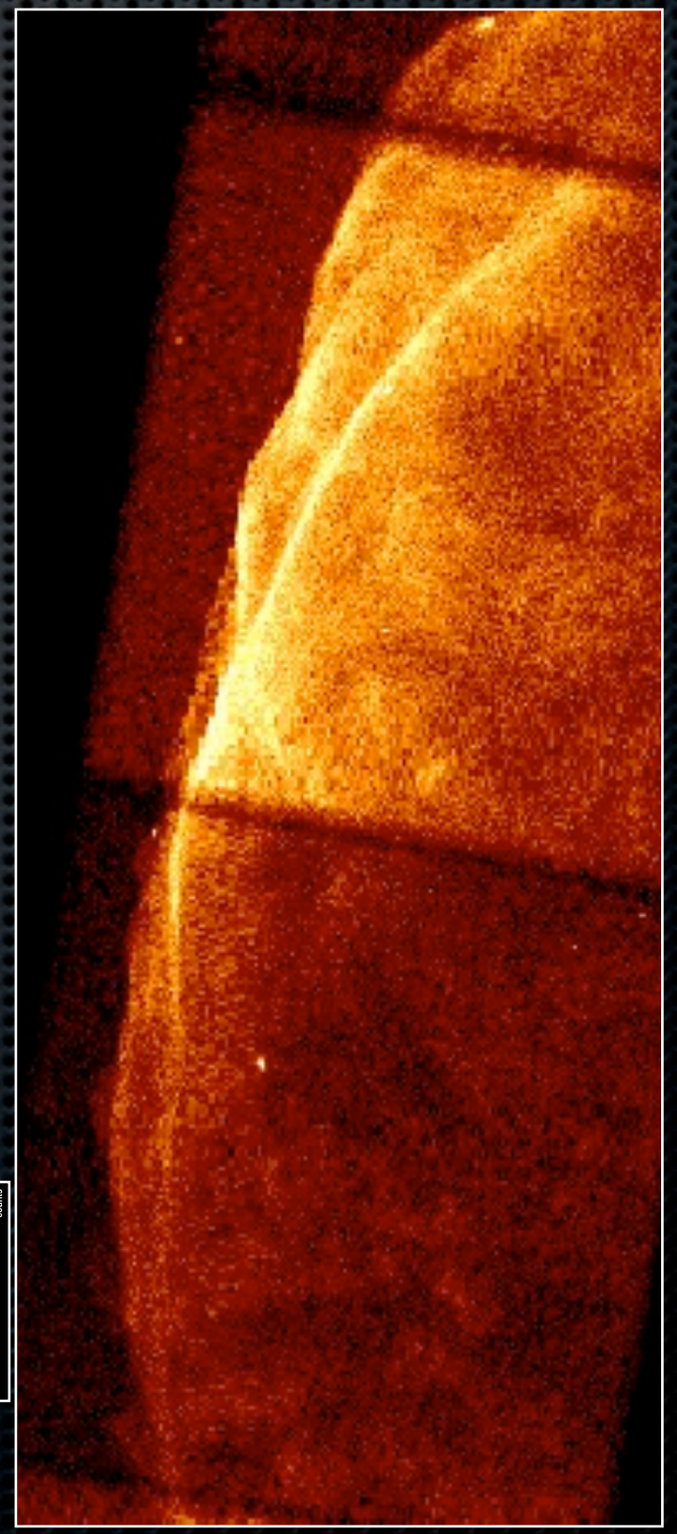
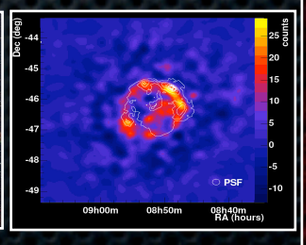
The GeV-TeV connection

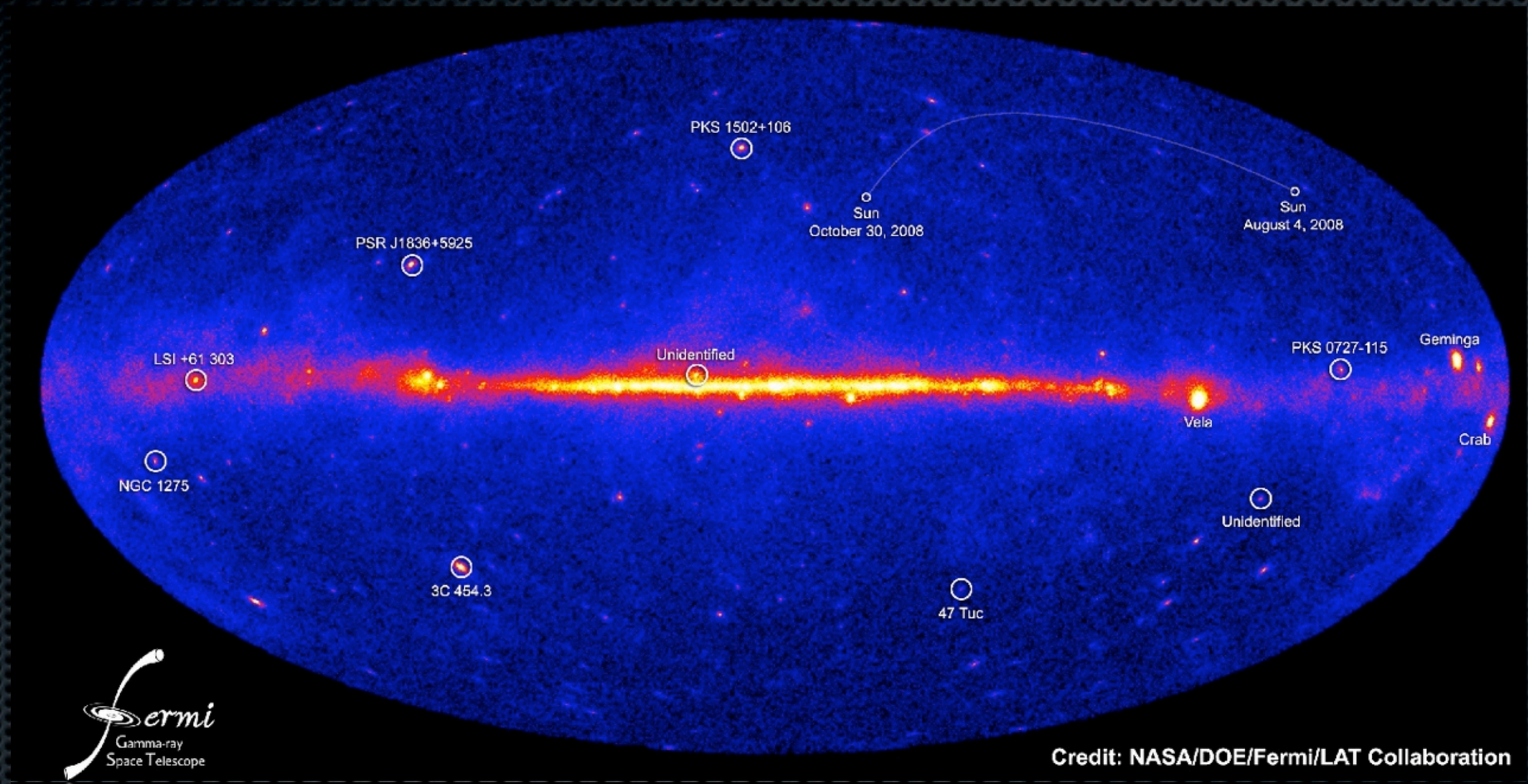


… and Supernova remnants, Pulsar Wind Nebulae and other Galactic sources



S. Funk, Kavli Institute for Astroparticle Physics & Cosmology, Stanford & SLAC

Start to connect LAT to TeV sources

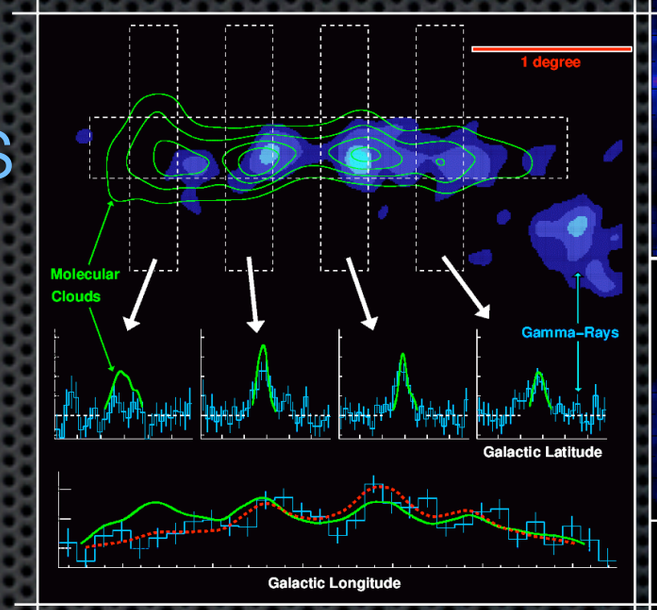


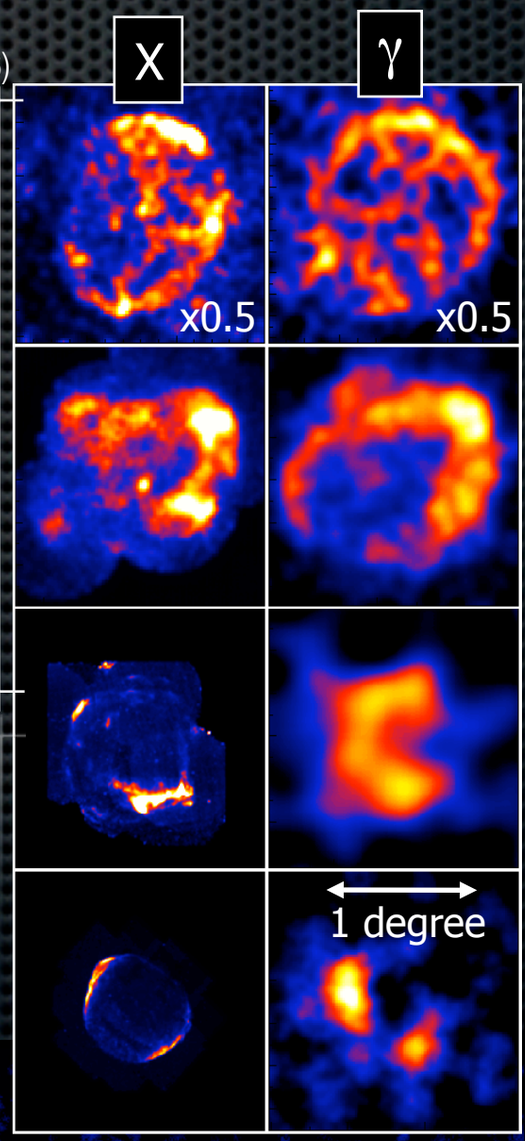
- will talk about what we knew before the LAT, what we expect and some very early results ...

