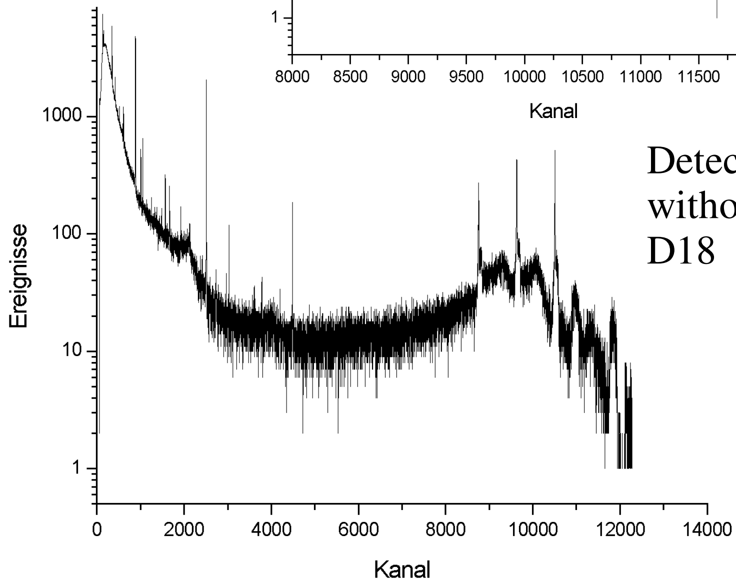
Detector with D18



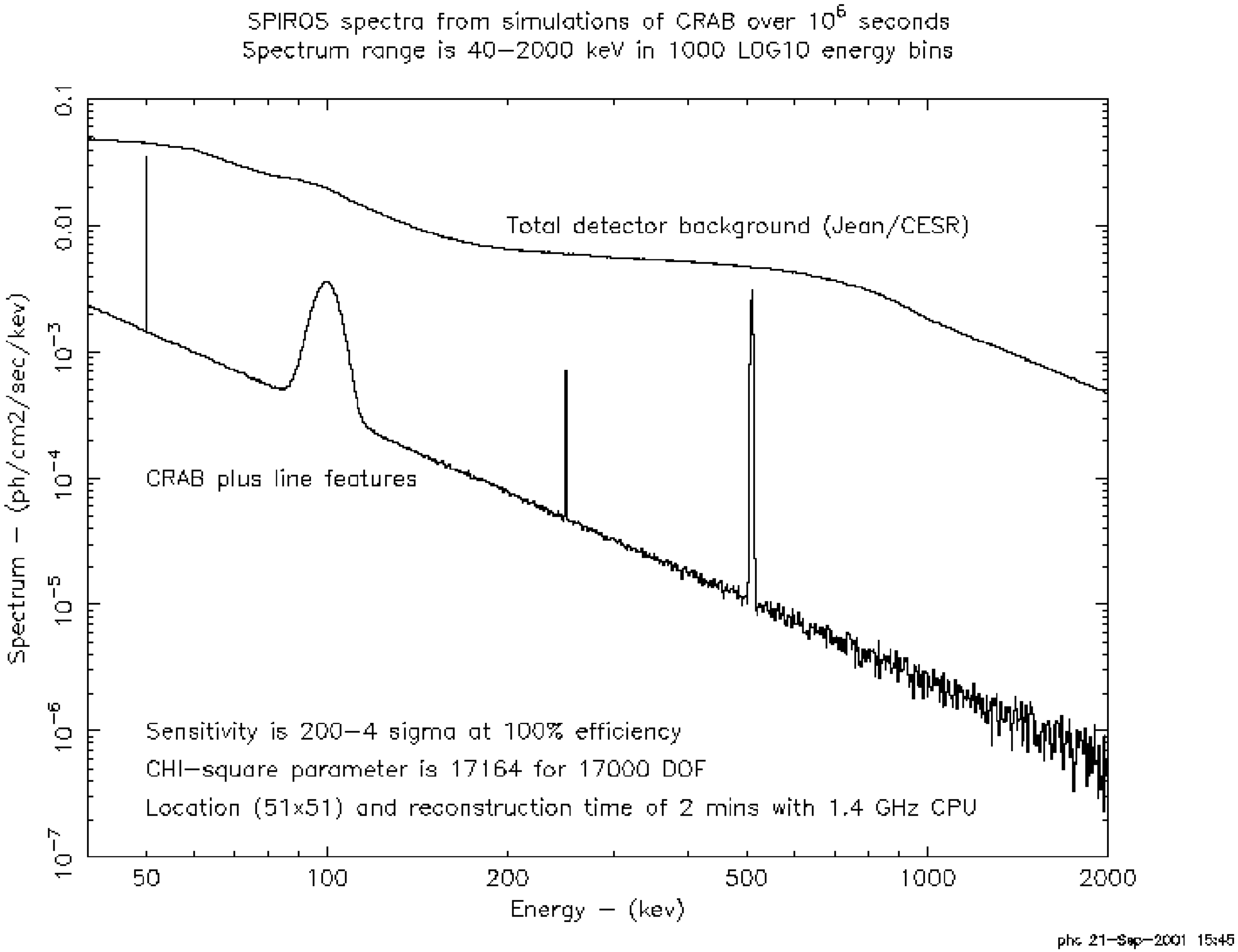




Detector without D18



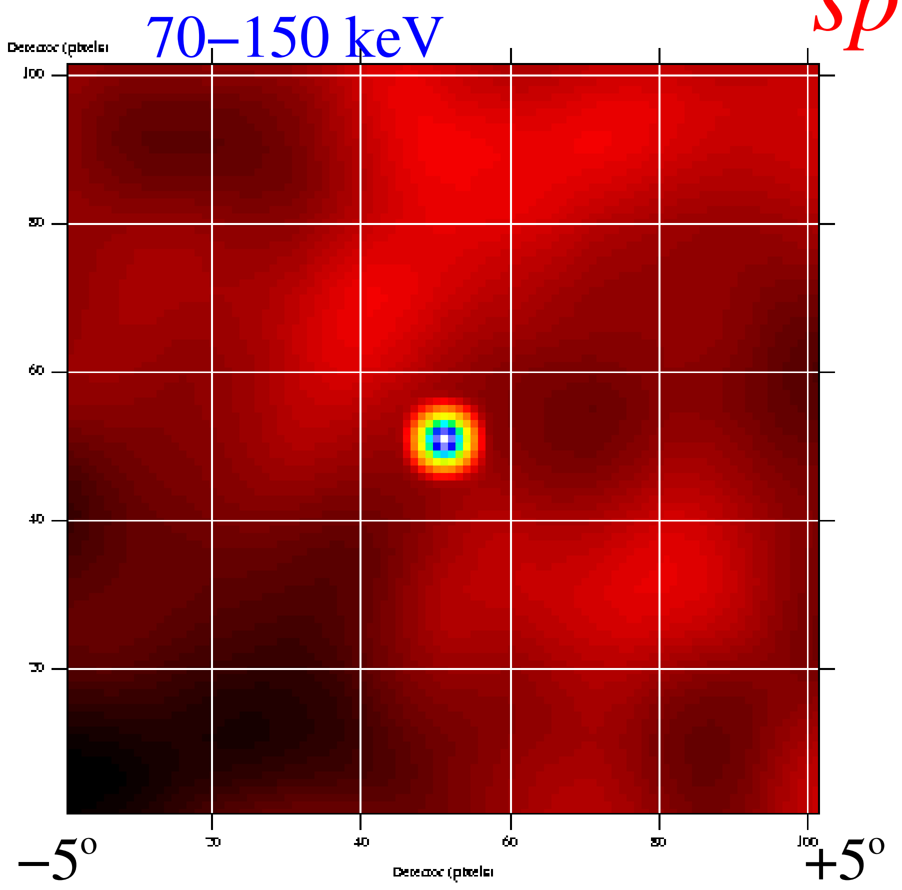
Spiros

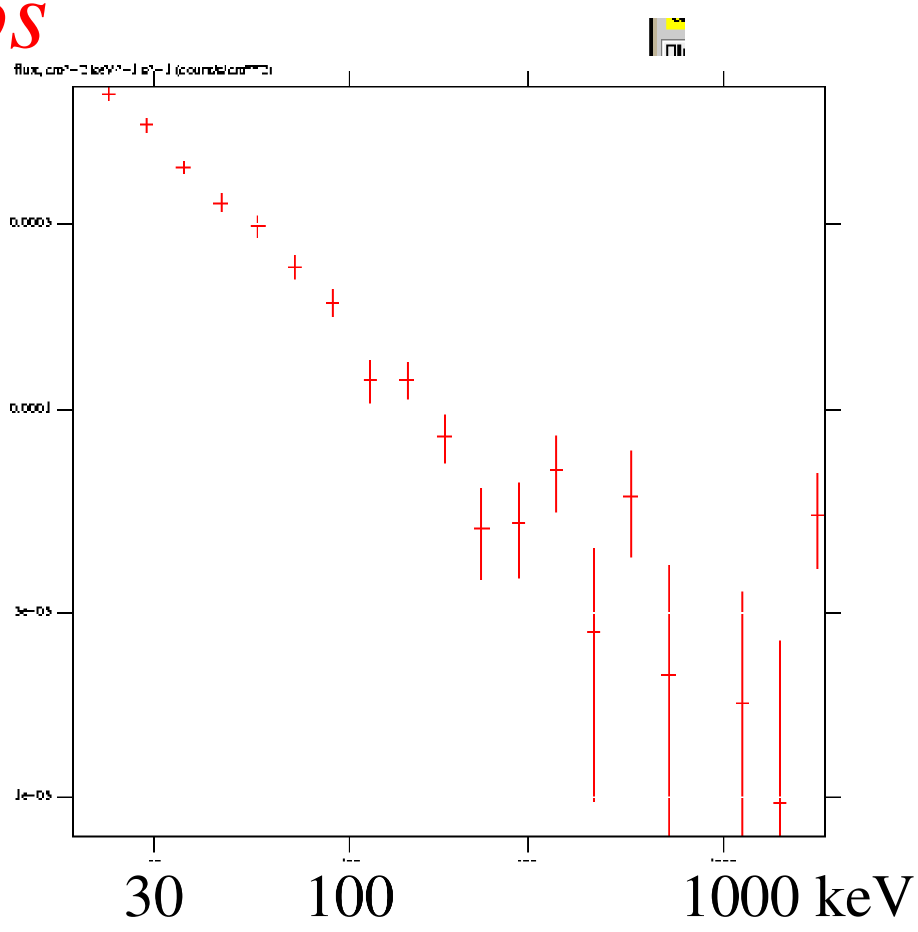


SPIROS spectra from simulations of CRAB over 10^6 seconds
Spectrum range is 40–2000 keV in 1000 LOG10 energy bins
Total detector background (Jean/CESR)
CRAB plus line features
Sensitivity is 200–4 sigma at 100% efficiency
CHI–square parameter is 17164 for 17000 DOF
Location (51x51) and reconstruction time of 2 mins with 1.4 GHz CPU
Spectrum – (ph/cm2/sec/kev)
Energy – (kev)
0.1
0.01
10^-3
10^-4
10^-5
10^-6
10^-7
50
100
200
500
1000
2000
phc 21–Sep–2001 15:45

