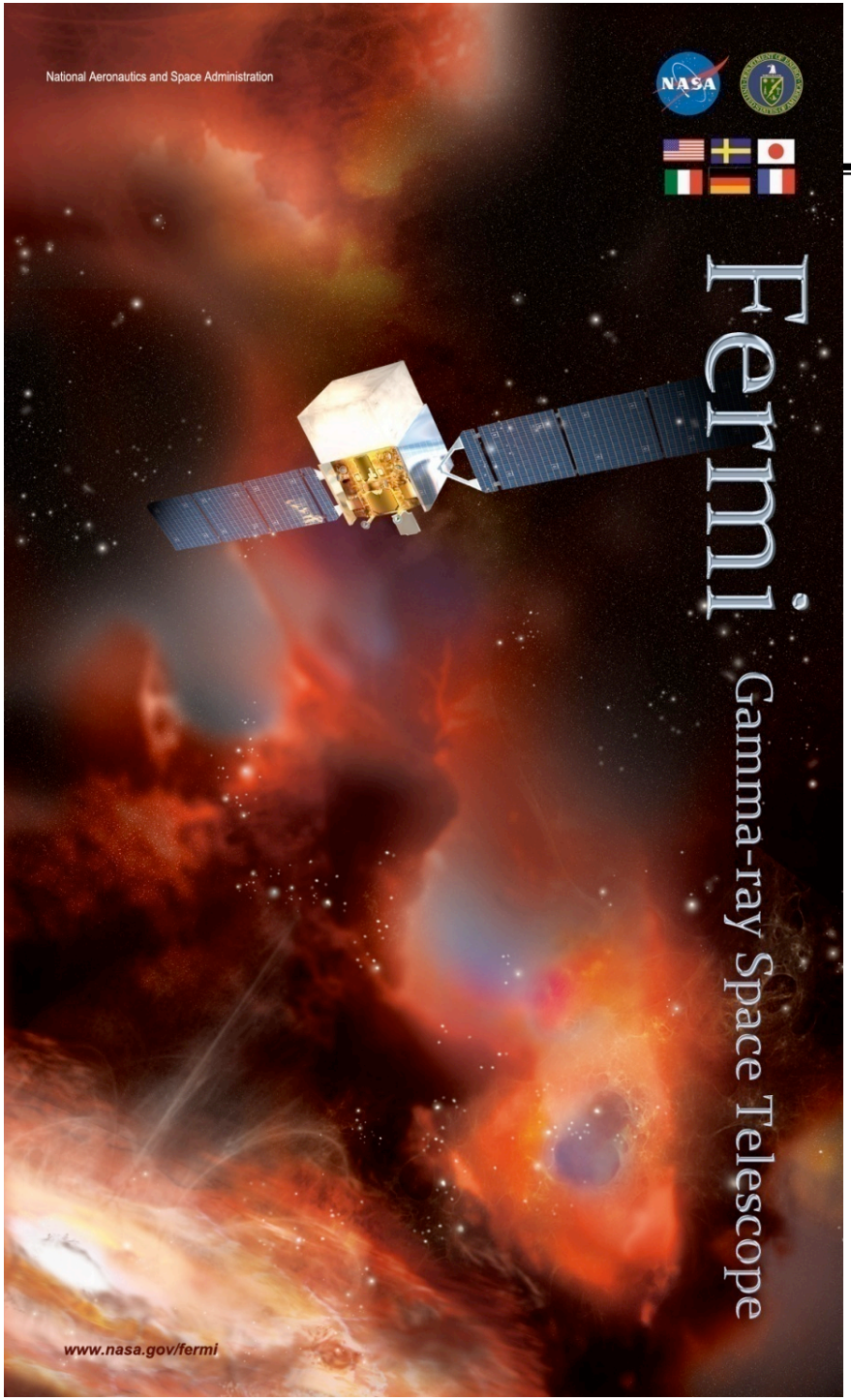



Fermi Gamma-ray Space Telescope

# The First Fermi LAT Catalog (1FGL)

**Dave Thompson**

**on behalf of the**

**Fermi Large Area Telescope Collaboration**

***Jean Ballet and Seth Digel were the leaders of the 1FGL paper.***

# The First LAT Catalog (1FGL)

- 11 months of data 100 MeV to 100 GeV, 23.3 Ms livetime
- 10.6 M events over the whole sky (Pass 6 v3 Diffuse class)
- Improved diffuse model and calibration with respect to 0FGL (Bright Source List)
- Very uniform exposure (factor 1.25 between north and south)
- Detection based on integrated data (not on flares)
- Good localization
- Characterization: spectral, variability
- Association with external catalogs

