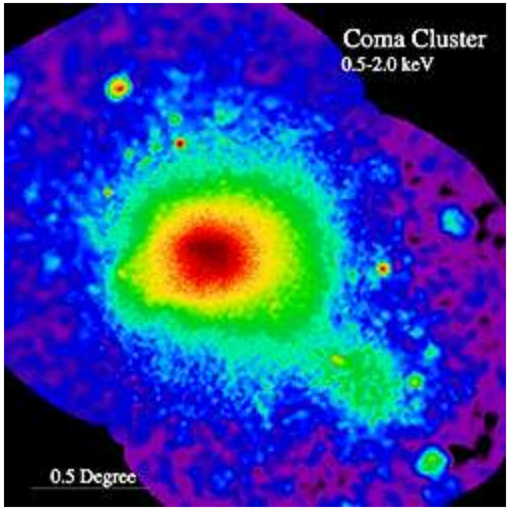

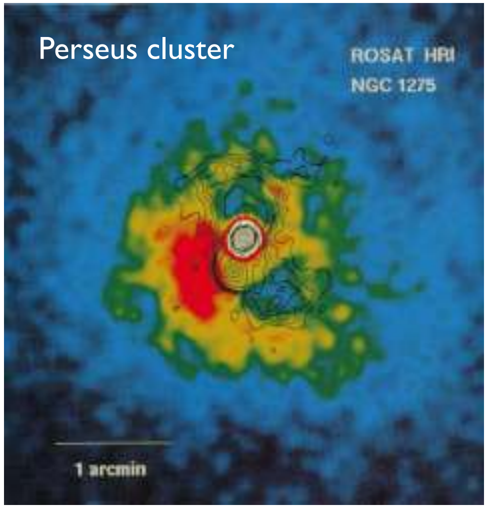

Fermi Observation of Clusters of Galaxies

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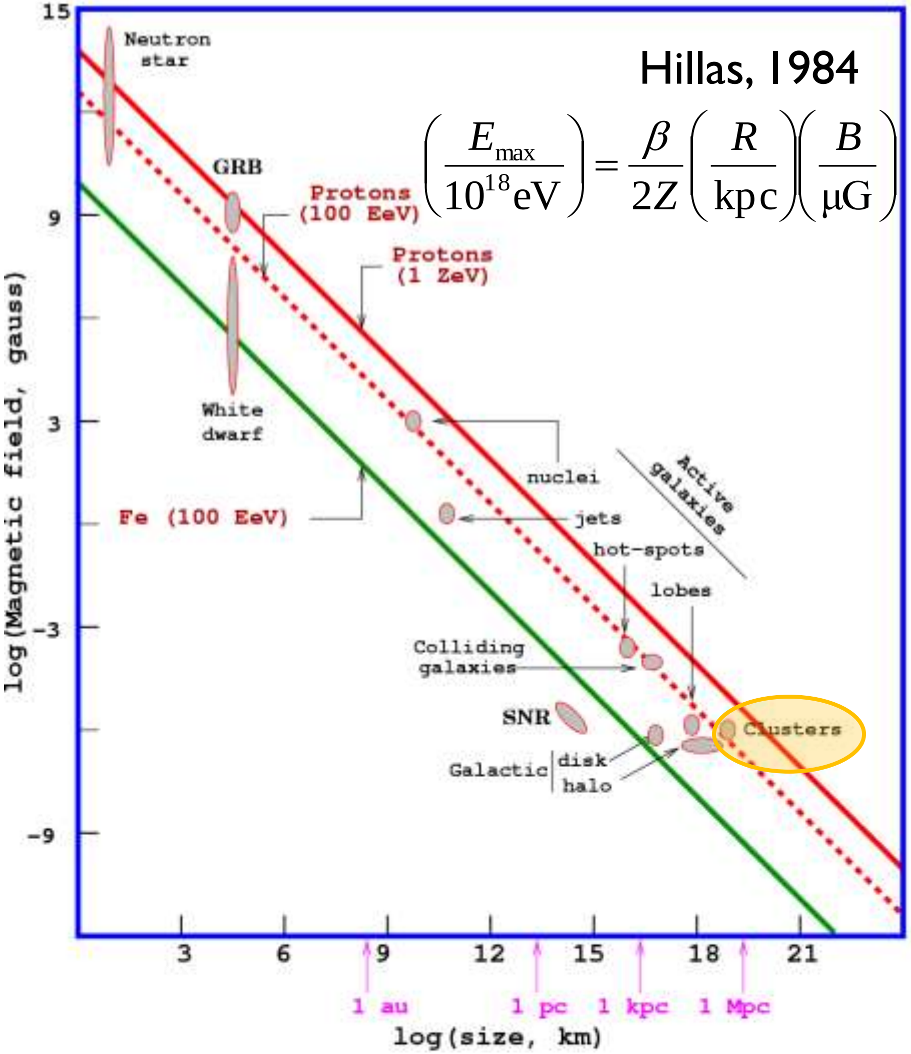
大阪大学大学院理学研究科宇宙地球科学専攻 宇宙進化グループセミナー
2010年2月10日

超高エネルギー宇宙線源としての銀河団

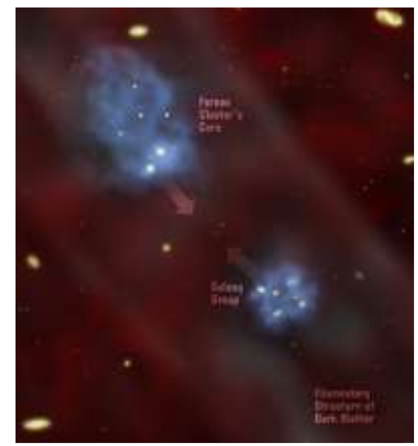


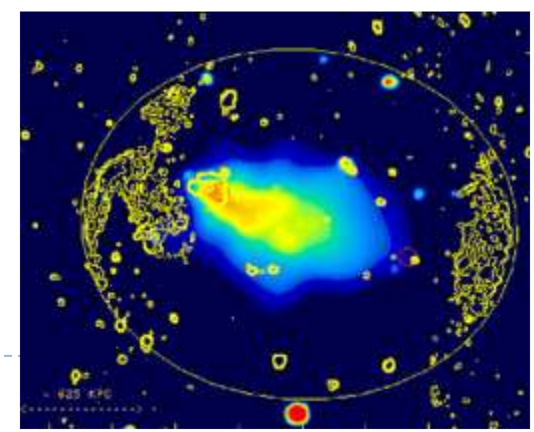
Hillas, 1984

$$\left(\frac{E_{\max}}{10^{18}\mathrm{eV}}\right) = \frac{\beta}{2Z}\left(\frac{R}{\mathrm{kpc}}\right)\left(\frac{B}{\mu\mathrm{G}}\right)$$

Two possible sites:

- Mergers
- Cluster accretion shocks





Völk & Atoyan, ApJ 541,88 (2000)

Model 1.

Hadronic emission: $p+p \rightarrow \pi^0 \ (\rightarrow \gamma+\gamma) + X$

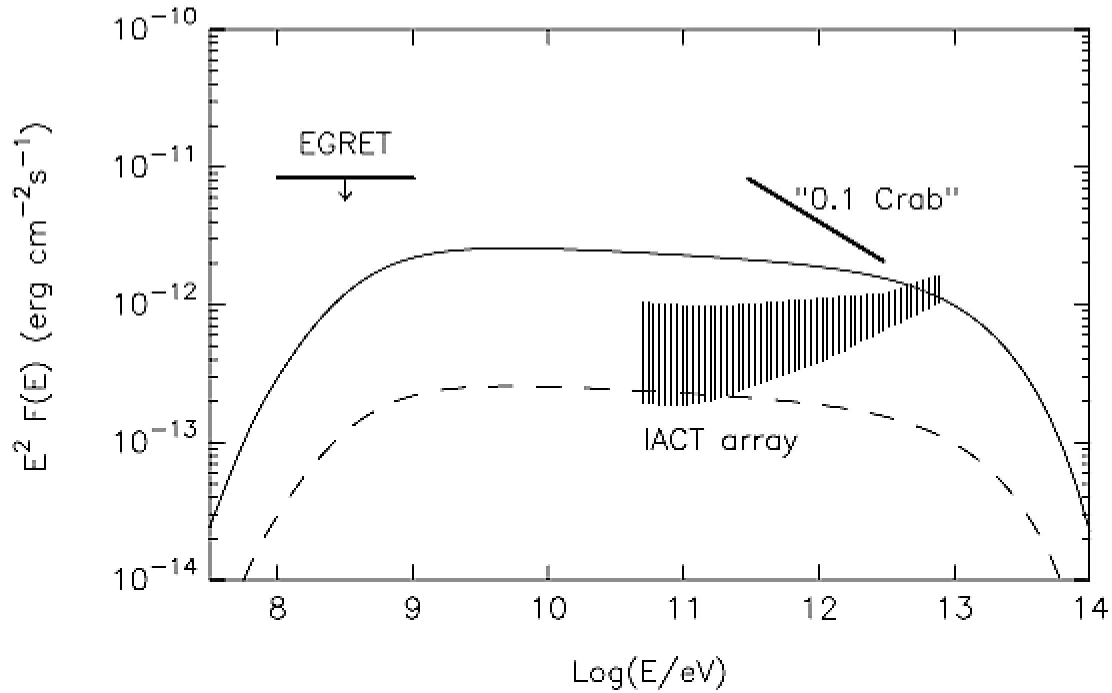


FIG. 2.—Hadronic γ-ray fluxes expected from the Coma Cluster for a proton differential energy spectrum with spectral index $\alpha_{CR} = 2.1$ and cutoff energy $E_c = 200$ TeV. The solid and dashed curves show the γ-ray fluxes produced in *pp* interactions of CRs with $E_{CR} = 3 \times 10^{62}$ ergs and $E_{CR} = 3 \times 10^{61}$ ergs, respectively, in an ICM with $n = 10^{-3}$ cm^{-3}; the lower CR energy content might reflect a lower acceleration efficiency at the galactic wind termination shocks. Also, the EGRET upper limit is shown (Sreekumar et al. 1996). The heavy bar shows the 10% level of the TeV γ-ray flux from the Crab Nebula (e.g., Konopelko 1999). The light vertical bars show the limiting fluxes for a 100 hr observation time with the H.E.S.S. imaging atmospheric Cerenkov telescope (IACT) array of a 1° extended source (*upper ends*), on the one hand, and of a point source (*lower ends*) on the other (see Aharonian et al. 1997a, 1997b).

Model 2.

Gabici & Blasi, Astropart. Phys. 20, 579 (2004)

IC emission from high-energy electron interactions with the CMB

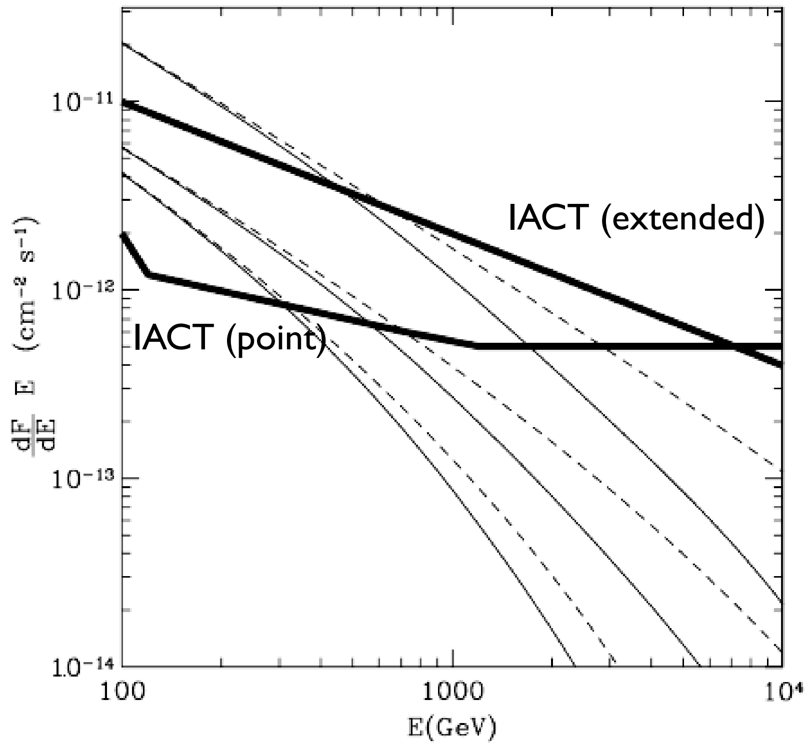


Fig. 3. Gamma ray emission in the 100 GeV–10 TeV region. The thick solid lines represent the sensitivities of a IACT for point sources (lower curve) and extended sources (upper curve). The predicted gamma ray fluxes from a Coma-like cluster at a distance of 100 Mpc with and without absorption of the infrared background are plotted as dashed and solid lines respectively.

From top to bottom:

(1) a merger between two clusters with masses $10^{15} M_\odot$ and $10^{13} M_\odot$;

(2) an accreting cluster with mass $10^{15} M_\odot$ with a magnetic field at the shock in the upstream region 0.1 μG;

(3) an accreting cluster with mass $10^{15} M_\odot$ with a magnetic field at the shock in the upstream region 0.01 μG.

Model 3. Inoue, Aharonian & Sugiyama, ApJ 628, L9 (2005)

Synchrotron and IC emission from secondary electron/ positron pairs produced in *p*-γ interactions with the CMB

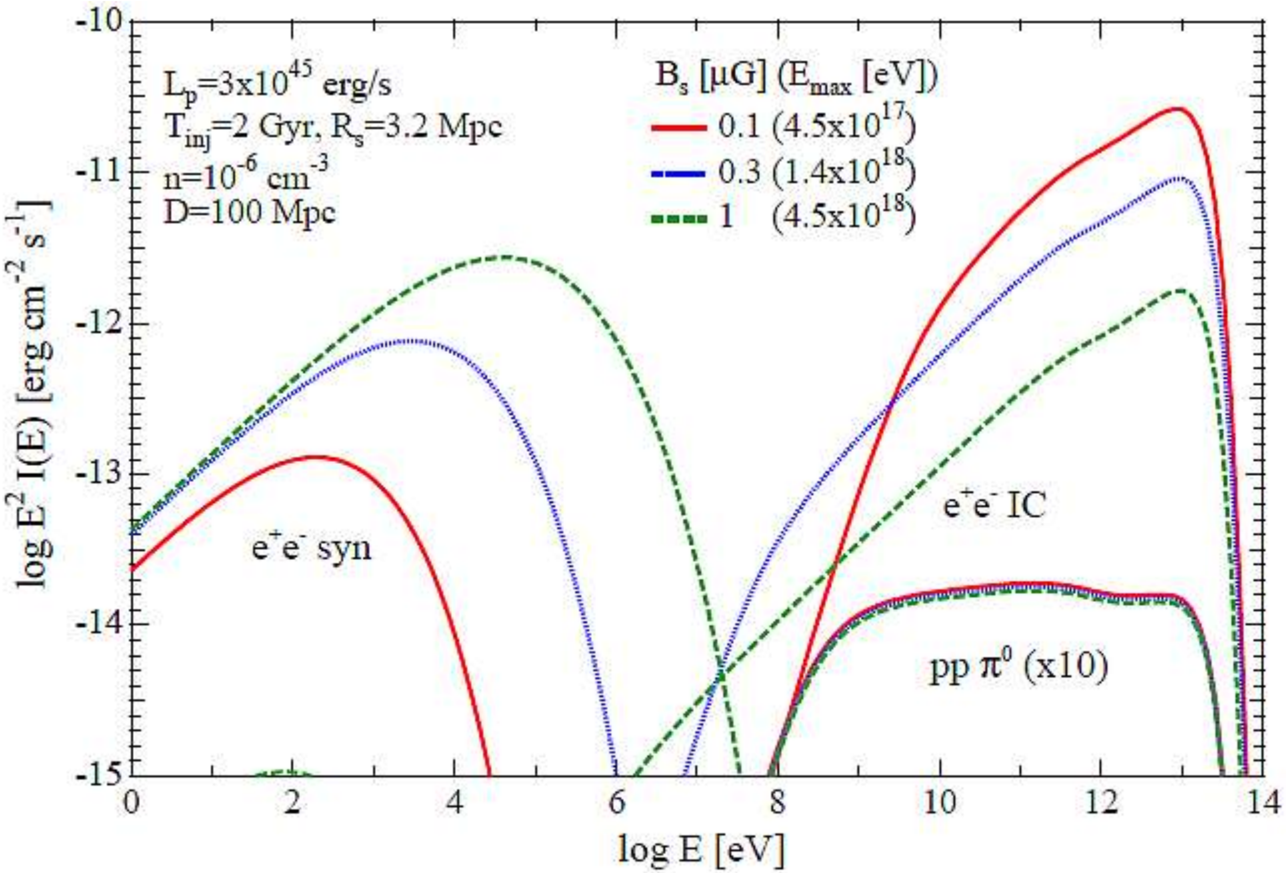


FIG. 1.— Spectra of proton-induced emission from our fiducial cluster accretion shock, for $B_s = 0.1$, 0.3 and 1μG. The p-p π^0 component has been multiplied by 10.

Model 4.

Pinzke & Pfrommer, arXiv: 1001.5023 (2010)

Simulation with a universal cosmic-ray spectrum and spatial distribution

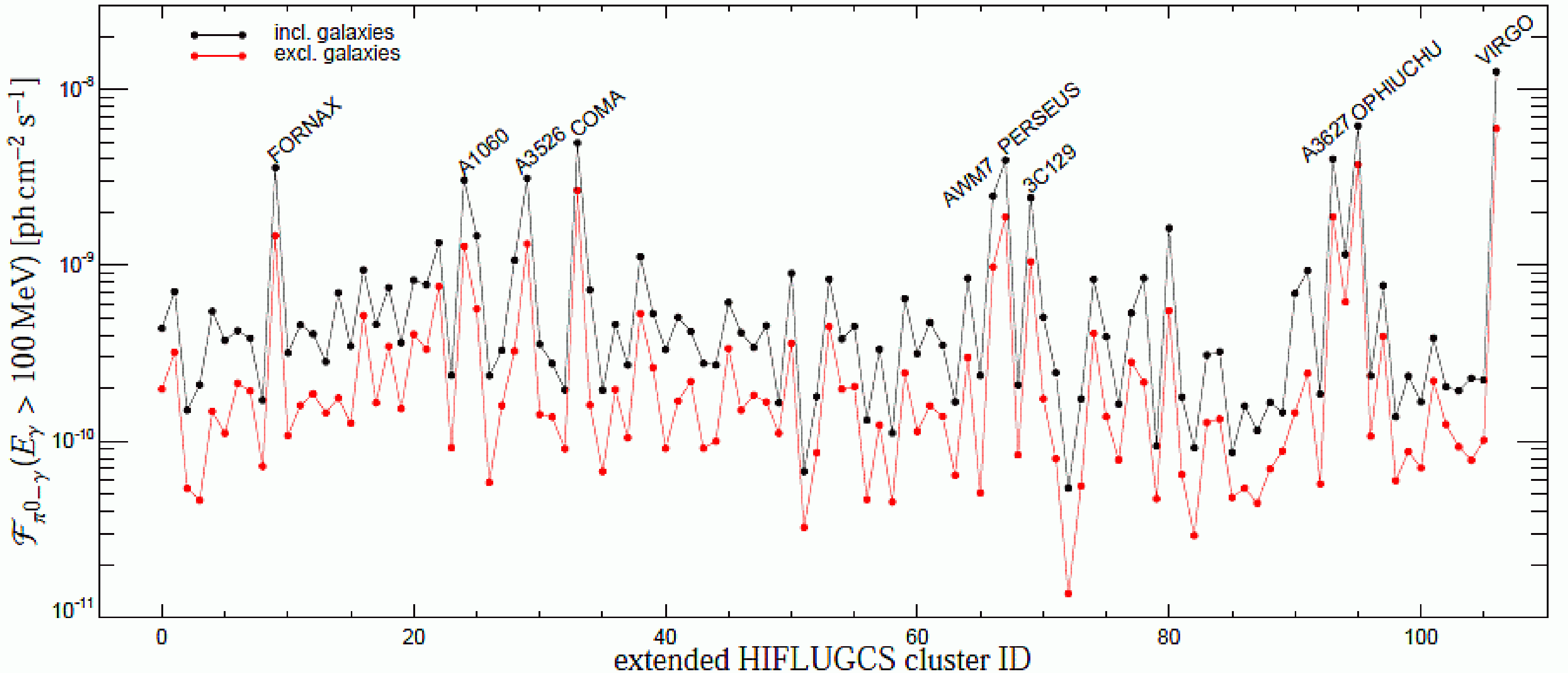


Figure 19. Predicted γ-ray flux above 100 MeV in clusters and groups in the extended HIFLUGCS catalog to which we also add the Virgo cluster. The flux comes from the region within the Fermi angular resolution at 100 MeV, i.e. a circular region of radius 3.5 degree that contains 68 per cent of the PSF, but with the limit at $3\,R_{\mathrm{vir}}$ for each cluster and group. The black line refers to our optimistic model where we include the flux contribution from galaxies and the red line shows the flux without galaxies (cf. Table 5). We name the clusters and groups with $\mathcal{F}_{\pi^0-\gamma}(E_\gamma > 100\,\mathrm{MeV}) > 2\times10^{-9}\,\mathrm{ph\,cm^{-2}\,s^{-1}}$ in our optimistic model which roughly corresponds to the sensitivity of the Fermi all-sky survey after two years of data taking.

Reimer et al., ApJ 588, 155 (2003)

EGRETによるGeV領域の上限

Number	Name	l (deg)	b (deg)	z	Flux (>100 MeV) (10^{-8} cm^{-2} s^{-1})
1	A426 (Per Cluster)	150.58	−13.26	0.0184	<3.72
2	Oph Cluster	0.56	9.27	0.028	<5.00
3	VIR Cluster	282.08	75.20	0.0038	<2.18
4	Coma Cluster	58.13	88.01	0.0238	<3.81
5	A2319	75.68	13.50	0.056	<3.79
6	A3571	316.31	28.54	0.04	<6.34
7	A3526 (Cen Cluster)	302.40	21.55	0.0109	<5.31
8	Tra Cluster	324.36	−11.38	0.051	<8.13
9	3C 129 (3A 0446+449)	160.39	0.13	0.0223	<5.29
10	AWM7 (2A 0251+413)	146.34	−15.63	0.018	<3.47
11	A754	239.20	24.71	0.054	<8.18
12	A2029	6.49	50.55	0.0768	<7.49
13	A2142	44.23	48.69	0.0899	<4.97
14	A2199	62.93	43.69	0.0299	<9.27
15	A3667	340.88	−33.39	0.055	<3.82
16	A478	182.43	−28.29	0.09	<5.14
17	A85	115.04	−72.06	0.055	<6.32
18	A3266	272.14	−40.16	0.0545	<4.42
19	A401	164.18	−38.87	0.075	<9.28
20	3A 0745−191	236.42	2.99	0.1028	<7.08
21	A496	209.57	−36.48	0.0327	<7.11
22	A1795	33.81	77.18	0.063	<3.98
23	A2256	111.10	31.74	0.056	<4.28
24	Cyg A Cluster	76.19	5.76	0.057	<4.46
25	2A 0335+096	176.25	−35.08	0.0349	<8.11
26	A1060	269.63	26.50	0.0114	<14.85
27	A3558	312.00	30.72	0.048	<3.58
28	A644	229.93	15.29	0.0704	<9.71
29	A1651	306.73	58.63	0.086	<3.75
30	A3562	313.30	30.35	0.0499	<3.62
31	A1367	234.80	73.03	0.0215	<2.72
32	A399	164.36	−39.46	0.072	<4.92
33	A2147	28.80	44.49	0.0356	<7.45
34	A119	125.74	−64.11	0.044	<4.51
35	A3158	264.68	−48.76	0.0575	<2.52

"58 nearby X-ray-bright galaxy clusters"

チェレンコフ望遠鏡による銀河団の観測

Name	Position	Redshift	Limit	Reference
Perseus	(03h19m, 41° 30')	0.018	<13% Crab (>400GeV, 0.3°)	Whipple (Perkins+ 2006)
↑			<1-2% Crab (>150GeV, point-like)	MAGIC (Aleksic+ 2009)
Abell 2029	(15h10m, 05° 45')	0.077	<14% Crab (>400GeV, 0.3°)	Whipple (Perkins+ 2006)
Abell 496	(04h34m, -13° 16')	0.033	<5% Crab (>0.57TeV, 0.6°)	H.E.S.S. (Aharonian+ 2008)
Abell 85	(00h42m, -09° 21')	0.055	<2% Crab (>0.46TeV, 0.49°)	H.E.S.S. (Aharonian+ 2008)
Coma	(12h59m, 27° 58')	0.023	<15% Crab (>1TeV, 0.4°)	H.E.S.S. (Aharonian+ 2009)
Abell 3667	(20h12m, -56° 50')	0.055	<29% Crab (>950GeV, 0.4°)	CANGAROO-III (Kiuchi+ 2009)
Abell 4038	(23h47m, -28° 12')	0.029	<12% Crab (>750GeV, 0.25°)	CANGAROO-III (Kiuchi+ 2009)

