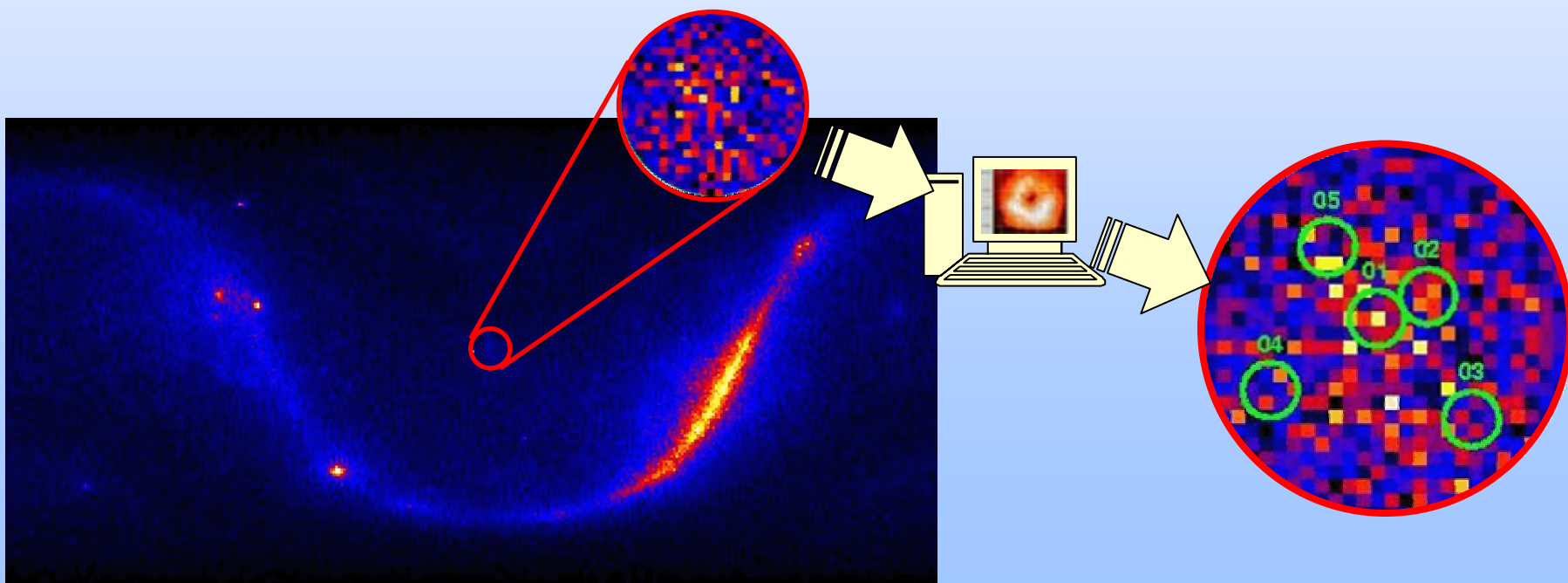**Riccardo Rando (rando@pd.infn.it),**
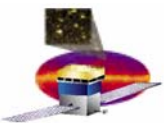**Francesco Longo, Riccardo Giannitrapani…**
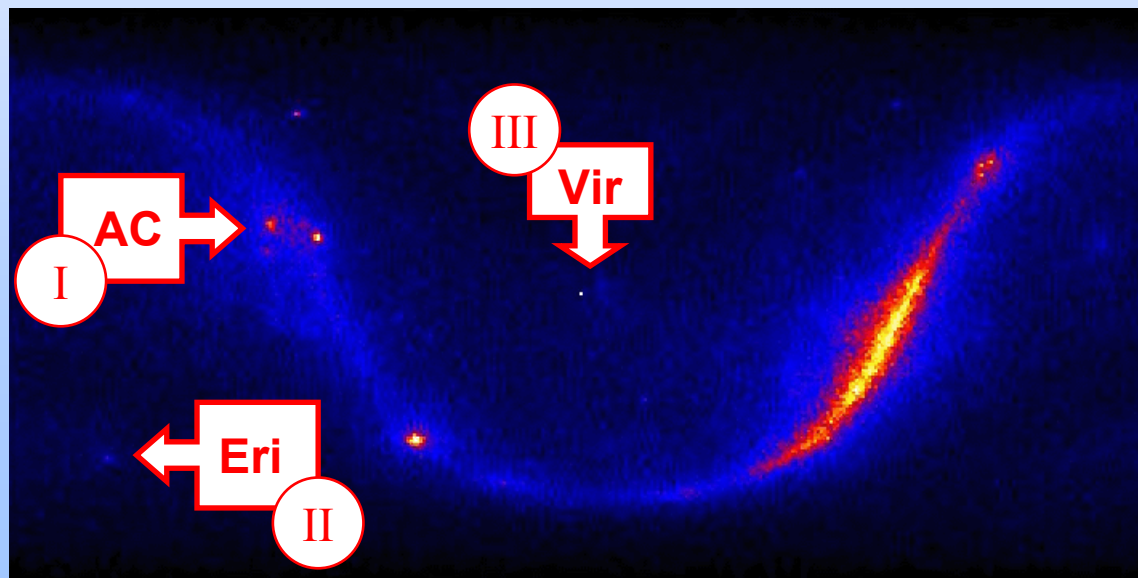
Likelihood analysis of some galactic and extragalactic sources