3C273, 10^6 sec 11*11 pointing pattern

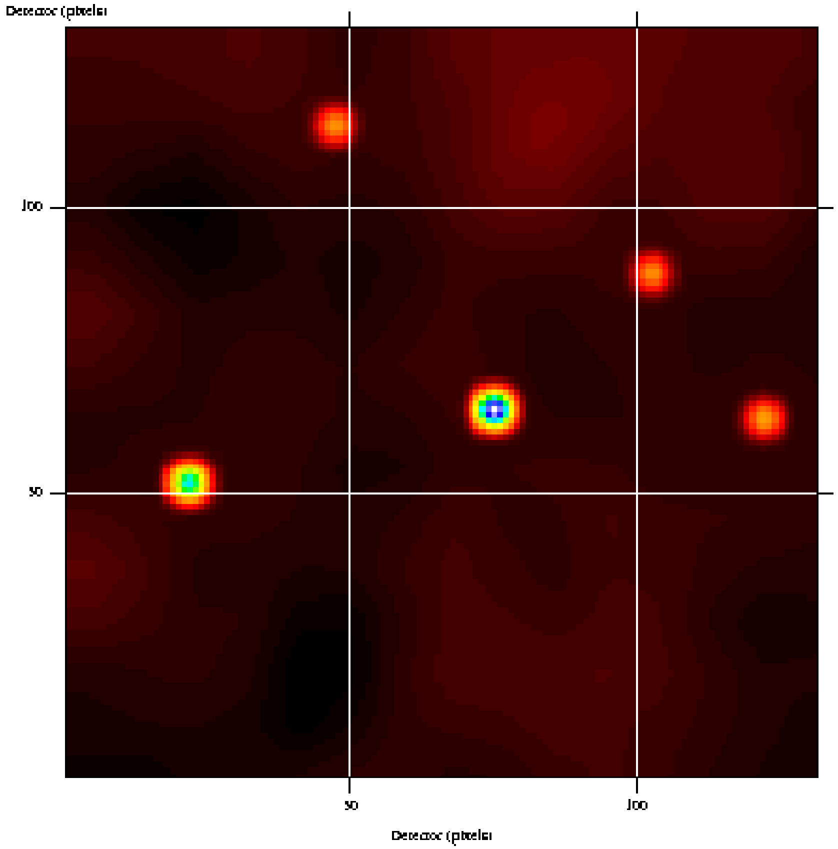
spiros





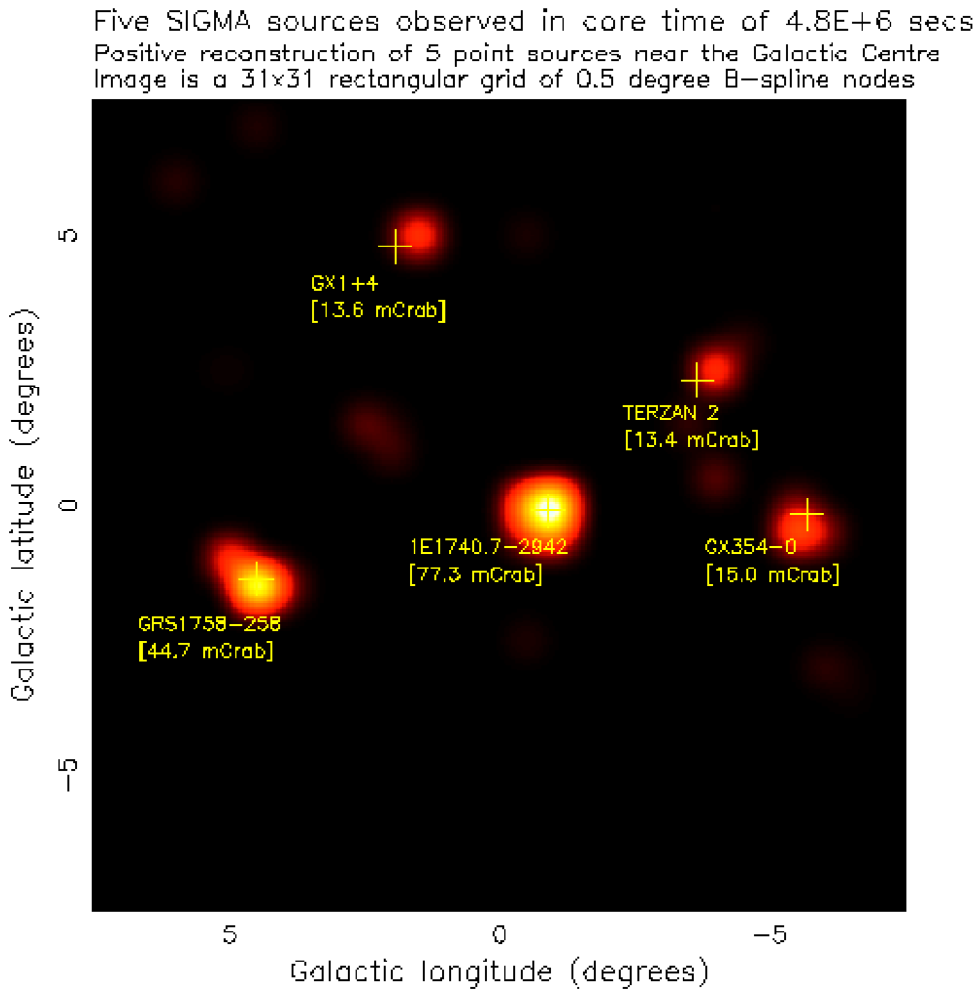
GCDE Galactic centre region, SIGMA sources

