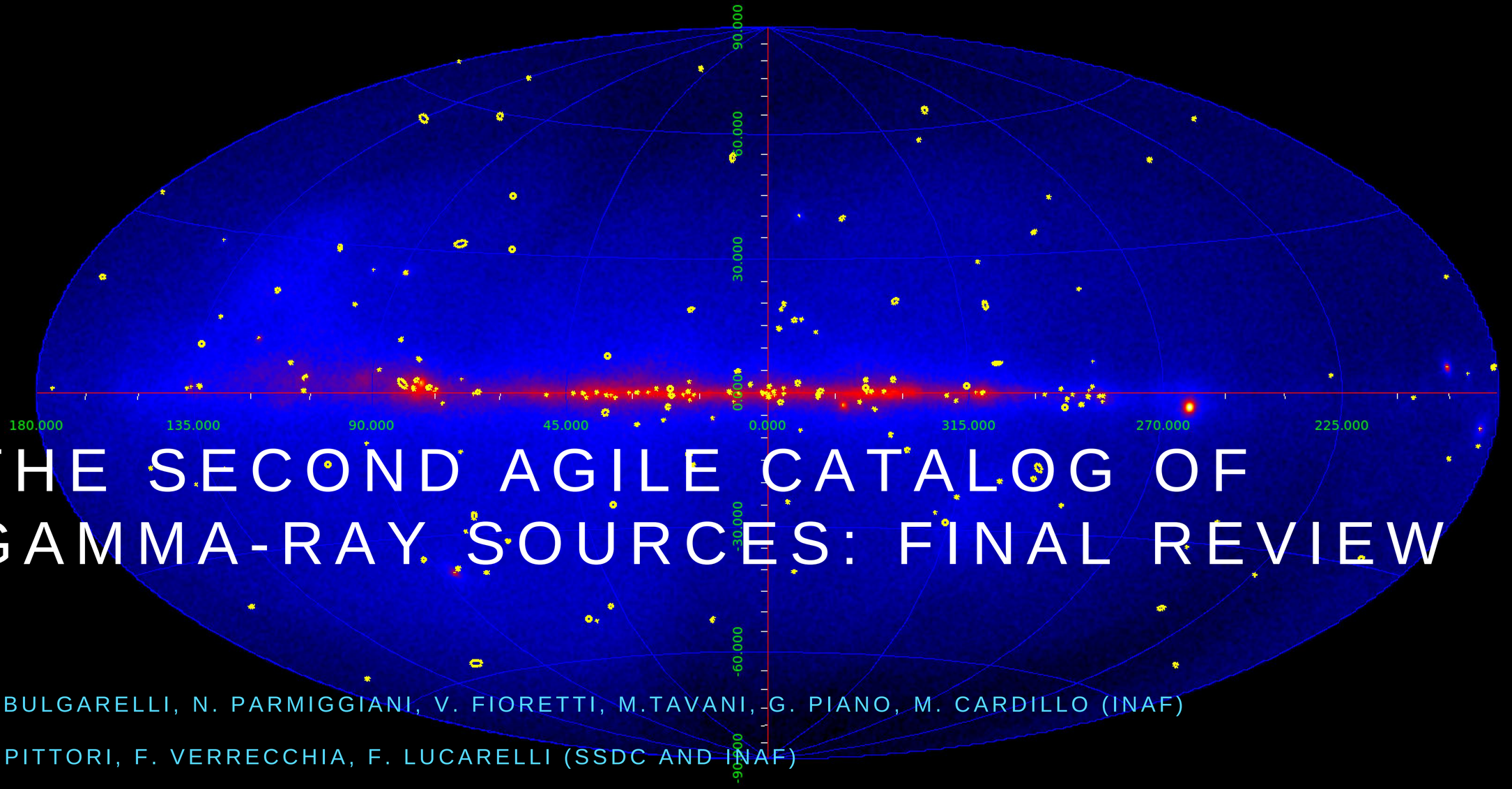

THE SECOND AGILE CATALOG OF GAMMA-RAY SOURCES: FINAL REVIEW

A. BULGARELLI, N. PARMIGGIANI, V. FIORETTI, M.TAVANI, G. PIANO, M. CARDILLO (INAF)

C. PITTORI, F. VERRECCHIA, F. LUCARELLI (SSDC AND INAF)

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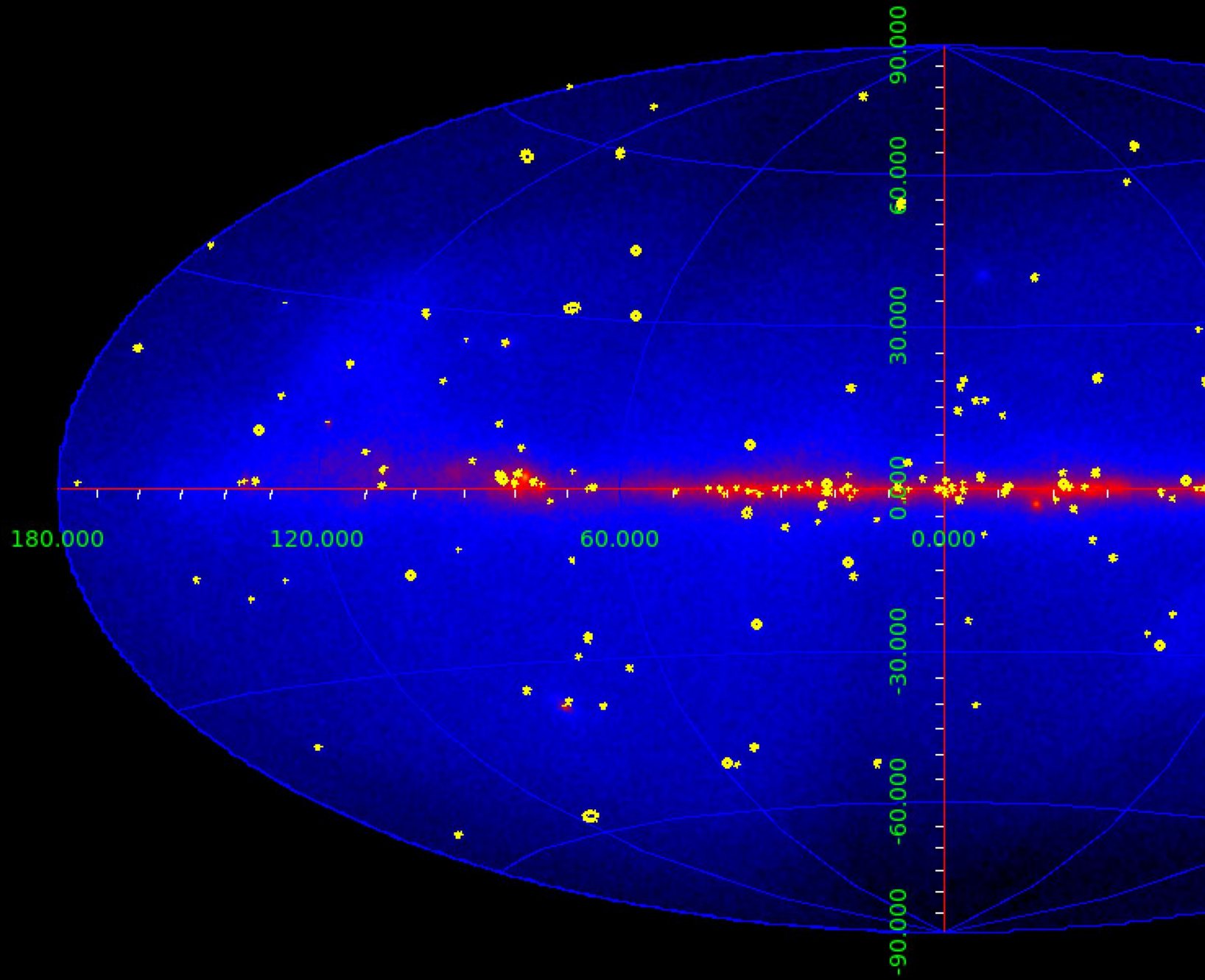
A. ABOUDAN (CISAS)

OUTLINE

- Updates
- Method
- Results
- Products
- Some regions:
  - Galactic Center region
  - Carina region
  - Cygnus region



- The 2th AGILE Catalog of gamma-ray sources: final review
- AGILE/GRID observations covering the time period July 4, 2007, to October 15, 2009 (the AGILE POINTING MODE).
- The analysis is based on data in the
  - 100 MeV to 50 GeV energy range
  - A check in the "*low*" energy range 30 MeV - 100 MeV has been performed for the most significant sources
- Source detection is based on the integrated data set, i.e., sources are detected according to their average fluxes over about 27 months.

Region Name	OB Number	Starting RA, Dec J2000 (deg)	Starting LII, BII (deg)	Start Observation (UTC)	End Observation(UTC)
SA Crab (8,24)	OB5510	108.283 , 28.625	188.9607 , 16.9953	2008-04-05 12:00	2008-04-07 12:00
SA Crab (15,26)	OB5520	111.762 , 35.688	183.0072 , 22.2023	2008-04-07 12:00	2008-04-08 12:00
Anti-Center 2	OB5530	110.404 , 20.758	197.2962 , 15.7167	2008-04-08 12:00	2008-04-10 12:00
Vulpecula Field	OB5600	286.259 , 20.819	53.0394 , 6.4733	2008-04-10 12:00	2008-04-30 12:00
North Gal Pole	OB5700	250.075 , 72.497	104.8522 , 35.4379	2008-04-30 12:00	2008-05-10 12:00
Cygnus Field 2	OB5800	304.286 , 35.974	74.0497 , 0.2720	2008-05-10 12:00	2008-06-09 18:00
ToO WComae ON+231	OB5810	182.285 , 29.614	195.5016 , 80.3738	2008-06-09 18:00	2008-06-15 12:00
Cygnus Repointing	OB5820	323.248 , 50.079	93.6645 , -1.1664	2008-06-15 12:00	2008-06-30 12:00
Antlia Field	OB5900	161.83 , -47.73	282.31 , 10.11	2008-06-30 12:00	2008-07-25 18:00
TOO 3C 454.3	OB5910	19.37 , 38.09	128.56 , -24.49	2008-07-25 18:00	2008-07-31 12:00
Estensione TOO	OB5920	25.09 , 40.12	330.46 , 28.98	2008-07-31 12:00	2008-08-15 12:00
3C454.3	-	-	-	-	-
Musca Field 2	OB6010	175.31 , -74.13	298.10 , -11.92	2008-08-15 12:00	2008-08-31 12:00
ToO SGR 0501+4516	OB6110	61.87 , 44.06	333.90 , 27.26	2008-08-31 12:00	2008-09-10 12:00
Gal. Center 3	OB6200	256.55 , -28.53	355.51 , 7.40	2008-09-10 12:00	2008-10-10 12:00
ToO PKS 0537-441	OB6210	98.80 , -46.77	255.44 , -22.05	2008-10-10 12:00	2008-10-17 12:00
Aquila Field	OB6310	290.97 , 10.10	45.62 , -2.51	2008-10-17 12:00	2008-10-31 12:00
Cygnus Field 3	OB6400	295.52 , 35.64	70.03 , 6.15	2008-10-31 12:00	2008-11-30 12:00
Cygnus Field 4	OB6500	320.40 , 35.50	81.95 , -10.17	2008-11-30 12:00	2008-12-20 12:00
Cygnus Field 5	OB6600	334.10 , 44.05	95.70 , -10.47	2008-12-20 12:00	2009-01-12 18:00
ToO Carina Field	OB6610	161.67 , -59.86	287.86 , -0.69	2009-01-12 18:00	2009-01-19 18:00
Cygnus Field 6	OB6710	325.75 , 68.11	106.75 , 11.37	2009-01-19 18:00	2009-02-28 12:00
Gal.Center 4	OB6800	247.20 , -29.03	349.85 , 13.43	2009-02-28 12:00	2009-03-25 12:00
Gal.Center Prolonged	OB6810	275.73 , -30.50	2.59 , -7.83	2009-03-25 12:00	2009-03-31 12:00
Crab Field	OB6910	102.70 , 31.71	184.07 , 13.75	2009-03-31 12:00	2009-04-07 12:00
Aquila Field 1	OB7010	288.88 , -19.31	18.06 , -13.82	2009-04-07 12:00	2009-04-15 12:00
Aquila Field 2	OB7100	290.88 , 16.16	50.92 , 0.44	2009-04-15 12:00	2009-04-30 12:00

UPDATES

- A long path… Updates from last Workshop:
  - The catalog adopts now different spectral shapes
    - Simple Power Law
    - Power Law with exponential cutoff
    - Power Law with super exponential cutoff
    - Log Parabola
  - The NEW BUILD25 (AGILE/GRID Science Tools) has been used, that include also the energy dispersion correction factor (EDP)
  - New Instrument Response Functions: H0025 -> energy range 100-300, 300-1000, 1000-3000, 3000-10000, 10000-50000 MeV