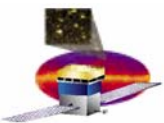# **Guideline**

- **Identify sources / obtain spectra**
- **Some well known source as reference (AC)**
- **Some less known source as test (Eri)**
- **Some badly resolved region just to try (Vir)**

Anticenter Region

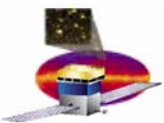• **Copy Likelihood tutorial analysis on DC1 data instead of using simulated data**

• **use simulated data from tutorial: 1 day ObsSim data to compare with "real" DC1 data**

• **Crab, Geminga, PKS** and diffuse extragalactic are simulated**

• **1550 events in ObsSim data, 10124 in DC1 data**

• **for DC1 data galactic diffuse component ("Egret d. c.") is relevant**
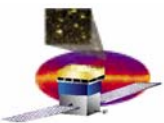
ObsSim

DC1

?
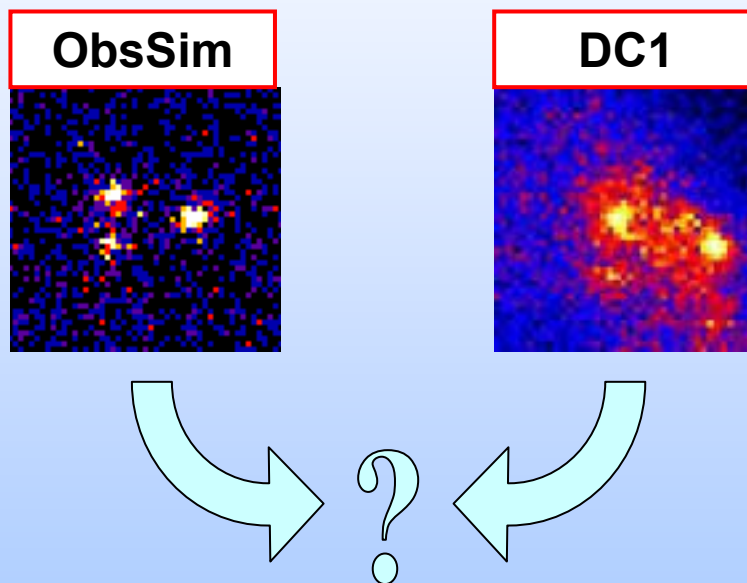
Anticenter: simple

- **A simple model, with point sources but with no diffuse component will fail!**

- **Let's try anyway to see what happens**

- **ROI, ExpMap, etc etc…**

- **almost everything is fair enough, but for Geminga spectral index, which is horrible!**

- **note: this is not the faintest source! PKS** generates 50% less photons than Geminga**

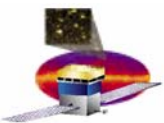- **prefactors are badly overestimated: we are counting diffuse photons as produced by our sources**

Fit: no diffuse component	Anticenter DC1	Anticenter obsSim
accepted events	10124	1550
Crab		
prefactor	709 +/- 16	24.8 +/- 2.6
scale	100	100
index	-2.407 +/- 0.019	-2.072 +/- 0.065
Geminga		
prefactor	507 +/- 16	23.9 +/- 1.9
scale	100	100
index	-2.414 +/- 0.025	-1.645 +/- 0.035
PKS0528+134		
prefactor	325 +/- 20	13.3 +/- 2.2
scale	100	100
index	-2.785 +/- 0.057	-2.36 +/- 0.14