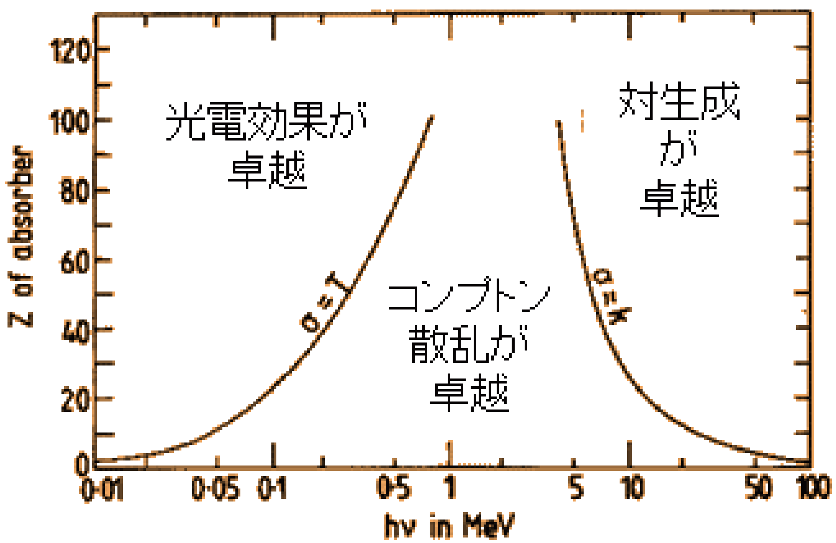
Fermi Gamma-ray Space Telescope

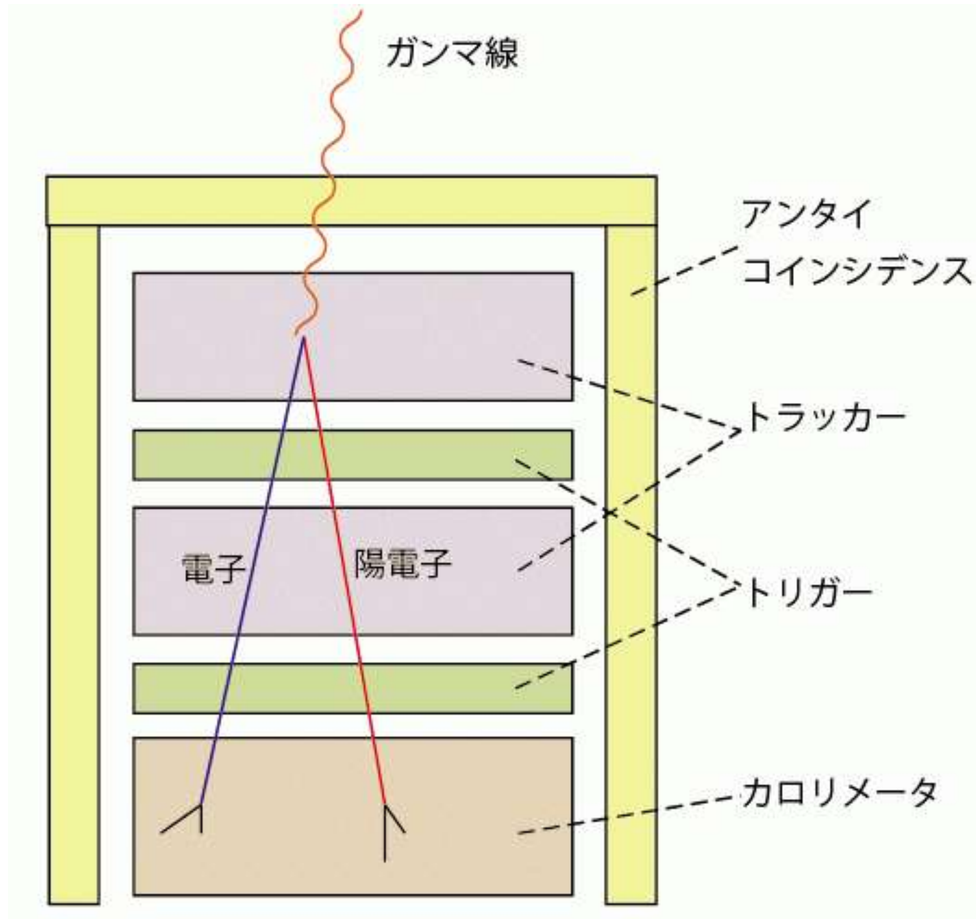
General Dynamics clean room, standing are: Chip Meegan, NASA Marshall Space Flight Center, Hunstville, Ala.; Peter Michelson, Stanford University, Stanford, Calif.; Steve Ritz, from NASA Goddard Space Flight Center, Greenbelt, Md. Kneeling are: Bill Atwood, University of California at Santa Cruz, Calif.; Dan Blackwood, NASA Headquarters; Rick Harnden, NASA Headquarters, Washington; and Neil Johnson, Naval Research Laboratory, Washington. In the right corner, a technician checks the satellite. Credit: NASA and General Dynamics

2008年6月11日打ち上げ

Pair telescope for high-energy gamma-rays

Evans 1955



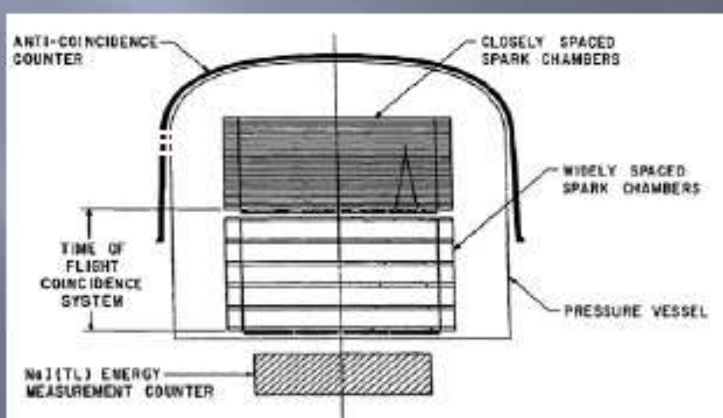


- OSO-3 (1967-1968)
- SAS-2 (1972-1973)
- COS B (1975-1982)
- CGRO/EGRET (1991-2000)
- AGILE (2007-)
- Fermi (2008-)

Fermi Gamma-ray Space Telescope: spec

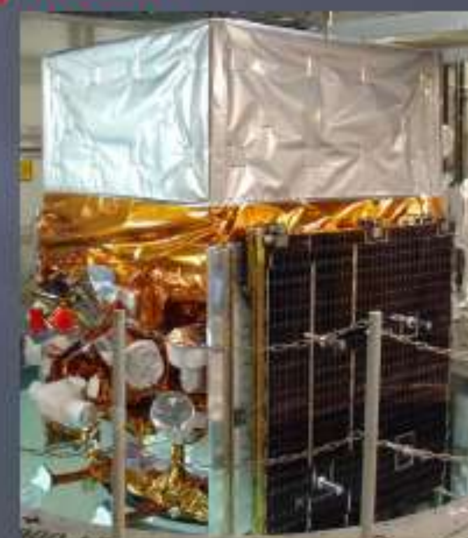
	Years	Ang. Res. (100 MeV)	Ang. Res. (10 GeV)	Eng. Rng. (GeV)	$A_{eff}\ \Omega$ (cm^2 sr)	# γ-rays
EGRET	1991–00	5.8°	0.5°	0.03–10	750	1.4 × 10^6/yr
AGILE	2007–	4.7°	0.2°	0.03–50	1,500	4 × 10^6/yr
Fermi LAT	2008–	3.5°	0.1°	0.02–300	25,000	1 × 10^8/yr

- LAT has already surpassed EGRET and AGILE celestial gamma-ray totals
- Unlike EGRET and AGILE, LAT is an effective All-Sky Monitor
  whole sky every ~3 hours



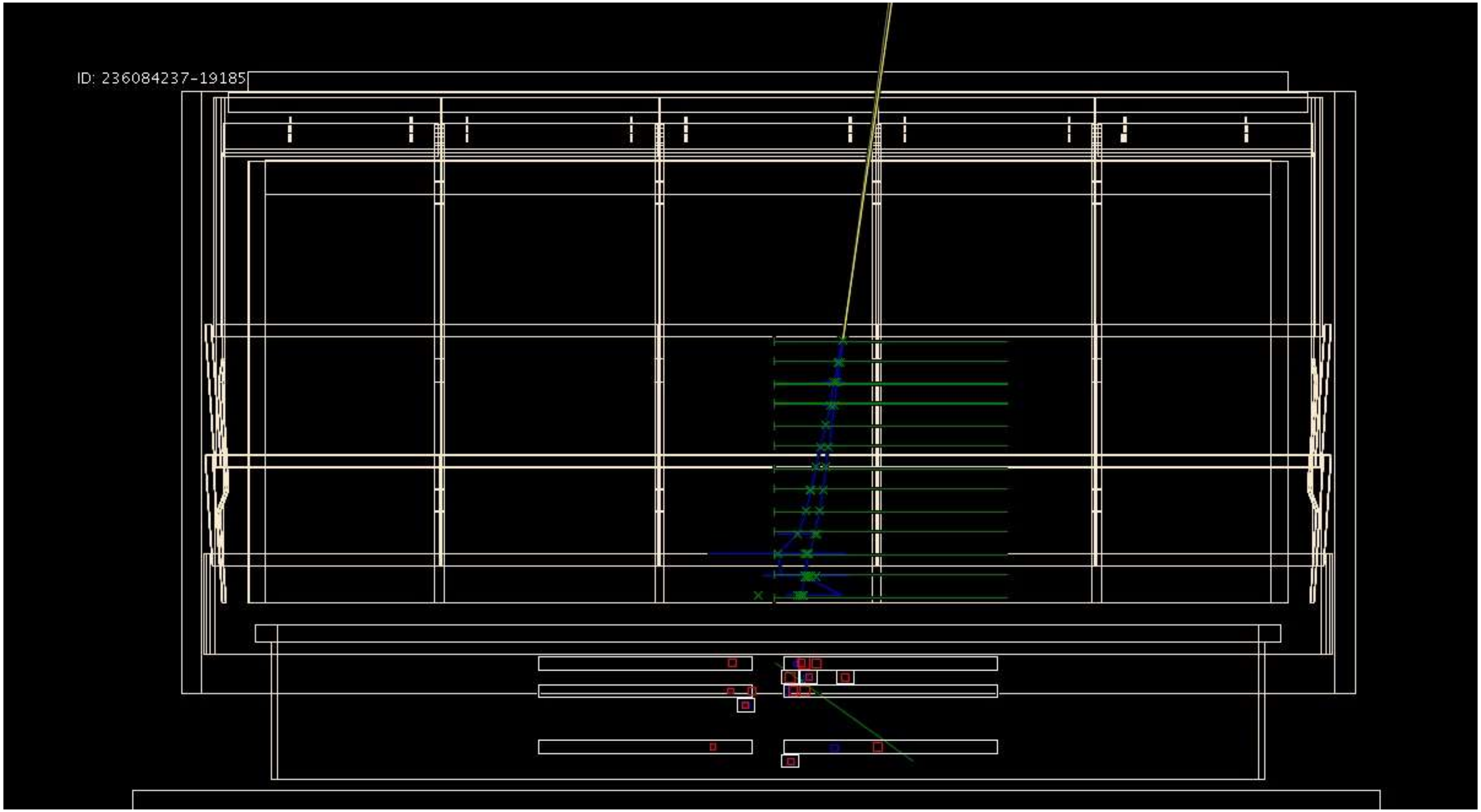
CGRO EGRET

AGILE (ASI)

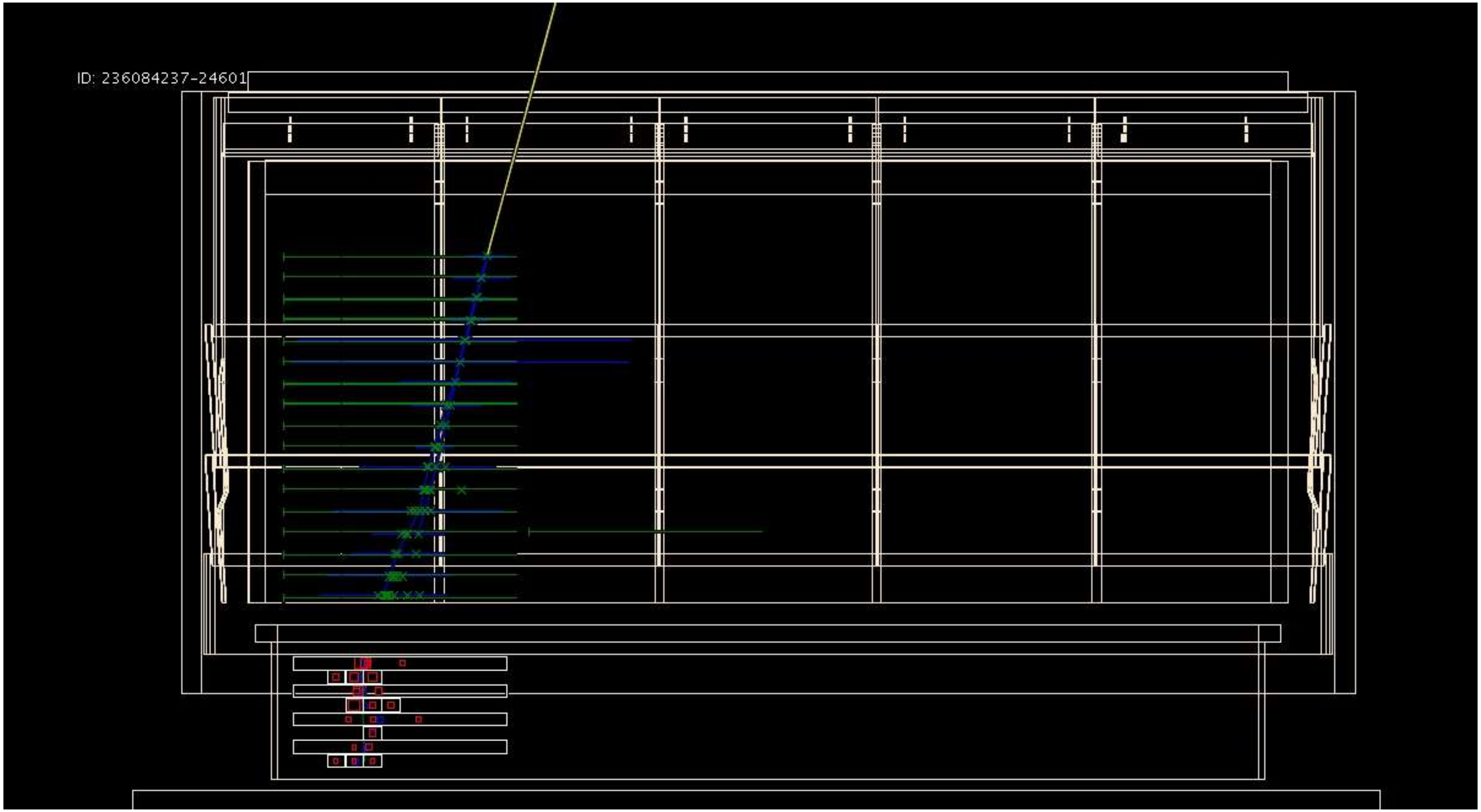


Fermi / LAT

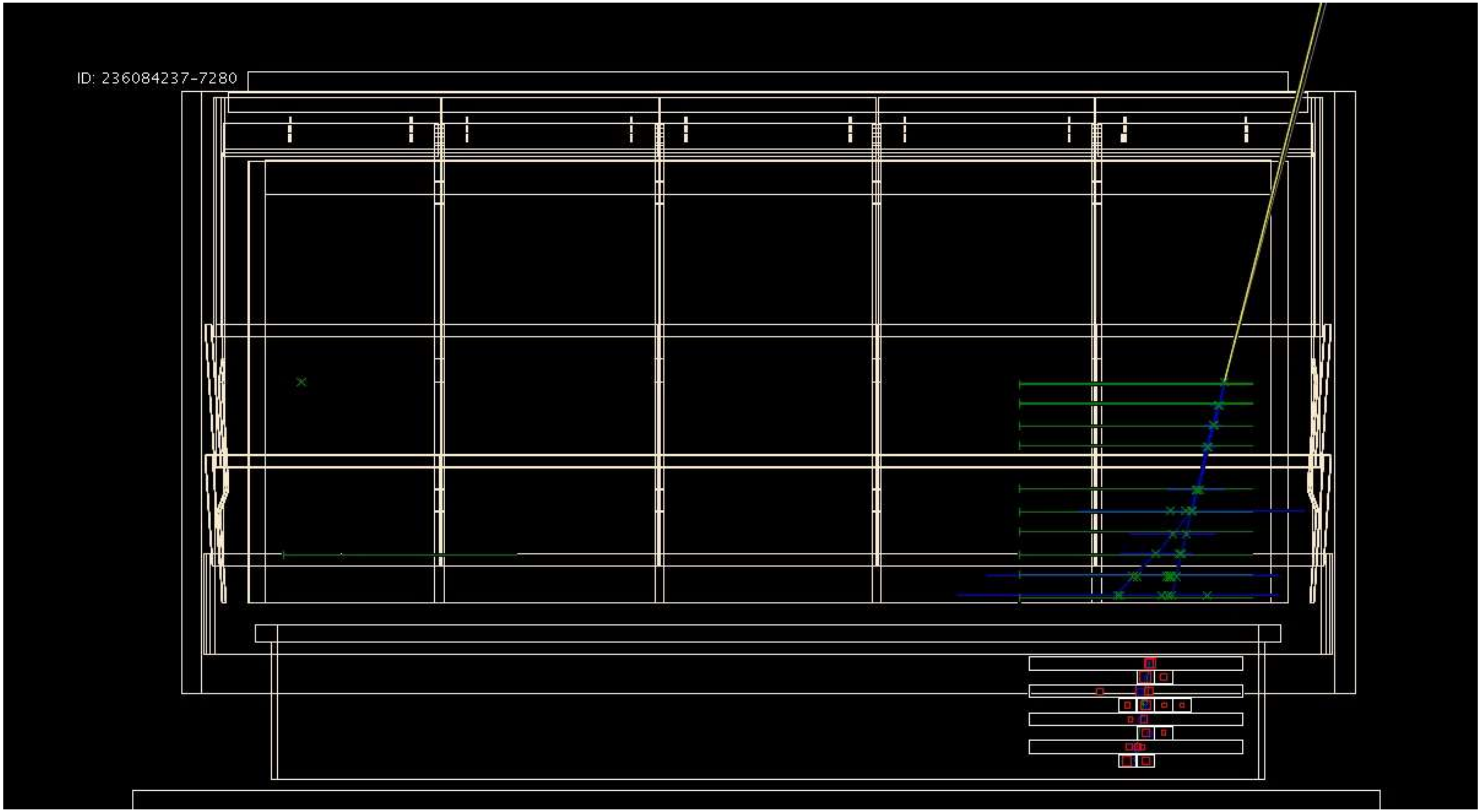
Sample event display (1)



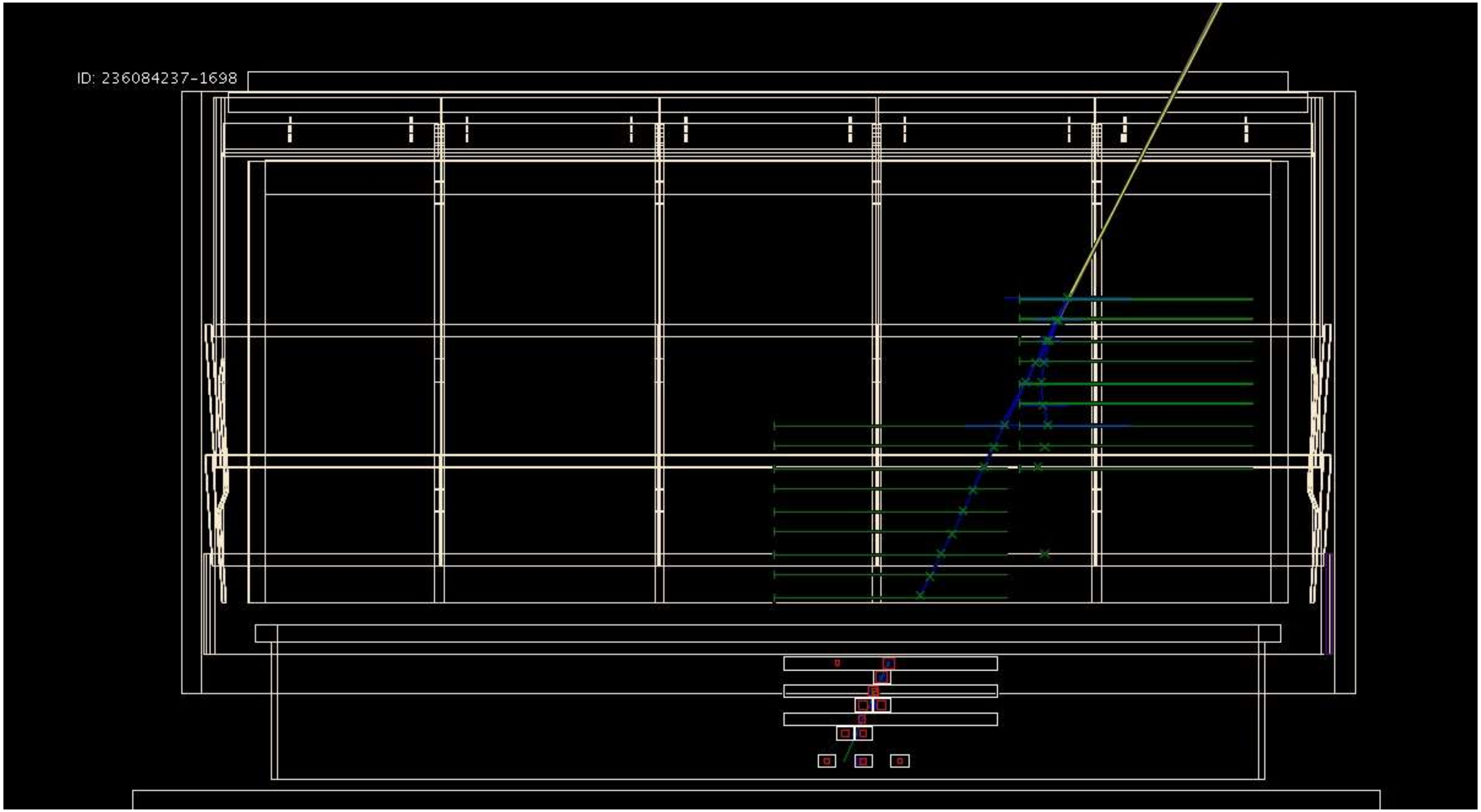
Sample event display (2)



Sample event display (3)



Sample event display (4)



Event class and effective area

Rando, arXiv:0907.0626

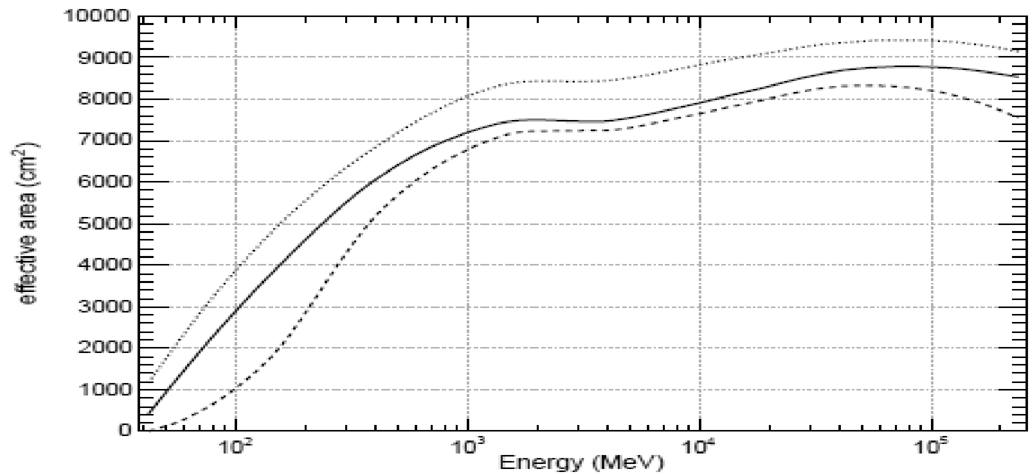
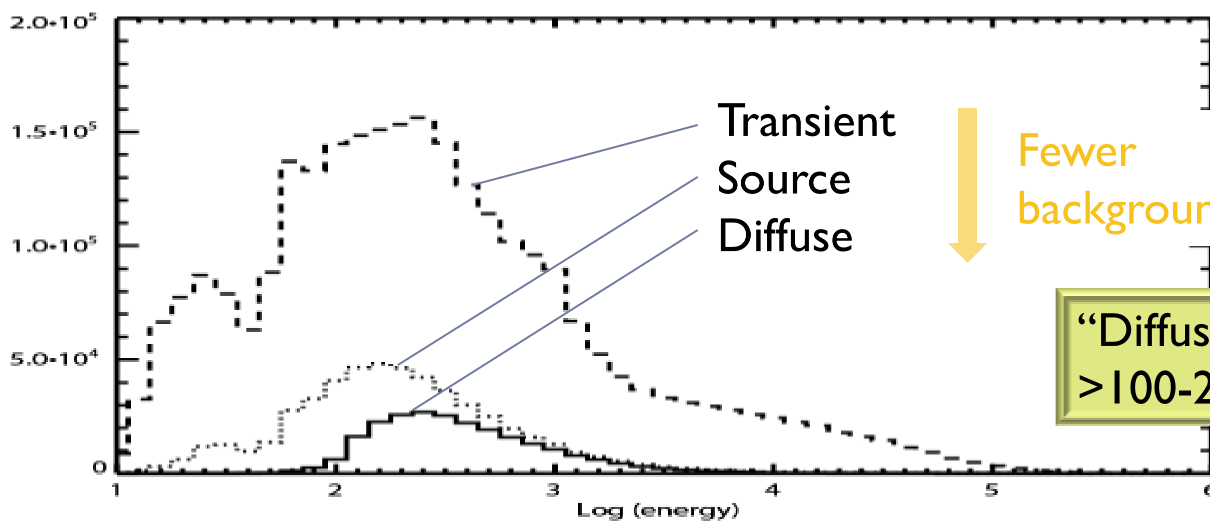


Fig. 2. Effective area versus energy at normal incidence for Diffuse (dashed), Source (solid) and Transient (dotted) P6_V3 event classes.

