UNIVERSITAT DE BARCELONA

Libertas Perfundet Omnia Luce

Institut de Ciències del Cosmos

Gamma-ray unidentified sources

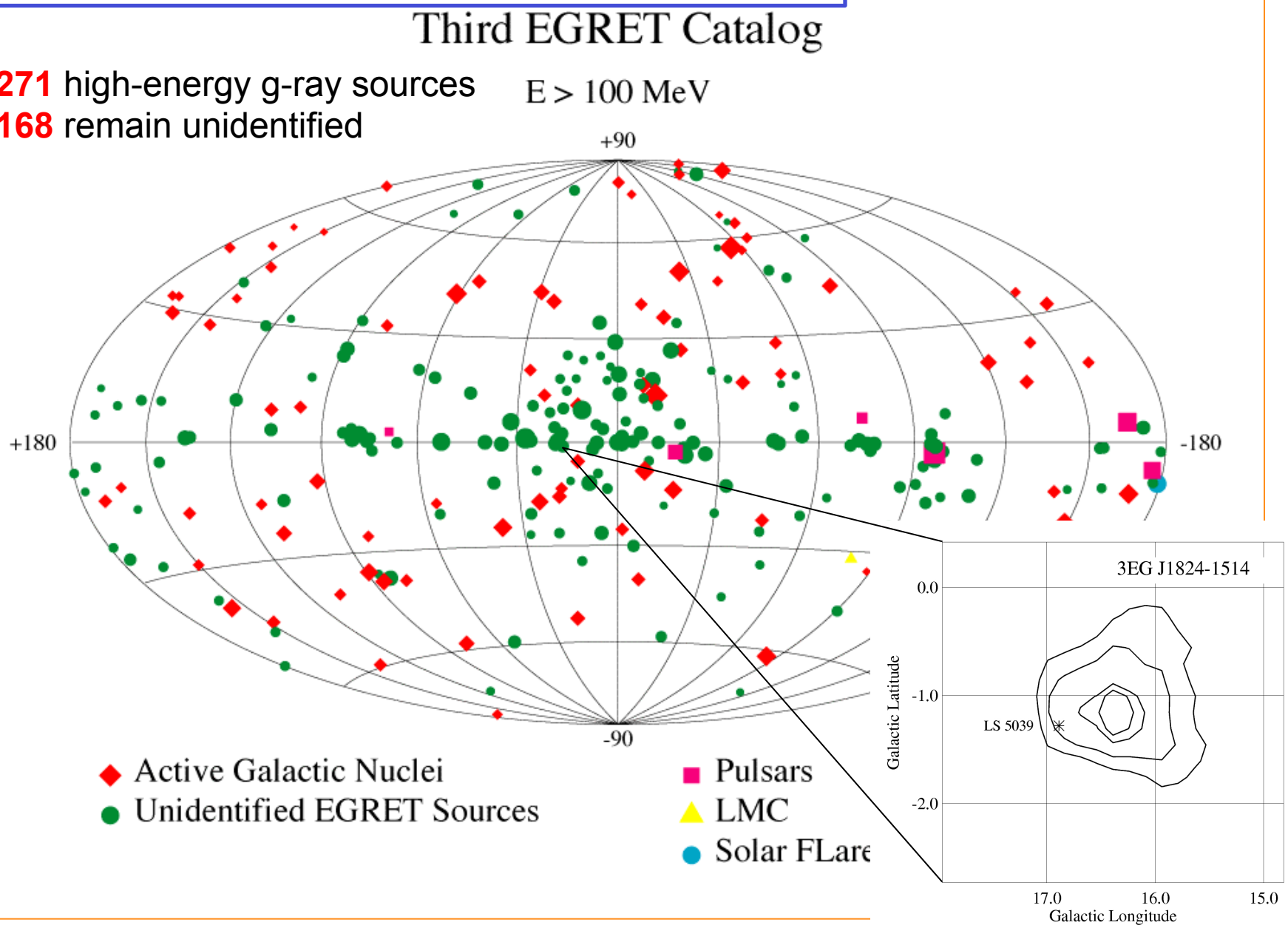
Josep M. Paredes

Physics with GAMMA-400
International Center Theoretical Physics (ICTP), Trieste
May 2 – 4, 2013

OUTLINE

1. The past in GeV: EGRET unidentified sources
2. Past and present: TeV unidentified sources
3. The present in GeV: Fermi unidentified sources

The HE (EGRET) gamma-ray sky

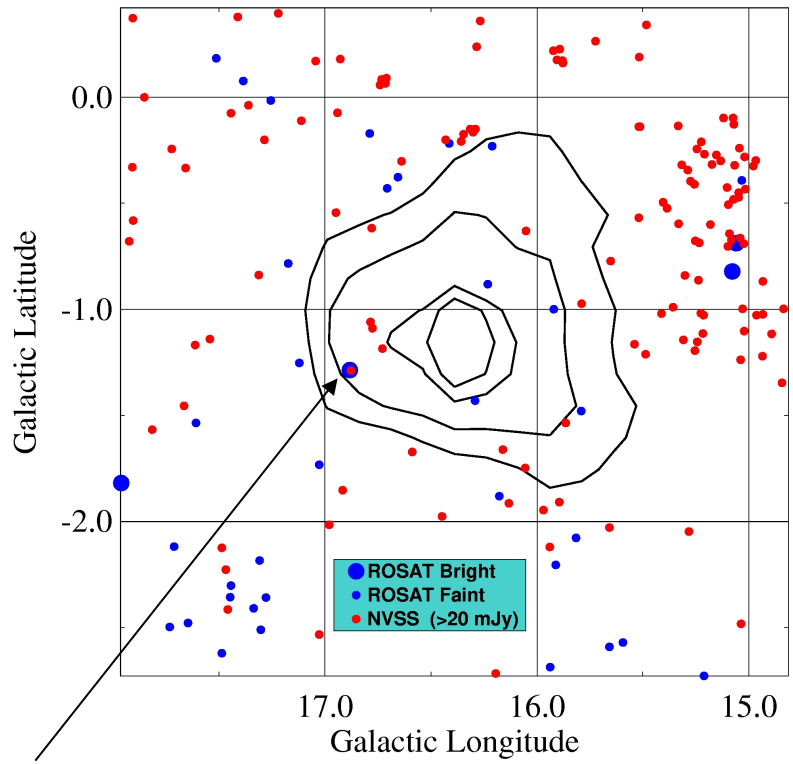


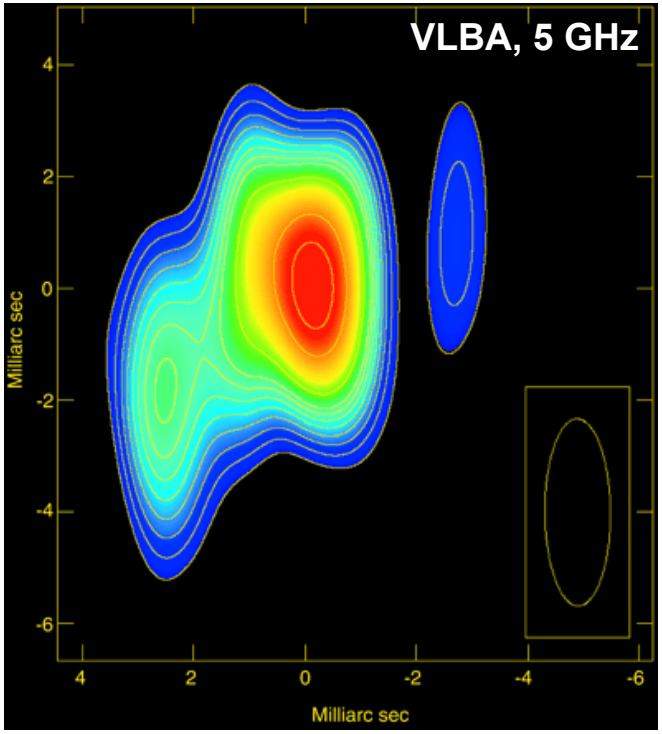
271 high-energy g-ray sources
168 remain unidentified

Hartman et al. 1999, ApJS 123, 79

EGRET candidate: LS 5039

3EG J1824-1514





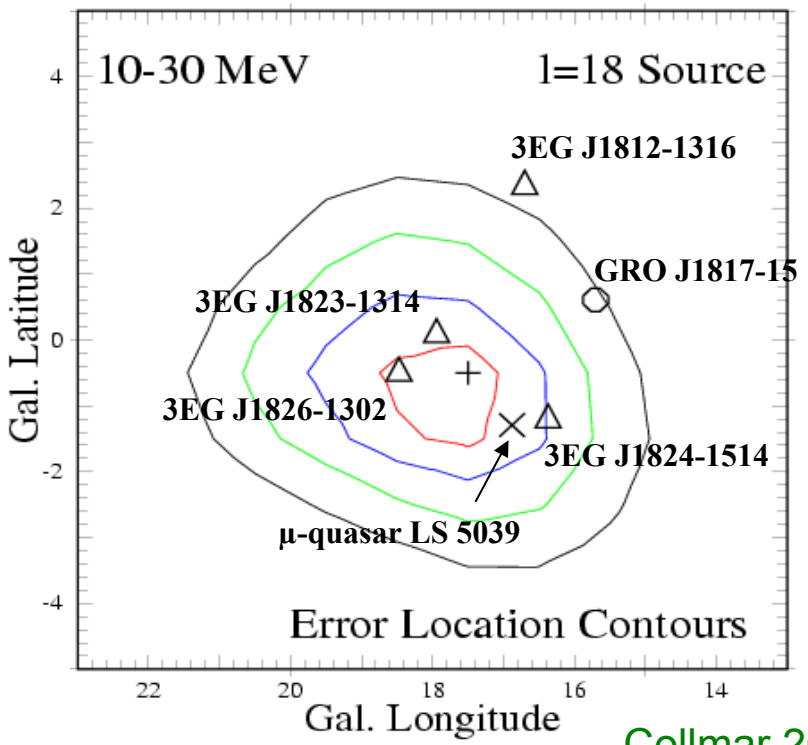
It is the only simultaneous X-ray/radio source within the 3EG J1824-1514 statistical contours