Anticenter: tweak a little bit

• **Let's add the EGRET galactic diffuse component**

• **this is modeled by an input FITS file (gas.cel) in the Likelihood package**

• **the amount of diffuse photons is BIG!**

• **for ObsSim data there is no need for this: we can subtract the extragalactic component to have a better extimate (again: see online tutorial)**
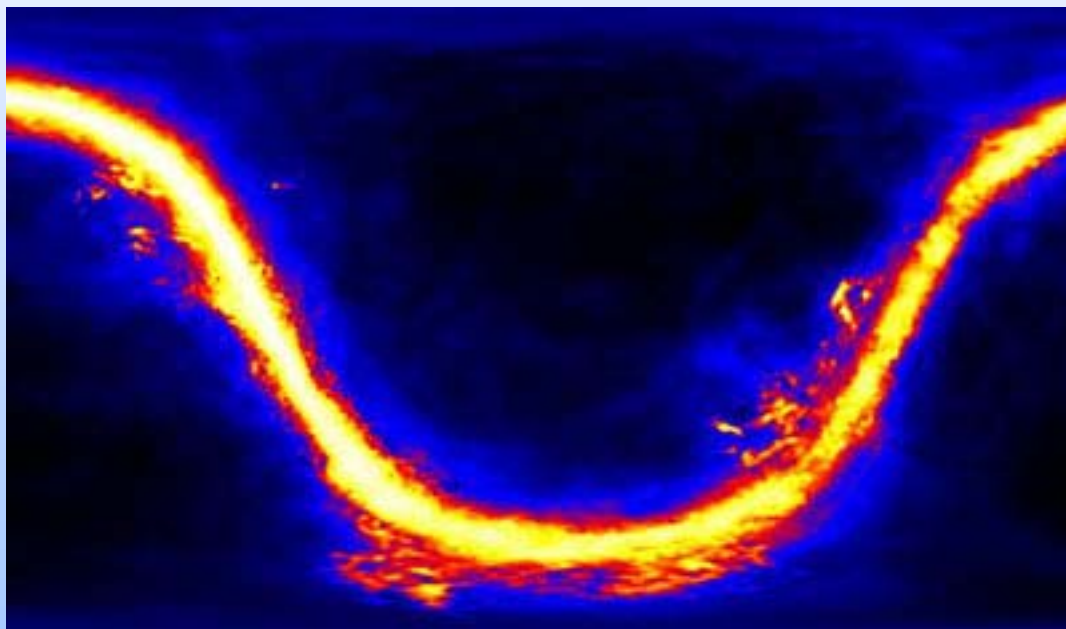
Anticenter: final result

- **Diffuse components were subtracted**

- **Spectral indexes are equal within uncertainties**
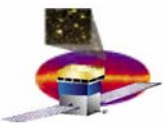
- **Even prefactors match (sheer luck??)**

much better!

| Fit: with diffuse component	Anticenter DC1	Anticenter obsSim
accepted events	10124	1550
Crab		
prefactor	26.9 +/- 1.4	24.9 +/- 2.6
scale	100	100
index	-2.190 +/- 0.088	-2.069 +/- 0.065
Geminga		
prefactor	27.0 +/- 1.1	24.0 +/- 2.0
scale	100	100
index	-1.660 +/- 0.025	-1.644 +/- 0.035
PKS0528+134		
prefactor	13.1 +/- 1.2	13.3 +/- 2.2
scale	100	100
index	-2.46 +/- 0.23	-2.23 +/- 0.11
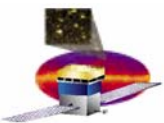
Anticenter: a look inside

• **We relied heavily on the Likelihood package; the only output is given by the fit parameters, other tools can be used to have a look inside the procedure**

• **we used ROOT to generate a couple of histo's and tried to fit by hand**

• **we selected a circular acceptance regions around point sources (radii: 2.875, 2.375, 1.875 deg)**