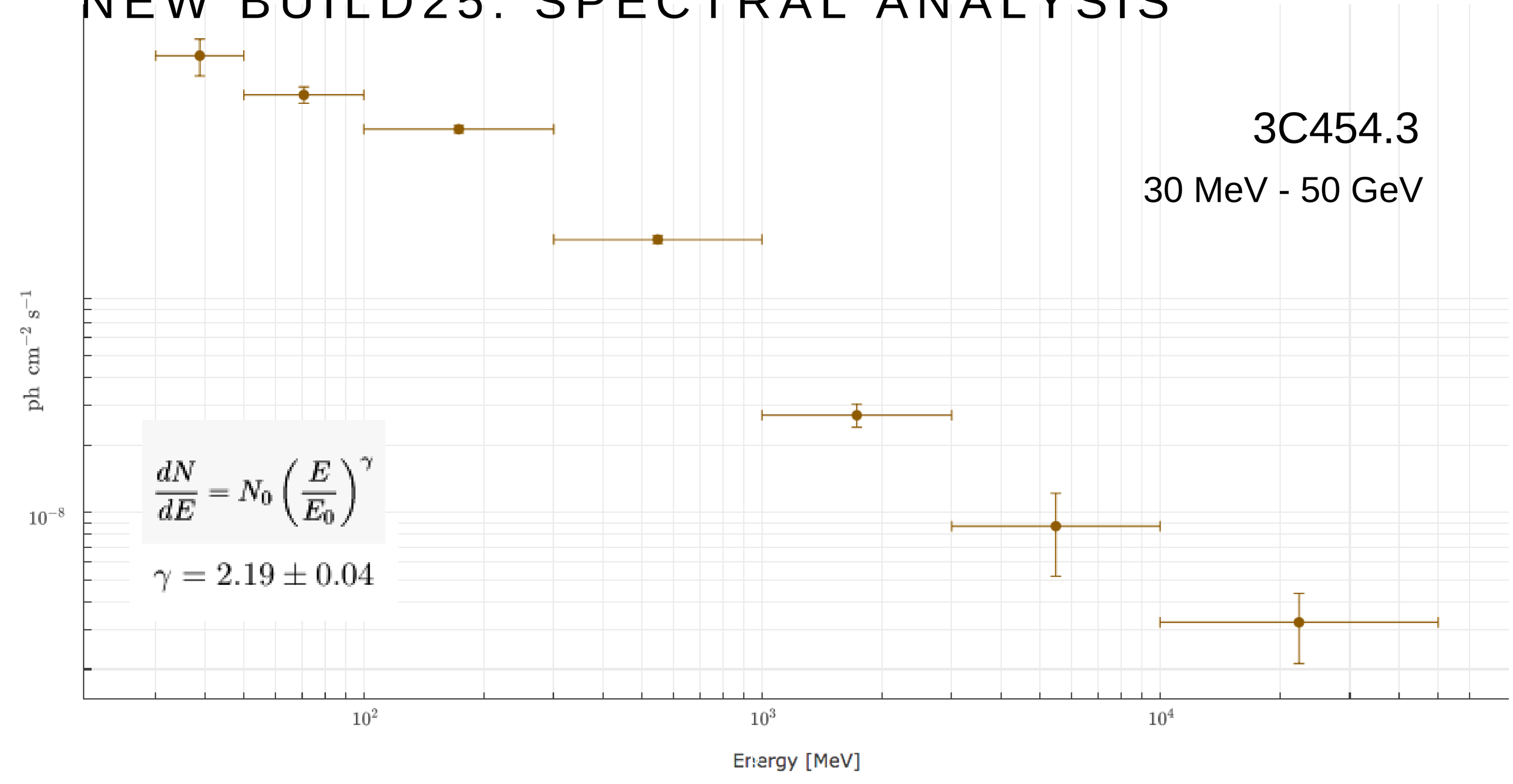
$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{\gamma}$$

$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{\gamma_1} \exp\left(-\left(\frac{E}{E_c}\right)\right)$$

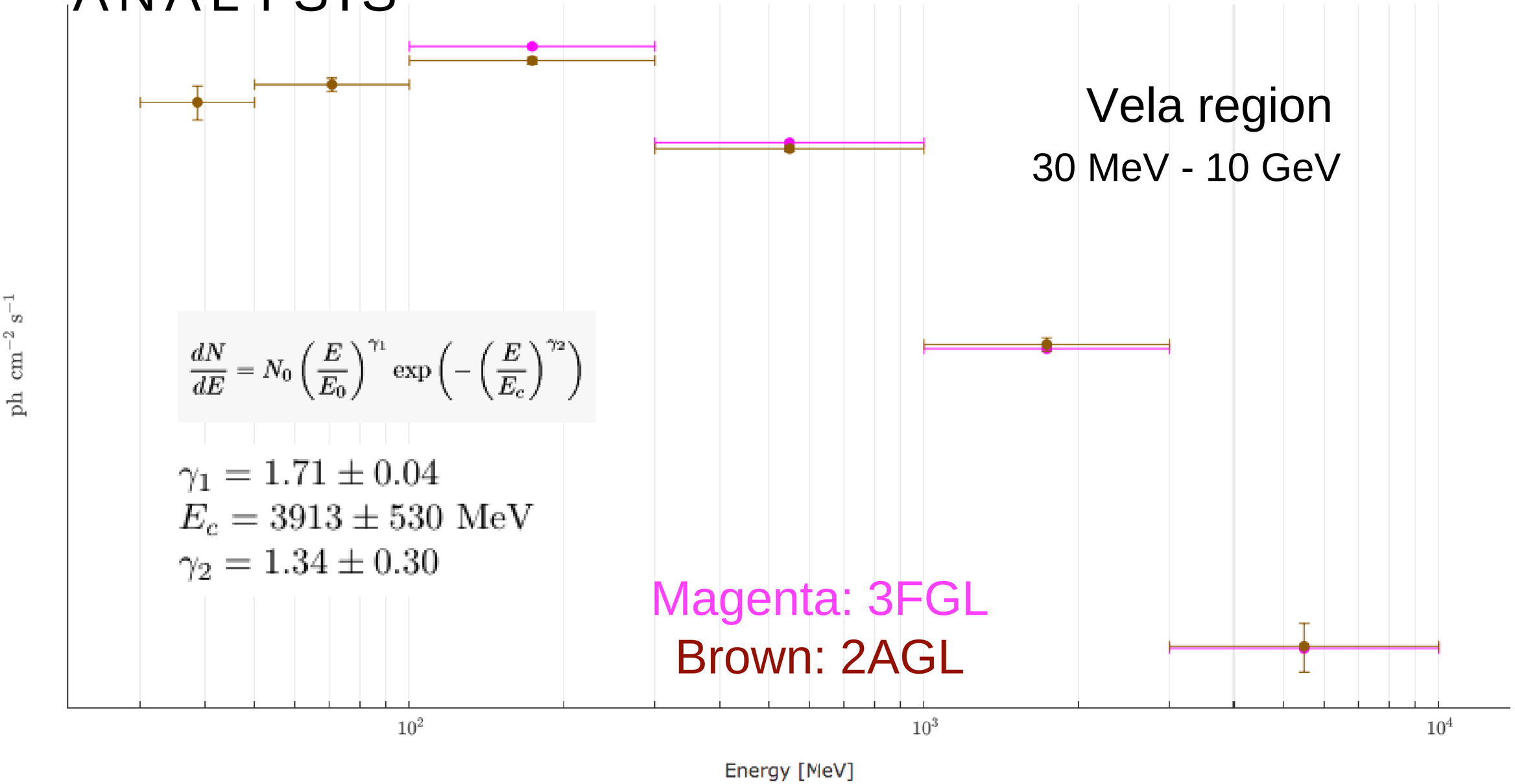
$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{\gamma_1} \exp\left(-\left(\frac{E}{E_c}\right)^{\gamma_2}\right)$$

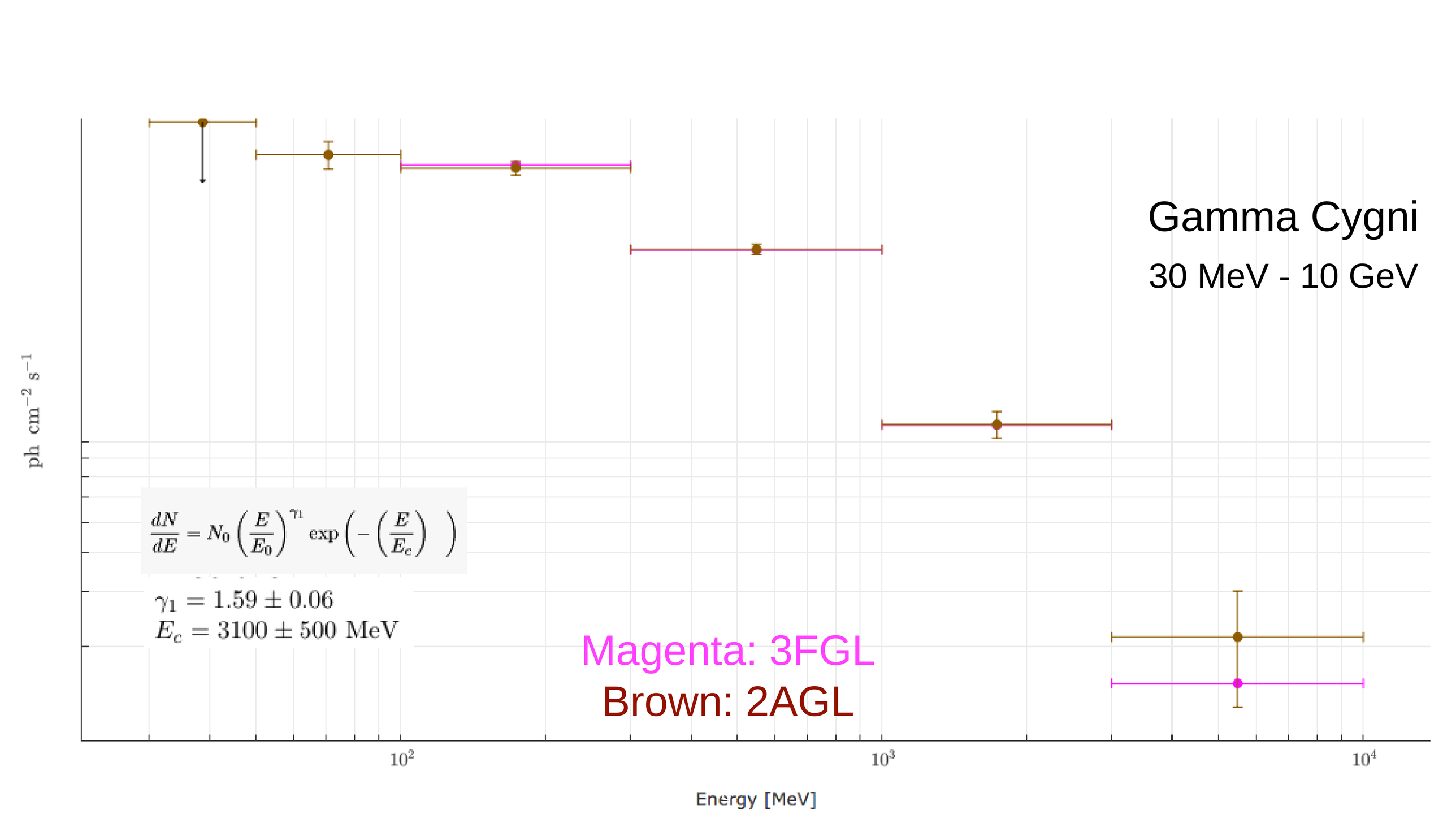
$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_b}\right)^{-(\alpha+\beta\log(E/E_b))}$$