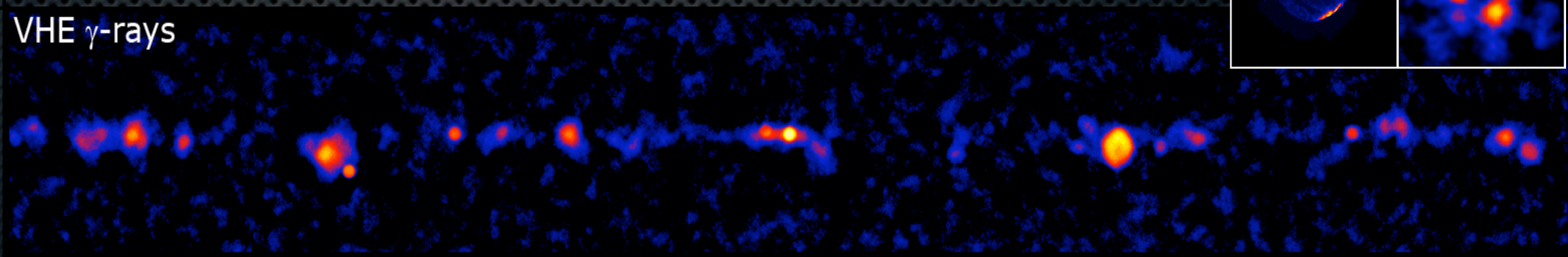
The GeV-TeV connection

- Stunning diversity of astrophysical TeV accelerators
- Patchy observations apart from scan of Galactic plane (l=+-60, b = +−5)
- Typical energy flux densities: 10^{-12} ergs cm^{-2} s^{-1} (1-10 TeV)

Aharonian et al., Nature, 439, 695 (2006)





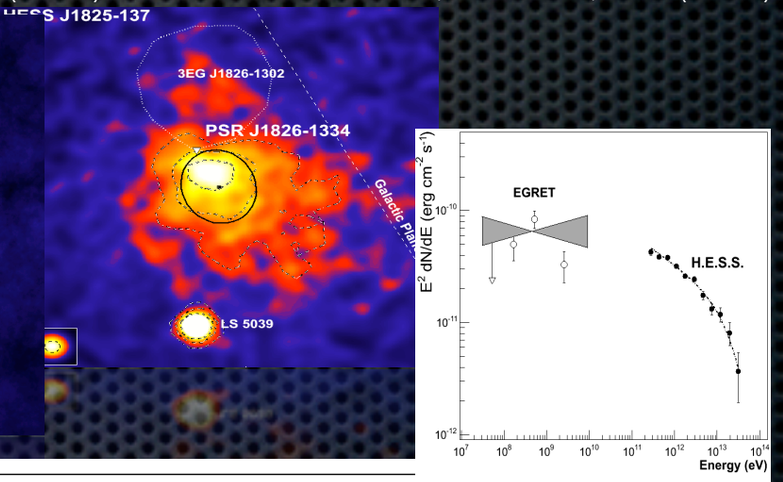


Comparing TeV sources to EGRET

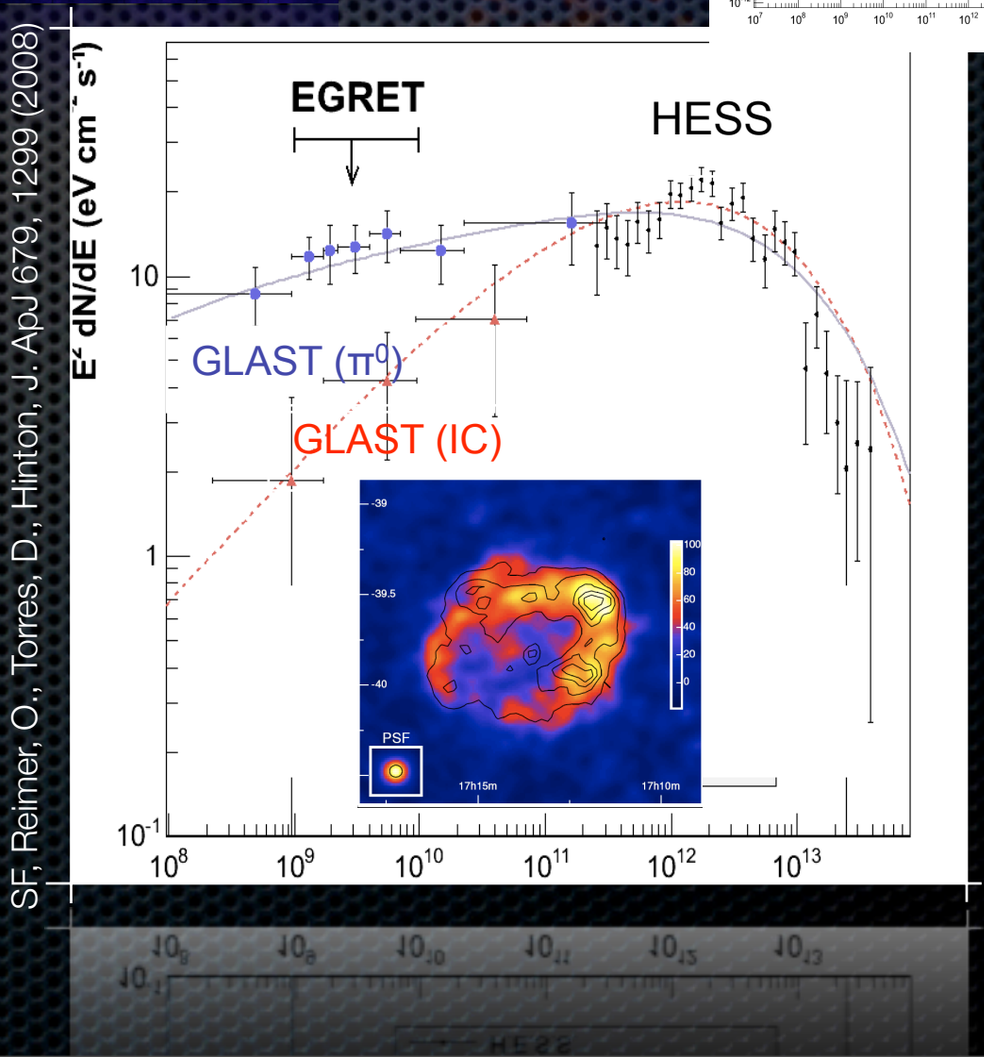
- Hints for GeV emission from EGRET for some of the most prominent and brightest TeV sources
  - Galactic Center
  - RX J1713.7-3946
  - LS 5039
  - Kookaburra, IC 443, HESS J1825-178
- More on this from Fermi-LAT

Reimer & Funk, ASSci, 309, 203 (2006)

Aharonian et al., A&A 460, 365 (2006)



SF, Reimer, O., Torres, D., Hinton, J. ApJ 679, 1299 (2008)