• **parameters are close to those found with Likelihood without subtracting the diffuse component**
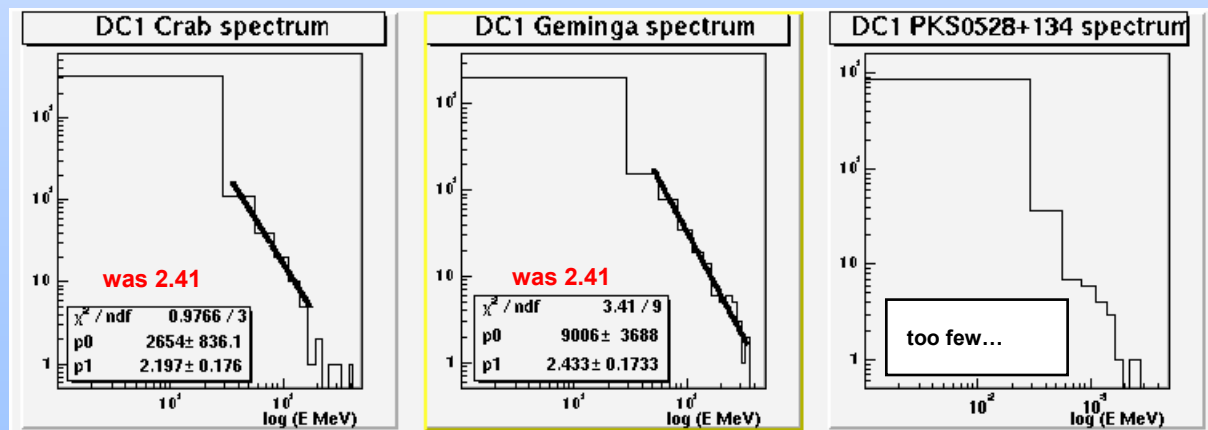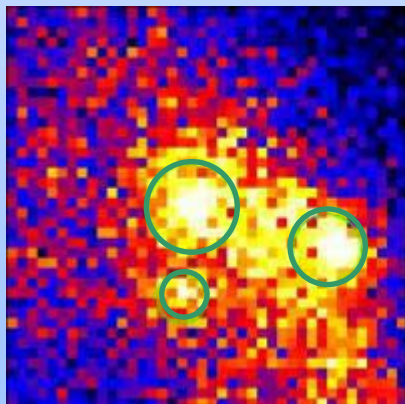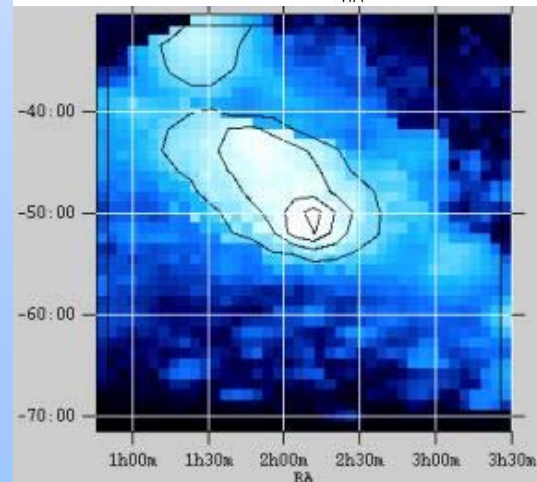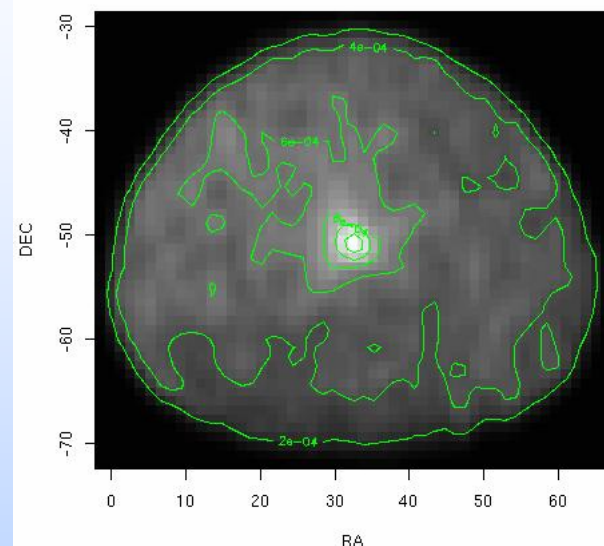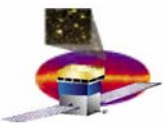
Eridanus

• let's select an isolated, extragalactic source

• we expect less influence of the diffuse
galactic component

• faintness is the primary issue
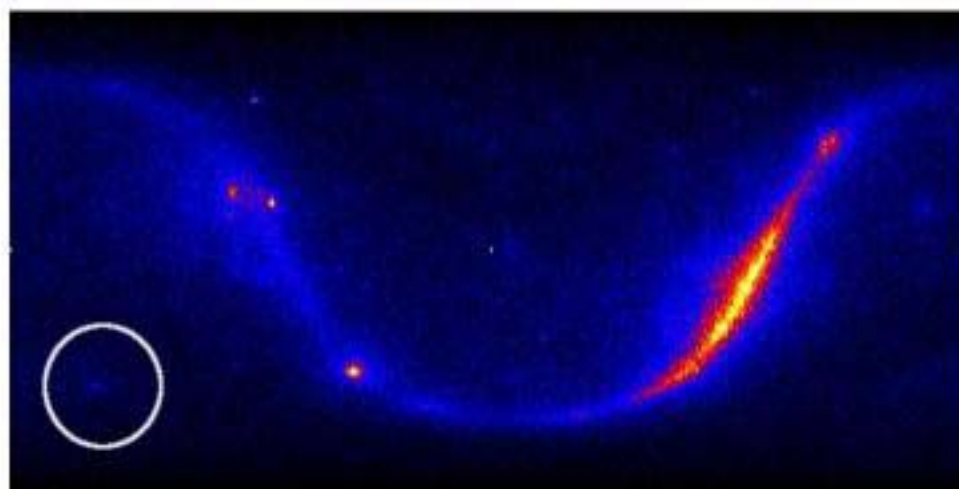
Eridanus: pointing