# Contents of the LAT source catalog

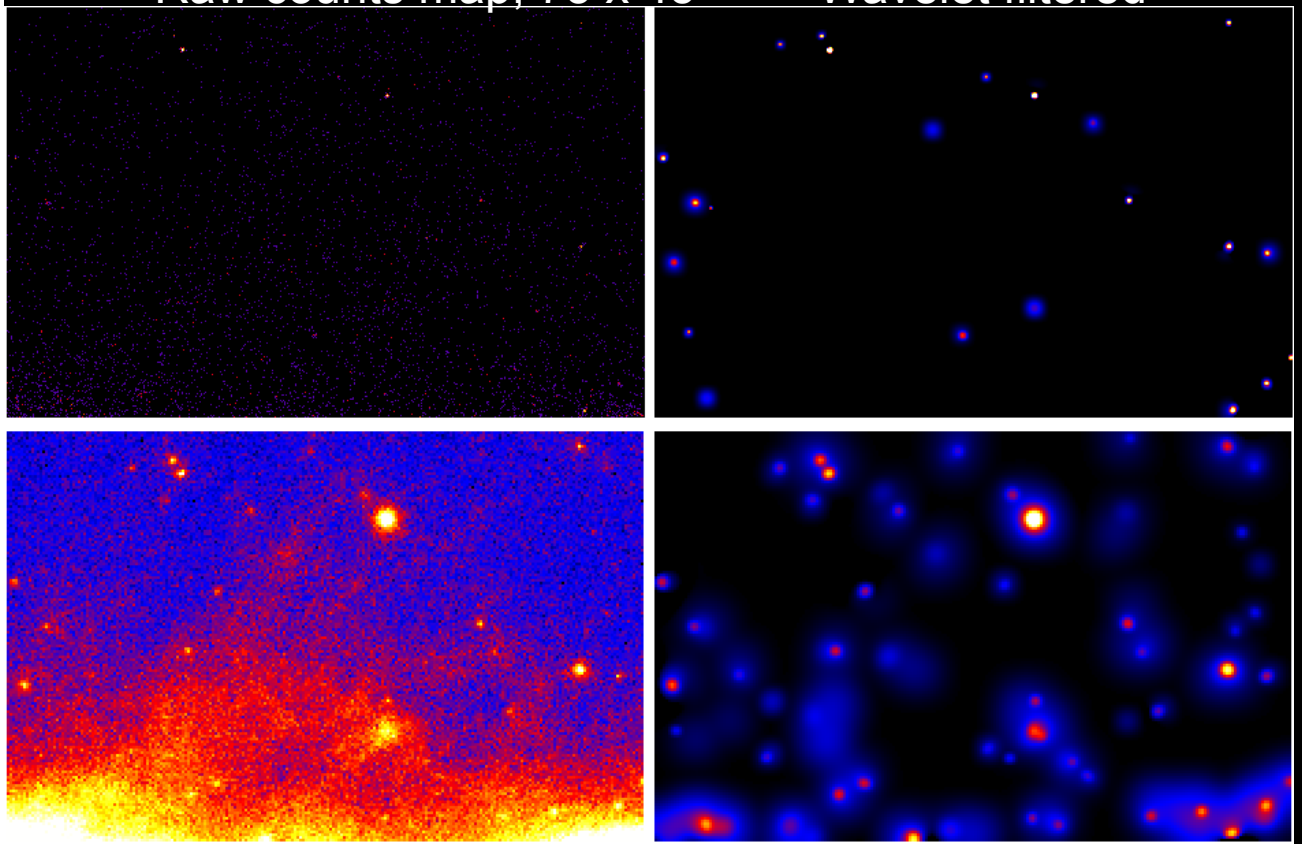
- Source coordinates and error ellipse at 95% confidence
- Source significance and overall spectral index
- Flux in 5 energy bands 0.1 – 0.3 – 1 – 3 – 10 – 100 GeV, spectral index for power-law fit
- Curvature flag indicates sources not well fit by a power law.
- Flux per month, variability flag - 250 high-confidence variable sources
- Quality flags: indicating sensitivity to diffuse model, confusion, error ellipse not well defined
- Associations with known sources

# Source Detection

- **Difficulty is that point spread function improves enormously from 5° at 100 MeV to nearly 0.1° above 10 GeV.**
- **No obvious optimal method to handle that in (α,δ,E) space**
- **Combine several energy bands, merge seeds from several detection methods.**