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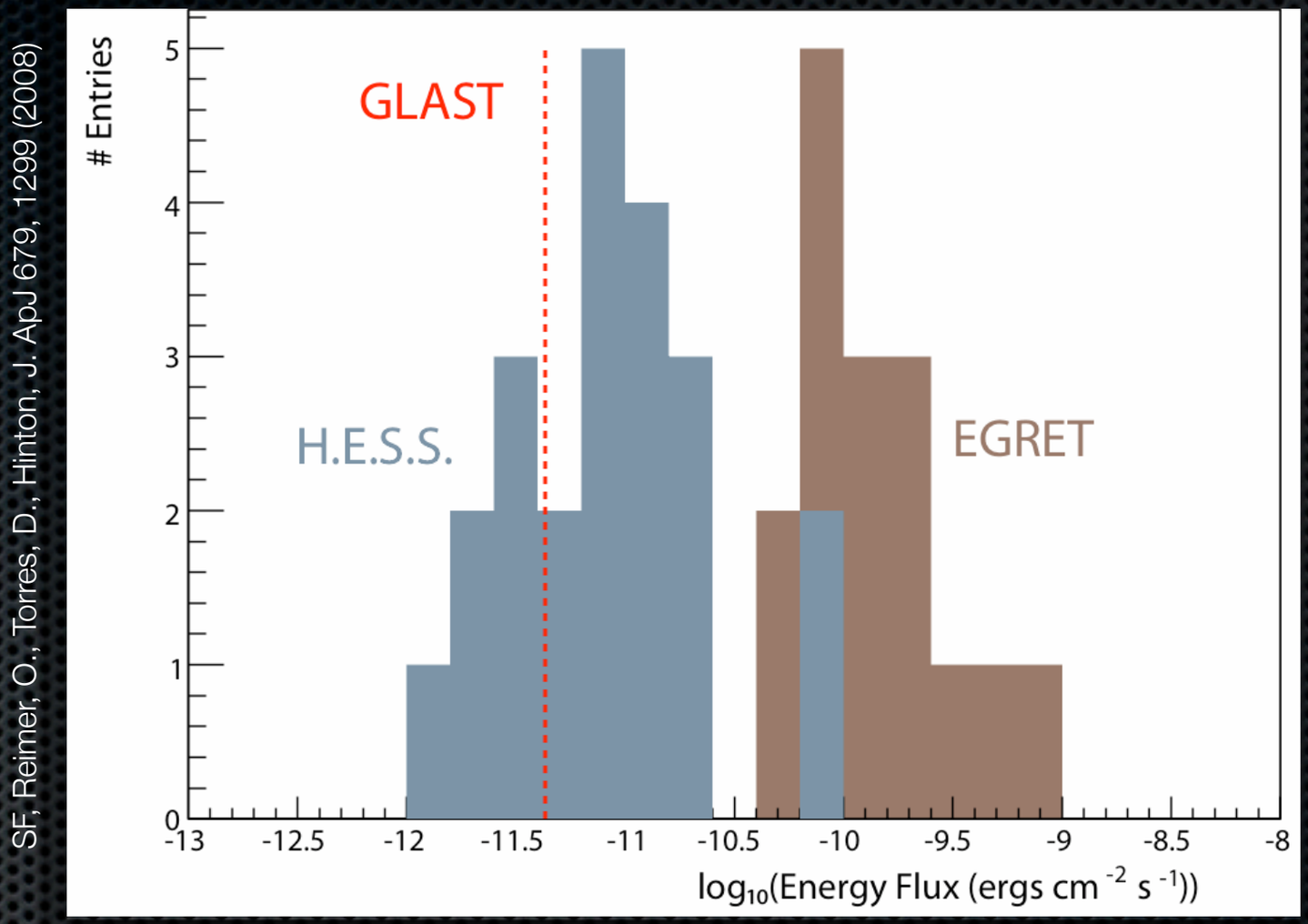
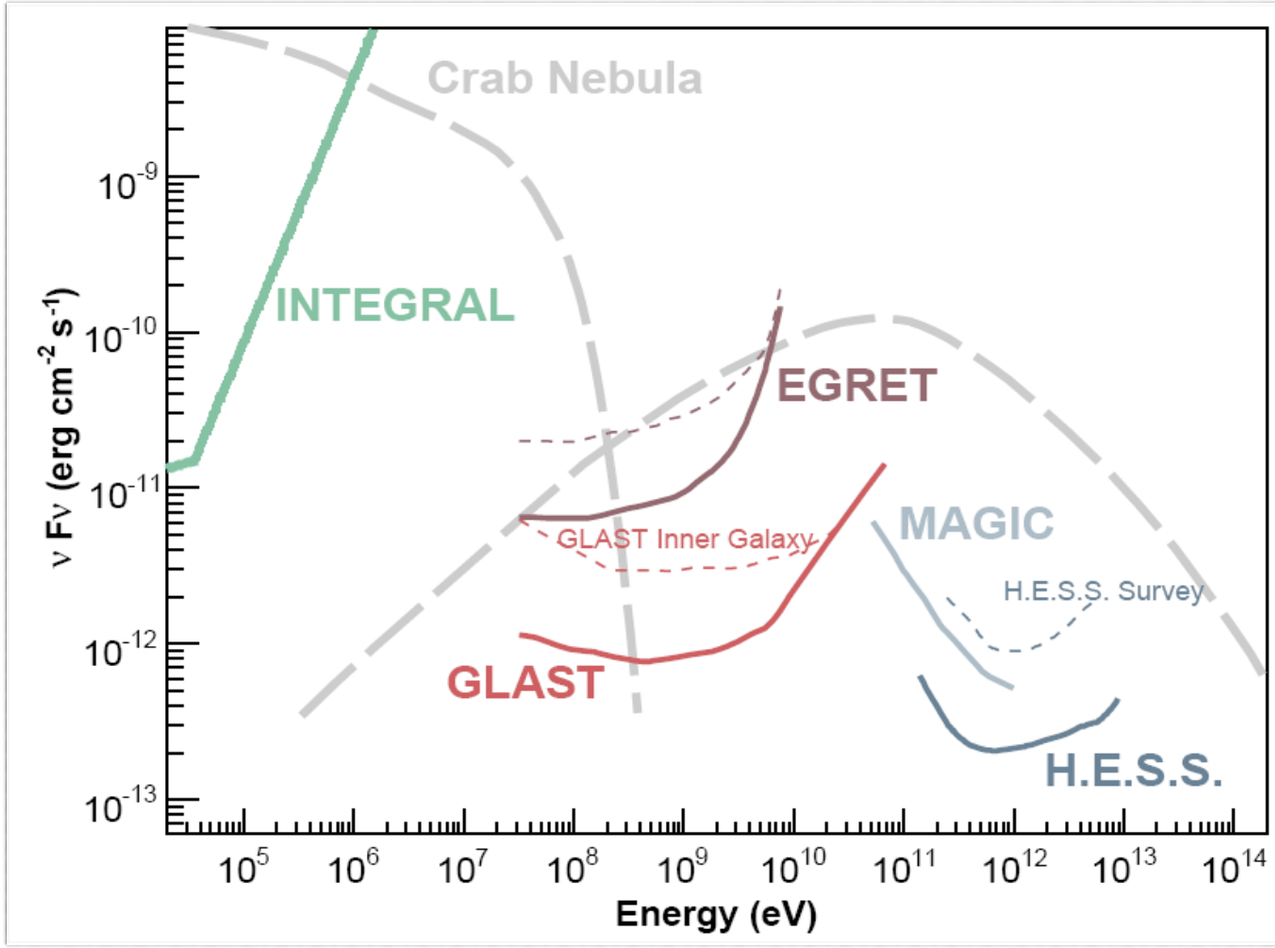
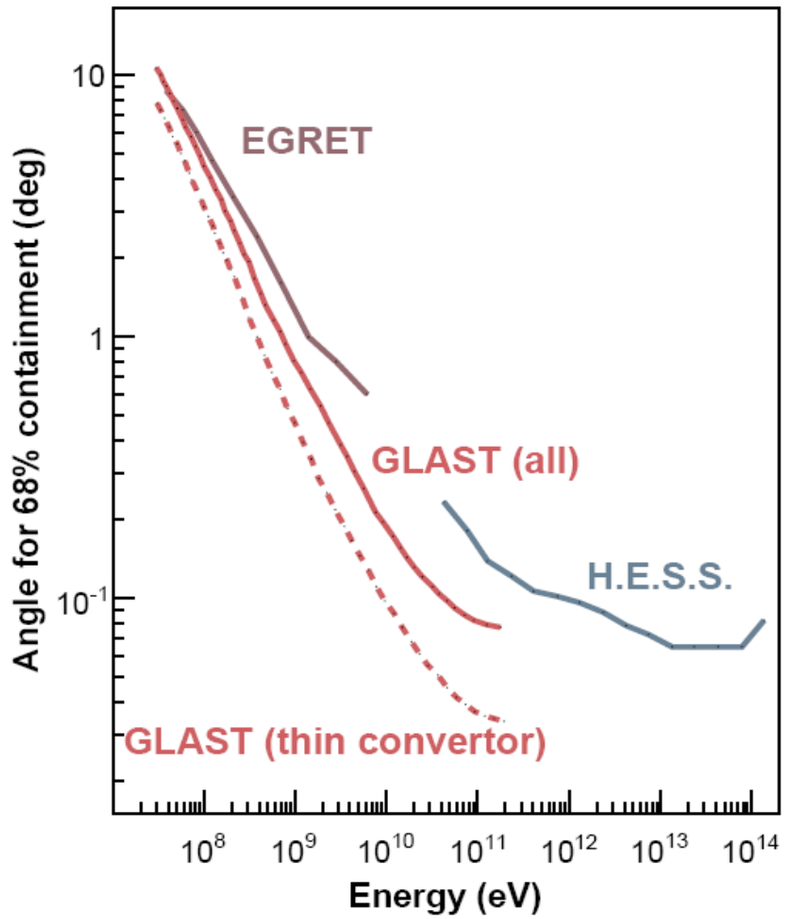


- EGRET: Energy flux (1-10 GeV)
- H.E.S.S.: Energy flux (1-10 TeV)
- GLAST: Sensitivity (1-yr) above 1 GeV (l=10, b=0)





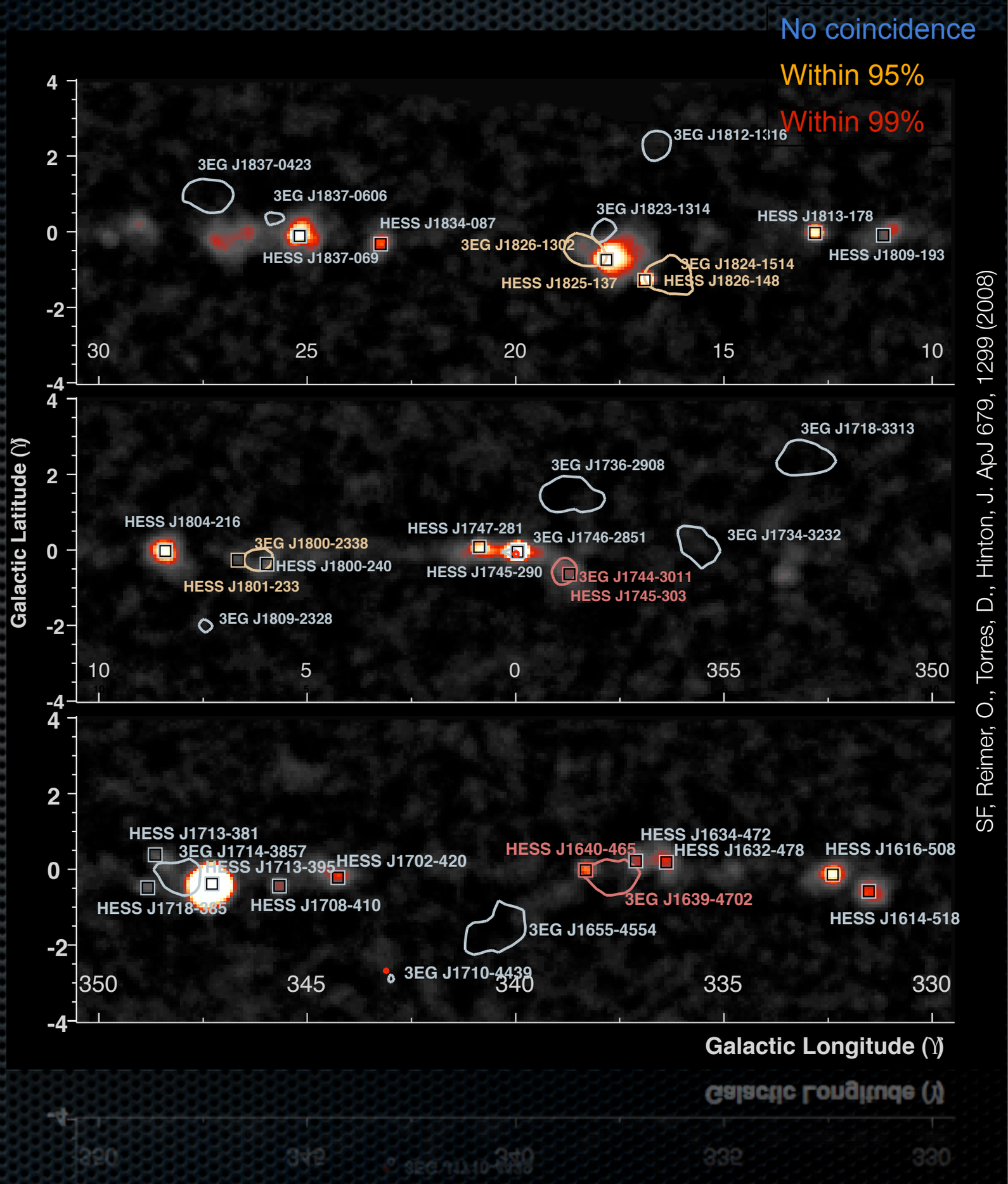
SF, Reimer, O., Torres, D., Hinton, J. ApJ 679, 1299 (2008)

