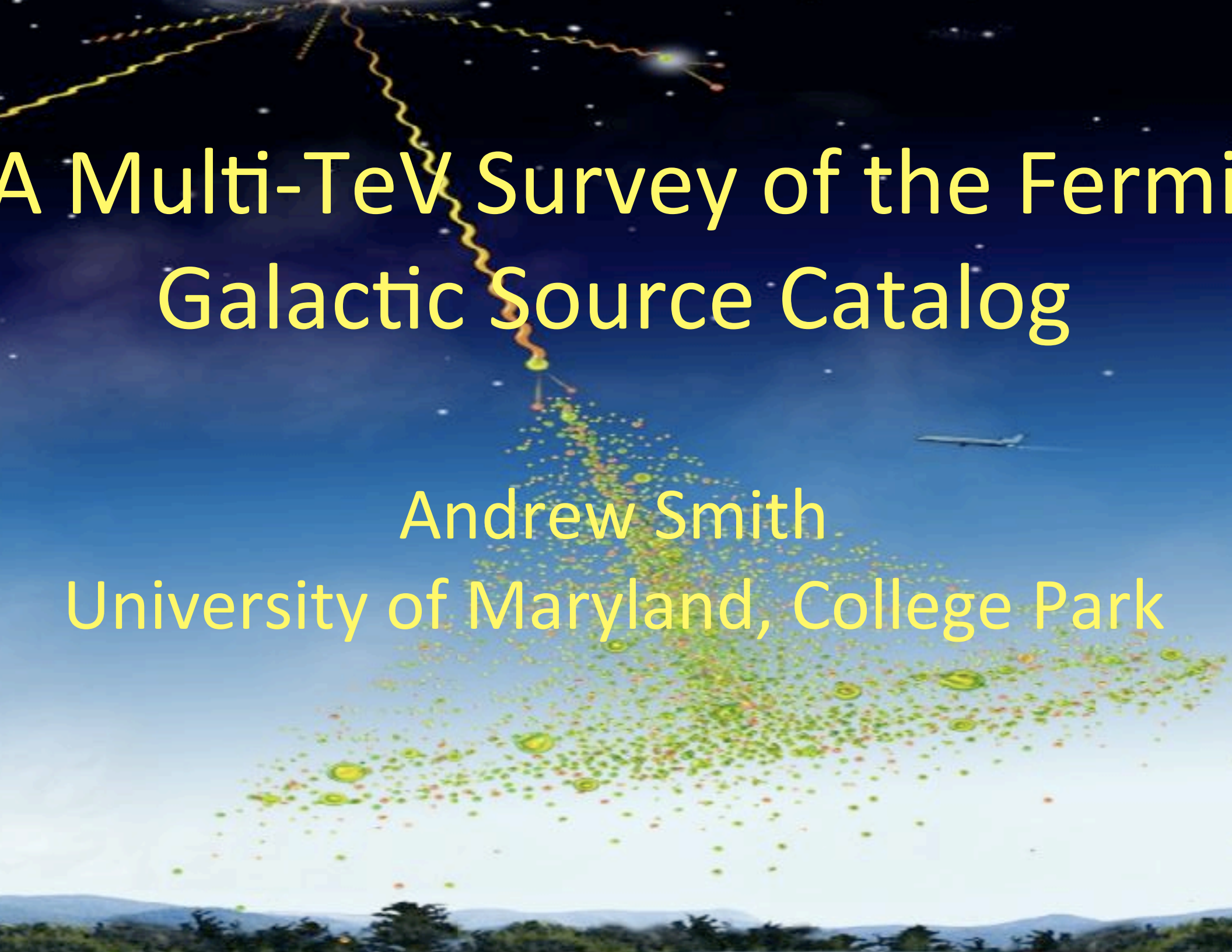


A Multi-TeV Survey of the Fermi Galactic Source Catalog

Andrew Smith
University of Maryland, College Park

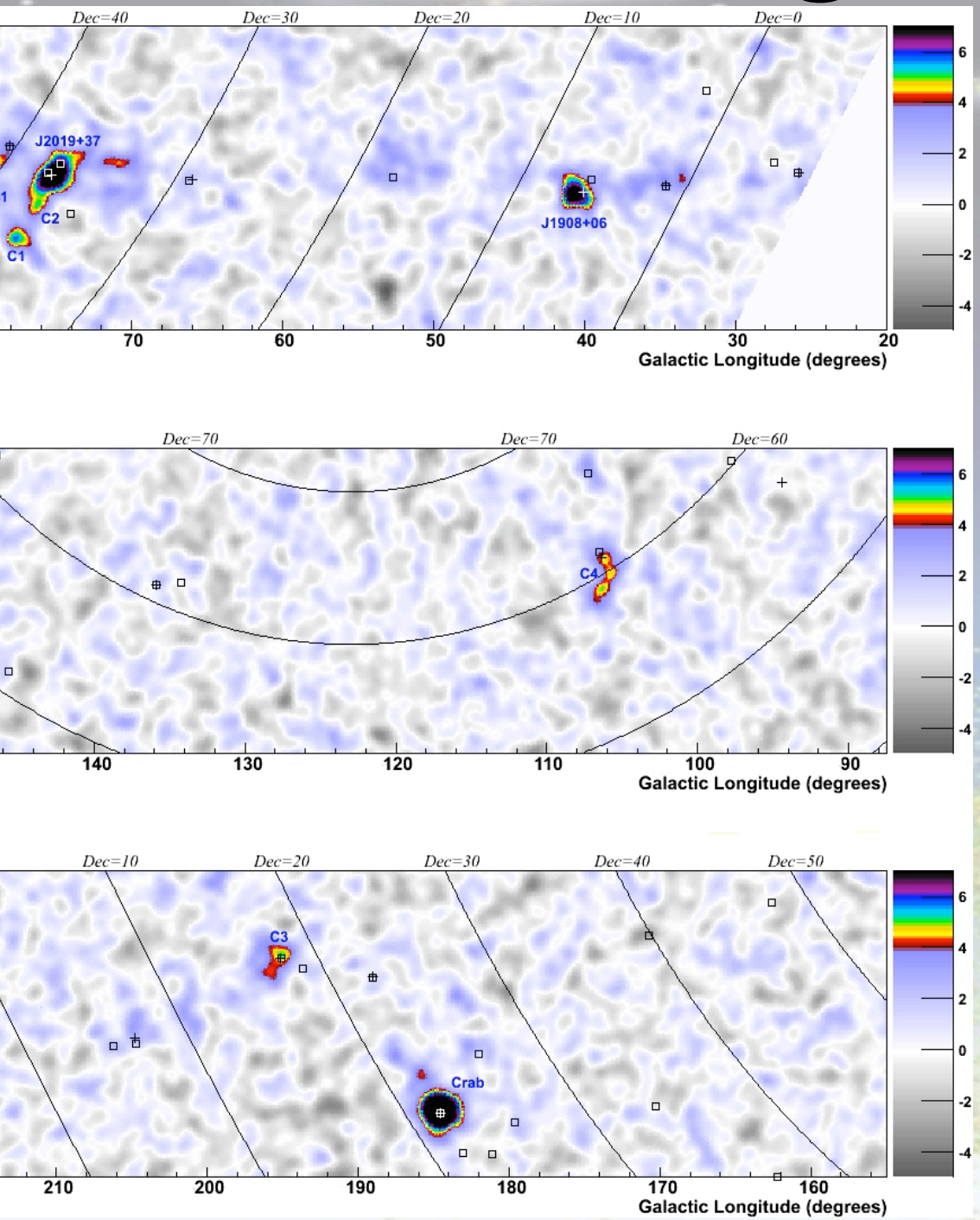
Milagro Collaboration

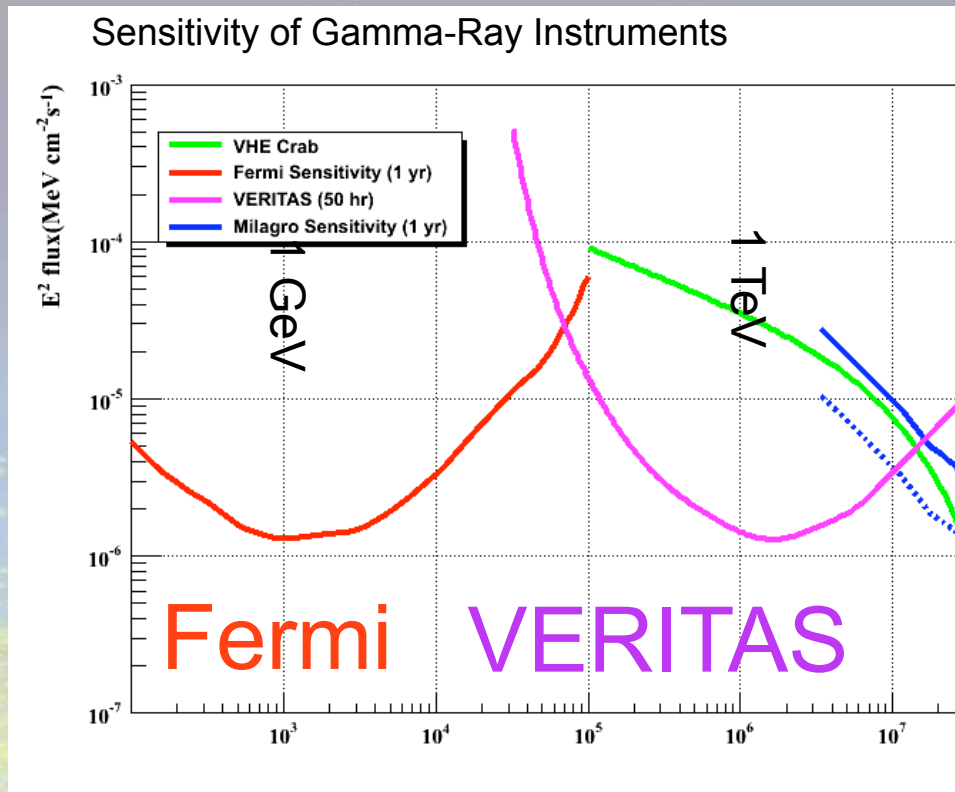
A. Abdo, B. Allen, D. Berley, G. Christopher, T. DeYoung, B.L. Dingus, R.W. Ellsworth, M.M. Gonzalez, J.A. Goodman, C.M. Hoffman,P. Huntemeyer, B. Kolterman, C.P. Lansdell, J.T. Linnemann, J.E. McEnery, A.I. Mincer, P. Nemethy, J. Pretz, J.M. Ryan, P.M. Saz Parkinson, A. Shoup, G. Sinnis, A.J. Smith, G.W. Sullivan, D.A. Williams, V. Vasileiou, G.B. Yodh

Milagro Detector

- Central Water Pond (80x60 meter)
- 450 PMTs under 1.5 m water
- 273 PMTs under 6 m water
- Outriggers
- 2.4 meter diameter
- 1.4 meter tall
- 175 PMTs in outrigger tanks