70–150 keV *spiros, source mode*



GCDE Galactic centre region, SIGMA sources

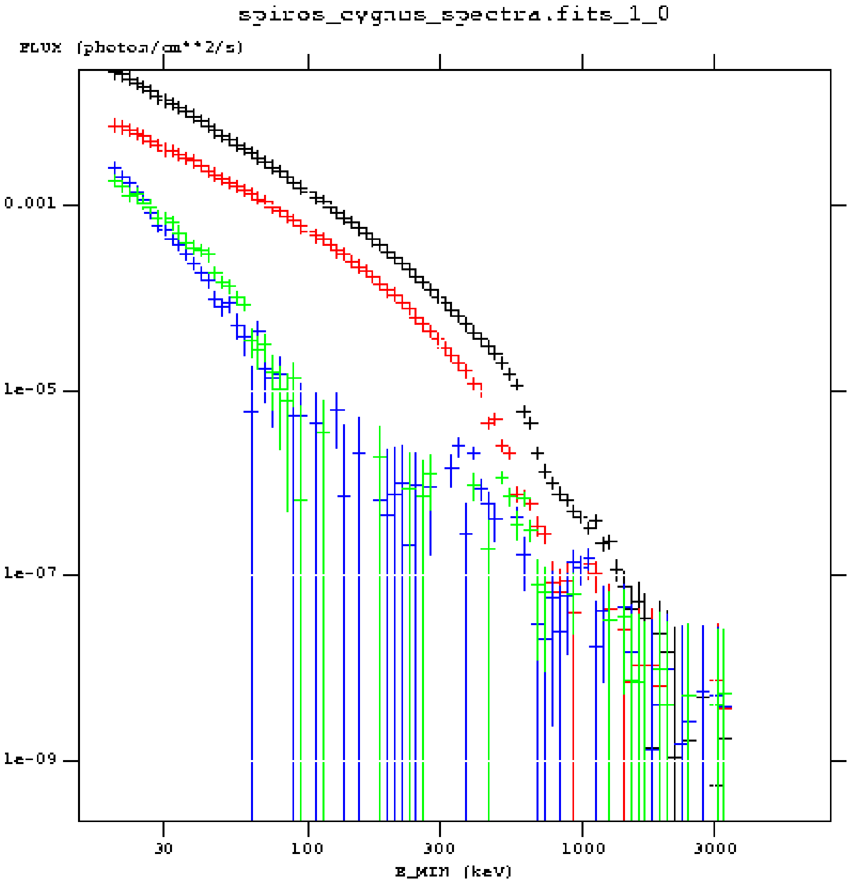
70–150 keV *spiros, imaging mode*



spiros

simulation of 4 sources

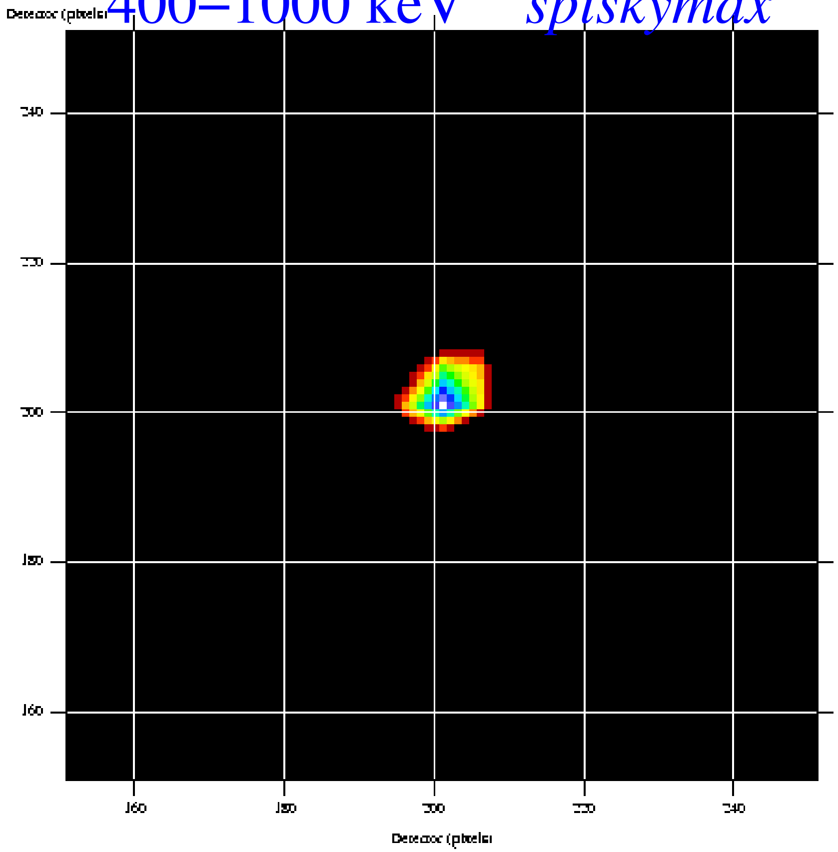
10^6 sec



3C273 –like flux, spectrum.
Singles + multiples. Realistic background estimate

10^6 sec, standard pointing pattern 5x5x2°

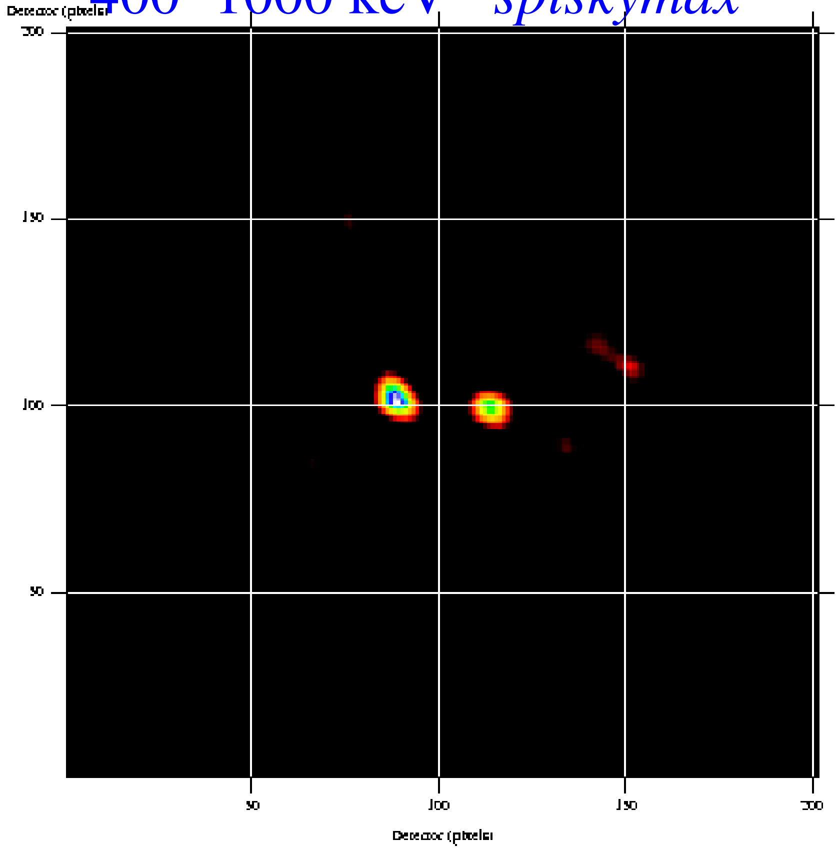
400–1000 keV *spiskymax*



2 sources with 3C273 –like flux, spectrum.
Singles+multiples. Realistic background estimate

10^6 sec, standard pointing pattern 5x5x2°

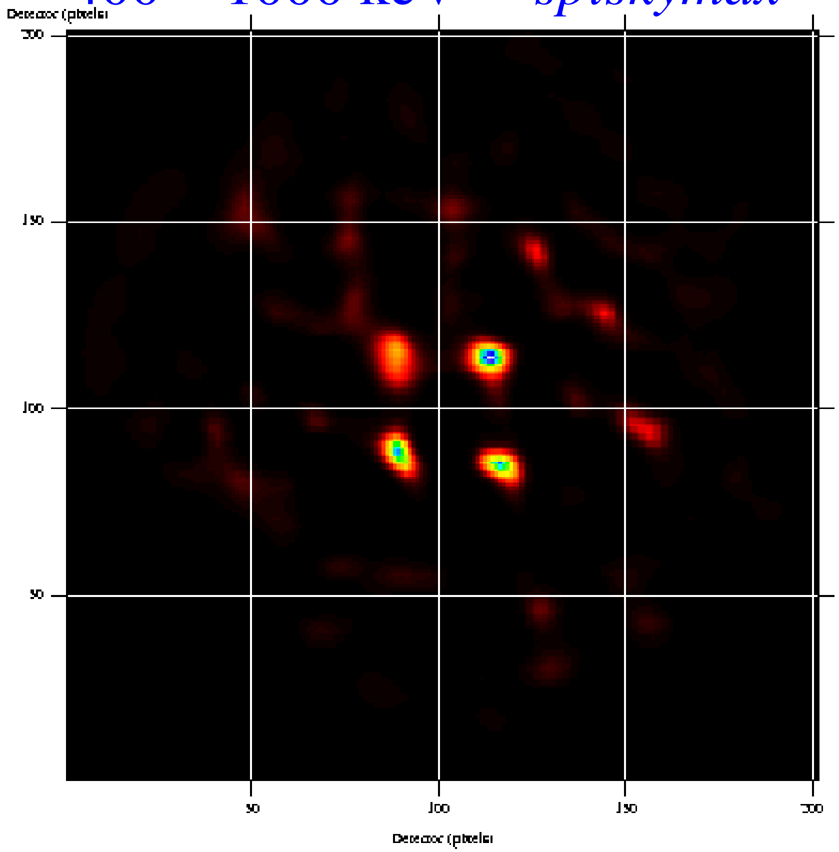
400–1000 keV *spiskymax*



4 sources with 3C273 –like flux, spectrum.
Singles+multiples. Realistic background estimate