Raw counts map, 75 x 45°

Wavelet filtered

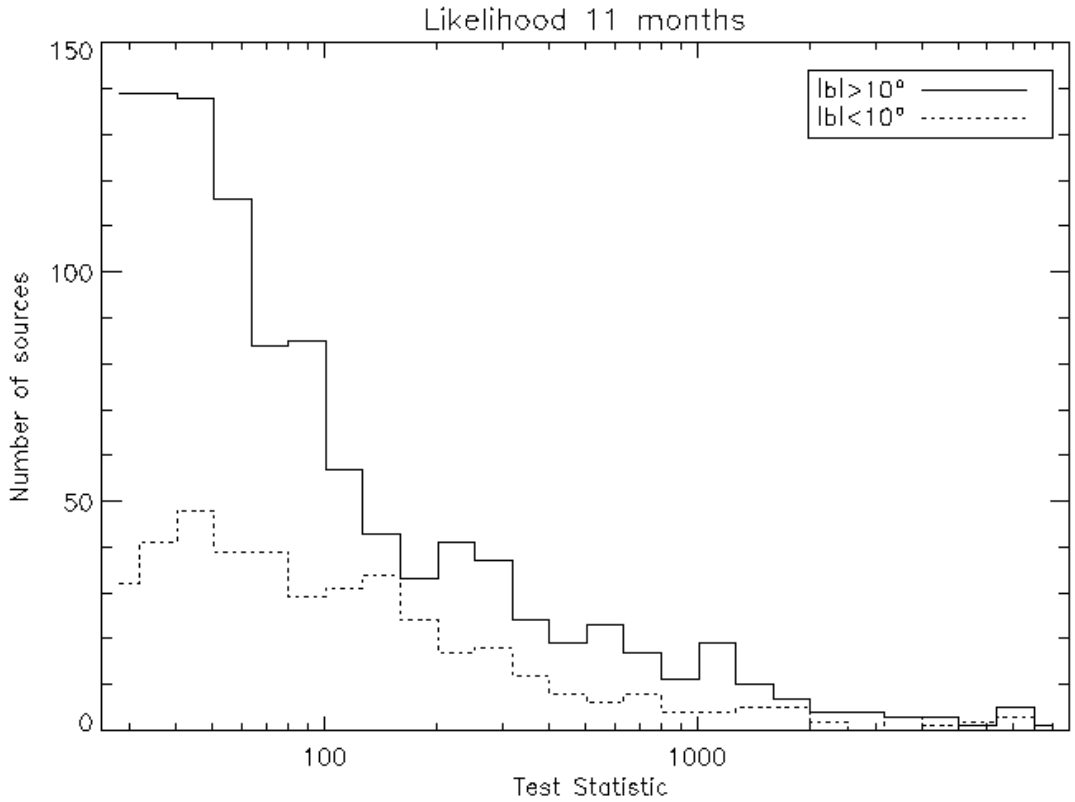


Front > 5 GeV
Back > 10 GeV
Very few events, very well localized

Front > 200 MeV
Back > 400 MeV
Many events, not so well localized

# Source Significance

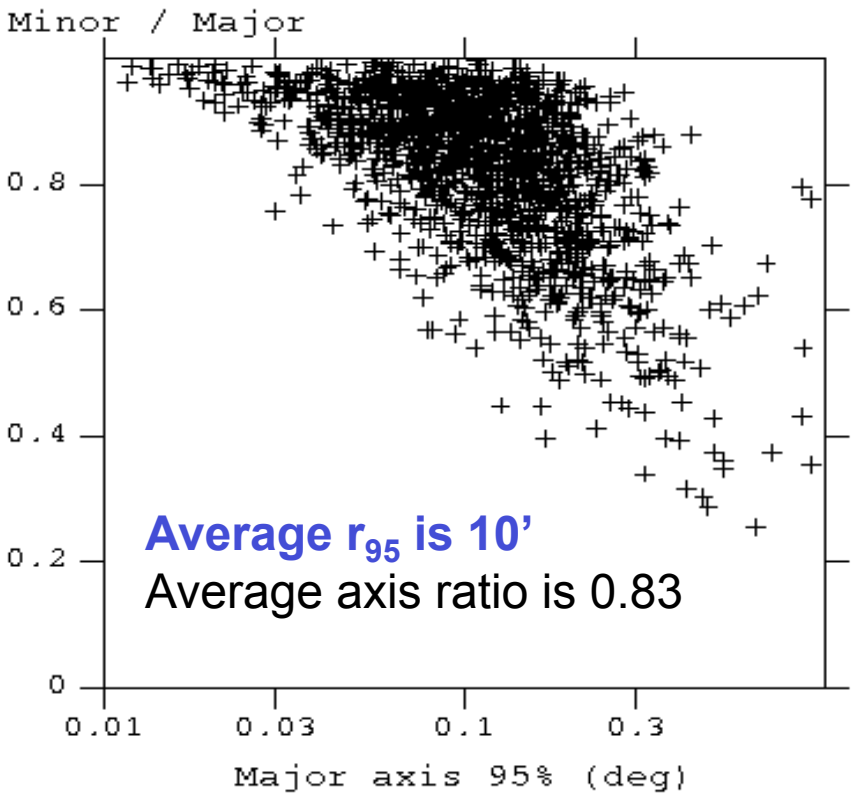
- **3D maximum likelihood analysis (position and energy) was used to determine source significance assuming power-law spectra on top of standard diffuse model**
- **Define Test Statistic TS = 2 Δlog(likelihood) comparing models with and without the source. Cut at TS = 25, corresponding to about 4 σ or 2.5E-5 probability (4 degrees of freedom including source position).**