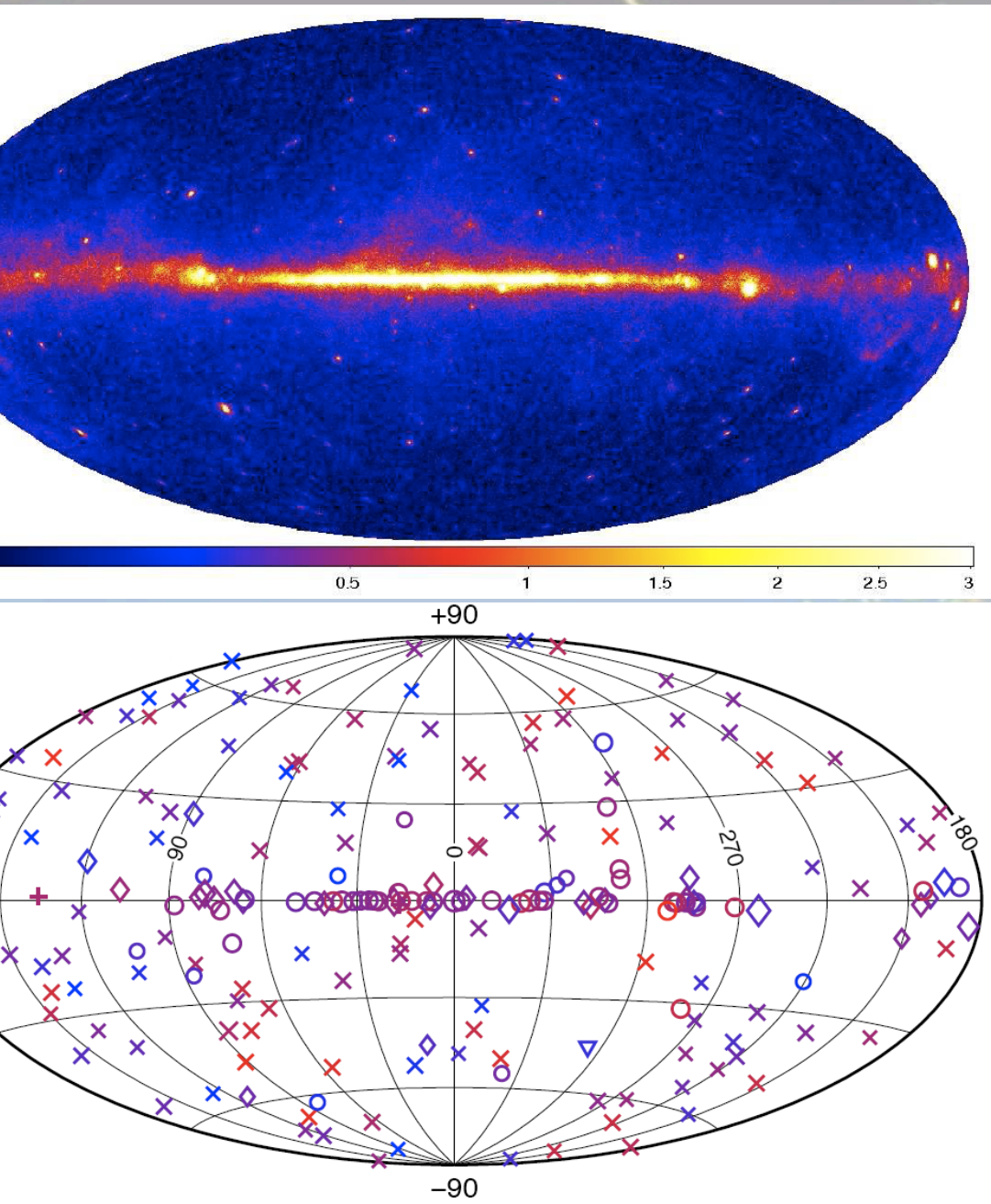
- 2640 meters a.s.l. elevation
- 4000 m^2 pond / 40000 m^2 outrigger
- 1700 Hz Trigger Rate
- 0.35^o – 1.0^o angular resolution
- Sensitivity 100 GeV – 100 TeV Media
  10 – 40 TeV (depending on cuts, weig
- Operated from 2000-2008
- Operated2004-2008 with outriggers
  sensitivity)





e 2007, more data, improved analysis
prehensive survey of the northern sky

Fermi-LAT Bright Source List



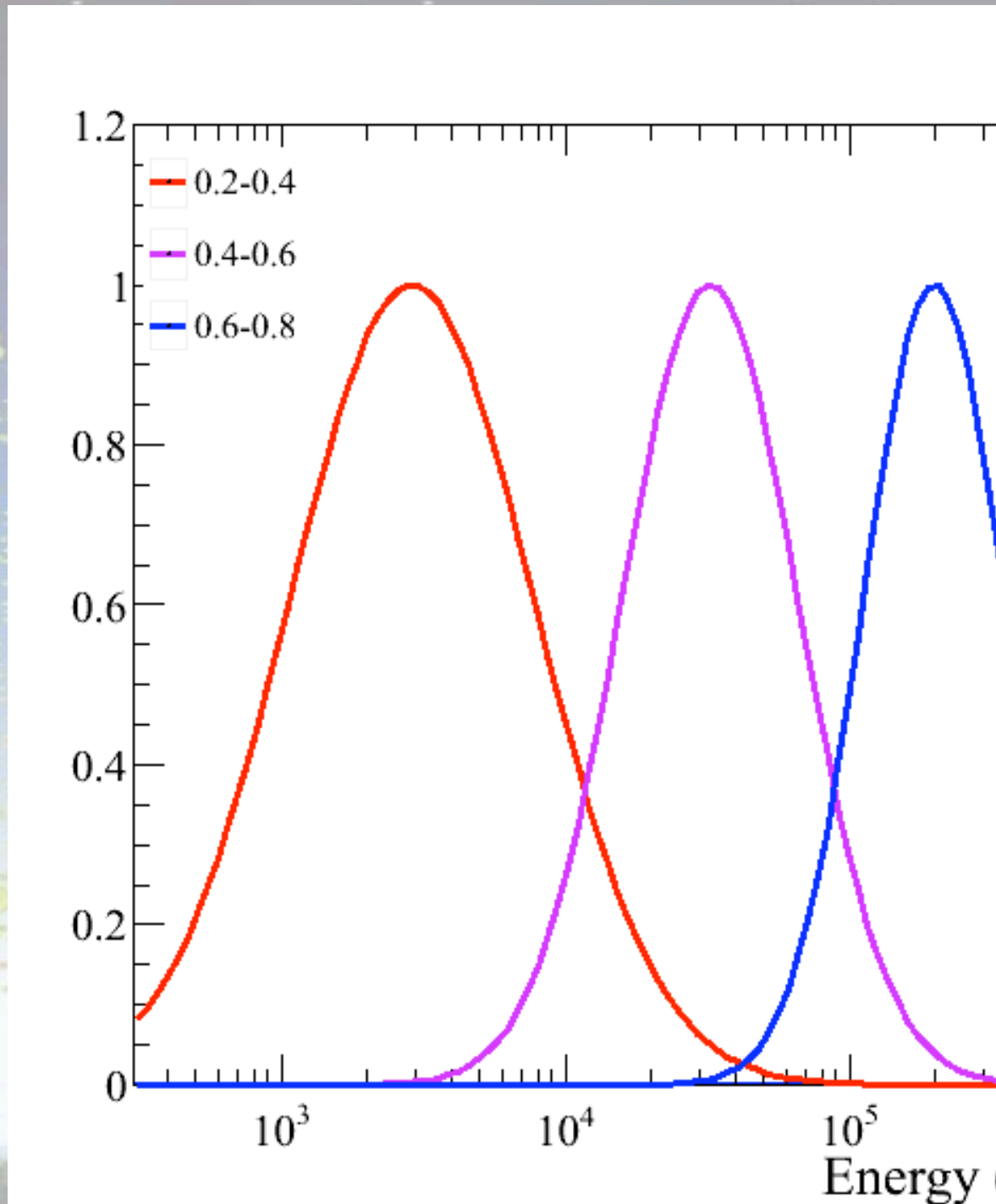
- Sensitivity from 100 MeV to hundreds of GeV
- 205 >10σ sources in 3 month data
- Blazars, pulsars identified by variability.
- Several new pulsars (pulsatio discovered in the GeV first)
- Angular resolution ~< 0.1°

Next Generation of Analysis - Energy

asor variable $\mathcal{F}$ tracks
ergy

$$\mathcal{F} = \frac{N_{AS}}{Live_{AS}} + \frac{N_{OR}}{Live_{OR}}$$

- Optimize weighting separately in each $\mathcal{F}$ bin.
- Excess in each $\mathcal{F}$ bin fit to MC to generate energy spectrum
- 5 years more data
- ab 15.0σ -> 17.2σ
- % - 25% cumulative crease in sensitivity
- edian energy 20 -> 35 TeV



from Galactic sources

205 BSL sources are possibly
tic and in Milagro's field of view
5°)

pulsars

-ray binary

NR

unknown

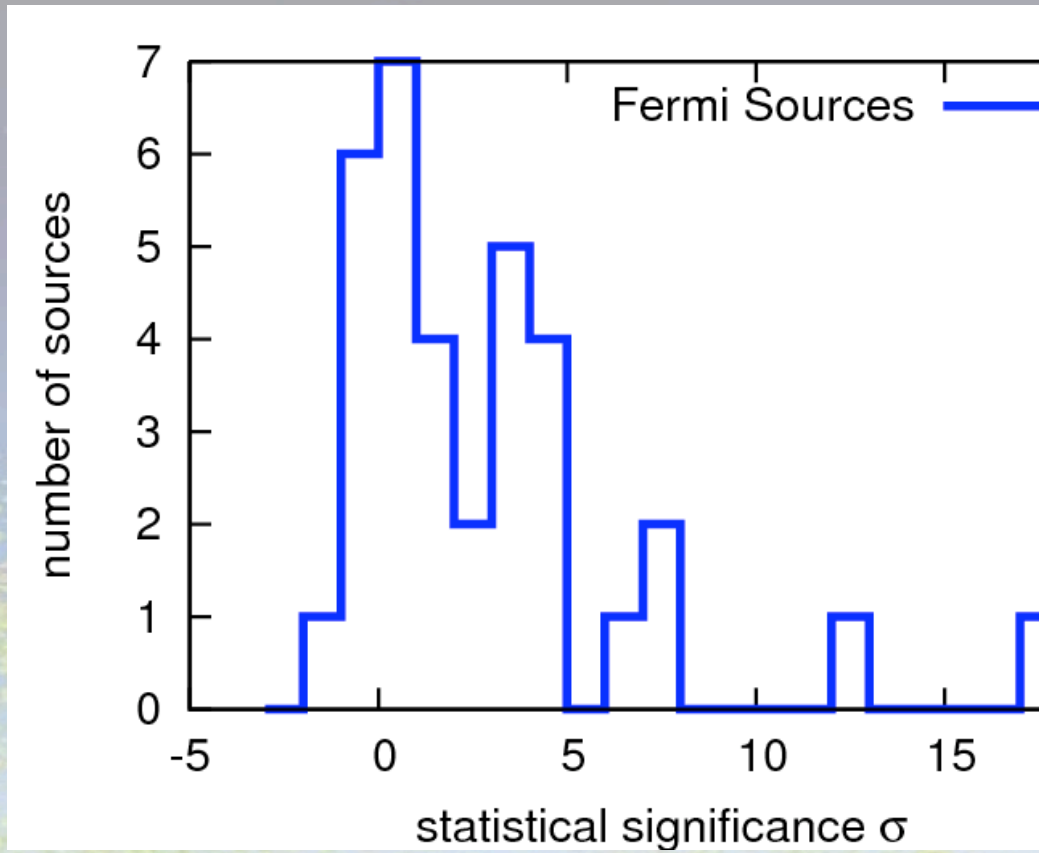
4 are observed at 3σ or more in
gro data

hese 14 have been previously
rted as sources or source
dates by Milagro and 2 by
.

viously unreported sources are
ified at >3σ.

>=3σ) = .04

>=3σ) = 6.7 x 10^{-4}



- 'Most' of the 3σ sources are T
  detections, but cannot be clai
  individually

ne GL)	type	RA (deg)	DEC (deg)	l (deg)	b (deg)	Flux ($\times 10^{-17}$ TeV^{-1} sec^{-1} cm^{-2})	Signif. (σ's)	TeV assoc.
+7303	PSR	1.85	73.06	119.69	10.47	< 90.4	2.6	
+0450	PSR	7.60	4.85	113.11	-57.62	< 20.9	-1.7	
+6113	HXB	40.09	61.23	135.66	1.07	< 26.2	0.7	LSI +61 303
+3205	PSR	59.39	32.08	162.71	-16.06	< 16.5	-0.1	
+2201	PSR	83.65	22.02	184.56	-5.76	162.6 ± 9.4	17.2	Crab
-0202	PSR	93.48	-2.05	210.47	-9.27	< 60.0	-0.0	
+2234	SNR[a]	94.36	22.57	189.08	3.07	28.8 ± 9.5	3.0	IC443
+1034	PSR	97.95	10.57	201.30	0.51	47.2 ± 12.9	3.7	
+0634	PSR	98.39	6.58	205.04	-0.96	< 50.2	1.4	
+1745	PSR	98.50	17.76	195.16	4.29	37.7 ± 10.7	3.5	MGRO C3 Geminga
+0858		100.82	8.98	204.01	2.29	< 30.5	0.3	
-0200		253.35	-2.01	16.55	24.96	< 51.0	-0.5	
+0617		277.58	6.29	36.16	7.54	< 32.8	0.2	
+5924	PSR	279.06	59.41	88.86	25.00	< 14.6	-0.9	
-0335		281.04	-3.59	28.91	-0.02	148.4 ± 34.2	4.3	
-0138		282.16	-1.64	31.15	-0.12	< 91.7	1.7	
+0126	SNR[a]	283.99	1.44	34.72	-0.35	< 89.5	2.2	
+0356		285.01	3.95	37.42	-0.11	70.7 ± 19.5	3.6	
+0602	PSR	286.89	6.03	40.14	-0.82	116.7 ± 15.8	7.4	MGRO J1908+06 HESS J1908+063
+0905	SNR[a]	287.76	9.09	43.25	-0.18	< 41.7	1.5	
+1411	SNR[a]	290.77	14.19	49.13	-0.40	39.4 ± 11.5	3.4	HESS J1923+141
+3249	PSR	298.32	32.82	68.75	2.73	< 17.0	0.0	
+2838	SNR[a]	298.61	28.65	65.30	0.38	37.1 ± 8.6	4.3	
+2848	PSR	299.53	28.80	65.85	-0.23	34.7 ± 8.6	4.0	
+4352		300.27	43.87	79.05	7.12	< 12.1	-0.9	
+3649	PSR	305.22	36.83	75.18	0.13	108.3 ± 8.7	12.4	MGRO J2019+37
+4026	PSR	305.40	40.44	78.23	2.07	35.8 ± 8.5	4.2	
+3334		306.88	33.57	73.30	-2.85	< 16.0	-0.2	
+4122	PSR	308.06	41.38	80.16	0.98	63.3 ± 8.3	7.6	TEV 2032+41 MGRO J2031+41
+2540		313.89	25.67	70.66	-12.47	< 17.6	-0.0	
+4608		317.70	46.14	88.26	-1.35	< 24.1	1.1	
+3002		333.70	30.05	86.91	-21.66	< 20.7	0.6	