Class =
"Transient"
"Source"
"Diffuse"

Real event distribution



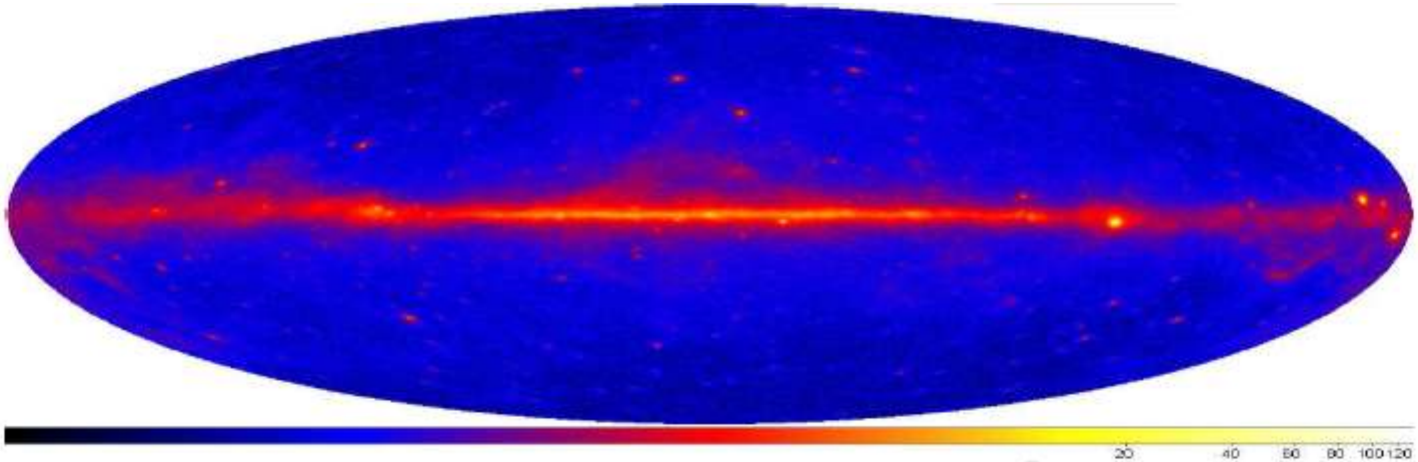
Fewer background

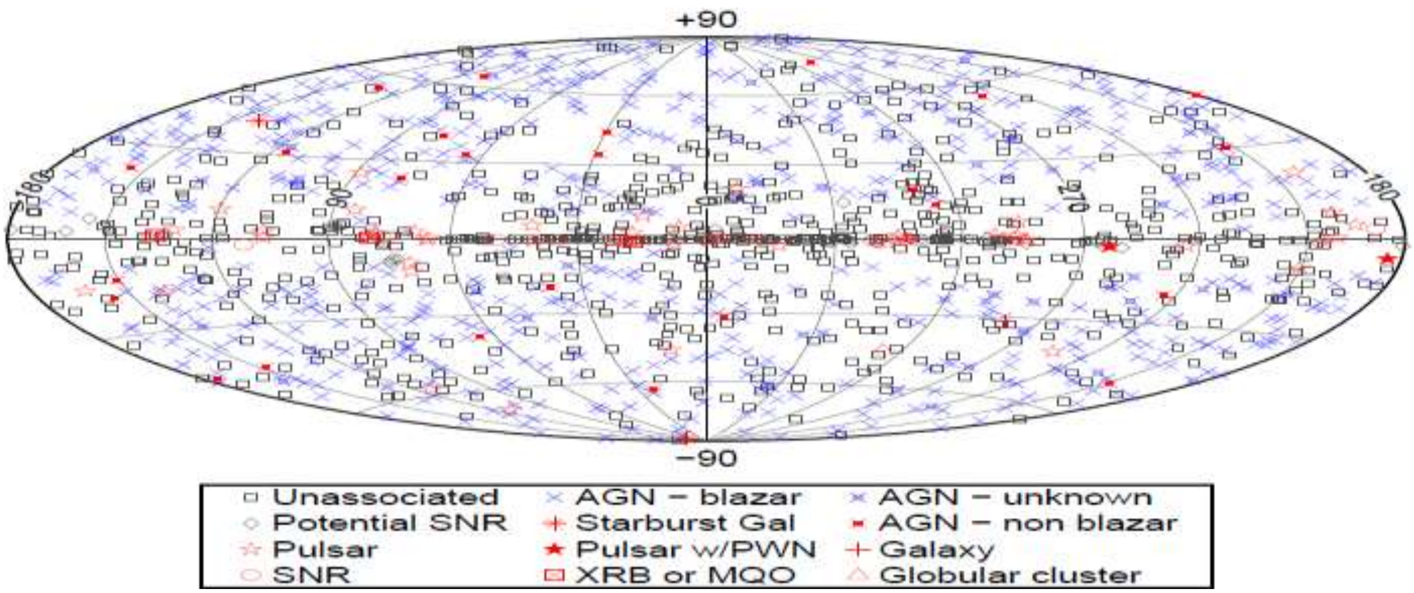
"Diffuse" class >100-200 MeV

http://fermi.gsfc.nasa.gov/ssc/data/access/lat/1yr_catalog/

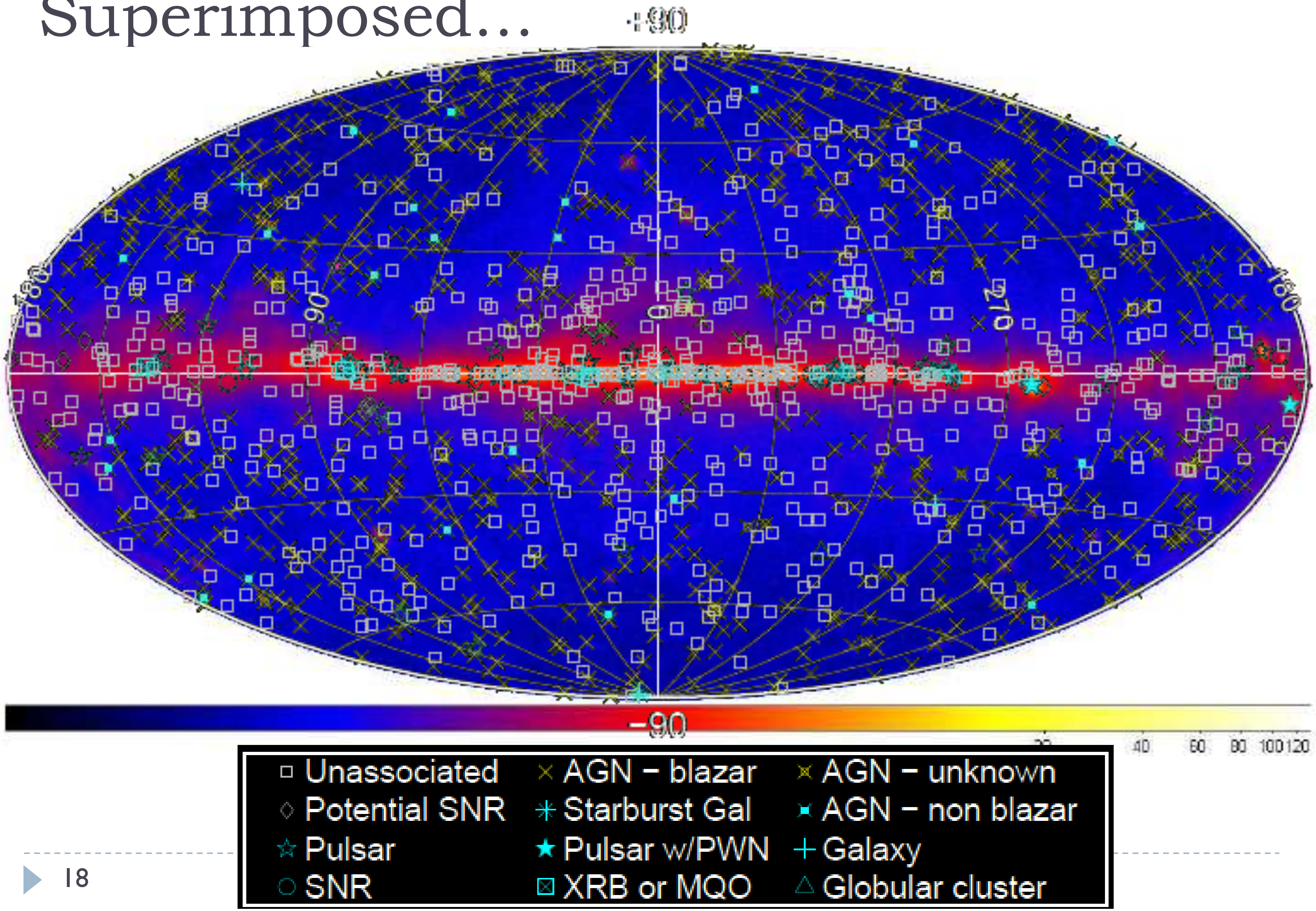
Fermi First Source Catalog (1FGL)

2010年1月14日発表、1451天体 (1.1×10^7 "Diffuse" events >100 MeV)

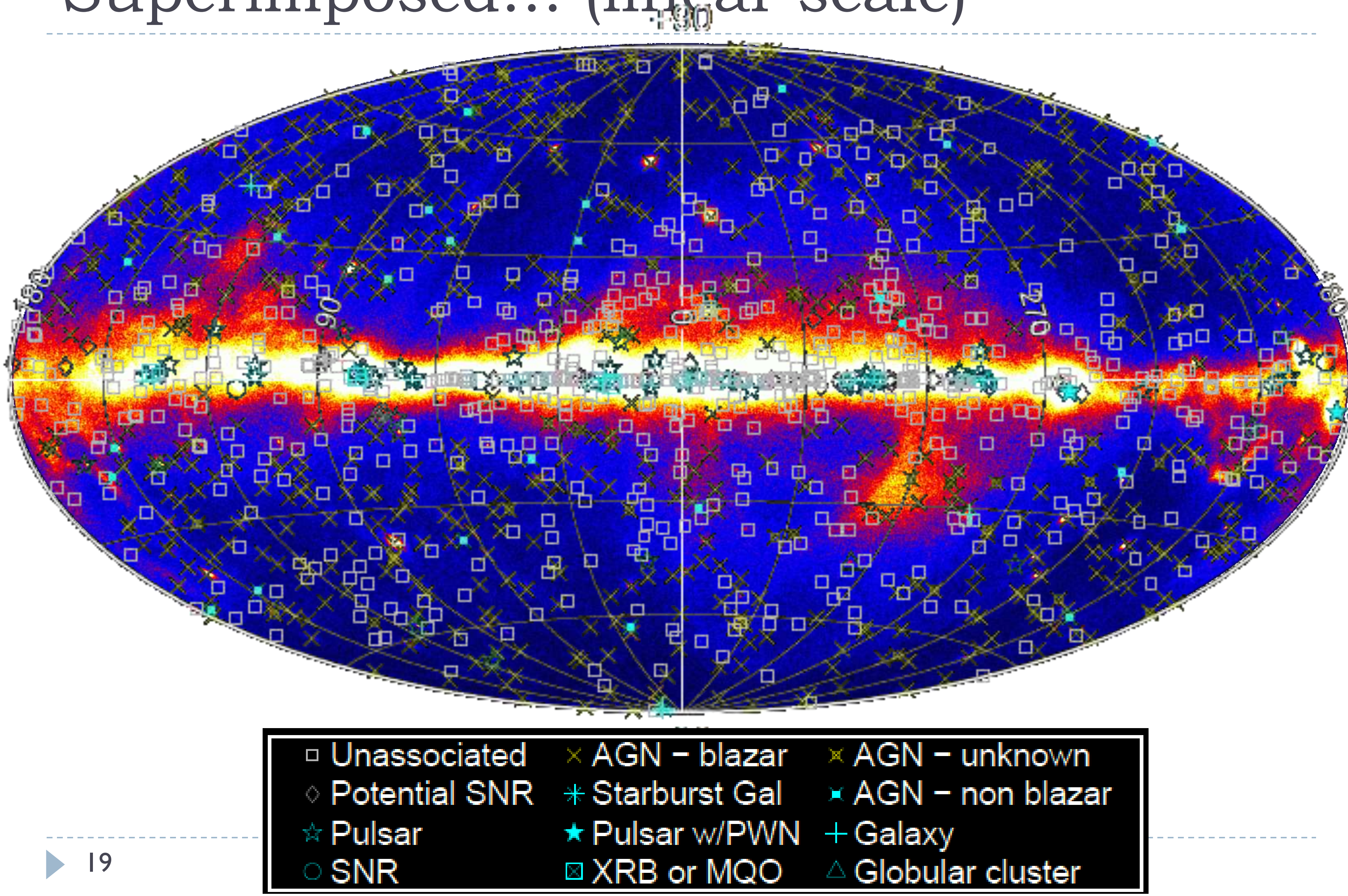




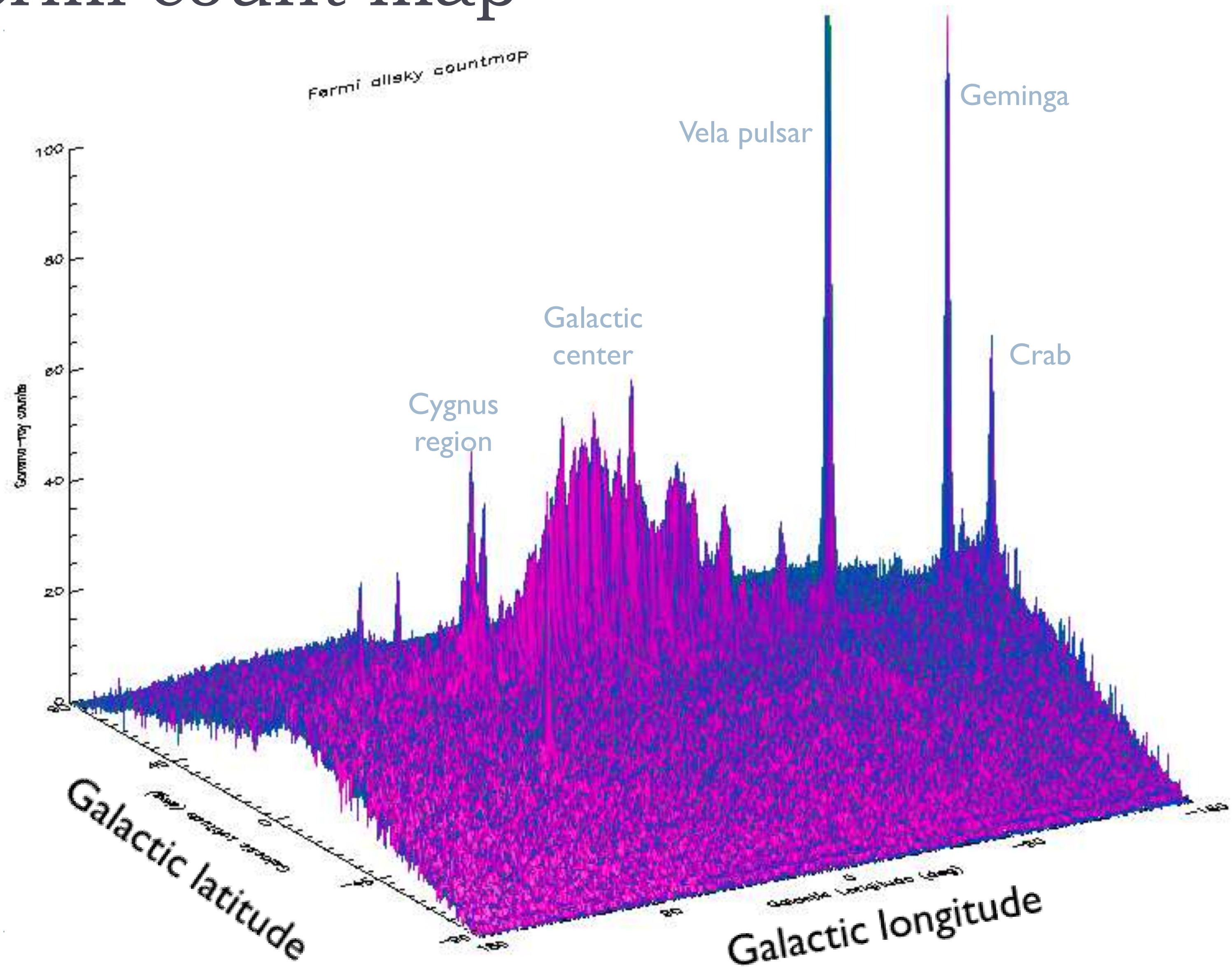
Superimposed…



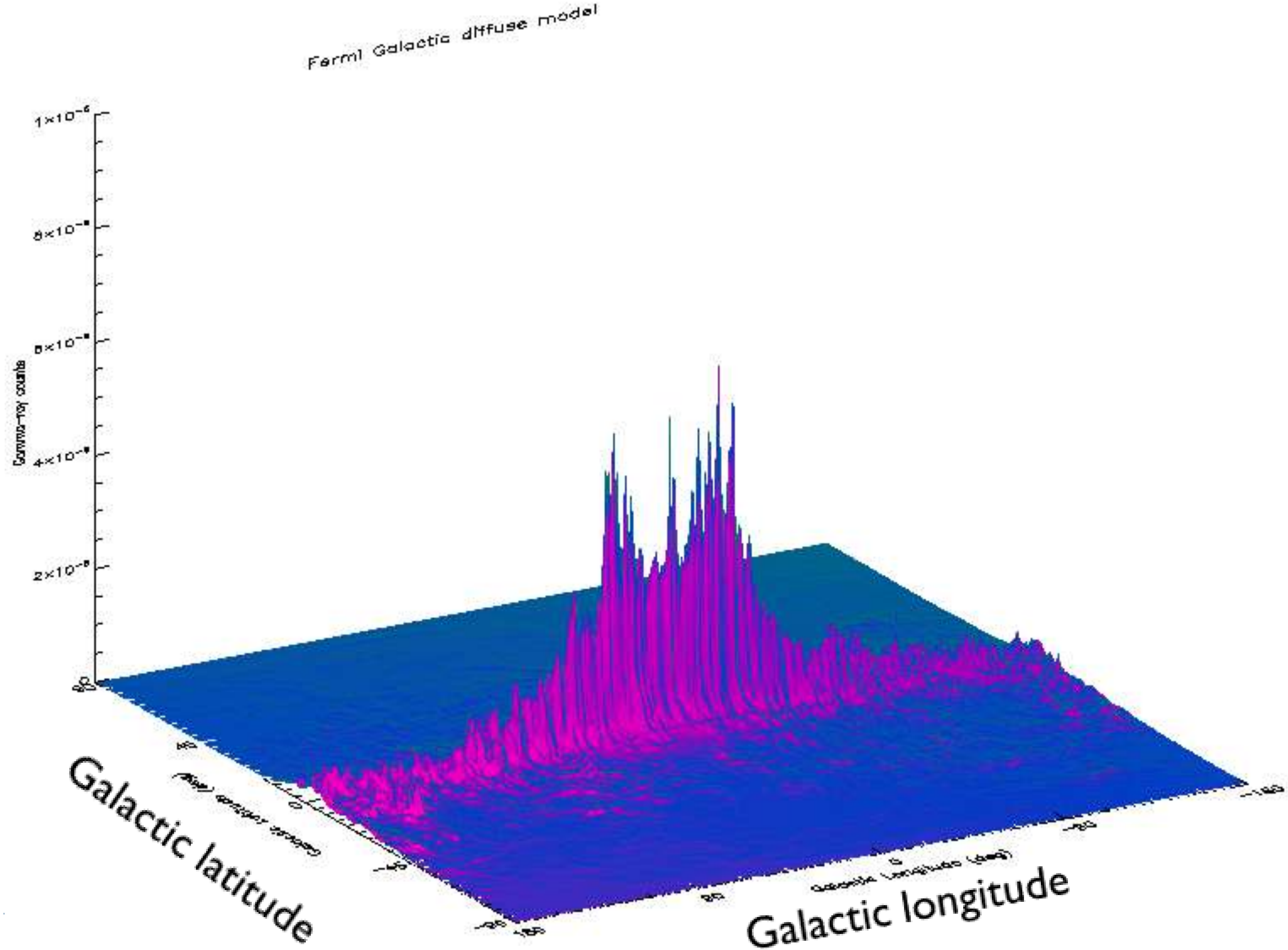
Superimposed… (linear scale)



