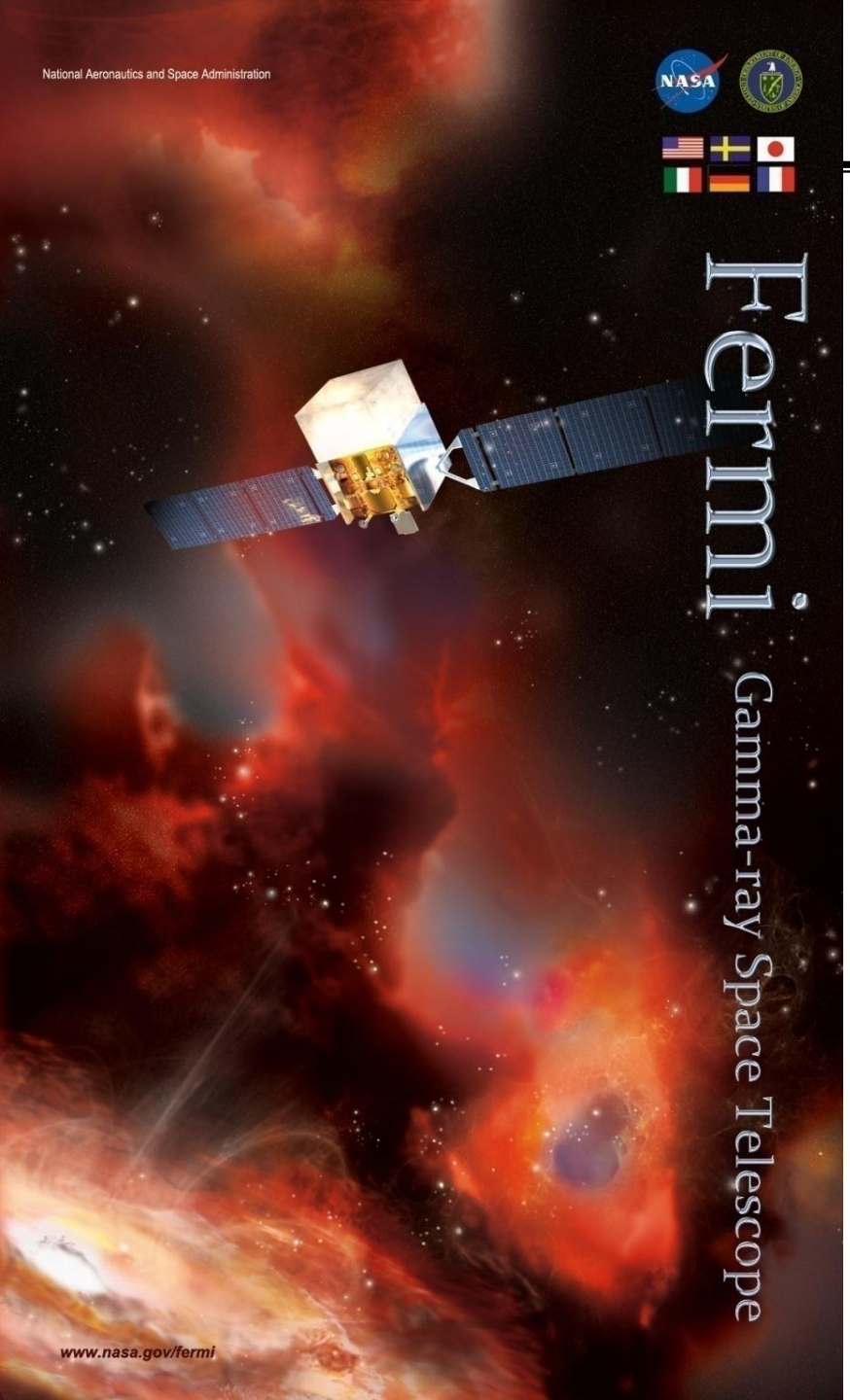

Fermi Gamma-ray Space Telescope

The Fermi LAT First Source Catalog

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on behalf of the
Fermi Large Area Telescope Collaboration

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 after selection
- Improved diffuse model (distributed with the data) and calibration (see poster by Riccardo Rando) with respect to 0FGL
- Very uniform exposure (factor 1.25 between north and south)
- Detection based on integrated data (not on flares)
- Improved localization

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
- Flux per month, variability index
- Extension flag (poster by J. Lande)
- Quality flag: sensitivity to diffuse model, confusion, error ellipse not well defined
- Associations with known sources in external catalogs