Abdo et al, ApJ Lett
L127-L131 (2009)

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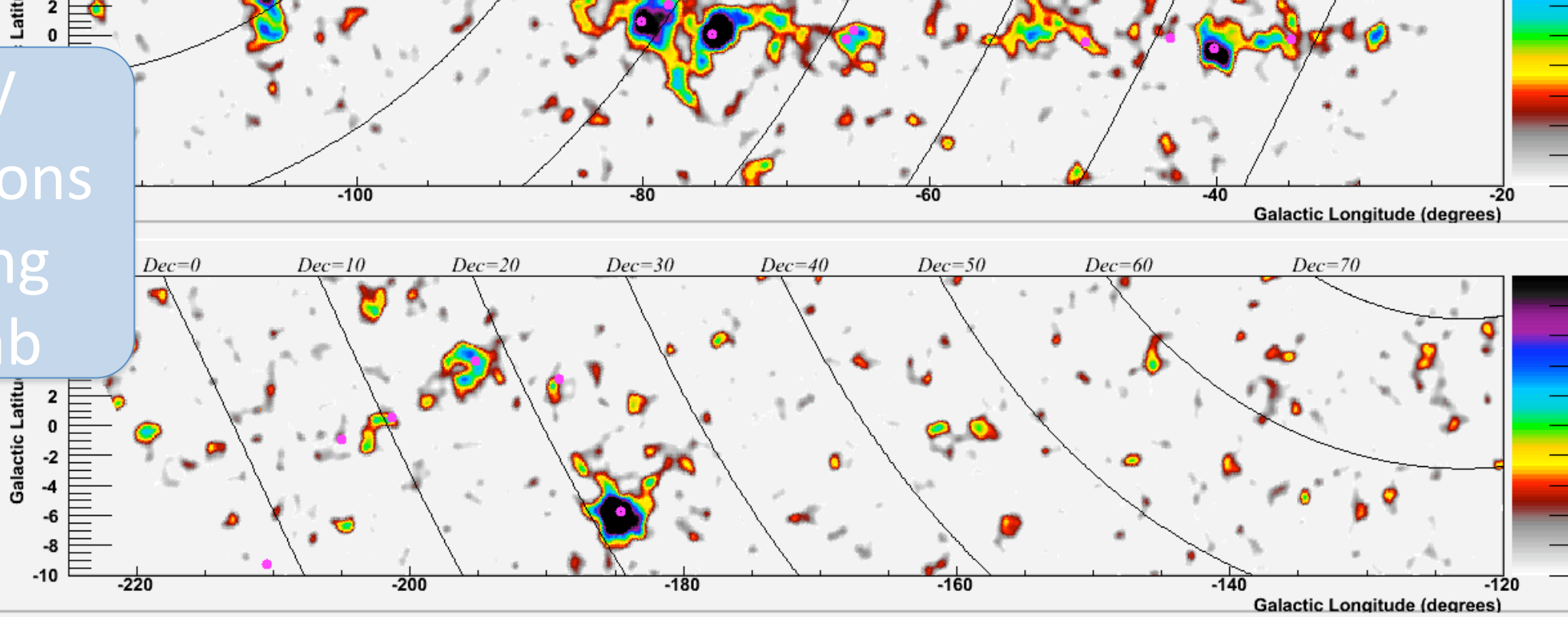
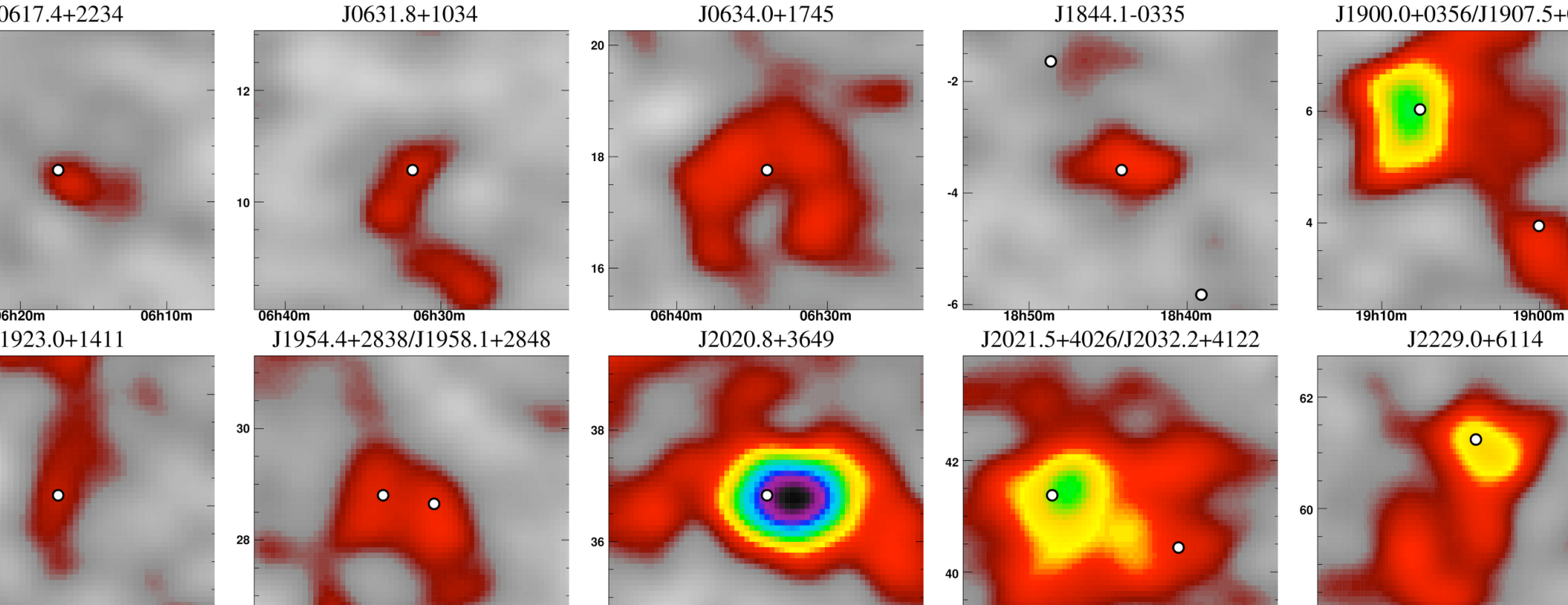
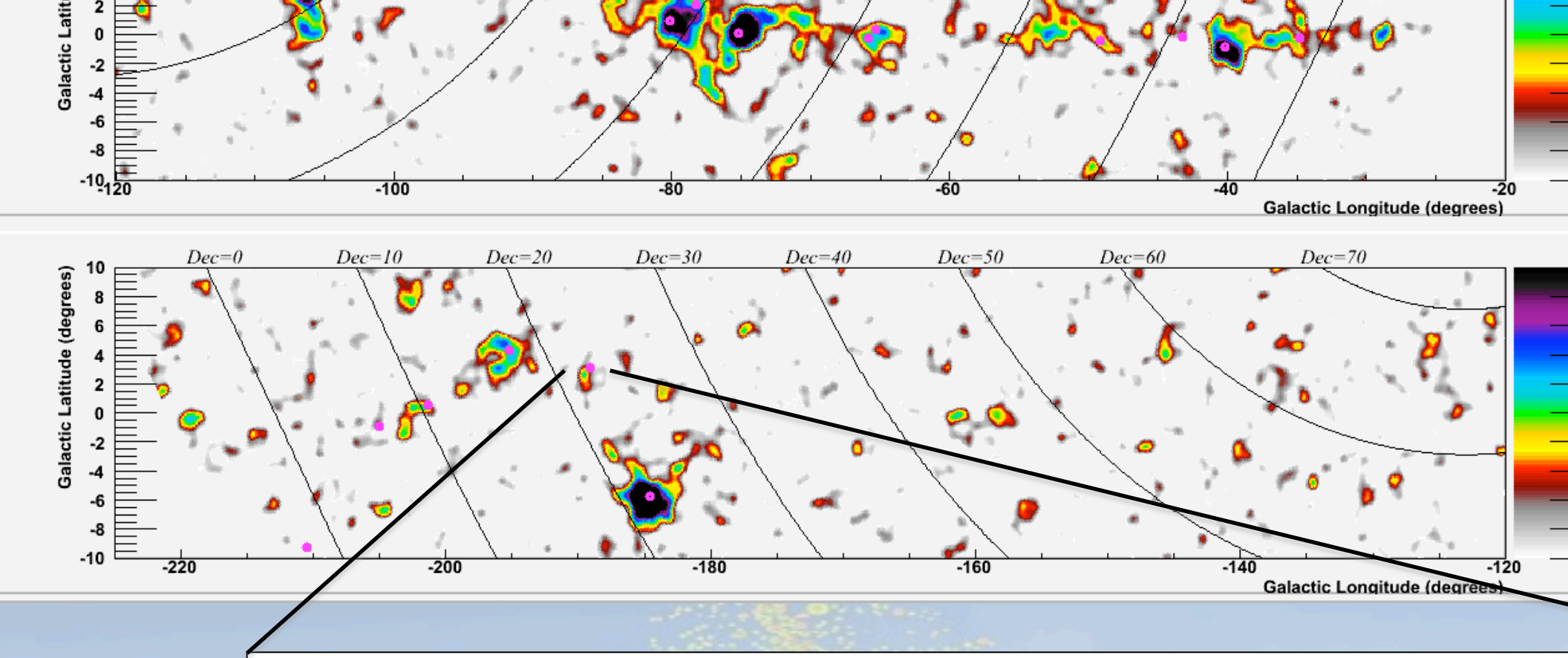
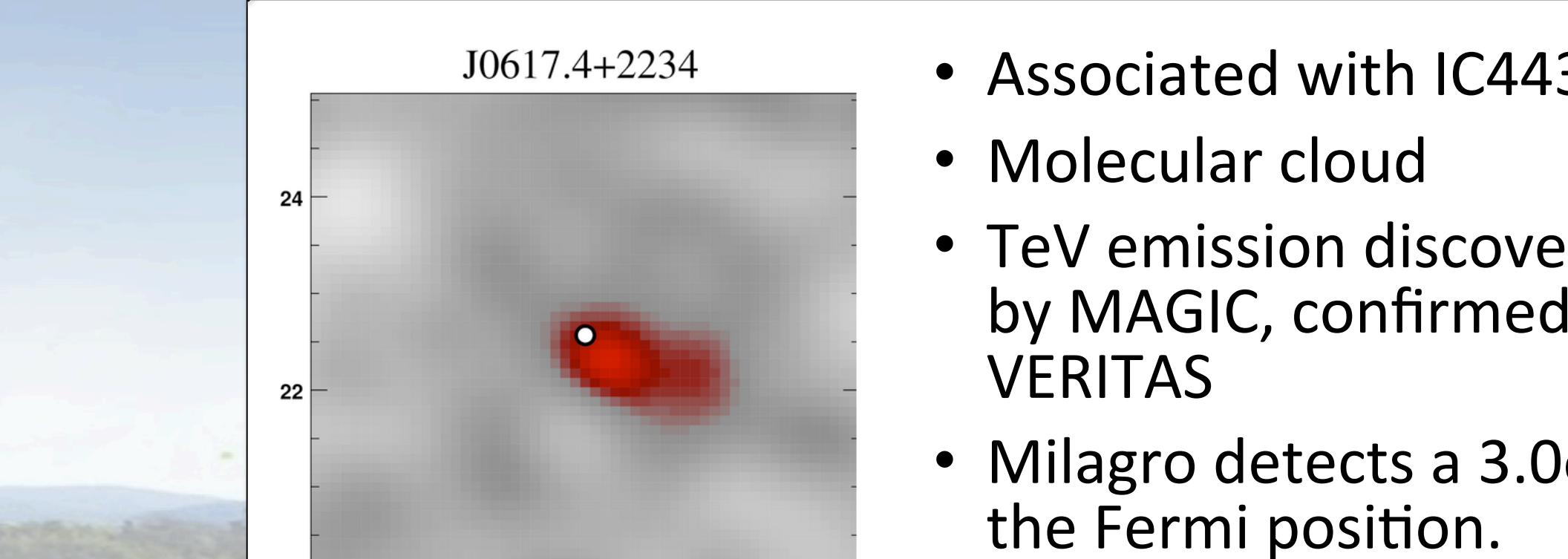
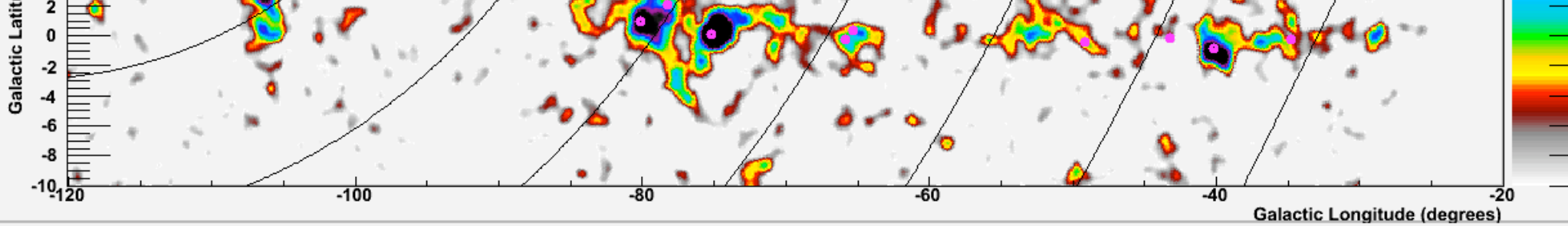