NEW BUILD25: SPECTRAL ANALYSIS



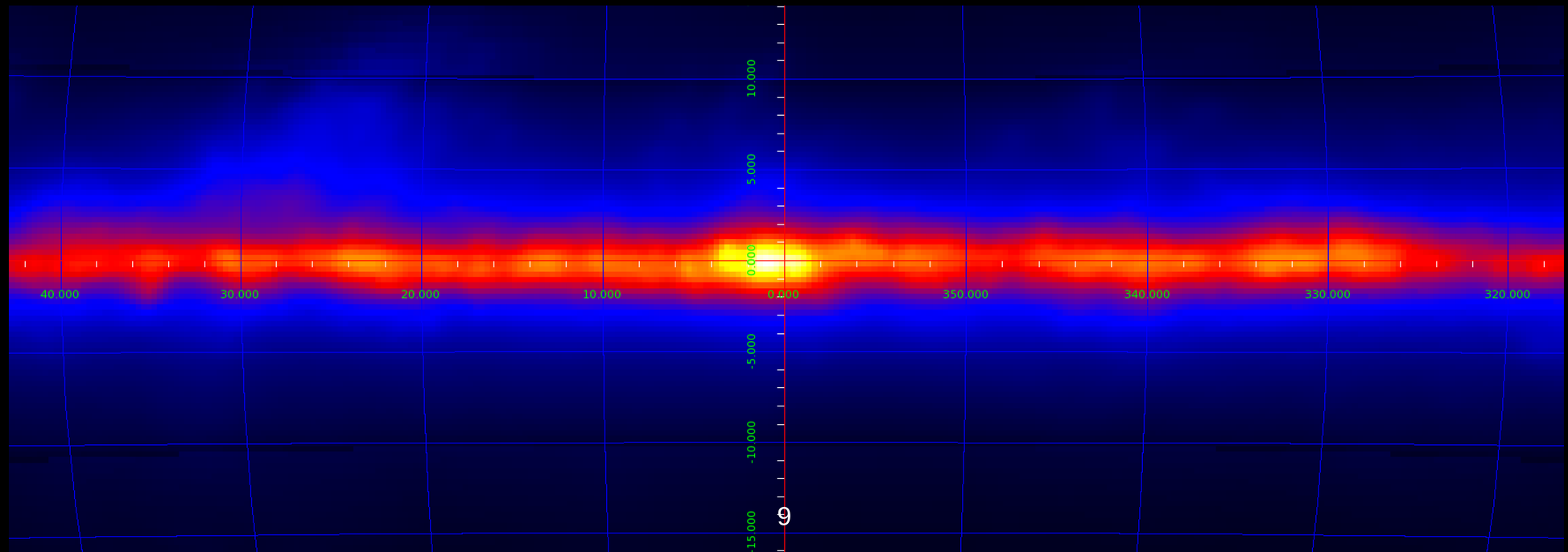
NEW BUILD25: CURVED SPECTRAL ANALYSIS



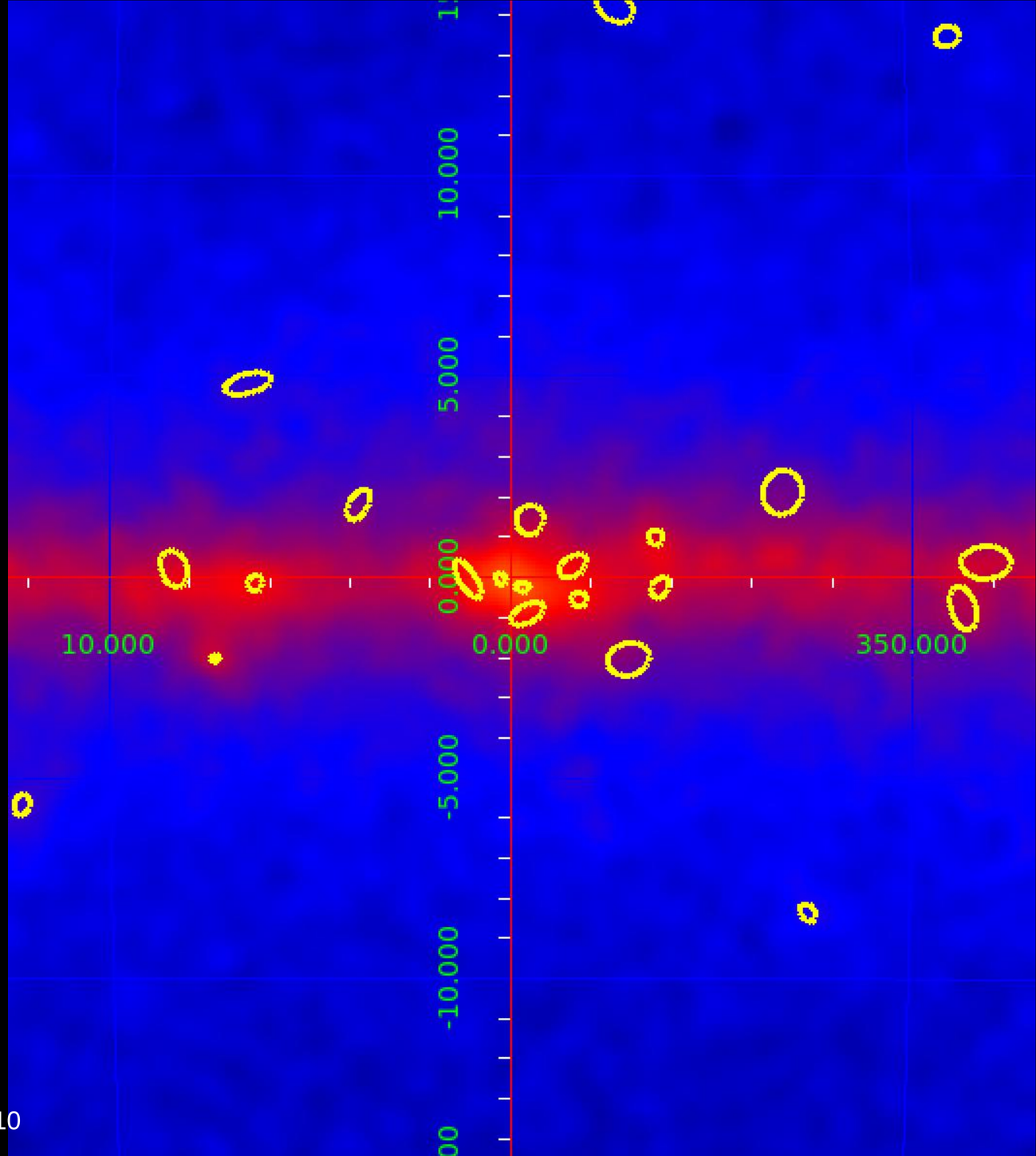

Gamma Cygni
30 MeV - 10 GeV
$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{\gamma_1} \exp\left(-\left(\frac{E}{E_c}\right)\right)$
$\gamma_1 = 1.59 \pm 0.06$
$E_c = 3100 \pm 500$ MeV
Magenta: 3FGL
Brown: 2AGL
ph cm^{-2} s^{-1}
10^2
10^3
10^4
Energy [MeV]

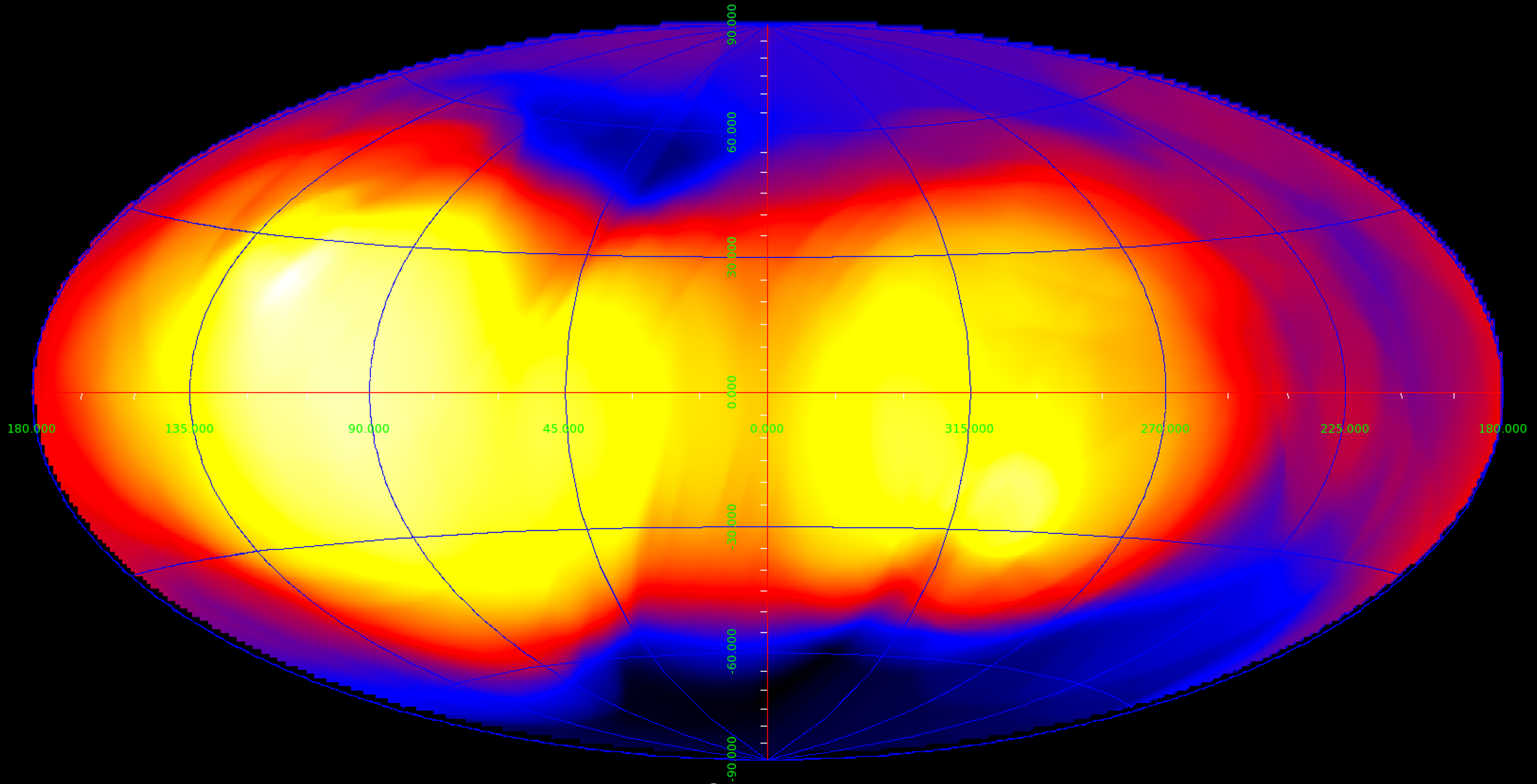
- Cross check with previous BUILD22@SSDC: only confirmed detections are included in the catalog

- The gamma-ray diffuse model used in the analysis has been improved. The diffuse model is particularly important for sources from low to mid Galactic latitudes.



METHOD



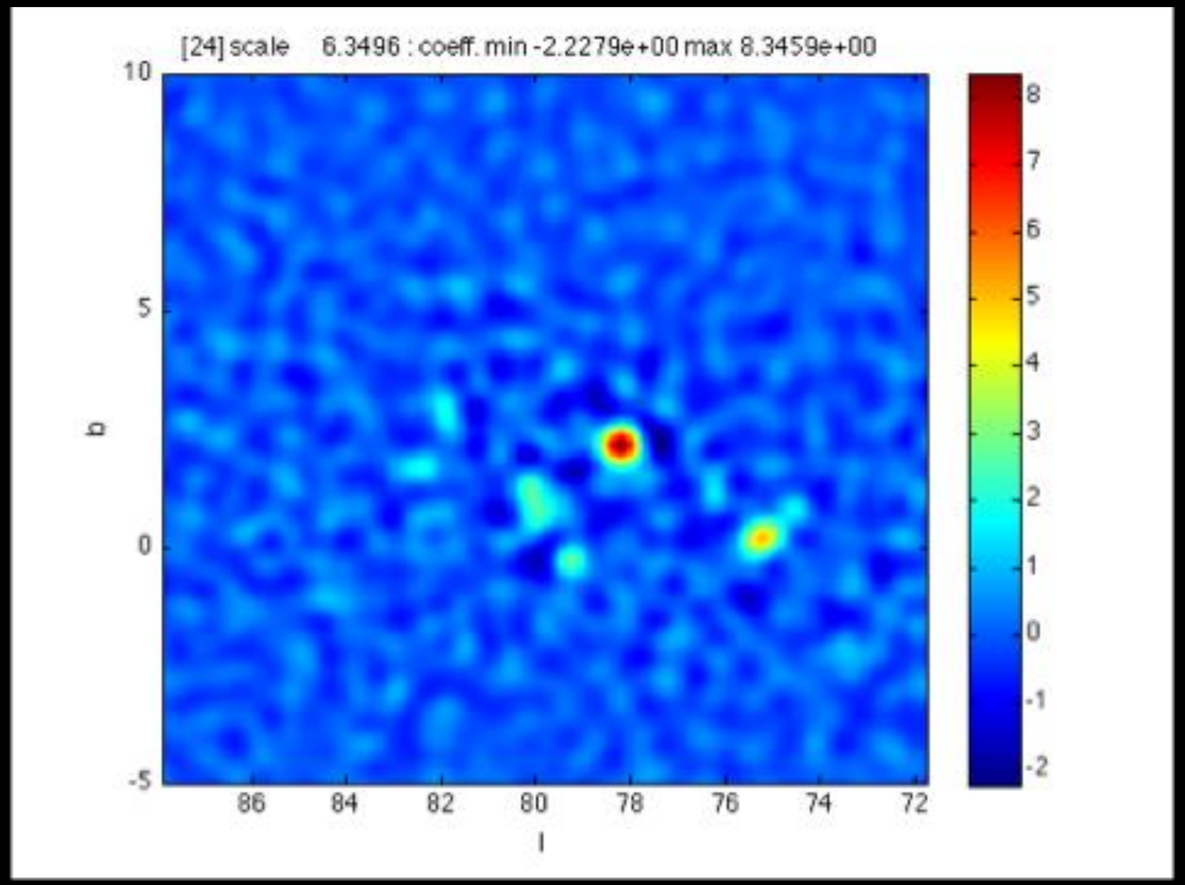


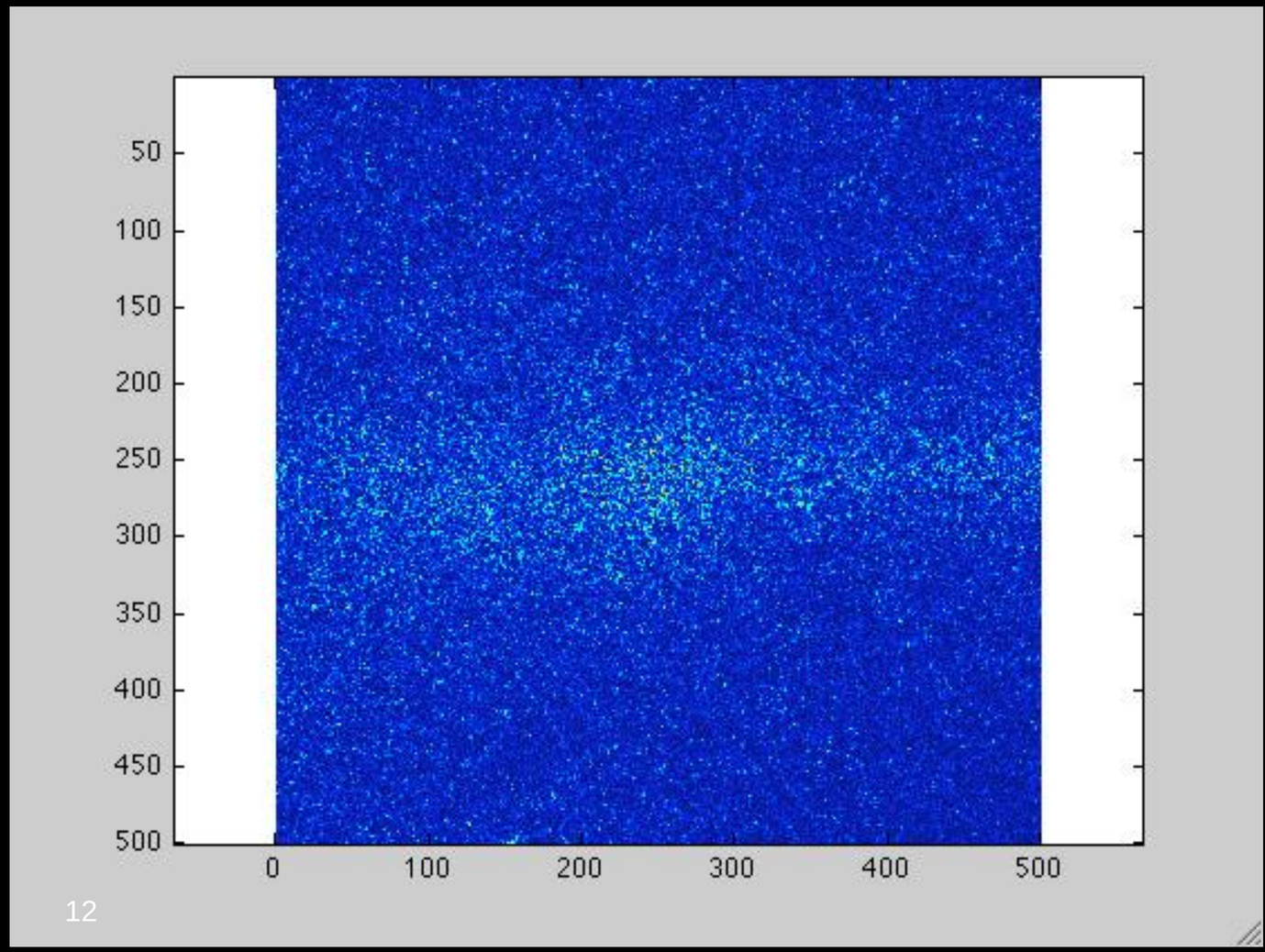
Exposure map (cm^2 / s sr) in pointing mode