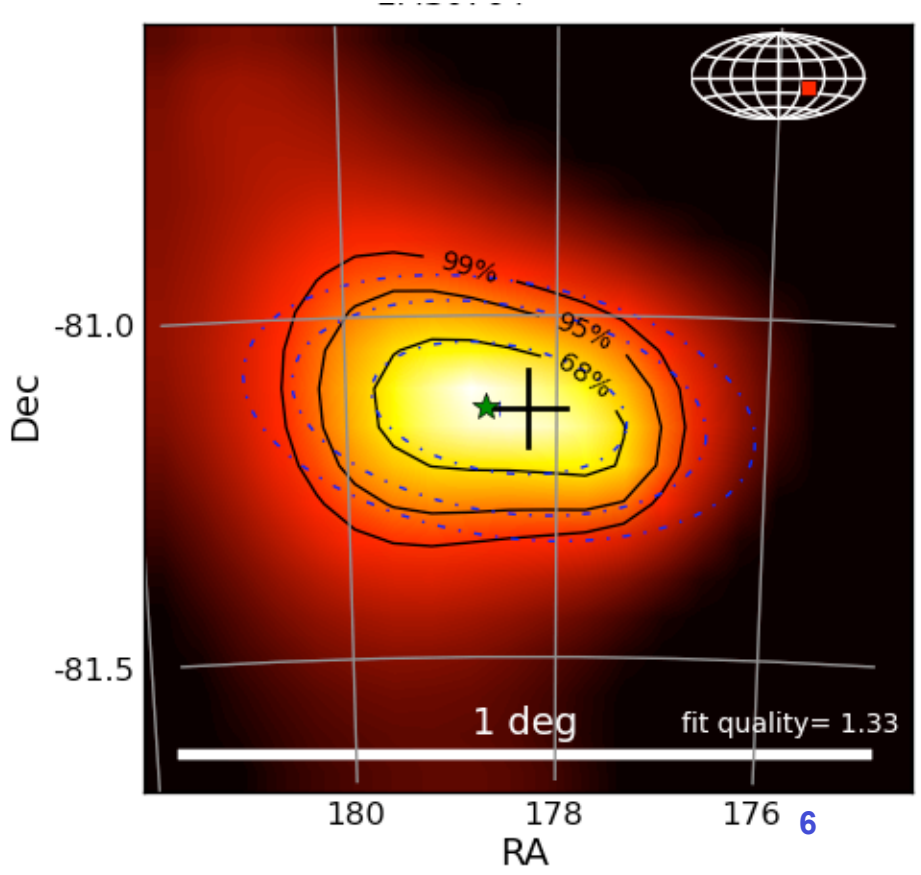

Works well at high latitudes. Peak in TS distribution at threshold.
TS distribution flatter close to Galactic plane. Faint sources are not detected.

# Source Localization

- Conservative error radii adjusted on known associations
- Elliptical parameters whenever can be extracted, mostly round.



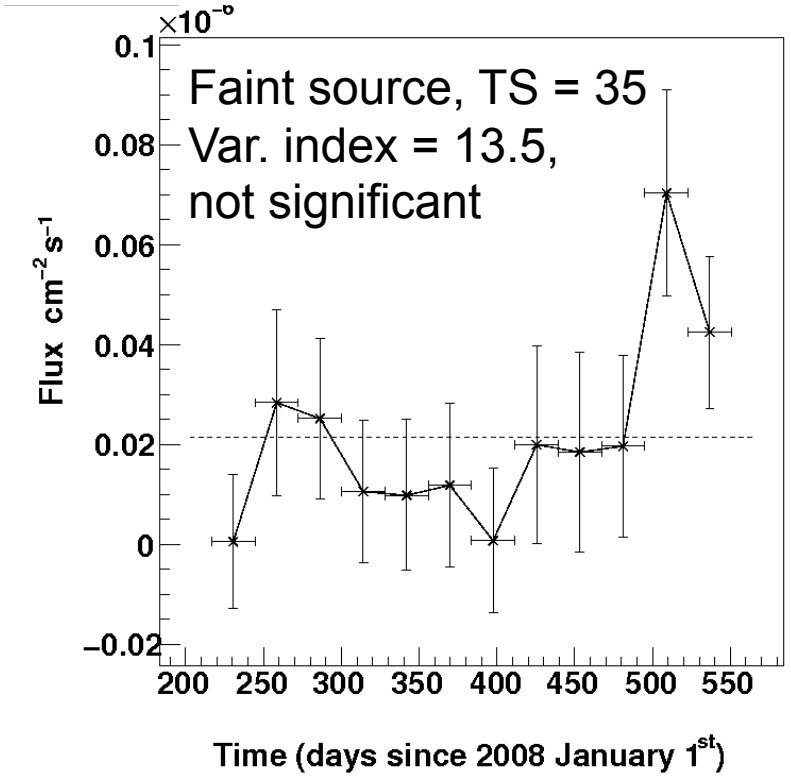

- A difficult example is below. Cross is 1σ 1D error from other localization method for comparison