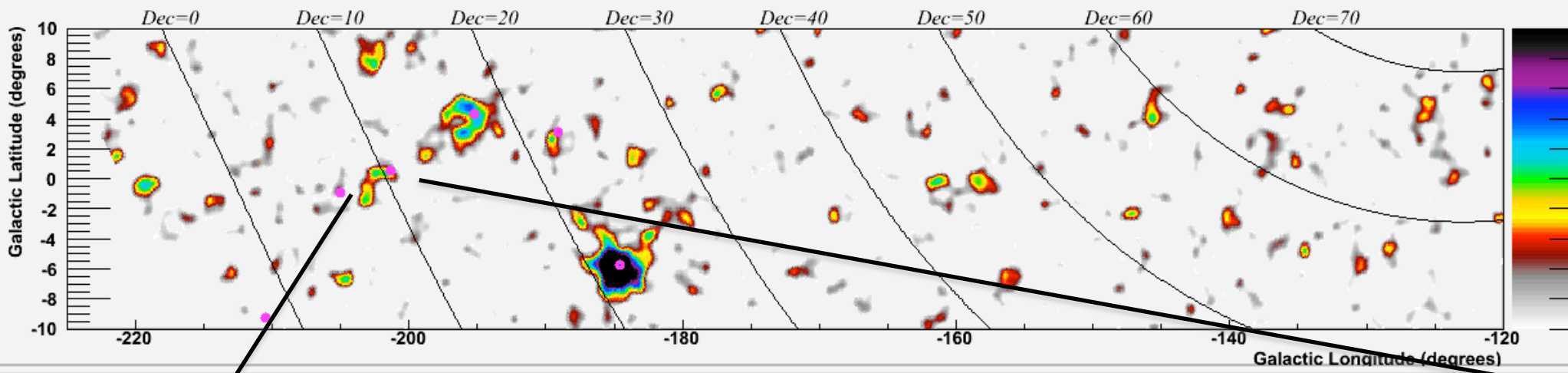






- Associated with IC443
- Molecular cloud
- TeV emission discove by MAGIC, confirmed VERITAS
- Milagro detects a 3.0 the Fermi position.





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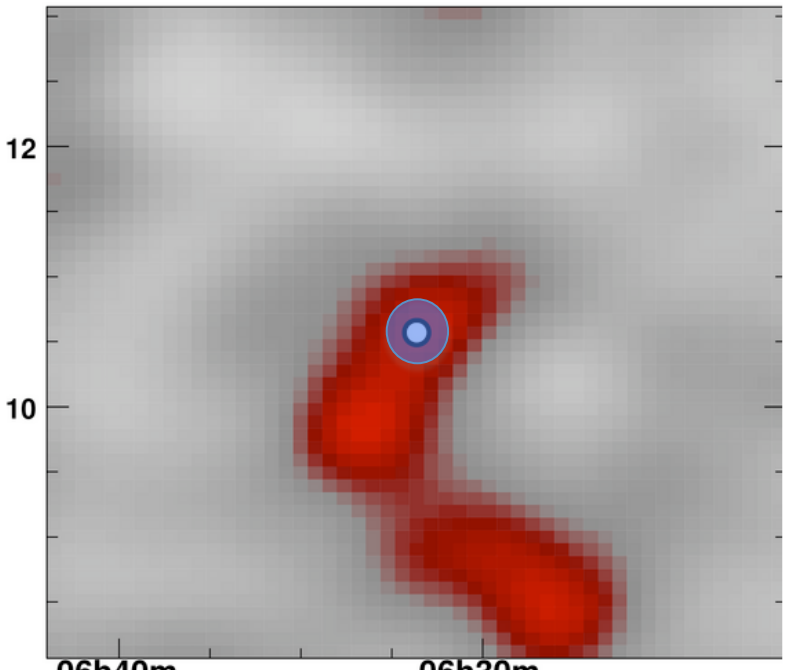
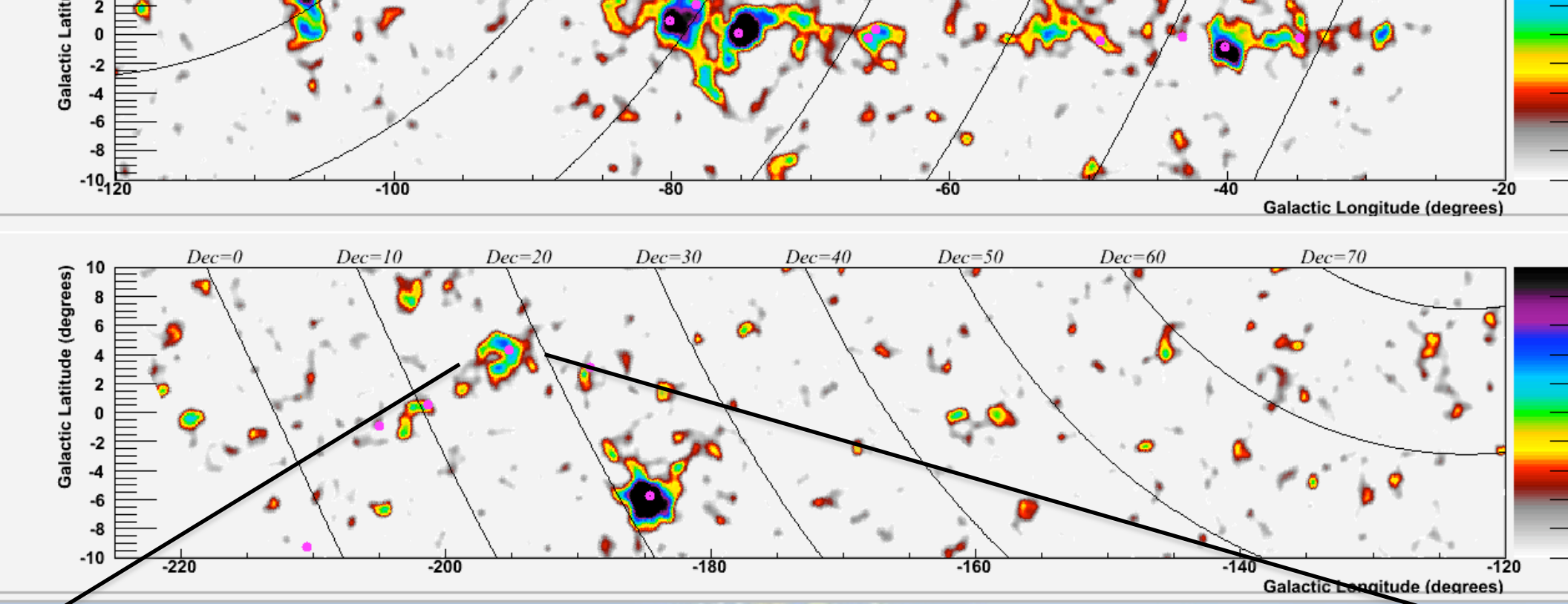
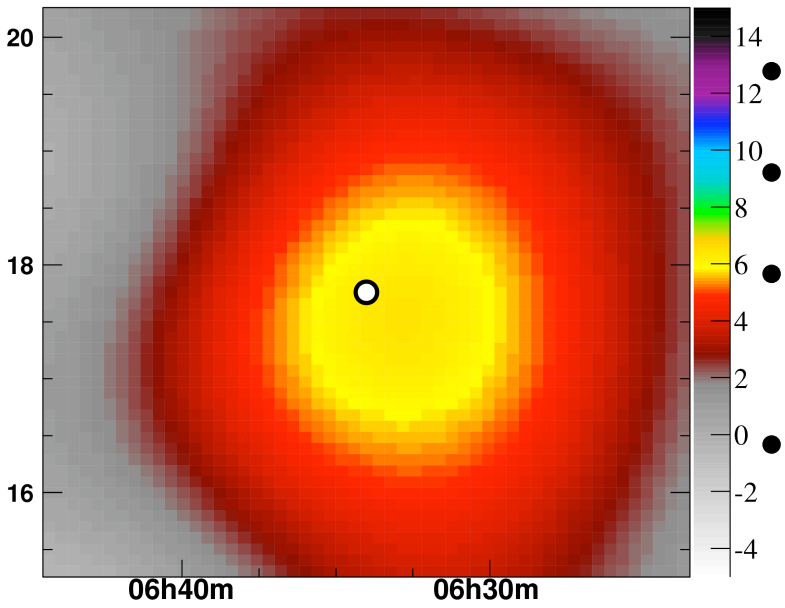
J0631.8+1034

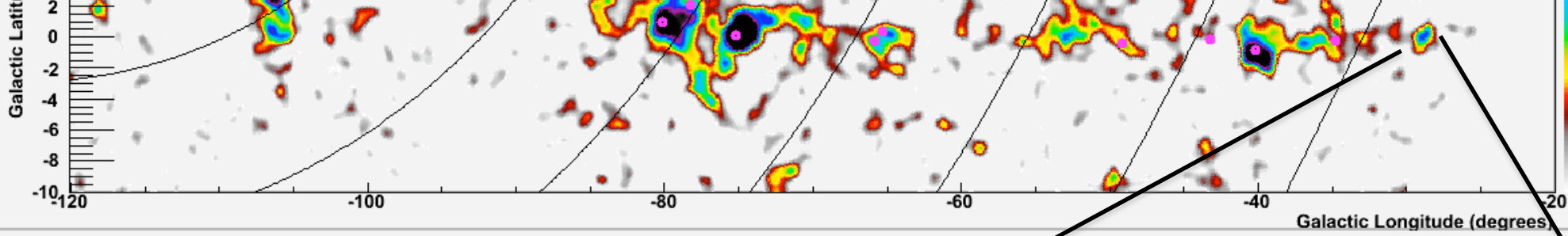


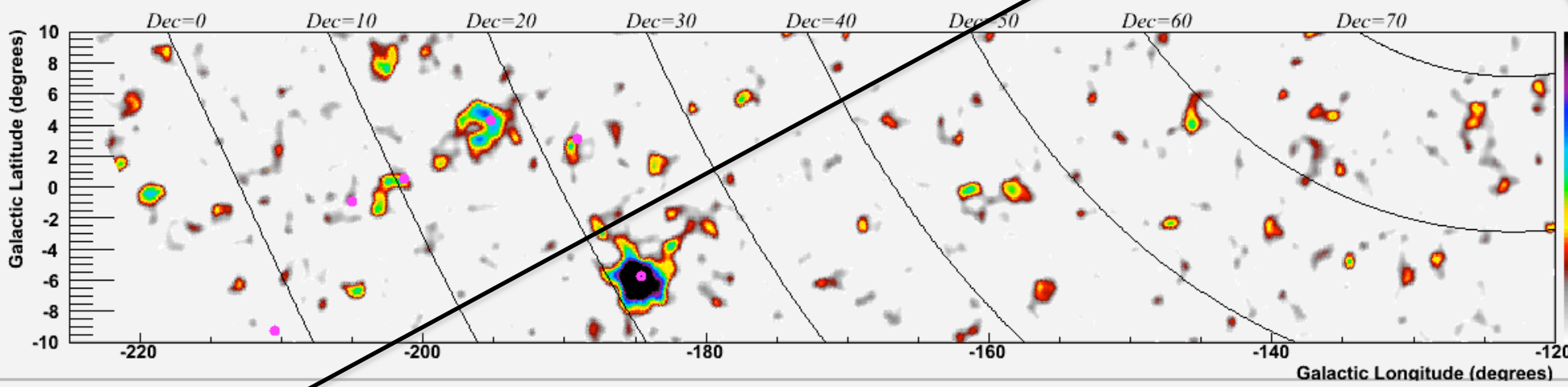
- Radio Pulsar J0631+102
- Period:288ms
- Age: 43000yr
- Distance 6.55 kpc
- VERITAS upper limit 13mC
- Milagro detects a 3.7σ exc

