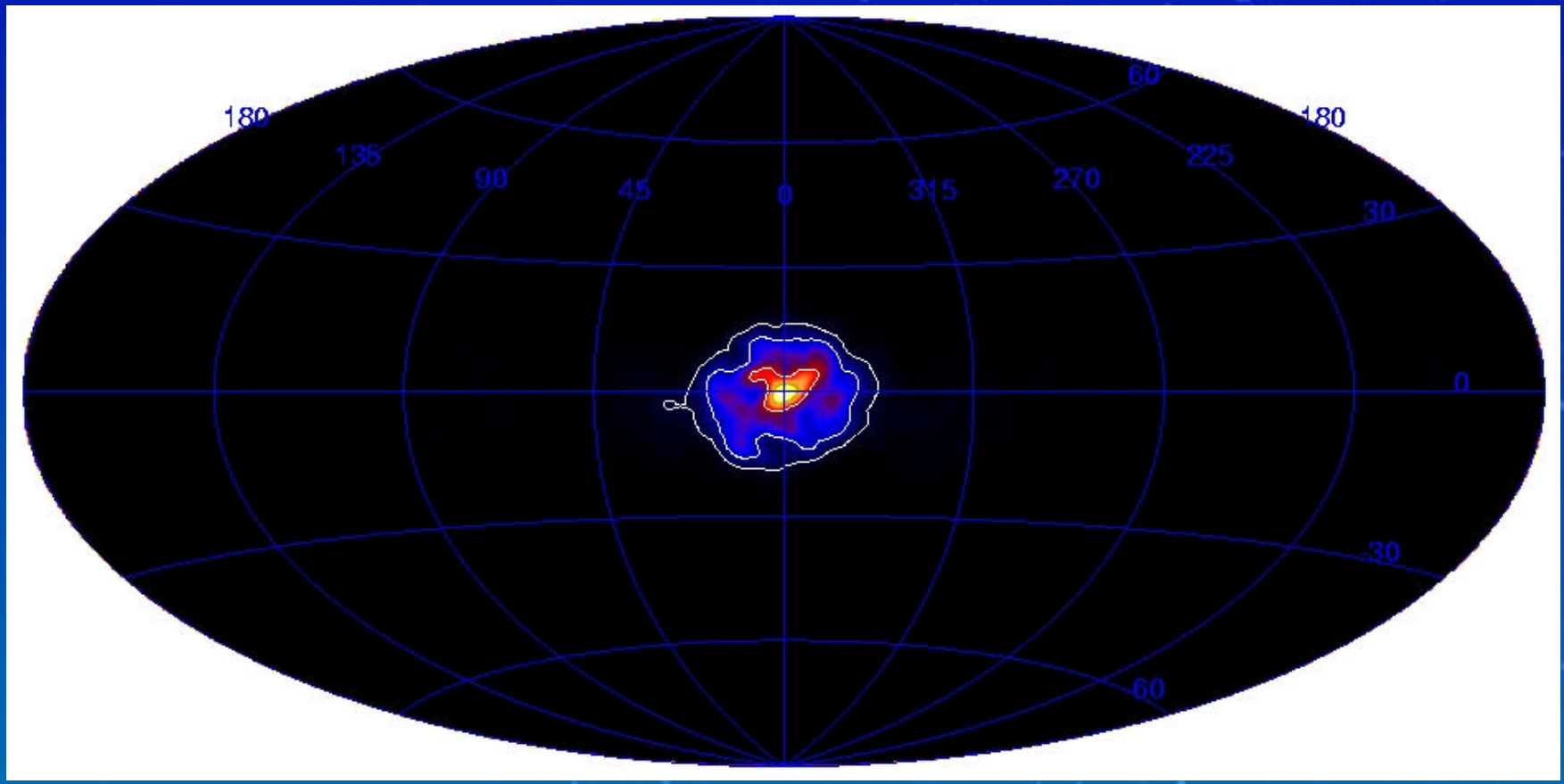
The all-sky distribution of 511 keV annihilation line emission



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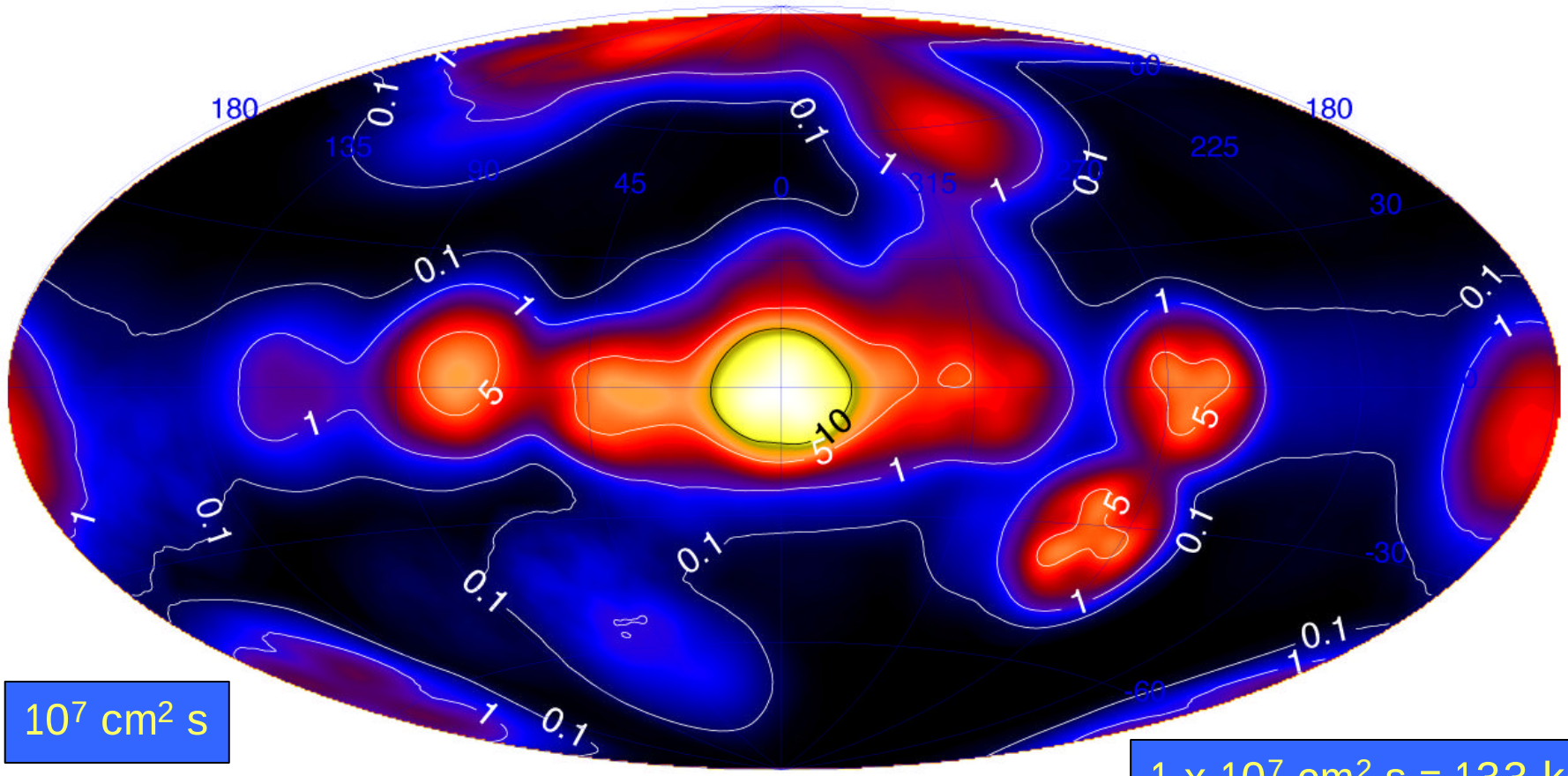
Centre d'Etude Spatiale des Rayonnements, Toulouse, France

SPI all-sky exposure after ~ first year

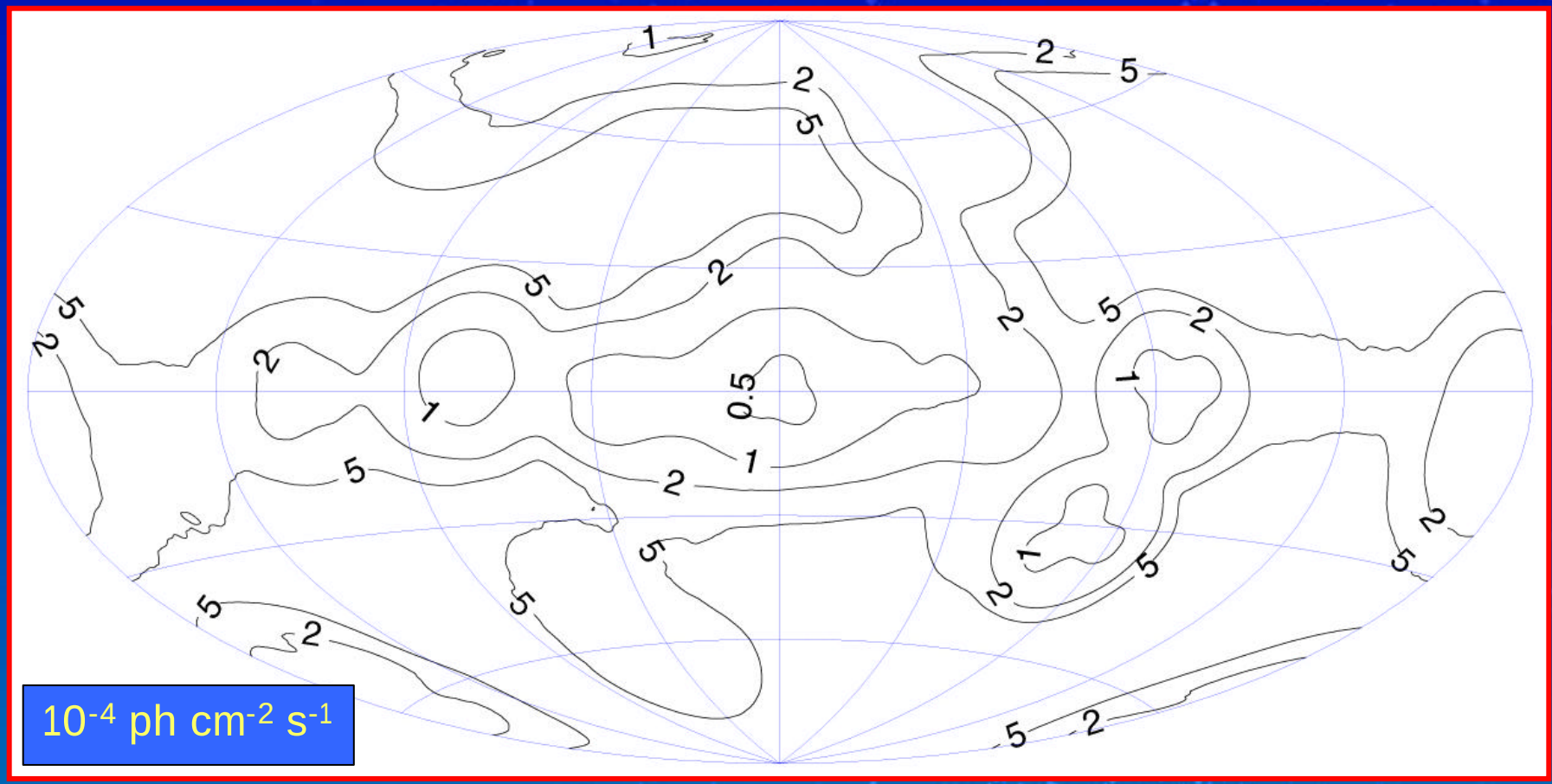
Jürgen Knödlseder, Pierre Jean, Vincent Lonjou, Georg Weidenspointner, Nidhal Guessoum, William Gillard, Gerry Skinner, Peter von Ballmoos, Gilbert Vedrenne, Jean-Pierre Roques, Stéphane Schanne, Bonnard Teegarden, Volker Schönfelder, C. Winkler,
in preparation for A&A



10^7 cm^2 s

1 x 10^7 cm^2 s = 133 ks

SPI 511 keV point-source sensitivity

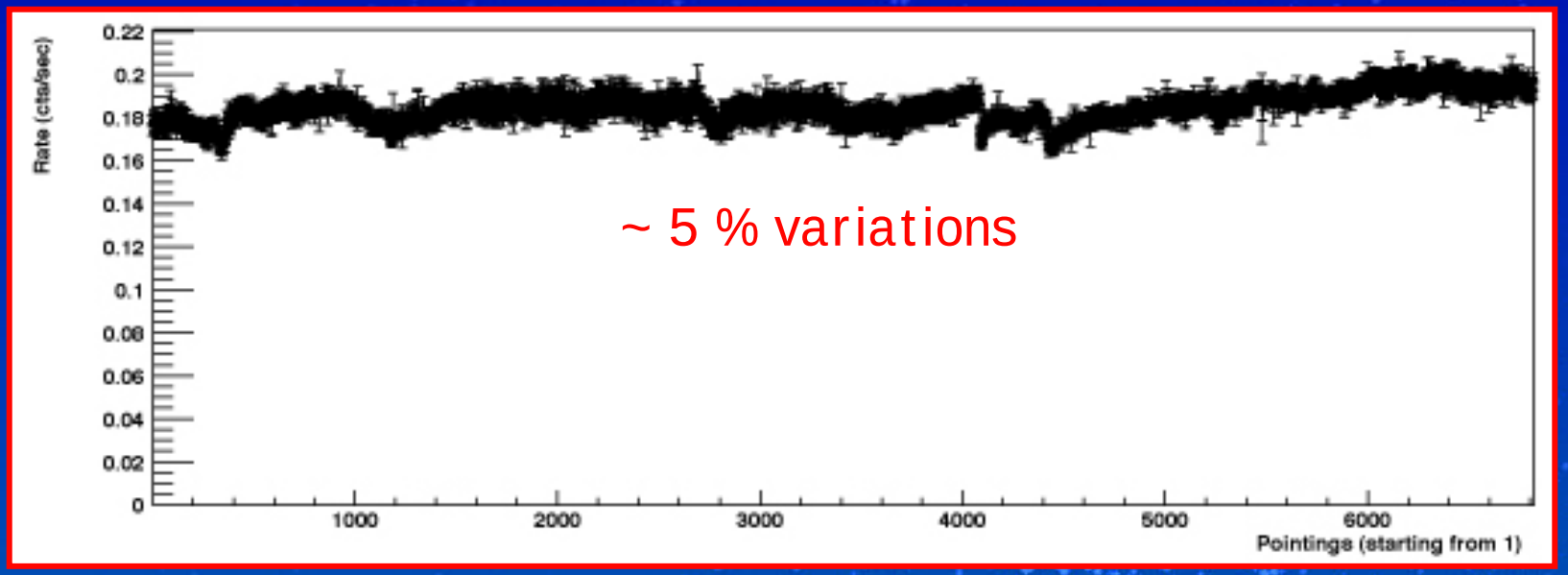


- **maximum : 5 x 10^{-5} ph cm^{-2} s^{-1} at GC**
- **large parts of galactic plane better than 2 x 10^{-4} ph cm^{-2} s^{-1}**
- **several high latitude regions better than 2 x 10^{-4} ph cm^{-2} s^{-1}**