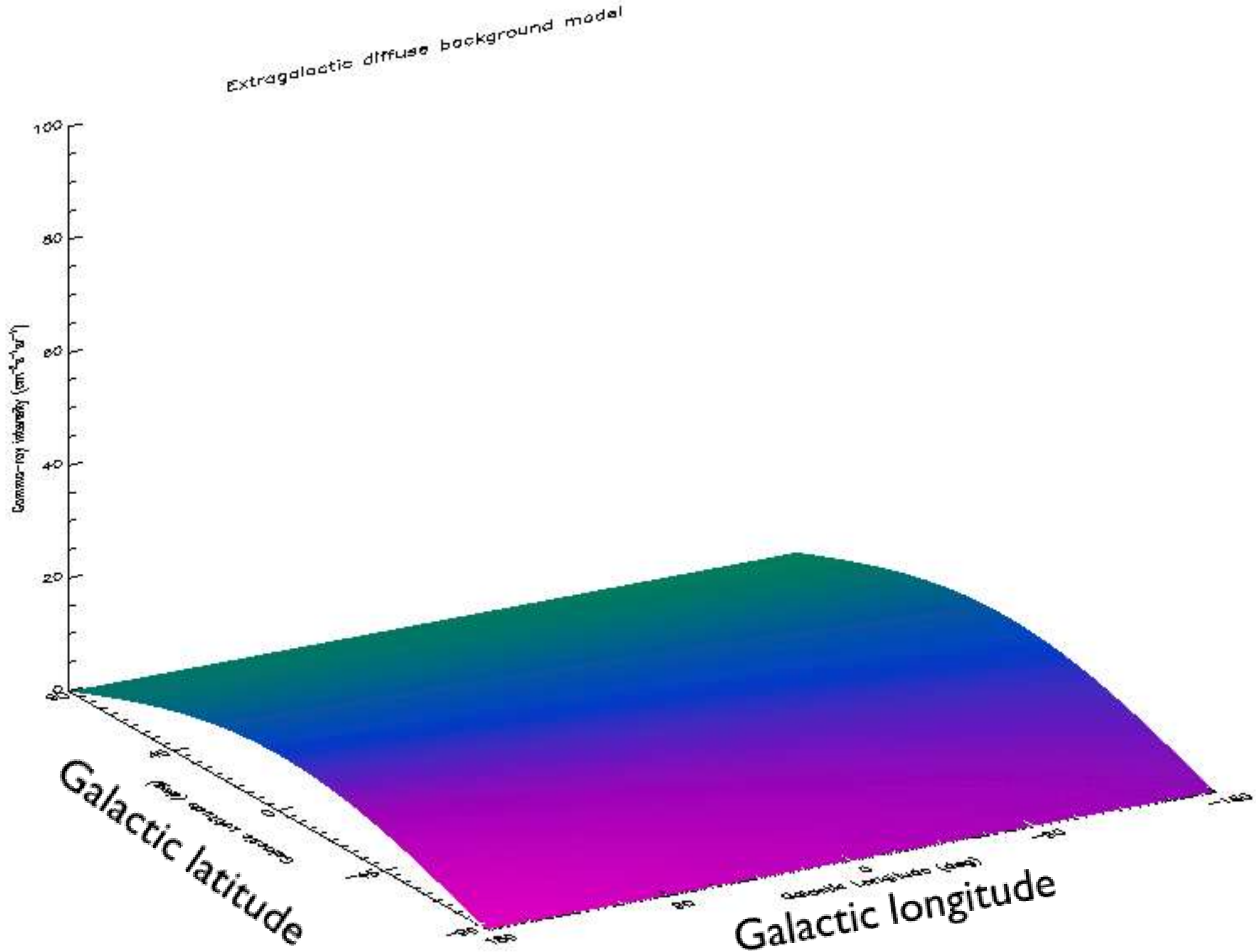
Fermi count map



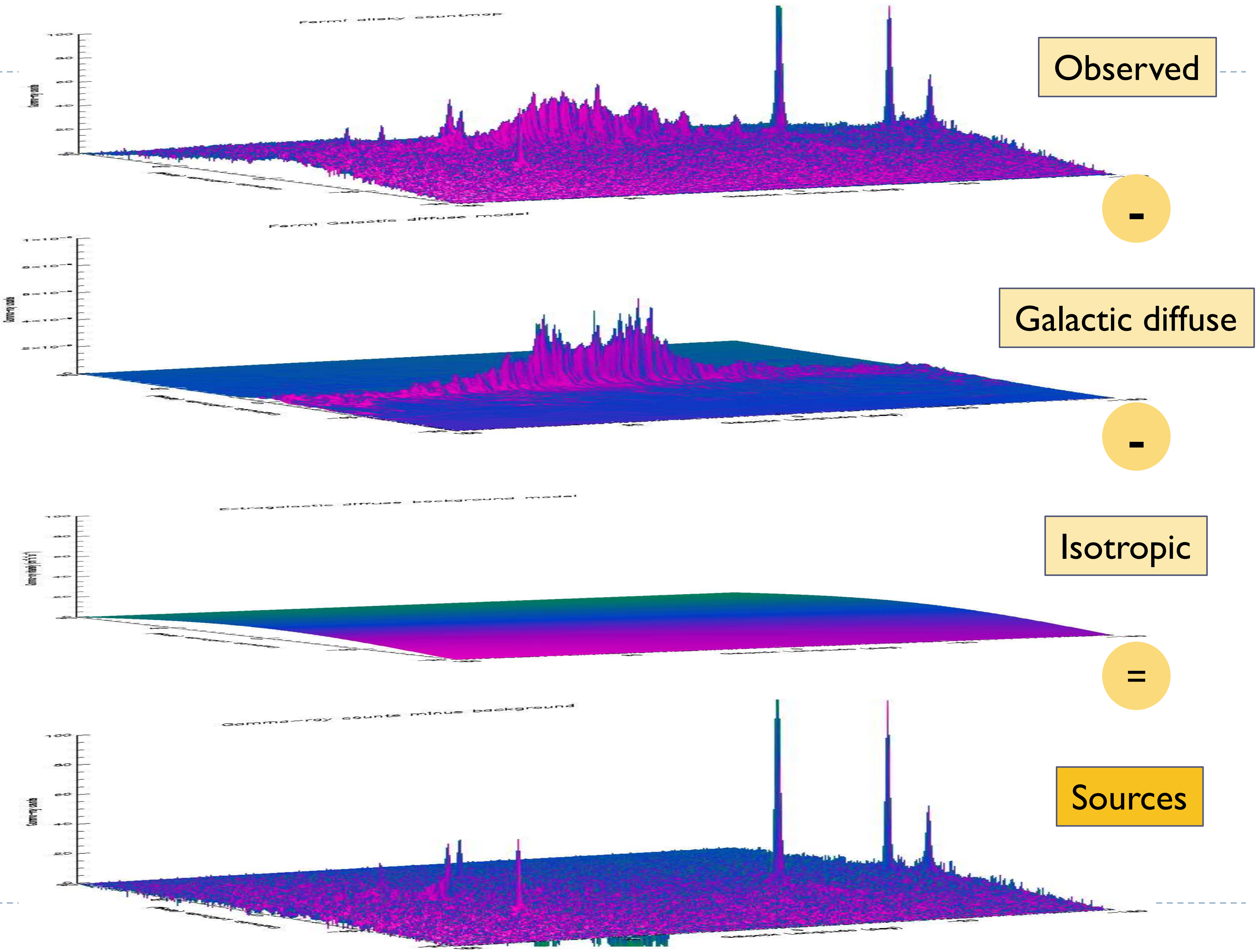
Fermi Galactic diffuse model



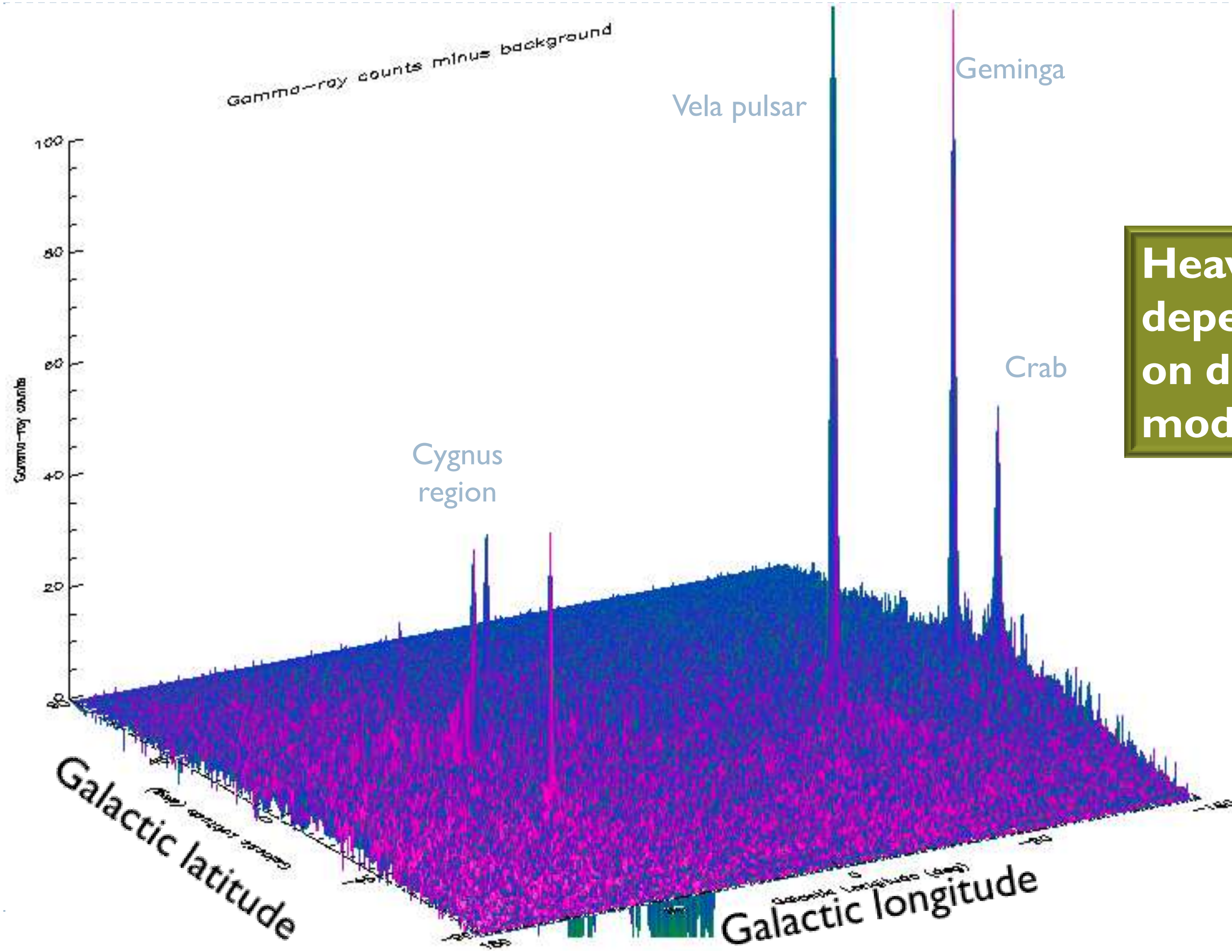
Fermi isotropic model



Point sources = Observed intensity – Diffuse model



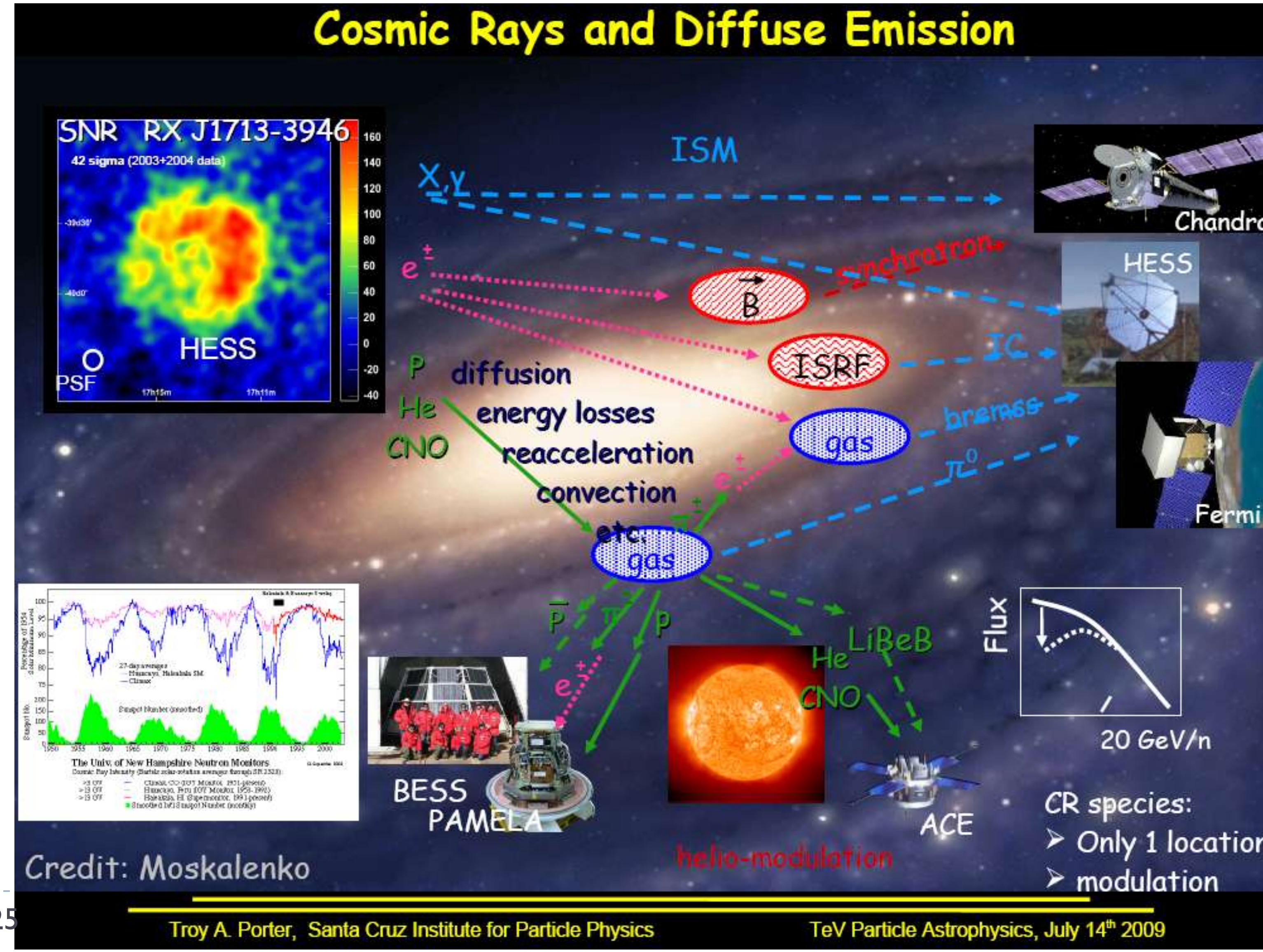
Sources = residuals



Heavily depends on diffuse model!

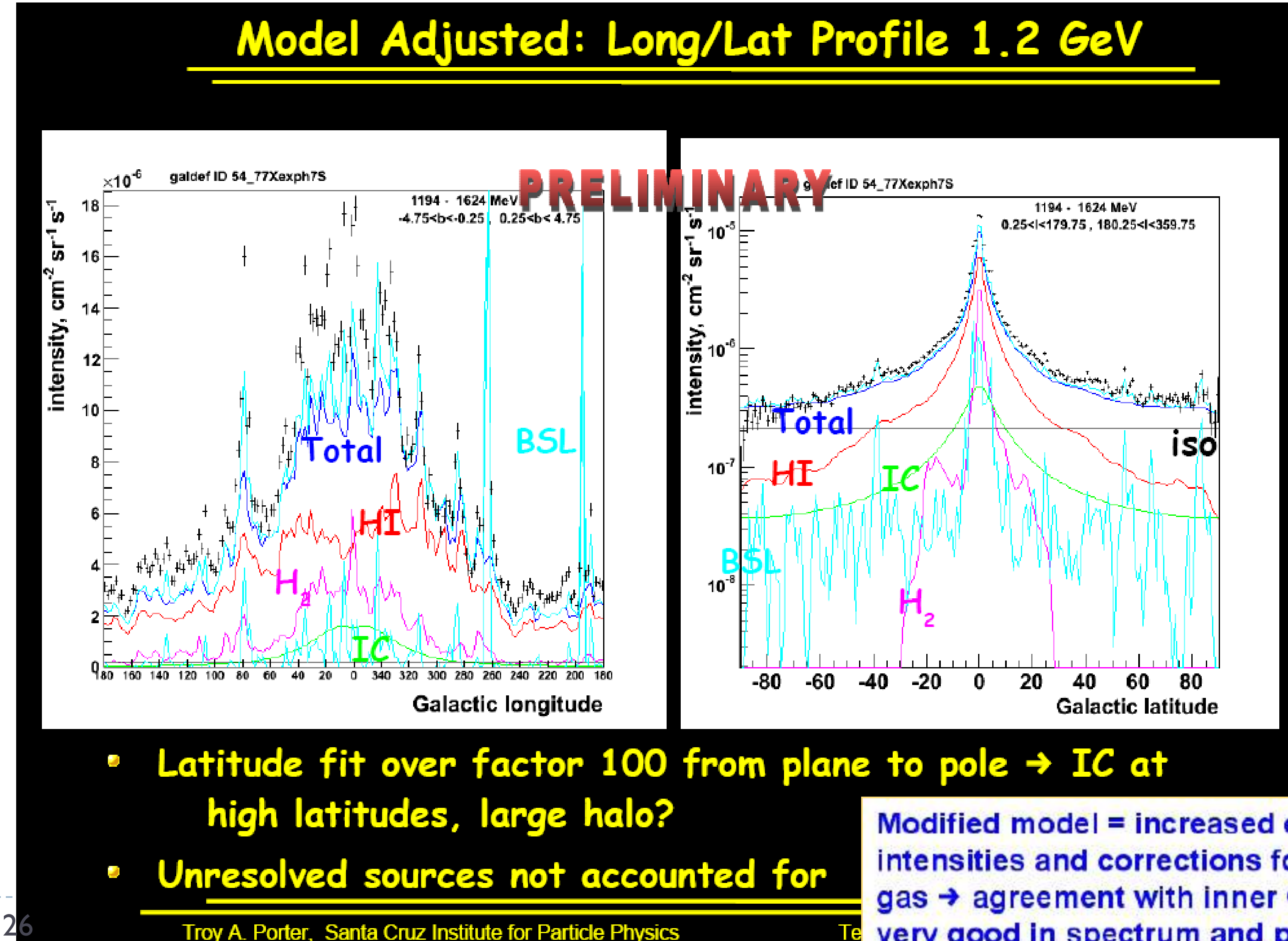
T. Porter, talk at TeV Particle Astrophysics (2009)

Galactic diffuse emission: components



T. Porter, talk at TeV Particle Astrophysics (2009)

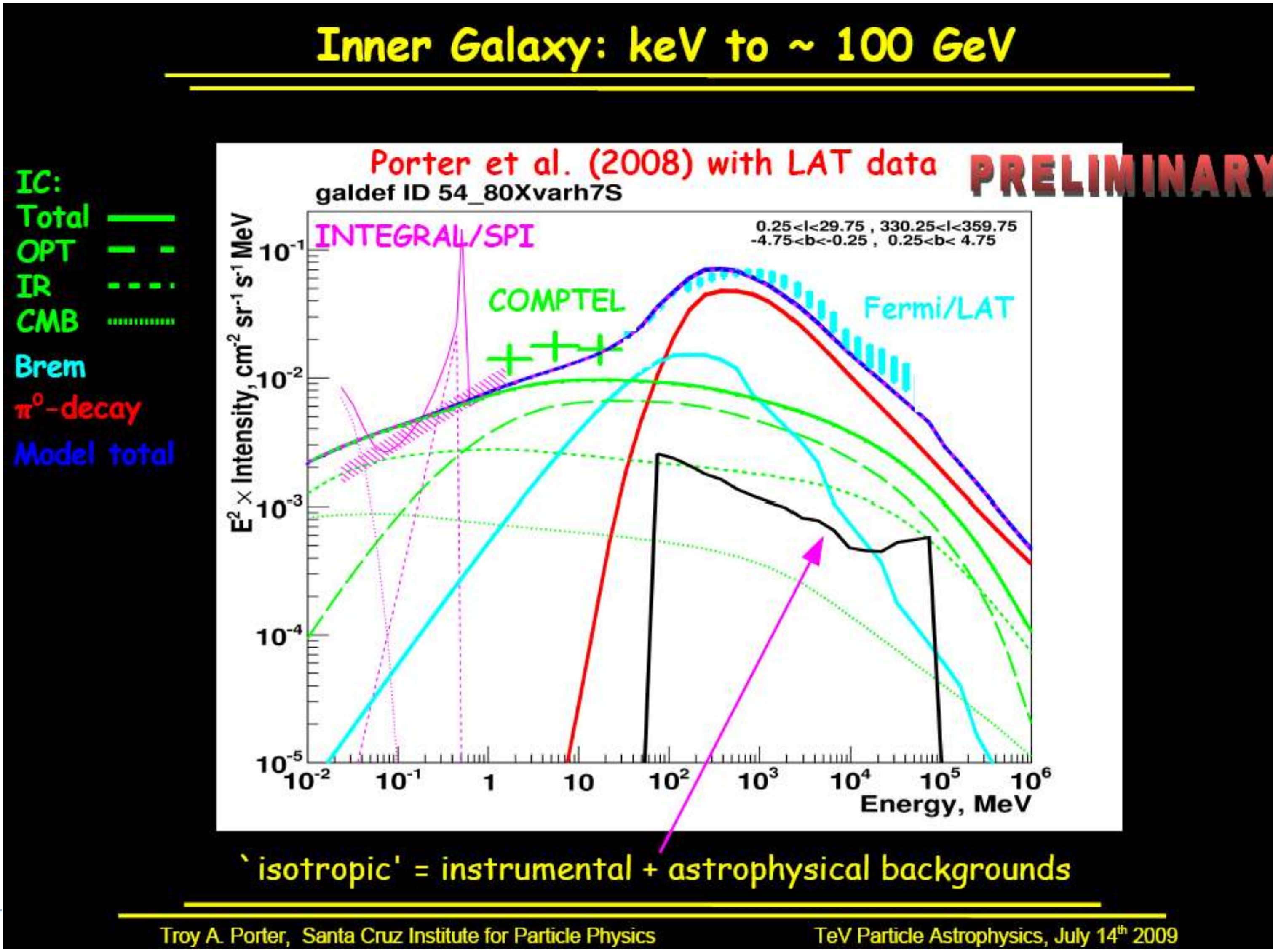
Galactic diffuse model: profile



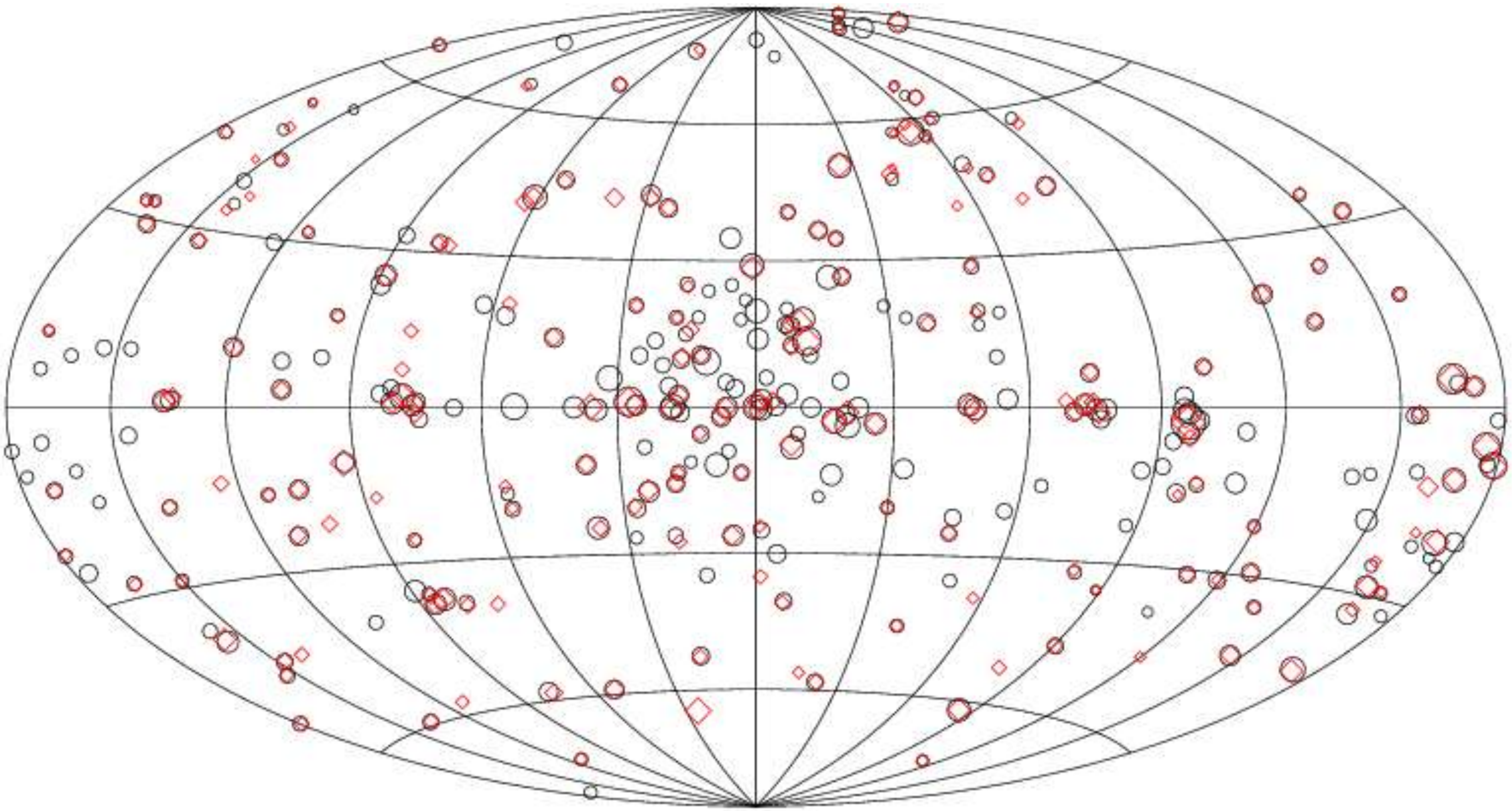
Modified model = increased cosmic-ray intensities and corrections for residual gas → agreement with inner Galaxy is very good in spectrum and profile

T. Porter, talk at TeV Particle Astrophysics (2009)

Galactic diffuse model: spectrum



Skymap of 3EG and revised catalog



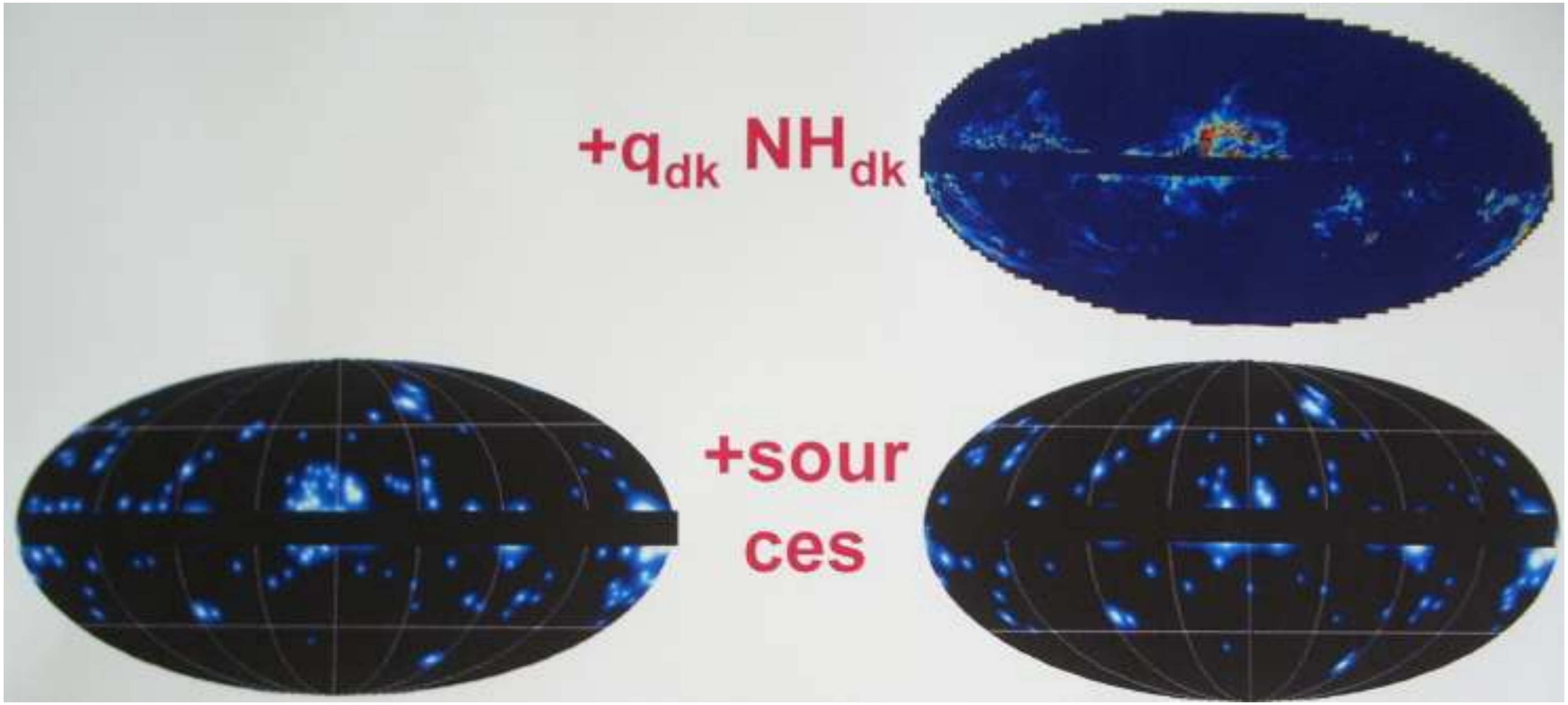
Black: 3EG (Hartman et al. ApJS 1999)

Red: EGR (Casandjian & Grenier, I.A. AA 489, 849 (2008)

Jean-Marc Casandjian and Isabelle Grenier, 2005

Dark gas contribution

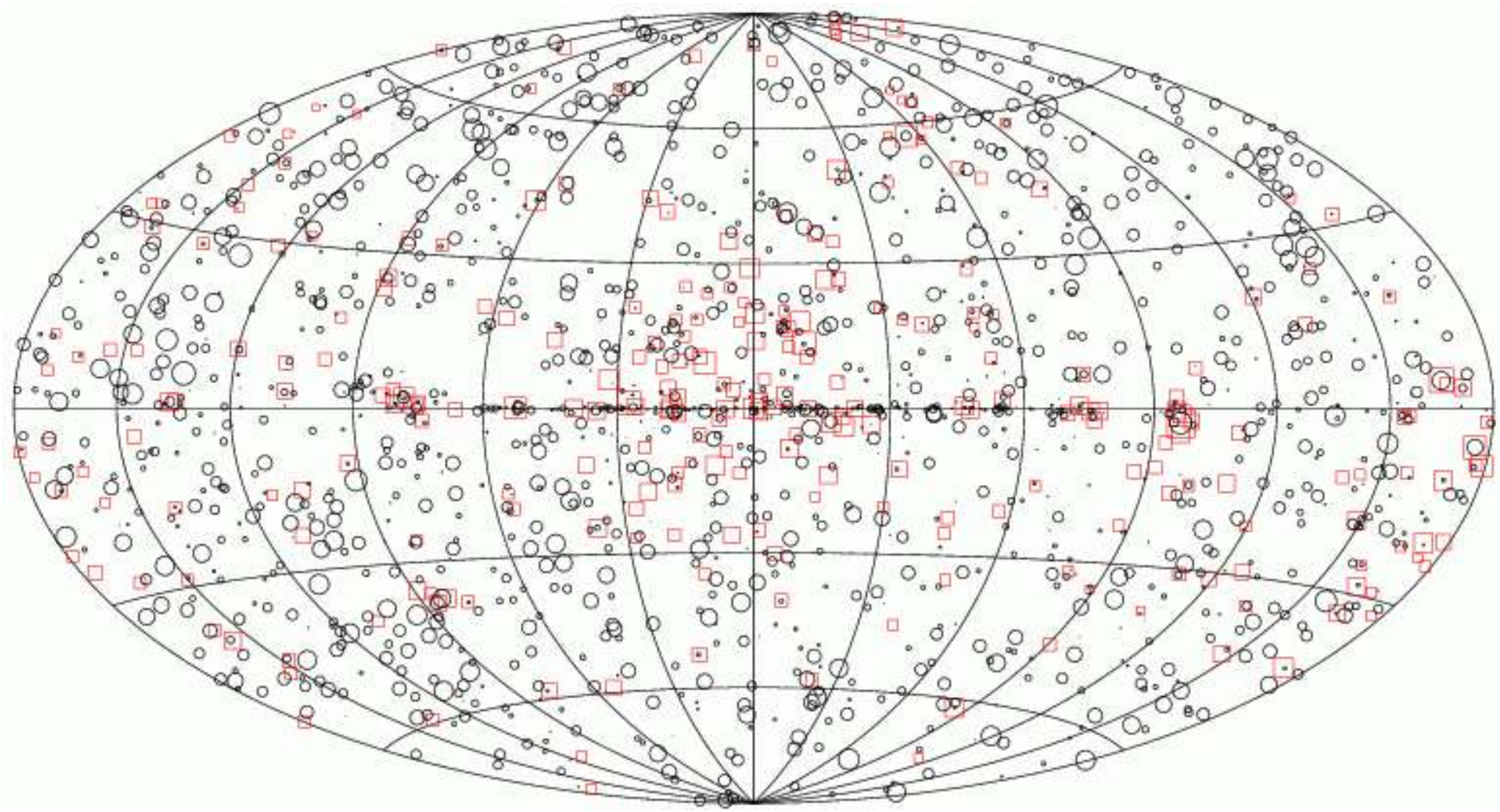
Dark gas contribution!