The exposure is not uniform

First step: the seeds

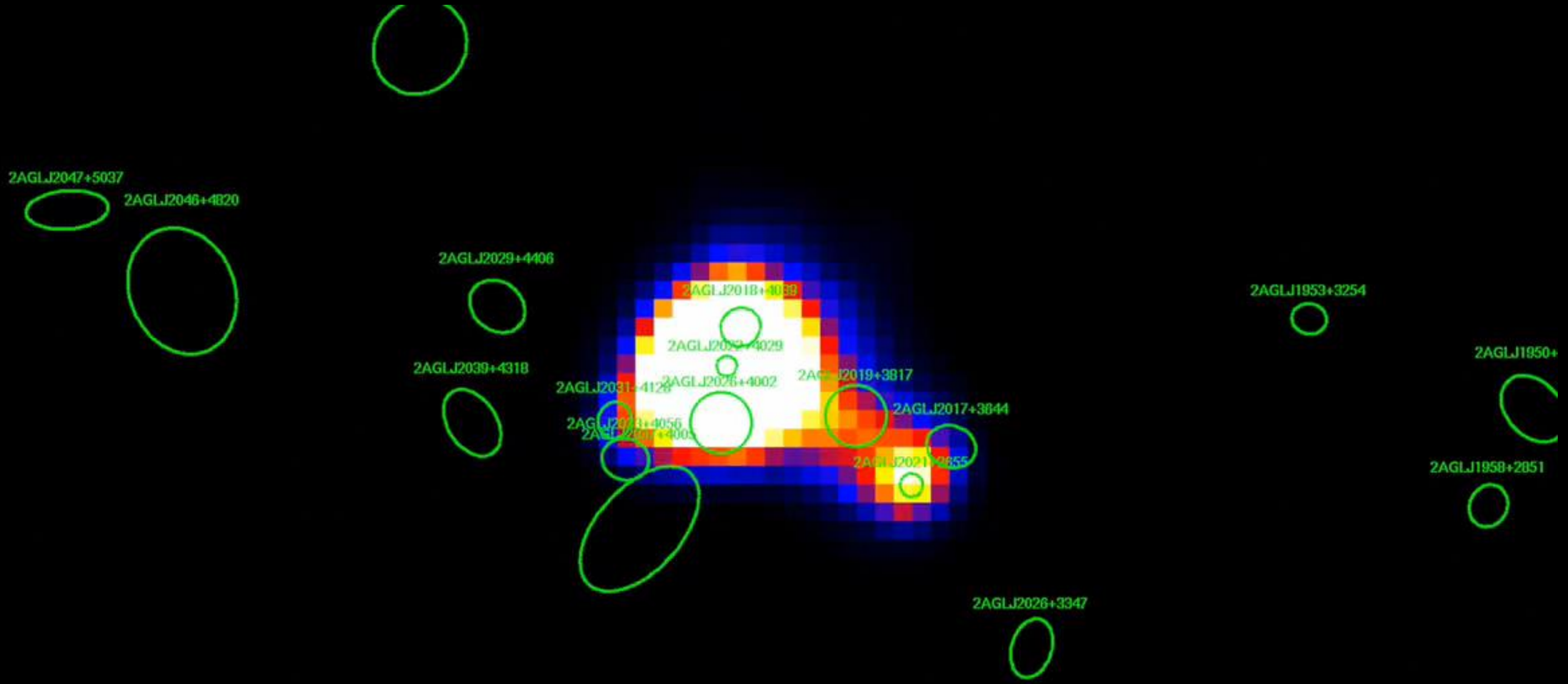
WAVELET ALGORITHM (THE SEED METHOD N° 1)





First step: the seeds

SIGNIFICANCE MAP (THE SEED METHOD N° 2)



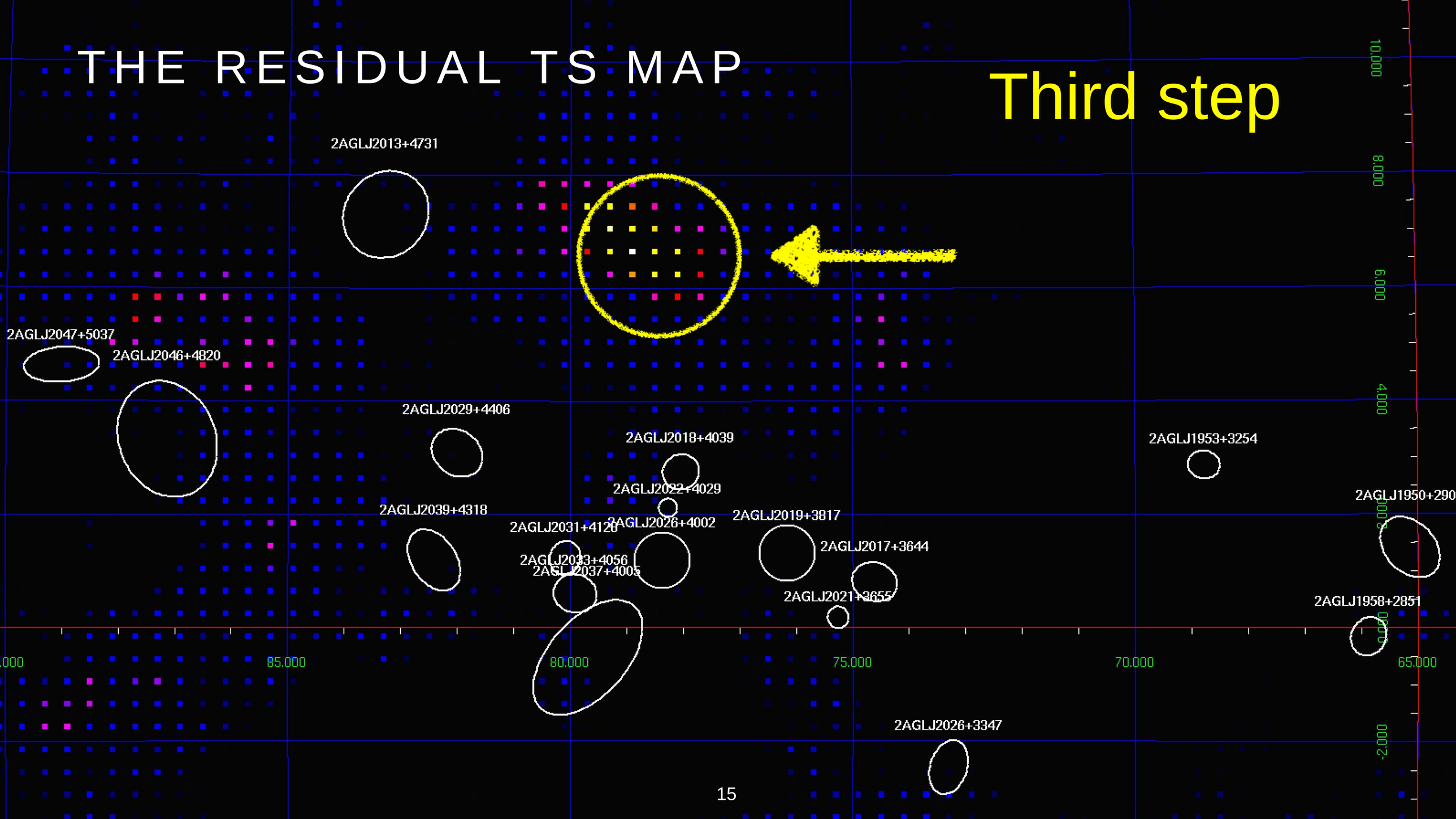
Second step

MANUAL ANALYSIS

- From the list of seeds using both methods…
  - Manual analysis
  - Final determination of position and flux

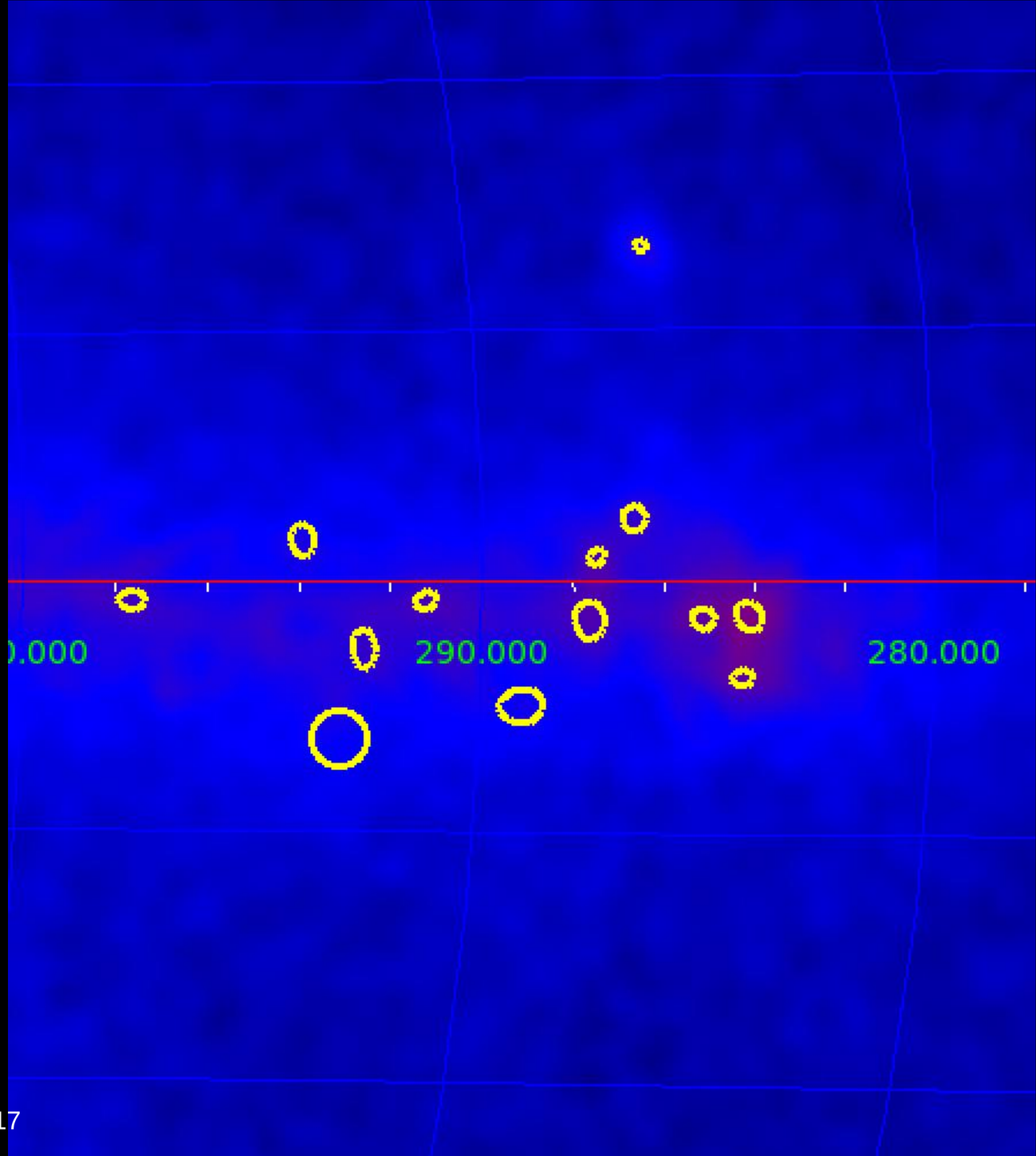
THE RESIDUAL TS MAP

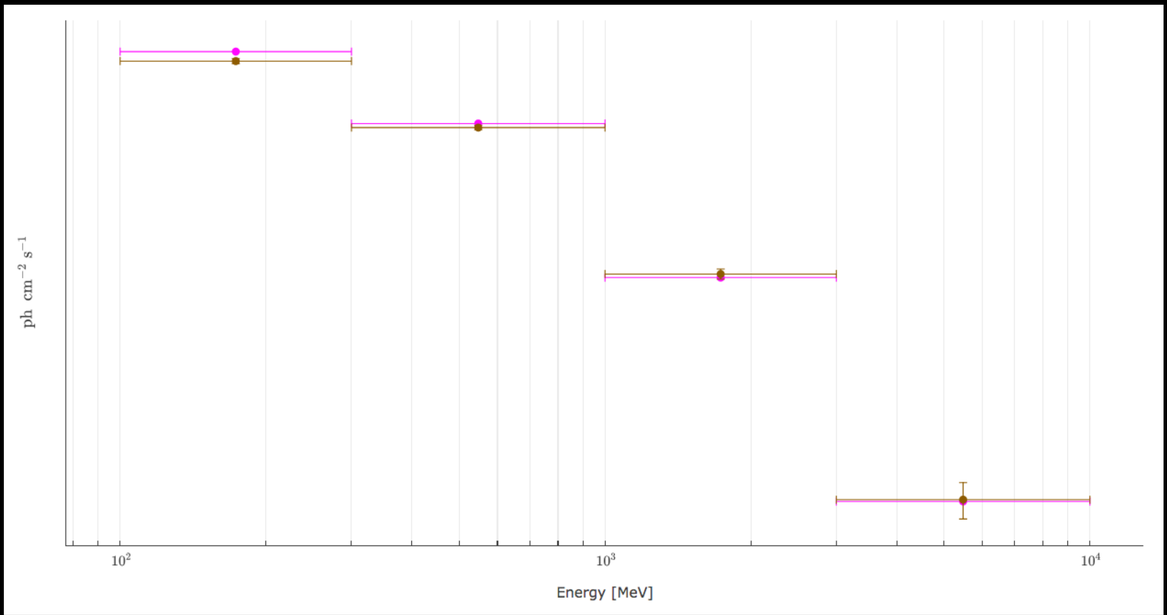
Third step



- After computing the maximum likelihood, the threshold for inclusion in the 2AGL Catalog is the likelihood Test Statistic TS > 16.

PRODUCTS





Spectra (100-10000 MeV)

Light curves (4 days)

$$TS_{curve} = 2(logL(CurvedSpectra) - logL(PL))$$

Curvature Index

Lets TS_0 the value of TS evaluating all the time bins at the same time but considering a constant flux, TS_1^i the value of TS optimizing the flux in each period of time i.

The variability index is

$TS_{var} = \sum_{i=1}^{N} TS_1^i - TS_0$

If the null hypothesis is correct TS_{var} is distributed as χ^2 with N degrees of freedom, and a value of $TS_{var} > h(N)$ is used to identify variable sources at a 99% confidence level.