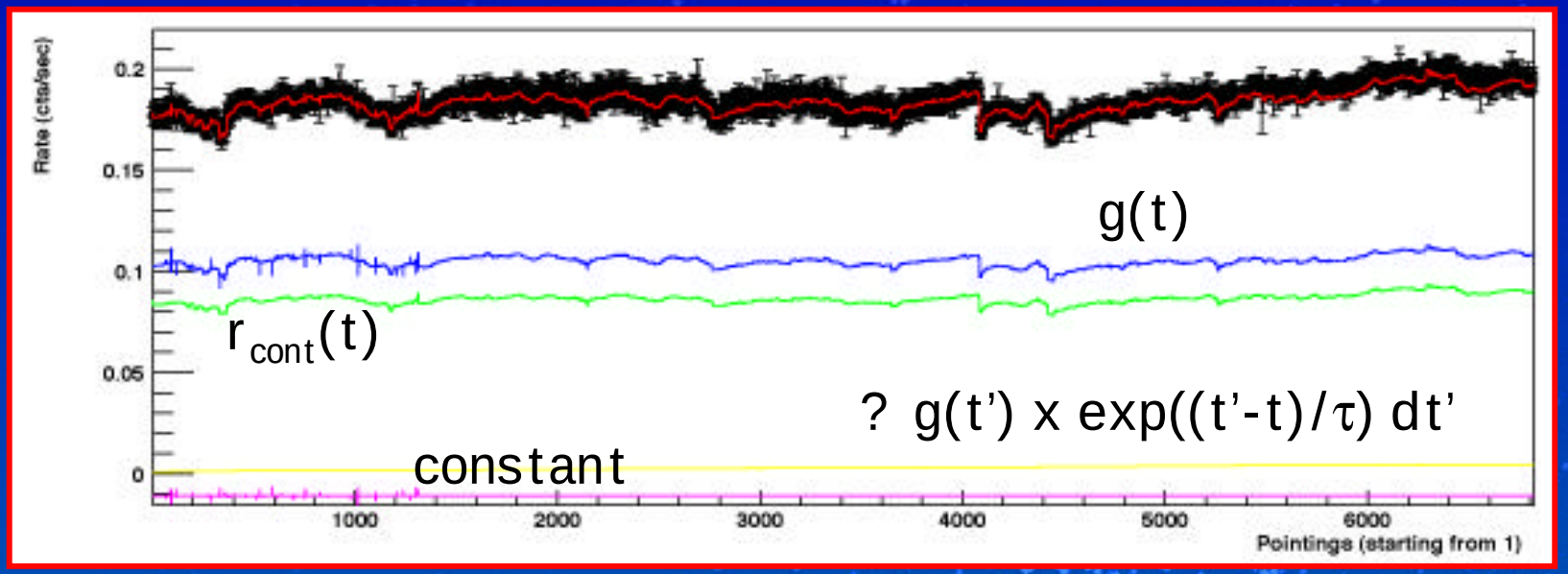
Step 1

Background modelling

511 keV background



511 keV background model



$r(t) = r_{cont}(t) + \beta_1 + \beta_2 \times g(t) + \beta_3 \times \int g(t') \times \exp((t'-t)/\tau)\, dt'$

$r_{cont}(t)$: continuum background (from adjacent energies)

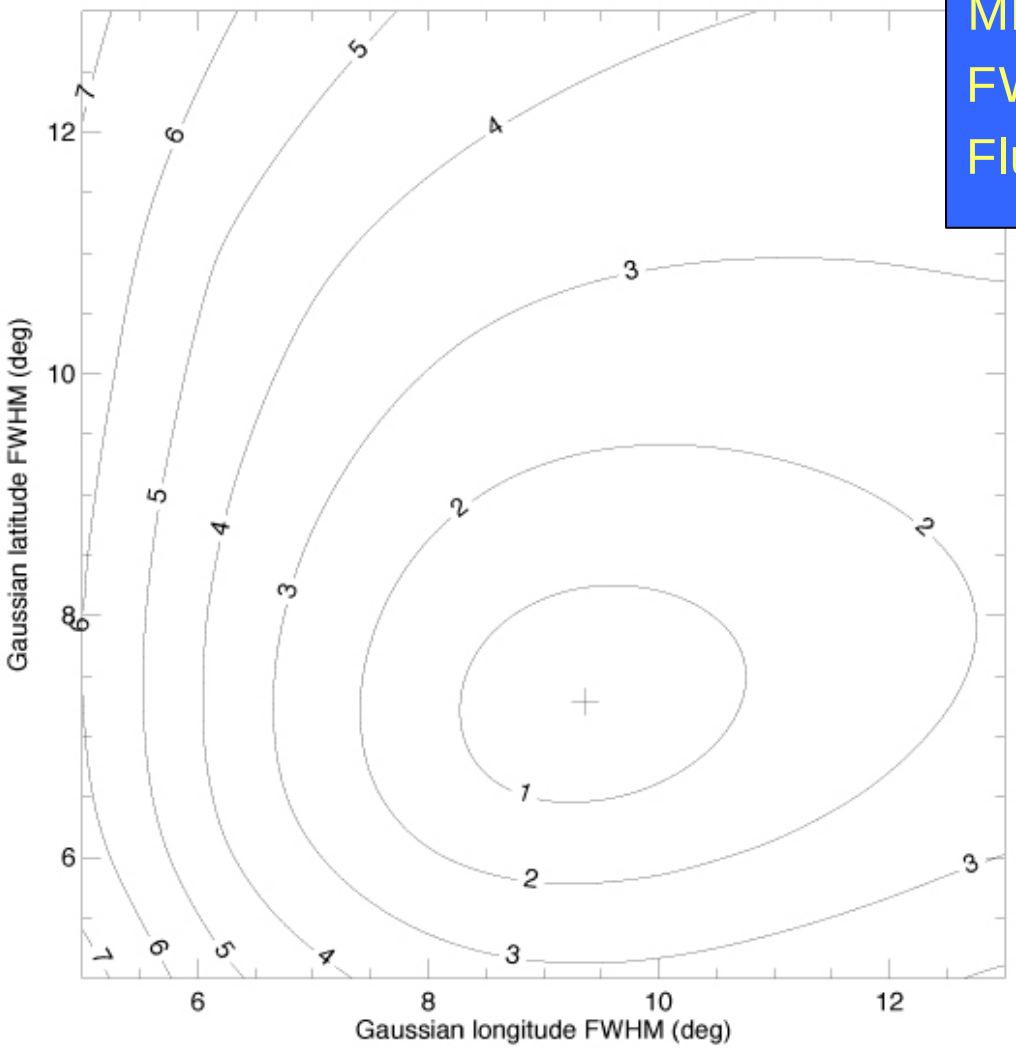
r(t) : predicted 511 keV line background rate

g(t) : GEDSAT rate

τ = 352 days

$\beta_1, \beta_2, \beta_3$: fitted coefficients (detector / orbit & detector)

DETE - 2d Gaussian model fitting

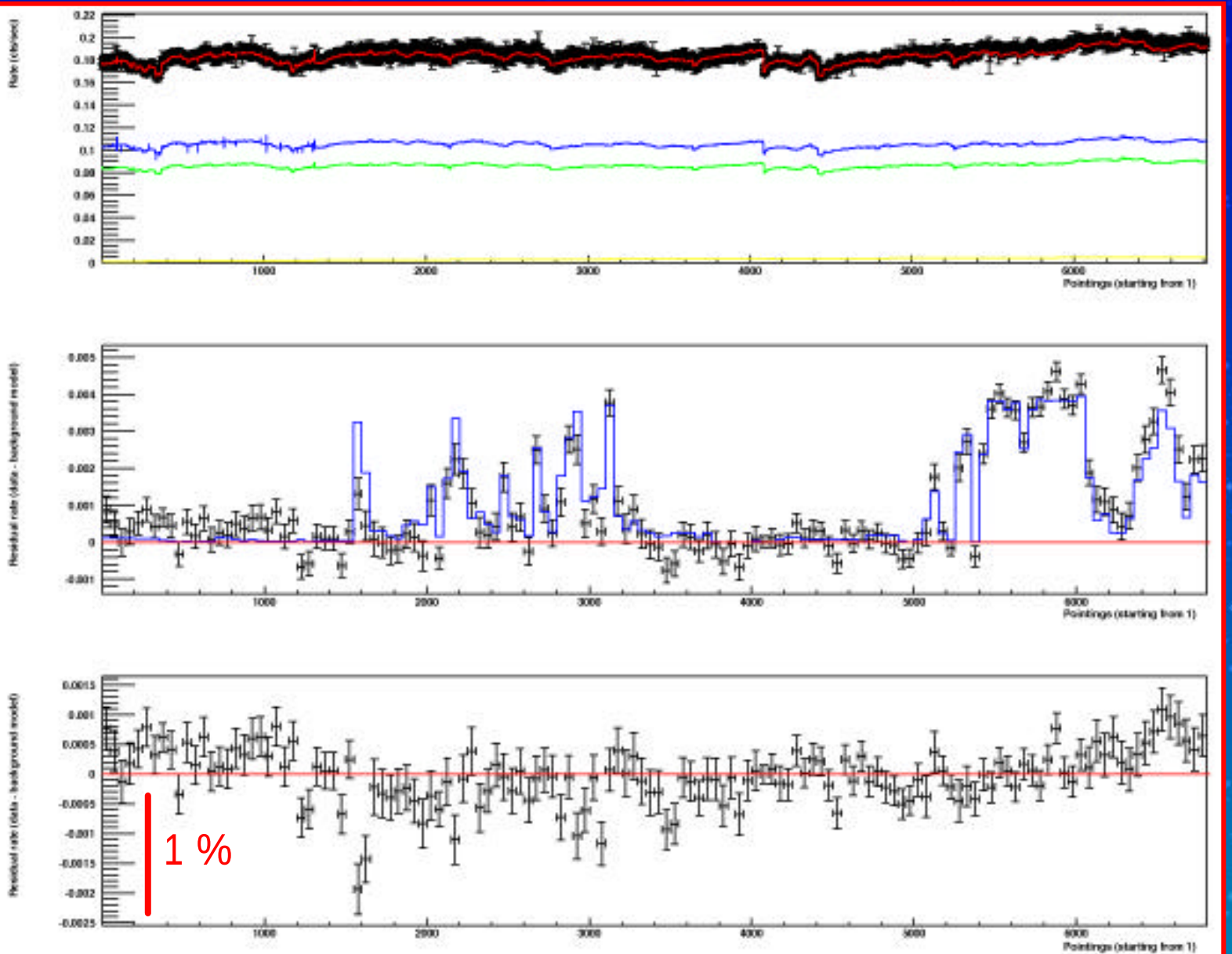


MLR = 2418.044 (49.2 σ)