10^6 sec, standard pointing pattern 5x5x2°

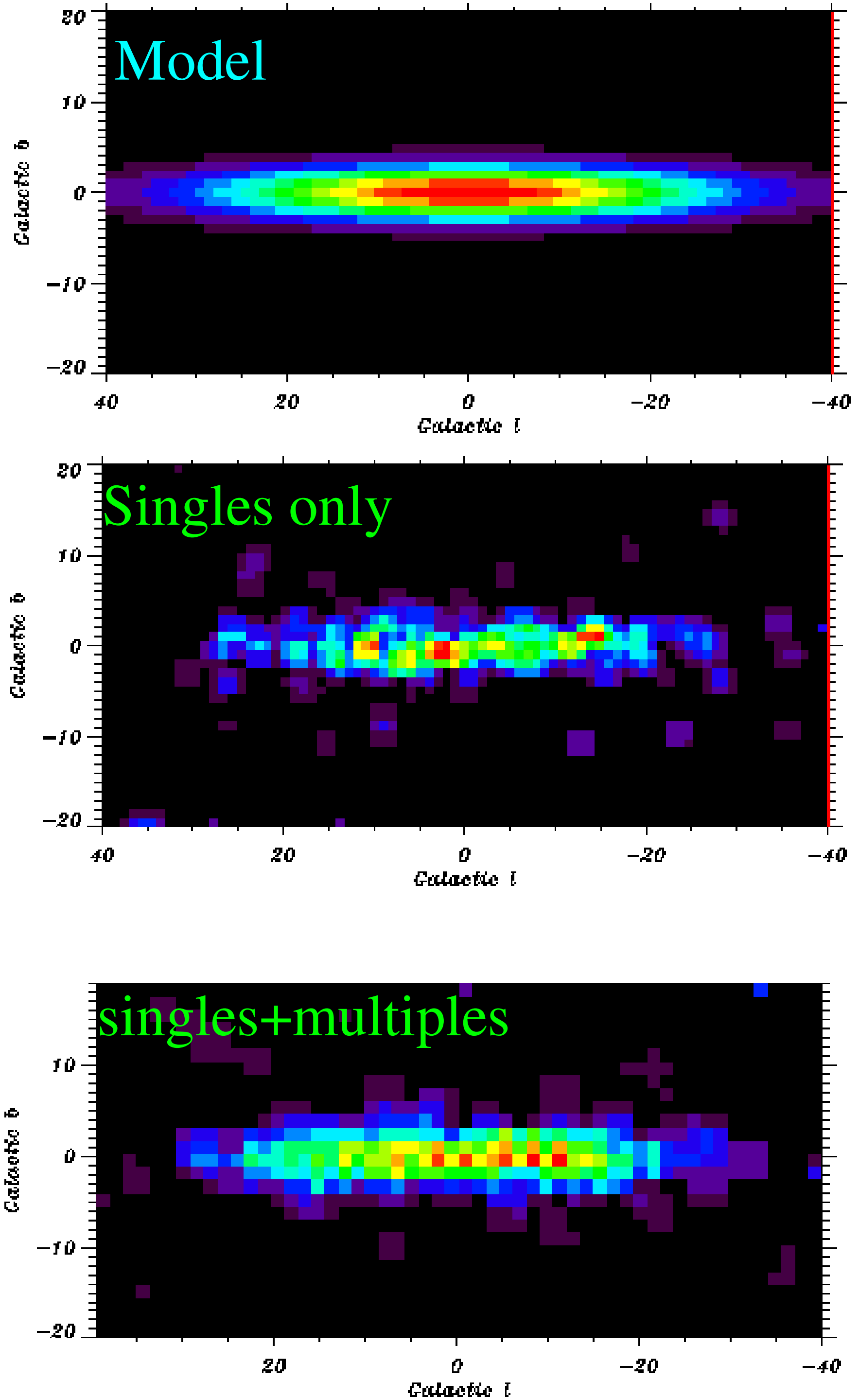
400 – 1000 keV *spiskymax*



Continuum
200 – 400 keV

GCDE 1 year

spiskymax

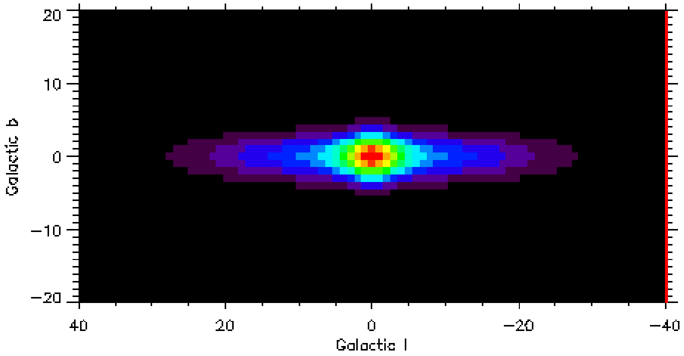


GCDE 1st year : 2 cycles 4.2 10^6 sec gcde.18

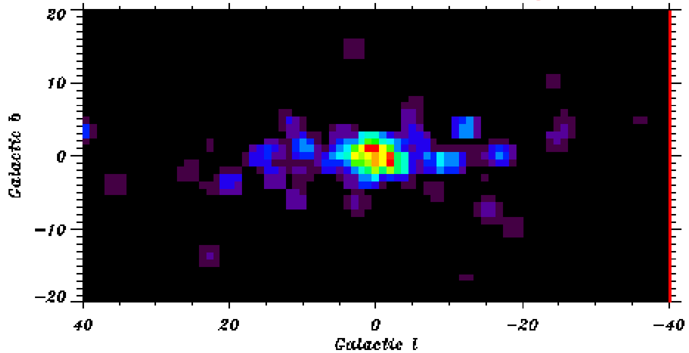
511 keV line singles only

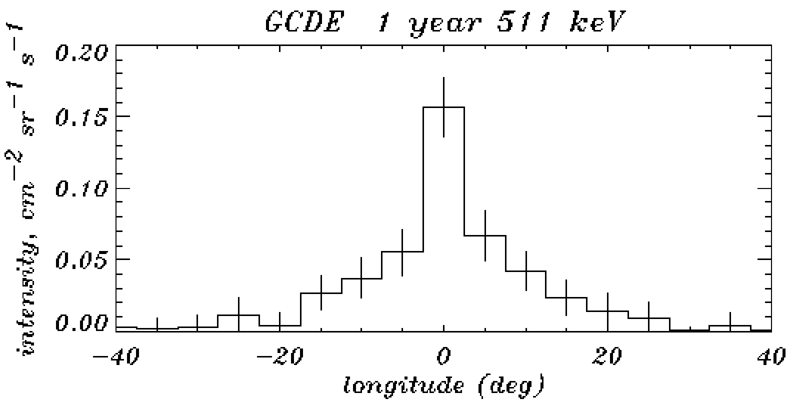
model based on Kinzer et al. (2001); background: P. Jean