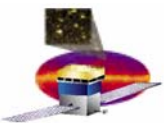• **To find point source coordinates we can either**
- ✓ **take the maximum of the photon countmap, or**
- ✓ **create a test-statistics map with no source in the model,**

• **both method agree quite well for an isolated source: we get J2000(32.5,-51.25)**

• **let's try to get a spectrum**

• **we add also the galactic diffuse background: should not matter, but as it's not a trouble either…**
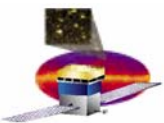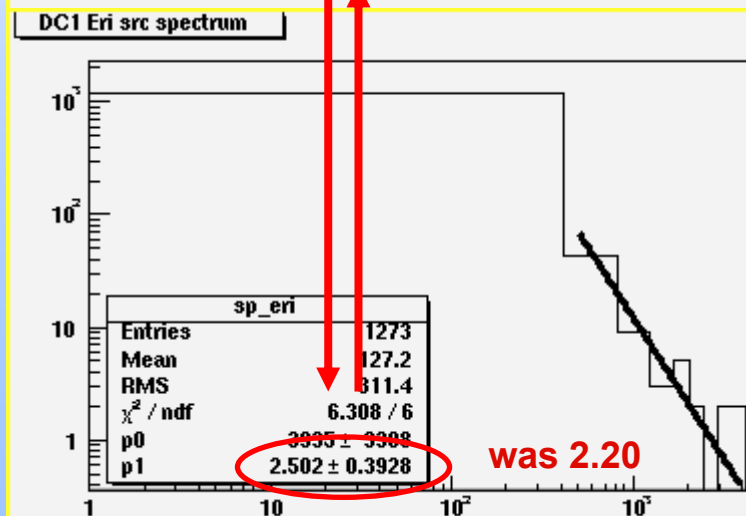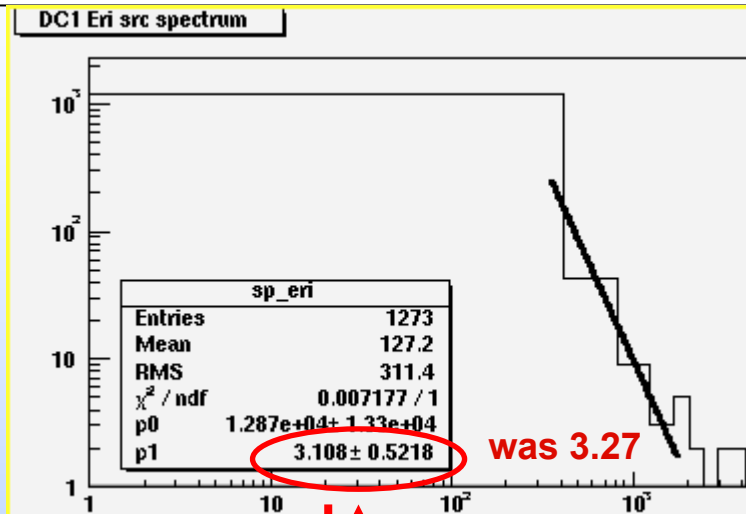
Eridanus: (not so good) results

• **We simulated 1 day observation with ObsSim for the usual comparison**

• **errors are big, yet we had 2000+ photons to start with**

• **GDE is not so small even here**

• **spectral indexes are awful**

• **let's try to look in more detail at what is happening here…**

| Fit: with diffuse component	Eridanus DC1	3EGJ0210-5055 (obsSim)
accepted events	2186	711
Gamma Source		
prefactor	117 +/- 12	12.2 +/- 3.4
scale	100	100
index	-3.27 +/- 0.15	-2.20 +/- 0.13
Galactic Diffuse Emission		
prefactor	76.0 +/- 2.9	19.4 +/- 1.2
scale	100	100
index	-2.262 +/- 0.029	-1.988 +/- 0.038