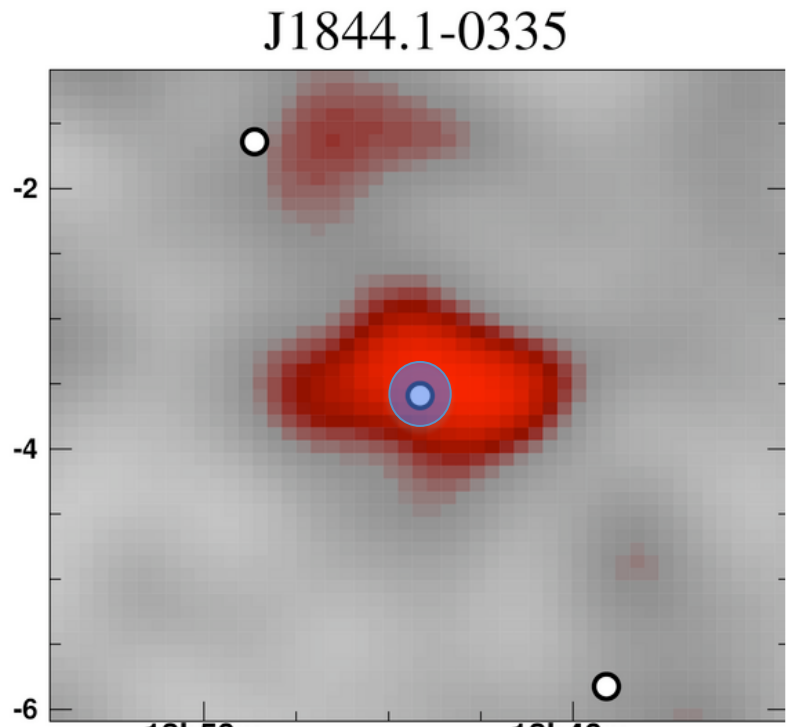




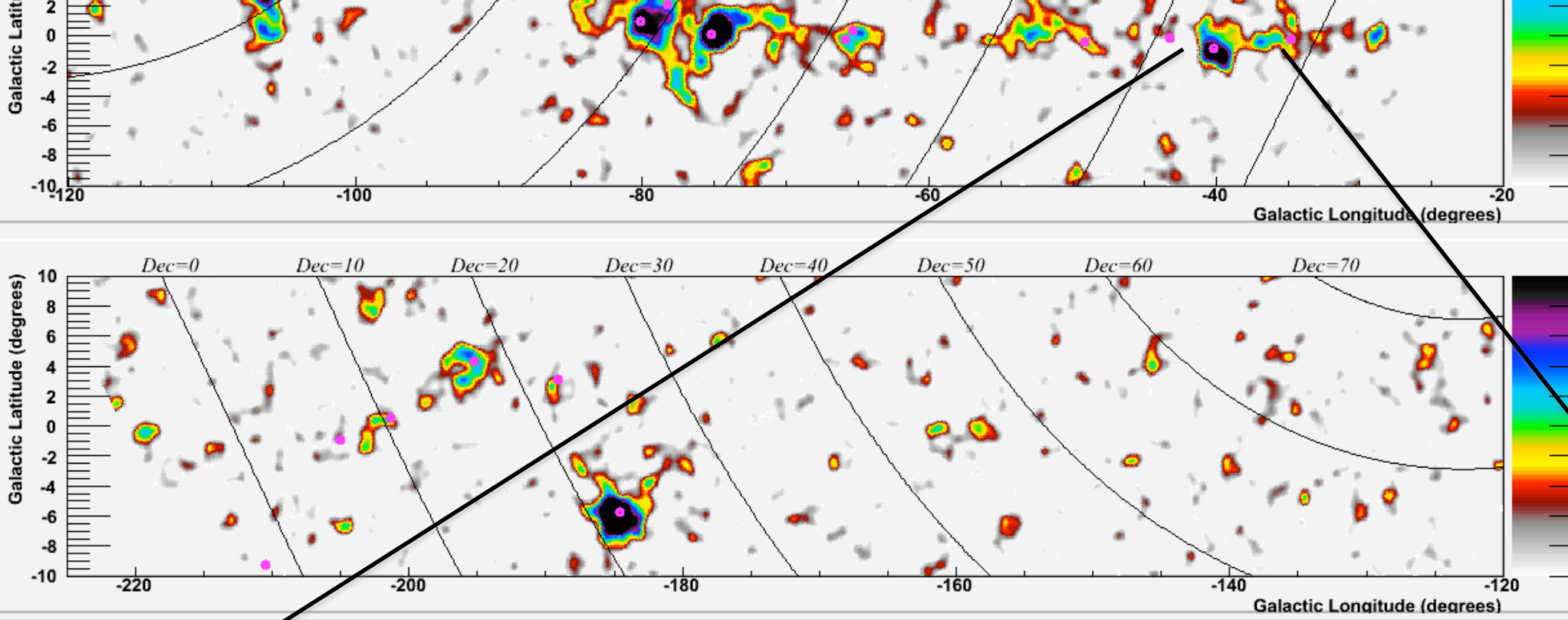
- Most Significant source in BSL
- Old (300 kyr) and nearby (169 pc)
- 3.5σ at the location of Geminga
- 6.3σ when assuming 1° extended source
- Fitted FWHM 2.6° extent, consistent with IACT observations of more distant PWN



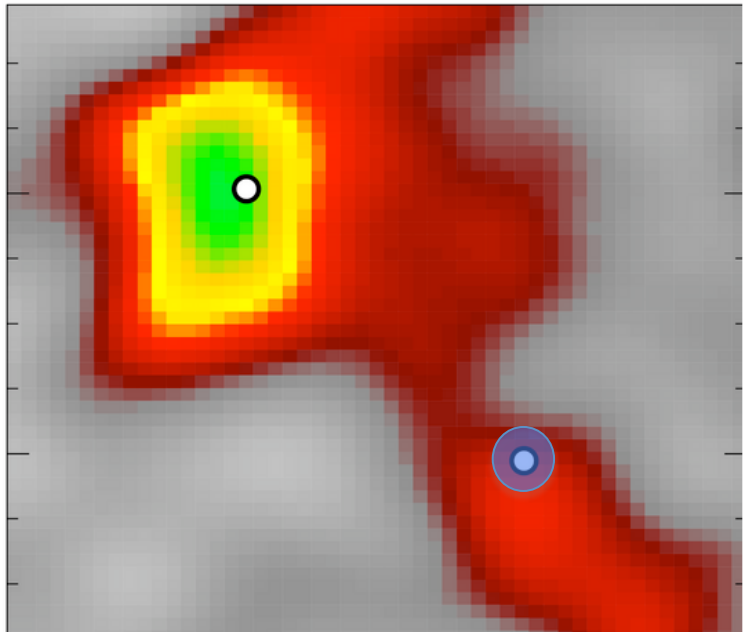




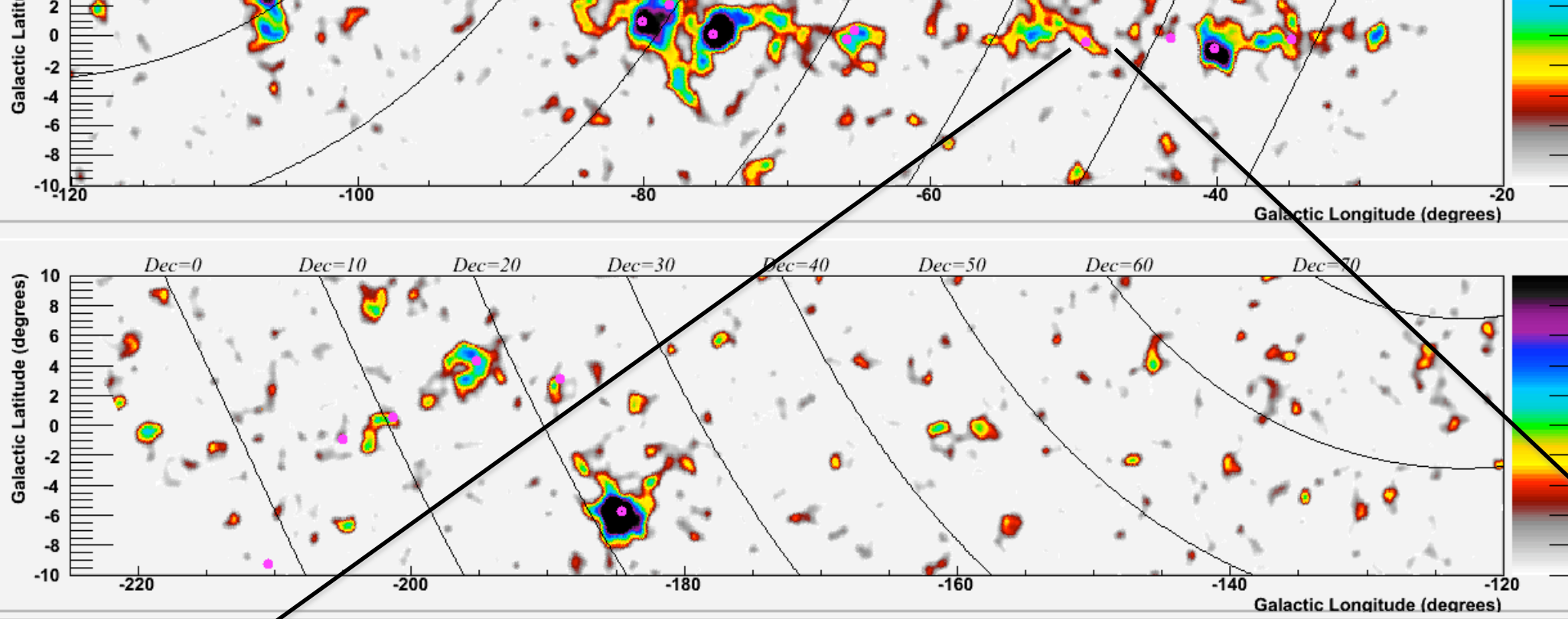
- Unassociated with an known source.
- Very far south -> very luminous at high ener
- Milagro detects a 4.3 excess at the position the Fermi source.