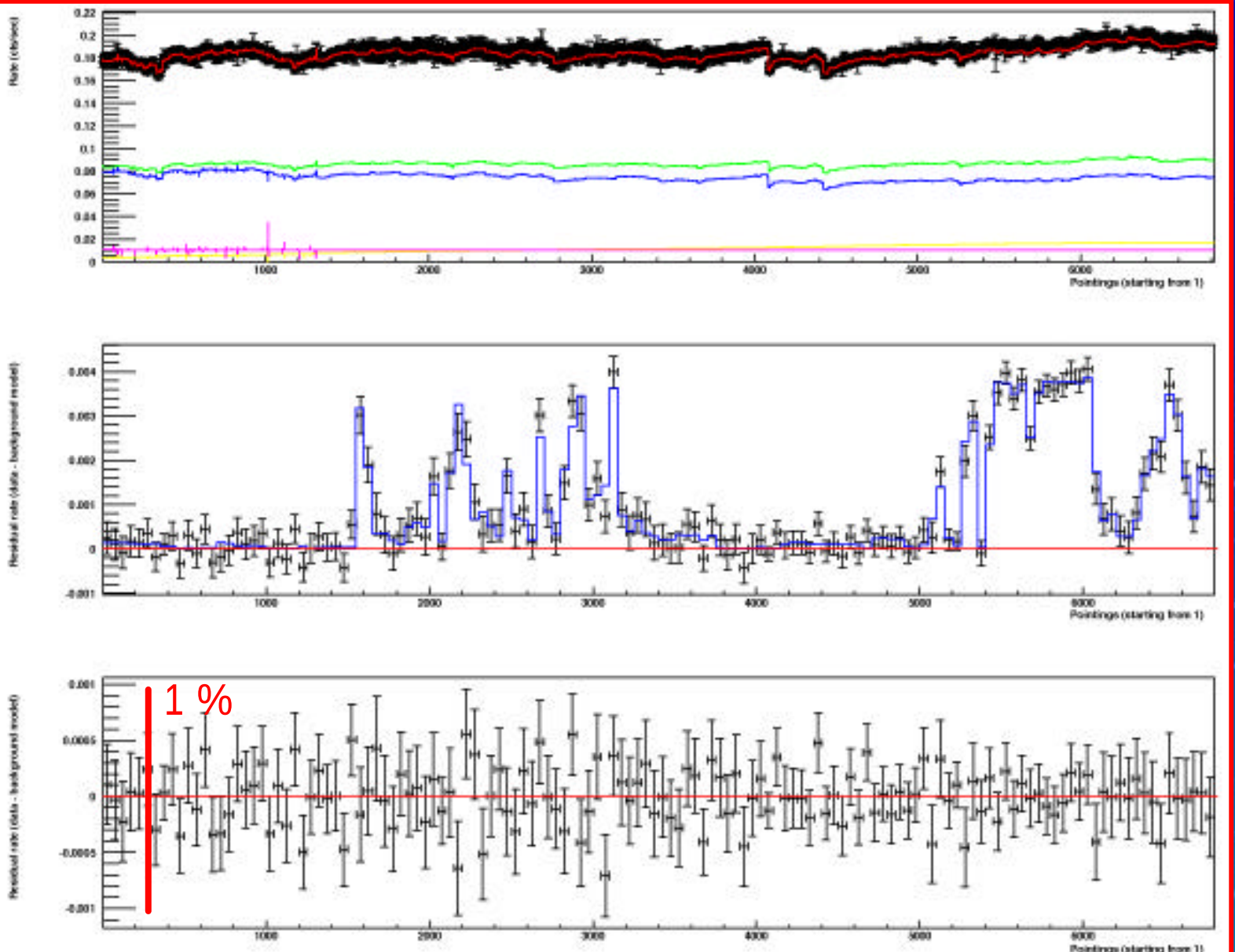
FWHM = 9.5° x 7.5°

Flux = (1.11 ± 0.03) x 10^{-3} ph cm^{-2} s^{-1}

DETE - background residuals



ORBIT-DETE - background residuals

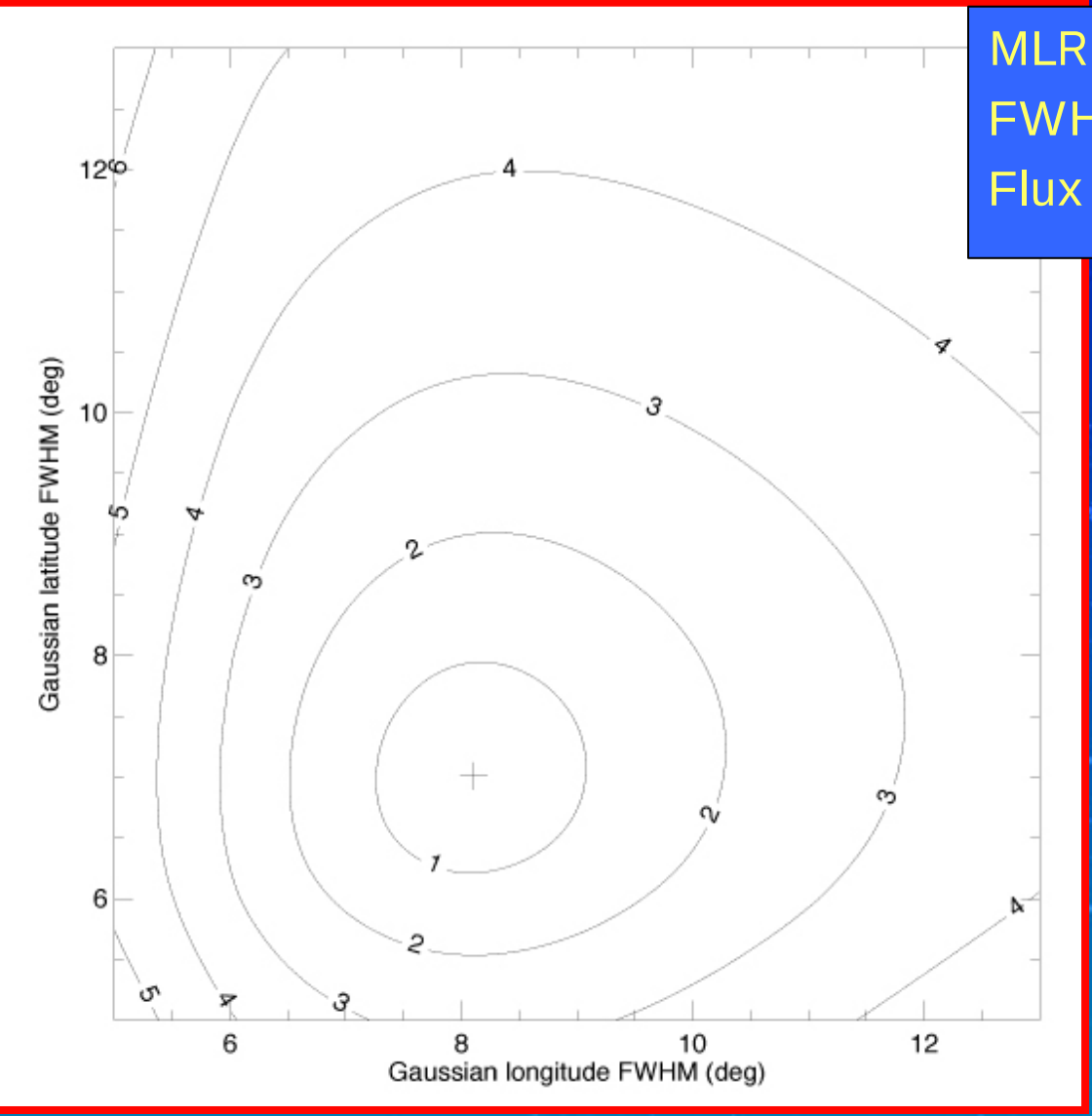


ORBIT-DETE - 2d Gaussian model fittin

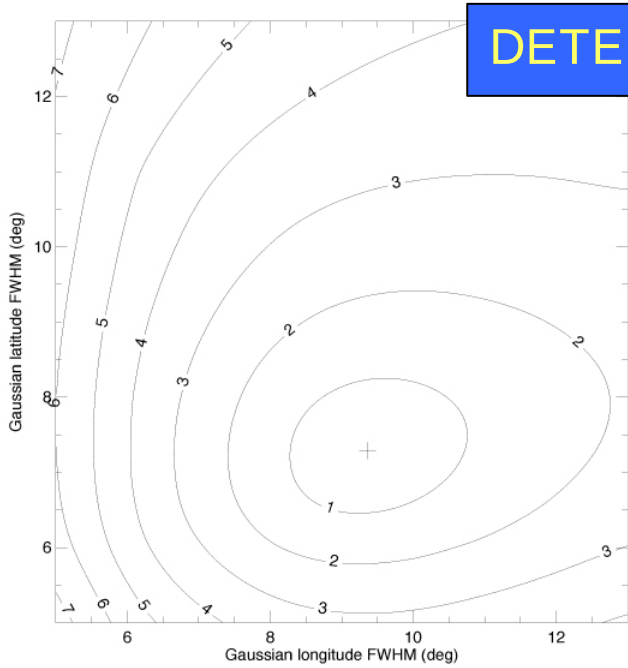
MLR = 465.424 (21.6 σ)

FWHM = 8.0° x 7.0°

Flux = (1.04 ± 0.05) x 10^{-3} ph cm^{-2} s



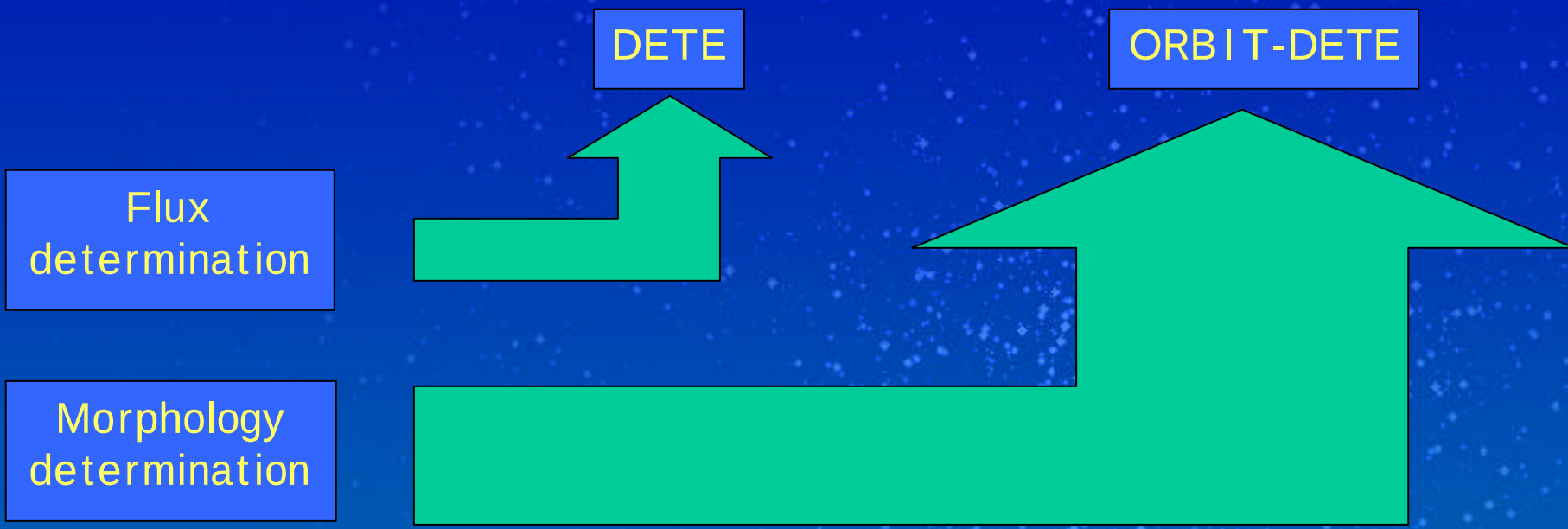
DETE



Step 1 : Conclusions

	DETE	ORBIT-DETE
Flux determination	Marginal systematic uncertainties	Substantial sensitivity decrease (~ factor 2)
Morphology determination	Significant systematic uncertainties	No sensitivity decrease