Eridanus: a look inside

• **ROOT again**

• **ROI radius is 5 degrees (~2×AC)**

• **we can replicate the bad result**

• **we can even approximate the ObsSim result with the same binning changing only the fit interval**

• **this can be explained with the limited number of events**

• **Likelihood works properly, but sometime a more pictorial representation helps**

• **BTW, the source was J0210-5055, and the spectral index was -1.99**

DC1 Eri src spectrum

sp_eri	
Entries	1273
Mean	127.2
RMS	311.4
χ^2 / ndf	0.007177 / 1
p0	1.287e+04± 1.33e+04
p1	3.108± 0.5218

was 3.27

DC1 Eri src spectrum

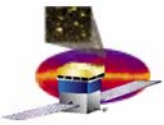| sp_eri	
Entries	1273
Mean	127.2
RMS	311.4
χ^2 / ndf	6.308 / 6
p0	3935± 3308
p1	2.502 ± 0.3928

was 2.20

Virgo

• **Something foolish: a complicated structure with many faint sources!**

• **near the NGP we spot something promising**

• **this is an extreme test of what we can do**

• **black box analysis, a polite way of saying I don't have the slightest idea of what I should find here (ignorance helps!)**
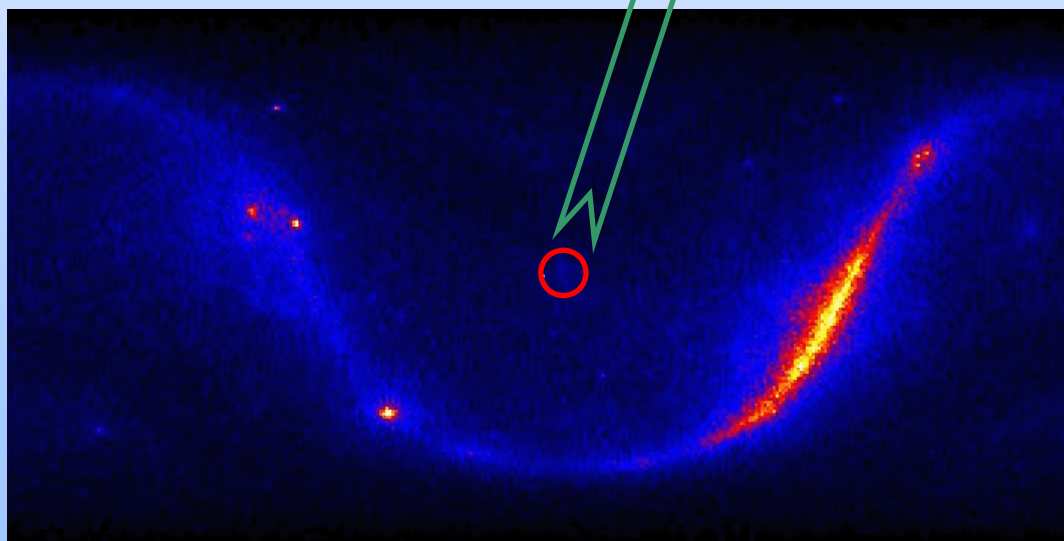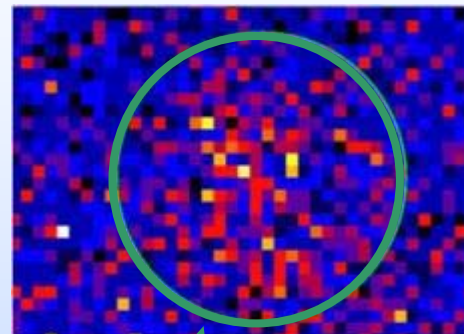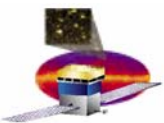
Virgo: find some sources

• **rather than an iterative process with many TSmap (too time consuming) we can choose an adequate binning and find the maxima in the photon countmap**