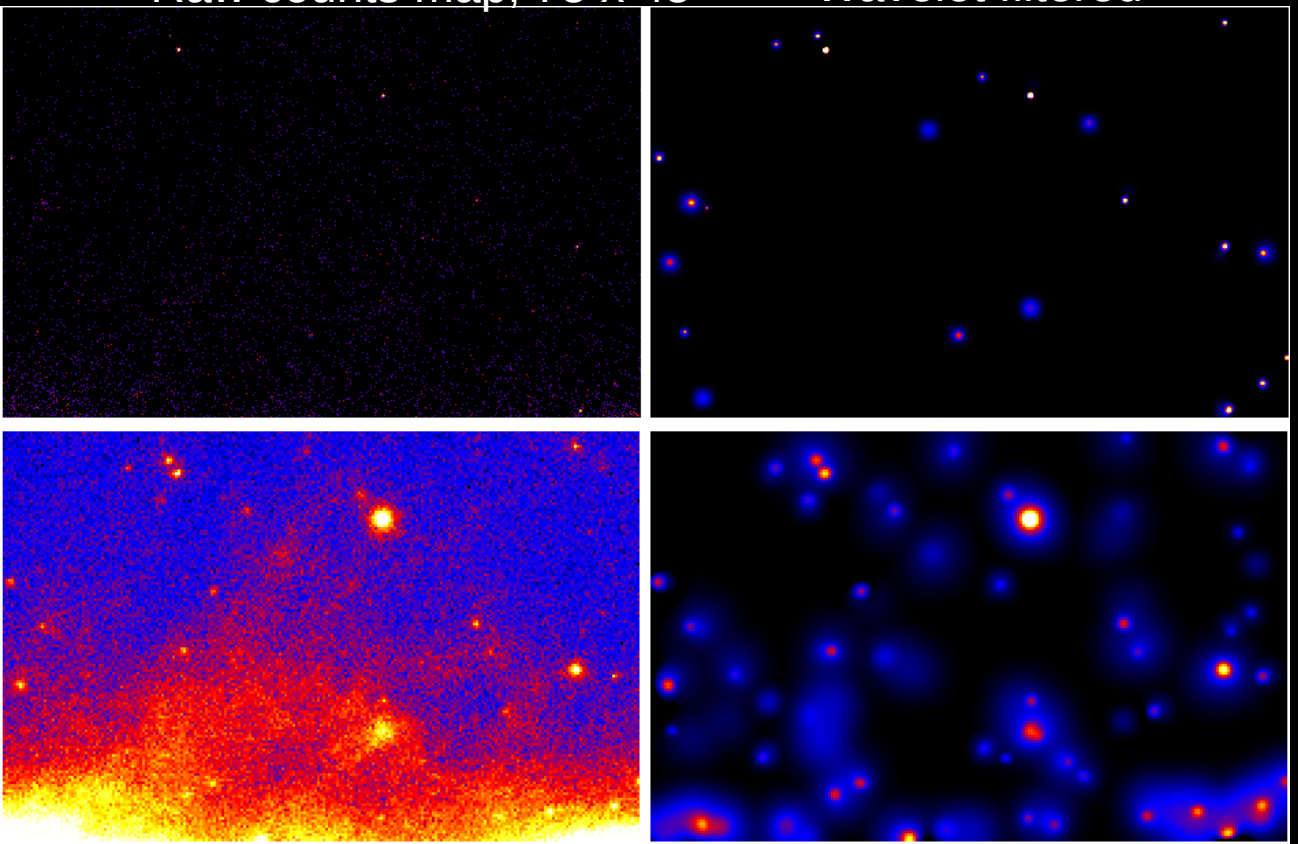
Other LAT catalogs

- The **AGN catalog**, drawn from sources above 10° latitude, excluding known non AGN. Goes with the full source catalog, which adopts the AGN associations. Similar to LBAS (ApJ 700, 597) vs BSL (ApJS 183, 46). Hear Benoit Lott and Marco Ajello, look at Steve Healey's poster.
- The **pulsar catalog**, drawn from all pulsed detections of both radio and γ-ray pulsars. First version (6 months of data) submitted to ApJ (arXiv:0910.1608). Hear Lucas Guillemot.
- The **gamma-ray burst catalog**, drawn from all GRB detections. Completely separate (bright GRBs are actually excluded from the data for the LAT source catalog). Available in quasi real time at Fermi SSC. Hear Nicola Omodei.