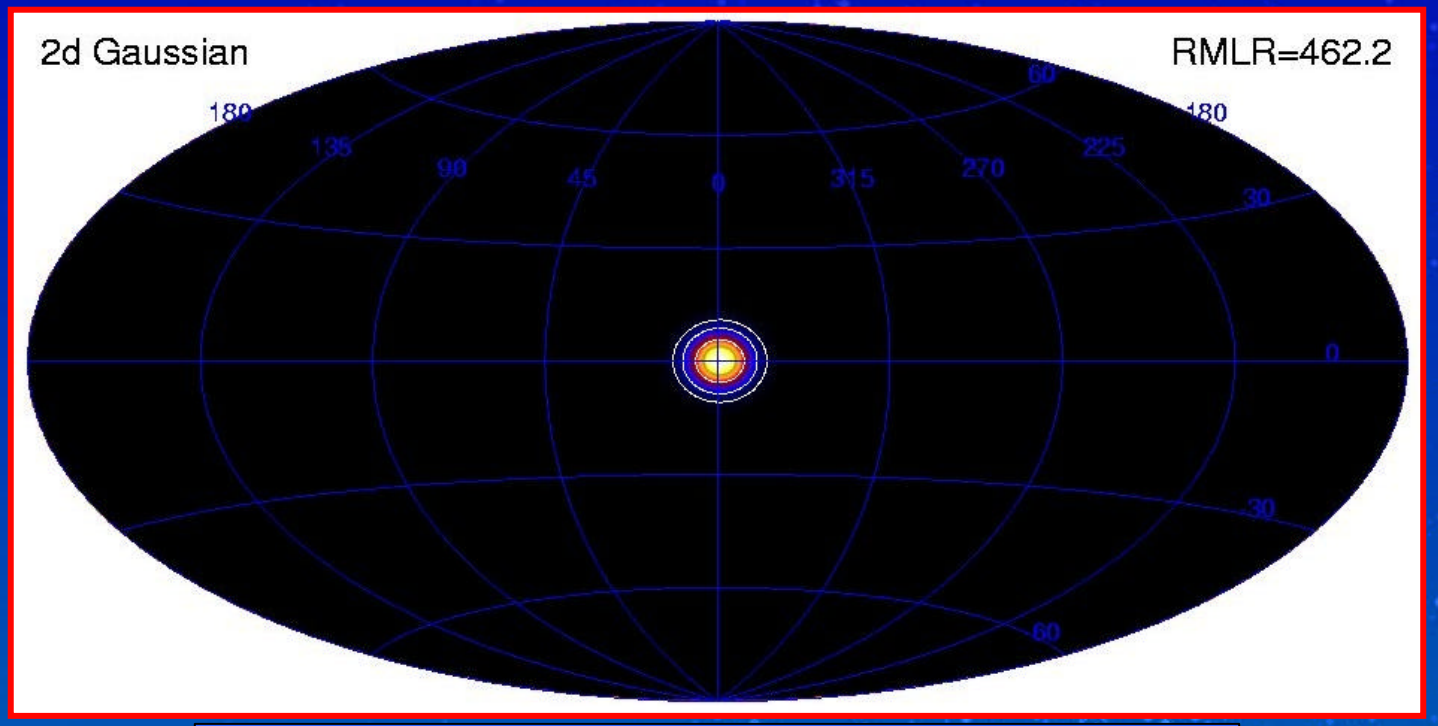
Step 1 : Conclusions



Step 2

Model fitting

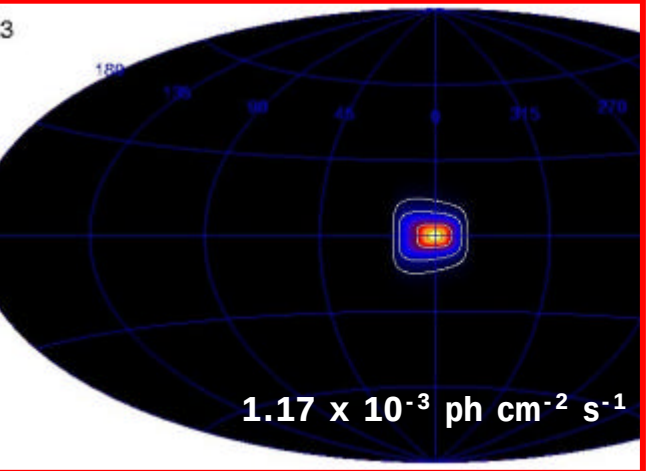
511 keV bulge emission morphology

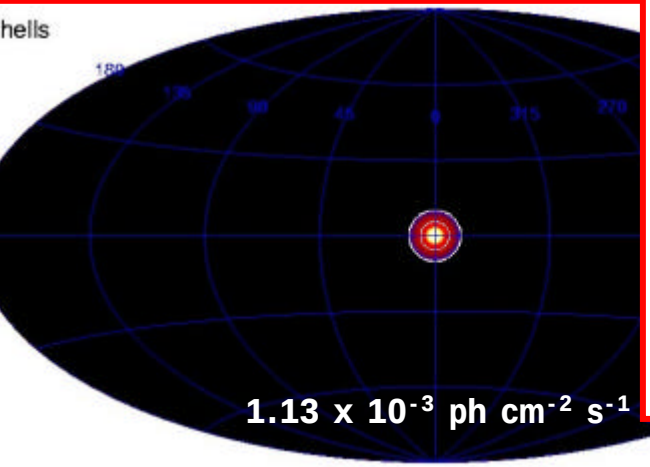


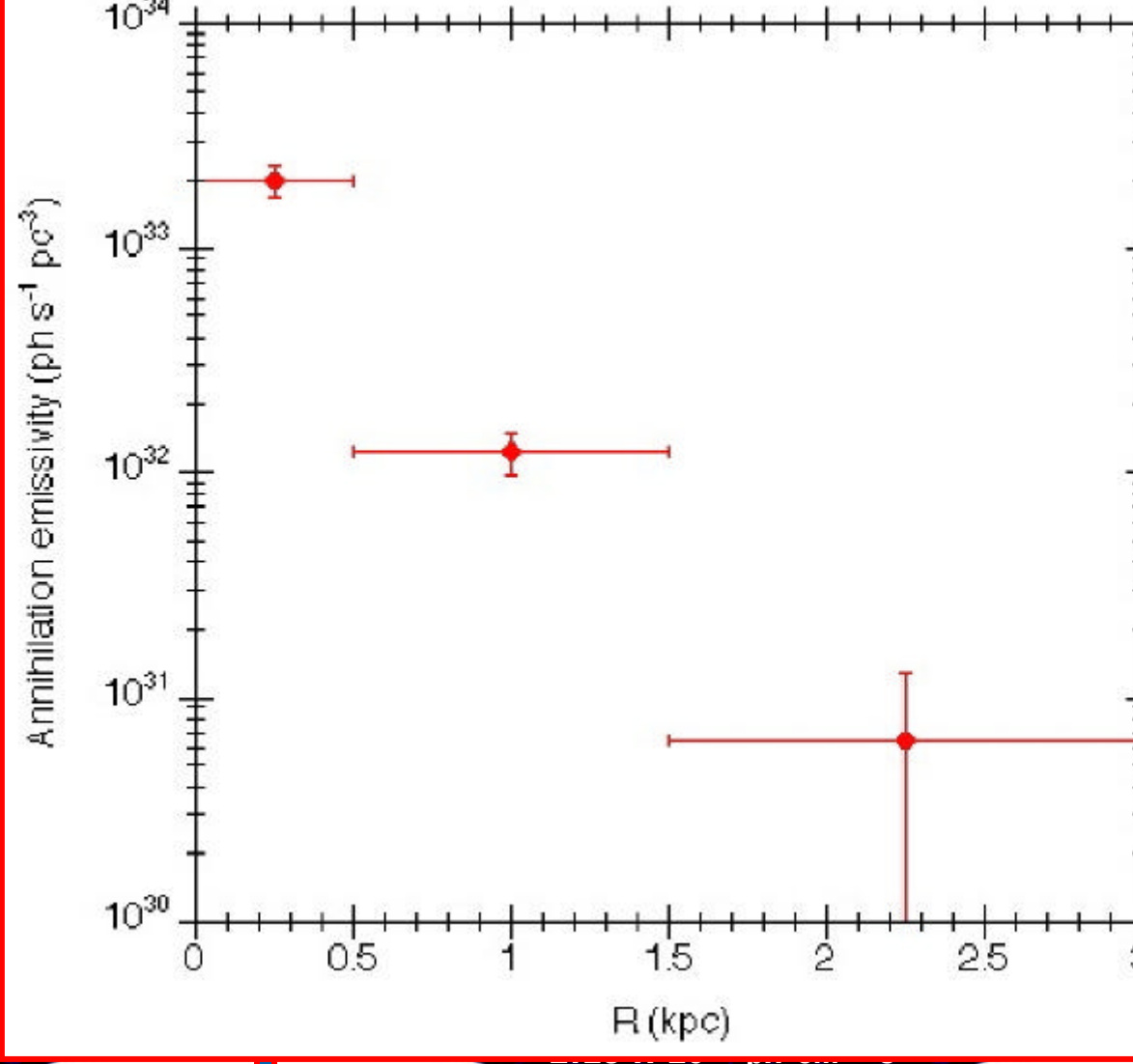
Modelling with a 2d Gaussian

l_0	-0.6° ± 0.3°
b_0	+0.1° ± 0.3°
Δl (FWHM)	8.1° ± 0.9°
Δb (FWHM)	7.2° ± 0.9°
Δb / Δl	0.89 ± 0.14
511 keV flux	1.09 ± 0.04 (10^{-3} ph cm^{-2} s^{-1})

Bu

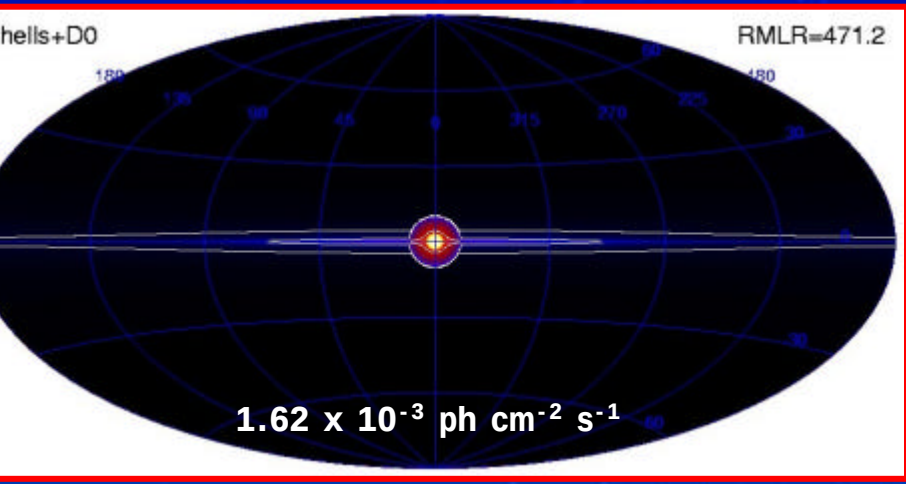


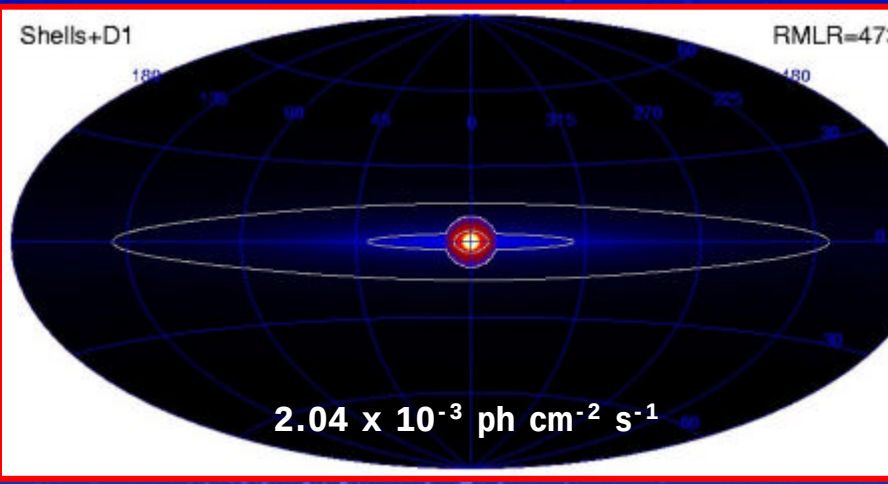


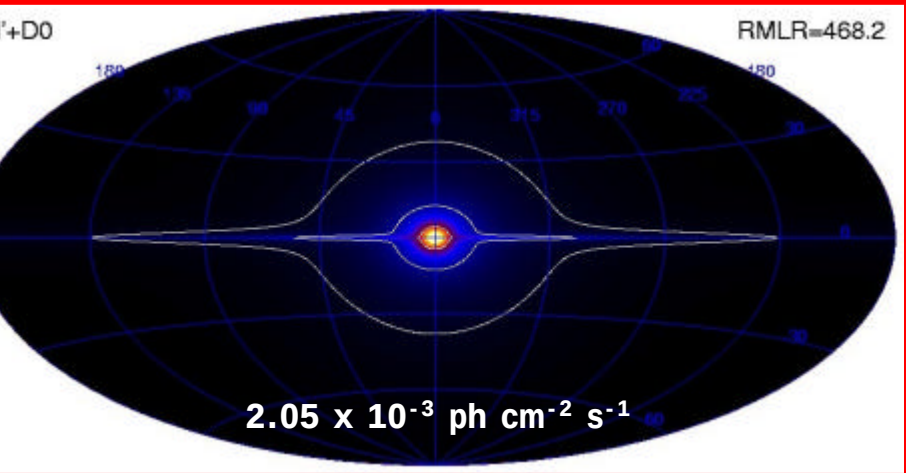


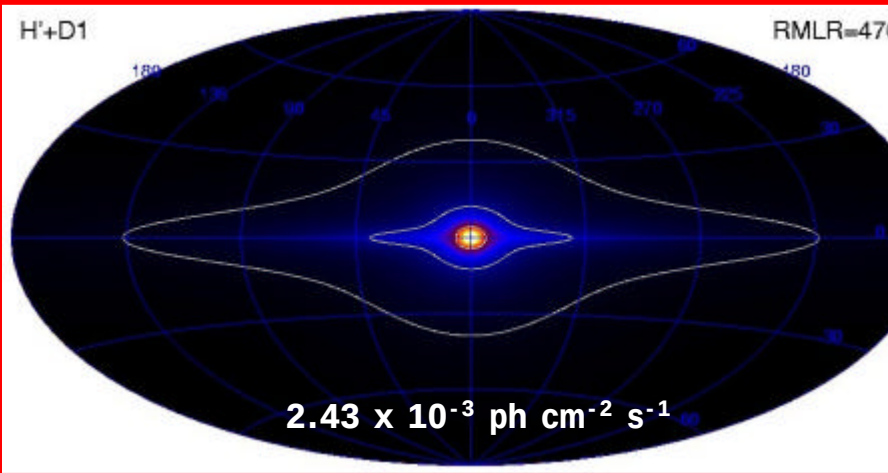
SPI 511 keV bulge flux : (1.1-2.2) x 10^{-3} ph cm^{-2} s^{-1}

Bulge/Halo + Disk models





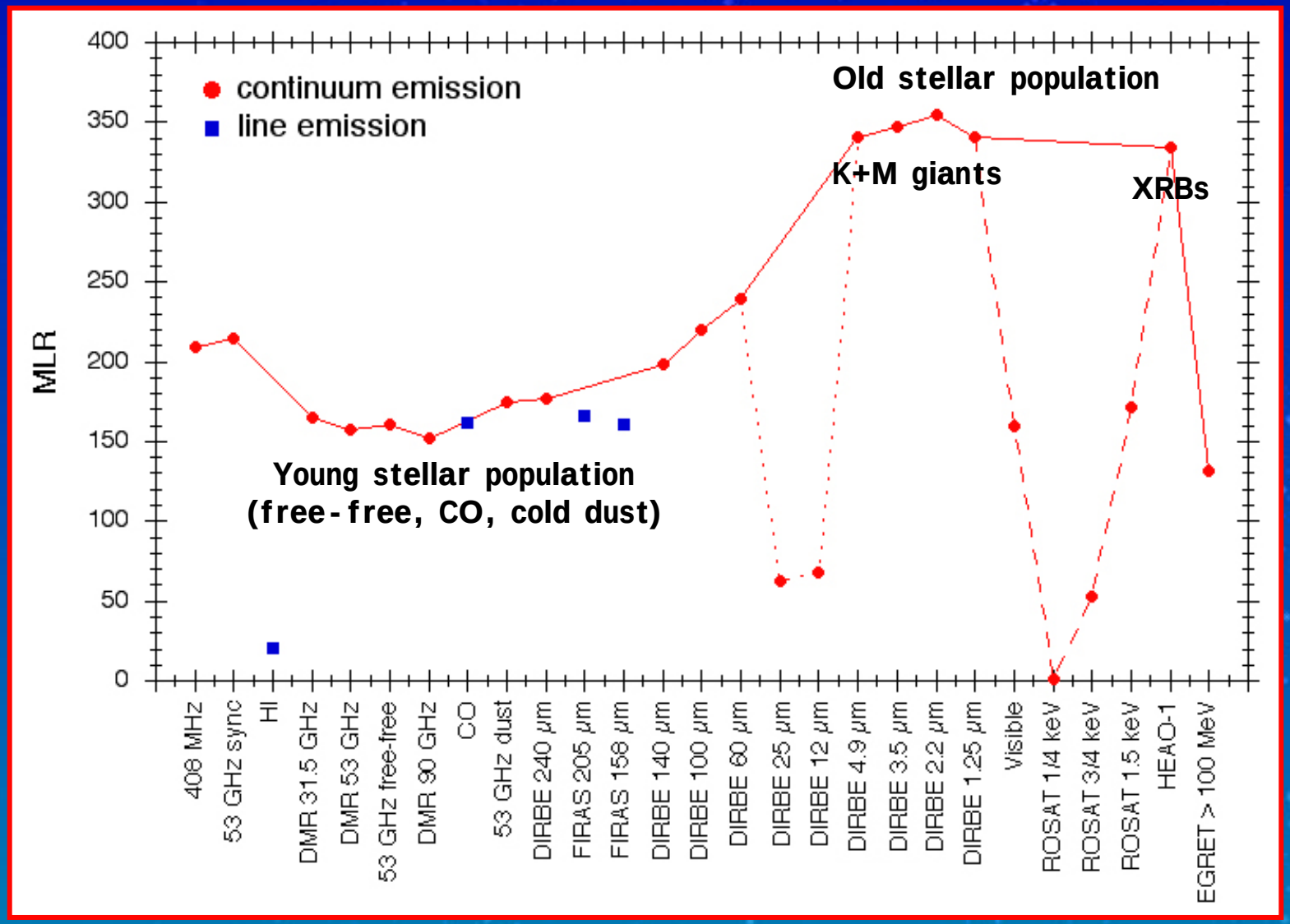




511 keV flux : (1.6-2.4) x 10^{-3} ph cm^{-2} s^{-1}
B/D flux ratio : 1-3 (D1-D0)
H/D flux ratio : 2-4 (D1-D0)

SMM flux (wide field-of-view)
(1.5-2.8) x 10^{-3} ph cm^{-2} s^{-1}

Comparison with tracer maps



Radio μ-waves FIR NIR V X-ray

Step 2 : Conclusions

	Bulge	Halo	Disk
Flux (10^{-3} ph cm^{-2} s^{-1})	1.05 ± 0.07	1.6 ± 0.5	0.7 ± 0.5**
L_{511} (10^{43} ph s^{-1})	0.90 ± 0.06	1.2 ± 0.3	0.2 ± 0.1
L_p (10^{43} s^{-1})*	1.50 ± 0.10	2.0 ± 0.5	0.3 ± 0.2

* assuming $f_p = 0.93$

** $F \sim 5 \times 10^{-4}$ ph cm^{-2} s^{-1} expected from ^{26}Al

The 511 keV line emission is bulge dominated :