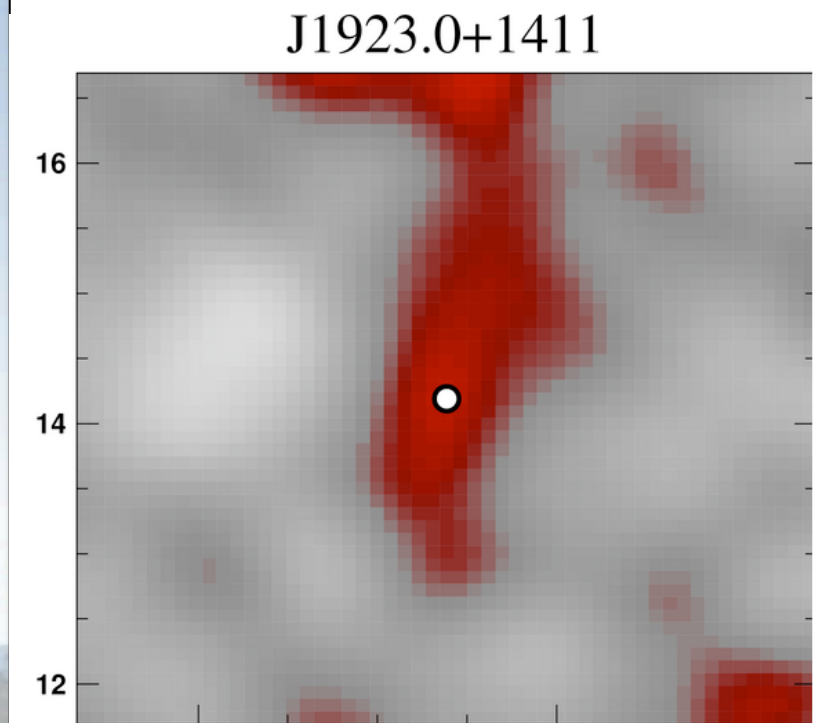


J1900.0+0356/J1907.5+0602

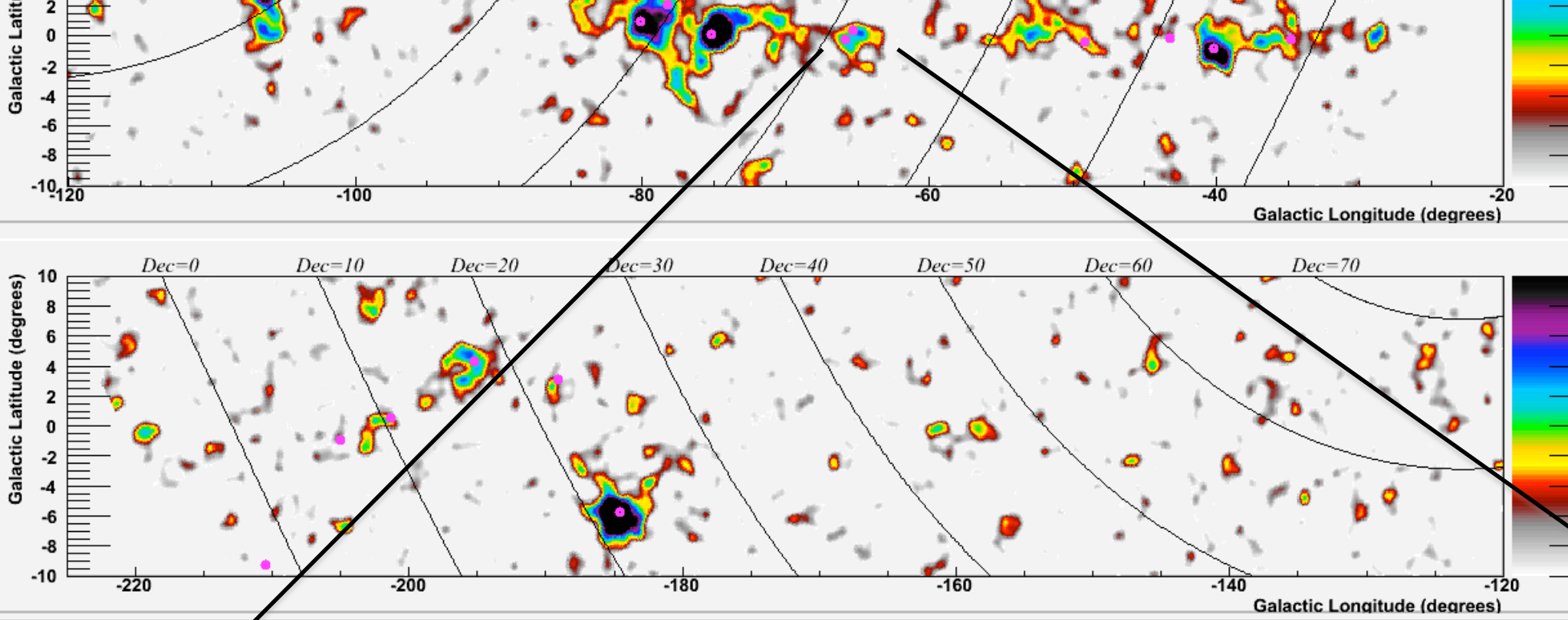


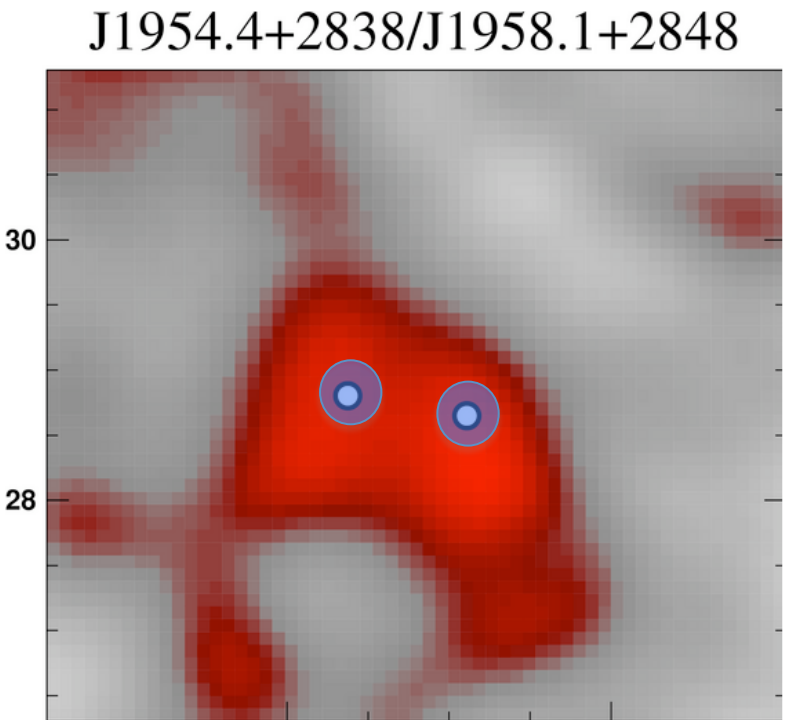
- Associated with MGRO J1908+
discovered by Milagro and cor
by HESS and VERITAS (left)
- J1900.0+0356 has no know
association (right)
- Milagro detects an excess of 7
and 3.6σ respectively at the lo
of the Fermi sources.



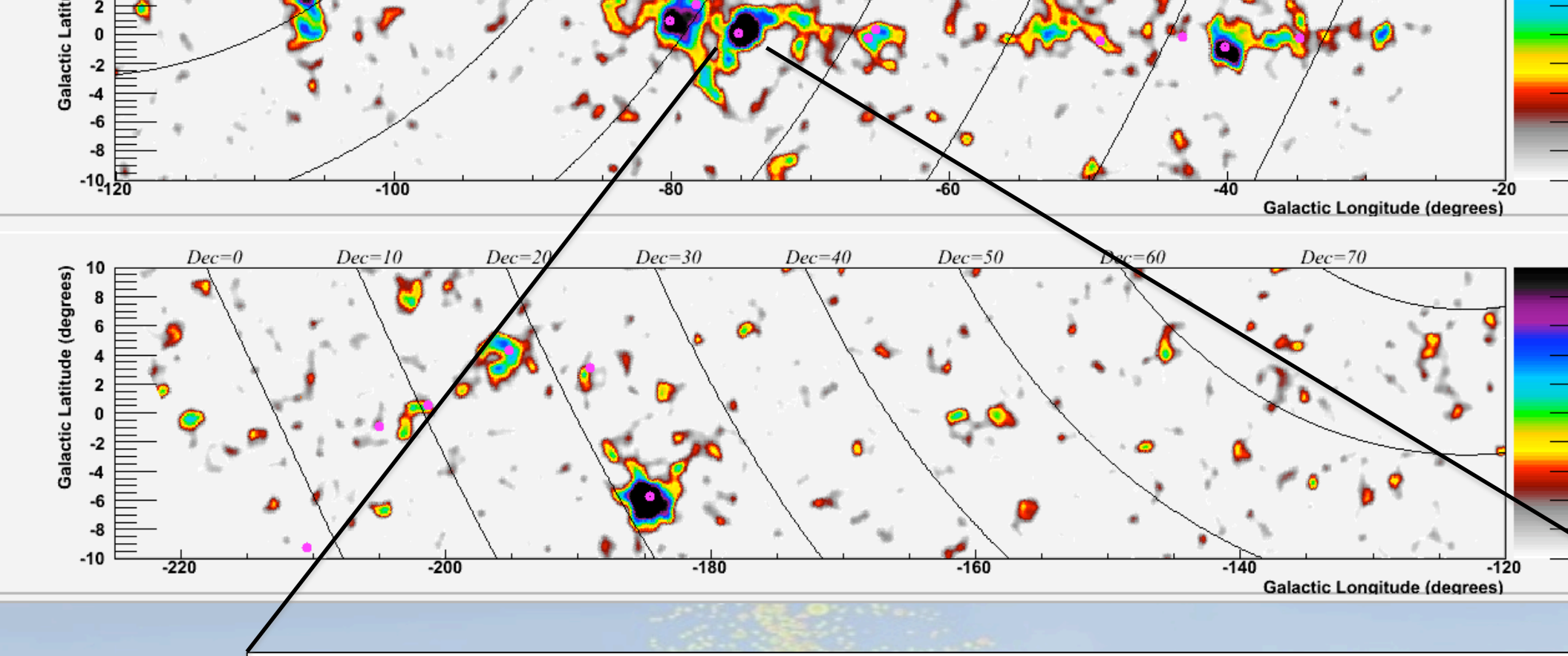


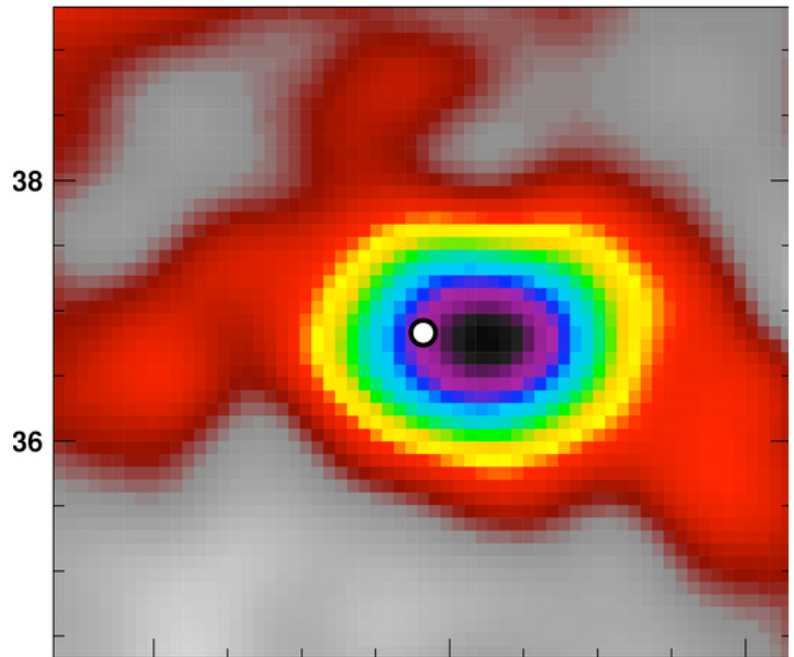
- Associated with SNR G49.2-0.7 (W51)
- HESS reported a detectio coincident with this sour
- Milagro detects a 3.4σ e at the position of the Fe source



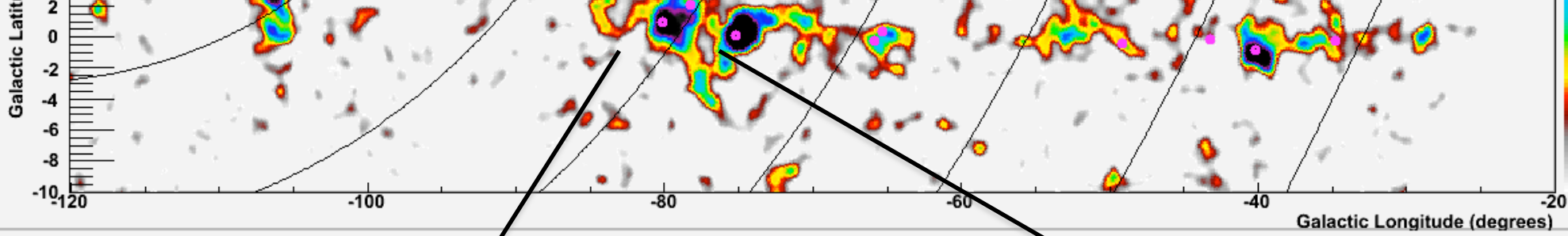


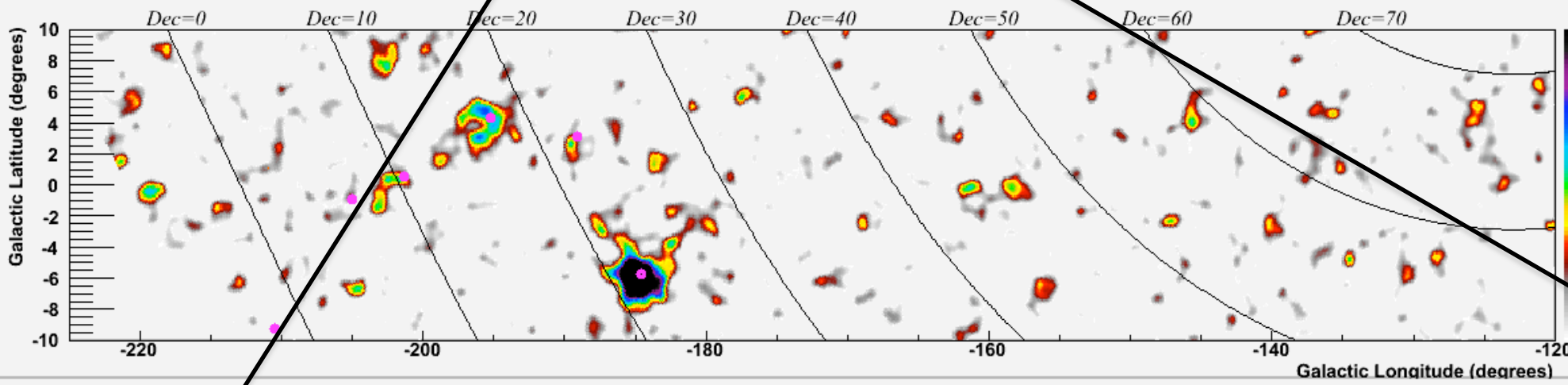
- Coincident with SNR G65.1+0.6 (left) and pulsar PSR J1957+28 (right)
- Milagro detects exce of significance 4.3σ a 4.0σ respectively.