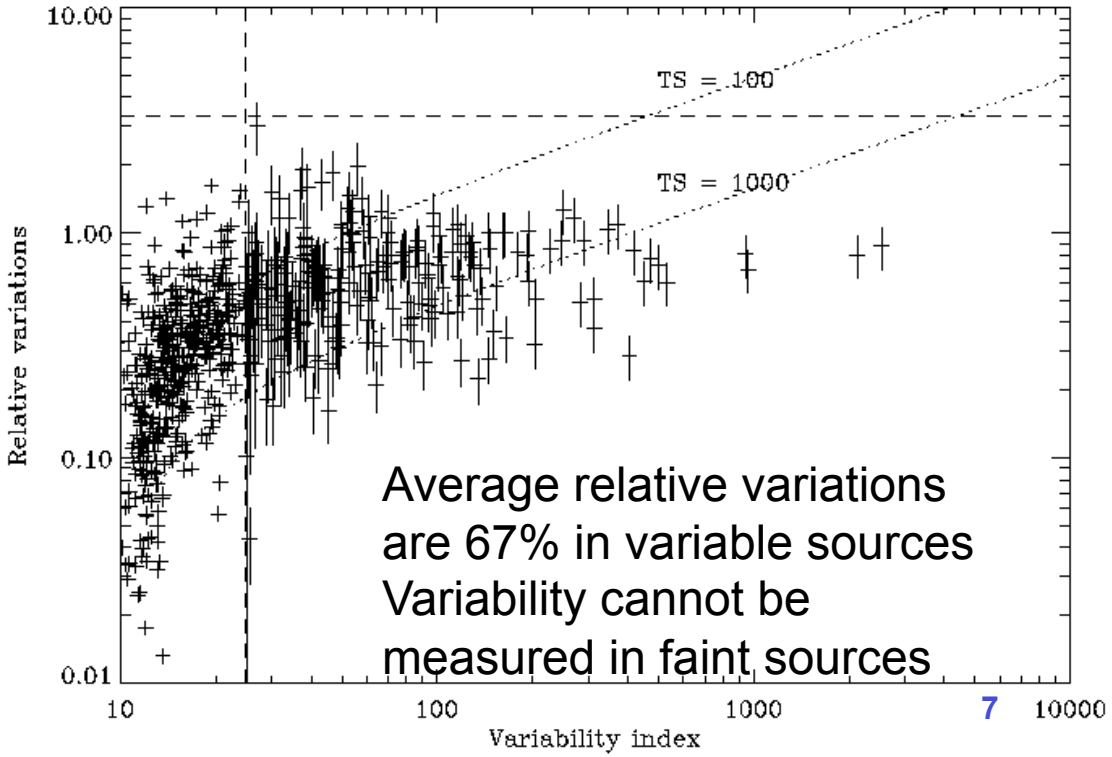


# Source Variability

- Build light curves of all sources on one-month time scale
- Pulsars are stable within 3%
- Bright blazars are very clearly variable

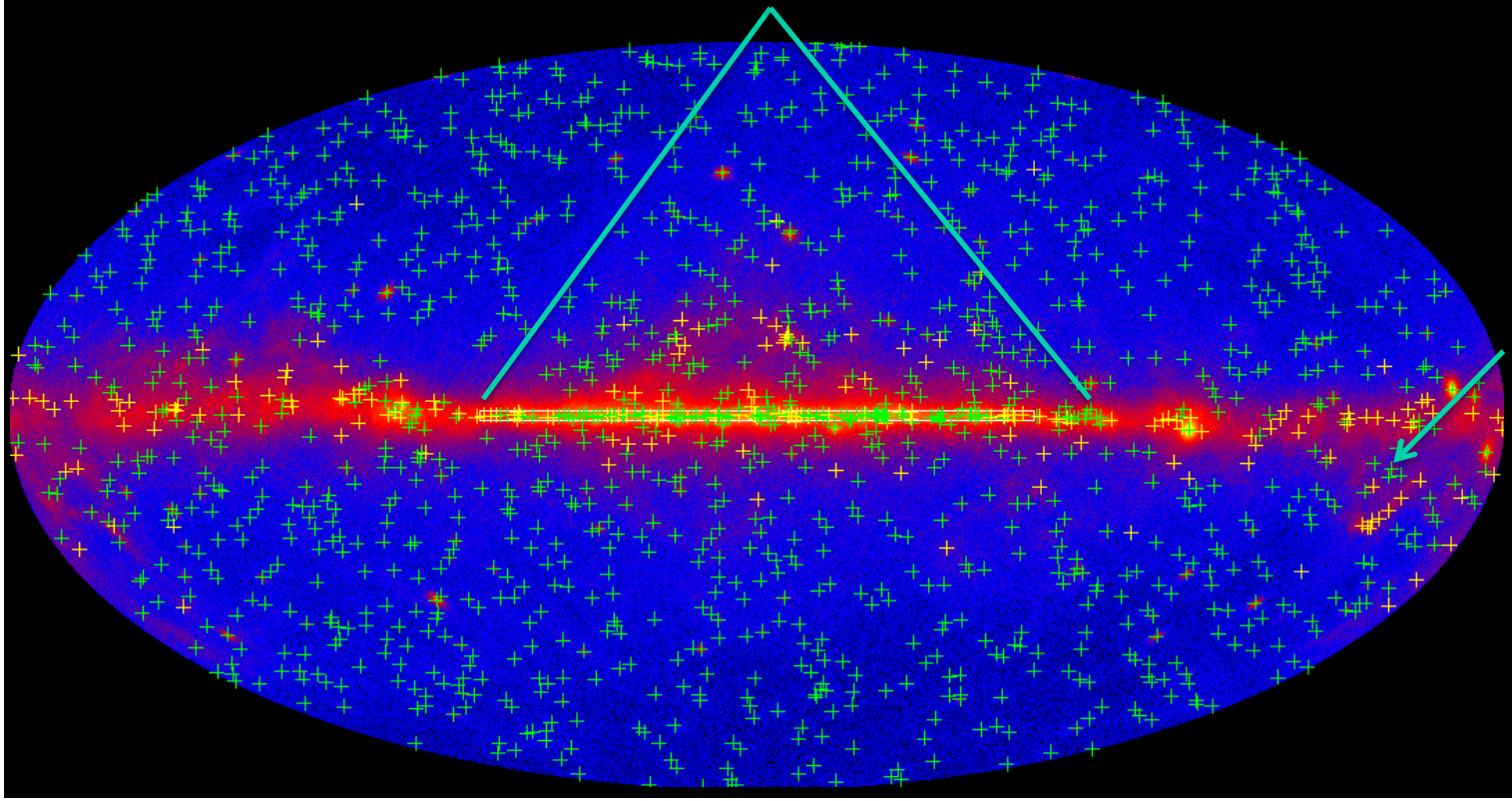
- Variability index: χ2 against constant hypothesis. 250 variable sources
- Relative variations: ΔF/F where $\Delta F^2$ = measured variance minus Poisson variance



# First LAT Source Catalog: Difficulties

- The Galactic ridge (|lat| < 1°, |lon| < 60°) has serious difficulties: sources are close to each other, are not high above the background below 3 GeV, and the Galactic diffuse model is very uncertain there. This even affects sources statistically very significant (TS > 100).
- We flag Galactic ridge sources and some near bright clouds (some 160 sources), and warn against using them without detailed analysis. Of course there are still many true sources in there, including pulsars and SNRs.