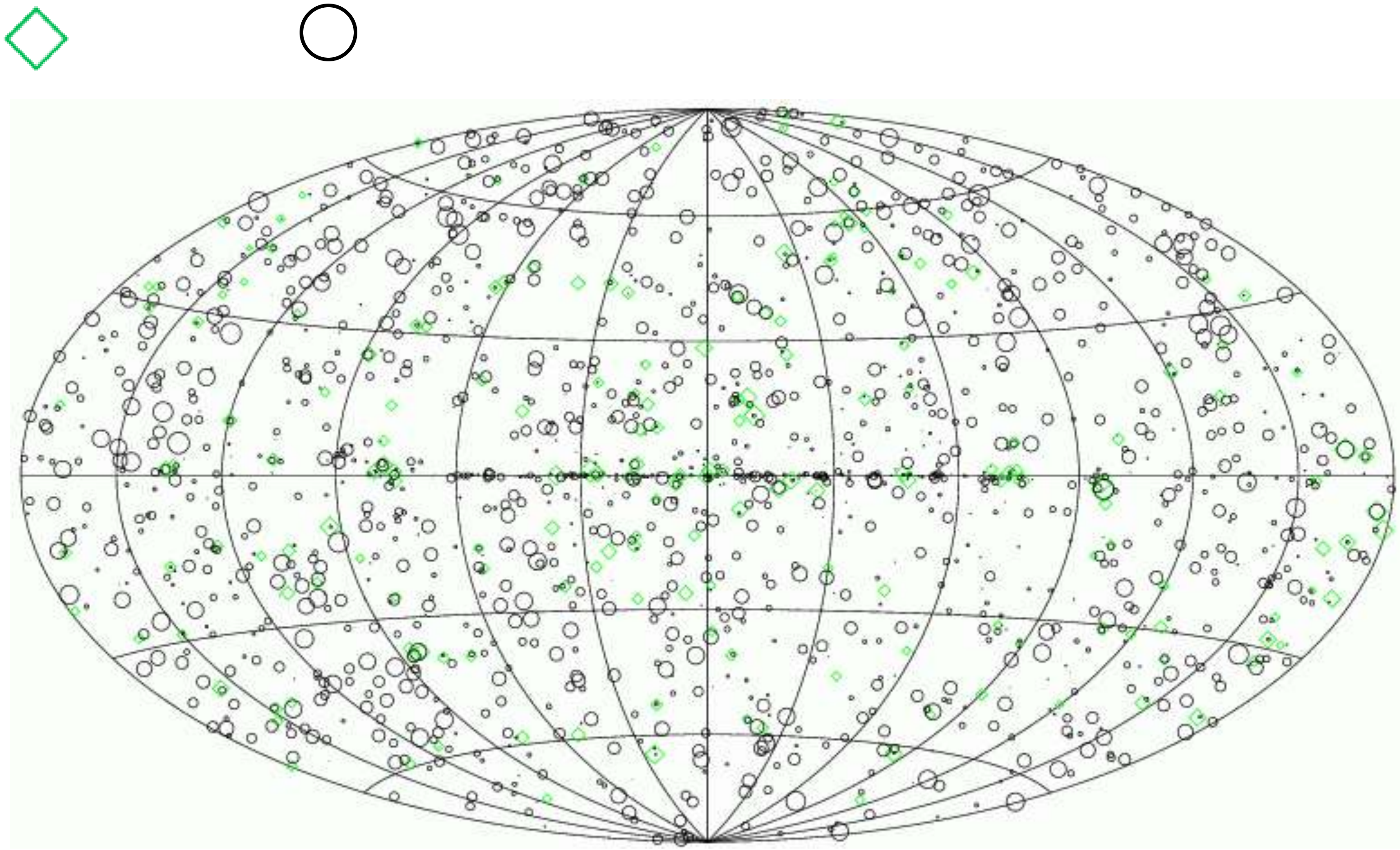
3EG catalog

"Extended" catalog

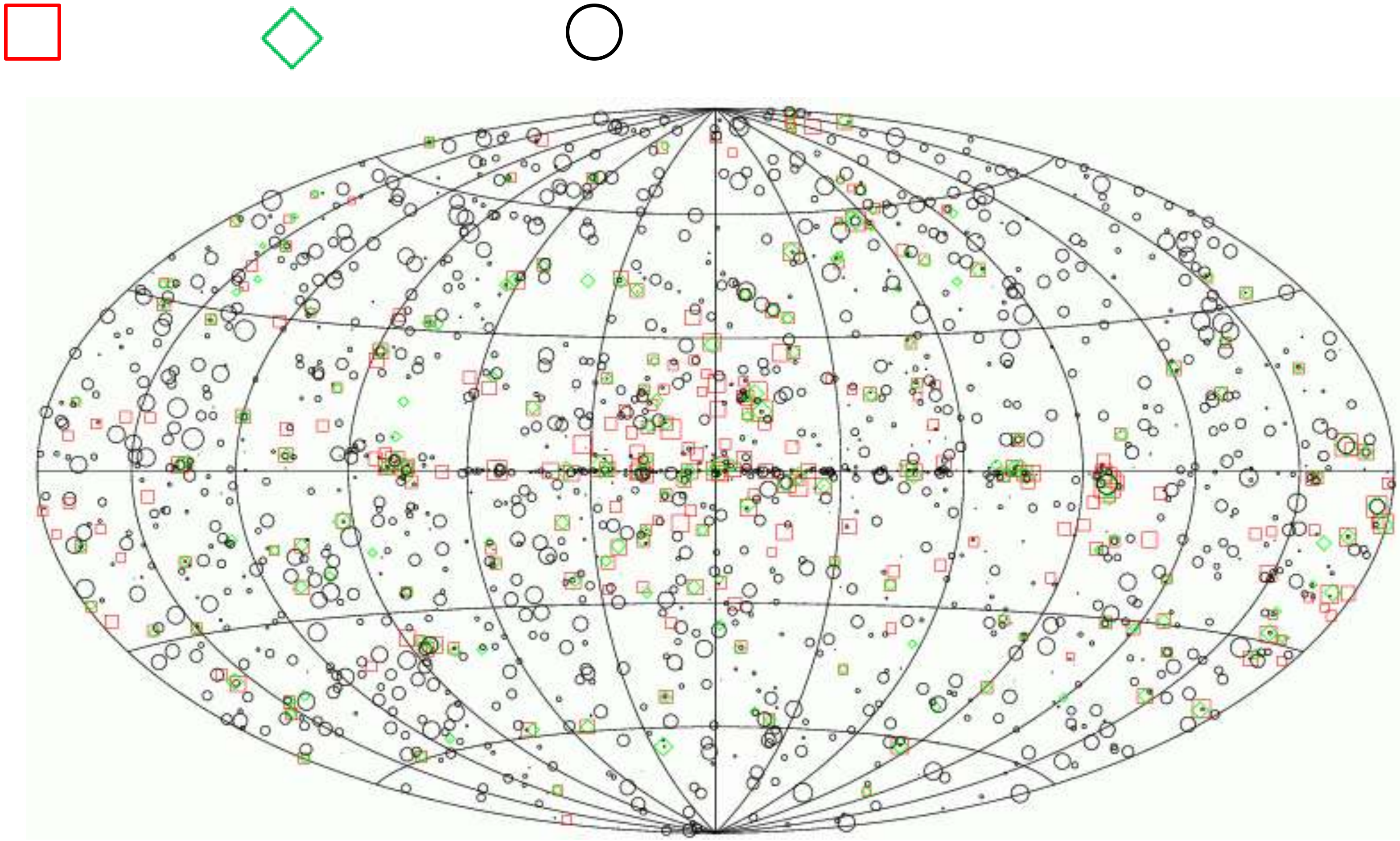
3EG / 1FGL sources



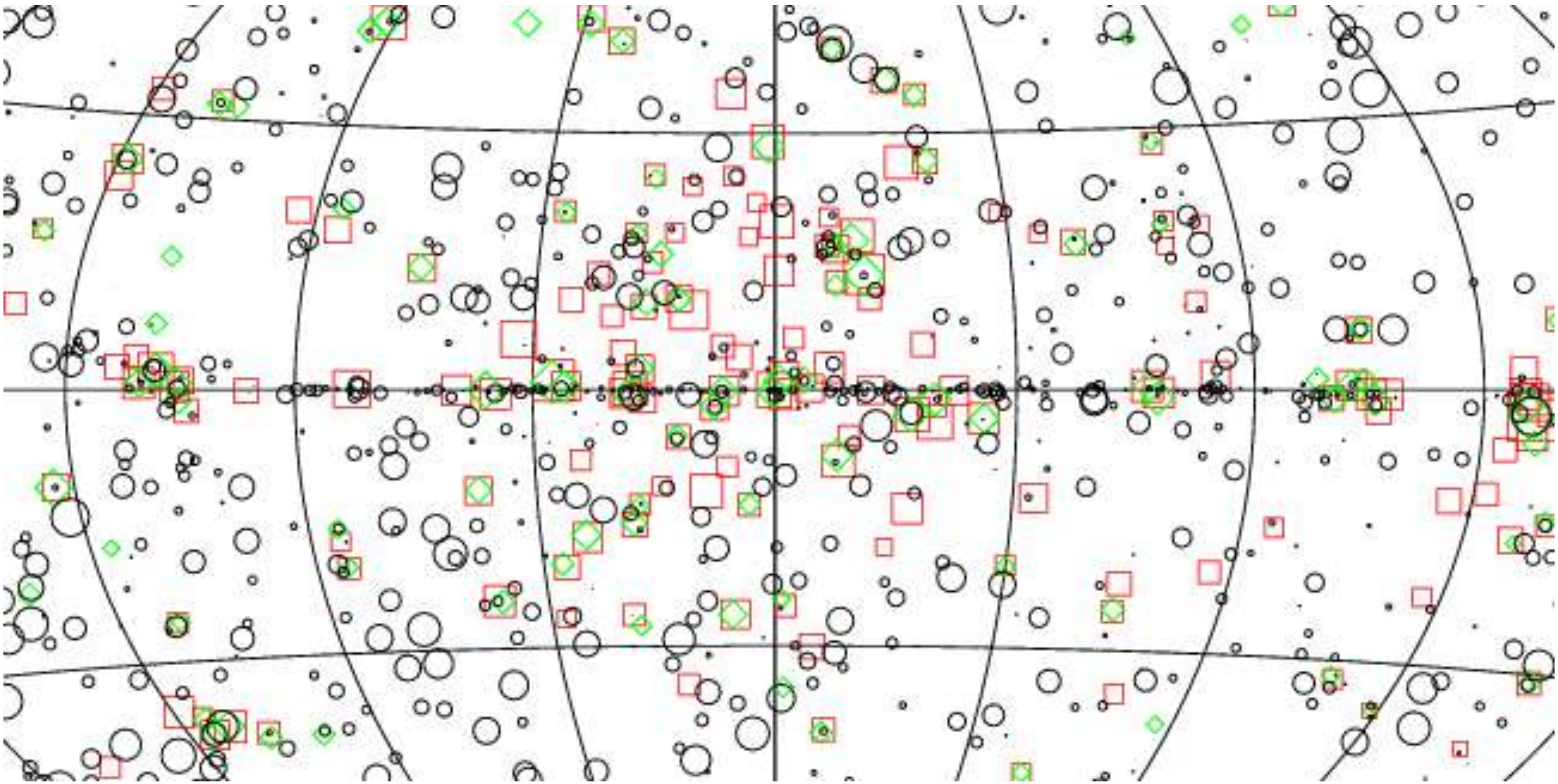
EGR / 1FGL sources



3EG / EGR / 1FGL sources



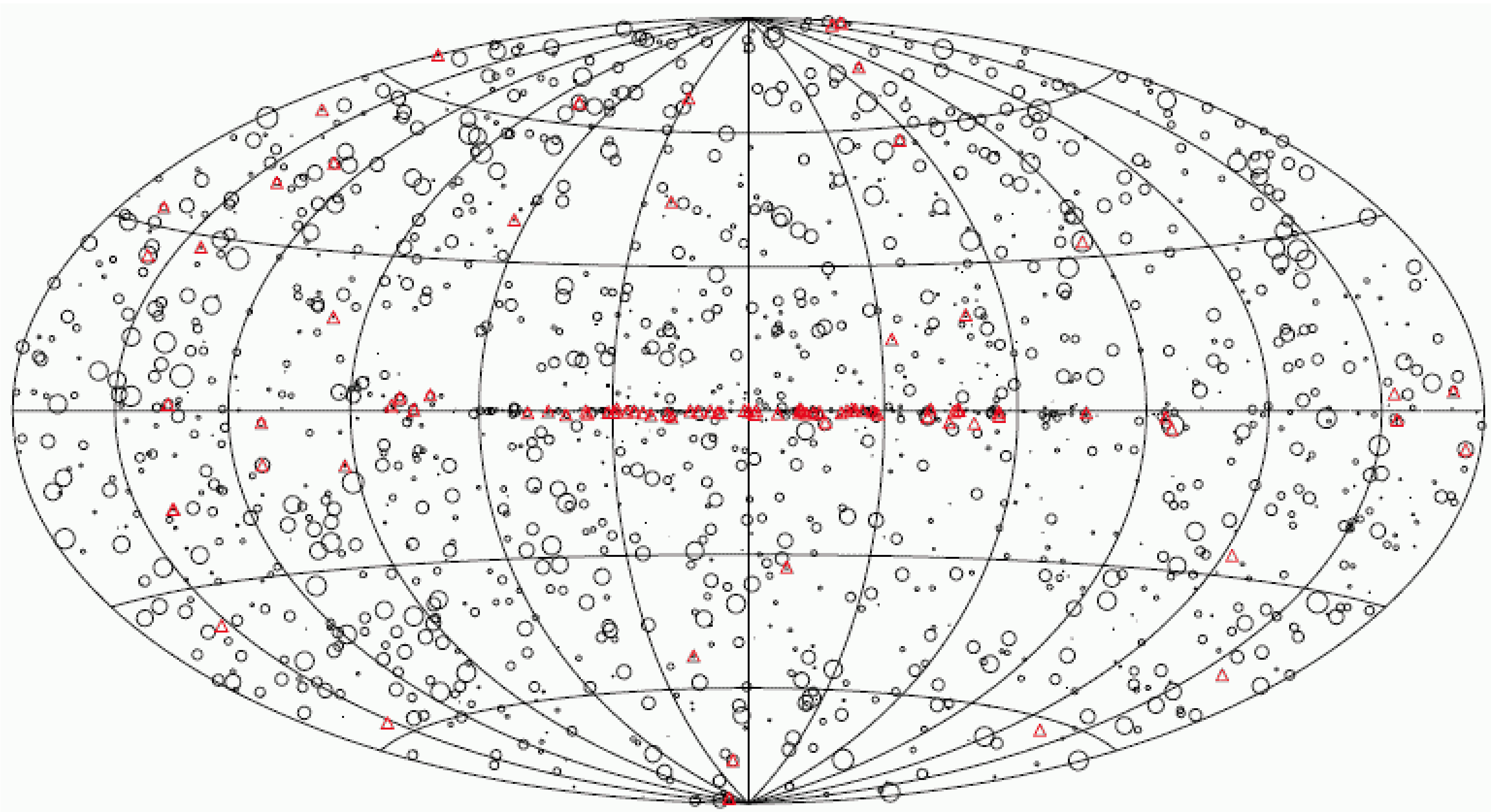
3EG / EGR / 1FGL sources: close up



No good consistency around the Galactic center…

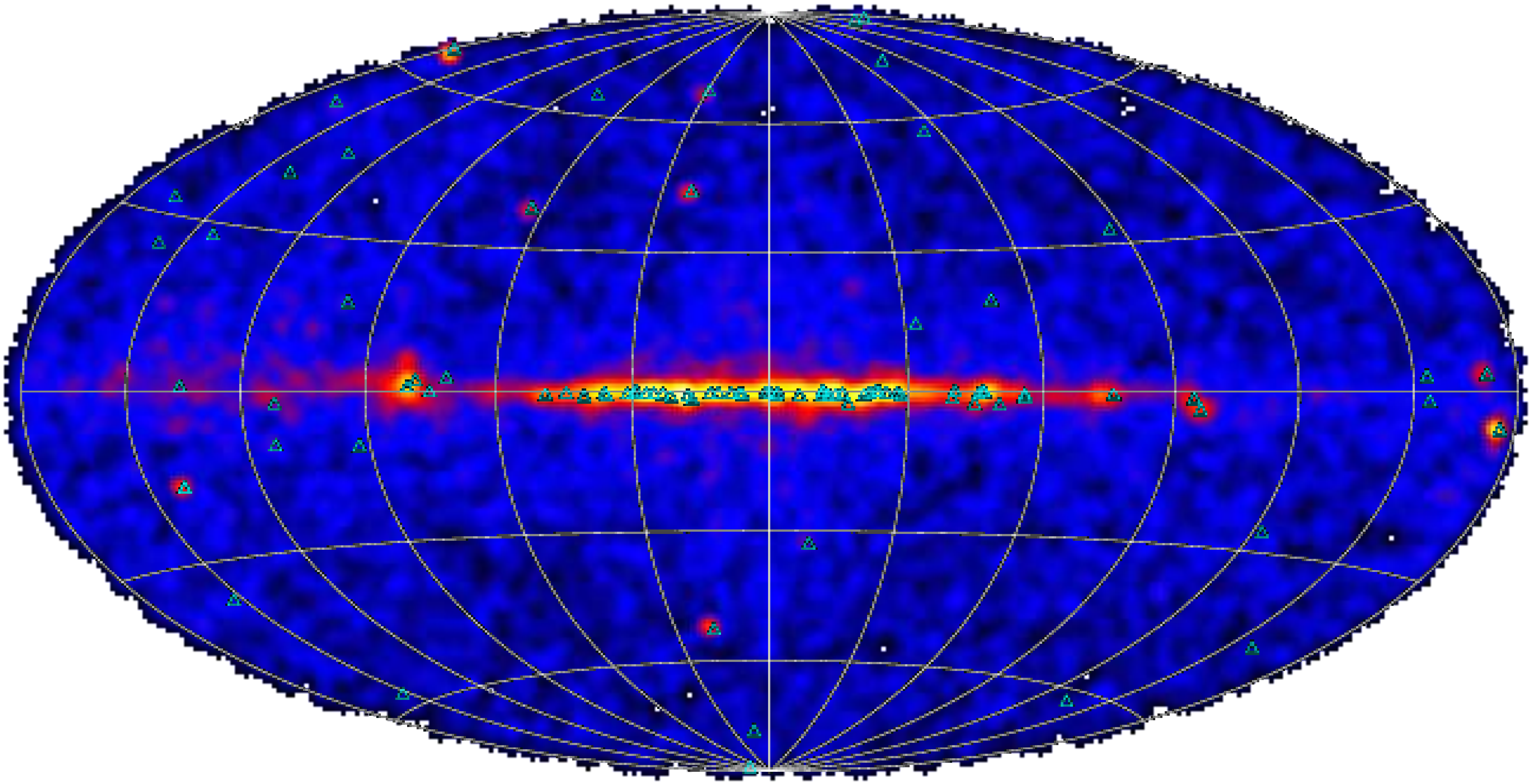
TeV / 1FGL

△ ○



>30GeV allsky map

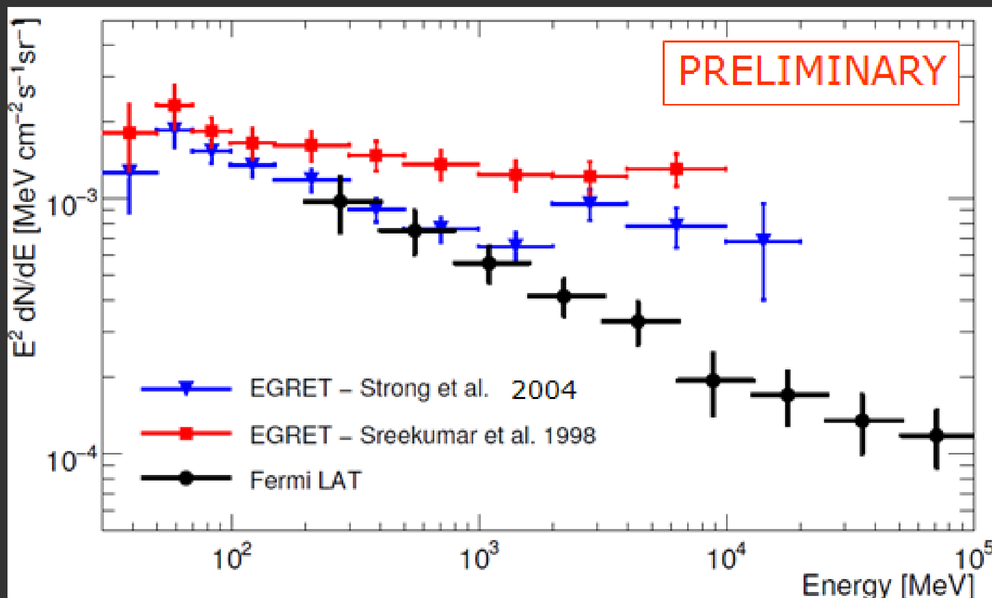
+ TeV sources



Ackerman, talk at Femi symposium (Nov. 2009)

Extragalactic diffuse emission

Comparison with EGRET results



- Considerably steeper than the EGRET spectrum by Sreekumar et al.
- No spectral features around a few GeV seen in re-analysis by Strong et al.

	Flux, E>100 MeV	spectral index
LAT (this analysis)	**1.03 +/- 0.17**	**2.41 +/- 0.05**
EGRET (Sreekumar et al., 1998)	1.45 +/- 0.05	2.13 +/- 0.03
EGRET (Strong et al. 2004)	1.11 +/- 0.10	
LAT + resolved sources below EGRET sensitivity	1.19 +/- 0.18	2.37 +/- 0.05
	x 10^{-5} cm^{-2} s^{-1} sr^{-1}	

http://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/

Fermi analysis of point sources

FITS files:

Photon data
Spacecraft data

Data extract
- FSSC website
- Specify position, period & energy

Tools:

Data selection
- Event selection
- Time selection

gtselect
gtmktime

Data display
ds9 / fv

Exposure calculation
- Livetime cube generation
- Exposure map generation

gtltcube
gtexpmap

Source model
modeleditor

Catalog sources

Source analyis
- Likelihood analysis
  - Unbinned / Binned

gtlike

Platform: Scientific Linux 4/5, Mac OS 10.4/10.5

♣ See also "Fermi Data Analysis Workshop" presentations:
Ex. http://fermi.gsfc.nasa.gov/workshops/da2010_boston/

LAT data server

http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/LATDataQuery.cgi

+ FSSC Home

Data

- Data Policy
- Data Access
- Data Analysis
- Newsletter
- FAQ

LAT Photon, Extended, and Spacecraft Data Query

The Photon database currently holds 246358649 photons collected between 2008-08-04T15:43:37 and 2010-01-19T07:40:15 (239557417 and 285579615 seconds Mission Elapsed Time (MET)).

NOTE: For queries encompassing the whole sky (or close to it), please use the pre-generated Weekly Allsky Files.

Allsky files are ready…

Start Search   Reset

NOTE: additional selections must be applied to data downloaded from the data server prior to use in a data analysis. See **recommended data selections** and **LAT caveats** for more details.

1. Do you want to search around a position ... ?

Mrk 501

Object Name Or Coordinates:
(e.g. '8 34 12, -45 45 00' or '128.55, -45.75' or 'Vela')

Coordinate System: J2000

Selection Radius: 15 degrees

... and/or search by date?

START, 2009-09-30 00:00:00

Observations Dates: Gregorian

If you do not enter anything, it will return results from the past 6 months.
For Gregorian dates, please enter in the format YYYY-MM-DD HH:MM:SS, with the start and (optional) end time separated by commas.
Enter the start and (optional) end MJD in the form MMMMM.mmmmm,MMMMM.mmmmm
For MET (Mission Elapsed Time), enter any integer values >= 0, separated by commas.
If you would like to search from the beginning of the mission, put in START instead of a start value.
If you would like to search up until the most recent point, put in END instead of an end value.

... and/or search by energy?

Energy Range: MeV
Enter the minimum and (optional) maximum energy, separated by a comma.
(By default, only data between 100 MeV and 300 GeV is returned.)

2. What missions and catalogs do you want to search?

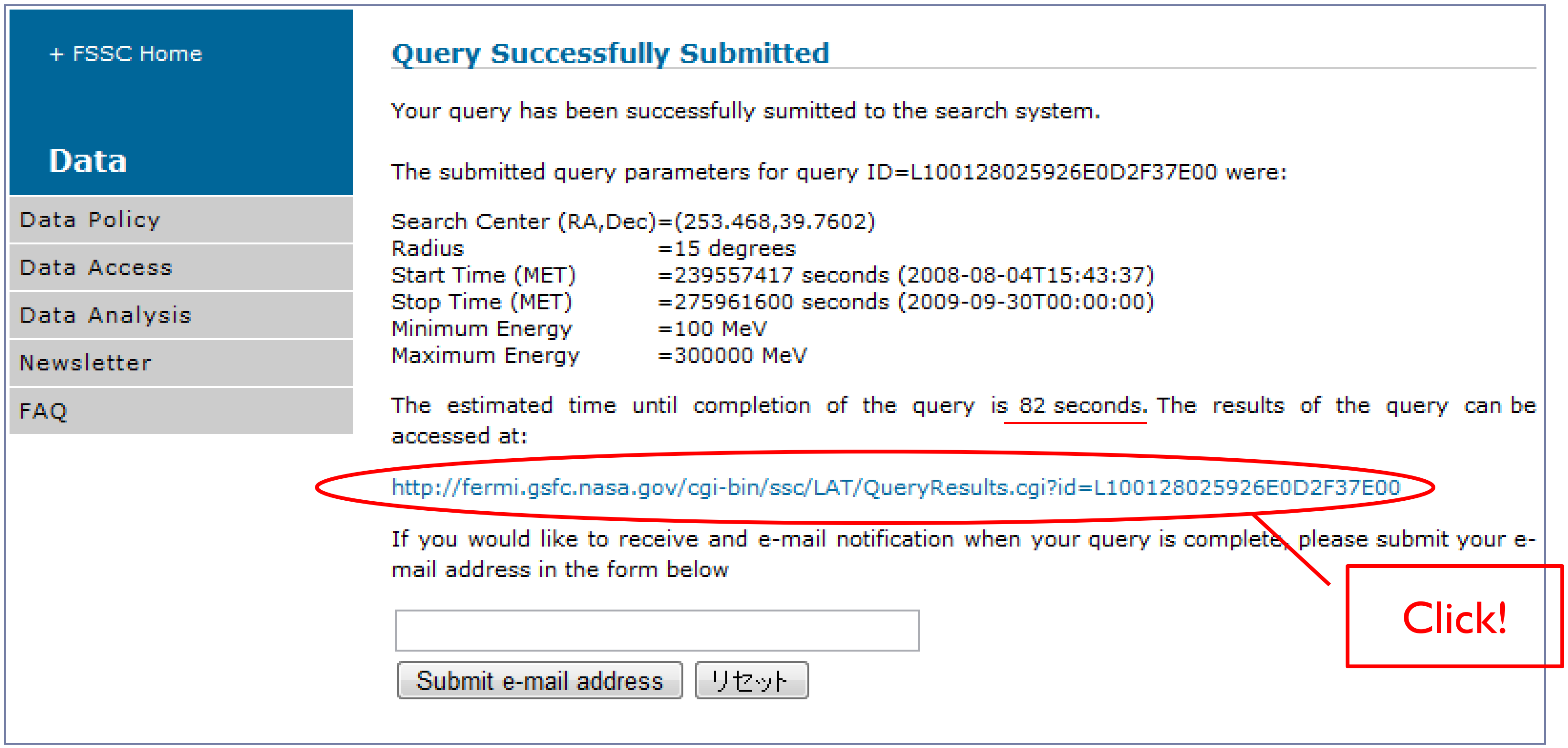
FERMI Data

☑ Photon Data   ☐ Extended Data   ☑ Spacecraft Data

NOTE: additional selections must be applied to data downloaded from the data server prior to use in a data analysis. See **recommended data selections** and **LAT caveats** for more details.

Start Search   Reset

Query



+ FSSC Home

Data

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Query Successfully Submitted

Your query has been successfully sumitted to the search system.

The submitted query parameters for query ID=L100128025926E0D2F37E00 were:

Search Center (RA,Dec)	=(253.468,39.7602)
Radius	=15 degrees
Start Time (MET)	=239557417 seconds (2008-08-04T15:43:37)
Stop Time (MET)	=275961600 seconds (2009-09-30T00:00:00)
Minimum Energy	=100 MeV
Maximum Energy	=300000 MeV

The estimated time until completion of the query is 82 seconds. The results of the query can be accessed at:

http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/QueryResults.cgi?id=L100128025926E0D2F37E00

If you would like to receive and e-mail notification when your query is complete, please submit your e-mail address in the form below

Submit e-mail address | リセット

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LAT Data Query Results

Welcome to the LAT Data Query Results page. This page provides access to the LAT data requested from the FSSC's data servers.