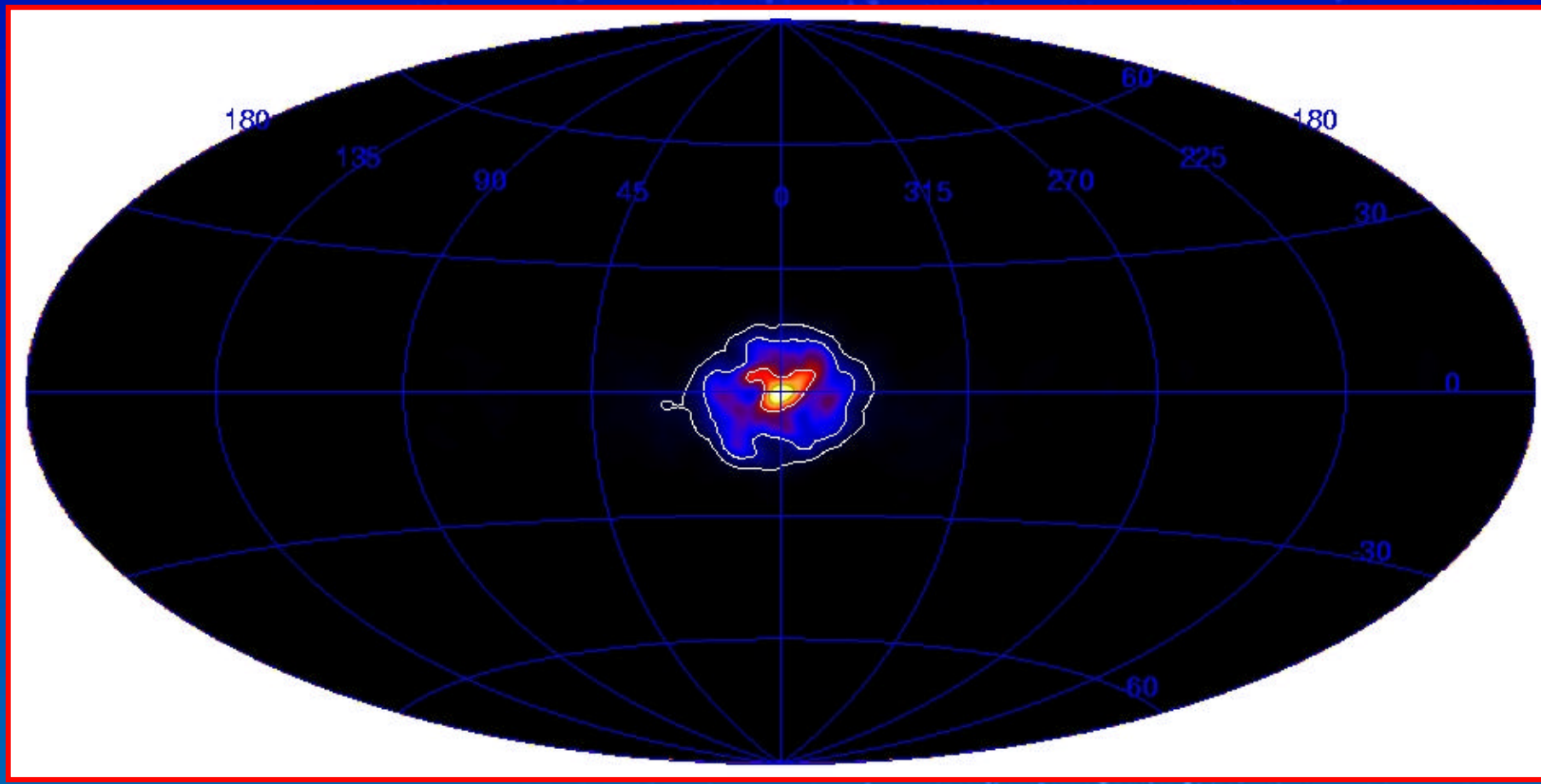
B/D flux ratio : 1 - 3

B/D luminosity ratio : 3 - 9

Step 3

Imaging

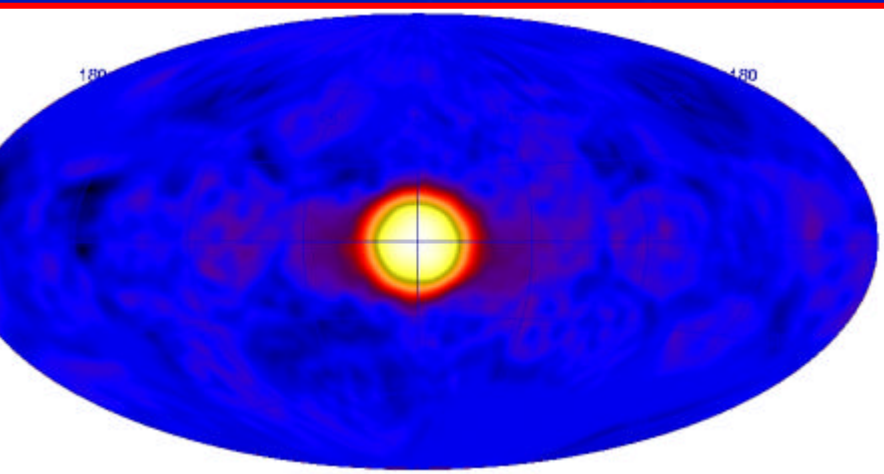
An all-sky image of 511 keV emission



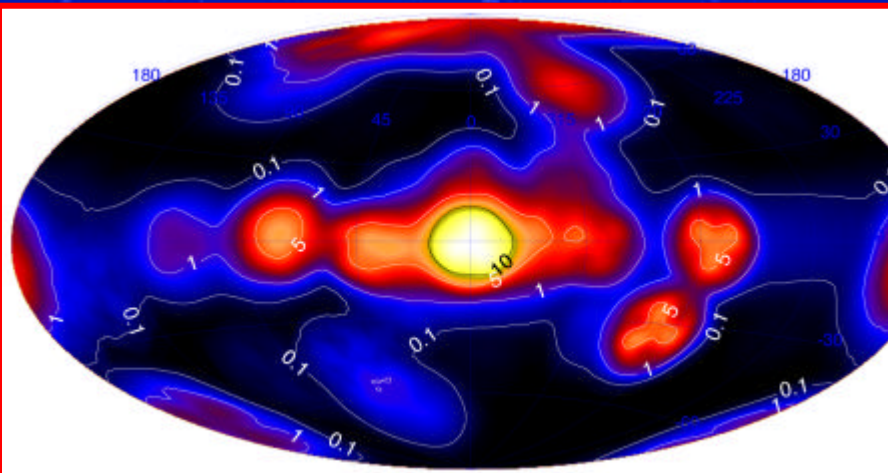
- Iteration 17 of accelerated Richardson-Lucy algorithm
- 5° x 5° boxcar smoothing
- Integrated 511 keV flux : 1.4 x 10^{-3} ph cm^{-2} s^{-1}