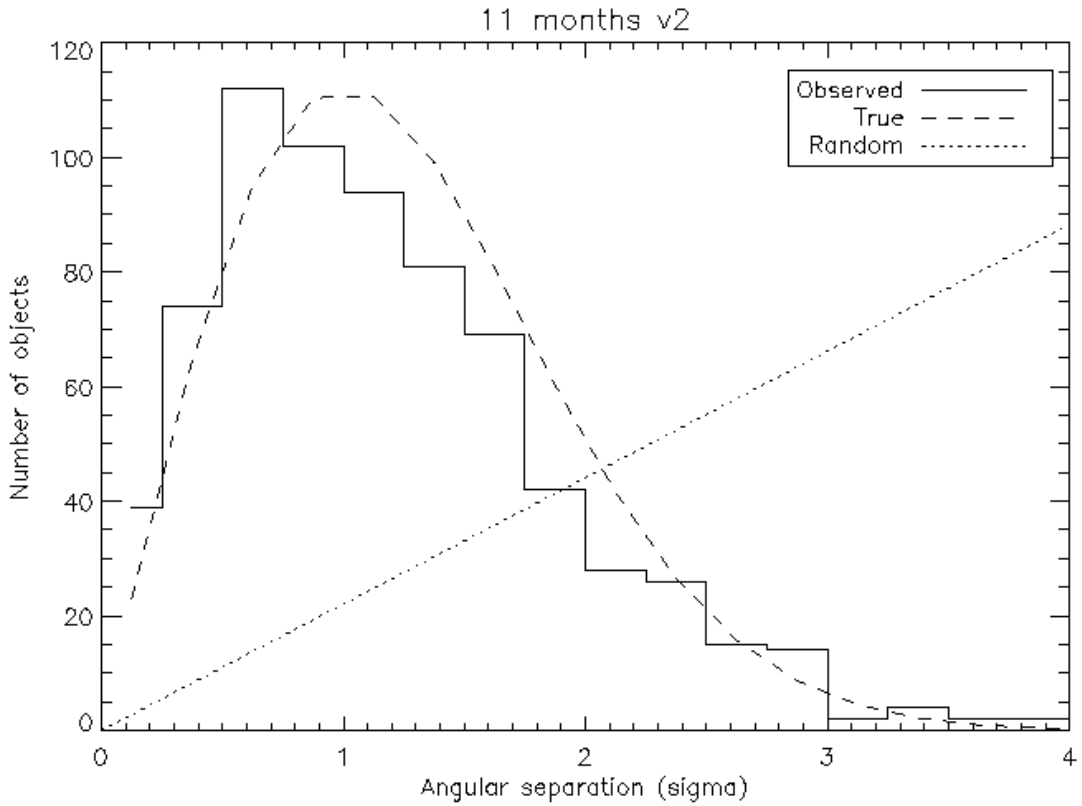


yellow flagged
green not flagged

Orion and ρ Oph clouds visible
Sources outside the Gal. ridge can be handled individually