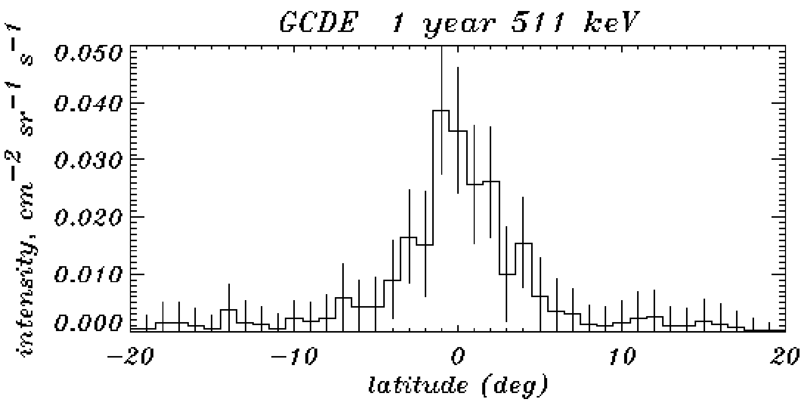
model



spiskymax image



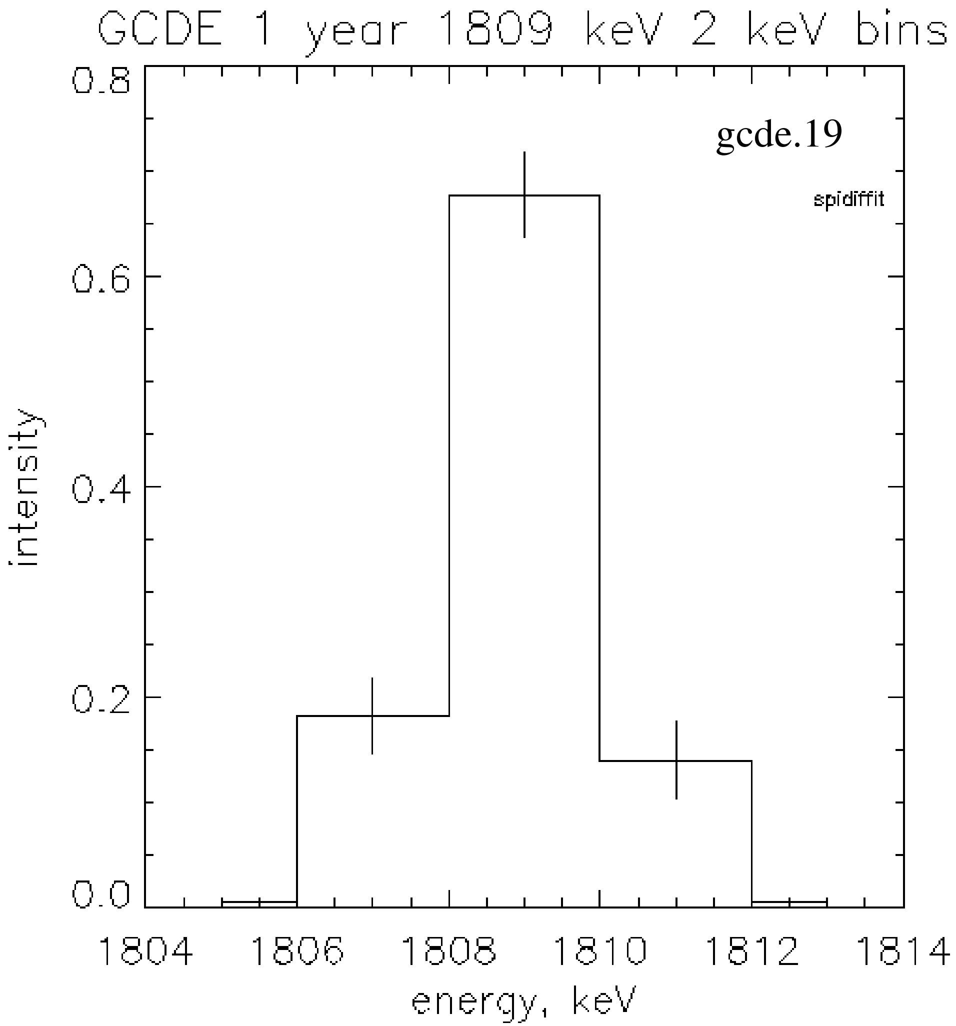


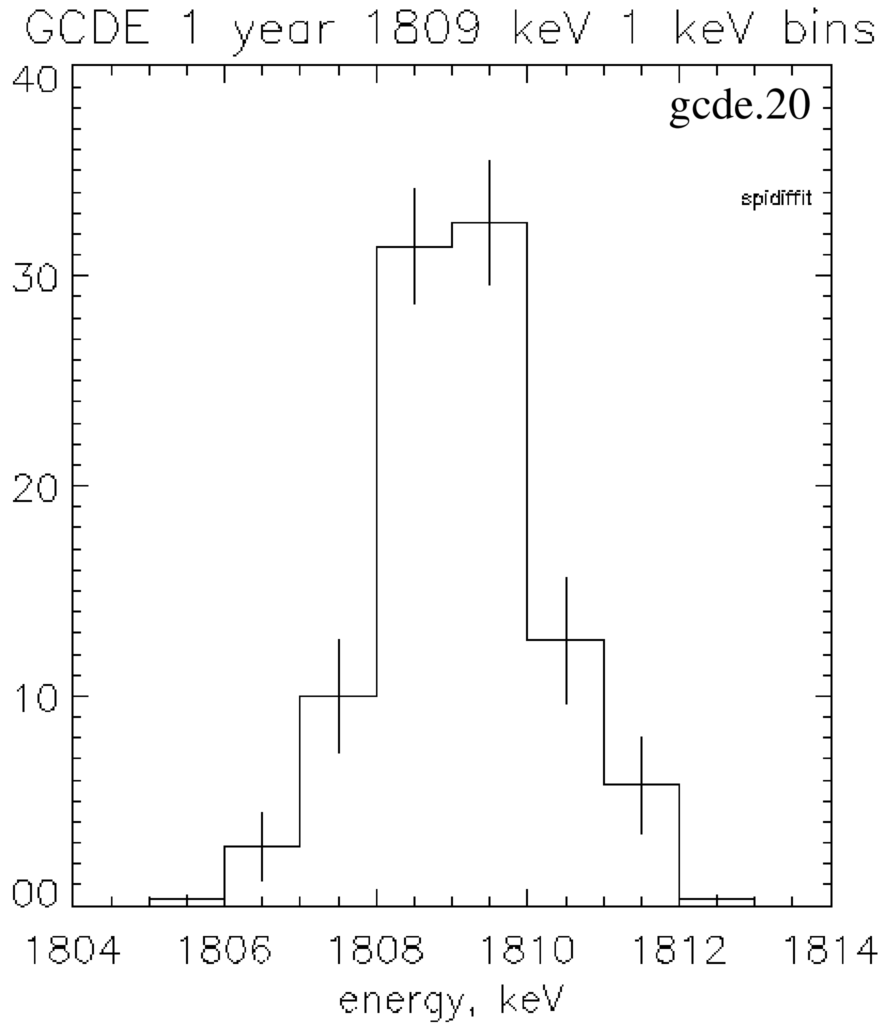


1809 keV 2.4 keV FWHM 240μm model scaled to COMPTEL maps

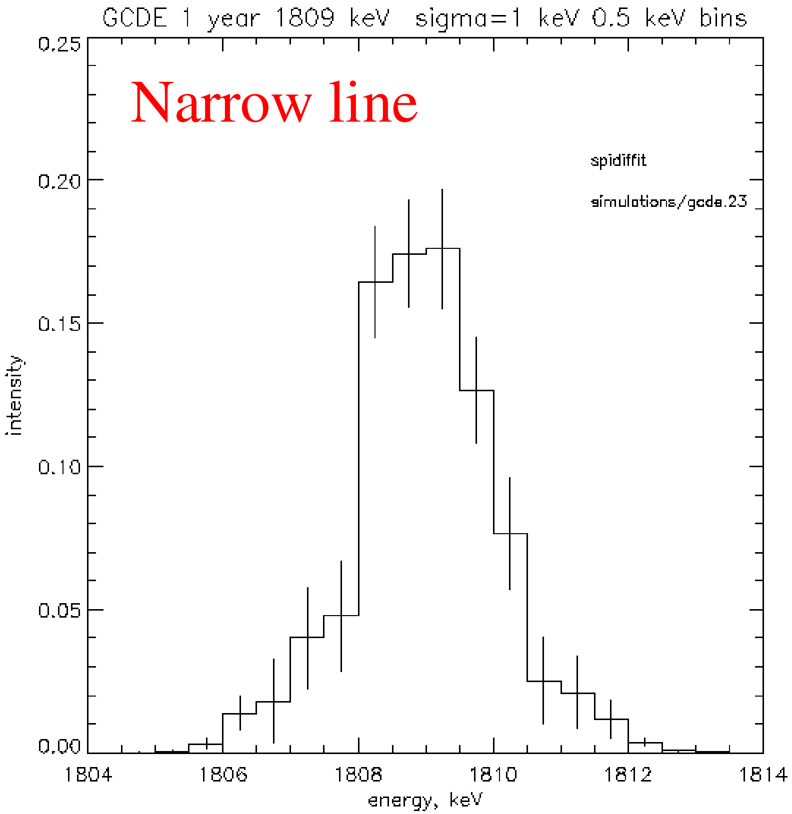
spidiffit, singles only

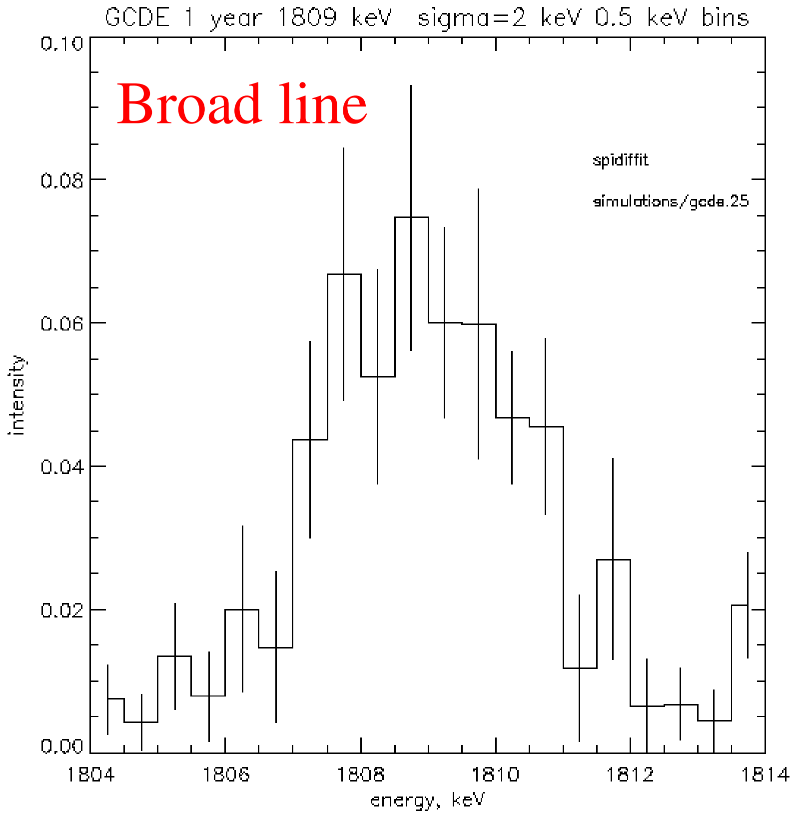