It is possible to introduce a corrective factor (similar to (Nolan 2012)):

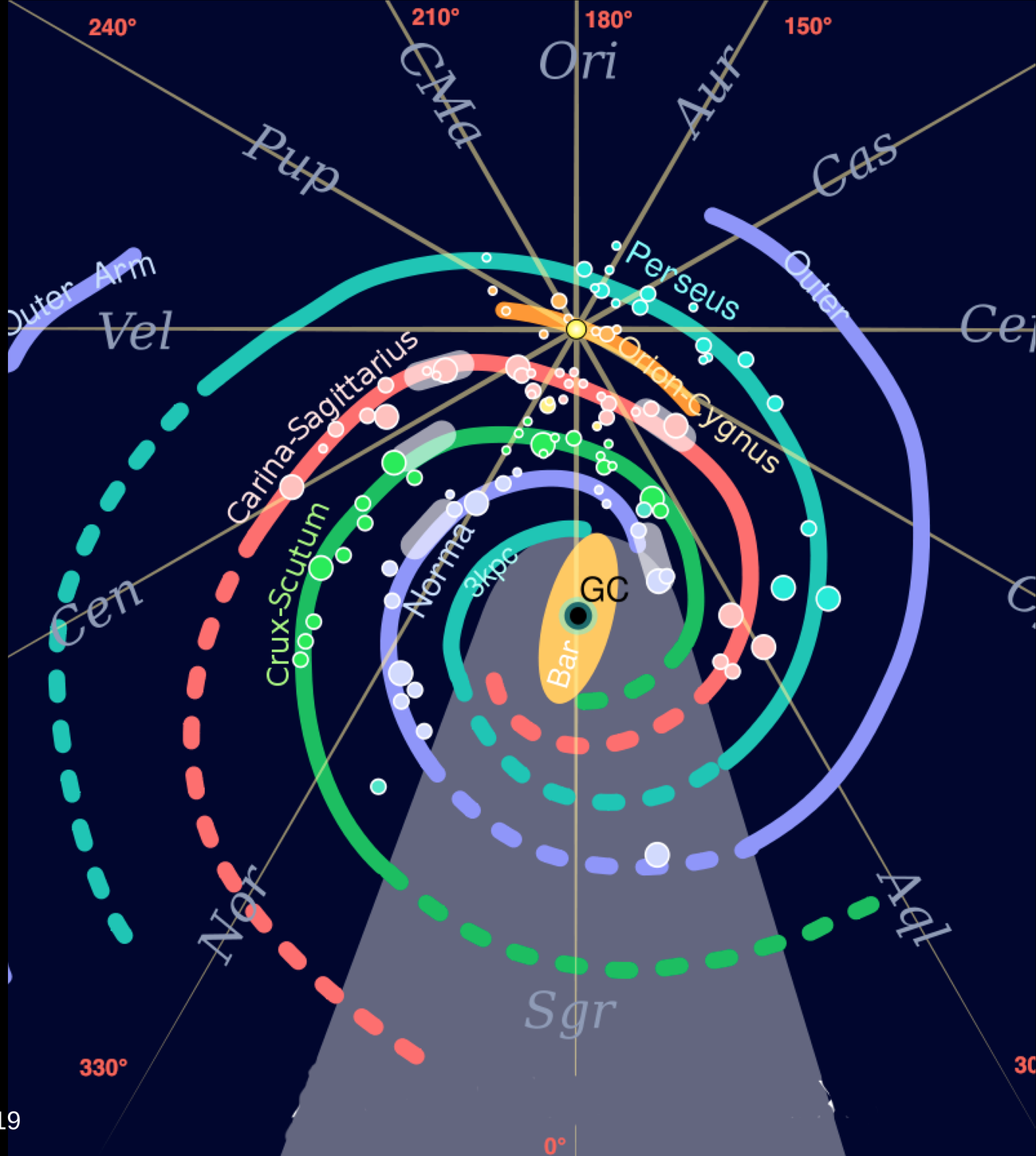
$TS_i^{corr} = F_{sigma_i}^2/(F_{sigma_i}^2 + f^2 * F_0^2)$

We consider $f = 0.01$ in our analysis. The variability index is

$TS_{var}^* = \sum_{i=1}^{N}(TS_i^{corr} * TS_1^i) - TS_0$

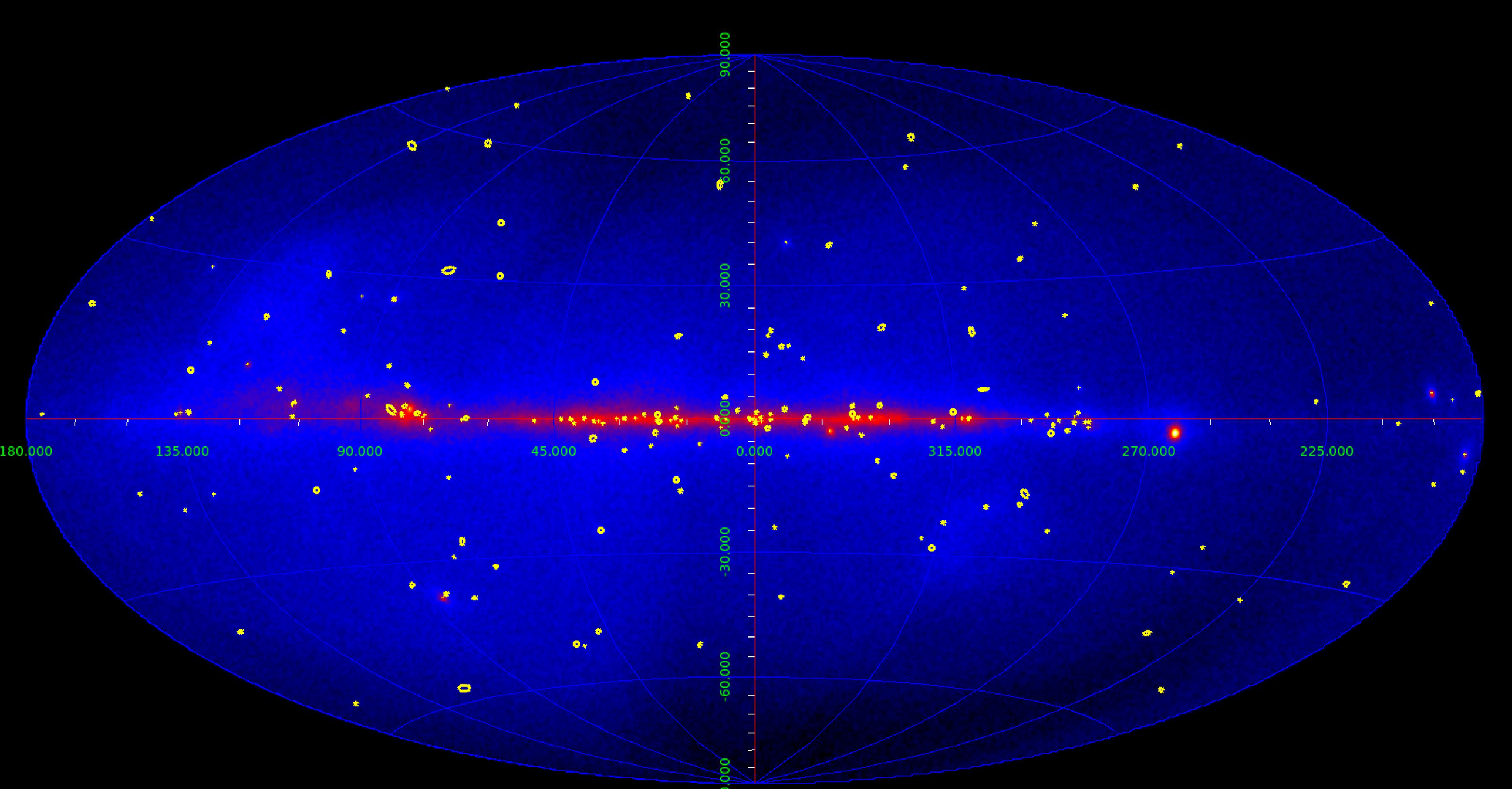
Variability Index

RESULTS


240°
210°
180°
150°
CMa
Ori
Aur
Pup
Cas
Perseus
Outer
Outer Arm
Vel
Cep
Carina-Sagittarius
Orion-Cygnus
Cen
Crux-Scutum
Norma
3kpc
GC
Bar
Nor
Aql
Sgr
330°
0°

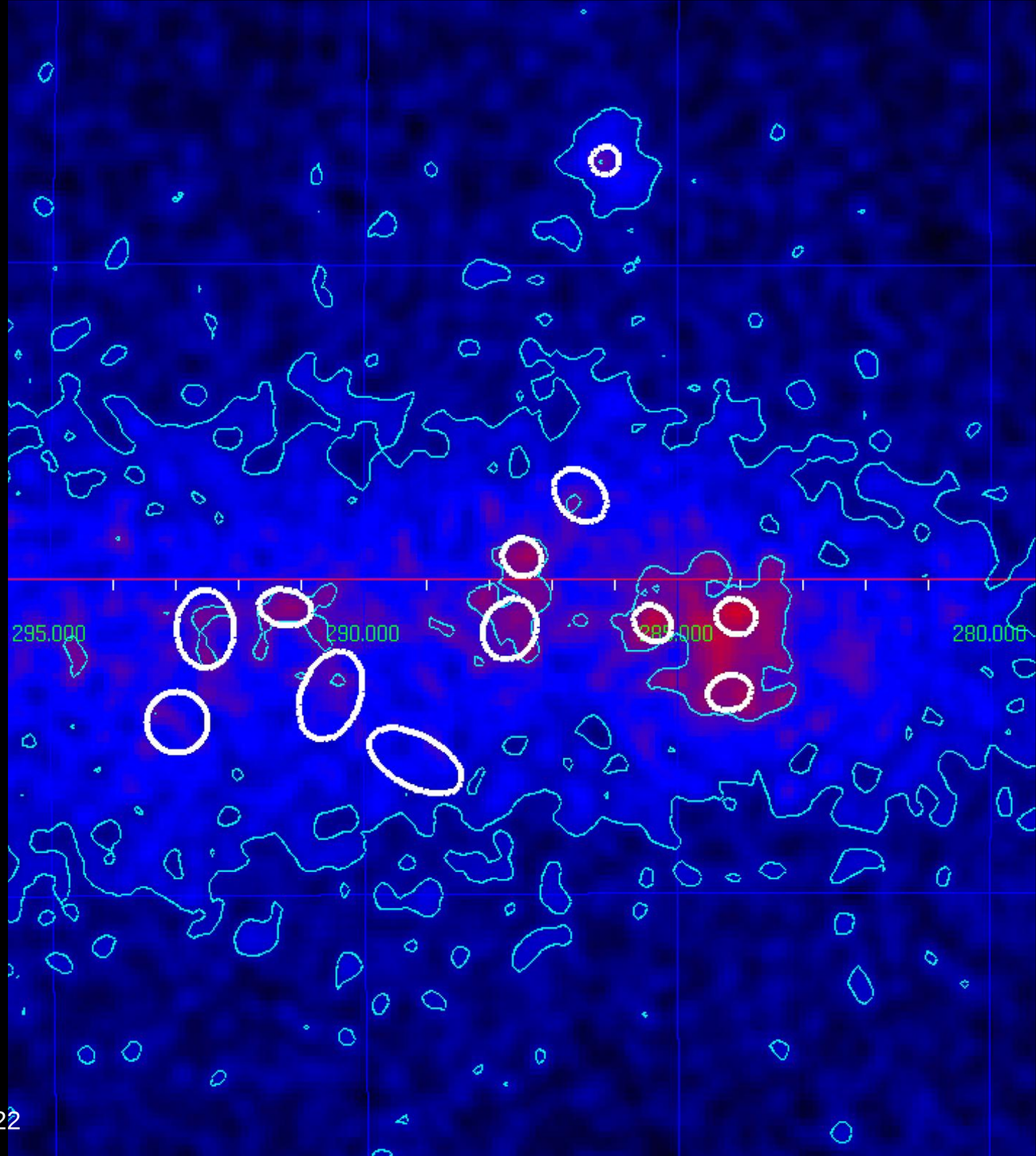
RESULTS

- Results
  - AGILE only sources
  - Associations
- WARNING: AGILE 0.1-50 GeV, Fermi 0.1-100 GeV



190 2AGL sources

ASSOCIATIONS



PRELIMINARY ASSOCIATIONS

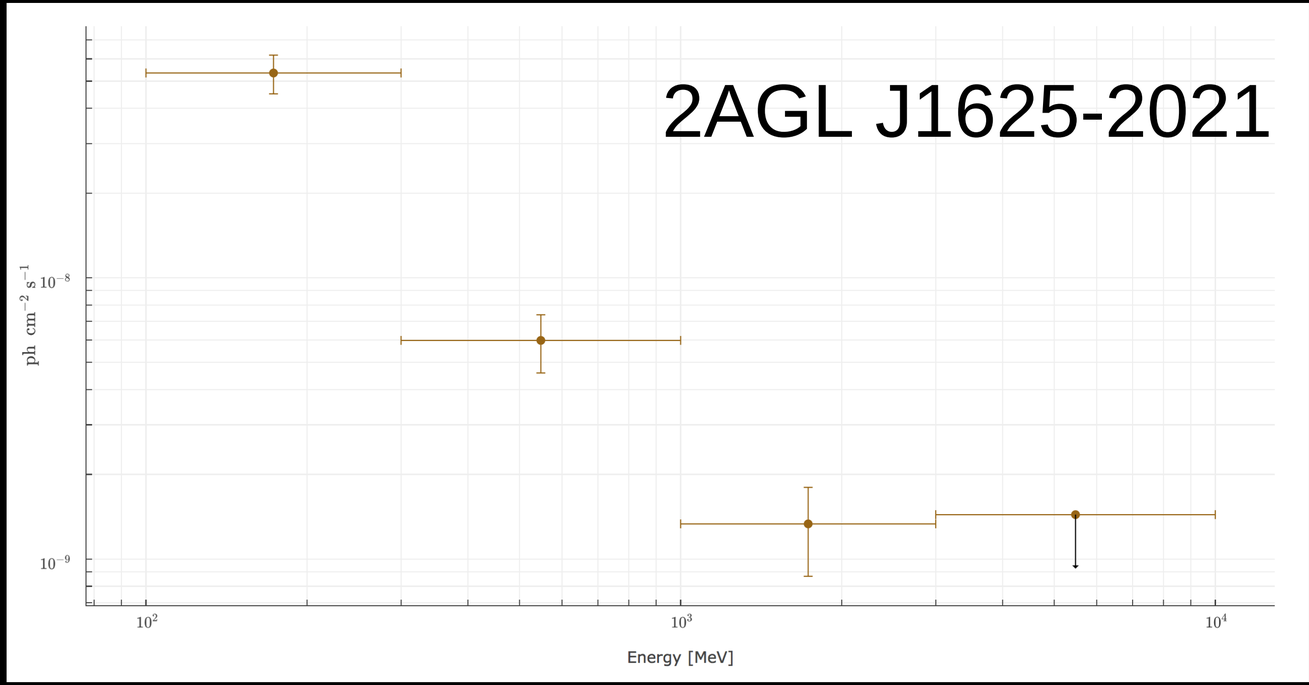
- Positional coincidence only
- These associations are not in general to be taken as firm identifications: a physical relationship is not established between gamma-ray sources and sources in other wavelenghts.
- 20 AGILE-only (no 3FGL) sources