LS 5039 could be related to the high energy γ-ray source 3EG J1824-1514

Paredes et al. 2000, Science 288, 2340

GRO J1823-12 (l/b: 17.5/-0.5)

COMPTEL



Summary

- complicated source region
- possible counterparts:
  - 3 known γ-sources (unid. EGRET) (MeV emission: superposition ?)
  - micro quasar RX J1826.2-1450/LS 5039 (sug. counterpart of 3EG J1824-1514; Paredes et al. 2000)
- work in progress

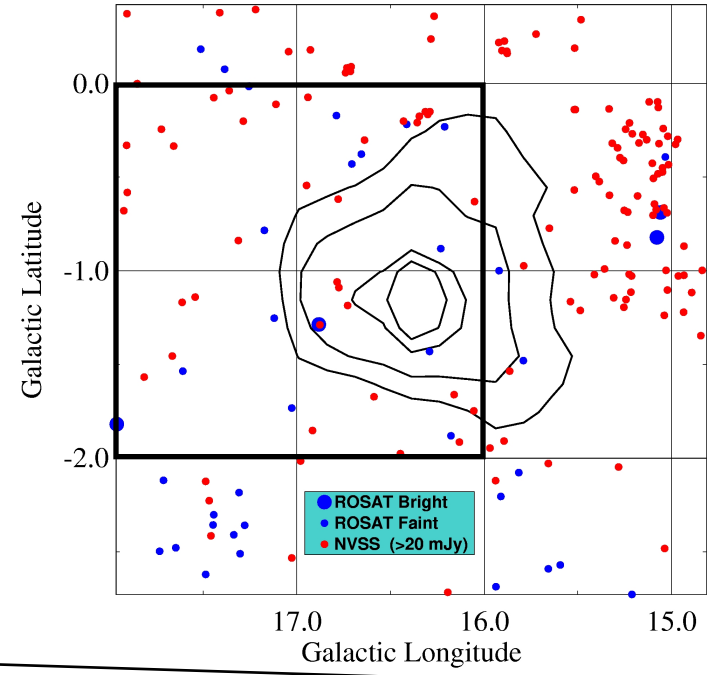
Collmar 2003, Proc. 4th Agile Science Workshop

Light curve with variable flux at 10-30 MeV !!!

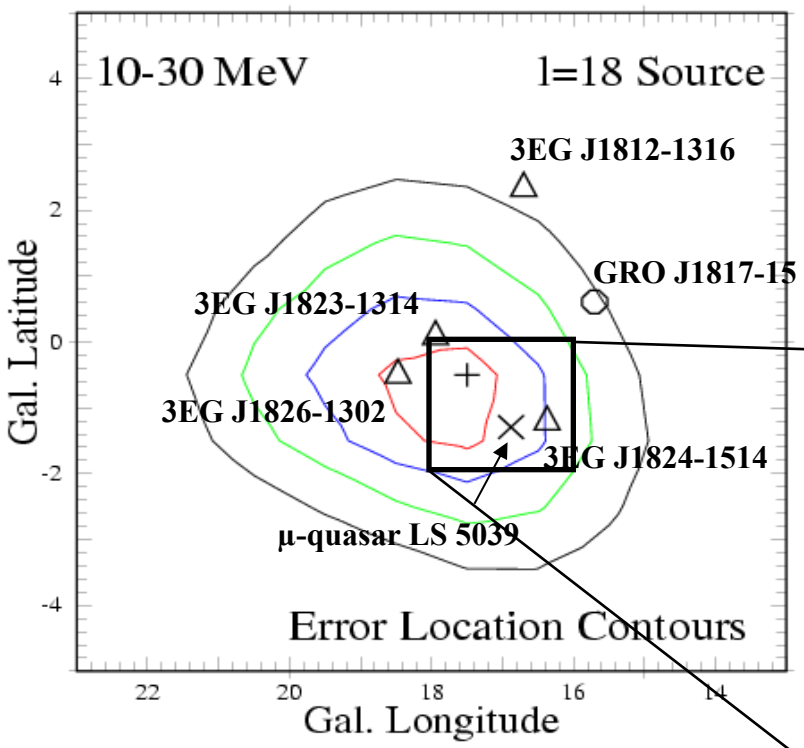
Collmar 2013, Variable galactic γ-ray sources, Barcelona, 16-18 April 2013

Reminder of different error box sizes. **Importance of position accuracy from TeV observations**

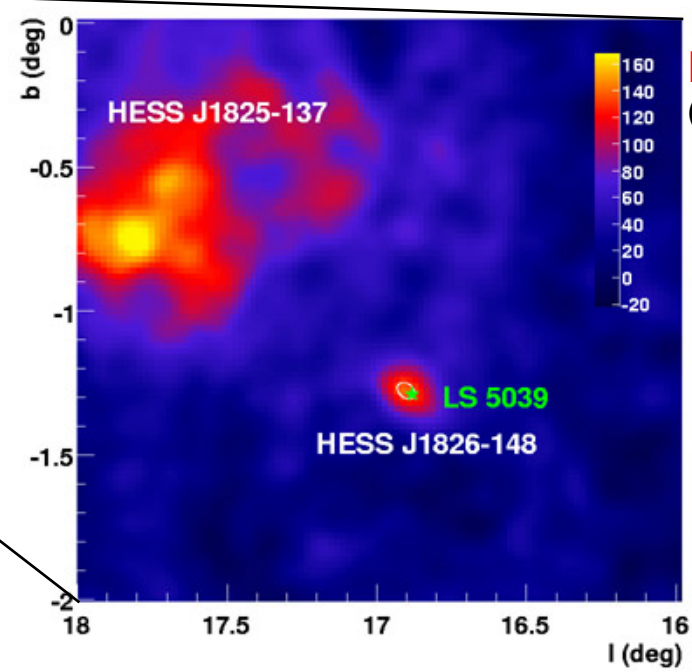
EGRET



COMPTEL

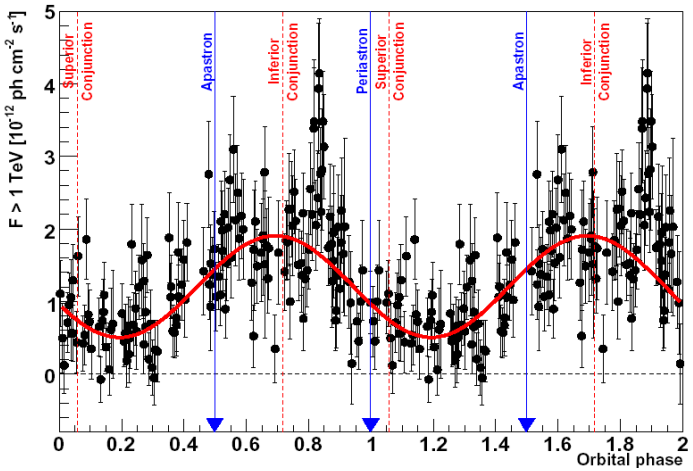


HESS
(> 100 GeV)



The source is point-like with a size upper limit of 50 arc sec (1σ) Aharonian et al. 2005, Sci 309, 746

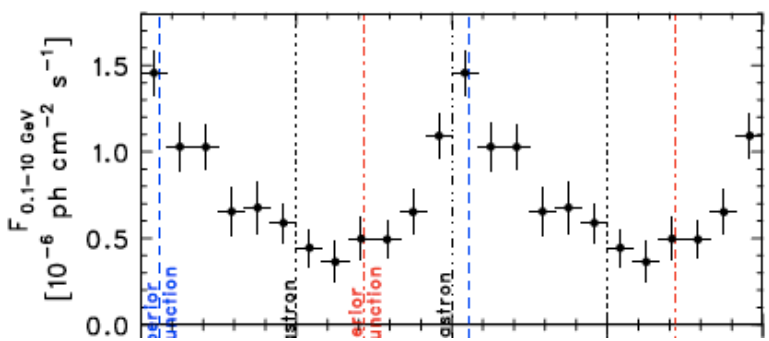
H.E.S.S.