• **"adequate" means "I like the picture"**

• **the 4 highest peaks are selected**

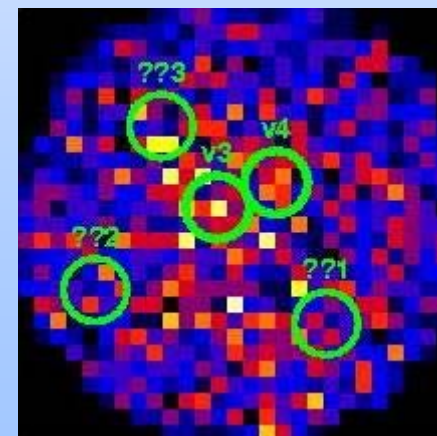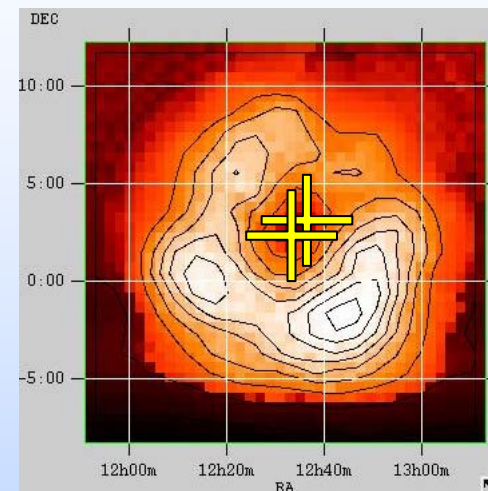| src	RA	DEC
v1	188.68	-1.98
v2	191.32	2.20
v3	187.44	2.29
v4	189.26	3.06

• **there was at least another one but already I don't like v1 and v2, they look slightly misplaced**
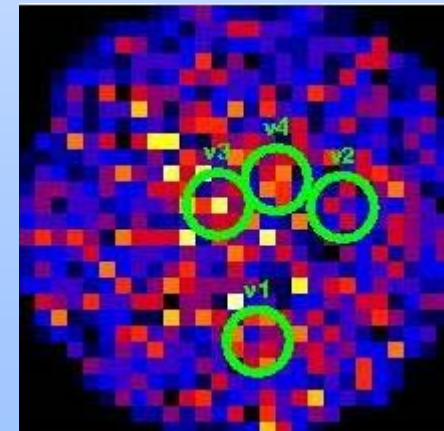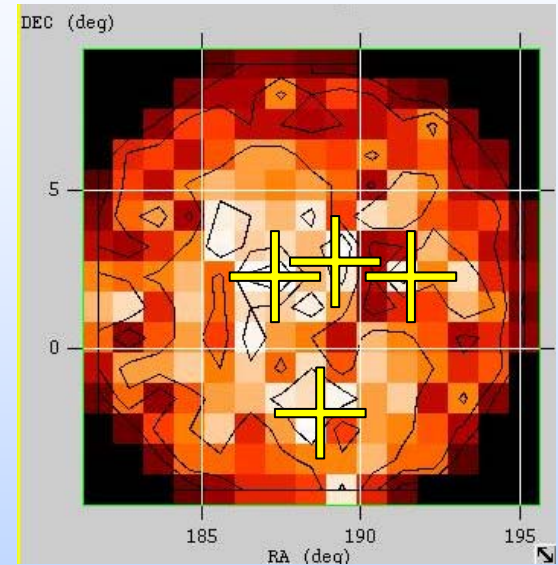
Virgo: from 4 to 2 to 5

- **let's delete v1 and v2**

- **v3 and v4 look fair enough, we keep them**

- **use TSmap to find a better positioning**

- **now we have three maxima:**

  - ➢ **a big one (slightly right of old v1)**
  - ➢ **a medium one (far left)**
  - ➢ **a small one (top left)**

- **the faintest is the one I like best!**

- **the one on the left looks dubious at best**

- **don't know what to think of the other: was it better placed before (v1) or now (??1) ?**

- **I could remove ??2 but with no reason… other that I don't believe it**
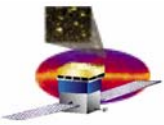
Virgo: status

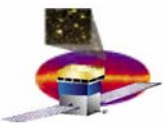• **We have found five sources:**

| src	RA	DEC
virgo_01 (v3)	187.44	2.29
virgo_02 (v4)	189.26	3.06
virgo_03 (??1)	190.826	-1.337
virgo_04 (??2)	183.638	-0.292
virgo_05 (??3)	185.693	4.823

• **one (virgo_04) seems unlikely**

• **seems that another (virgo_03) can be placed rather arbitrarily**
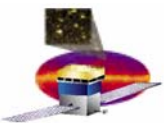
• **errors on fit parameters are big**

Fit, with diffuse component		Virgo region	
accepted events		1201	
virgo_01		virgo_02	
prefactor	66 +/- 19	prefactor	41 +/- 10
scale	100	scale	100
index	-2.73 +/- 0.20	index	-2.61 +/- 0.17
virgo_03		virgo_04	
prefactor	60.4 +/- 7.7	prefactor	42.6 +/- 7.3
scale	100	scale	100
index	-2.68 +/- 0.11	index	-2.62 +/- 0.14
virgo_05		Diff. em.	
prefactor	37.2 +/- 6.8	prefactor	43.0 +/- 9.9
scale	100	scale	100
index	-2.38 +/- 0.12	index	-2.02 +/- 0.10