Instrumental parameters

- Differential sensitivity significantly better in TeV instruments
- All sky coverage for Fermi-LAT vs patches of the sky
- Angular resolution: only comparable at the high-energy end
- Diffuse model is additional complication for Fermi-LAT

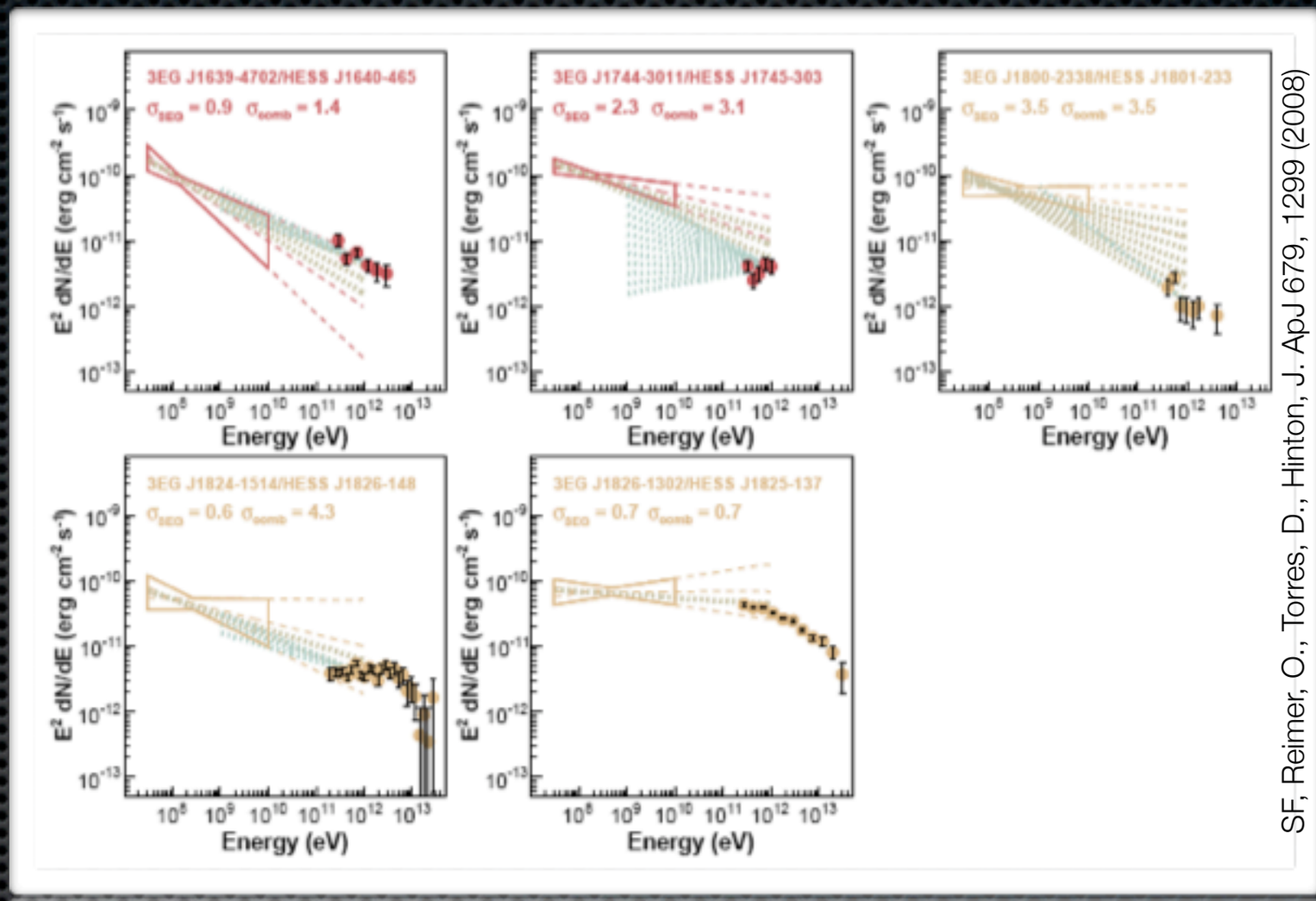
Before Fermi-LAT

- Systematic study in inner Galaxy between EGRET and H.E.S.S.
- Check whether H.E.S.S. src is within EGRET contour
  - 0 sources within 68% (chance coinc.: 0.5)
  - 2 sources within 95% (chance coinc.: 1.4)
  - 3 sources within 99% (chance coinc.: 2.5)



Spectral connection

- For some of the positionally coincident sources there is a good spectral match
- For some sources H.E.S.S. data put severe constraints on emission model
- Fermi-LAT will measure through whole band



SF, Reimer, O., Torres, D., Hinton, J. ApJ 679, 1299 (2008)

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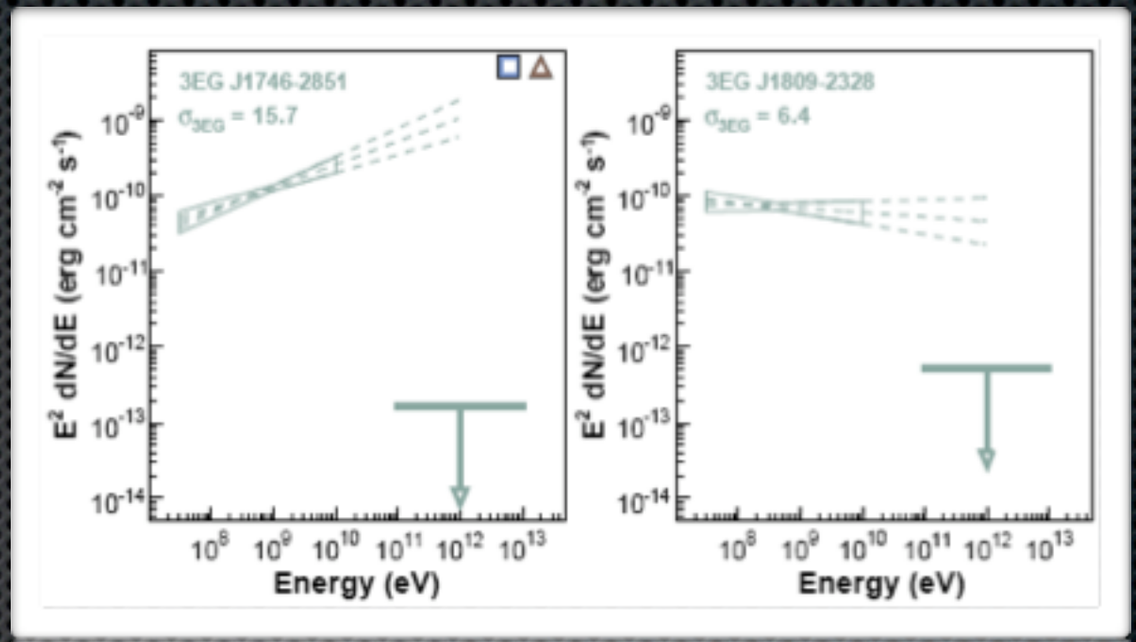
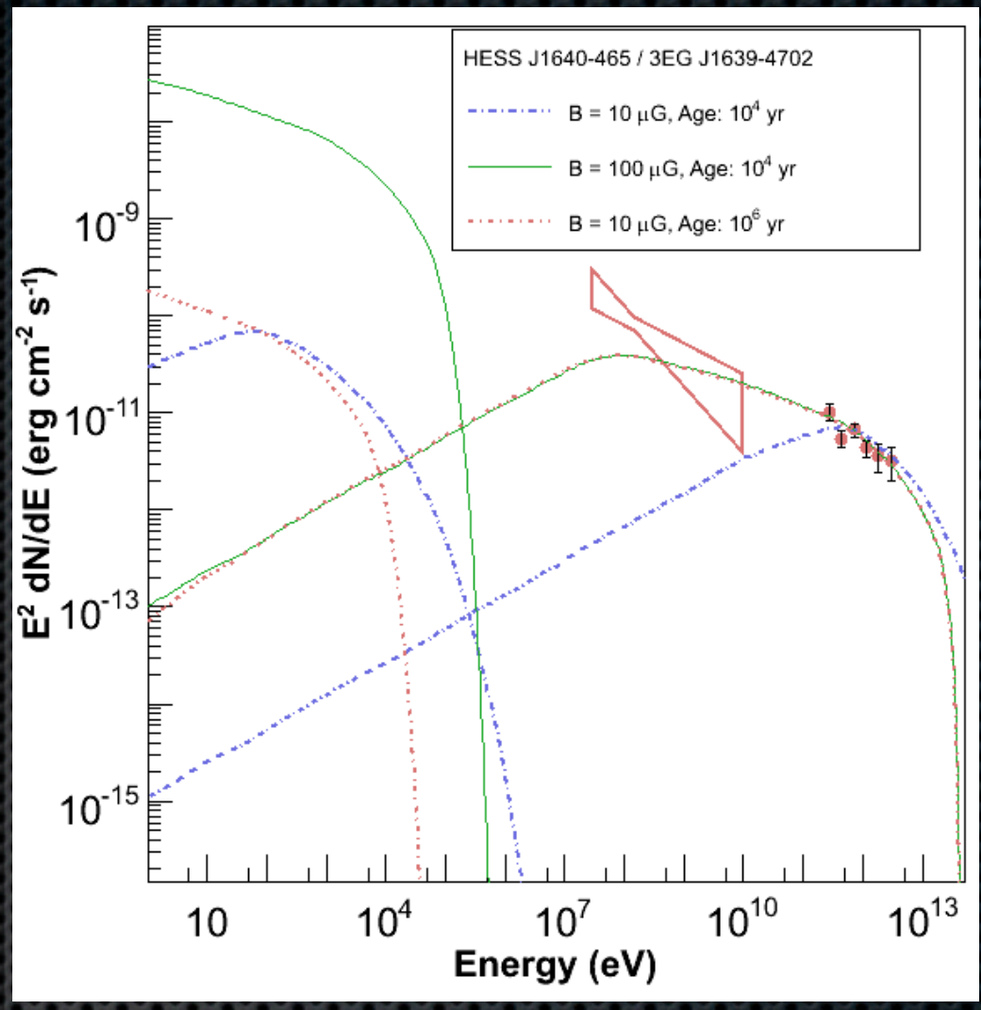