GCDE 1 year





1809 keV 240µm model scaled to COMPTEL maps
spidiffit, singles only
GCDE 1 year





GCDE 5 years : 10 cycles 21 10^6 sec

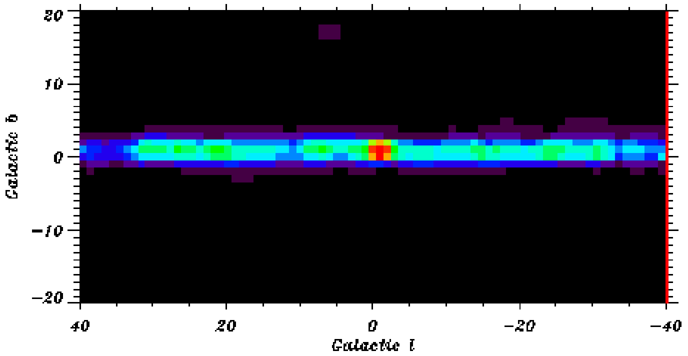
gcde.20

1809 keV line, 2.4 keV FWHM. 2 keV bins singles only

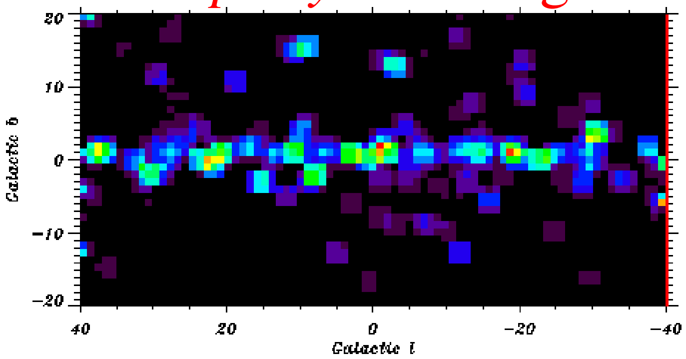
model based on 240µm emission,