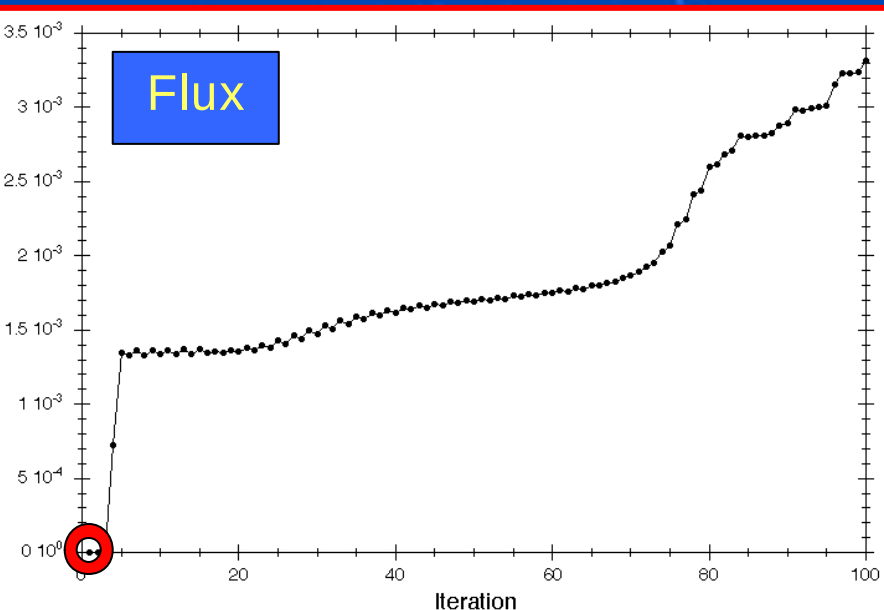
Choice of iteration

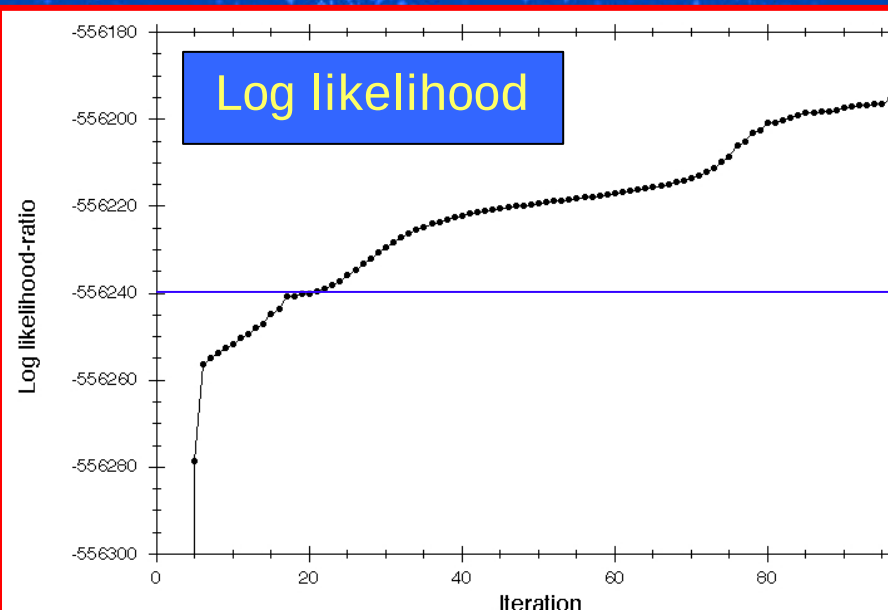
Iteration 1



Exposure

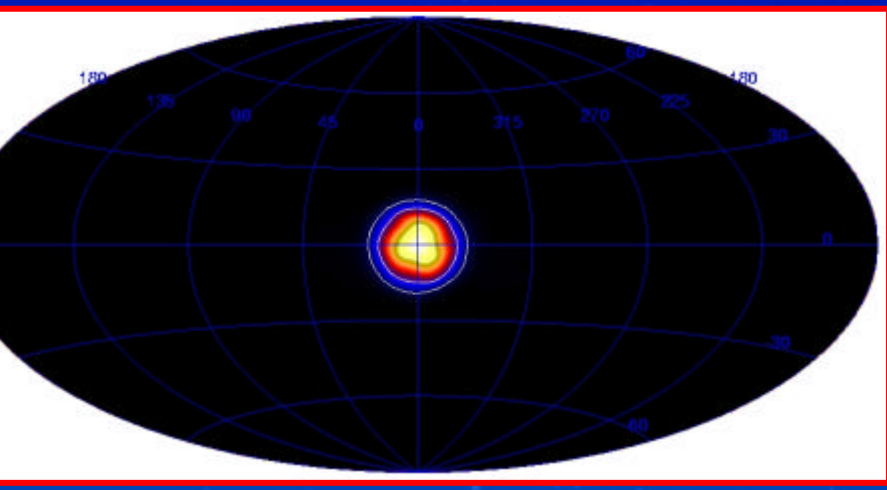




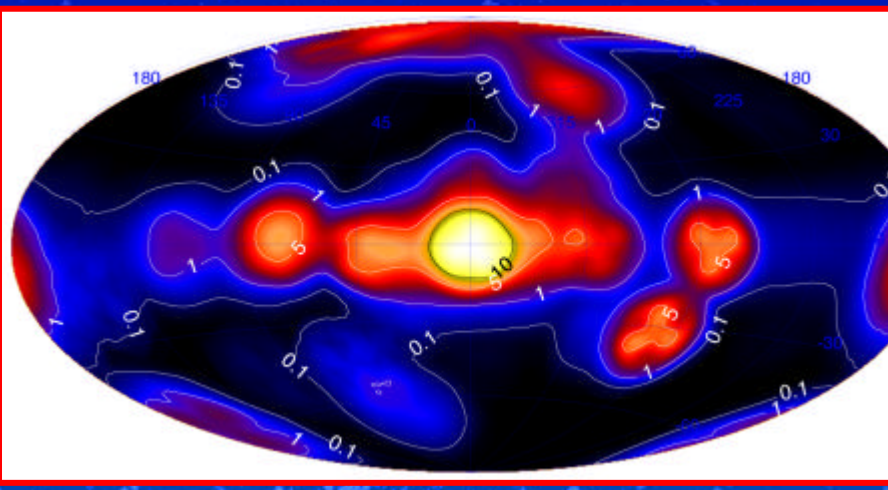


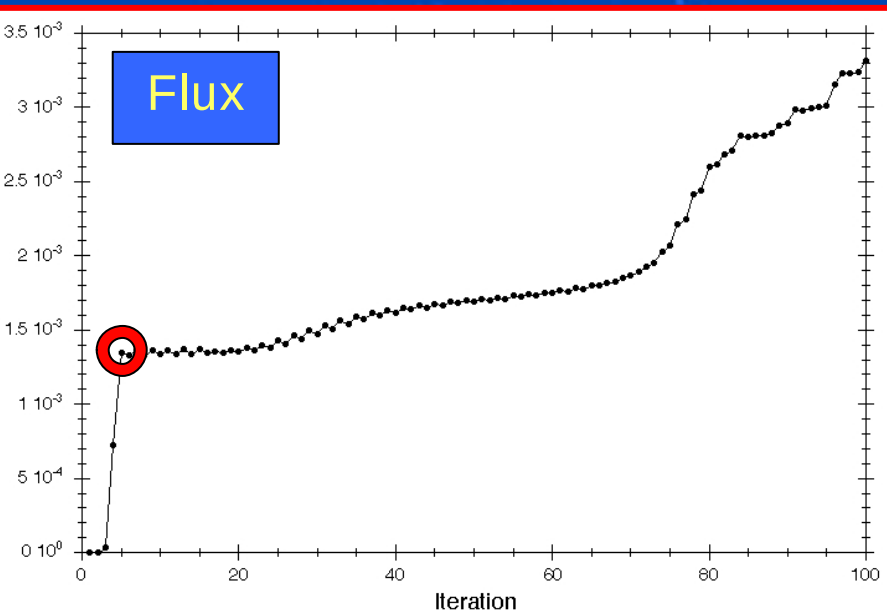
Choice of iteration

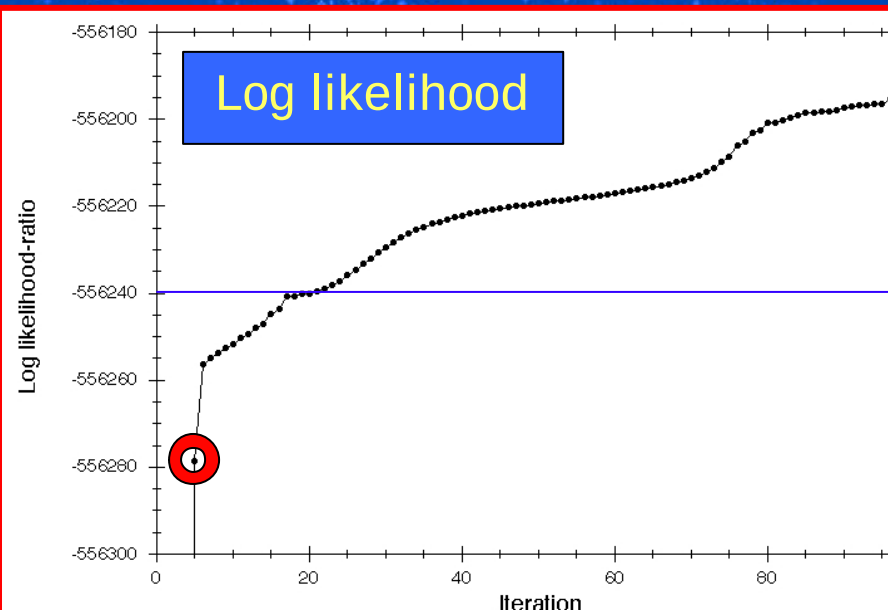
Iteration 5



Exposure

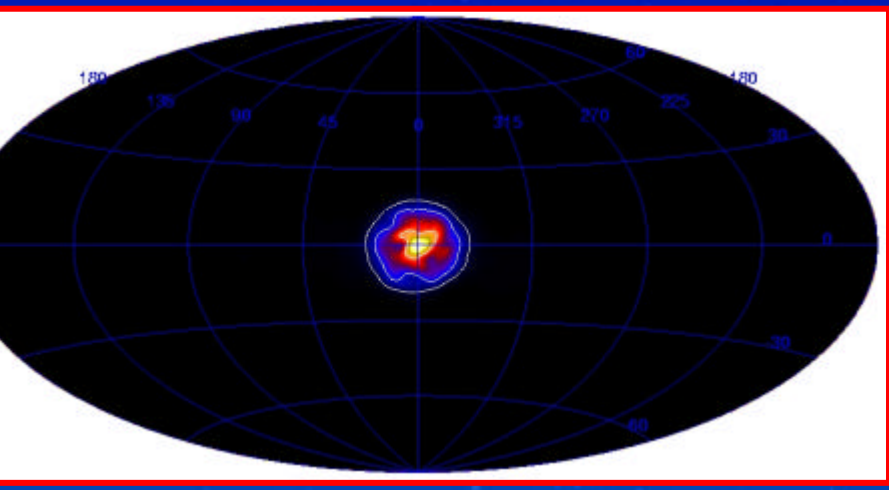




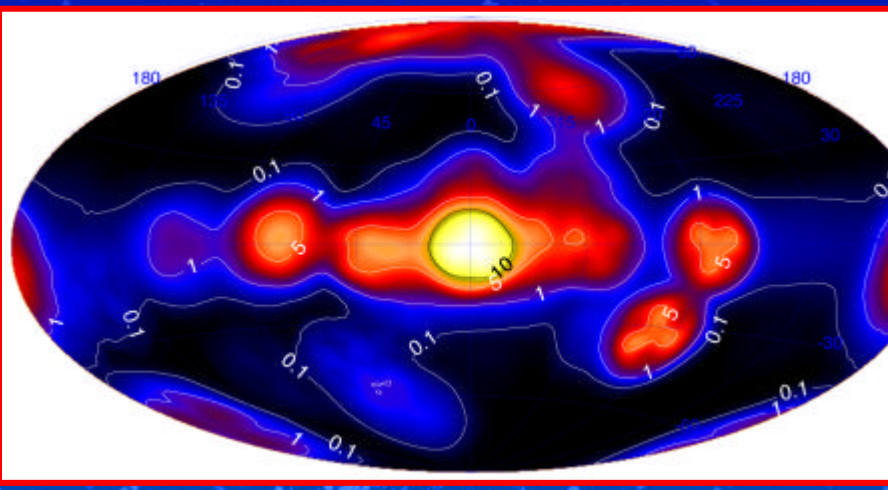


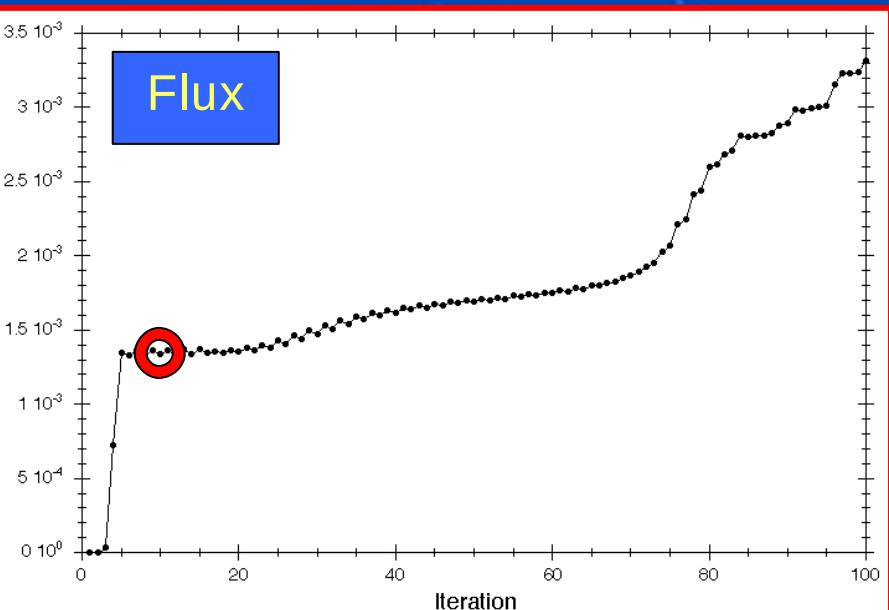
Choice of iteration

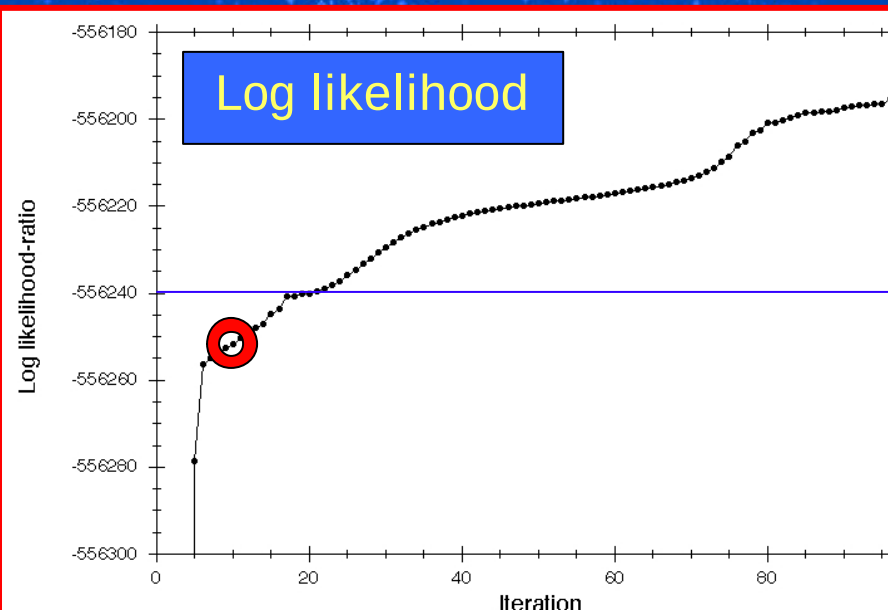
Iteration 10



Exposure

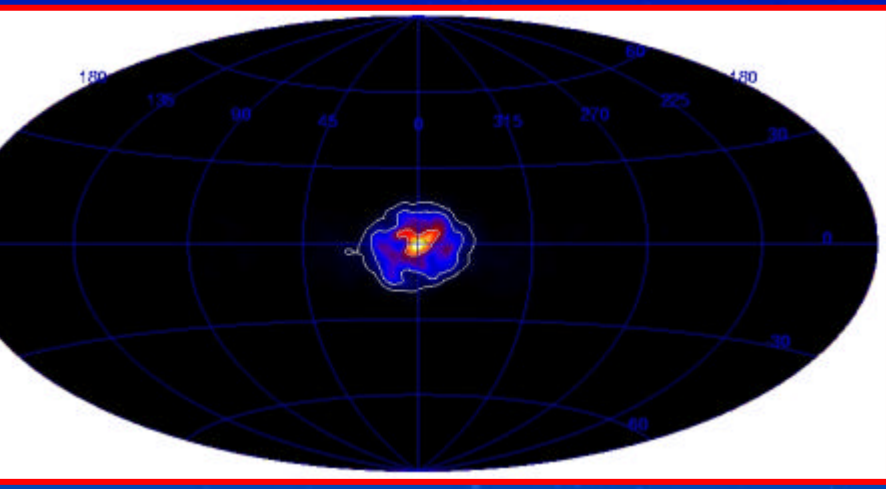




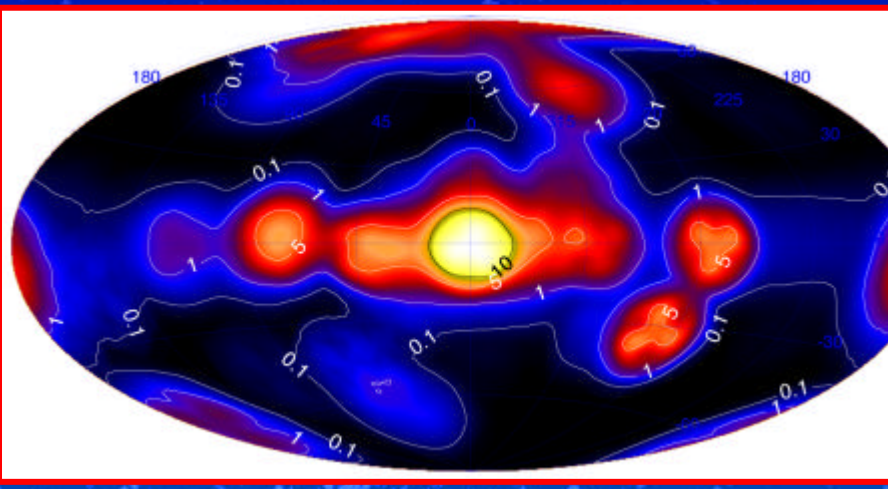


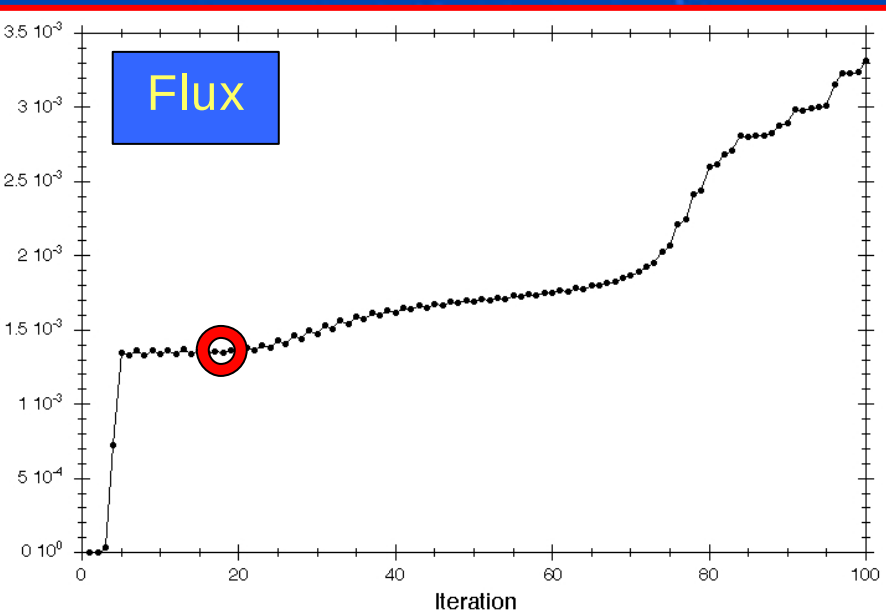
Choice of iteration

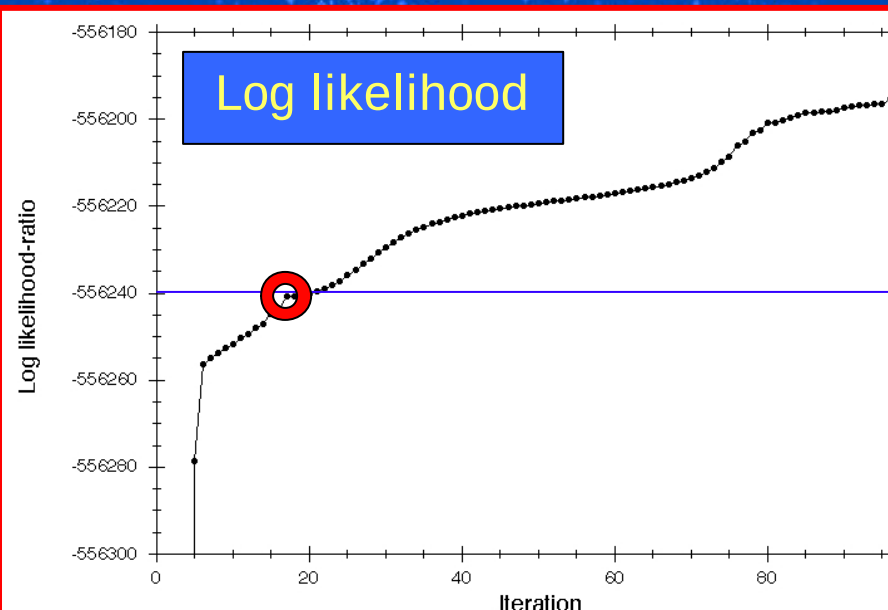
Iteration 17



Exposure

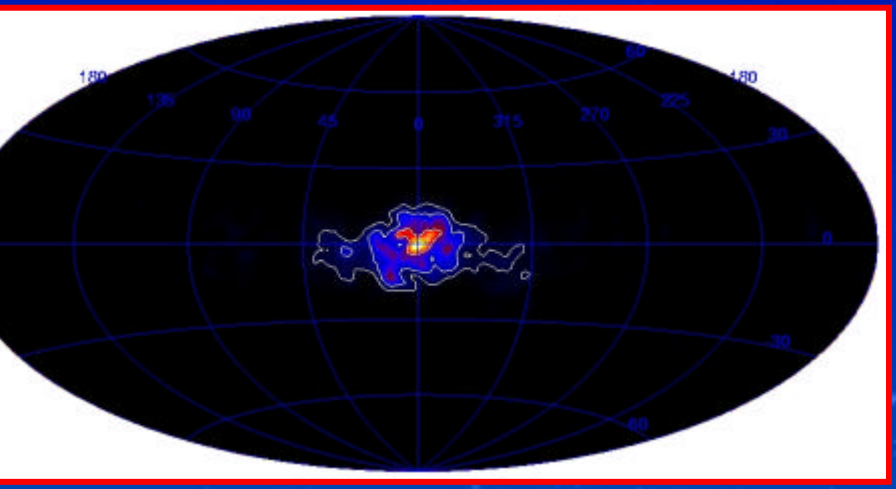