H.E.S.S. found orbital modulation of the VHE γ-ray flux Aharonian et al. 2006, A&A 460, 743

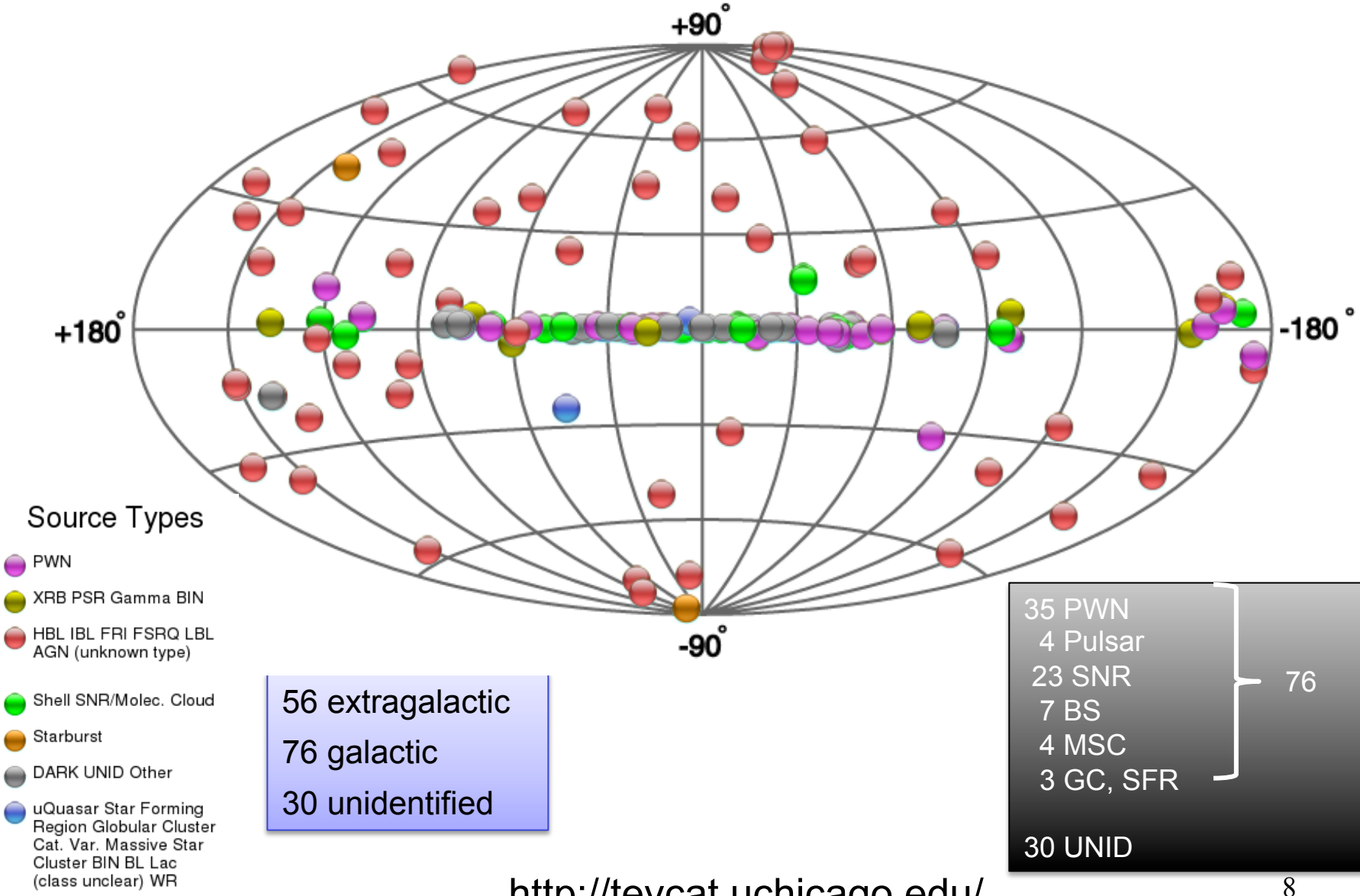
Fermi (> 100 MeV) detected LS 5039 at a level of 28.5σ and the location with a 95% error of 0.054° Abdo et al. 2009, ApJ 706, L56

Fermi



The initial association of LS 5039 with the EGRET source 3EG J1824–1514 (Paredes et al. 2000b) had remained tentative due to the large EGRET error circle and the lack of timing signatures. The association was bolstered by the discovery of point-like, modulated gamma-ray emission above 100 GeV (Aharonian et al. 2005b, 2006). The *Fermi* observations enabled the detection of an orbital modulation, indicating that the binary is also a source of gamma rays above 100 MeV.

The VHE (E_γ > 100 GeV) gamma-ray sky



56 extragalactic
76 galactic
30 unidentified

35 PWN
4 Pulsar
23 SNR
7 BS
4 MSC
3 GC, SFR
} 76

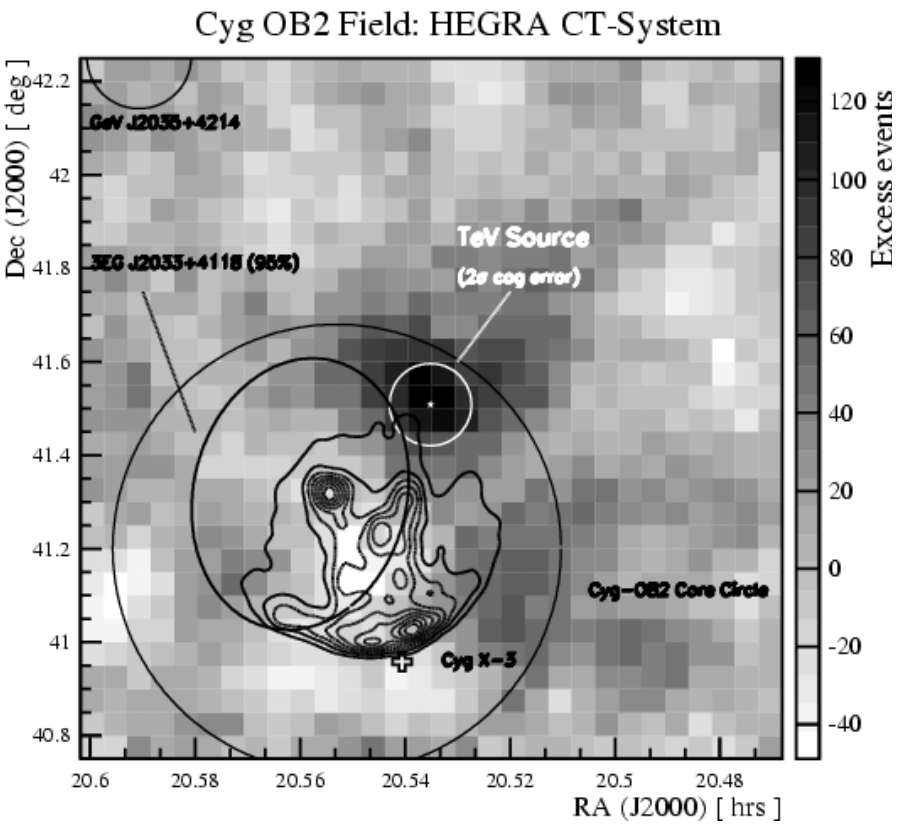
30 UNID

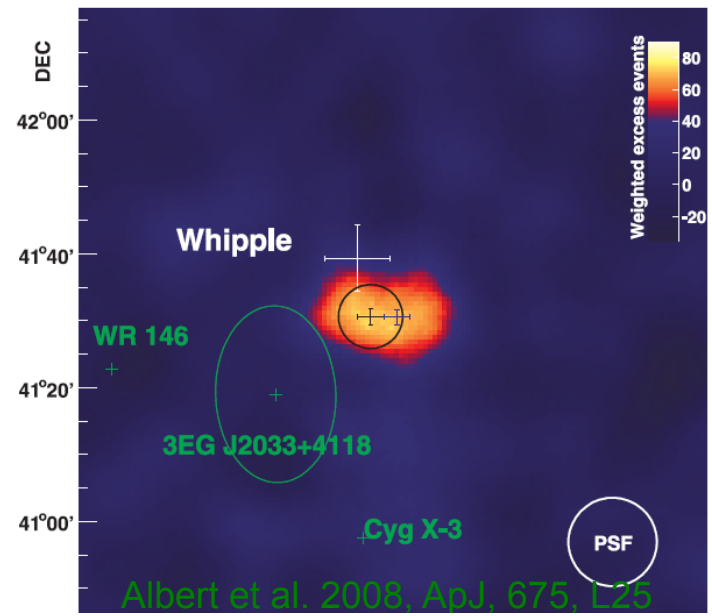
http://tevcat.uchicago.edu/

Unidentified sources

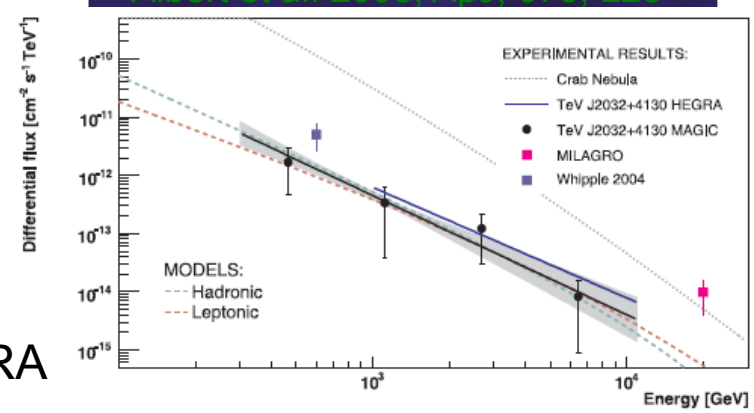
TeV J2032+415

The first one, and a good example, is **TeV J2032+413**, discovered by HEGRA (Aharonian et al. 2002)