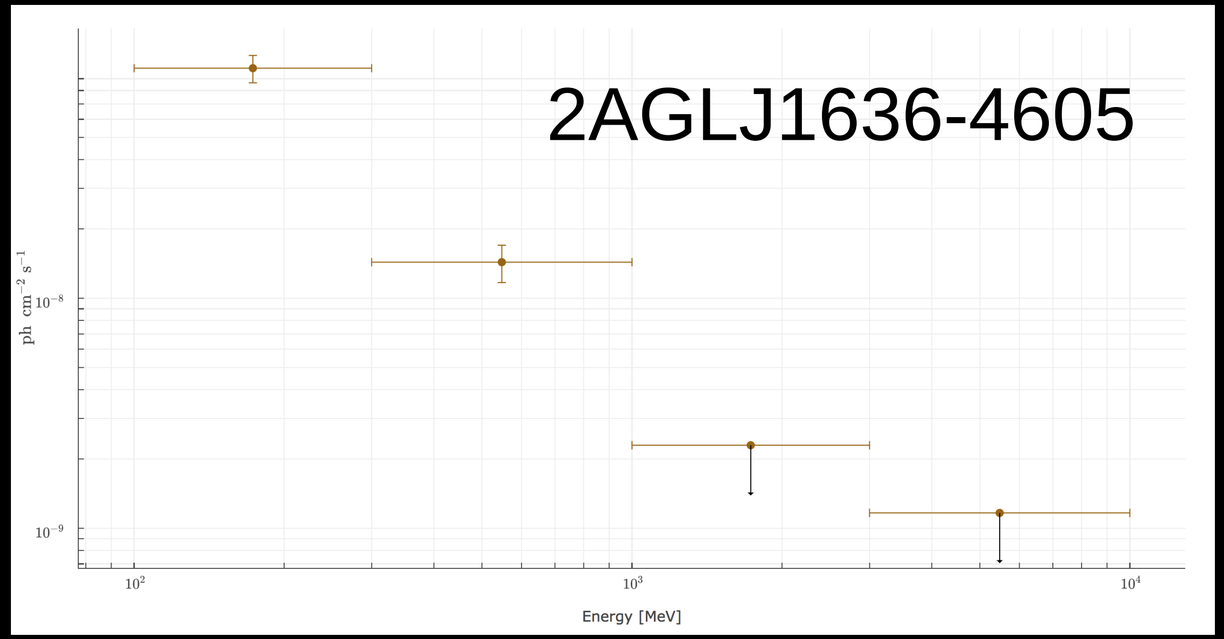
AGN

Description	number
BCU (Blazar candidate of uncertain type)	10
BLL (BL Lac type of blazar)	17
FSRQ (FSRQ type of blazar)	31
RDG (Radio galaxy)	2 (CenA, NGC1275)
BIN (Binary)	1 (Eta Carinae)
GLC (Globular cluster)	1 (Terzan 5)
HMB (High-mass binary)	3
PSR (positional only)	50
PWN	3
SNR	9
SPP	7
	134

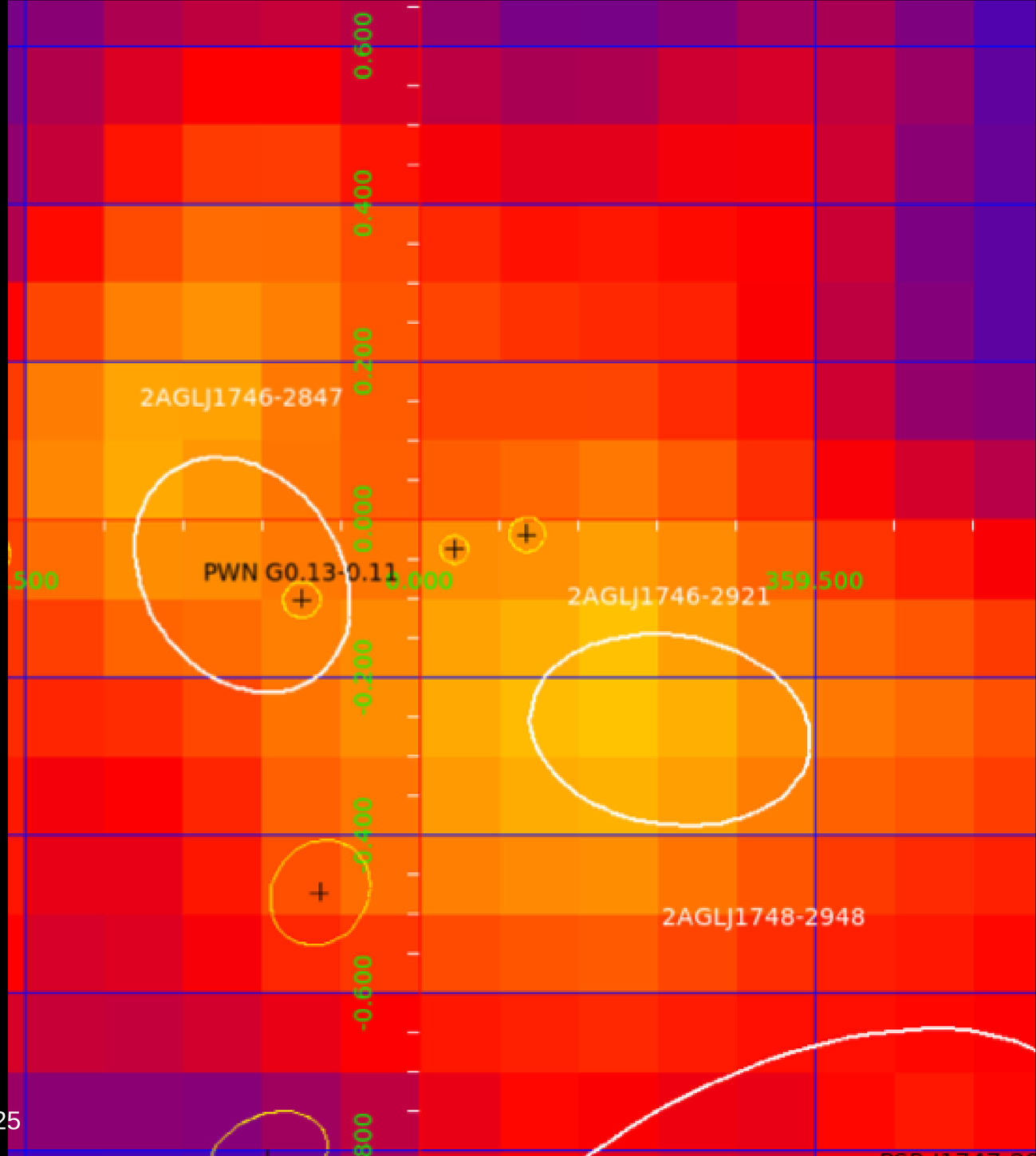
HMB (High-mass binary)	LSI+61 303, 1FGLJ1018.6-5856, Cygnus X-3
SNR	IC443, CTB37A, W28, W30, W44, W49B, W51, GammaCygni, HB21
PWN	Crab Nebula, HESSJ1632-478, PWNG0.13-0.11)