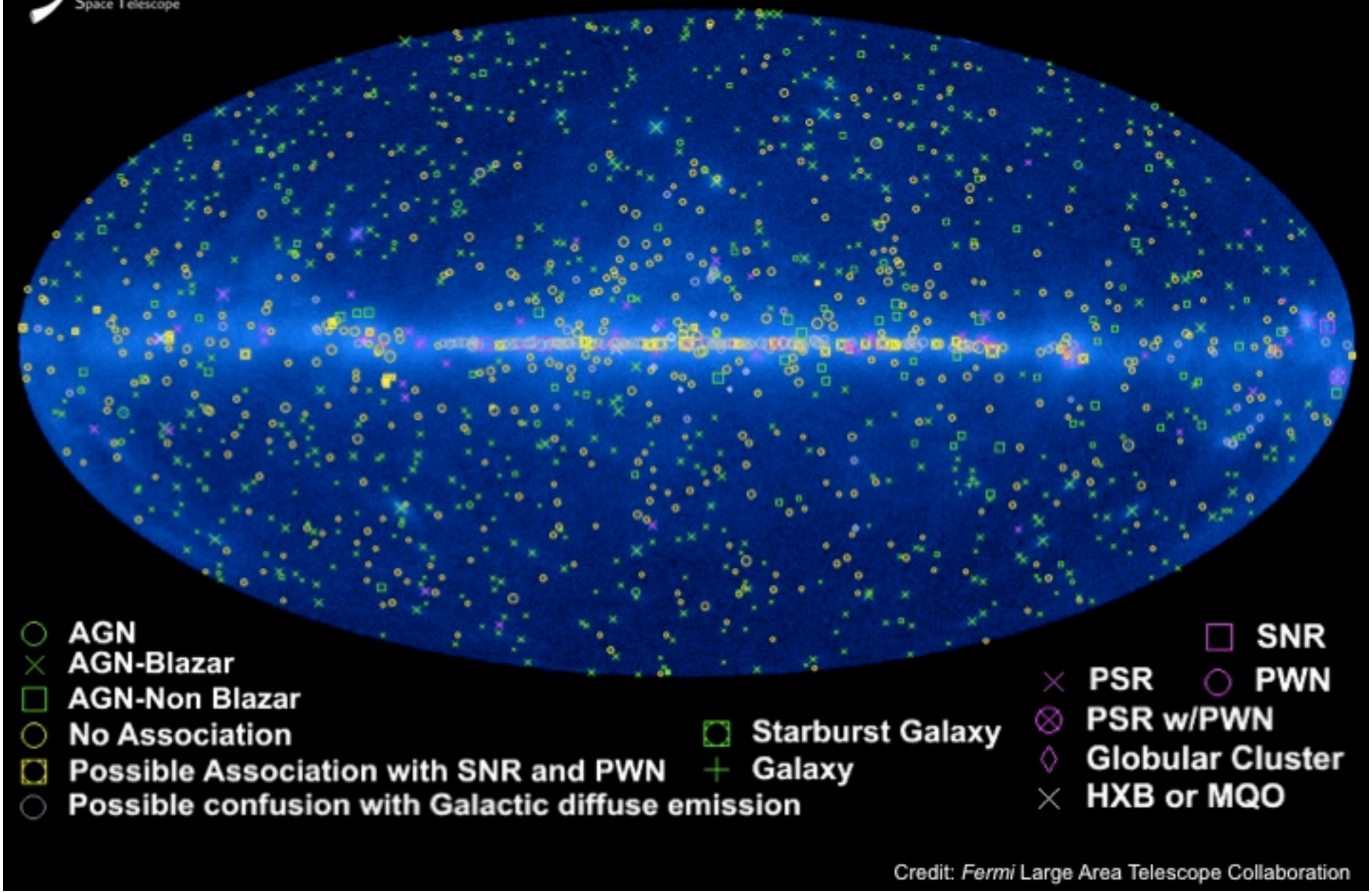
# Source Association

- **Likelihood ratio between true association (gaussian distribution with width defined from $r_{95}$) and random association (flat at counterpart density)**
- **Typically one half of the sources are associated with a plausible counterpart (blazar, pulsar, PWN, SNR, HMXRB), down from 2/3 at 0FGL (brighter)**




Point sources only
No doubt that most of these associations are true.
$r_{95}$ was multiplied by 1.1 to cover the tail.
The distance distribution may be more complex than a simple gaussian