Physical expectation

- For IC sources a GeV-TeV connection is rather unlikely (need old source or high B-field)
- For pion-decay: connection natural, but remember the difference in energy flux sensitivity



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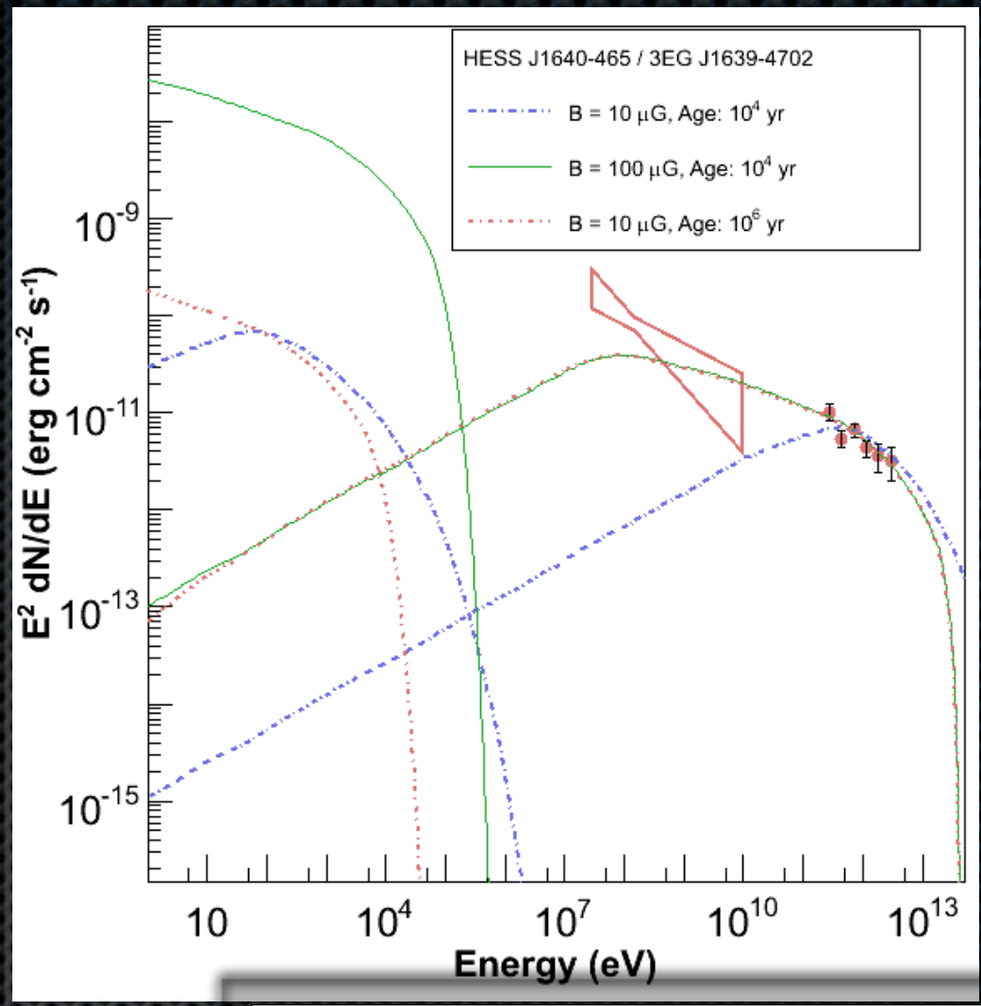

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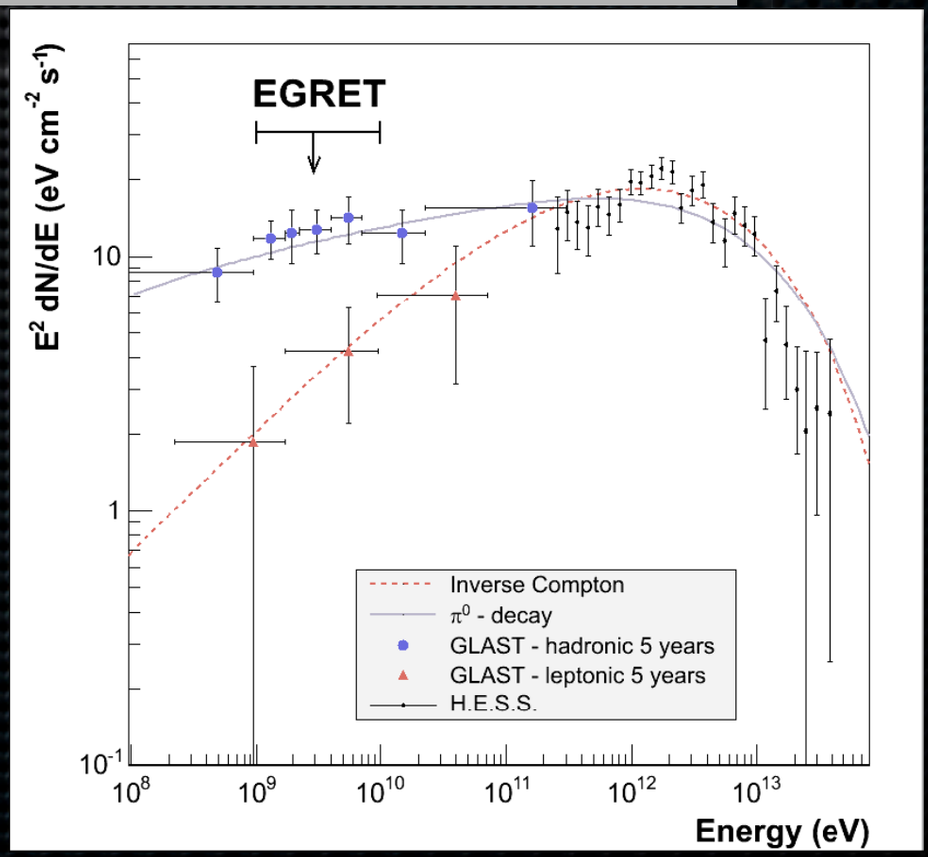
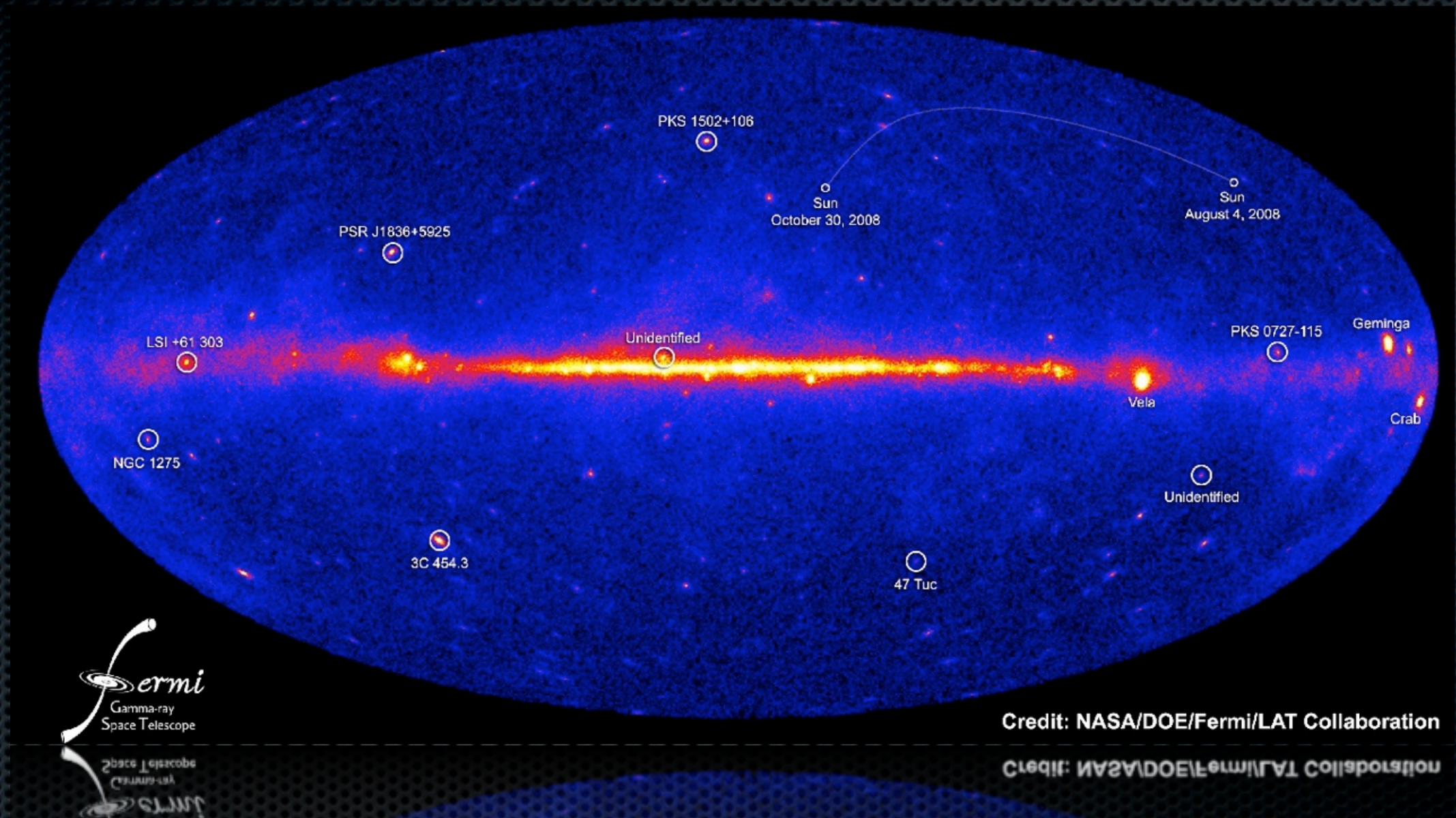