The submitted query parameters for query ID=L100128025926E0D2F37E00 were:

Search Center (RA,Dec)	=(253.468,39.7602)
Radius	=15 degrees
Start Time (MET)	=239557417 seconds (2008-08-04T15:43:37)
Stop Time (MET)	=275961600 seconds (2009-09-30T00:00:00)
Minimum Energy	=100 MeV
Maximum Energy	=300000 MeV

Server	Position in Queue	Estimated Time Remaining
Photon Server	Query Completed	N/A
Spacecraft Server	Query Completed	N/A

The filenames of the result files consist of the Query ID string with an identifier appended to indicate which database the file came from. The identifiers are of the form: _DDNN where DD indicates the database and NN is the file number. The file number will generally be '00' unless the query resulted in a very large data return. In that case the data is broken up into multiple files. The values of the database field are:

- PH - Photon Database
- SC - Spacecraft Pointing, Livetime, and History Database
- EV - Extended Database

Filename	Number of Entries	Size (MB)	Status
L100128025926E0D2F37E00_PH00.fits	886317	77.83	Available
L100128025926E0D2F37E00_SC00.fits	1008229	133.69	Available
L100128025926E0D2F37E00_PH01.fits	612538	53.79	Available
L100128025926E0D2F37E00_PH02.fits	810327	71.15	Available

Save as …

To get the results from another query, enter the query ID string below:

Submit リセット

You may submit a new search at:

FERMI LAT Data Query Page

Data exploration

Data

Photon data	Spacecraft data

“gtselect”

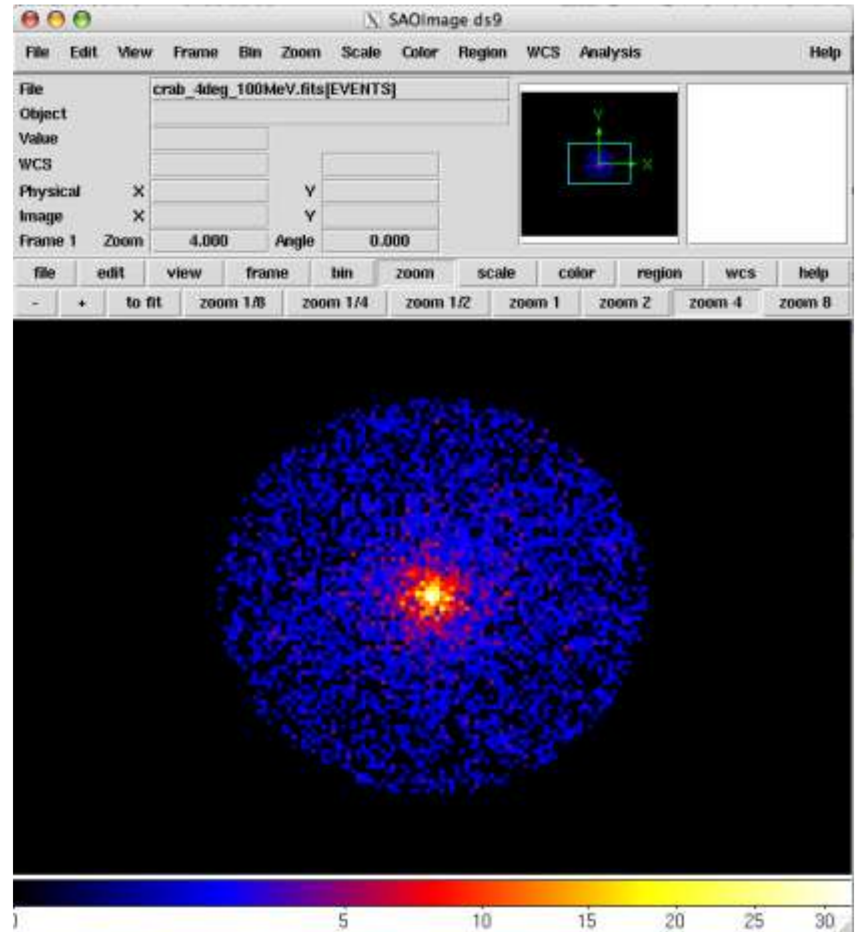
Event data

“gtmktime”

Event data in GTI (good time interval)

“gtbin”

Count map



Count map viewed by “ds9”

Likelihood analysis

Maximize *L* to get best fit:

The likelihood is the probability of the observed EGRET data for a specific model of high-energy γ-ray emission. It is the product of the probability for each pixel:

$$L = \prod_{ij} p_{ij} \,, \tag{3}$$

where

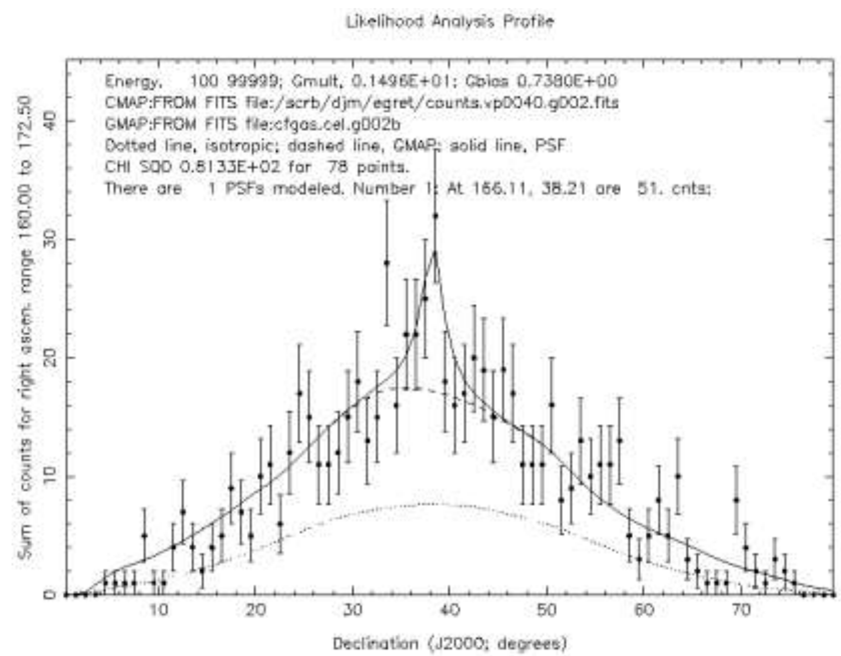
$$p_{ij} = \frac{\theta_{ij}^{n_{ij}} e^{-\theta_{ij}}}{n_{ij}!} \tag{4}$$

is the Poisson probability of observing n_{ij} counts in pixel ij when the number of counts predicted by the model is θ_{ij}. The logarithm of the likelihood is more conveniently calculated

$$\ln L = \sum_{ij} n_{ij} \ln(\theta_{ij}) - \sum_{ij} \theta_{ij} - \sum \ln(n_{ij}!) \,. \tag{5}$$

Because the last term is model independent, it is not useful for estimation or for the likelihood ratio test. Neglecting the last term,

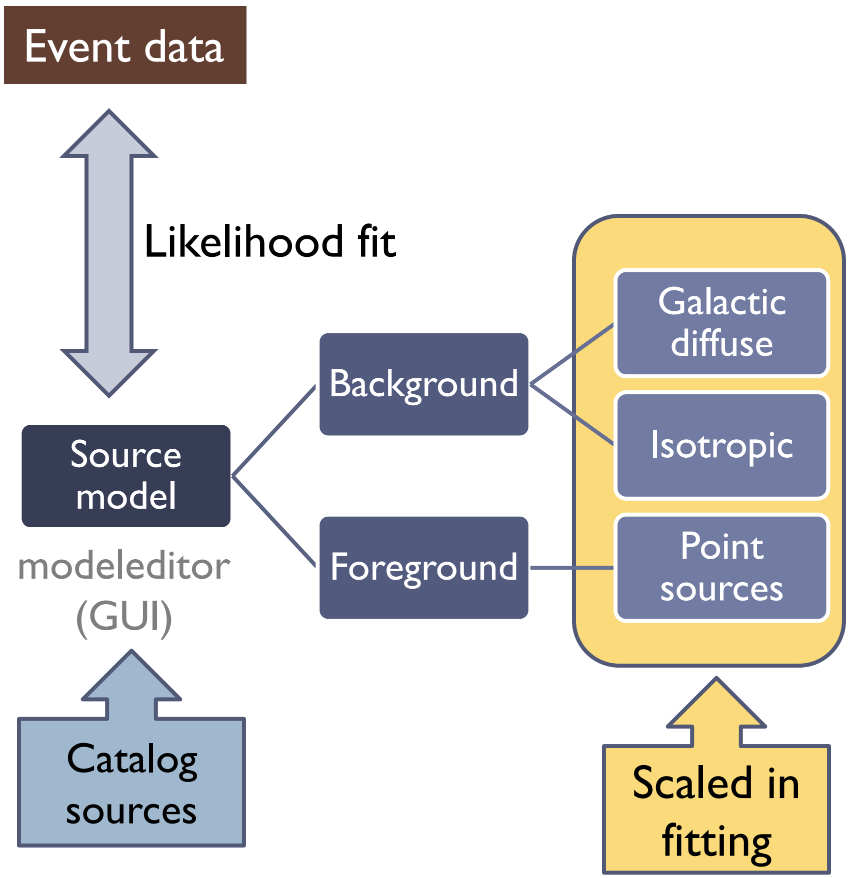
$$\ln L = \sum_{ij} n_{ij} \ln(\theta_{ij}) - \sum_{ij} \theta_{ij} \,. \tag{6}$$



Model = $K_1 \times$(diffuse model)
$+K_2 \times$(isotropic)
$+\Sigma_i F_i \times (\mathrm{PSF})_i$

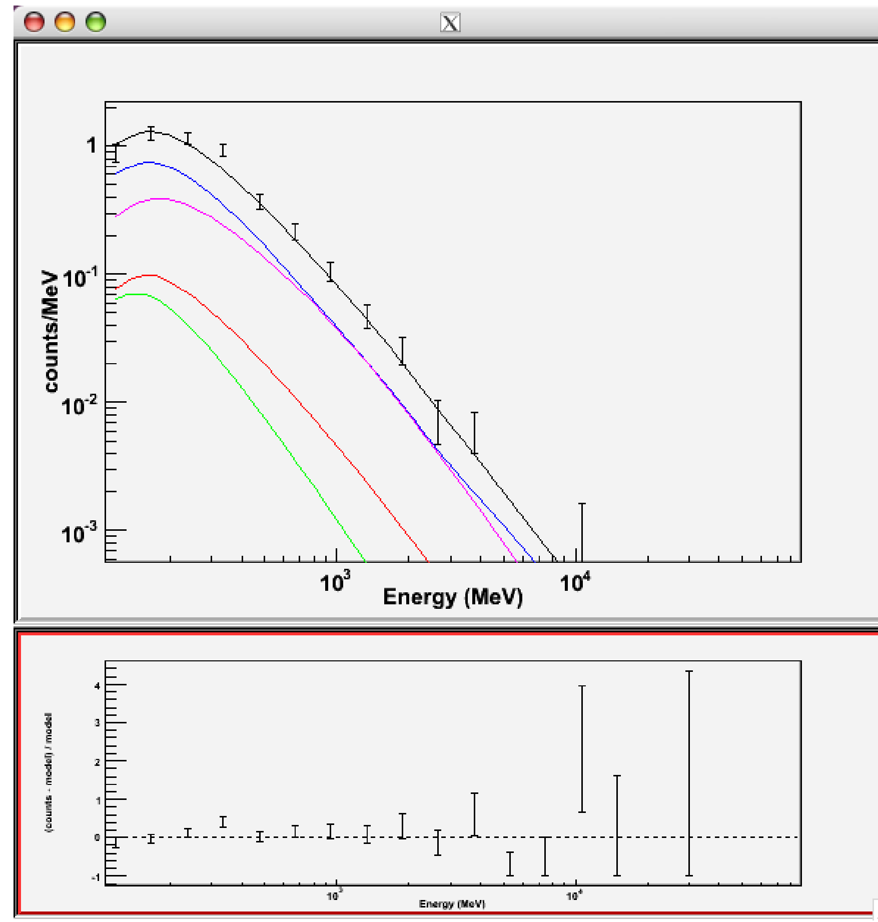
Adjust K_1&K_2 and seek for best fit with F_i

Likelihood fit with "gtlike"



Least-square fitting routines: MINUIT etc.

Resulting energy spectra



Built-in spectral functions

- **PowerLaw** (see example XML Model Definition) This function has the form

$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{\gamma}$$

where the parameters in the XML definition have the following mappings:

  - Prefactor = N_0
  - Index = γ
  - Scale = E_0

- **BrokenPowerLaw** (see example XML Model Definition)

$$\frac{dN}{dE} = N_0 \times \begin{cases} (E/E_b)^{\gamma_1} & \text{if } E < E_b \\ (E/E_b)^{\gamma_2} & \text{otherwise} \end{cases}$$

where

  - Prefactor = N_0
  - Index1 = γ_1
  - Index2 = γ_2
  - BreakValue = E_b

- **PowerLaw2** (see example XML Model Definition). This function uses the integrated flux as a free parameter rather than the Prefactor:

$$\frac{dN}{dE} = \frac{N(\gamma+1)E^{\gamma}}{E_{\max}^{\gamma+1} - E_{\min}^{\gamma+1}}$$

where

  - Integral = N
  - Index = γ
  - LowerLimit = $E_{\min}$
  - UpperLimit = $E_{\max}$

The UpperLimit and LowerLimit parameters are always treated as fixed, and as should be apparent from this definition, the flux given by the Integral parameter is over the range (LowerLimit, UpperLimit). Use of this model allows the errors on the integrated flux to be evaluated directly by likelihood, obviating the need to propagate the errors if one is using the PowerLaw form.

- **BrokenPowerLaw2** (see example XML Model Definition). Similar to PowerLaw2, the integral flux is the free parameter rather than the Prefactor:

$$\frac{dN}{dE} = N_0(N, E_{\min}, E_{\max}, \gamma_1, \gamma_2) \times \begin{cases} (E/E_b)^{\gamma_1} & \text{if } E < E_b \\ (E/E_b)^{\gamma_2} & \text{otherwise} \end{cases}$$

where

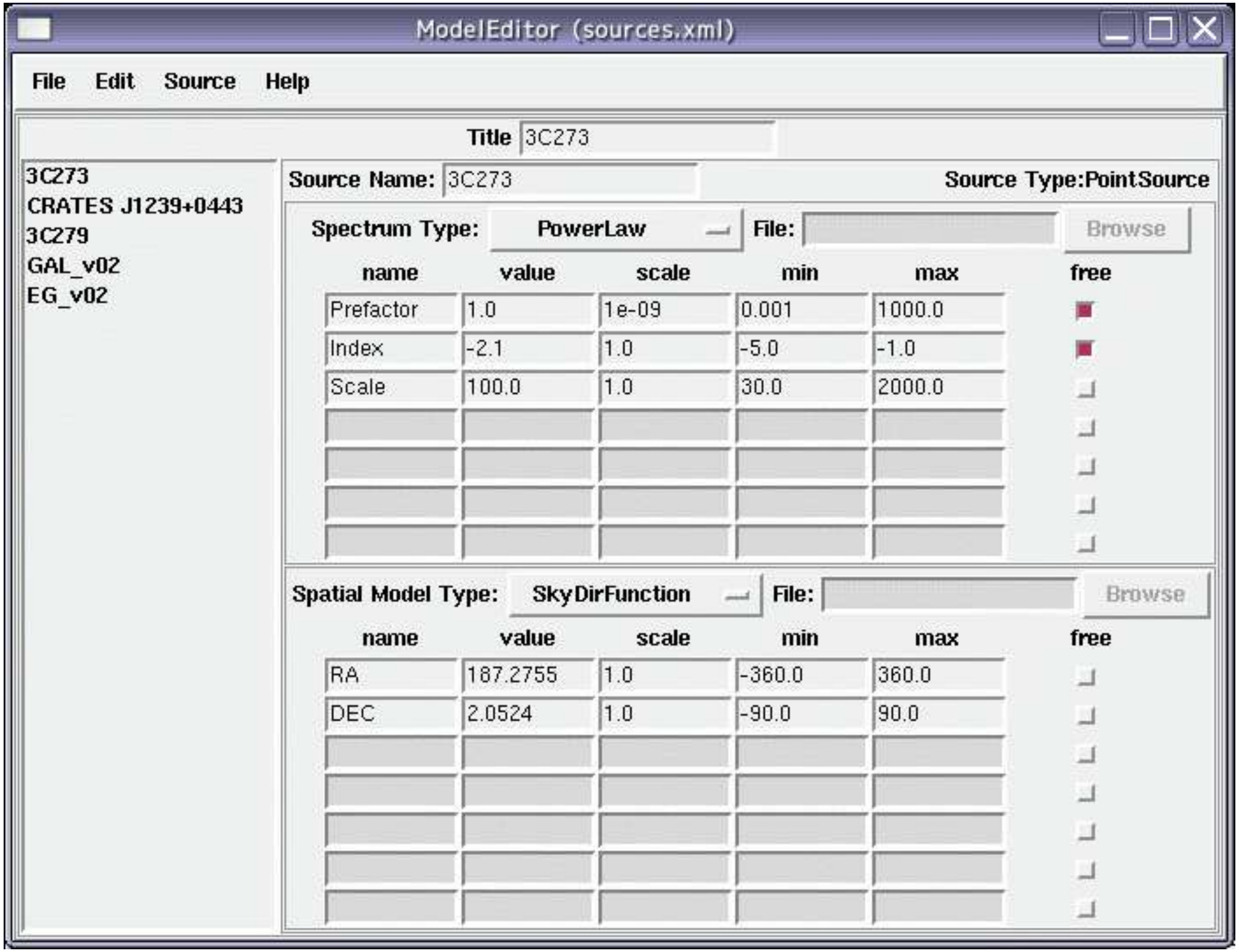
$$N_0(N, E_{\min}, E_{\max}, \gamma_1, \gamma_2) = N \times \begin{cases} \left[\int_{E_{\min}}^{E_{\max}} \left(\frac{E}{E_b}\right)^{\gamma_1} dE\right]^{-1} & E_{\max} < E_b \\ \left[\int_{E_{\min}}^{E_{\max}} \left(\frac{E}{E_b}\right)^{\gamma_2} dE\right]^{-1} & E_{\min} > E_b \\ \left[\int_{E_{\min}}^{E_b} \left(\frac{E}{E_b}\right)^{\gamma_1} dE + \int_{E_b}^{E_{\max}} \left(\frac{E}{E_b}\right)^{\gamma_2} dE\right]^{-1} & \text{otherwise} \end{cases}$$

and

  - Integral = N
  - Index1 = γ_1
  - Index2 = γ_2
  - BreakValue = E_b
  - LowerLimit = $E_{\min}$
  - UpperLimit = $E_{\max}$

Also available:
- LogPrabola
- BPLExpCutoff
- Gaussian
- ConstantValue
- BandFunction
- PLSuperExpCutoff

Modeleditor



XML-format file … can be a part of the catalog XML file

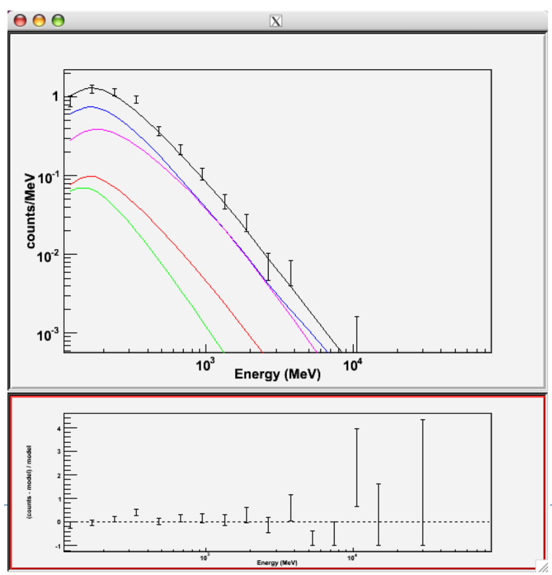
Example session of “gtlike”

prompt> gtlike refit=yes plot=yes
Statistic to use (BINNED|UNBINNED) [UNBINNED]
Spacecraft file[none] spacecraft_data_file.fits
Event file[none] events_diffuse_filtered_gti.fits
Unbinned exposure map[none] expMap.fits
Exposure hypercube file[none] expCube.fits
Source model file[] src_model.xml
Response functions to use[P6_V3_DIFFUSE]
Optimizer (DRMNFB|NEWMINUIT|MINUIT|DRMNGB|LBFGS) [DRMNFB]NEWMINUIT

Be patient…

(MORE OUTPUTS HERE...)

Computing TS values for each source (4 total)
....!



3C 273:
Prefactor: 10.7154 +/- 4.79318
Index: -2.39036 +/- 0.261339
Scale: 100
Npred: 28.651
ROI distance: 10.4409
TS value: 58.0328

$(10.7 \pm 4.8)\times 10^{-9}(E/100)^{-2.39\pm 0.26}$
TS=58

3C 279:
Prefactor: 8.97673 +/- 5.45668
Index: -2.8986 +/- 0.470354
Scale: 100
Npred: 13.8568
ROI distance: 0
TS value: 17.8267

TS: Test statistics,
Behave like $(TS)^{1/2} \sim \sigma$

EG_v02:
Normalization: 1.11606 +/- 0.234866
Npred: 278.964

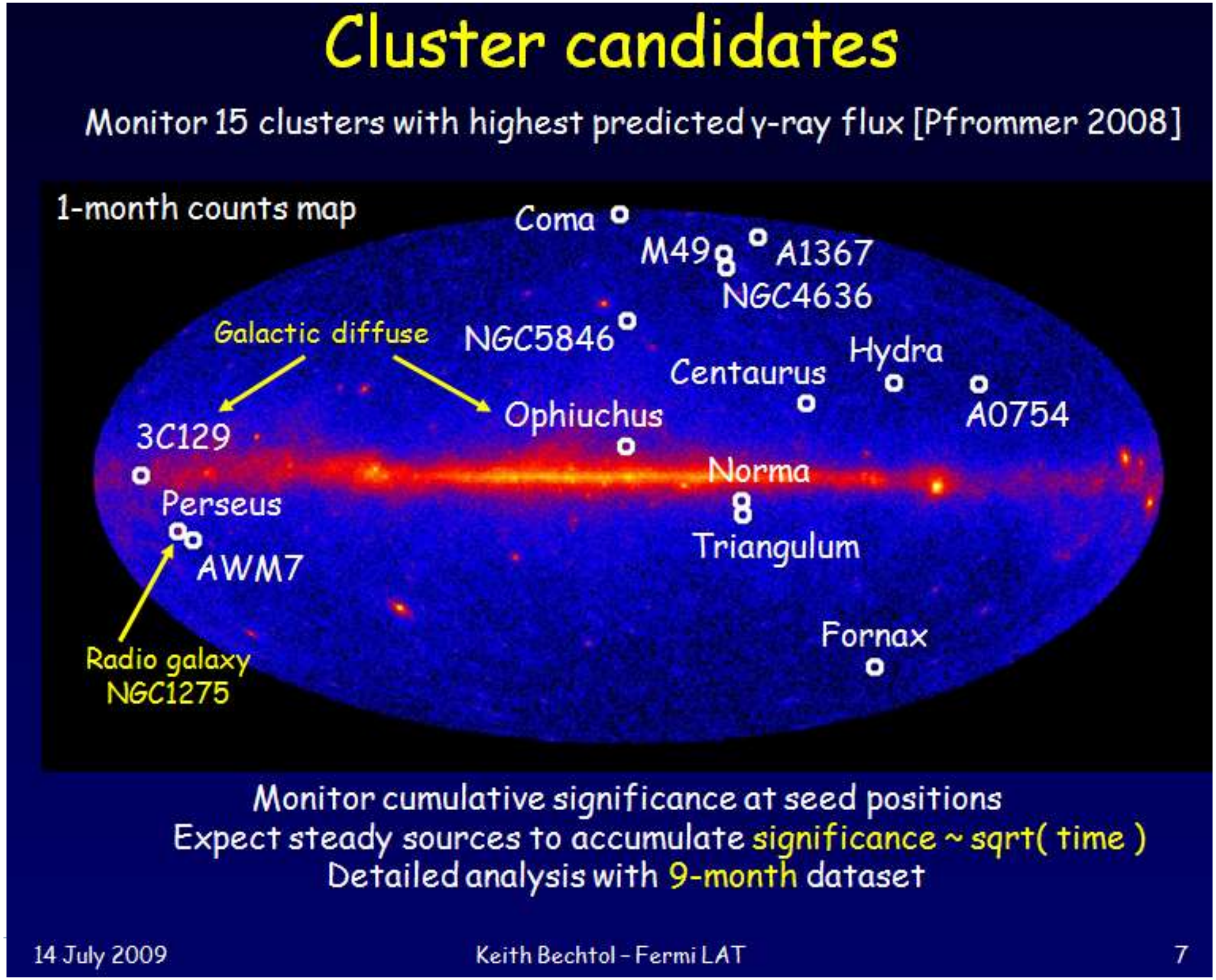
GAL_v02:
Value: 1.161 +/- 0.328156
Npred: 199.892
WARNING: Fit may be bad in range [100, 146.235] (MeV)
WARNING: Fit may be bad in range [4472.14, 6539.83] (MeV)

Total number of observed counts: 521
Total number of model events: 521.364

-log(Likelihood): 5979.486023

Bechtol et al., talk at TeV Particle Astrophysics (2009)

Fermiによる銀河団の観測 (Becktol+2009)



Bechtol et al., talk at TeV Particle Astrophysics (2009)

Fermiによる銀河団の観測 (Becktol+2009)

Non-detection -> Upper limits

Flux upper limits

Event selection

- E > 100 MeV
- 9-month data set

Assume

- Point source spatial model
- Power law spectral model

  $dN/dE \sim E^{-\Gamma}$

- Photon index $\Gamma = 2$

Plan to address alternative spatial and spectral models in a 1-year publication

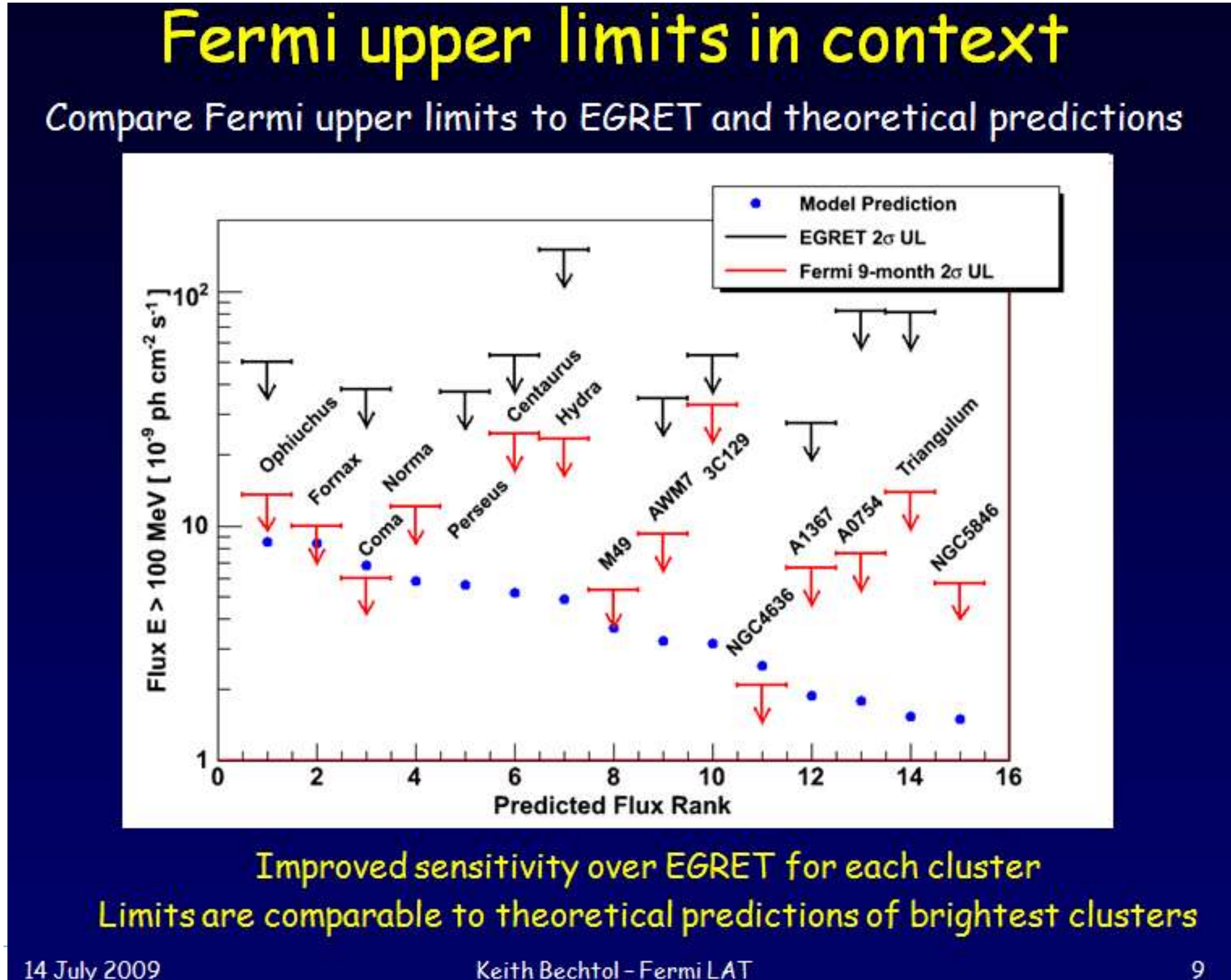
95% C.L. UL Flux E>100 MeV [1e-8 ph cm^{-2} s^{-1}]