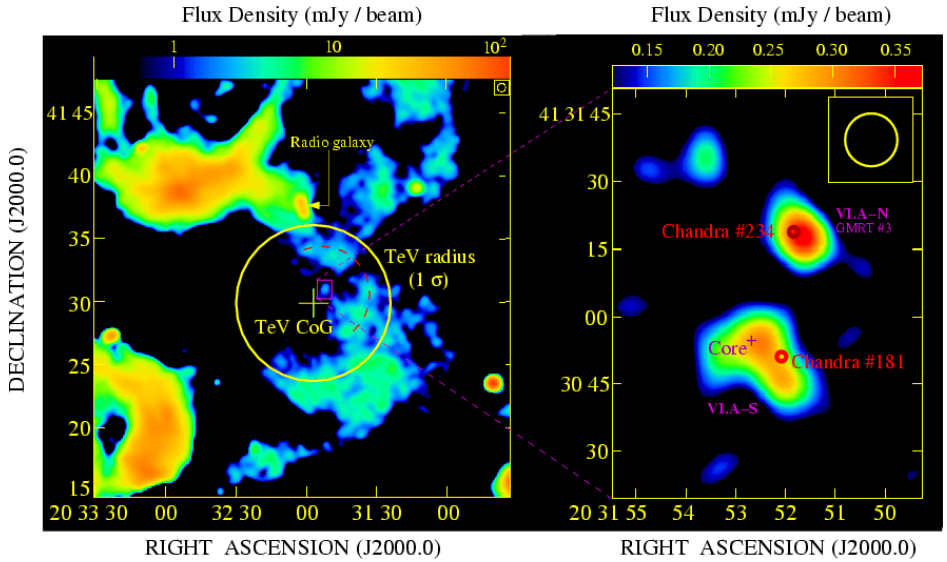




Albert et al. 2008, ApJ, 675, L25



No flux variability over 3 yr, compatible with HEGRA



VLA, 20 cm

VLA, 6 cm

Fermi: GeV pulsar LAT PSR J2032+4127

Abdo et al. 2009, Sci 325, 840

GBT: radio pulsar

same position and period GeV pulsar

same position than GMRT#5 Be star

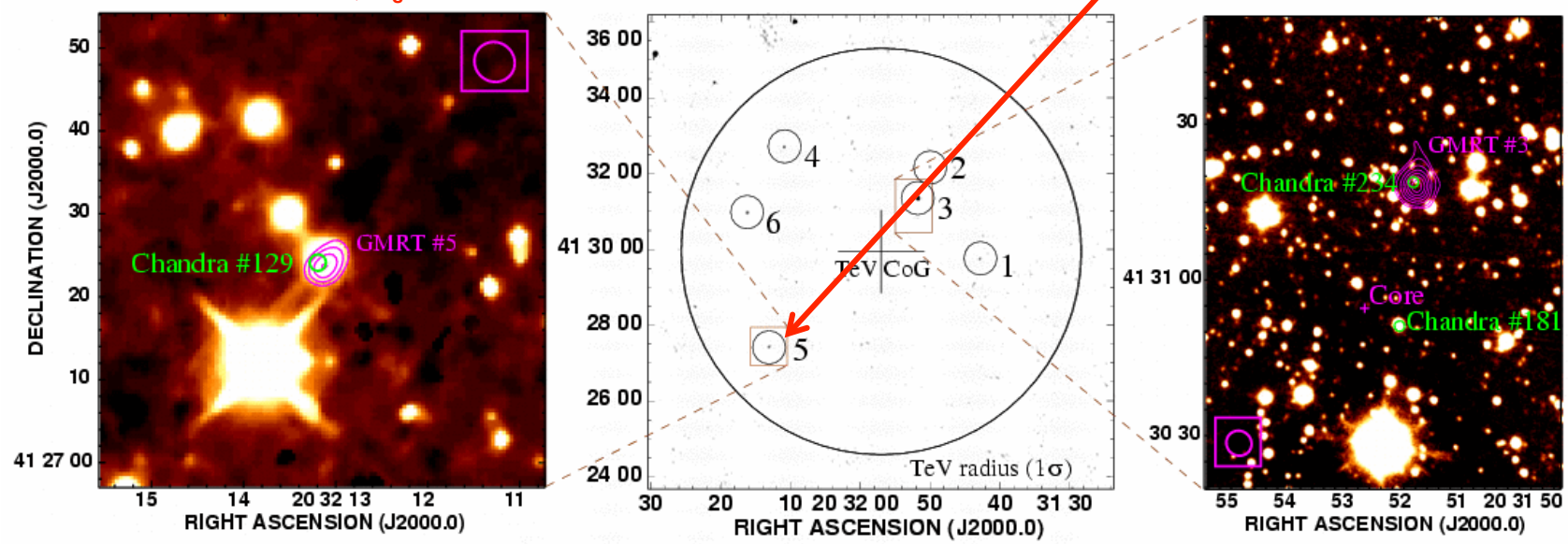
Camilo et al. 2009, ApJ 705,1

PWN ??

WHT, K_s

GMRT, 45 cm

WHT, K_s

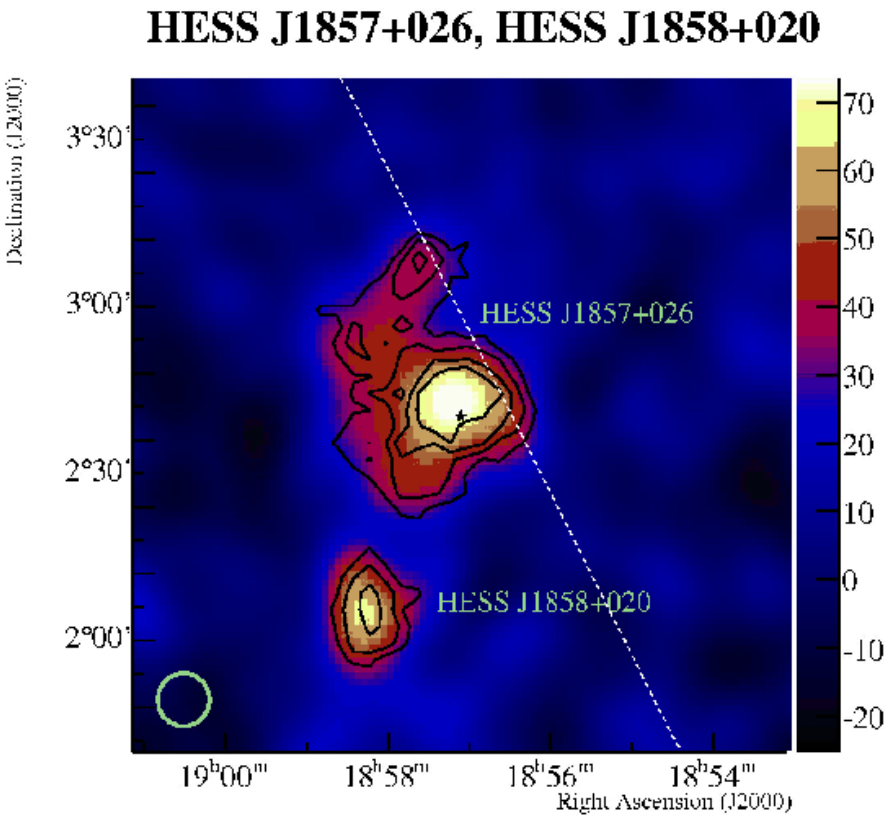


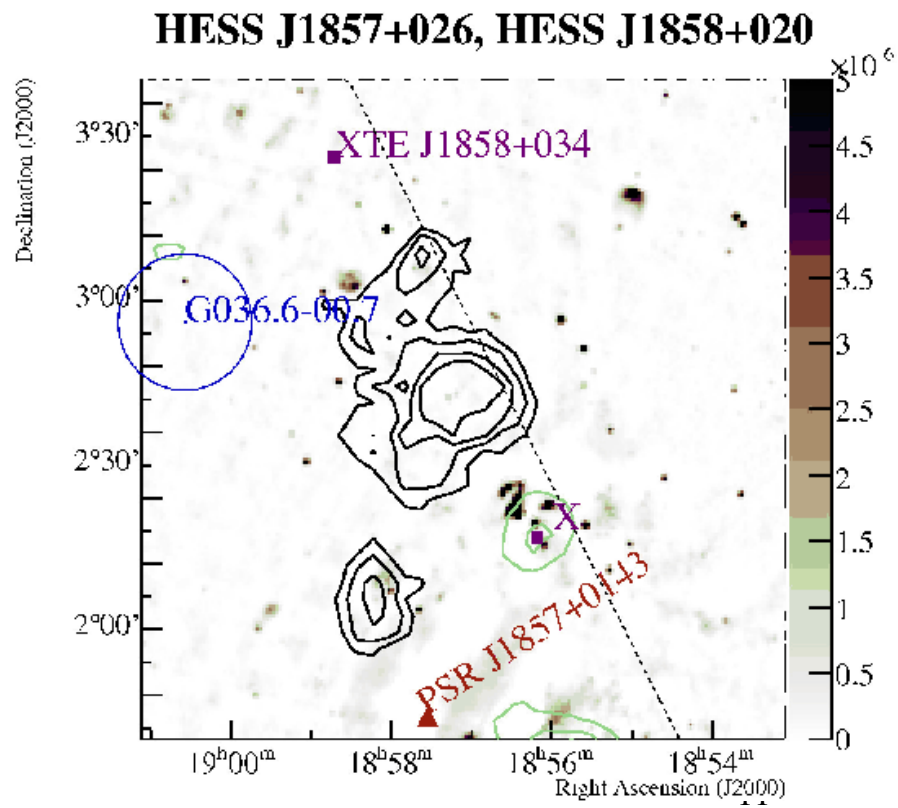
Paredes et al. 2007, ApJ 654, L135

HESS Galactic Plane Survey: unidentified sources

Aharonian et al. 2008, 477, 353

8 VHE gamma-ray sources
Angular sizes 3-18'
Spectrum: power-law (2.1-2.5)
No clear counterpart in lower-energy wavebands. If confirmed → a new class VHE?