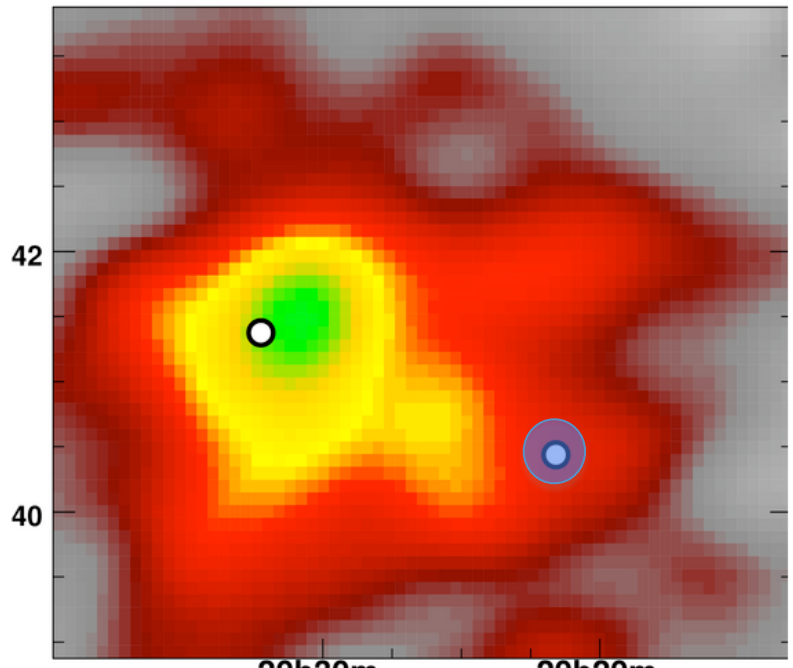


- BSL source associated with pr reported MGRO J2019+37
- Most significant source in the data set apart from the crab.
- Young pulsar (17.2kyr) discove AGILE
- Milagro detects a 12.4σ excess position of the Fermi source

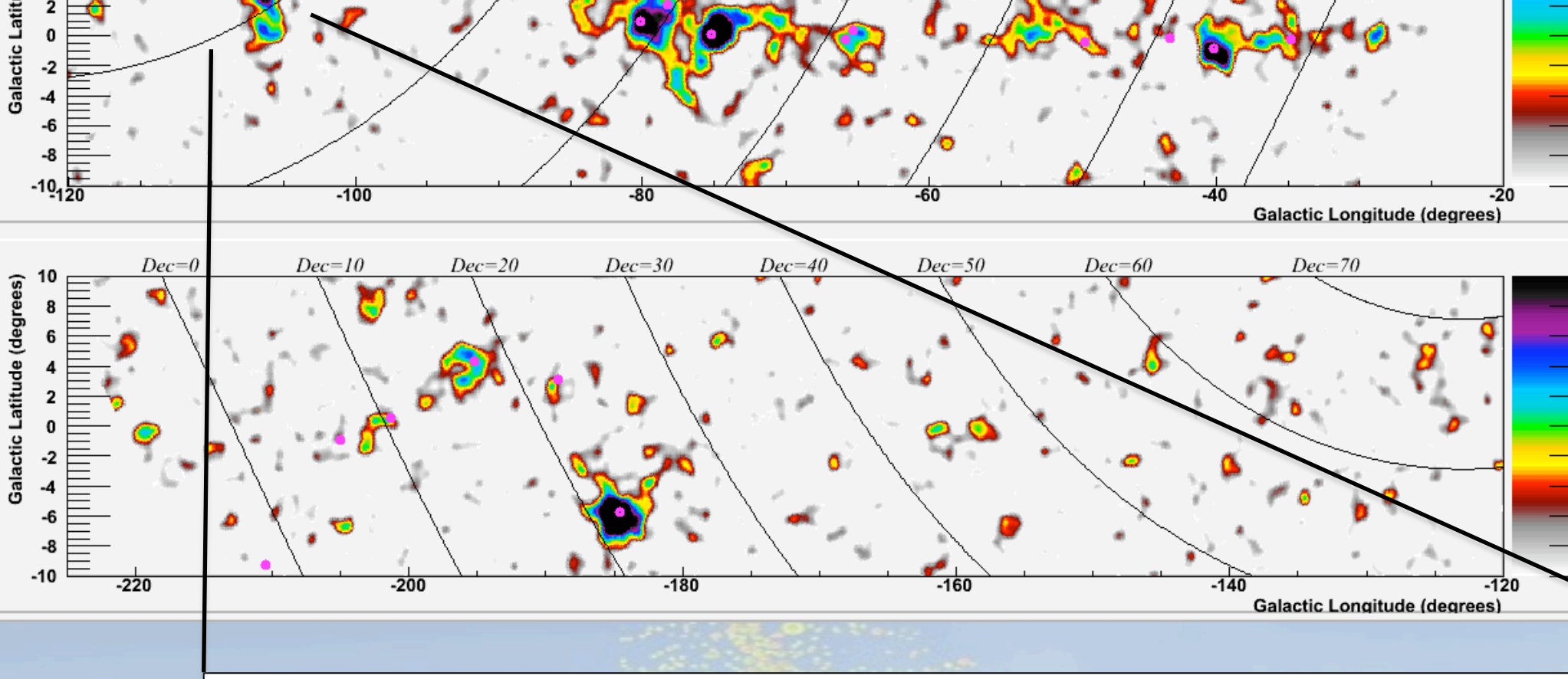


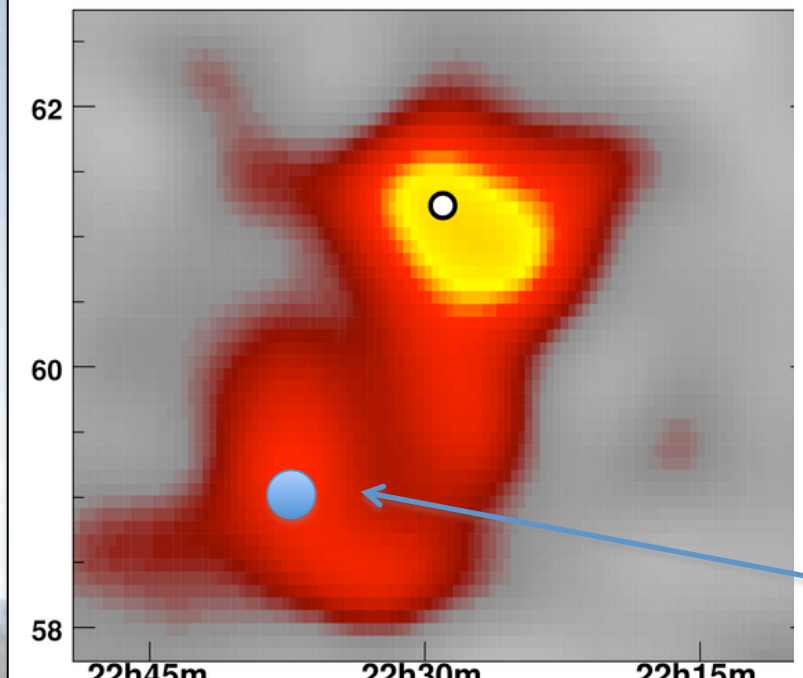


J2021.5+4026/J2032.2+4122



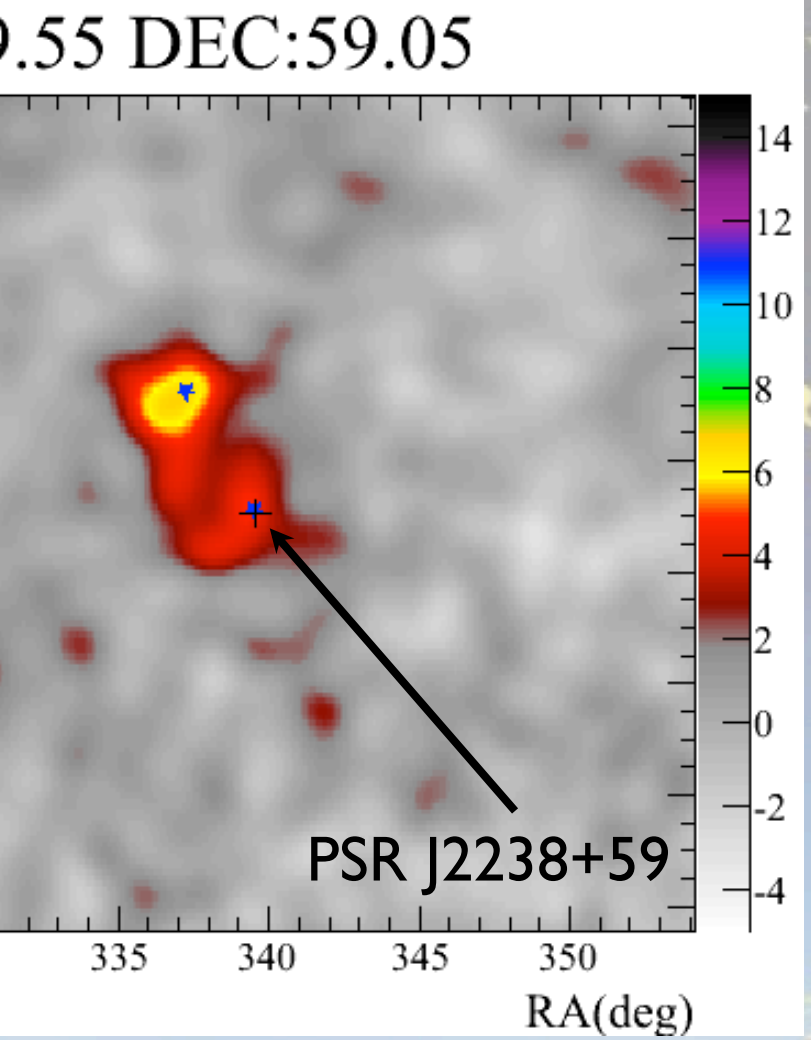
- J2021.5+4026 LAT discovered associated with gamma-Cygni
- J2032.2+4122 is a LAT discove pulsar associated with HEGRA, Milagro and MAGIC TeV detec
- Milagro observers excesses of and 7.6σ respectively at the po of the Fermi sources.