AGILE ONLY SPECTRA

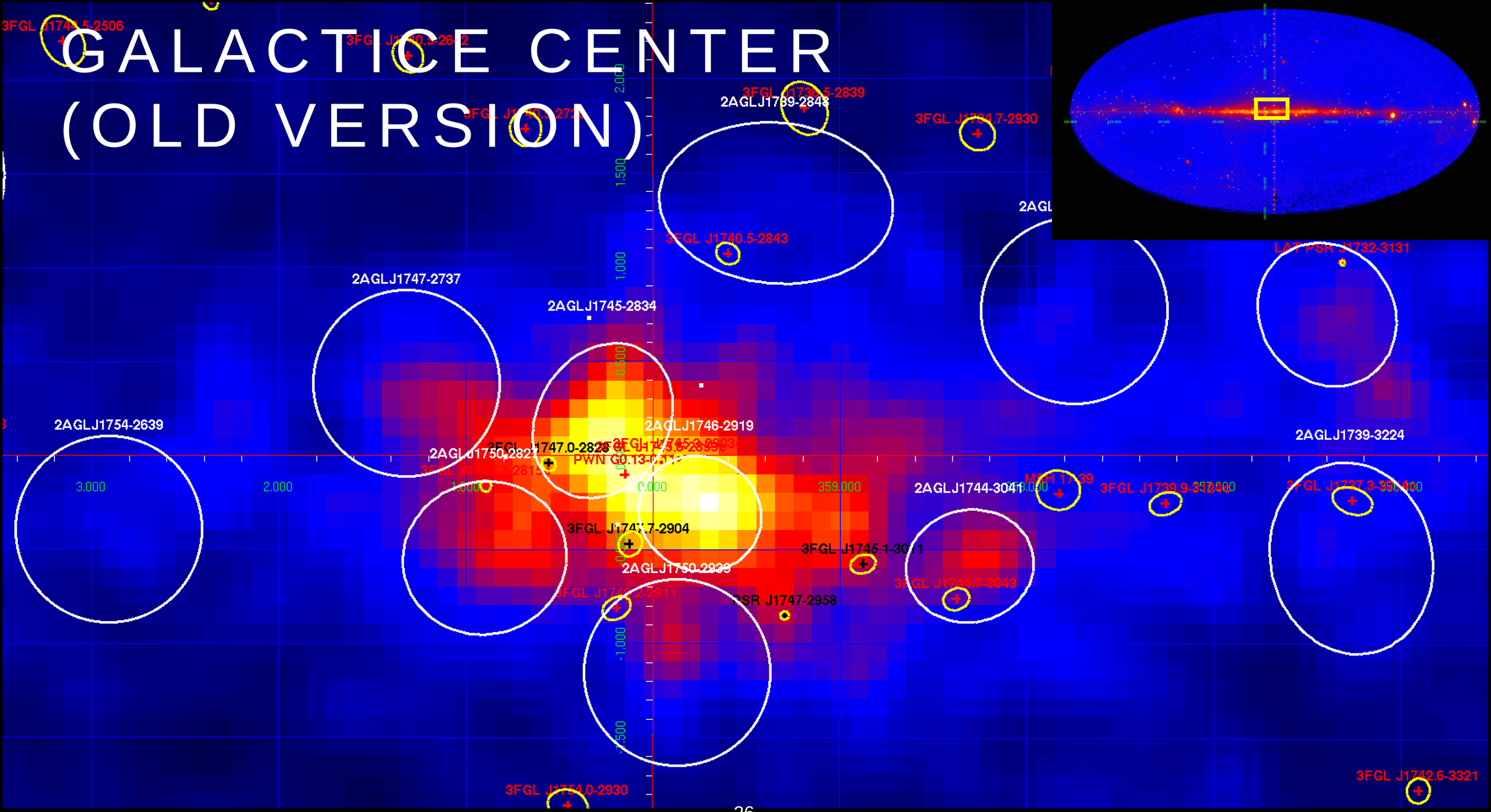




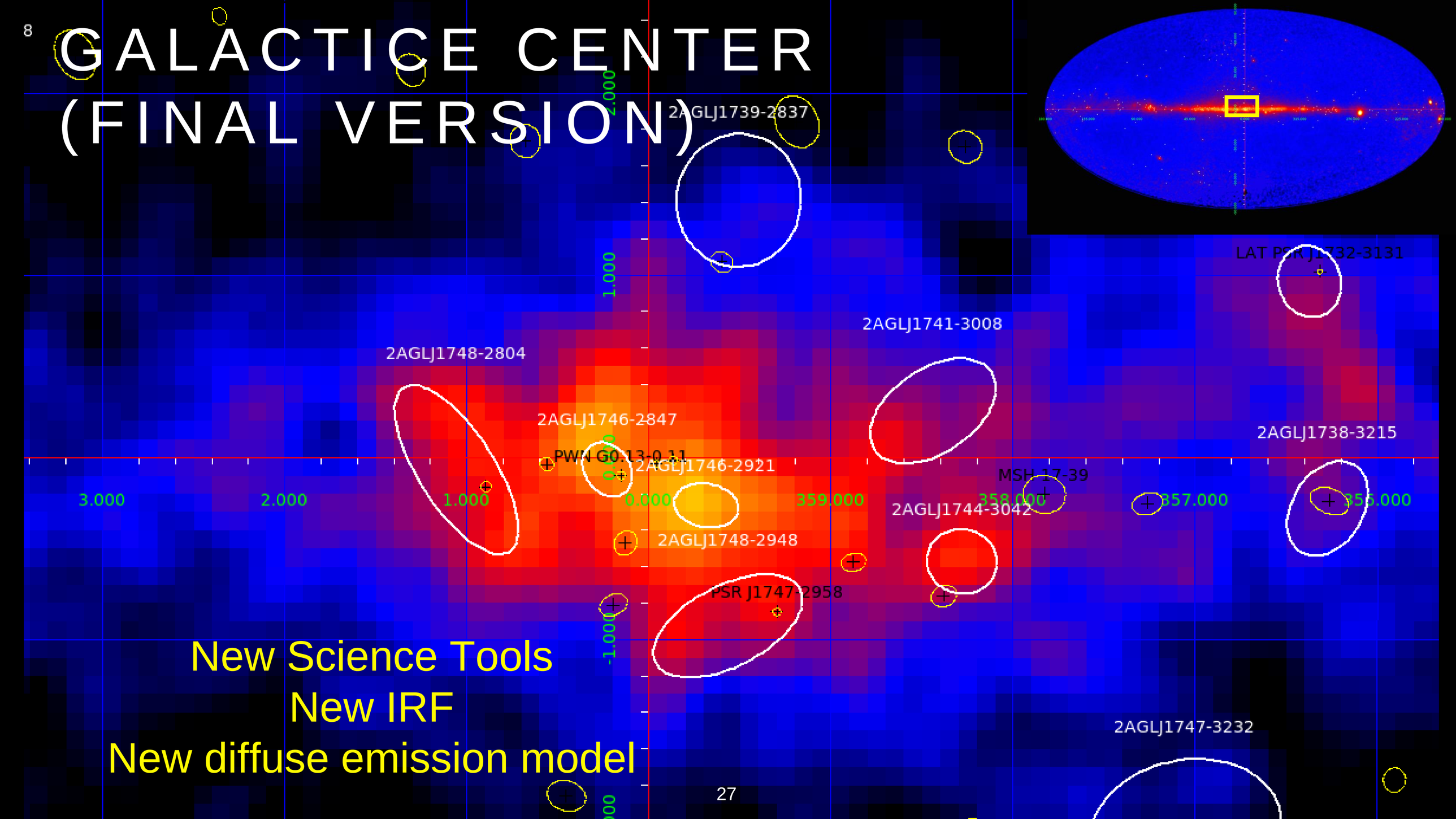
THE GALACTIC CENTER



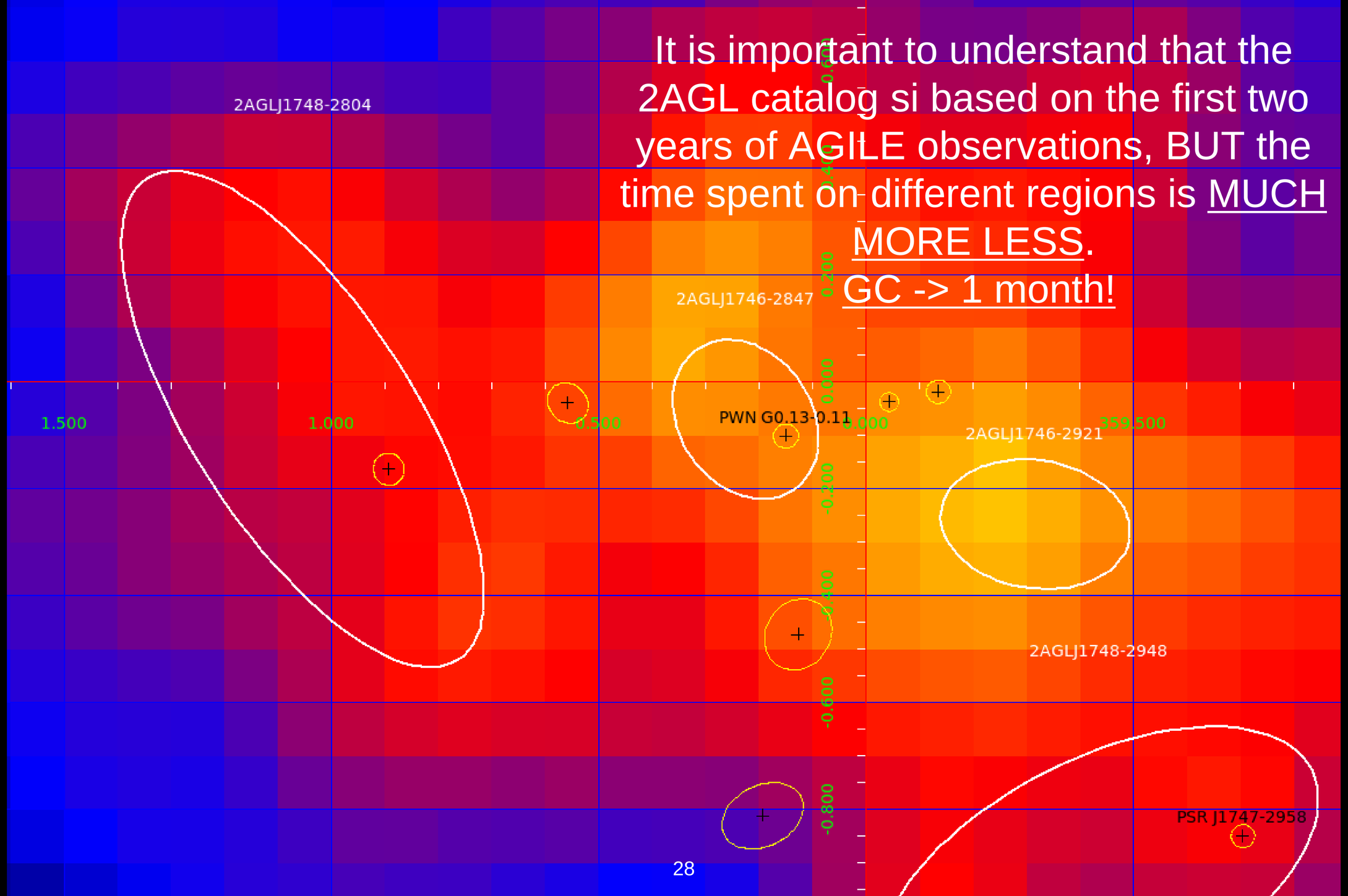
GALACTICE CENTER (OLD VERSION)



GALACTICE CENTER (FINAL VERSION)

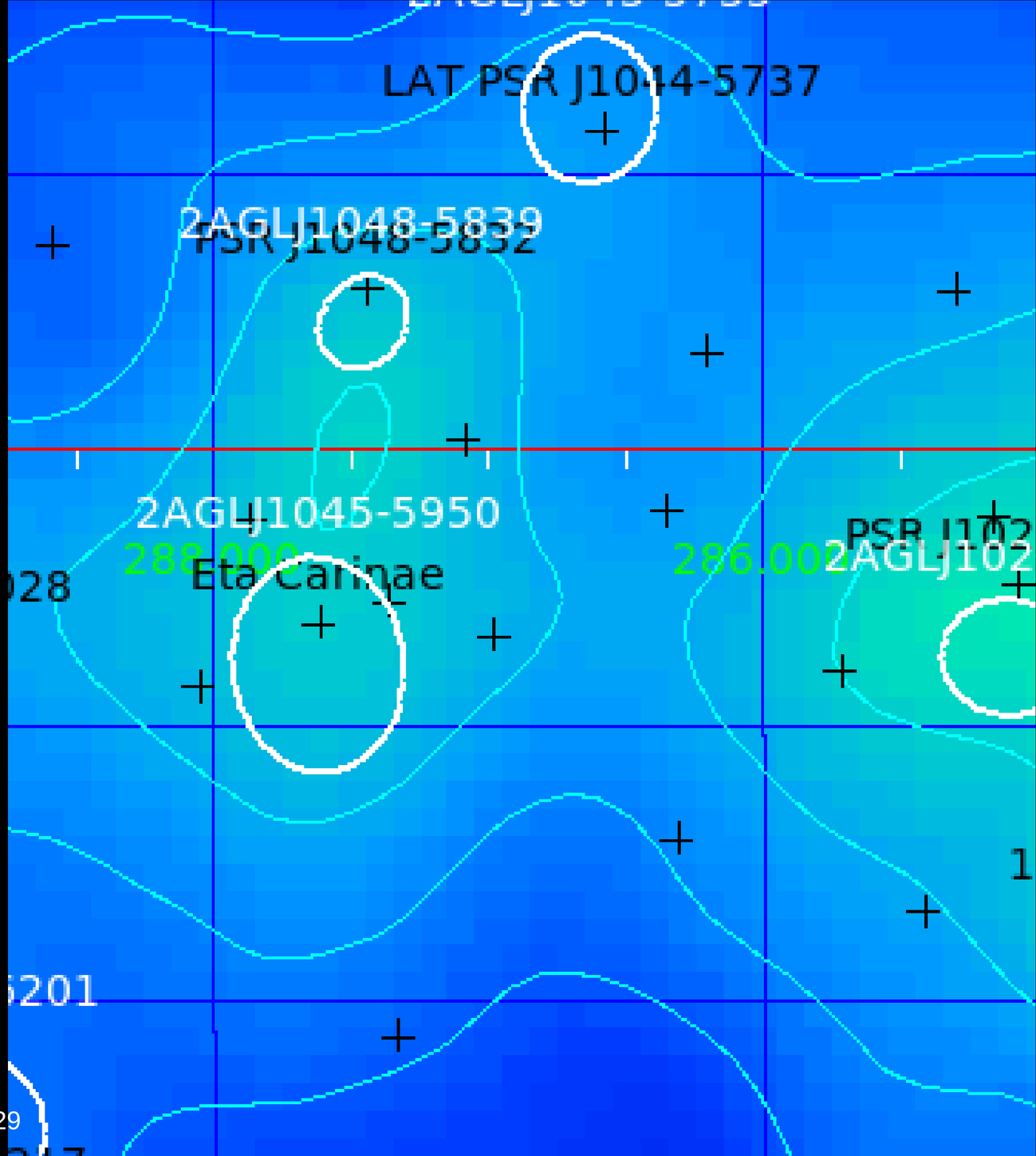


New Science Tools
New IRF
New diffuse emission model

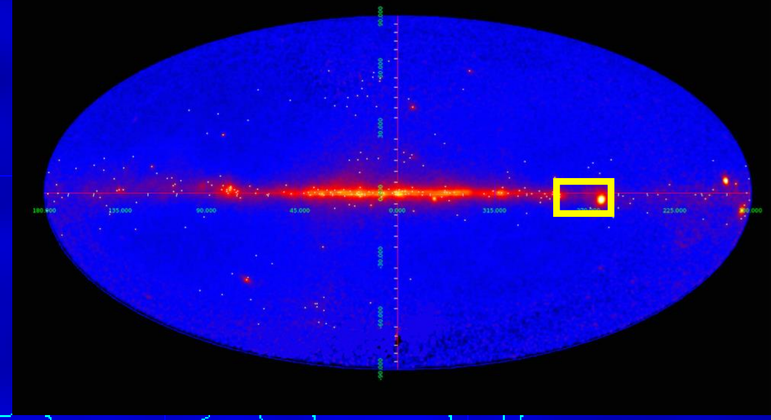


It is important to understand that the 2AGL catalog si based on the first two years of AGILE observations, BUT the time spent on different regions is MUCH MORE LESS.
GC -> 1 month!