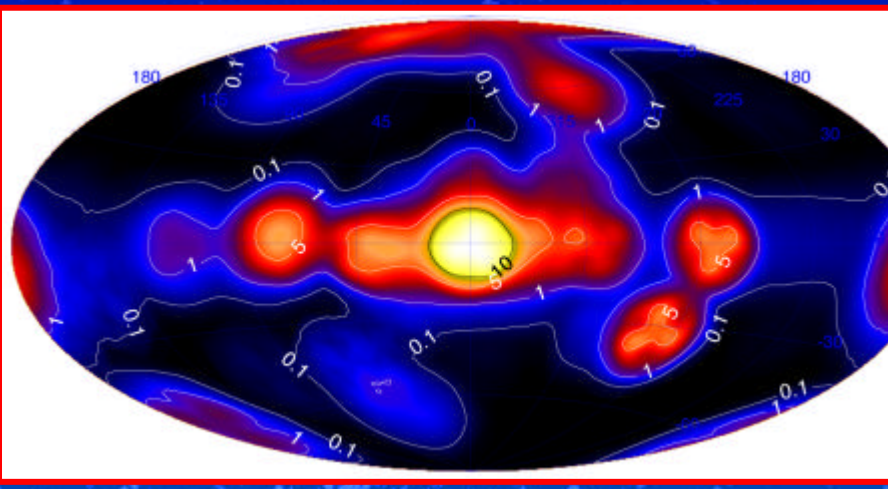


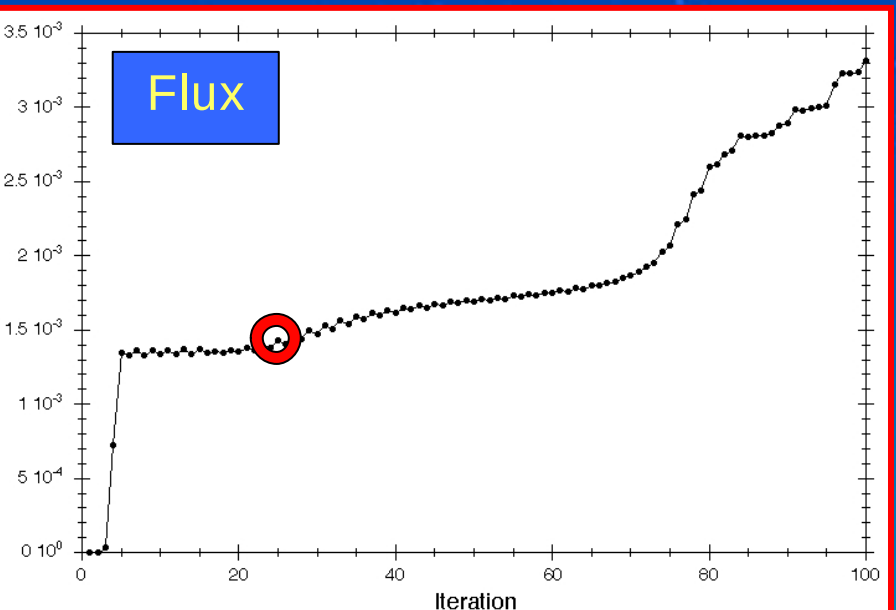
Choice of iteration

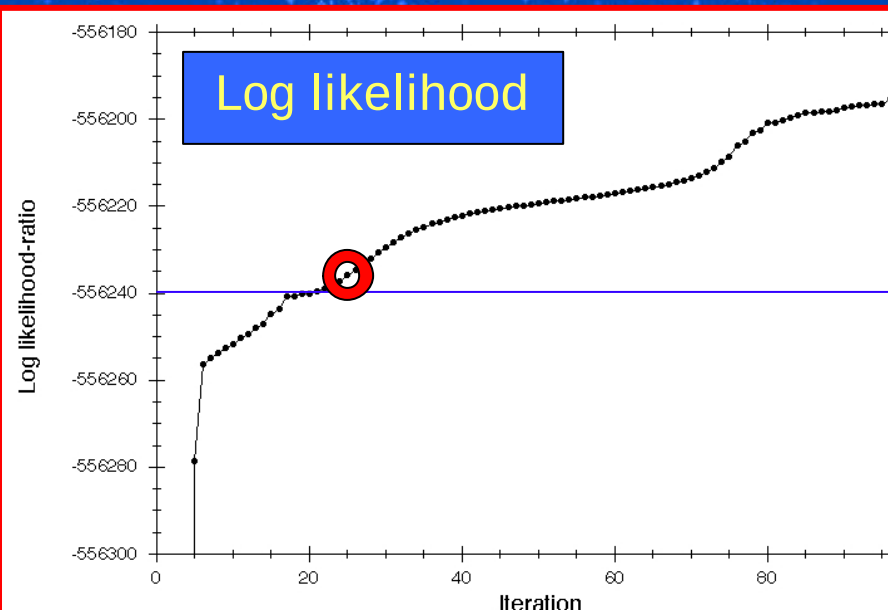
Iteration 25



Exposure

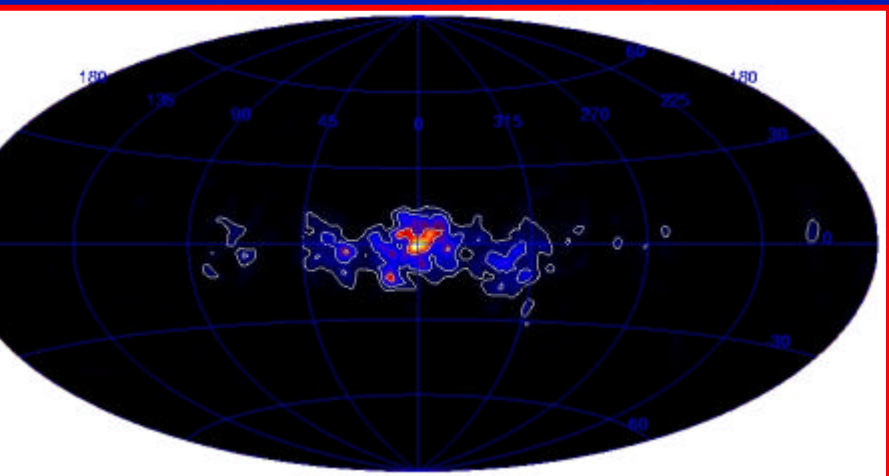




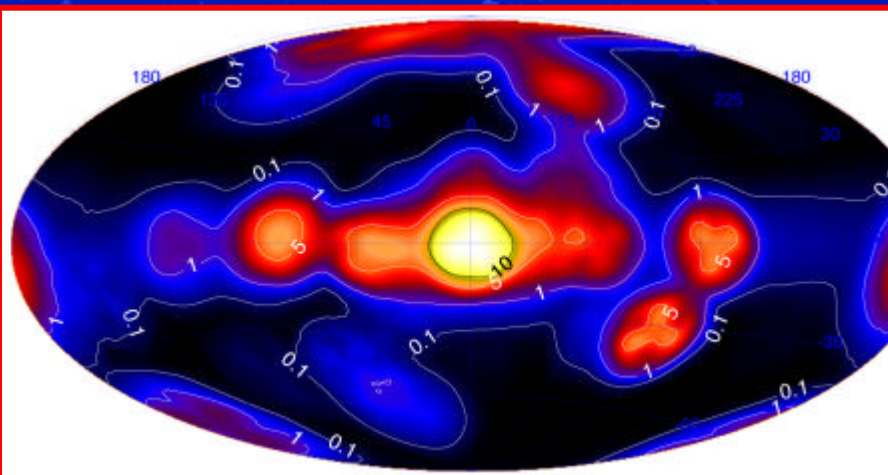


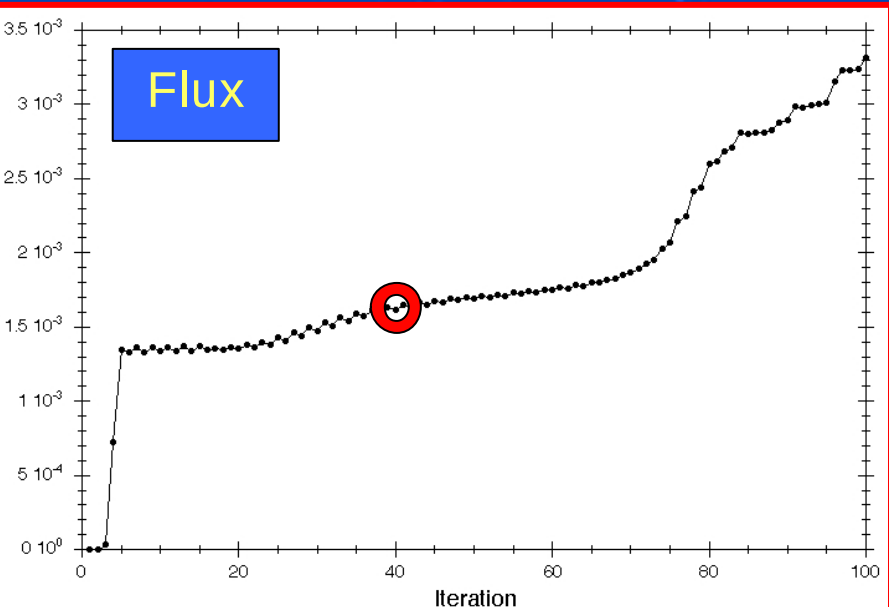
Choice of iteration

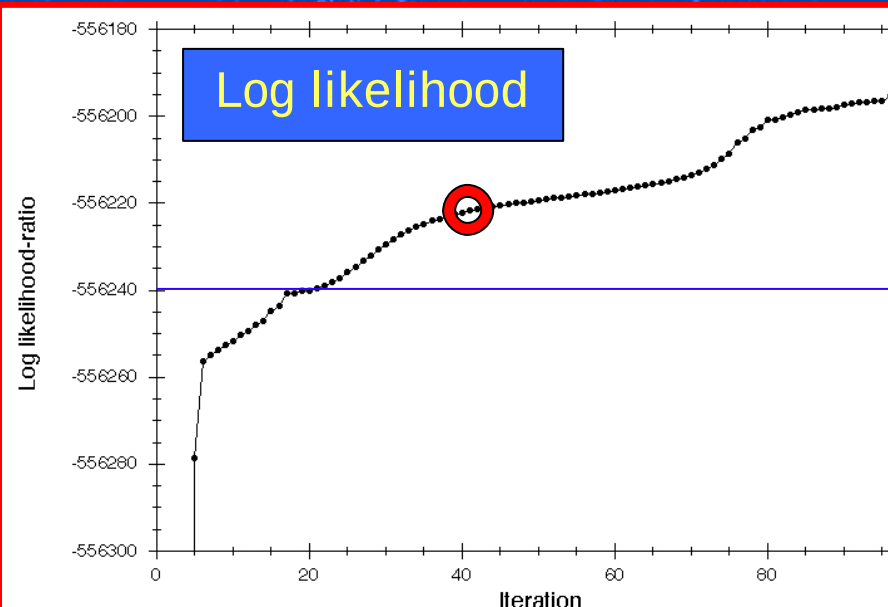
Iteration 40



Exposure

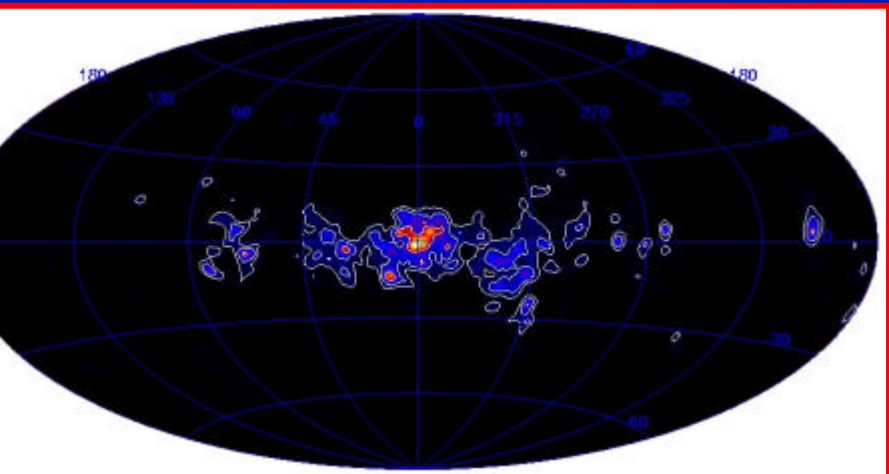




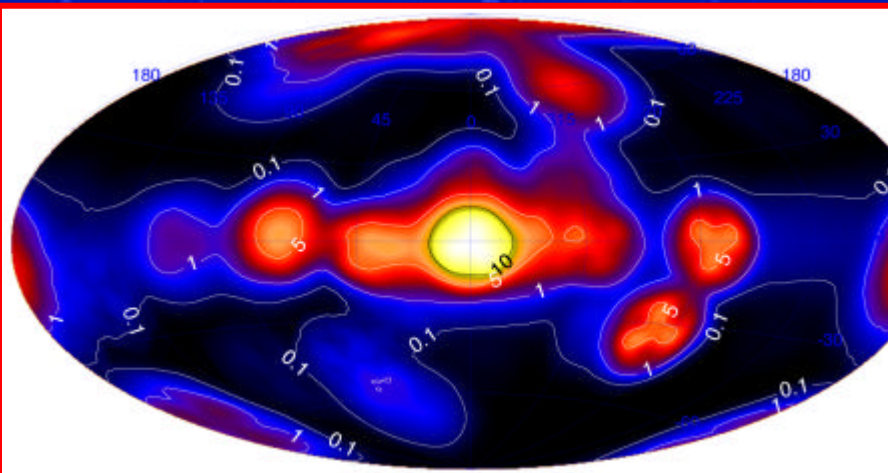


Choice of iteration

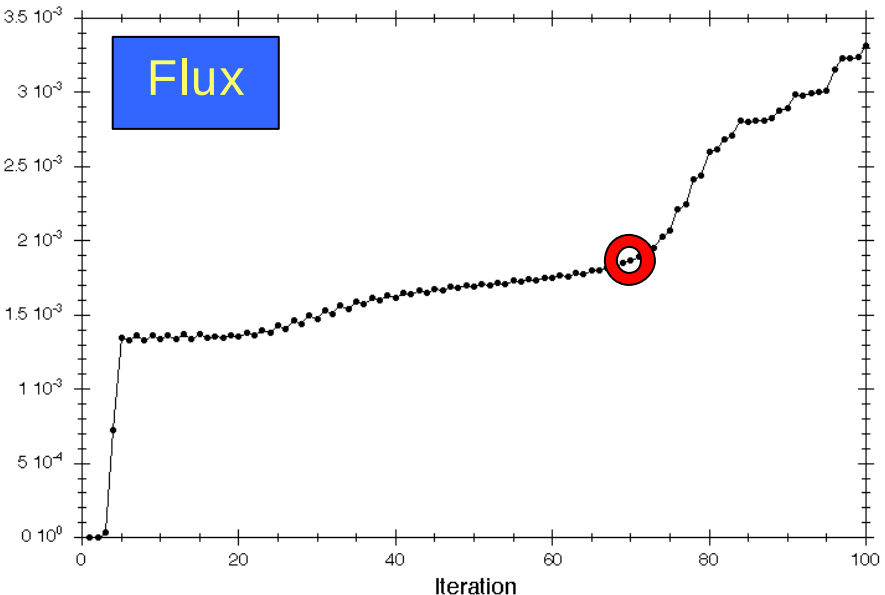
Iteration 70



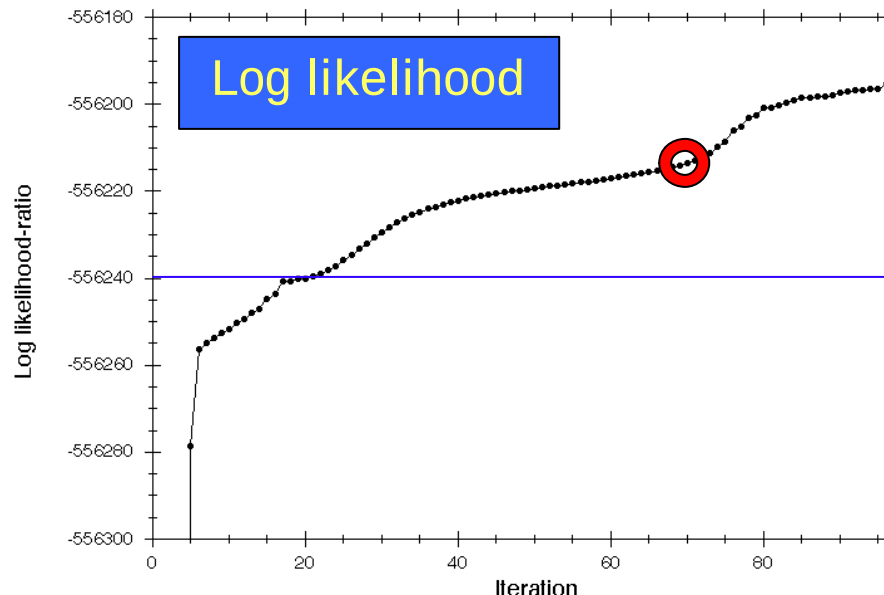
Exposure



Flux

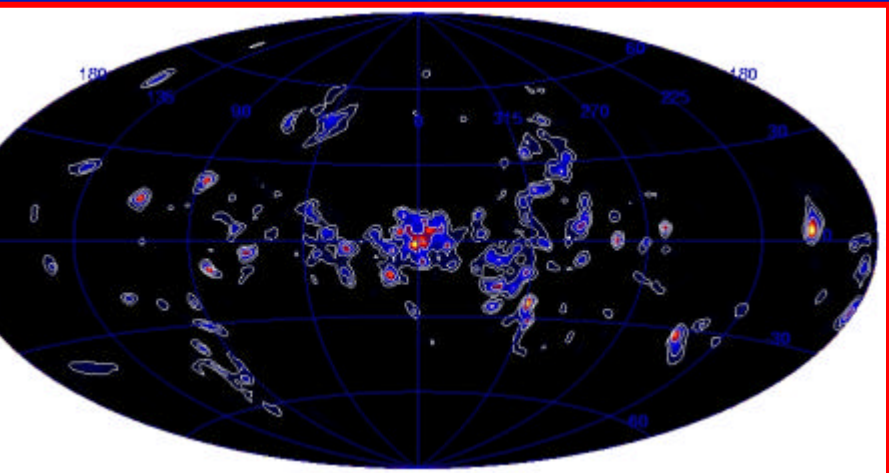


Log likelihood

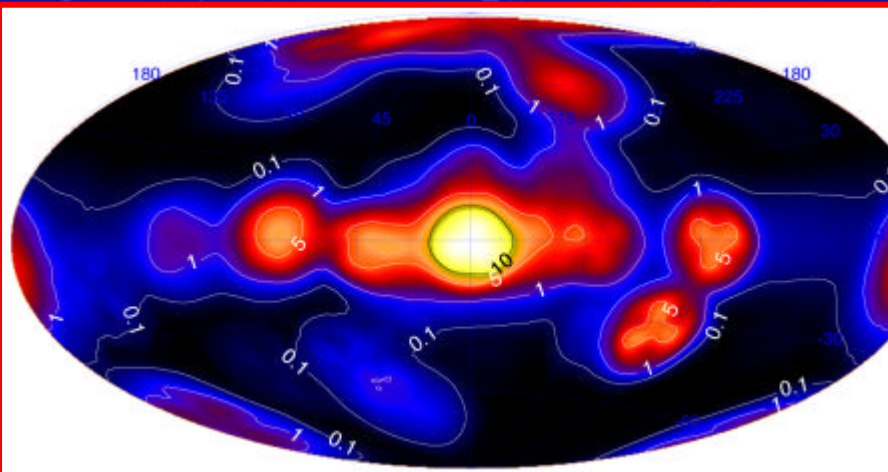


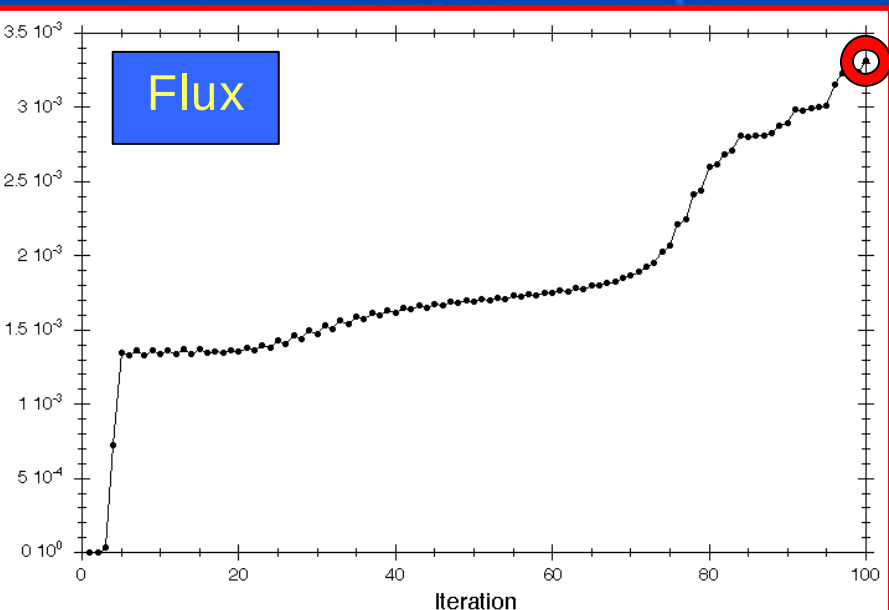
Choice of iteration

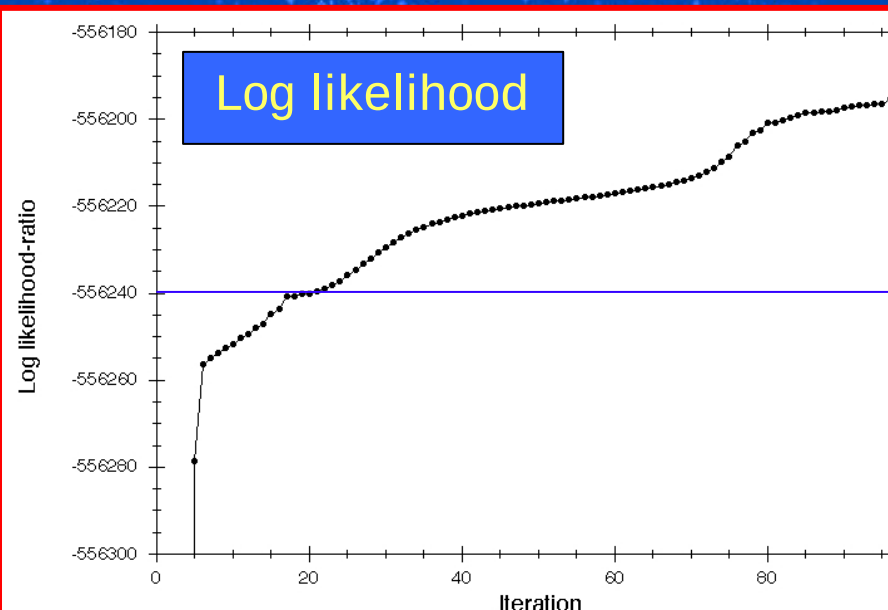
Iteration 100