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. Poster by E. Massaro**

Raw counts map, 75 x 45˚ Wavelet filtered

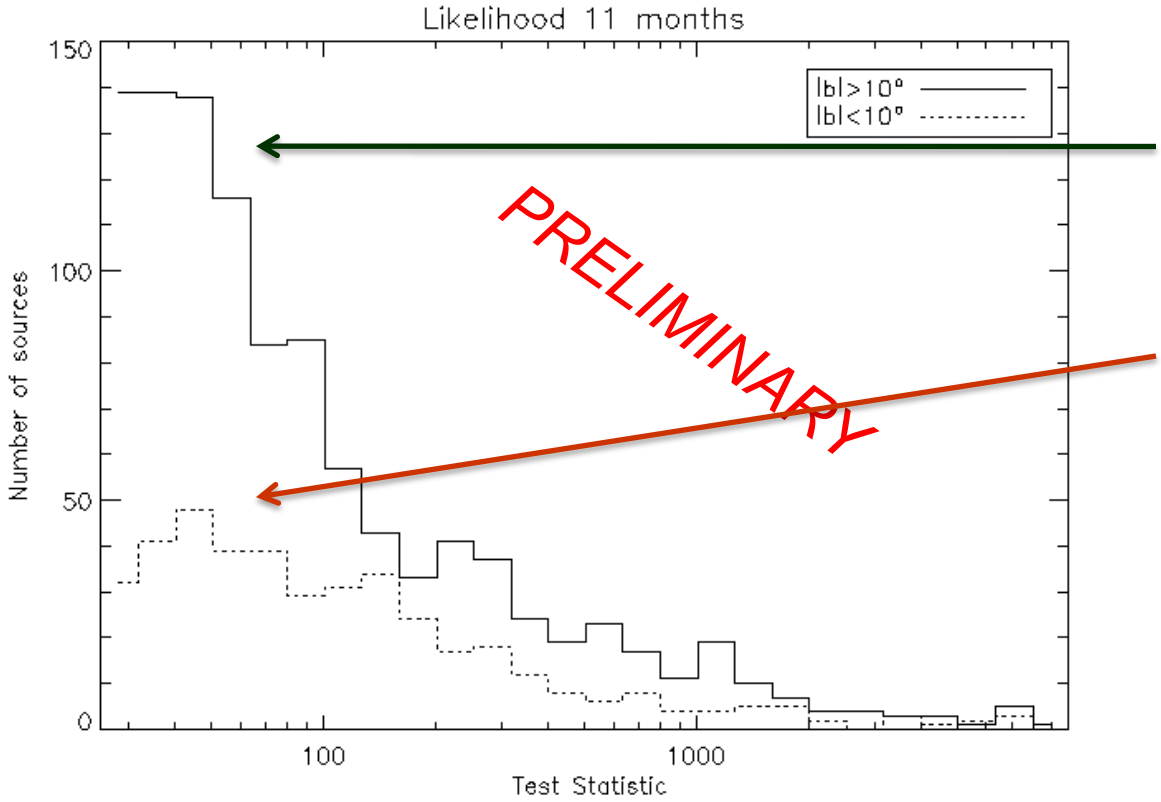


Front > 5 GeV
Back > 10 GeV
Very few events, very well localized

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

Source significance

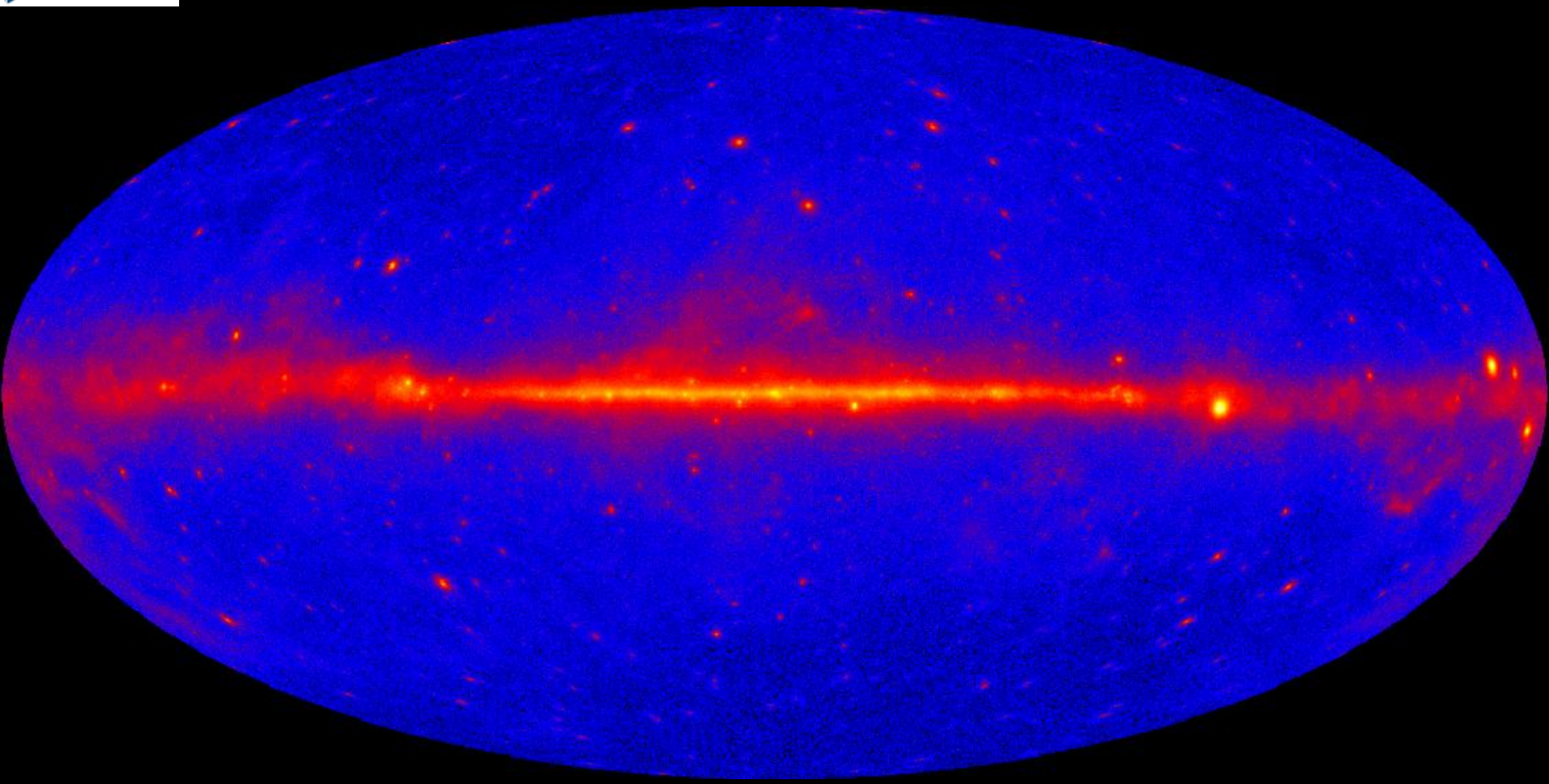
- **3D maximum likelihood analysis** (position and energy) was used to determine source significance assuming power-law spectra on top of standard diffuse model
- Define TS = 2 Δlog(likelihood) comparing models with and without the source. Cut at TS = 25, corresponding to about 4 σ or 2.5E-5 probability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