Cluster	EGRET	Fermi 9-month
Ophiuchus	5.0	1.4
Fornax		1.0
Coma	3.8	0.6
A3627		1.2
Perseus	3.7	19.9
A3526	5.3	2.5
A1060	14.9	2.3
M49		0.5
AWM7	3.5	0.9
3C129	5.3	3.2
NGC4636		0.2
A1367	2.7	0.7
A0754	8.2	0.8
Triangulum	8.1	1.4
NGC5846		0.6

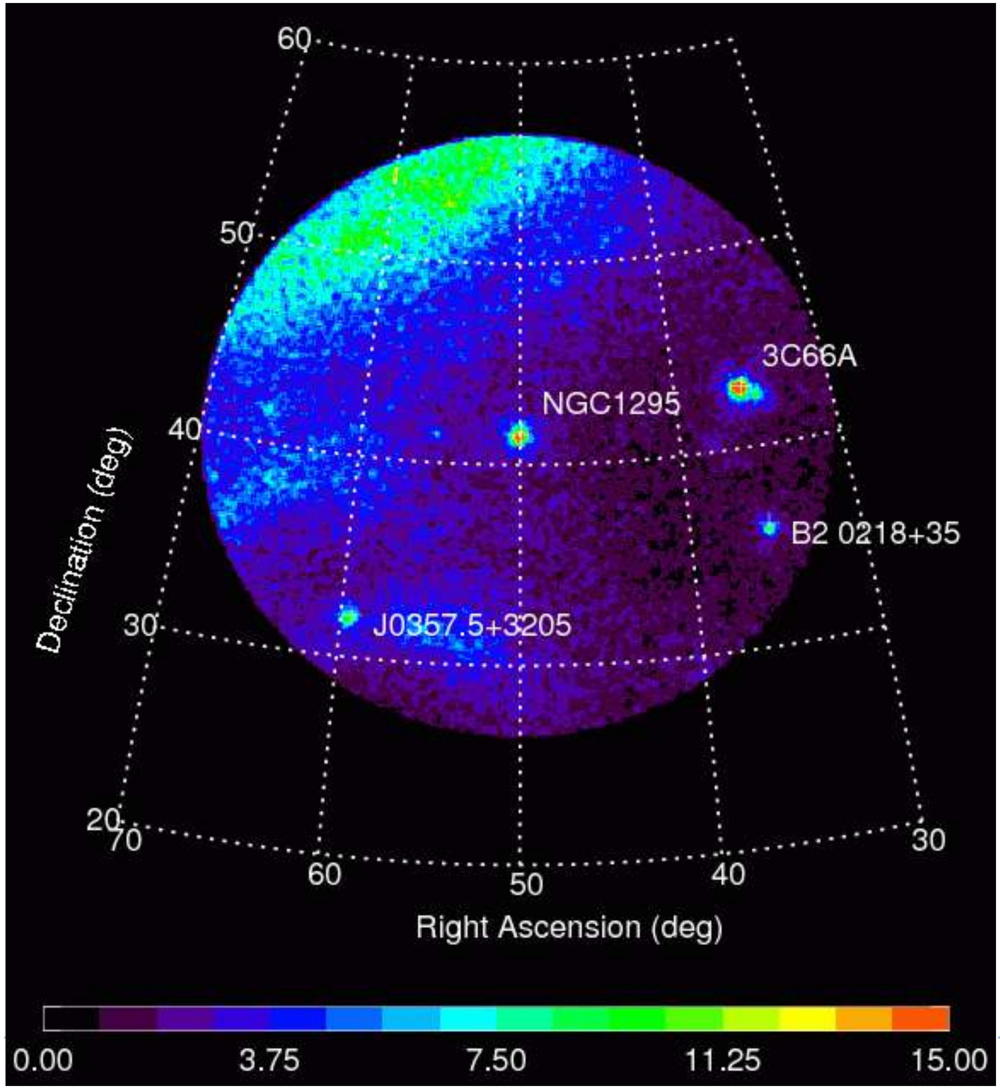
14 July 2009 Keith Bechtol - Fermi LAT 8

Bechtol et al., talk at TeV Particle Astrophysics (2009)

Fermiによる銀河団の観測 (Becktol+2009)

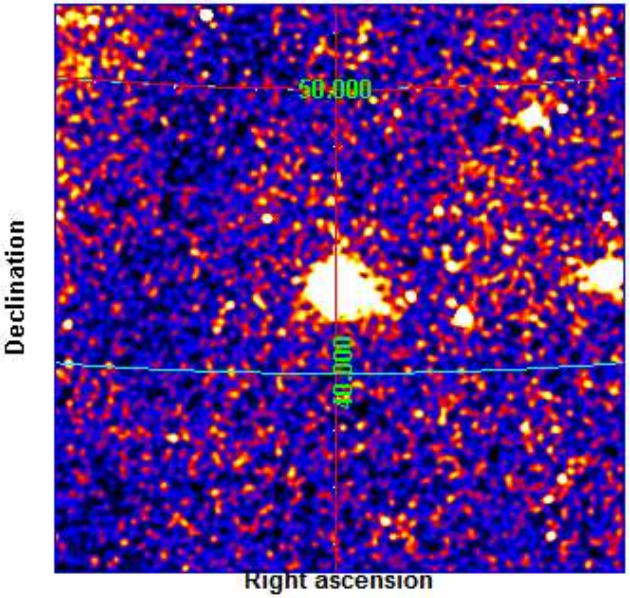


Fermi/LAT count map: Perseus

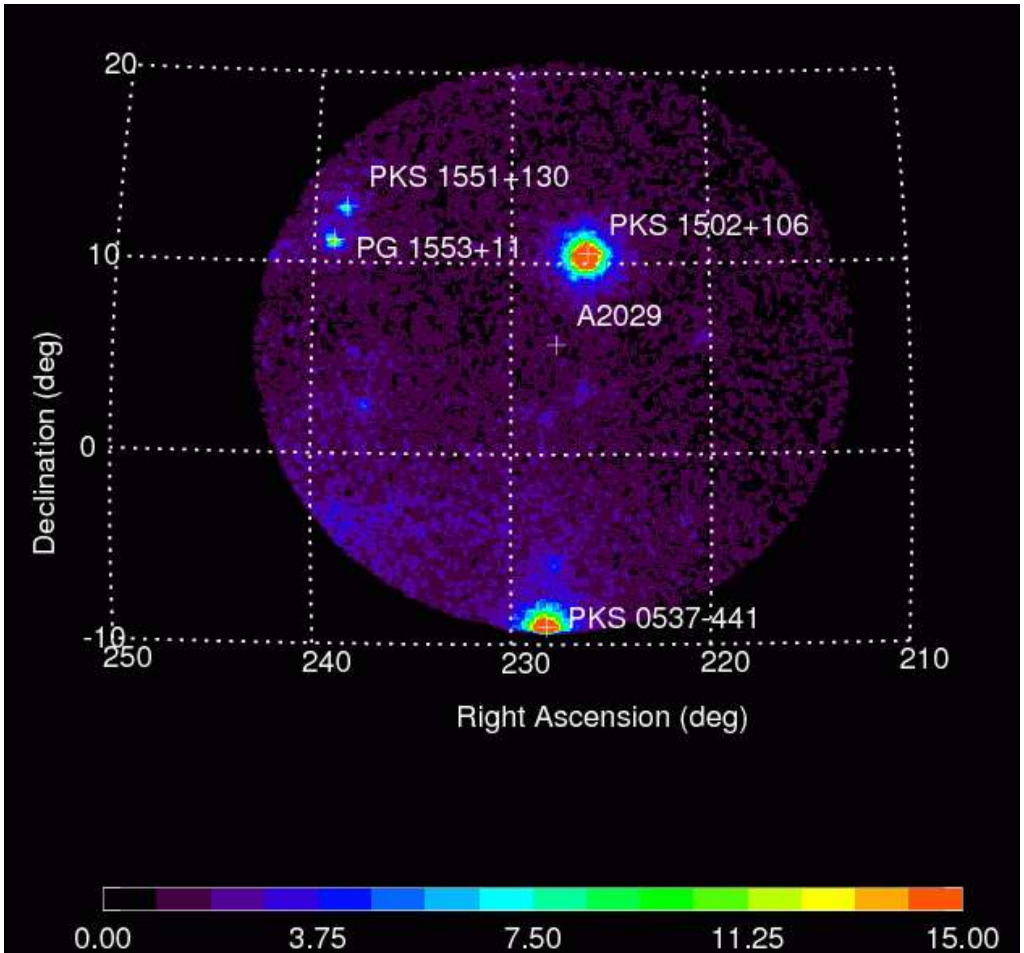


0.2-10 GeV
2008Aug-2009Sep

Ref: RASS (broad)

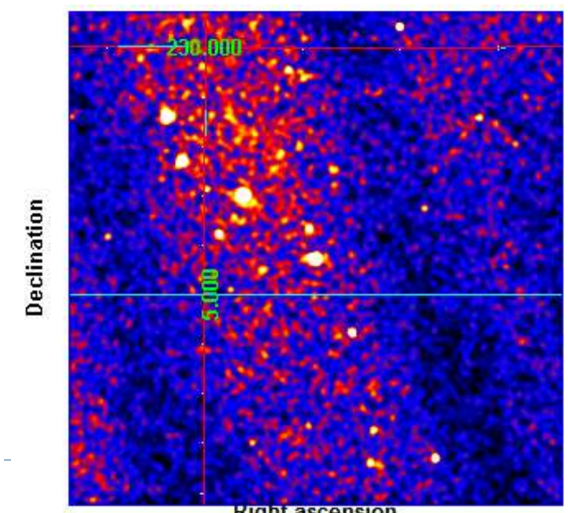


Fermi/LAT count map: Abell 2029



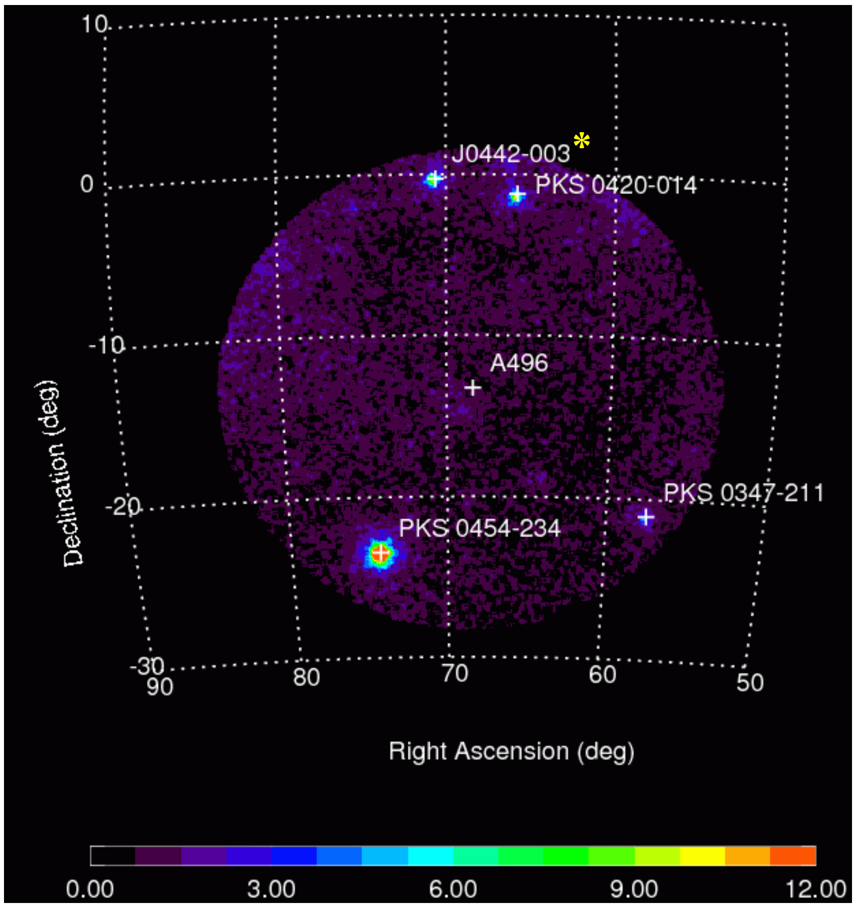
0.2-10 GeV
2008Aug-2009Sep

Ref: RASS (broad)

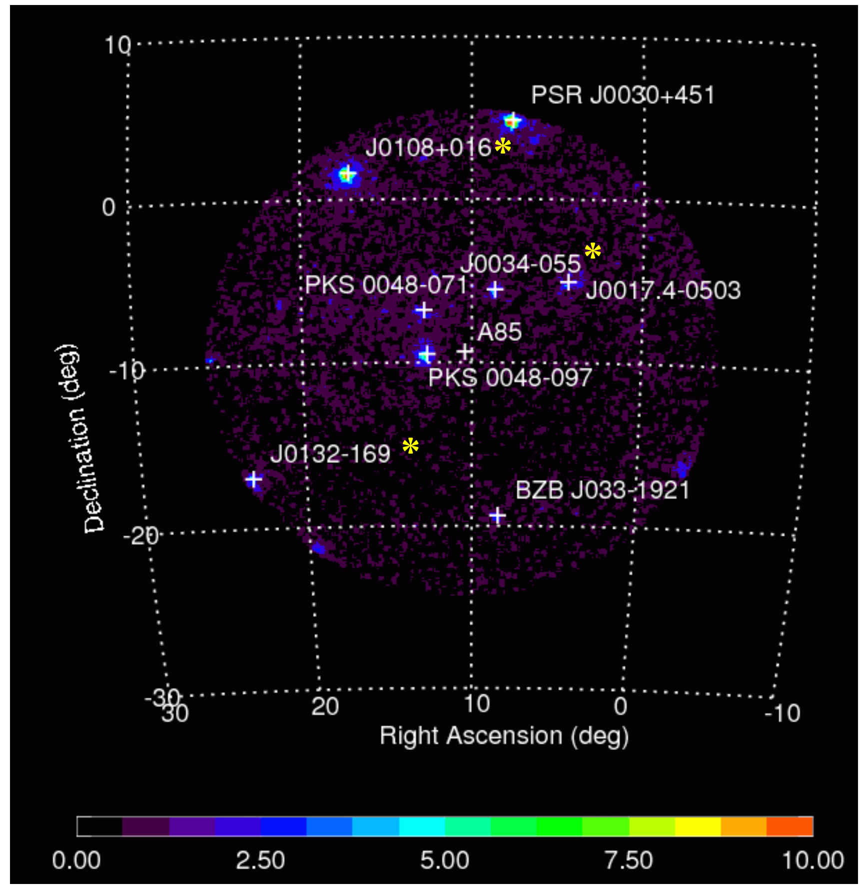


Fermi/LAT count map: Abell 496/85

Abell 496



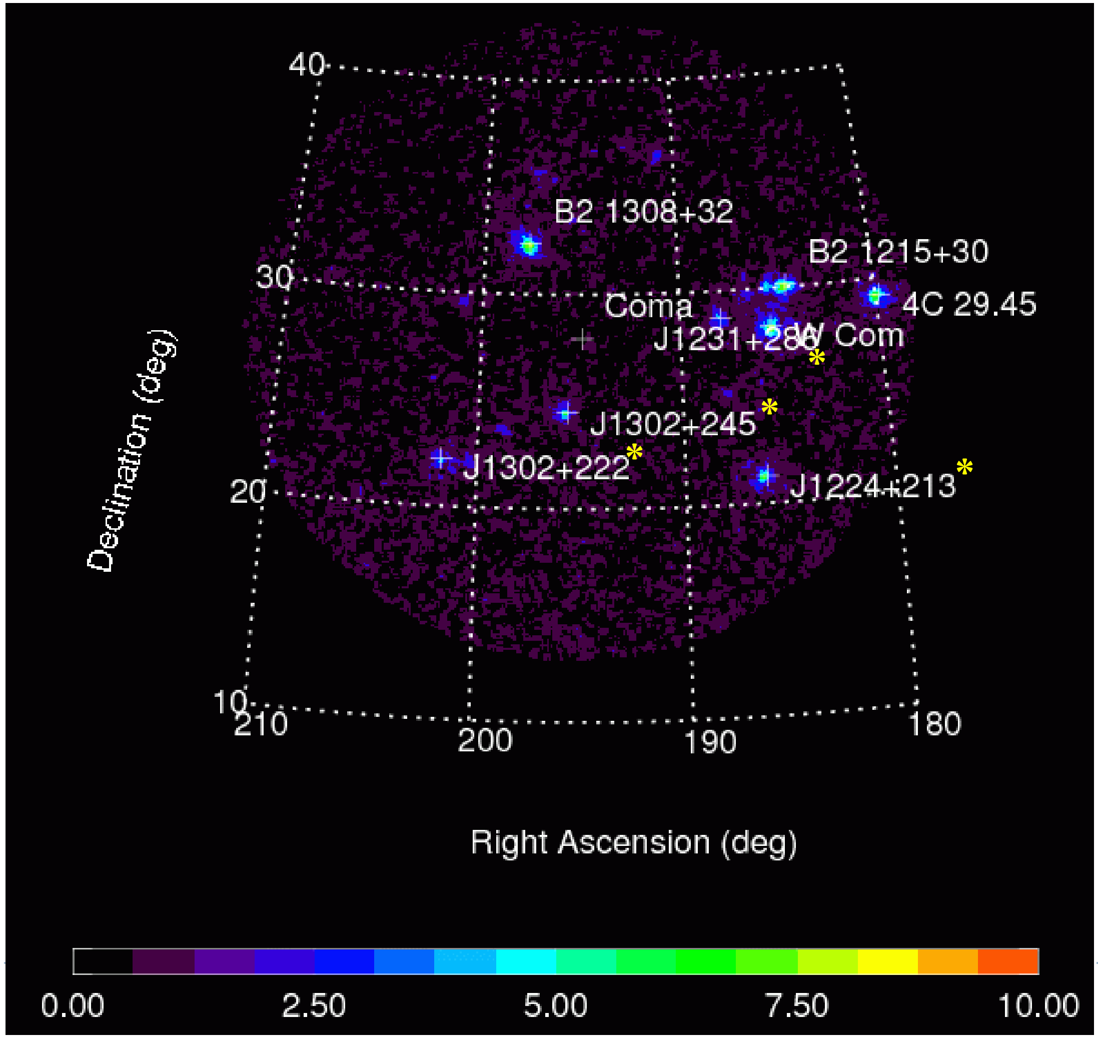
Abell 85



0.2-10 GeV, 2008Aug-2009Oct

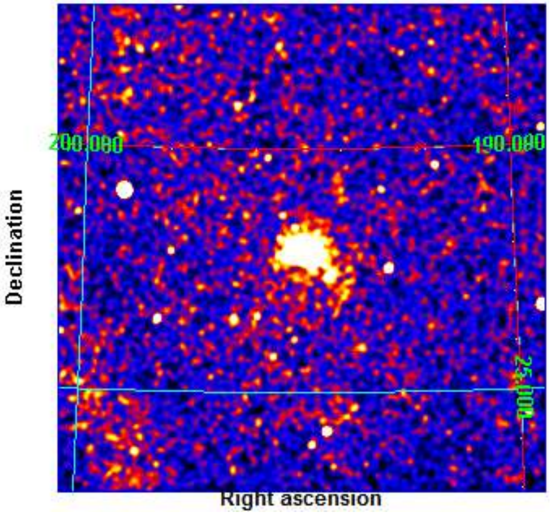
* : not 0FGL source

Fermi/LAT count map: Coma

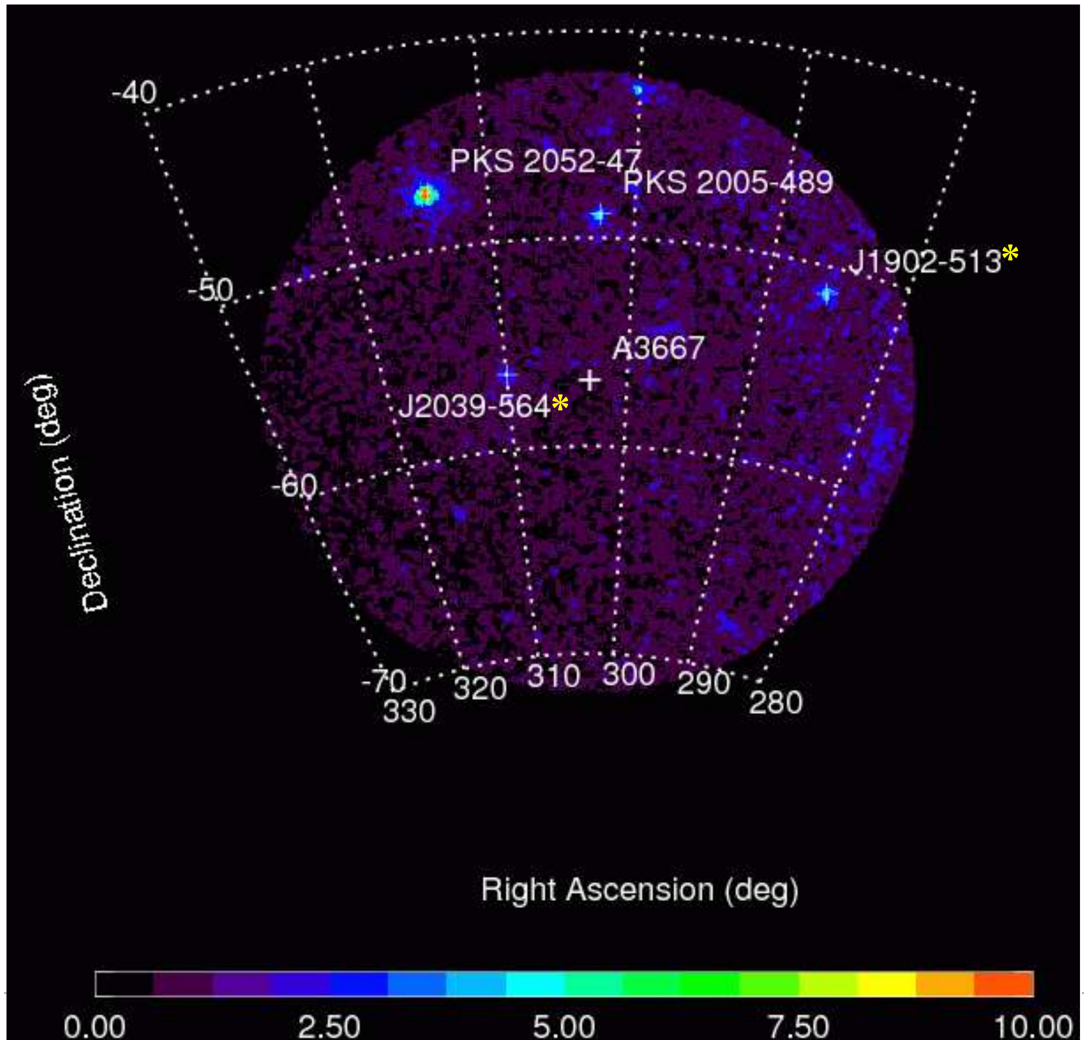


0.2-10 GeV
2008Aug-2009Sep
* : not 0FGL source

Ref: RASS (broad)

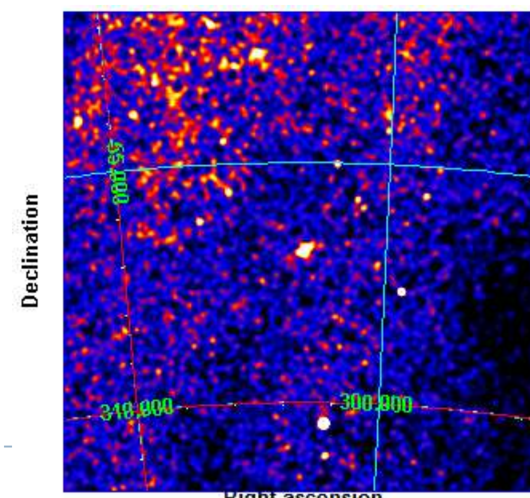


Fermi/LAT count map: Abell 3667

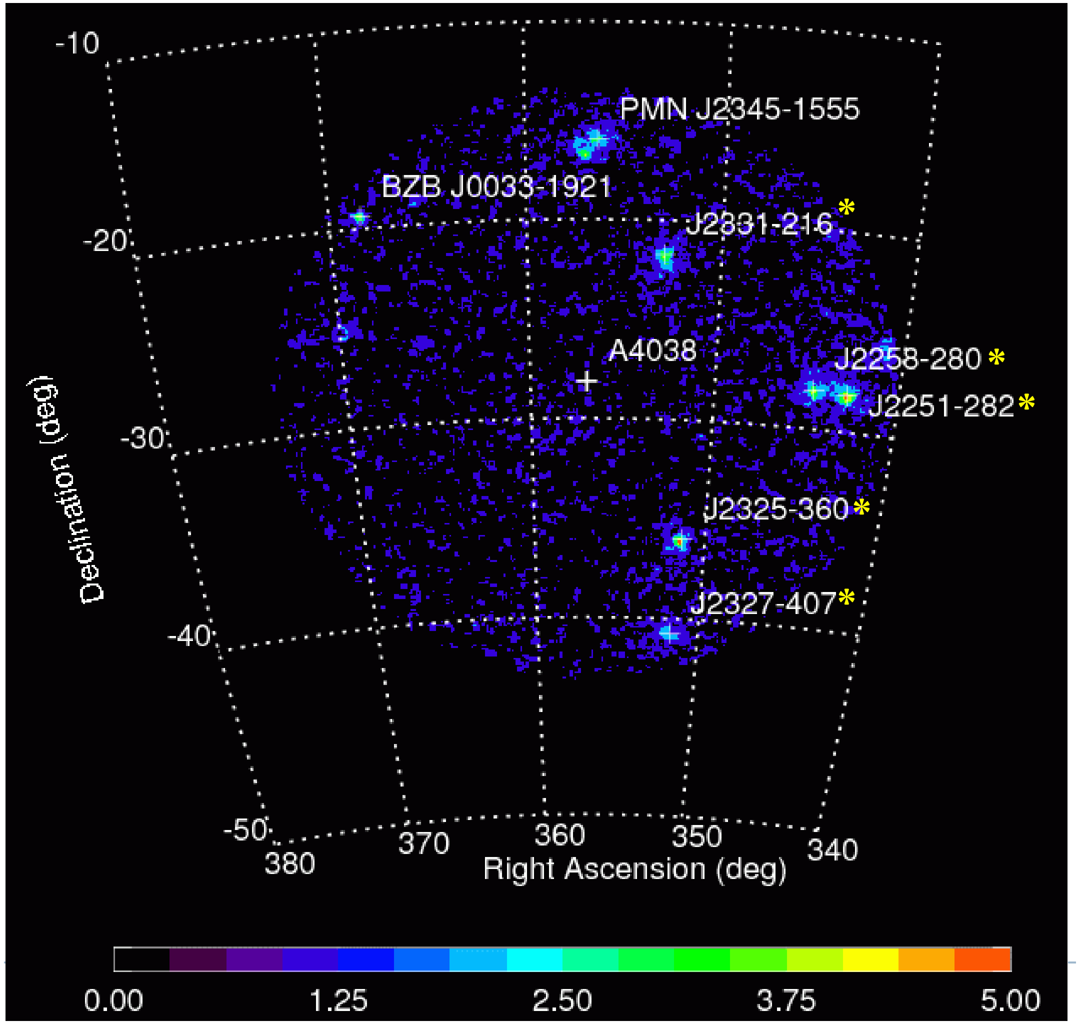


0.2-10 GeV
2008Aug-2009Sep
* : not 0FGL source

Ref: RASS (broad)