scaled to COMPTEL map. Background: P.Jean

model

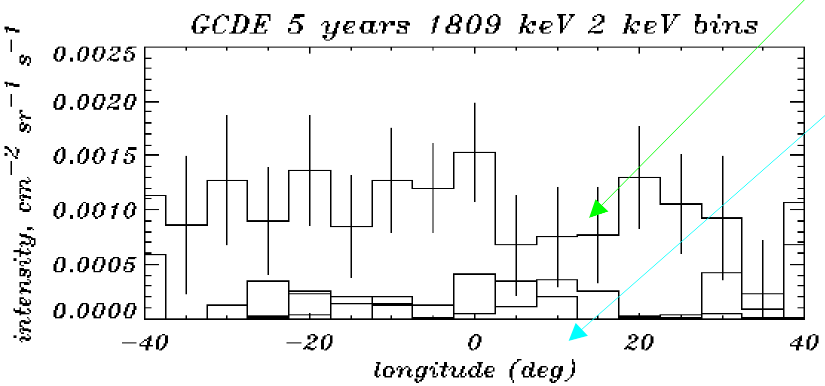


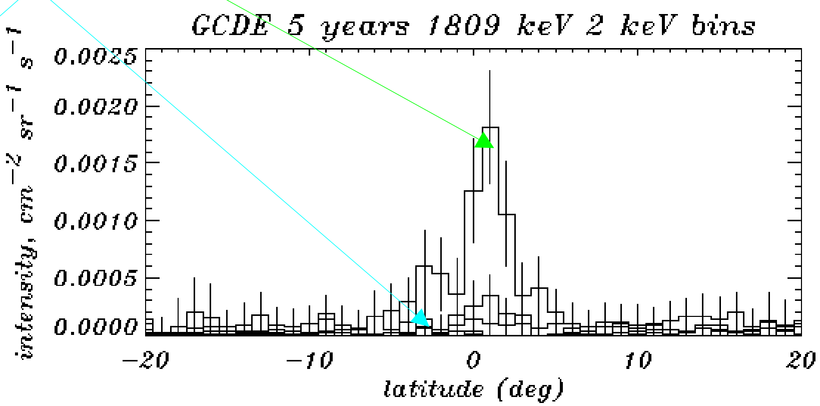
spiskymax image



Line 1808–1810 keV

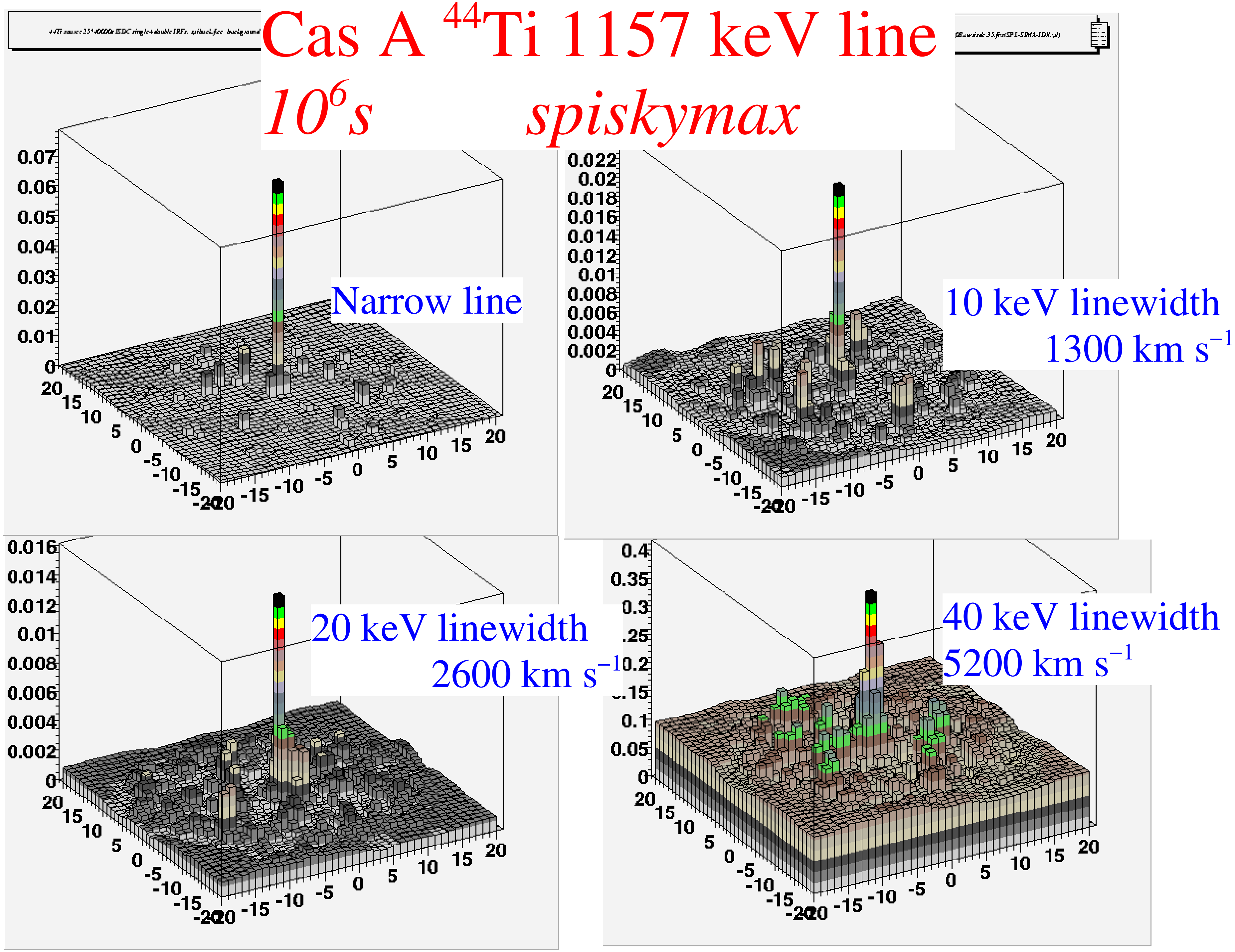
1804–6–8, 1810–12–14





Cas A ^{44}Ti 1157 keV line

10^6 s *spiskymax*



Young SNR, ^{26}Al 1809 keV line
5 keV linewidth