# The Fermi LAT 1FGL Source Catalog



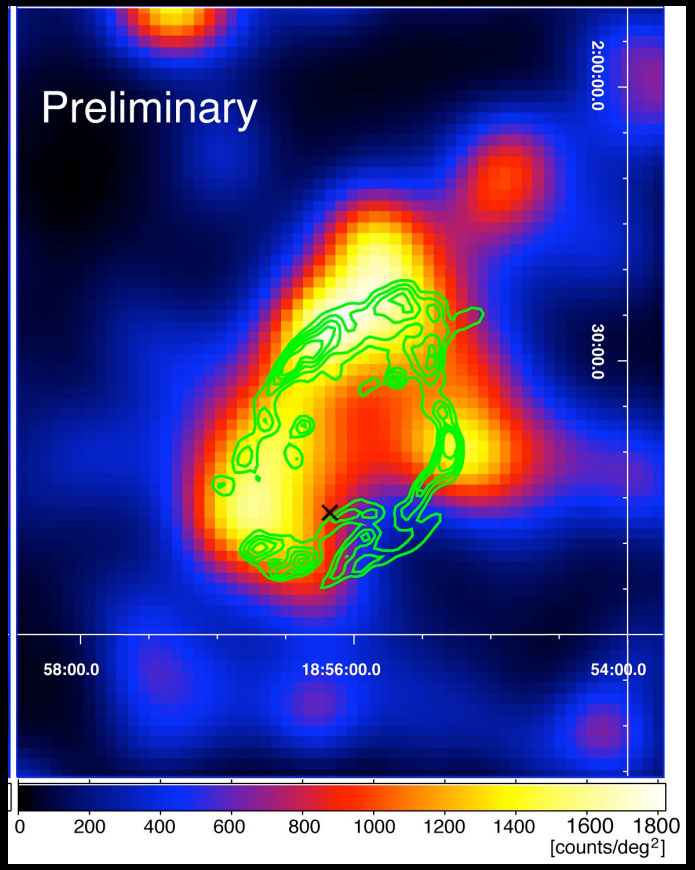

Credit: *Fermi* Large Area Telescope Collaboration

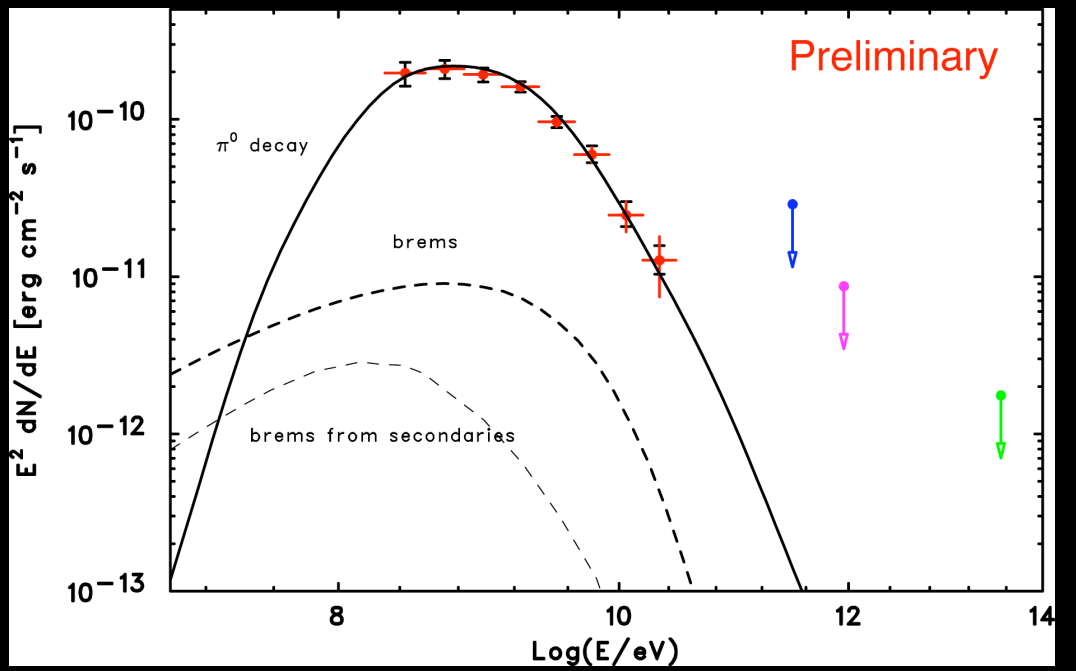
# First LAT Source Catalog: New Source Classes

- Supernova remnant W44 - spatially resolved. 2-10 GeV front-converting events, deconvolved image.

Green contours are from Spitzer IRAC

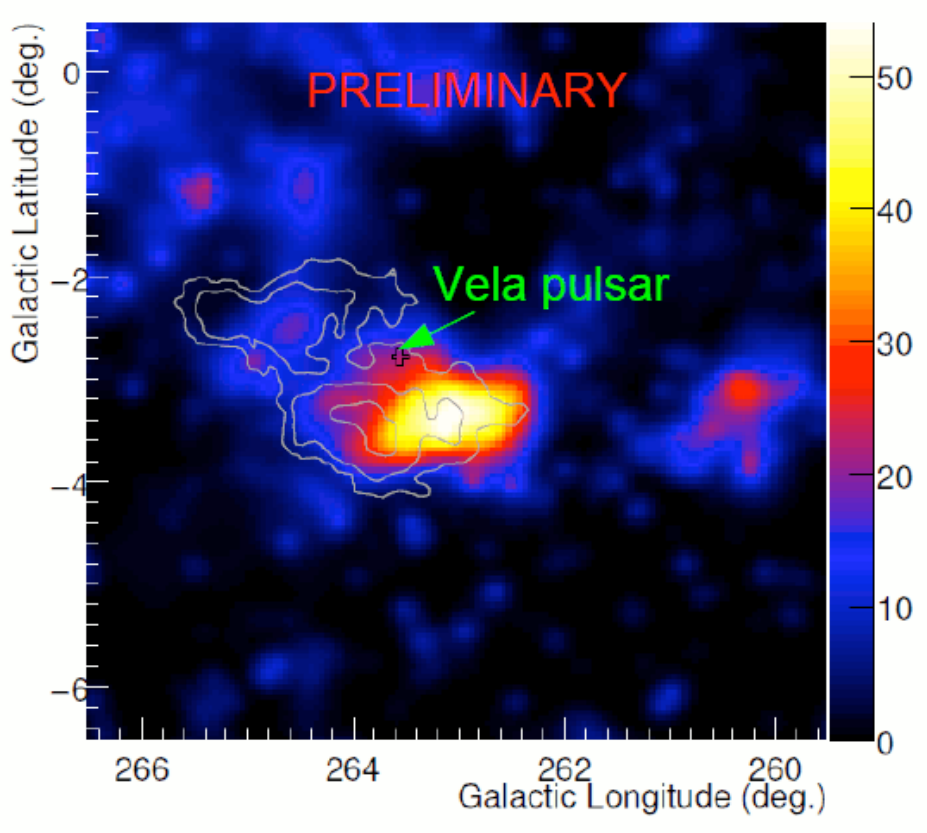
Black cross is PSR B1853+01, not seen as a pulsed source.



# First LAT Source Catalog: New Source Classes

- Vela X Pulsar Wind Nebula. Test Statistic Map for the off-pulse phase interval of the Vela Pulsar.




Gray contours are from WMAP

The gamma-ray emission can be modeled as inverse Compton scattering of several photon fields by the same electron population that produces the WMAP emission.

# First LAT Source Catalog Conclusions

- Extends 0FGL to much fainter sources
- Typical 95% error radius is 10 arcmin. Absolute accuracy is better than 1'
- About 250 sources show evidence of variability
- About half the sources are associated positionally, mostly with blazars and pulsars
- Other classes of sources exist in small numbers (XRB, PWN, SNR, starbursts, globular clusters, radio galaxies, narrow-line Seyferts)
- Uncertainties due to the diffuse model, particularly in the Galactic ridge, should be kept in mind for low-latitude and local cloud studies