Virgo: open the box

• **looking in the Egret catalogue we can fill that sky region with point sources**

• **our candidates are indicated by the red boxes**

• **the first two match!**

• **the one on the bottom was better placed before our last change…**

• **the fourth is a bogus (I knew it!)**

• **the fifth is far left of the possible right place (by 3.5 degrees)… yet I would have bet on it…**
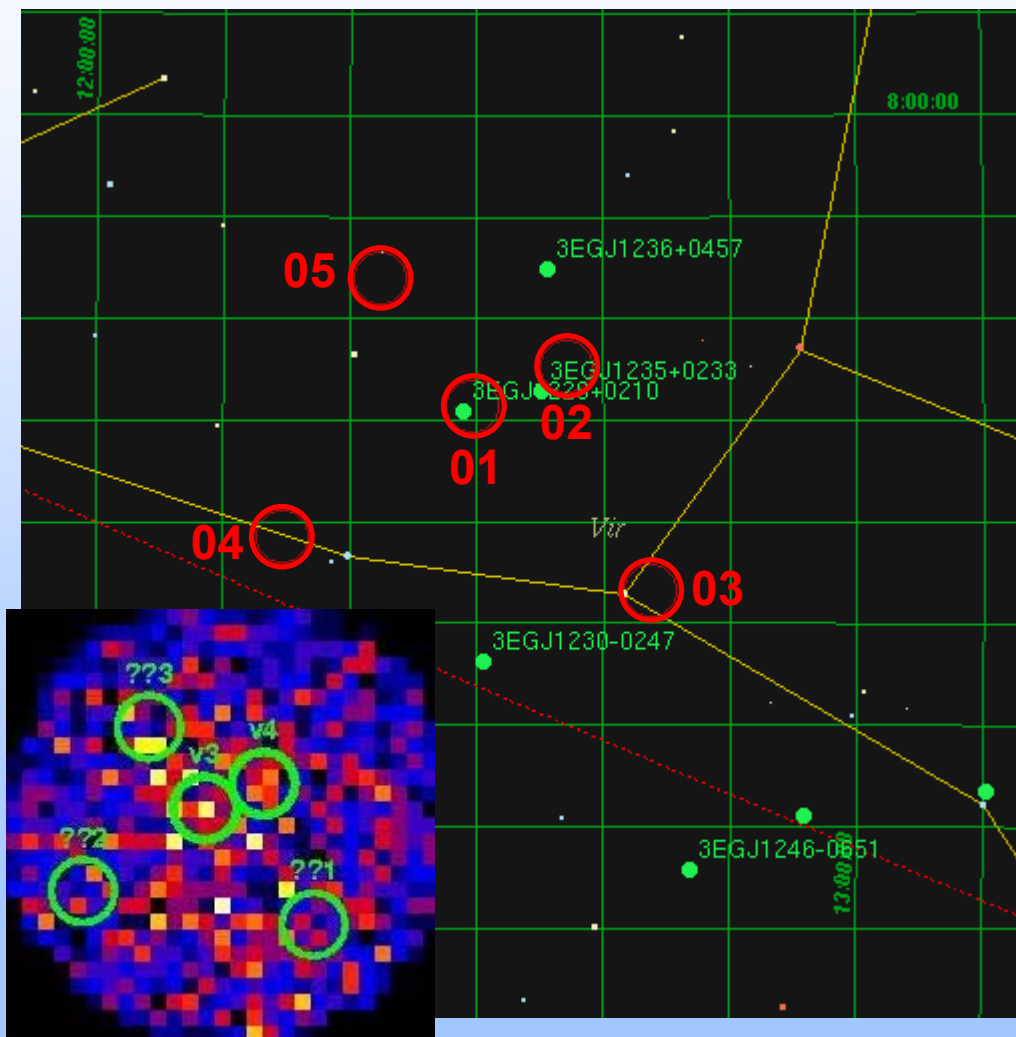
Conclusions

• **we played with the Likelihood package**

• **reliable results, but "black box behavior": we get parameters & errors but it's hard to have a hint on what we could do to improve them**

• **external tools (like ROOT) can help decide/understand in many cases**

• **faint sources/complicated structures can be troublesome, but don't seem impossible**

• **user has much to say about the final result**