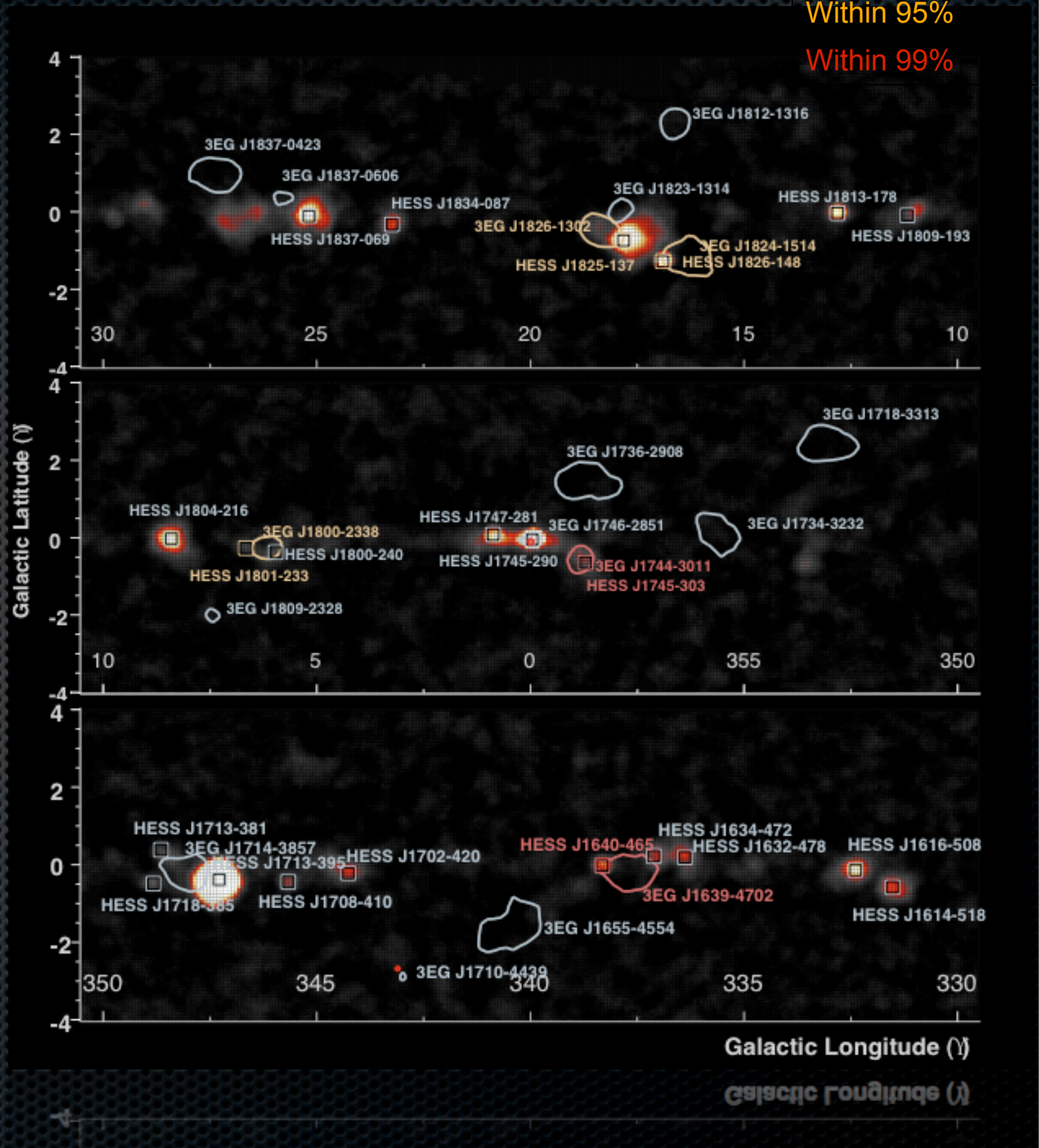
The 3-month Fermi-LAT data



- Fermi all-sky data allows for systematic study with TeV data.
- Identified sources are AGN, Pulsars, LMC, high-mass X-ray binaries, the Earth, the Sun and the Moon

The Inner Galaxy

- 3 sources within 95% EGRET contour
- Now with the LAT:
  - Confirm 2 of the 3
    - LS 5039
    - W28 SNR
  - + GC source
  - + HESS J1616-508
  - + HESS J1834-087
  - + HESS J1804-216
- Beyond Inner Galaxy:
  - LS I61+303
  - IC443, ...



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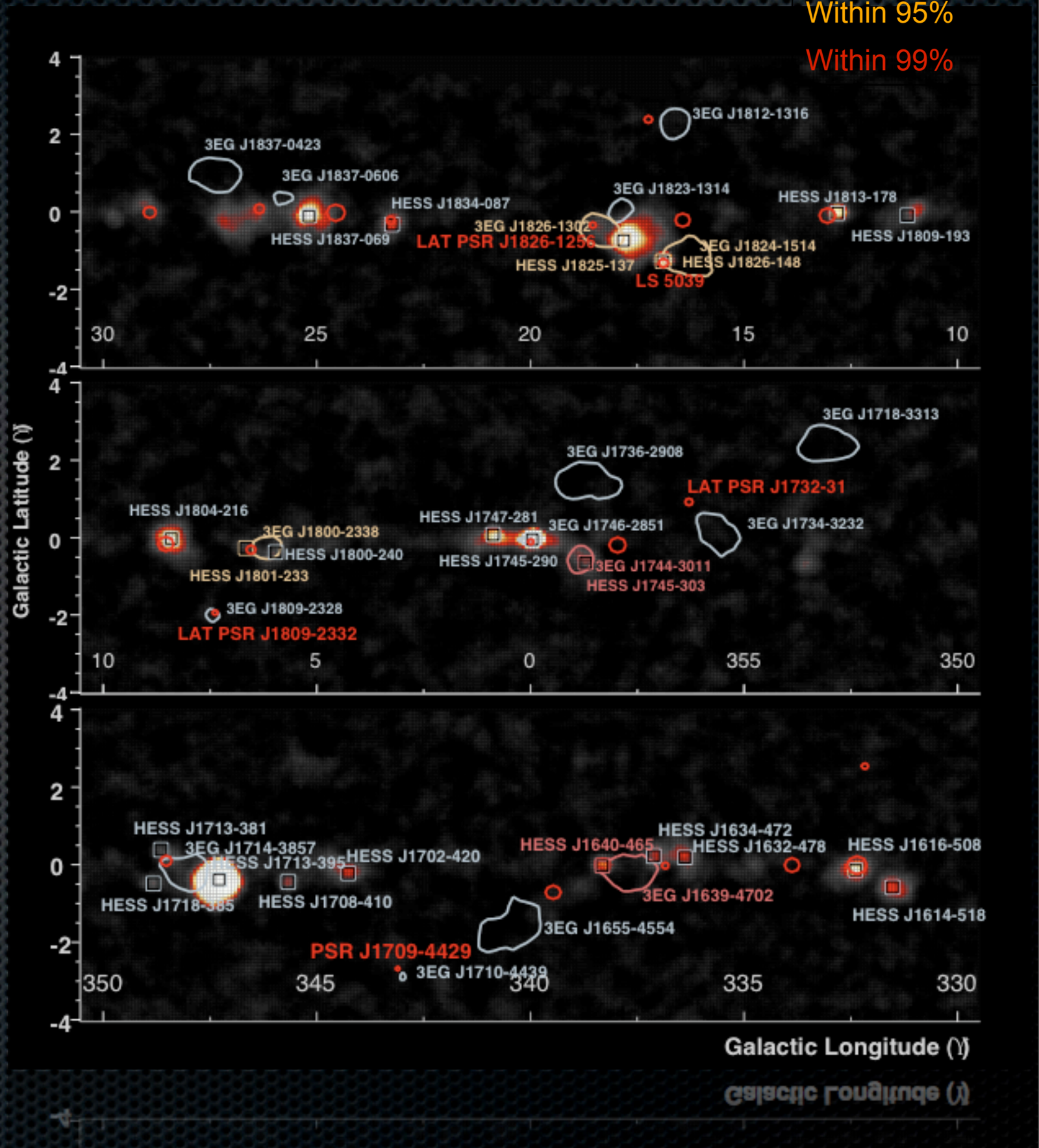
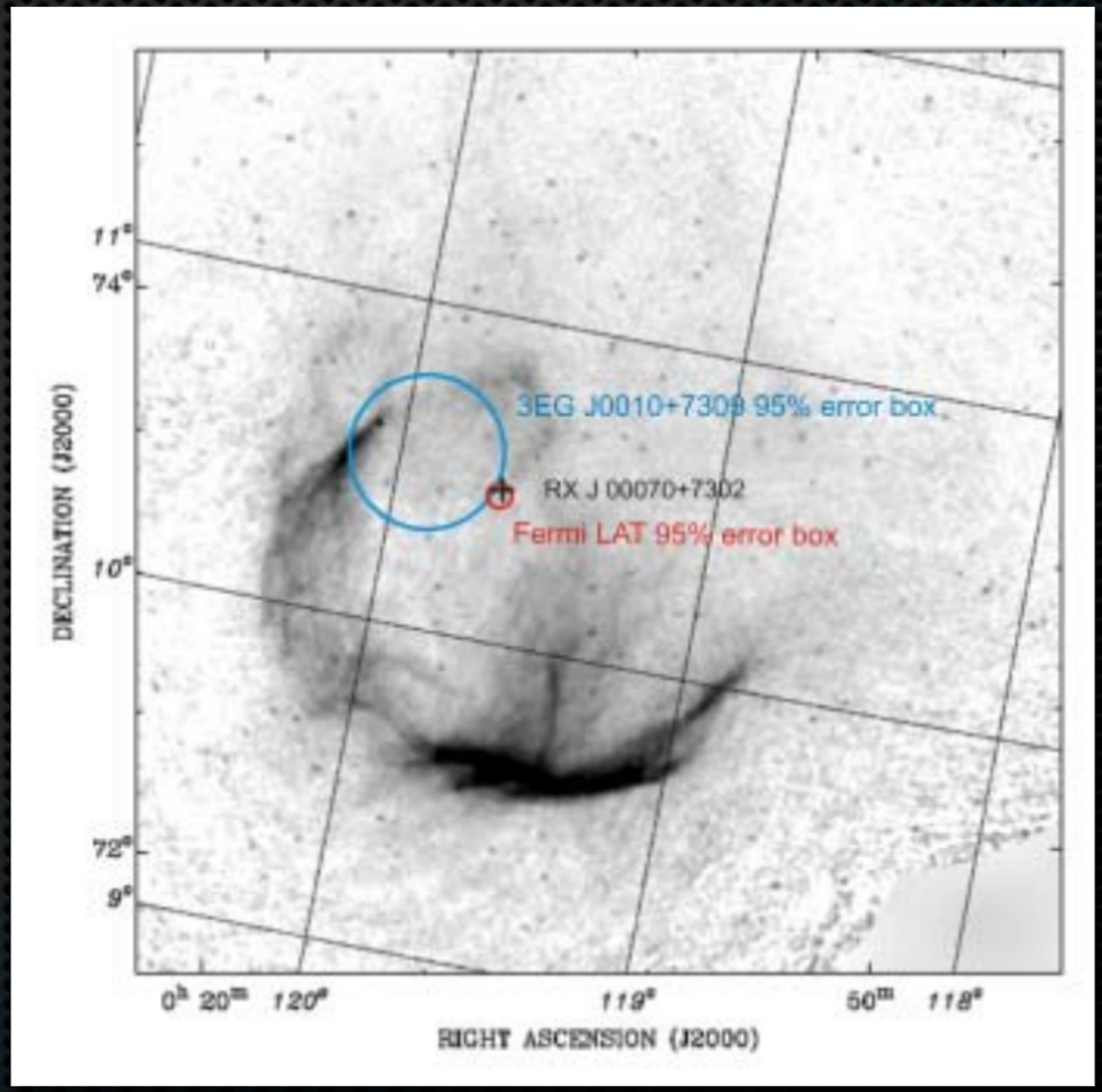