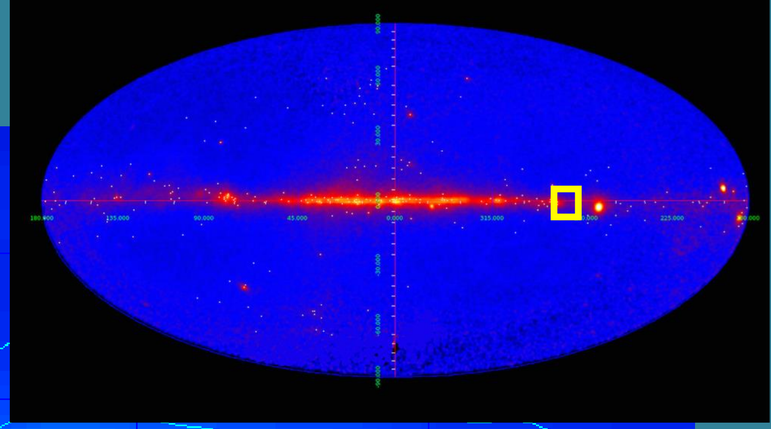
THE CARINA REGION



CARINA AND VELA REGIONS

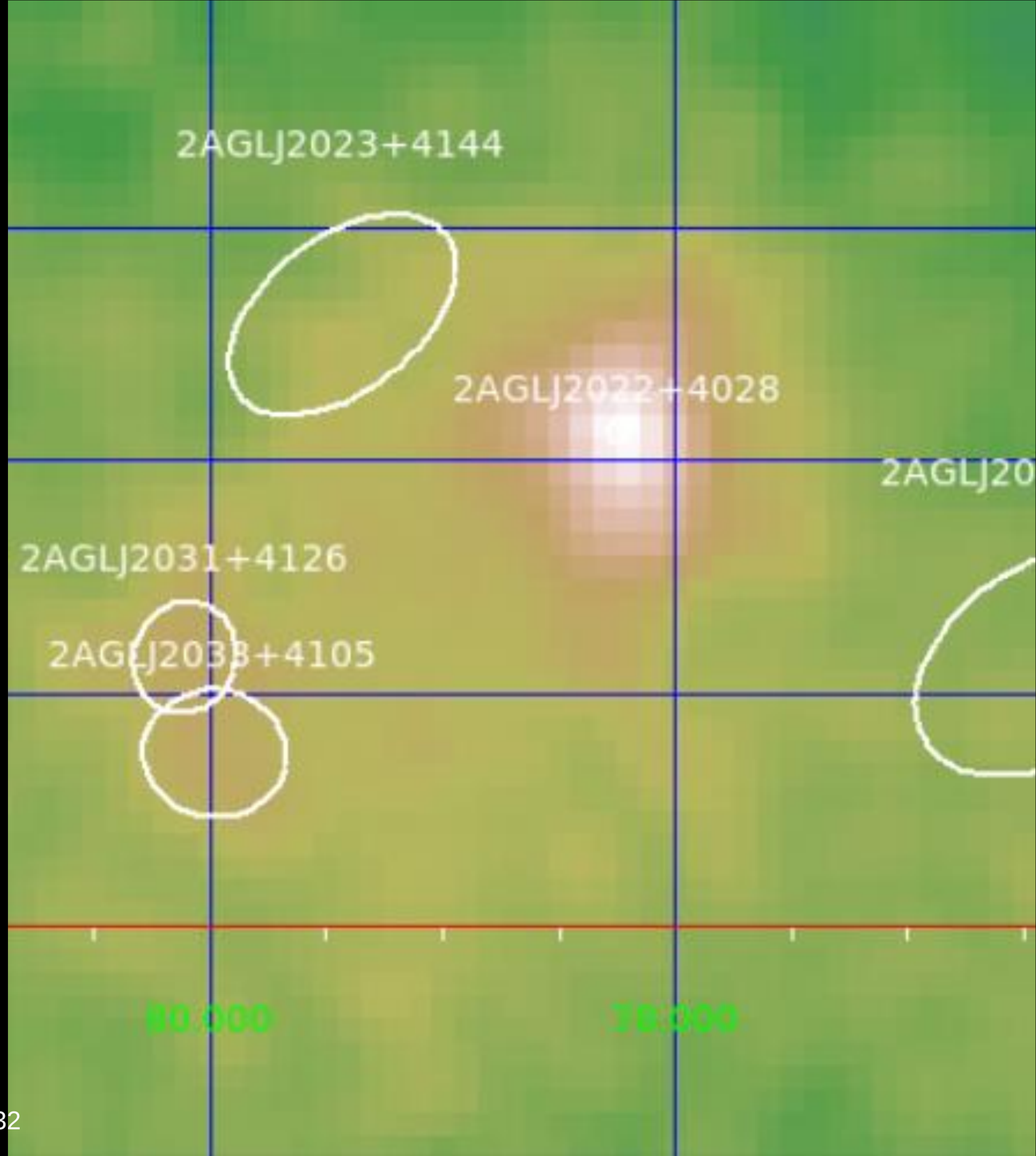


CARINA REGION

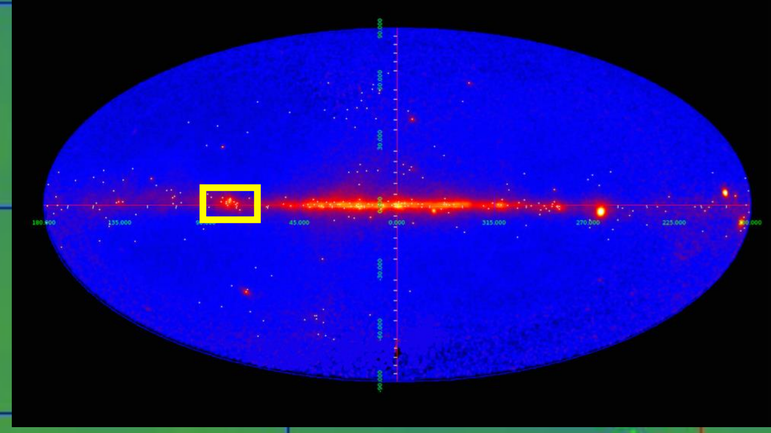


PSR J1125-5825
PSR J1124-5916
2AGLJ1136-6045
PSR J1125-6014
LAT PSR J1135-6055
LAT PSR J1135-6055
2AGLJ1205-6247
PSR J1203-63
PSR J1263-63
2AGLJ1112-6100
PSR J1112-6103
PSR J1119-6127
2AGLJ1120-6222
?
PSR J1112-6103
2AGLJ1045-5735
LAT PSR J1044-5737
LAT PSR J1044-5737
2AGLJ1048-5839
PSR J1048-5832
PSR J1048-5832
2AGLJ1045-5950
Eta Carinae
Eta Carinae
PSR J1028-5819
LAT PSR J1023-5746
PSR J1019-5749
1FGL J1018.6-5856
2AGLJ1017-5904
PSR J1016-5857
PSR J1016-5857
2AGLJ1049-6201
*2AGLJ1118-6414
AT20G J112319-641735
AT20G J112319-641735
PMN J1047-6217
PMN J1047-6217

THE CYGNUS REGION



CYGNUS REGION



2AGLJ2023+4144

2AGLJ2029+4403

2AGLJ2022+4028

2AGLJ2020+3824

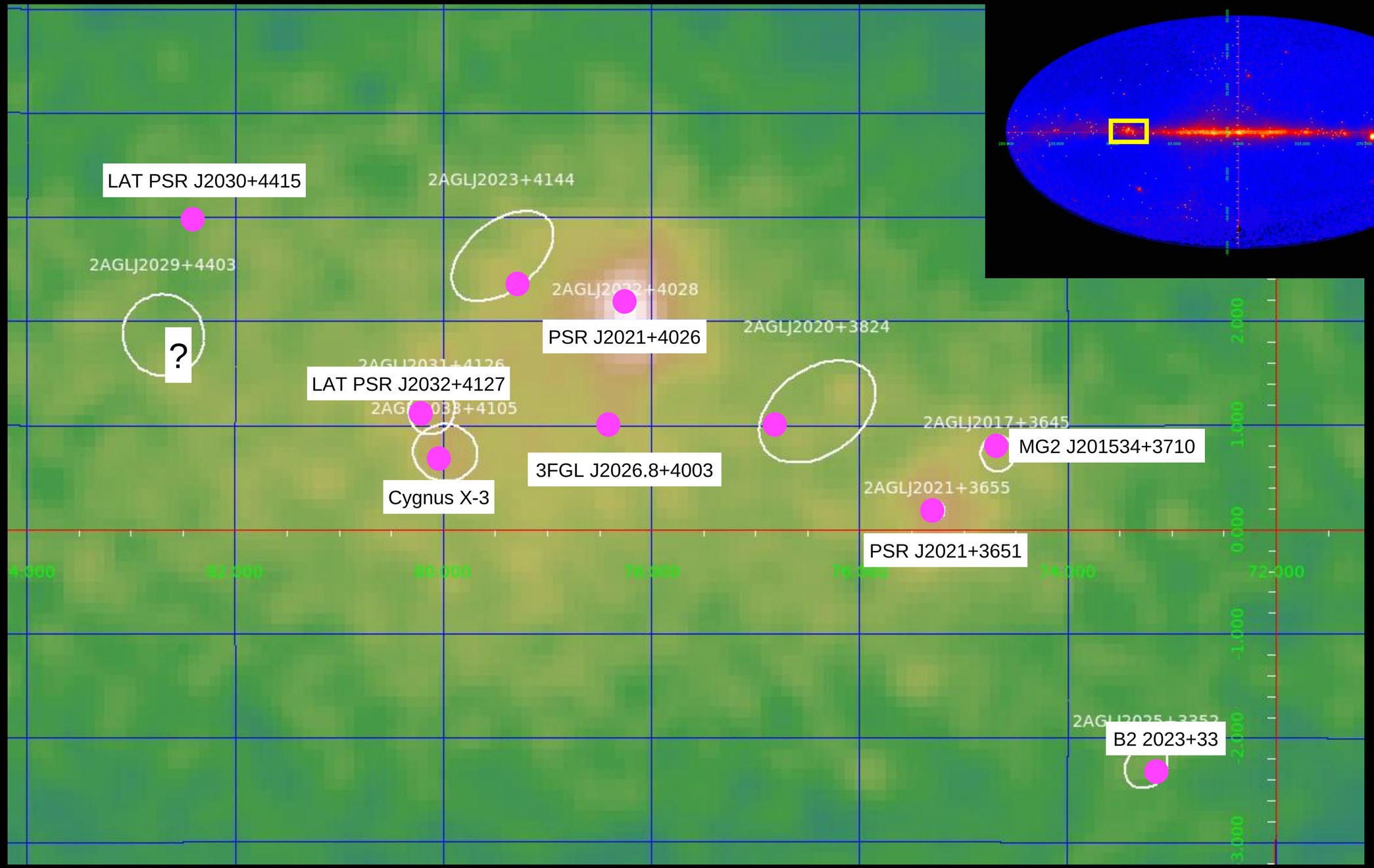
2AGLJ2031+4126

2AGLJ2033+4105

2AGLJ2017+3645

2AGLJ2021+3655

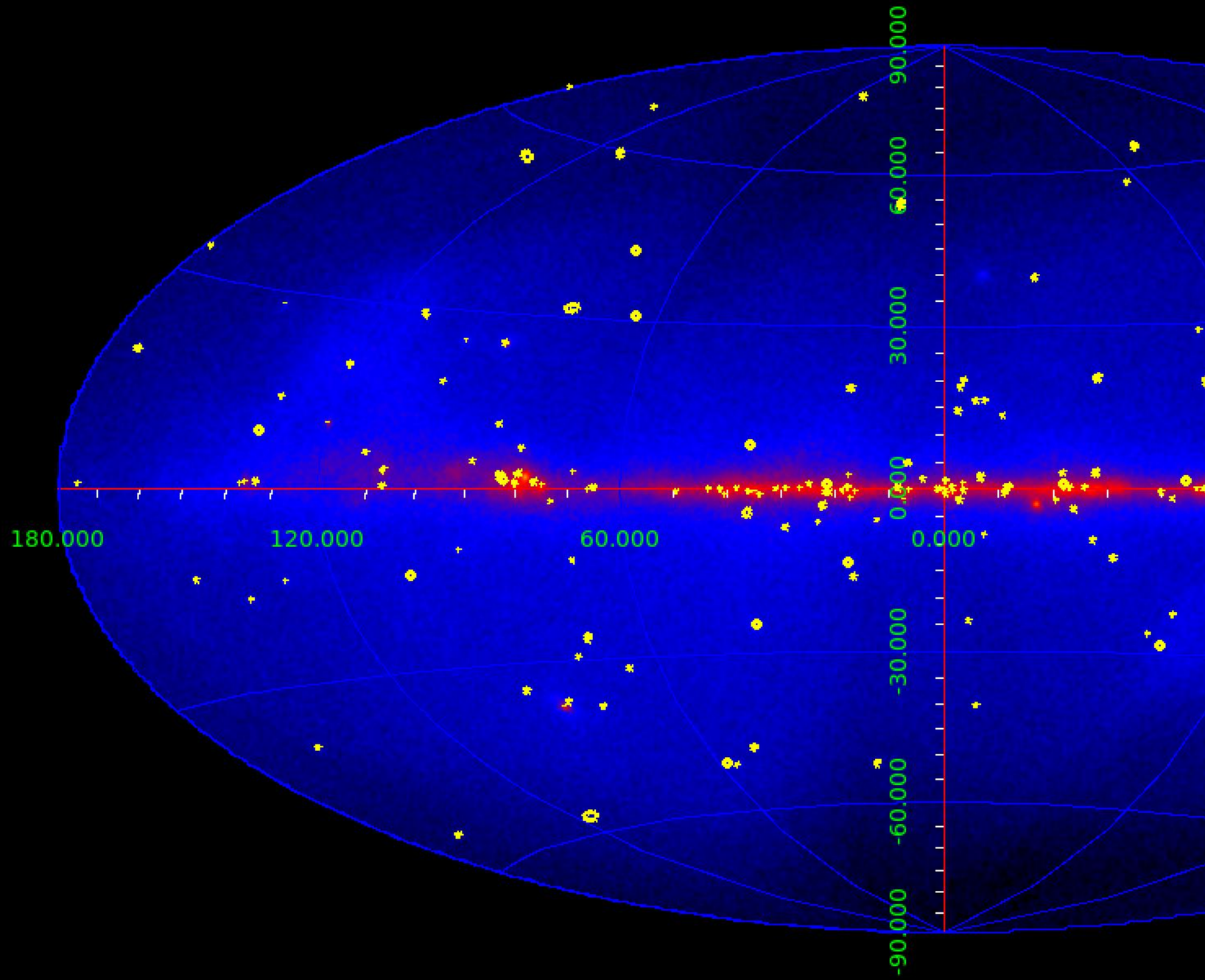
2AGLJ2025+3352


LAT PSR J2030+4415
2AGLJ2023+4144
2AGLJ2029+4403
2AGLJ2022+4028
PSR J2021+4026
?
2AGLJ2020+3824
LAT PSR J2032+4127
2AGLJ2033+4105
2AGLJ2017+3645
MG2 J201534+3710
3FGL J2026.8+4003
Cygnus X-3
2AGLJ2021+3655
PSR J2021+3651
B2 2023+33

Name 2AGL	l (deg)	b (deg)	[a]Pos. Error (95%) (deg)	$\sqrt{(TS)}$	$\Gamma \pm error$	[c]Mean Flux & Error ($\times 10^{-8}$ ph cm^{-2} s^{-1})	γ-ray assoc.	Confirmed Counterp.	Classification
2AGLJ1746-2847	0.22	-0.07	0.14	9.4	2.14 ± 0.06	78.4 ± 9.2	1FGL J1746.4-2849c	PWN G0.13-0.11	PWN
							2FGL J1746.6-2851c	-	-
							3FGL J1746.3-2851c	PWN G0.13-0.11	PWN
							3EG J1746-2851	2EG J1746-2852	9999
2AGLJ1748-2804	1.05	-0.07	0.34	8.5	2.14 ± 0.08	42.9 ± 5.5	TeV J1747-2809	SNR G0.9+0.1	PWN
							3FGL J1748.3-2815c	-	-
2AGLJ1748-2448	3.76	1.78	0.31	9.1	2.43 ± 0.1	38.9 ± 5.7	TeV J1747-2448	Terzan 5	GC
							TeVJ1747-248	Terzan 5	-
							1FGL J1747.9-2448	Terzan 5	GLC
							2FGL J1748.0-2447	Terzan 5	GLC
							3FGL J1748.0-2447	Terzan 5	GLC
2AGLJ1801-2334	6.34	-0.18	0.19	13.3	2.19 ± 0.06	56.6 ± 5.9	2FHL J1801.3-2326e	W28	SNR
							1AGL J1803-2258	-	SNR
							0FGL J1801.6-2327	UNDEFINED	SNR/PWN SEE PAPER
							2FGL J1801.3-2326e	SNR G006.4-00.1	SNR
							3FGL J1801.3-2326e	W28	SNR
							3EG J1800-2338	2EG J1801-2312	9999
2AGLJ1810-2337	7.33	-2.06	0.1	14.2	1.74 ± 0.09	41.1 ± 5.5	1AGL J1809-2332	-	-
							1AGLR J1809-2333	-	-
							0FGL J1809.5-2331	LAT PSR J1809-2332	PULSAR
							1FGL J1809.8-2332	LAT PSR J1809-2332	PSR
							2FGL J1809.8-2332	LAT PSR J1809-2332	PSR
							3FGL J1809.8-2332	PSR J1809-2332	PSR
							3EG J1809-2328	2EG J1811-2339	9999
2AGLJ1804-2138	8.36	0.19	0.39	8.1	2.47 ± 0.13	42.8 ± 6.5	TeV J1804-2143	HESS J1804-216	-
							TeVJ1804-216	HESS J1804-216	EXTENDED
							1AGL J1805-2143	-	-
							1AGLR J1805-2149	-	-
							0FGL J1805.3-2138	UNDEFINED	UNIDENTIFIED
							1FGL J1803.1-2147c	-	-
							1FGL J1805.2-2137c	-	SPP
							2FGL J1803.3-2148	-	-
							3FGL J1803.1-2147	LAT PSR J1803-2149	PSR

CONCLUSIONS

- The 2th AGILE catalog has been finalized
- 190 2AGL gamma-ray sources: (134 with positional association). 20 AGILE only sources (under investigation)



“Thank you.”

–ANDREA