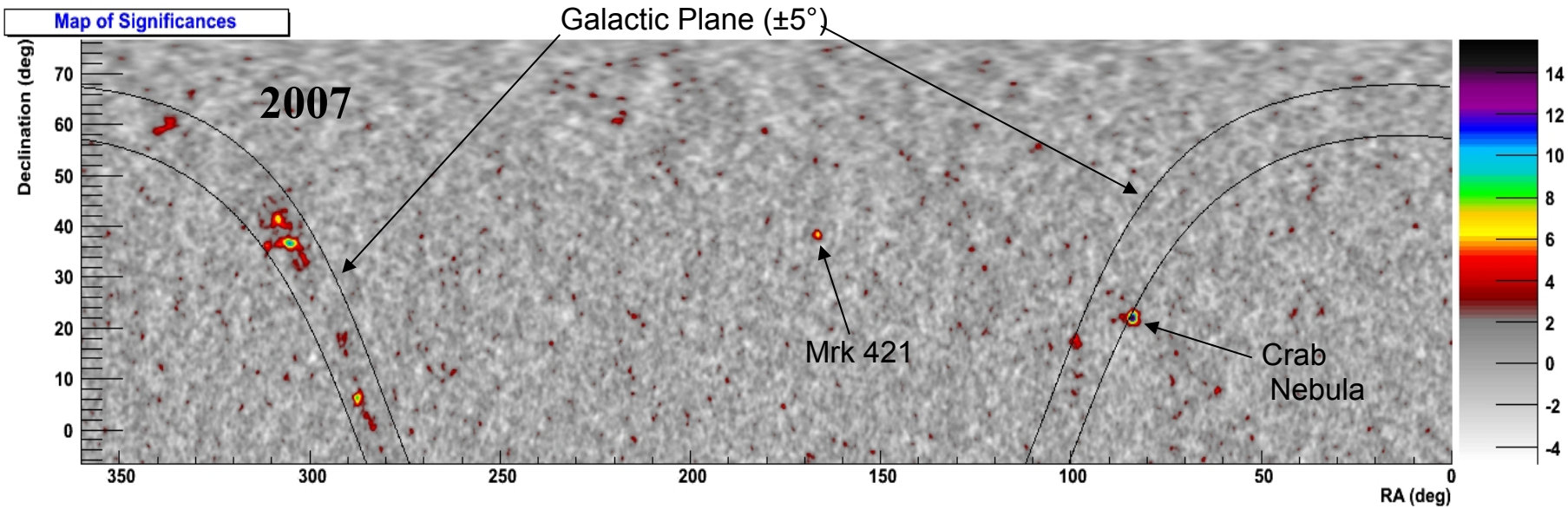


ROSAT

NVSS (grey scale)

MILAGRO Sky Survey

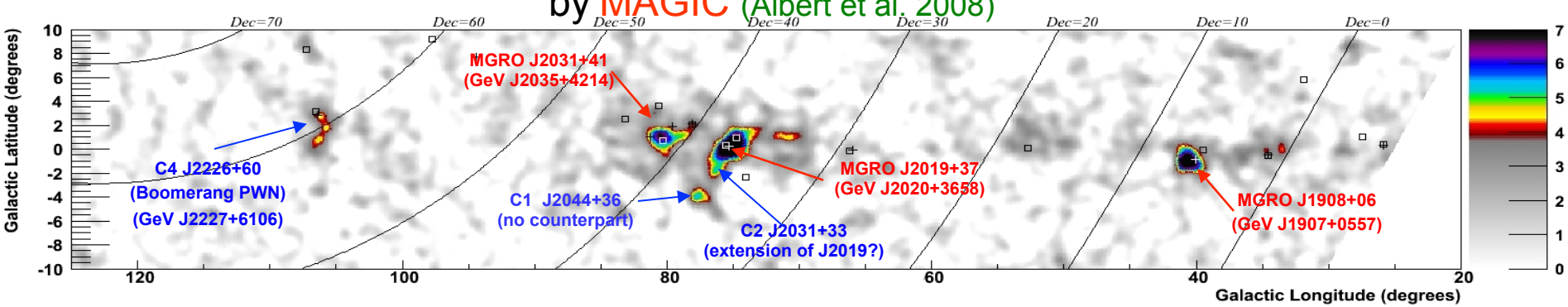
Energy range 4-150 TeV. 6.5 yr of data (July 2000 -January 2007). (Abdo et al. 2007).



MGRO J1908+06 has been detected by HESS (Djannati-Atai et al. 2007)

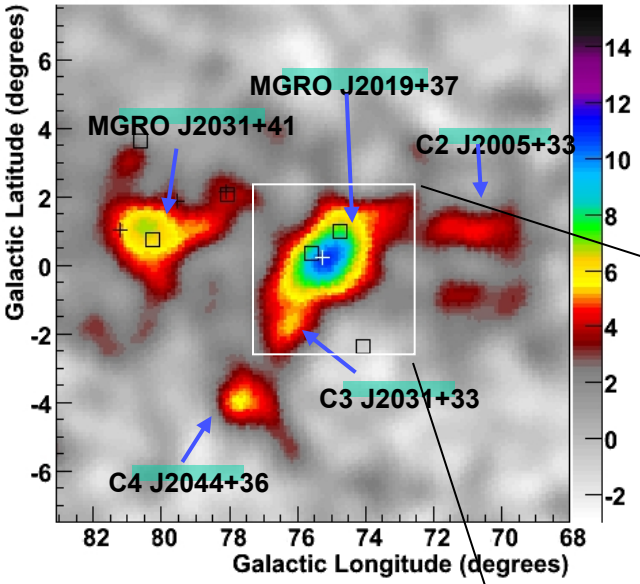
MGRO J2019+37 has been detected by Tibet As-g (Wang et al. 2007)

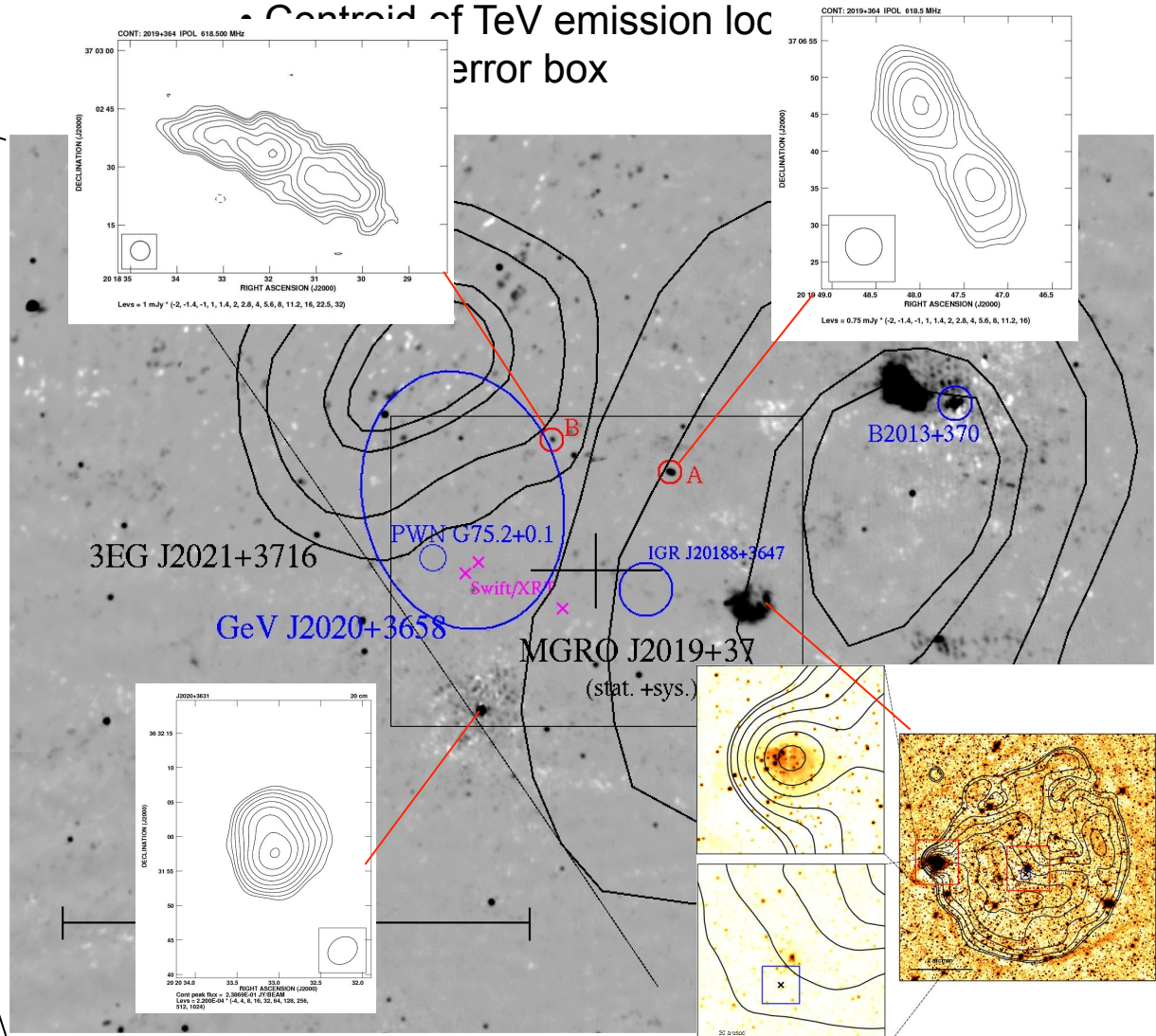
MGRO J2031+41 was detected by HEGRA (Aharonian et al. 2002) and by MAGIC (Albert et al. 2008)



The Cygnus Region by MILAGRO

- Part of a complex TeV emission region partly correlated with molecular cloud density (CO data)
- Extended emission (σ = 0.32º± 0.12º)
- Centroid of TeV emission loc
  error box