Coincidences with SNRs / PWNe

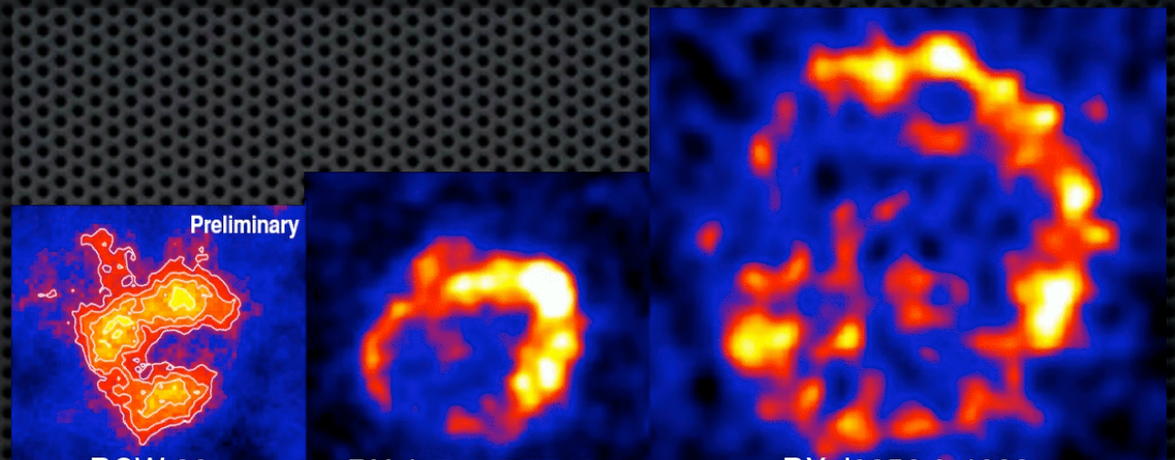
- Positional coincident sources with SNRs and PWNe such as:
  - W28, W41, W51, IC443, Kookaburra, ...
- As seen for CTA 1 and many others, the LAT detects many pulsars
- Pulsed emission and extension analysis crucial for association

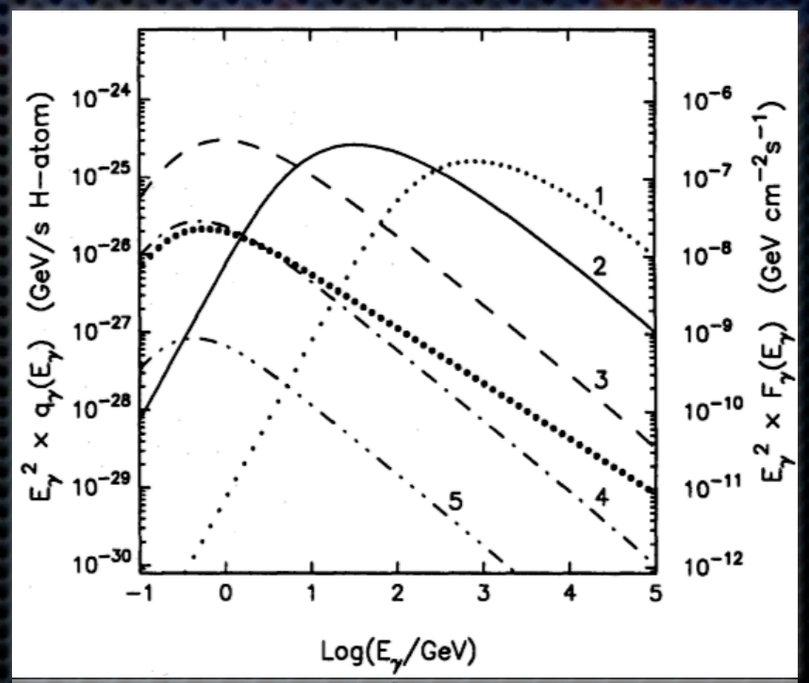


Abdo et al, Science, 322, 1218 (2008)

... but probably not young SNRs

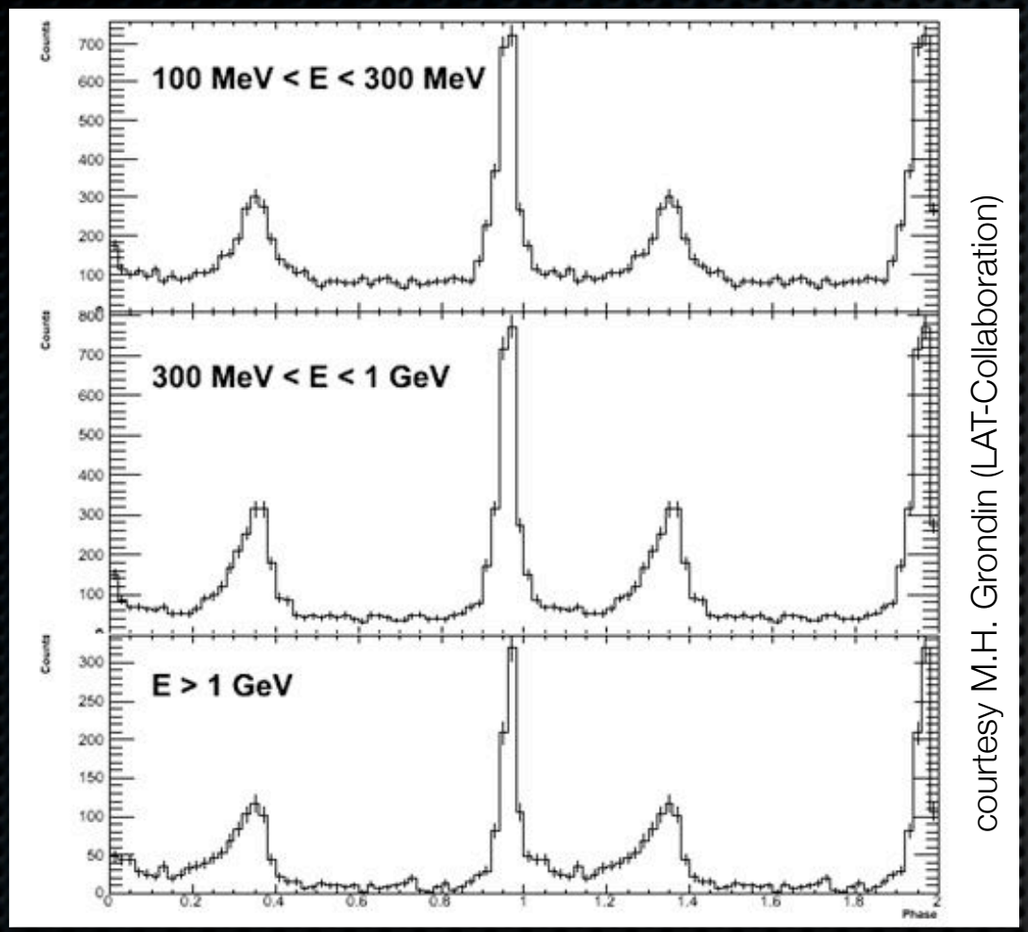
- Brightest young TeV SNR (RX J1713.7-3946) not in the bright source list (same for Cas A, RCW 86, Vela Jr., SN 1006)
- Remember difference in energy flux sensitivity between Fermi-LAT and TeV telescopes
- Old SNRs are preferred targets (lots of GeV-emitting protons still there)



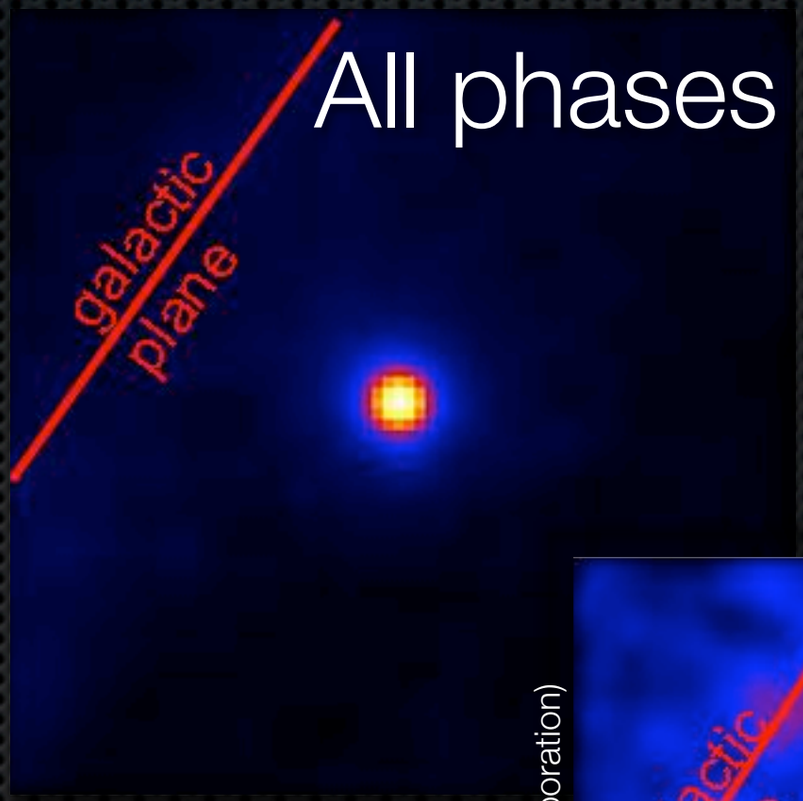


Aharonian & Atoyan, A&A 309, 917 (1996)