- "Boomerang" PWN, Also detected VERITAS
- Associated with radio pulsar J2229
- Milagro detects a 6.6σ excess at th location of the Fermi source.
- Noted excess was very extended (
- New Fermi pulsar (Science last Sur located in the southern 'tail' with Milagro data.

on	lat	P-dot	E-dot	d (kpc)	d (kpc)	E-dot/d^2	Energy Flux	Fermi TS	Milagro (σ's)	Signif ratio	
			10^{34} erg/s			10^34 erg/s/kpc^2	ergs/cm^2/s				
19.7	10.5	361	45.2	1.4	1.4	23.1	38.2	7384	2.6	33.1	
13.1	-57.6	1.00E-05	0.3	0.3	0.3	3.3	5.3	960	-1.7		
30.7	3.1	194	2700	2.9	2.9	321.0	6.6	346	-1.0		
39.5	-17.5	7.70E-06	24	2.5-4	3.25	2.3	3.6	119	2.9		
37.0	0.4	55.1	21	2-9	2-9		3.07	103	1.54		
62.7	-16.0	12.0	0.5		0		6.38	949	-0.1		
53.4	-42.0	1.40E-05	0.3	0.156	0.156	12.3	1.9	172			
84.6	-5.8	423	46100	2.0	2.0	11525.0	130.6	21507	17.2	8.5	
10.4	-9.3	9.00E-06	1.3	0.48	0.48	5.6	3.2	285	0.0		
01.2	0.5	105	17.3	0.75-3.62	2.25	3.4	3.0	86	3.7	2.5	
05.0	-1.0	79.5	11.9		0		8.0	370	1.4		
95.1	4.3	11.0	3.3	0.25	0.25	52.8	338.1	62307	3.5	71.3	G
01.1	8.3	55.0	3.8	0.288	0.288	45.8	3.2	206	0.8		
43.8	-2.4	16.8	14.3	2.07	2.07	3.3	1.8	47			
02.7	21.1	6.00E-06	0.6	0.60	0.60	1.7	1.1	37	-0.4		
63.6	-2.8	124	688	2.87	2.87	83.5	879.4	219585			
85.1	-0.5	16.1	83.2	2.33	2.33	15.3	17.7	620			
87.4	0.6	96.3	201	2.71	2.71	27.4	17.2	881			
86.0	6.6	5.8	3.0	0.72	0.72	5.8	27.2	4961			
92.0	1.8	747	1190	4.8	4.8	51.6	3.8	111			
13.3	0.1	170	495	2-5	2-5		23.5	162			
13.5	0.2	83.2	1000	5.6	5.6	31.9	15.8	63			
17.9	-1.8	25.5	91.9		0		10.56	337			
20.0	-0.6	9.2	51.5	2.6	2.6	7.6	9.7	262			
52.5	20.3	4.00E-06	0.5	1.27	1.27	0.3	2.7	149			
43.1	-2.7	93.0	341	1.4-3.6	2.5	54.6	124.0	16009			
49.0	-0.4	13.2	125	3.82	3.82	8.6	6.7	105			
56.2	0.9	26.1	13.6		0		24.2	1002			
6.4	4.6	16.9	0.9	0.38	0.38	6.2	12.8	935			
4.8	9.2	7.00E-06	0.4		0		2.8	78			
59.3	-0.8	61.3	251	2-5	2-5		13.1	213			
7.4	-2.0	34.4	43.0	1.7	1.7	14.9	41.3	3451			
7.2	2.4	17.6	626		0		16.9	482			
8.5	-0.4	121	358		0		33.4	1152			
21.5	-0.9	202	3370	4.7	4.7	152.6	10.1	110			
38.9	25.0	1.5	1.2	<0.8	0.8	1.9	59.9	20982	-0.9		
40.2	-0.9	87.3	284		0		27.5	1209	7.4	4.7	
68.8	2.8	5.8	374	2.0	2.0	93.5	13.4	1008	0.0		
65.9	-0.2	222	35.8		0		8.45	491	4.0	5.5	
75.2	0.1	95.6	338	2.1	2.1	76.6	47.0	3138	12.4	4.5	
78.2	2.1	54.8	11.6	1.5	1.5	5.2	97.6	10180	4.2	24.0	



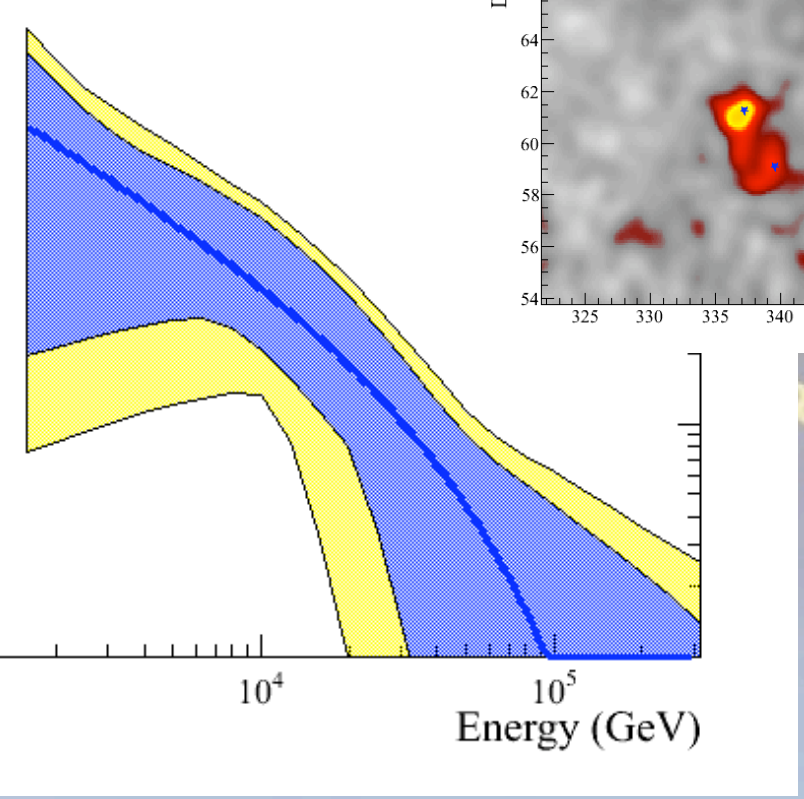
6 additional targets from PSR ca

PSR	Milagro Signif (σ's)	Period (ms)	Age (ky)	E-dot (10^{34} erg
J0205+6449	-0.96	65.7	14	2700
J0218+4232	2.94	2.3	5.00E+05	24
J0248+6021	1.54	217	63	21
J0659+1414	0.84	385	110	3.8
J0751+1807	-0.44	3.5	8.00E+06	0.6
J2043+2740	-0.88	96	1200	5.6
J2238+59	4.70	163		90.3

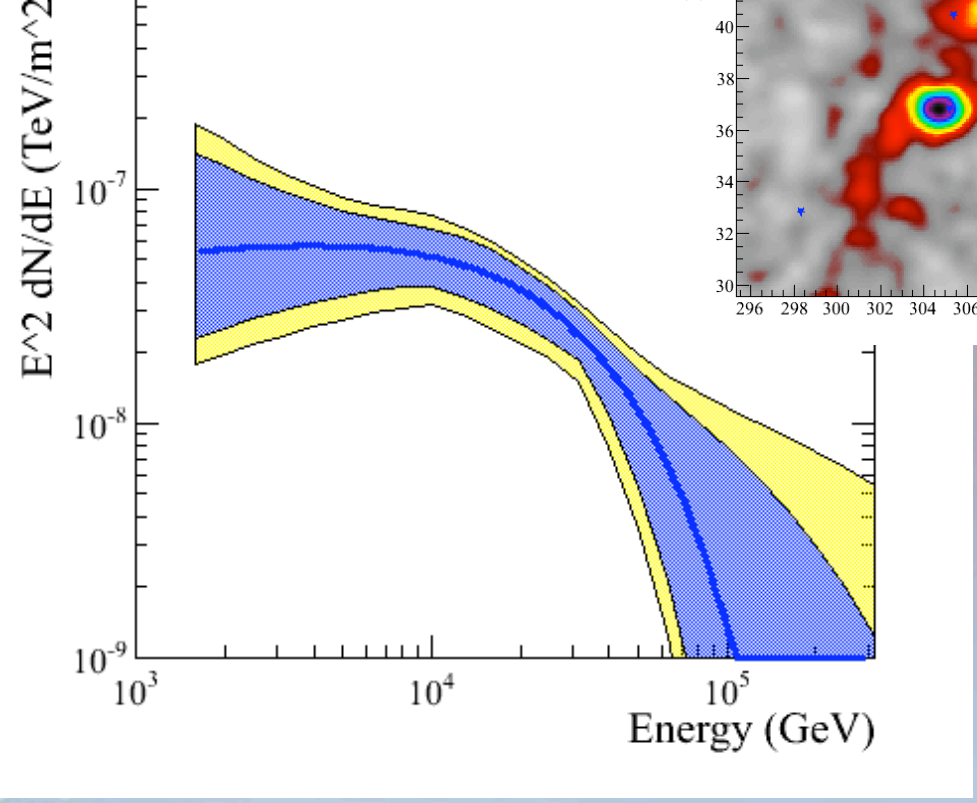
ignificance detections all have high $\dot{E}/d^2$:
+2200 (17.2σ), J2229+6114 (6.6σ), J2021+3651 (12.4σ)

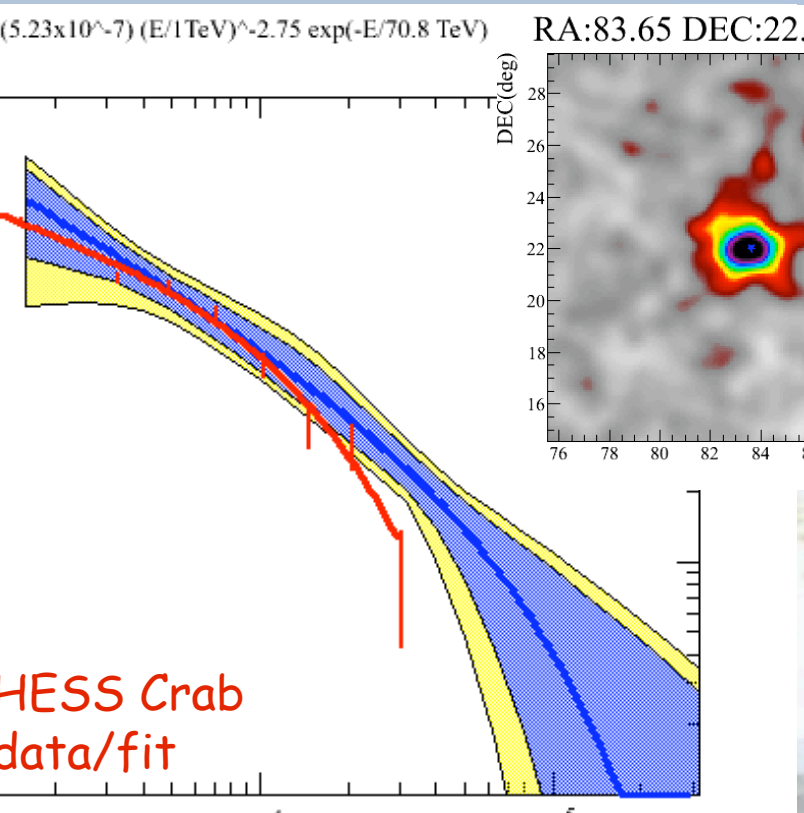
ome high $\dot{E}/d^2$ pulsars are not observed:
+6449 (-1.0σ), J1952+3252 (0.0σ)

r correlation found in HESS PWN (Carrigan, S., et al. 2007, in Proceedings

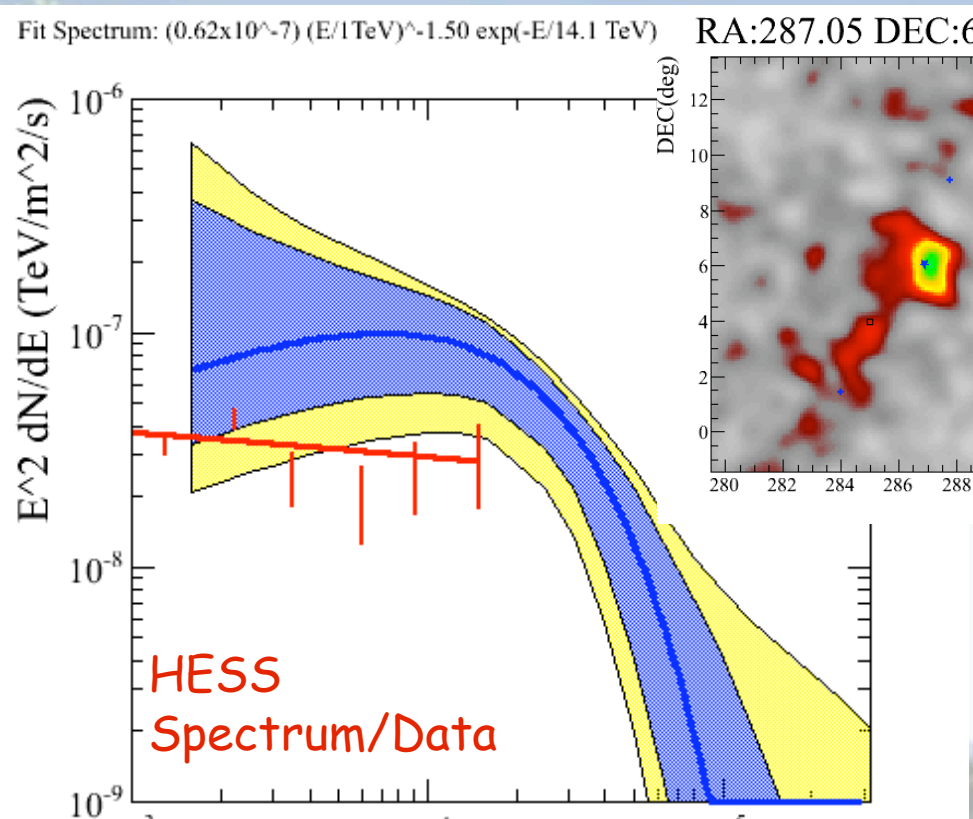


PSR J2021+3651





PSR J1907+06



Conclusions

ilagro was decommissioned in June 2008 and analysis
nal dataset is nearly complete.

st of sources and potential TeV emitters is growing. Ap
be mostly TeV PWN associated with MeV-GeV pulsars

tended PWN with spectra extending past 10 TeV comm
GeV pulsars.

vidence of spectral break if hard spectral index is assum