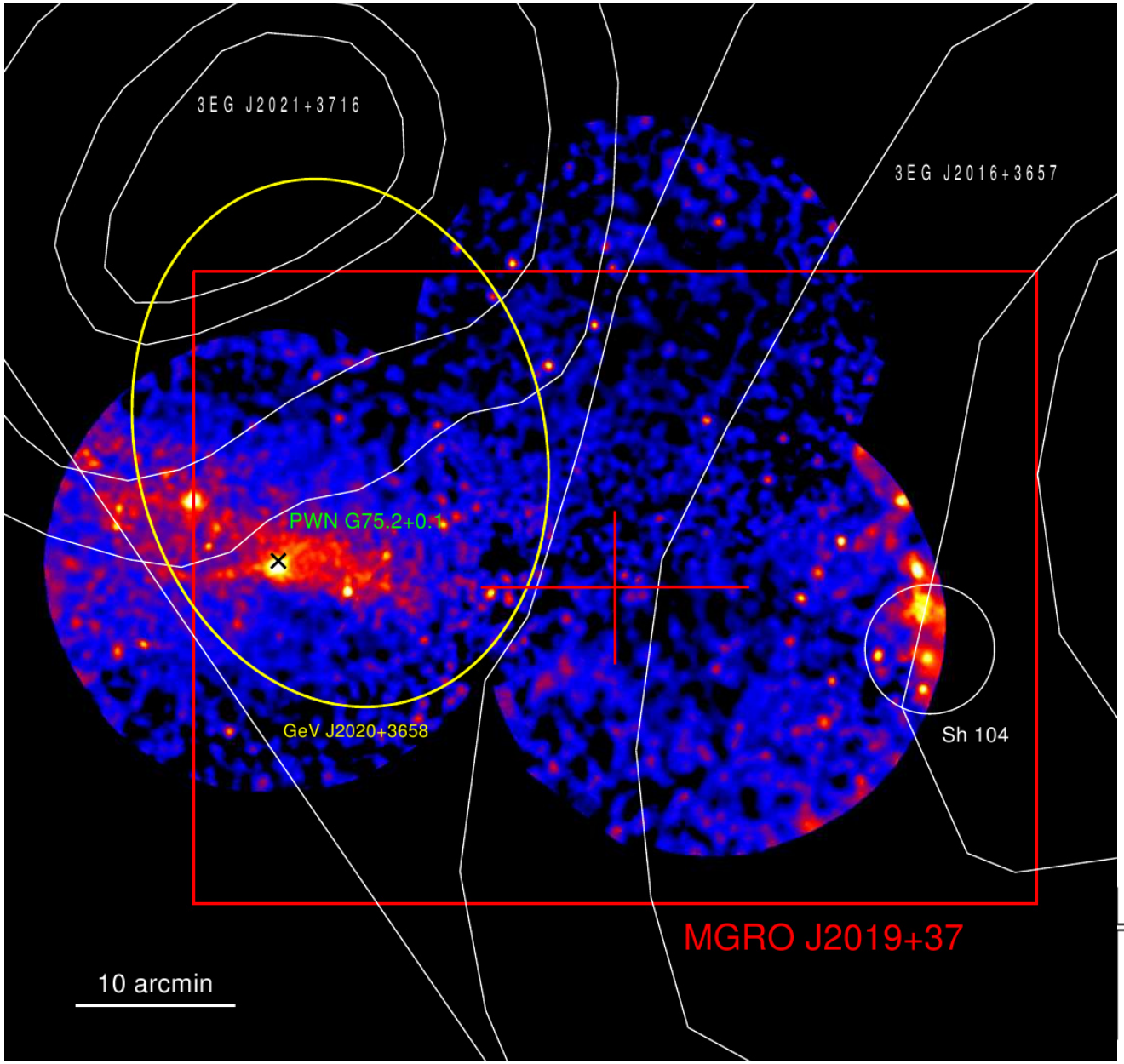


MGRO J2019+37 Region

GMRT 610 MHz

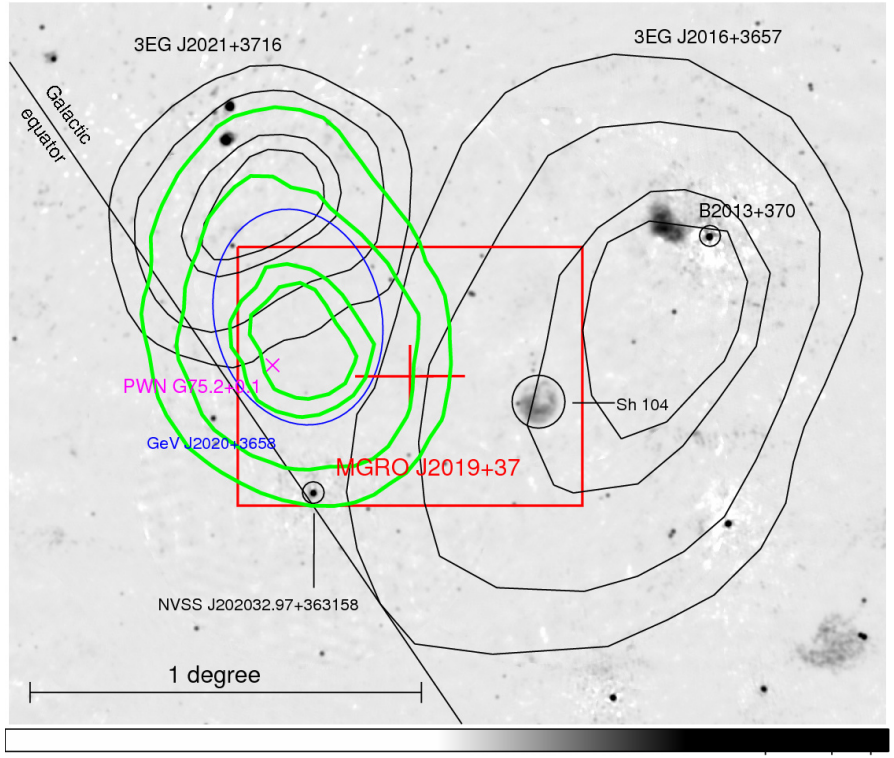
Paredes et al. 2009, A&A 507, 241

XMM-*Newton* X-ray mosaic



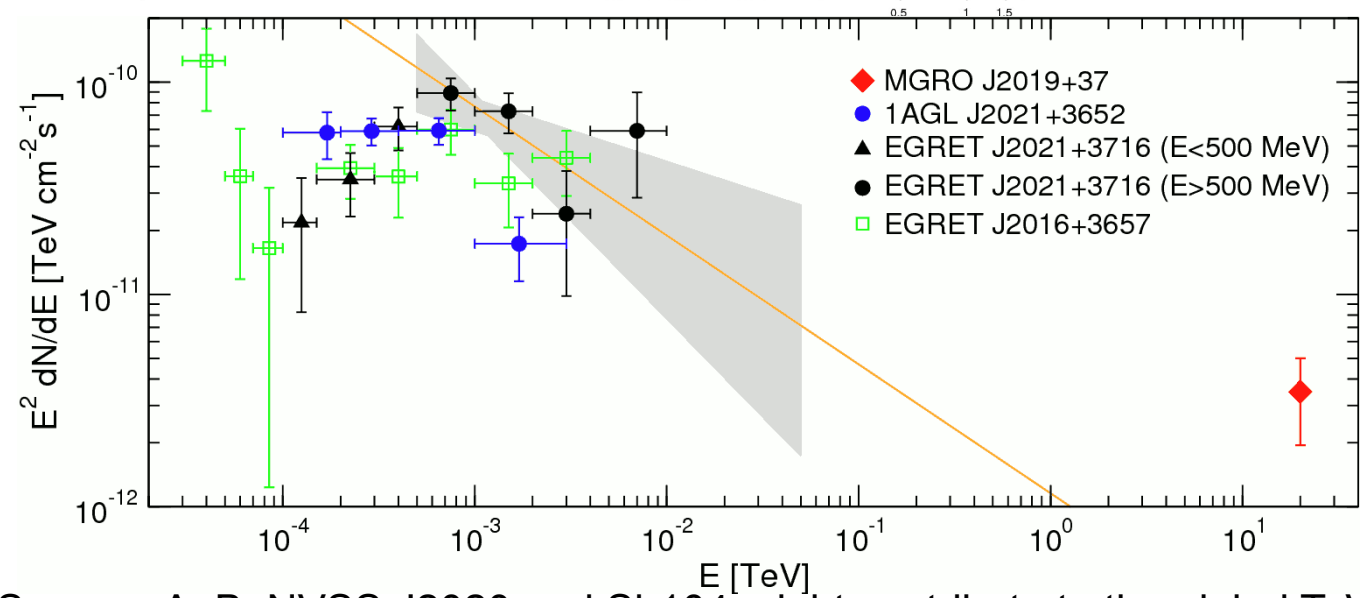
Length	Clean time
50 ks	44 ks
2x20 ks	27 ks
15 ks	14 ks