Exposure

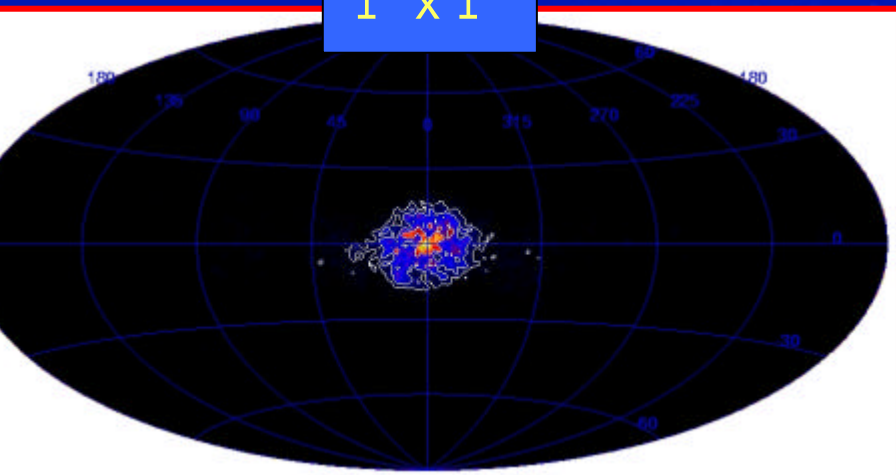




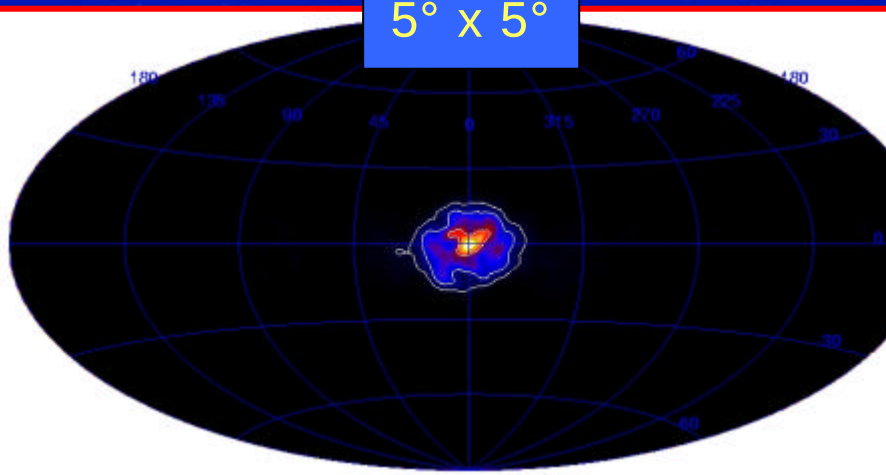


Choice of the smoothness

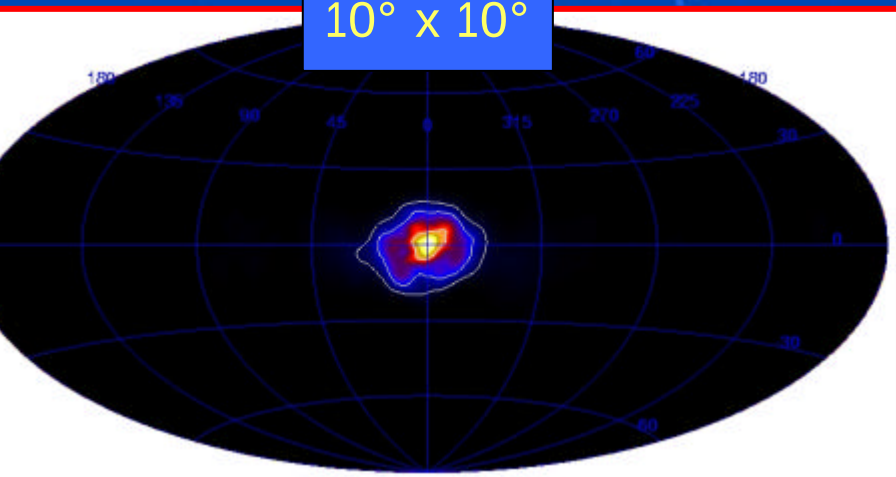
1° x 1°



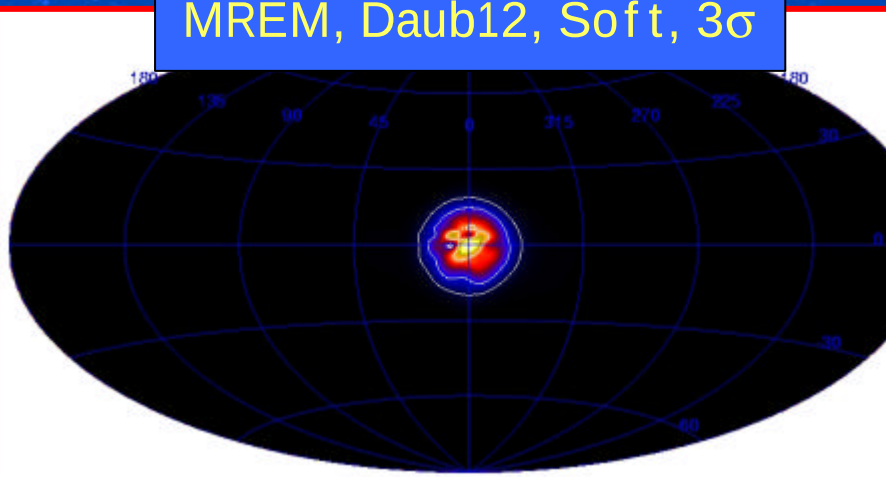
5° x 5°



10° x 10°



MREM, Daub12, Soft, 3σ



General conclusions

- The 511 keV sky is bulge / halo dominated
- The disk component could be entierly explained by β^+ decay of radioactive ^{26}Al ($3\ M_\odot = 3.5 \times 10^{42}\ s^{-1}$)
- Annihilation rate (assuming $f_p = 0.93$)

  Bulge $1.5 \times 10^{43}\ s^{-1}$
  Halo $2.0 \times 10^{43}\ s^{-1}$
  Disk $0.3 \times 10^{43}\ s^{-1}$

- What is the bulge / halo e^+ source ?
- Has the bulge / halo e^+ source a disk component ?

- Observe nearby candidate sources (SNR, LMXB)
- Deep observations at high galactic latitudes & galactic plane