The Crab Pulsar and Its Nebula



courtesy M.H. Grondin (LAT-Collaboration)



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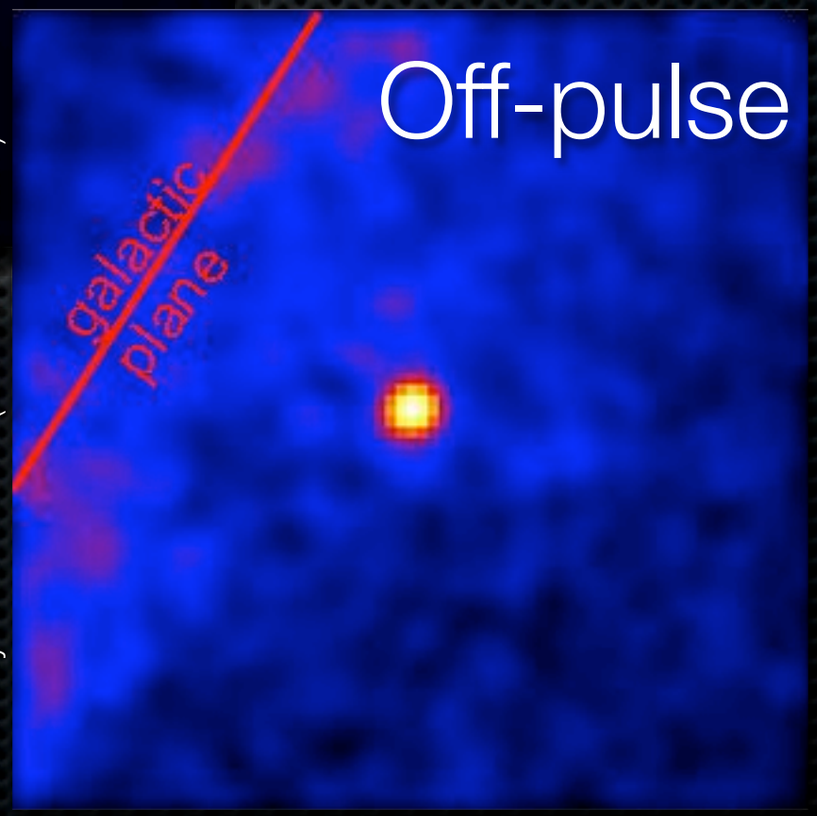
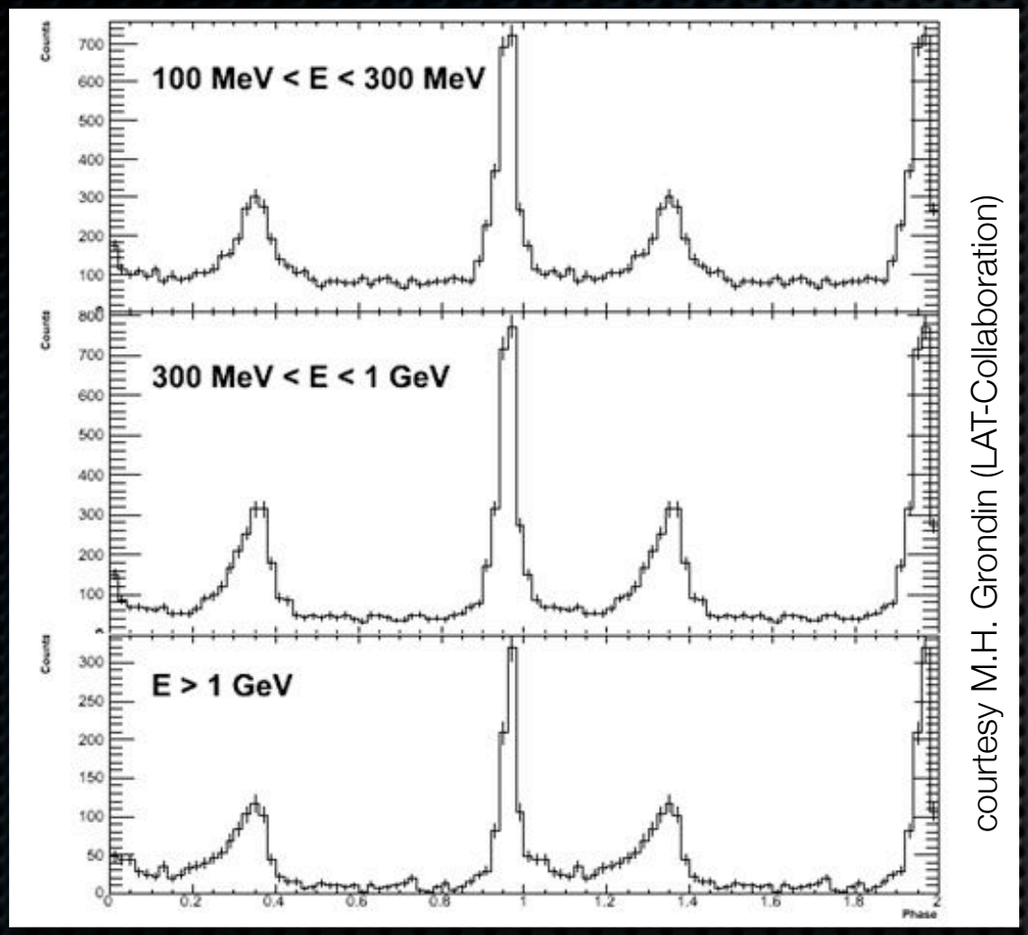


courtesy M.H. Grondin (LAT-Collaboration)

- Most prominent example: Crab Nebula
- Clearly detected in off-pulse emission
- Spectrum matches the TeV spectrum

The Crab Pulsar and Its Nebula



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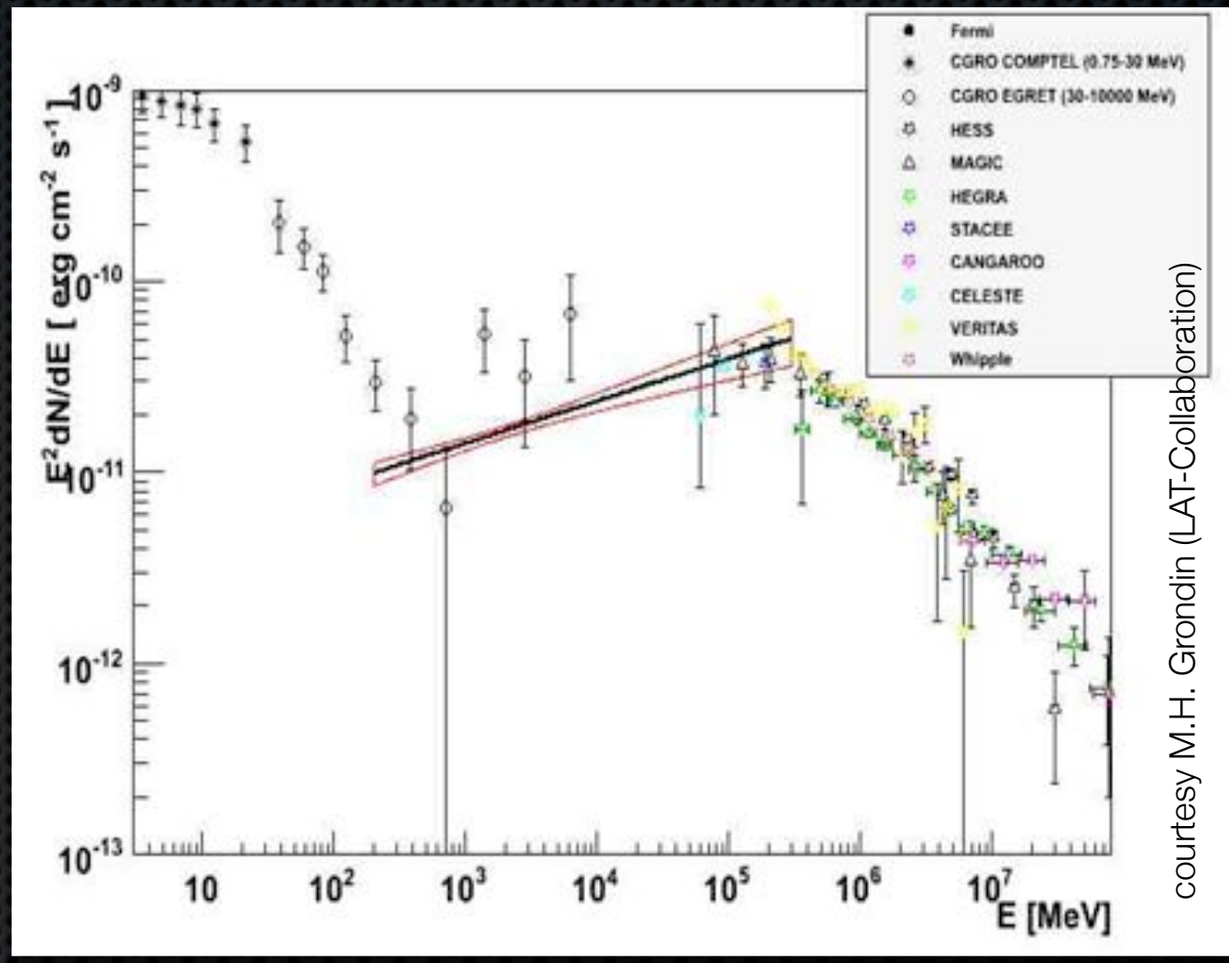

courtesy M.H. Grondin (LAT-Collaboration)

- Most prominent example: Crab Nebula
- Clearly detected in off-pulse emission
- Spectrum seems to connect nicely to the TeV spectrum

Summary

- We have just started the process of systematically comparing the GeV to TeV sky
- Bright TeV sources might not be bright GeV sources (and vice versa)
  - Young SNRs not in bright source list
  - Many pulsars, need extension measurement for association
- … exciting times ahead of us