AGILE

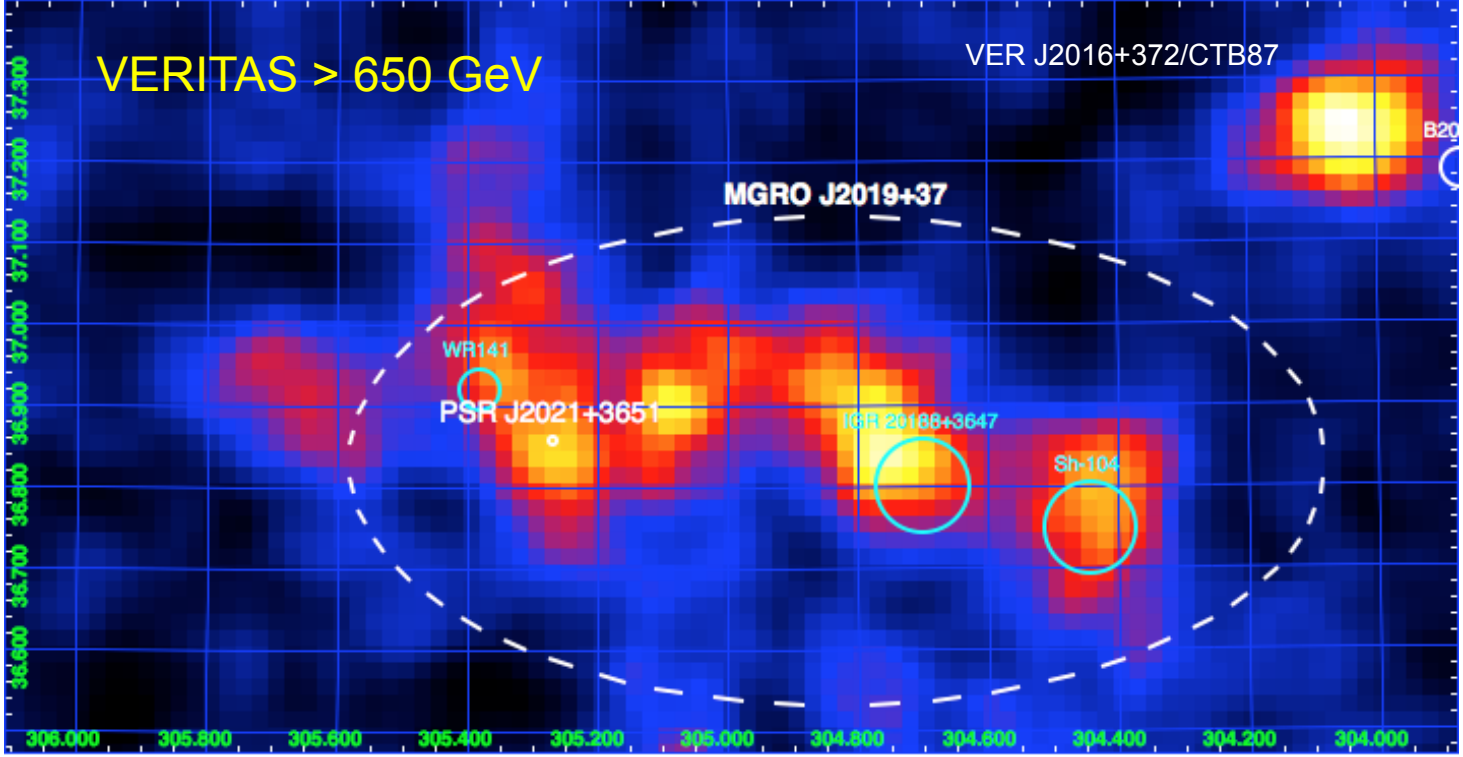


Detection of gamma-ray pulsed emission from PSR J2021+3657 with *AGILE* (Halpern et al. 2008, ApJ, 688, L33)

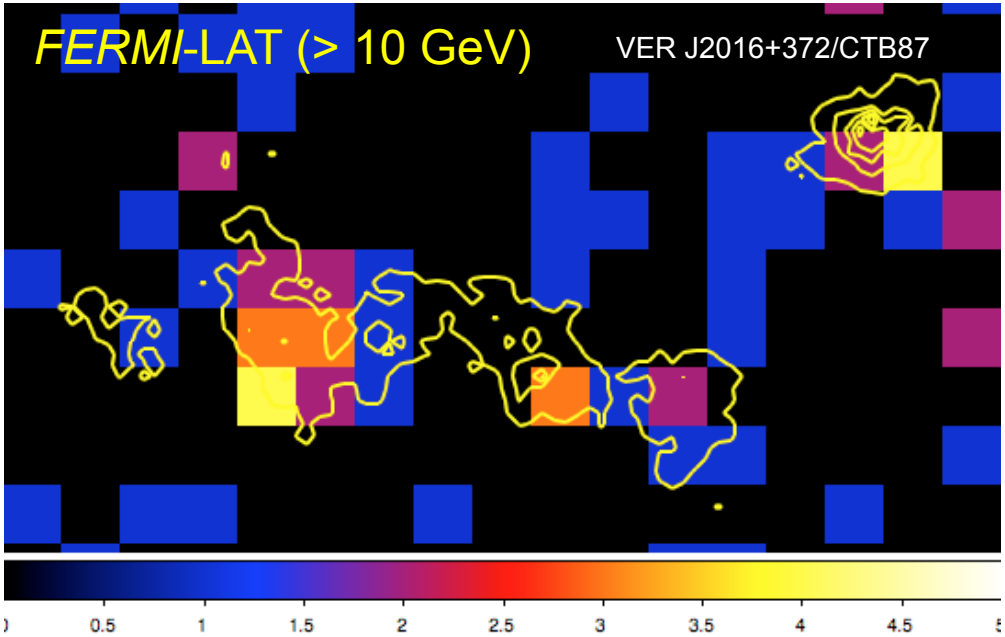
Detected also by *Fermi* (Abdo et al. 2009, ApJ 700, L127)



Sources A, B, NVSS J2020 and Sh104 might contribute to the global TeV emission



Aliu et al. 2011
Fermi Symposium



AGL J2241+4454

(l, b) = (100.0°, -12.2°) ± 0.6°

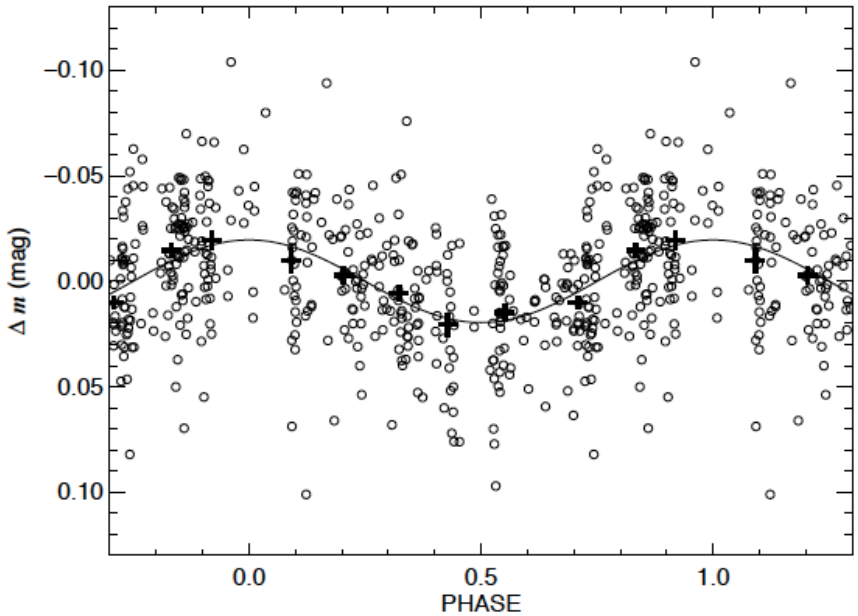
Lucarelli et al. 2010, Atel 2761

Integrating from 2010-07-25 01:00 UT to 2010-07-26 23:30 UT, a maximum likelihood analysis yields a detection at a significance level larger than 5 sigma, and a flux above 150 × 10^{-8} ph/cm^2/s (E > 100 MeV)

Be star **HD 215227**

b = −12° ➔ the star is quite far from the GP, and hence it may be a runaway star formed by a SN explosion in a binary system

Williams et al. 2010, ApJ 723, L93



P= 60.37 ± 0.04 d

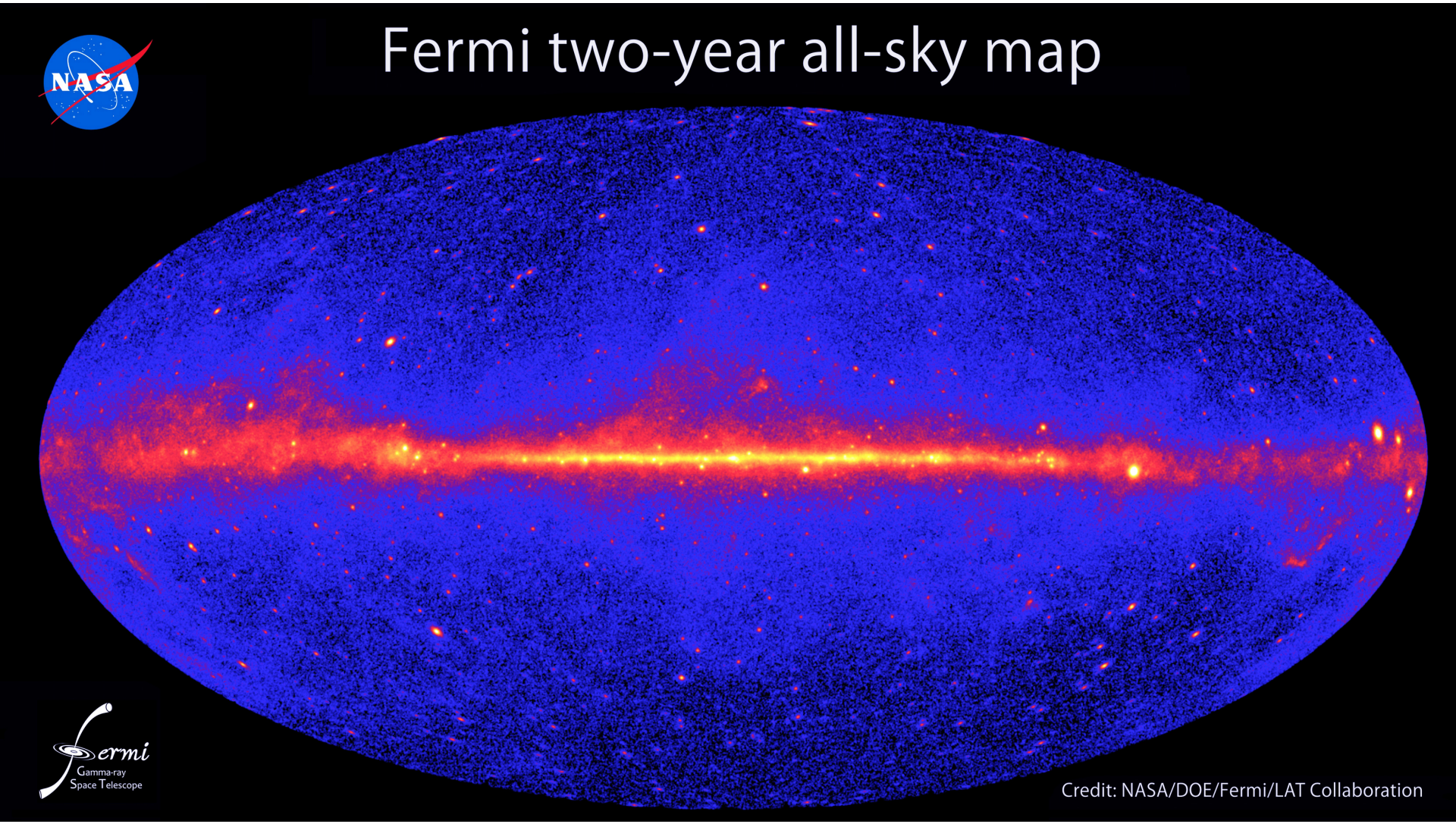
Orbital parameters (MWC 656)
Casares et al. 2012, MNRAS 421, 1103