Fermi/LAT count map: Abell 4038

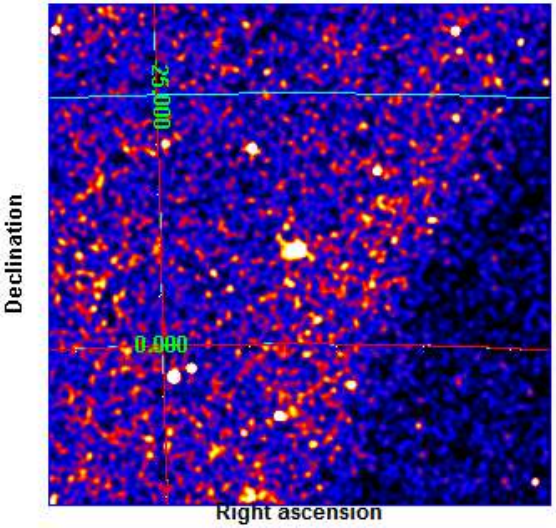


0.2-10 GeV

2008Aug-2009Sep

* : not 0FGL source

Ref: RASS (broad)



Preliminary

Upper limits

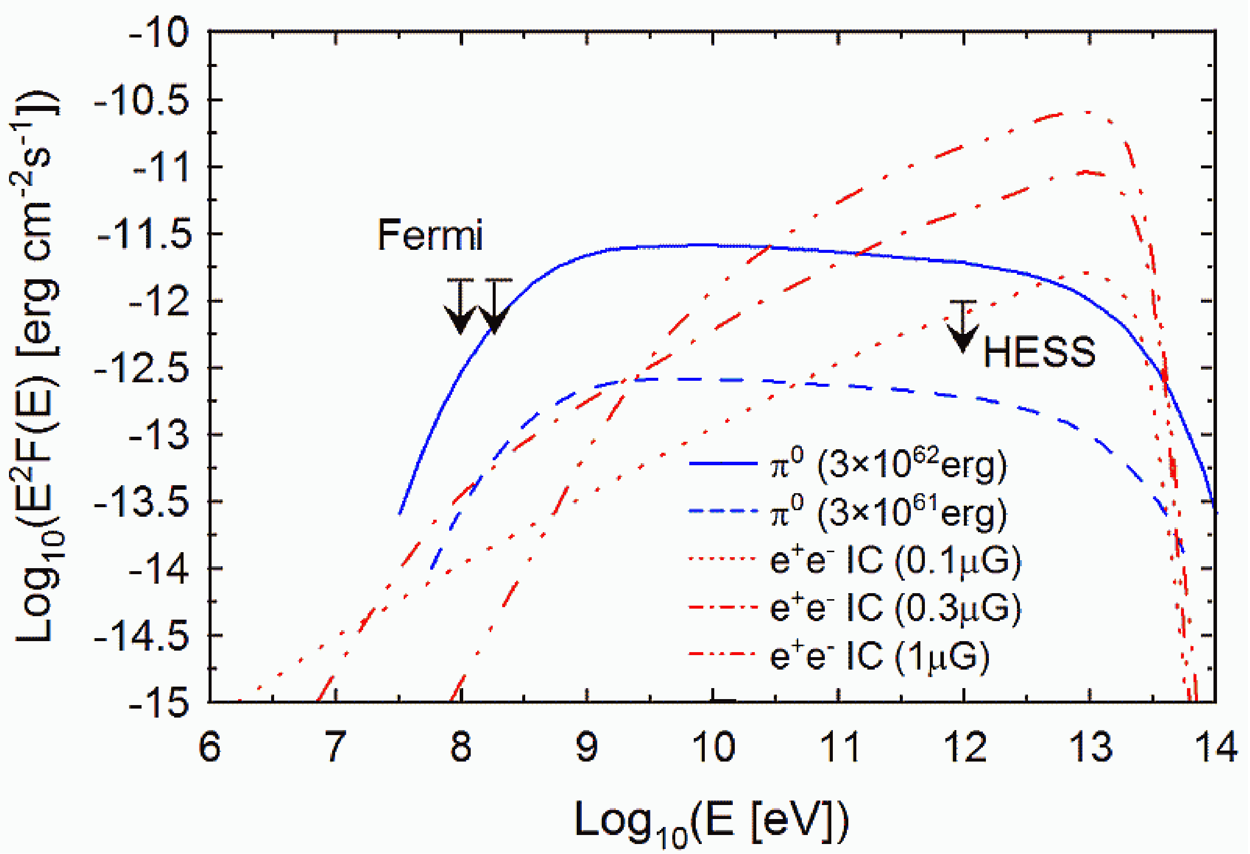
[Unit: $10^{-8} cm^{-2} s^{-1}$]

Name	>100MeV (95% C.L.)	>200MeV (95% C.L.)	Bechtol et al. (>100 MeV, TeVPA 2009)	EGRET (>100MeV, Reimer+)	Note
Perseus	—	—	20	3.72	NGC1275 (point source)
Abell 2029	4.8	1.3	—	7.49	
Abell 496	1.2	0.61	—	7.11	
Abell 85	0.12	0.062	—	6.32	
Coma	0.88	0.44	0.6	3.81	
Abell 3667	0.23	0.095	—	3.82	
Abell 4038	0.52	0.45	—	3.60	

Fermi Science Tools v.9.15.2, *gtlike* (unbinned), point-like source, "PowerLaw2" model
Upper limits were calculated by Profile method

Upper limits compared with model/TeV data (1)

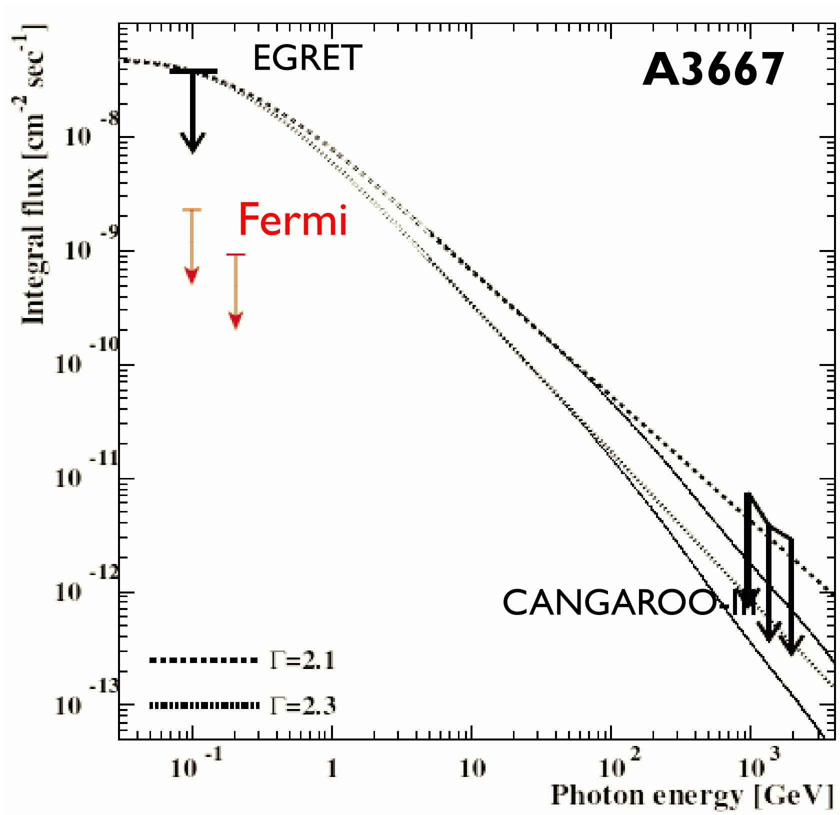
Coma (E^{-2} assumed, HESS: 0.4°)

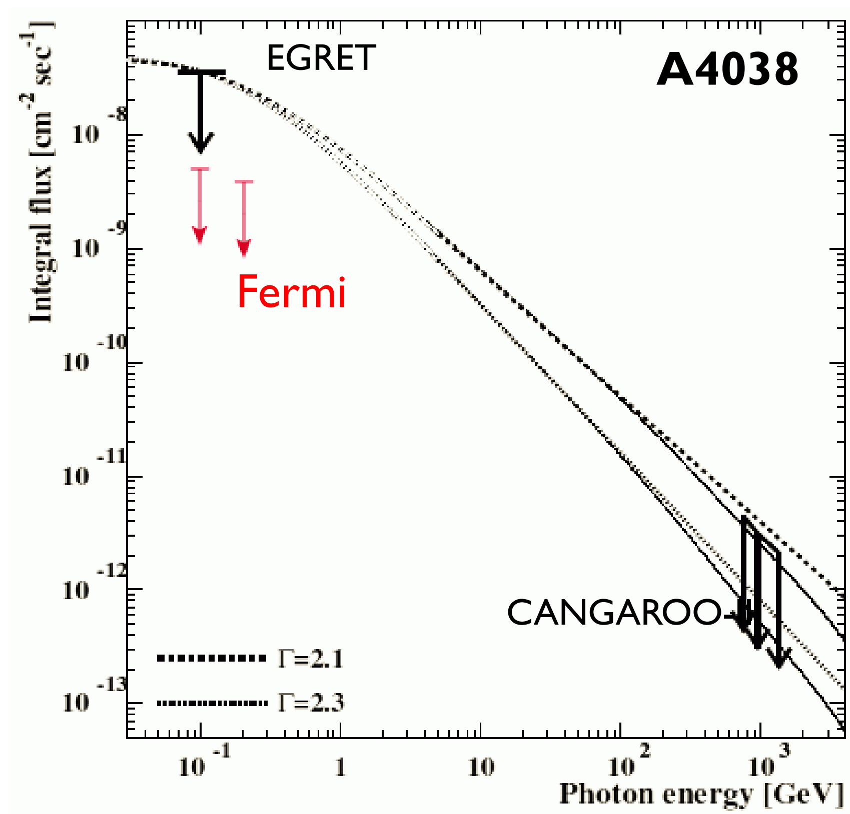


π^0 model: Völk & Atoyan, ApJ 541,88 (2000)

e^+e^- IC model: Inoue, Aharonian & Sugiyama, ApJ 628, L9 (2005)

Upper limits compared with model/TeV data (2)





Figures taken from Kiuchi et al., ApJ 704, 240 (2009)

Upper limits compared with model/TeV data (3)

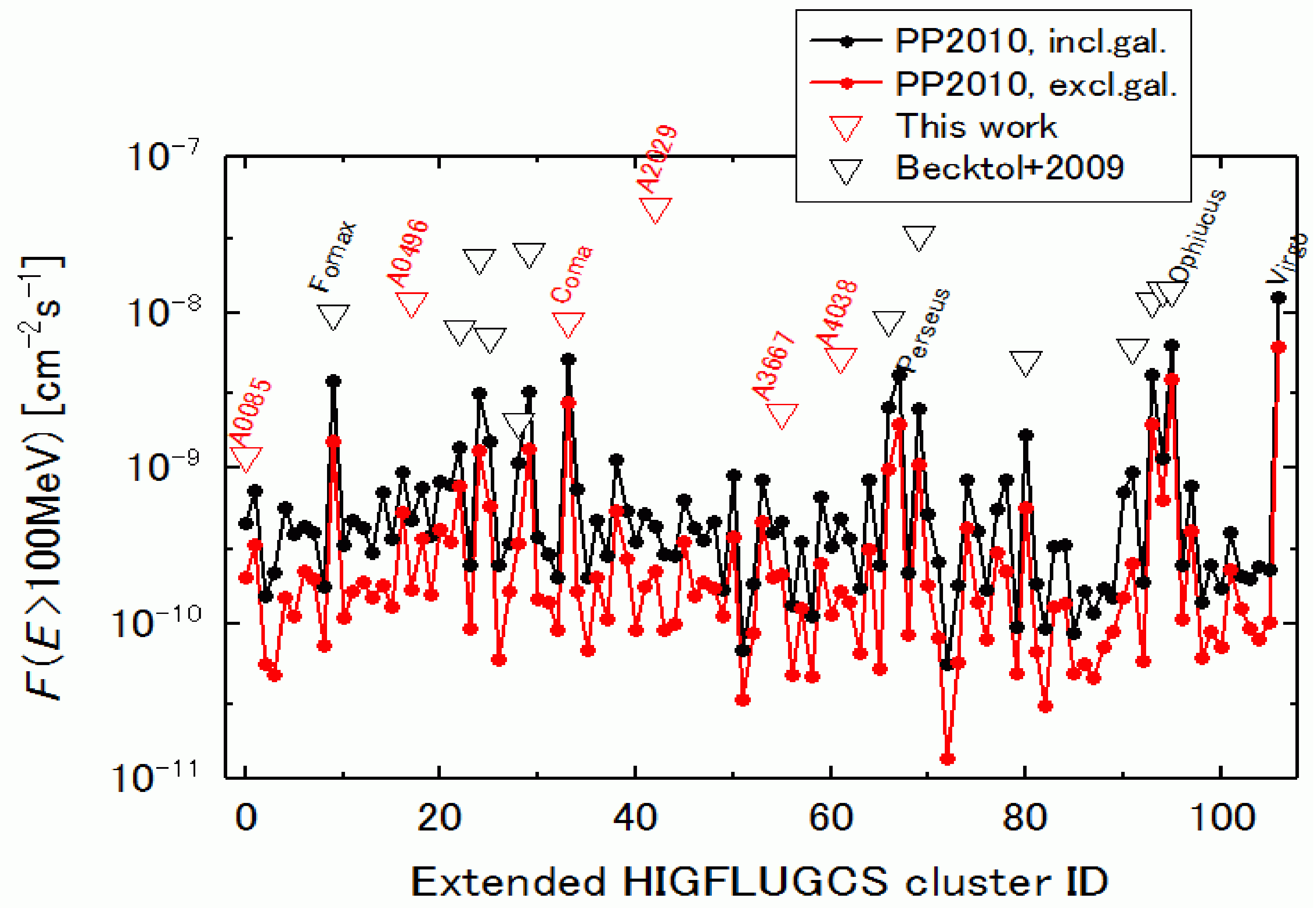
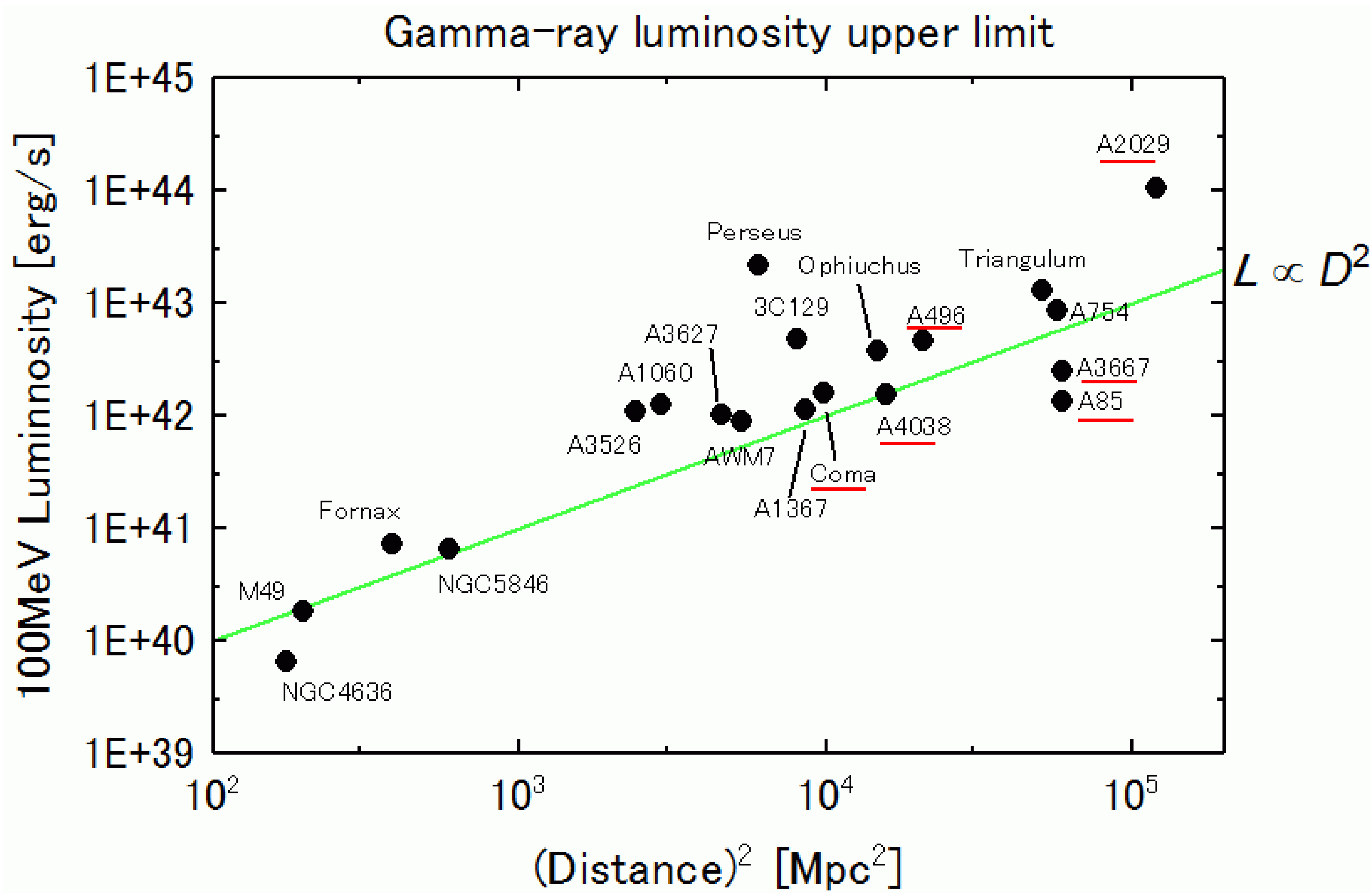
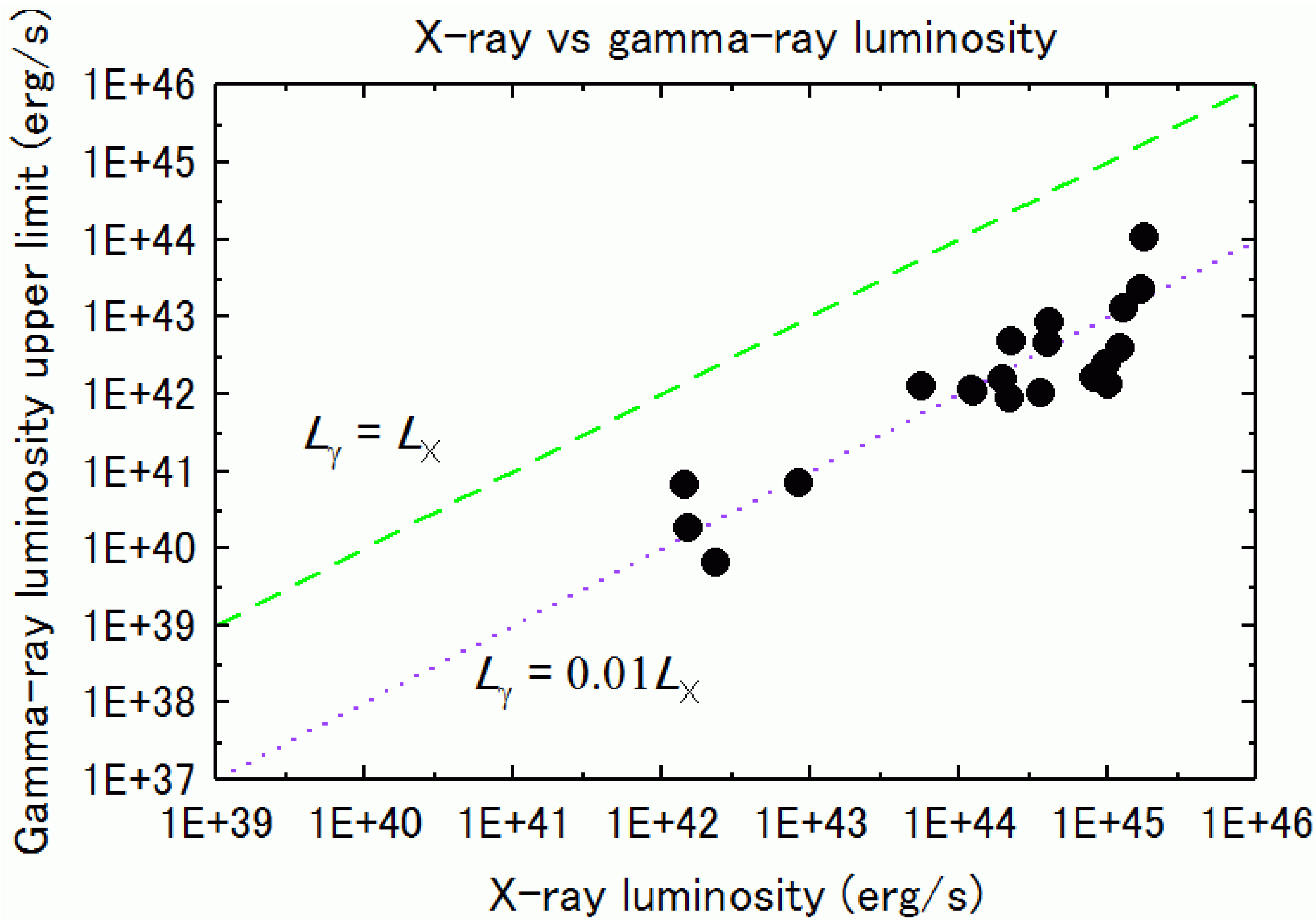


Figure taken from Pinzke & Pfrommer, arXiv: 1001.5023 (2010)

Gamma-ray luminosity upper limit

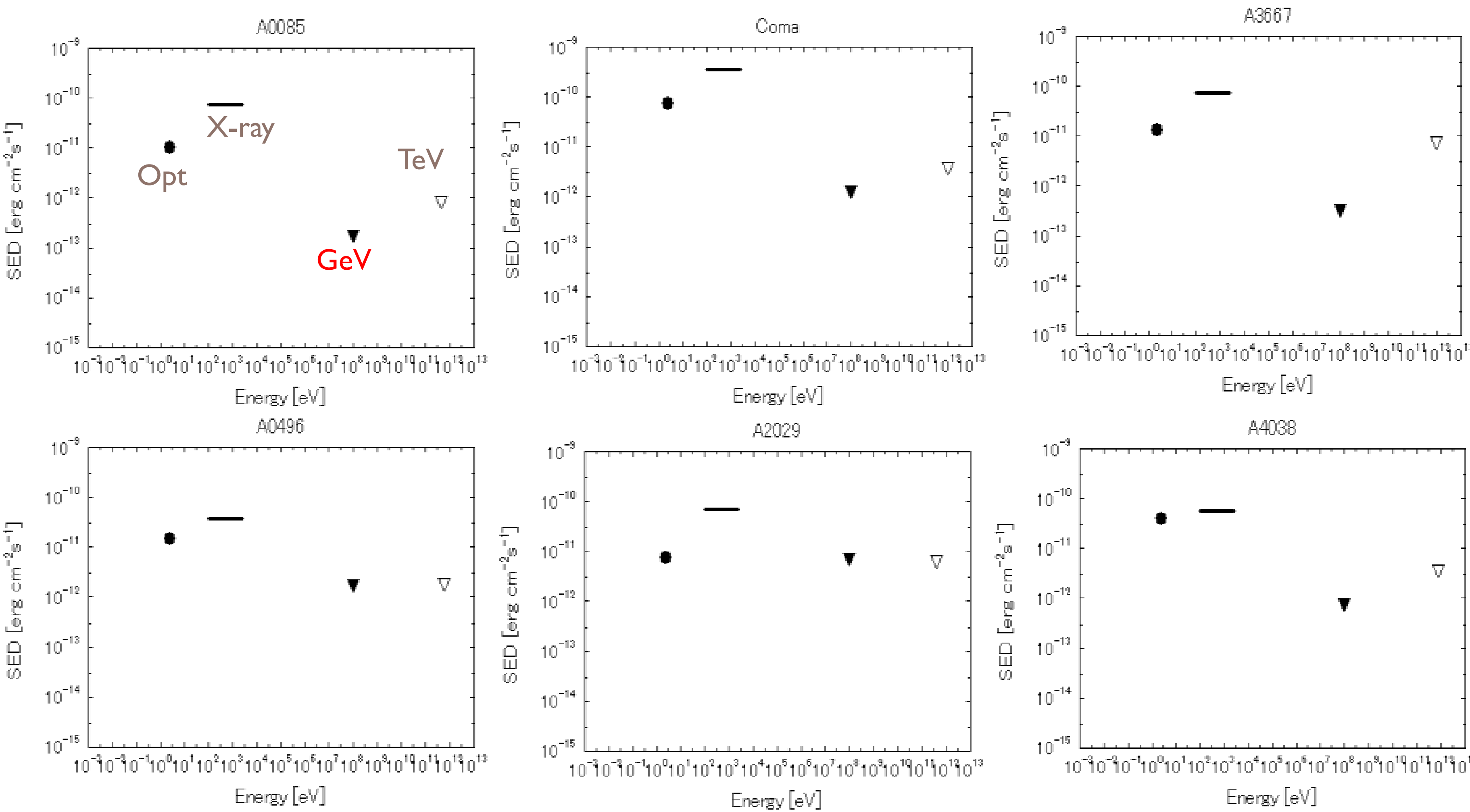


X-ray vs gamma-ray luminosity



X-ray luminosity: Reiprich & Bohringer, ApJ 567, 716 (2002) [HIFLUGSCS]

Spectral energy distribution



Opt: Abell, X-ray data: HIFLUGCS (ApJ 567, 716, 2002), GeV/TeV: upper limits

Summary

- チェレンコフ望遠鏡で観測されていた銀河団からのGeVガンマ線放射を探索した。点源(NGC1275) を含むPerseus cluster [as reported in Abdo et al. ApJ 699, 31, 2009]以外からはガンマ線信号が見つからなかった。.
- EGRETの結果より一桁厳しい上限値が6つの銀河団に対し得られた。 [95% C.L., >100MeV, preliminary]
  - Perseus —
  - A2029 0.78 $\times 10^{-8} cm^{-2} s^{-1}$
  - A496 0.43
  - A85 0.020
  - Coma 0.24
  - A3667 0.13
  - A4038 0.035
- 銀河団の高エネルギーガンマ線放射はX線放射量より少なく、上限値からは放射モデルに対する制限が得られた。