AGILE flare took place around periastron

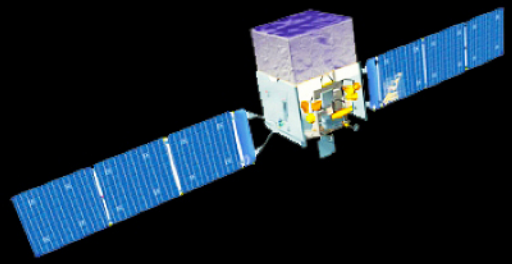
Optical counterpart of AGL J2241+4454 ?

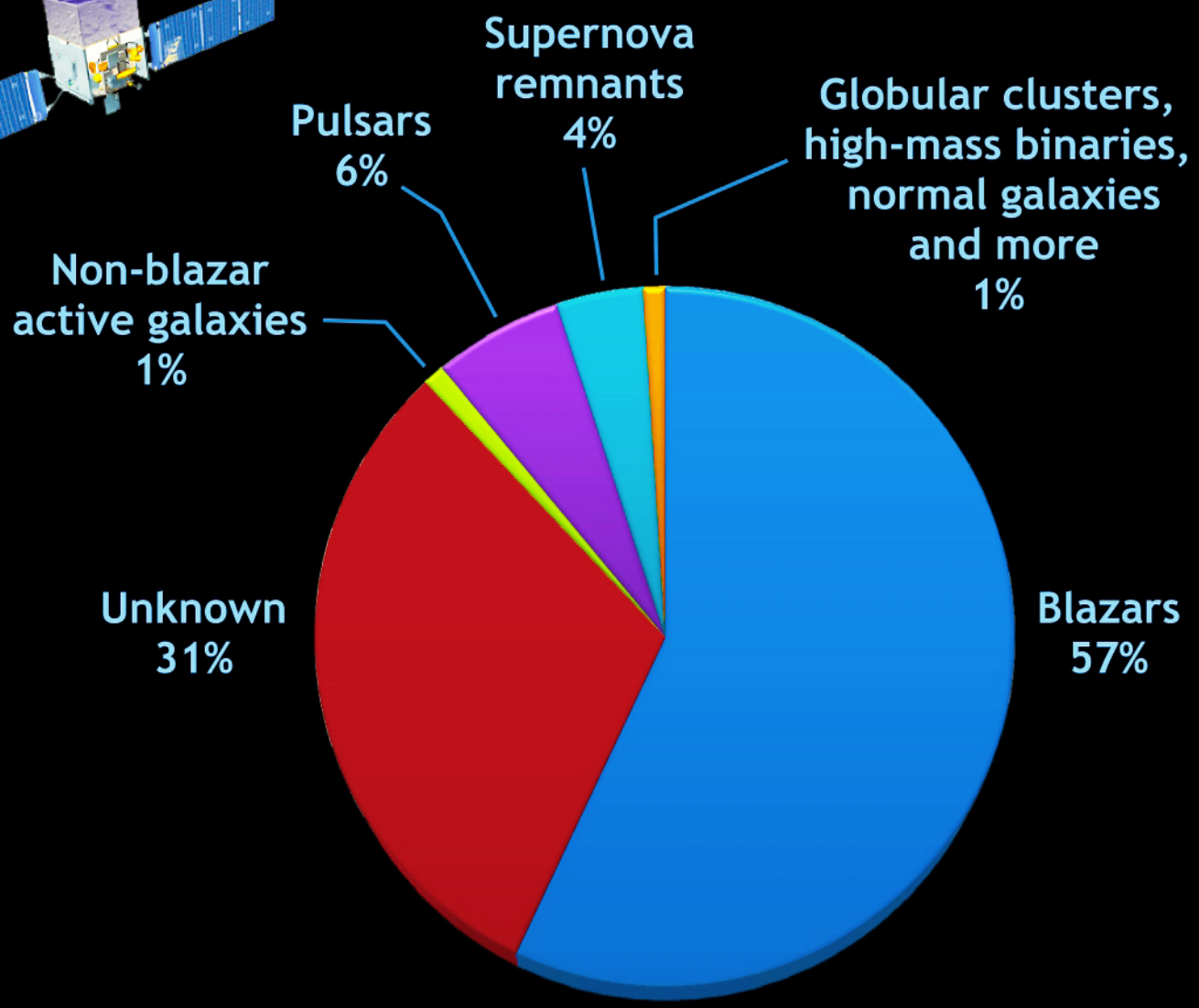
The HE (Fermi) gamma-ray sky

20 MeV to 300 GeV



What has Fermi found: The LAT two-year catalog





Credit: NASA/Goddard Space Flight Center

1873 sources, 575 unassociated

About a few hundred GeV γ-ray sources in the Galactic plane have no clear associations with known objects in the Galaxy

- Many of them are probably
  - pulsars (GeV)
  - PWNe (TeV)

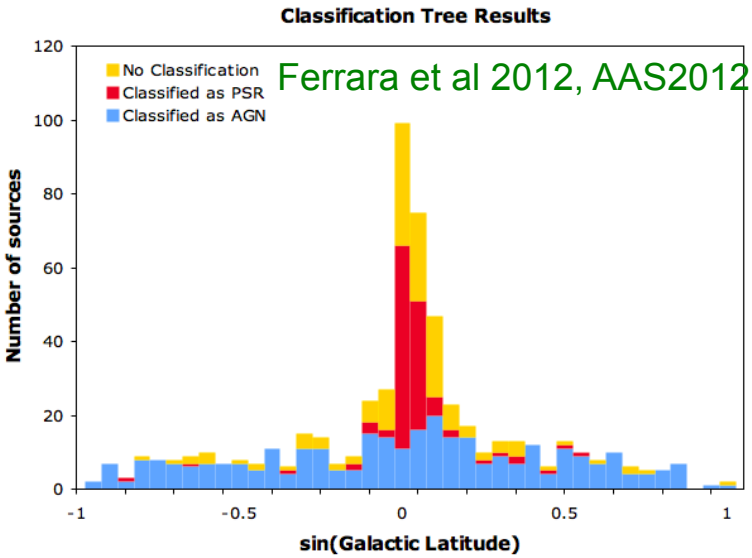
- At least some fraction of the unassociated 2FGL sources at low latitudes may be local emission maxima of diffuse Galactic emission that are not adequately modeled by the Galactic diffuse model

Nolan et al 2012, ApJSS 199, 31

- Several of the unassociated GeV sources show curved spectra suggesting that their TeV emission may be on a much lower level.

  Cut-off or a second high energy spectral component?

Need of good quality spectra at energies clearly below ~100 GeV



Fermi-LAT Unassociated Sources in the 2FGL Catalog. Using classification techniques: 315 AGN candidates, 114 pulsar candidates and 144 sources unable to be classified by this method.

Unid
EGRET 62%
Cherenkov 18%
Fermi 31%

17 unidentified TeV sources are associated with the 2FGL

The lack of radio or X-ray counterpart only put minor constraints on:

- the γ-ray radiation mechanism (leptonic, hadronic ?)
- the transport process of particles in the sources
- on their evolution

Observations of the unidentified GeV-TeV γ-ray objects, with an order of magnitude **more sensitive** instrument and with the **better angular resolution** will provide important constraints on the sites of particle acceleration in the Galaxy.

Such instrument → Investigate fine structures of the much extended sources (e.g., MILAGRO sources. The number of such extended sources will certainly increase with the next generation of the water tank Cherenkov detectors)

→ Locate bright transient sources with high accuracy

Galper et al 2013, Advances in Space Research 51, 297

A comparison of basic parameters of space-based and ground-based instruments.

	Spaced-based					Ground-based			
	EGRET	AGILE	Fermi	CALET	**GAMMA-400**	H.E.S.S.	MAGIC	VERITAS	CTA
Energy range, GeV	0.03–30	0.03–50	0.1–300	10–10000	**0.1–3000**	>100	>50	>100	>10
Angular resolution, deg ($E_\gamma > 100$ GeV)	0.2 $E_\gamma \sim 0.5$ GeV	0.1 $E_\gamma \sim 1$ GeV	0.1	0.1	**~0.01**	0.1	0.1	0.1	0.1
Energy resolution, % ($E_\gamma > 100$ GeV)	15 $E_\gamma \sim 0.5$ GeV	50 $E_\gamma \sim 1$ GeV	10	2	**~1**	15	20	15	15

Conclusion

- To unveil the nature of the unidentified sources a gamma-ray instrument with high angular resolution (and sensitivity) is mandatory