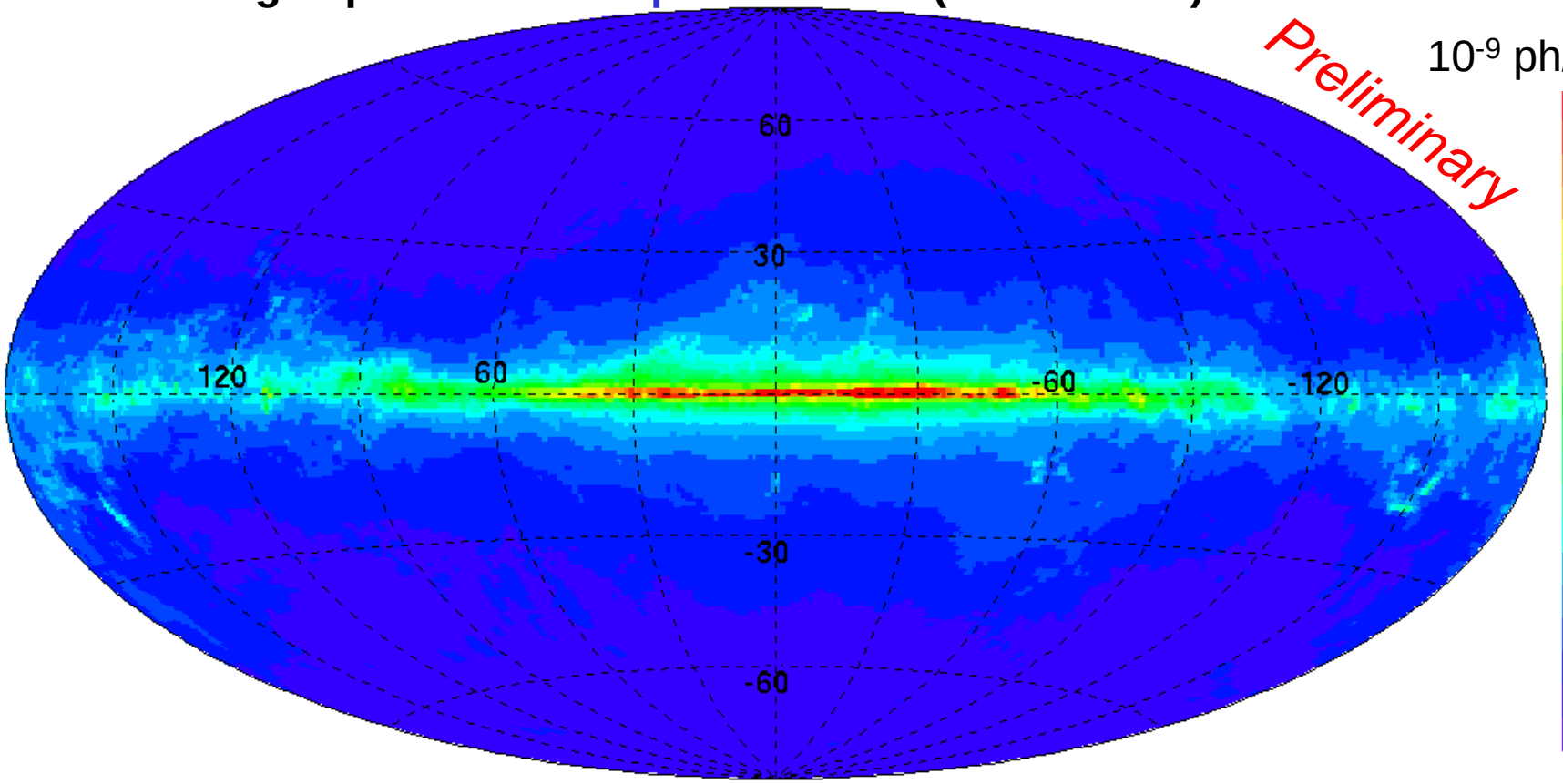
> 1000 LAT sources



- Front > 200 MeV, Back > 400 MeV, log color scale
- Galactic coordinates, Aitoff projection

Sensitivity map

- **Structure is mostly that of the interstellar medium**
- **Below 10^{-8} ph/cm^2/s outside the Galaxy (|b| > 30°)**
- **Strong dependence on spectral index (hear B. Lott)**

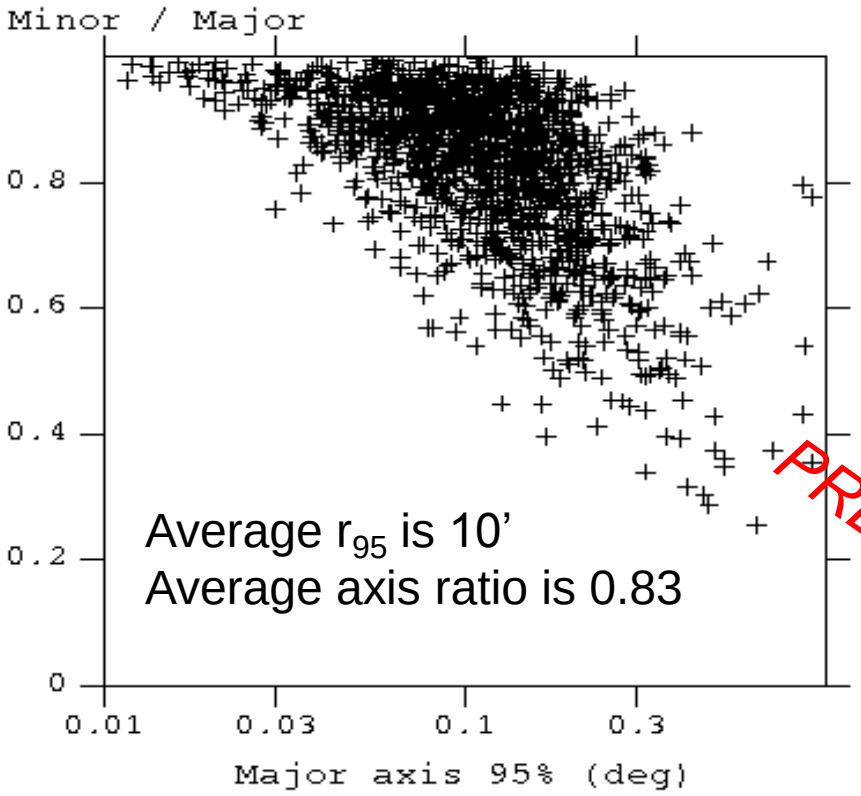


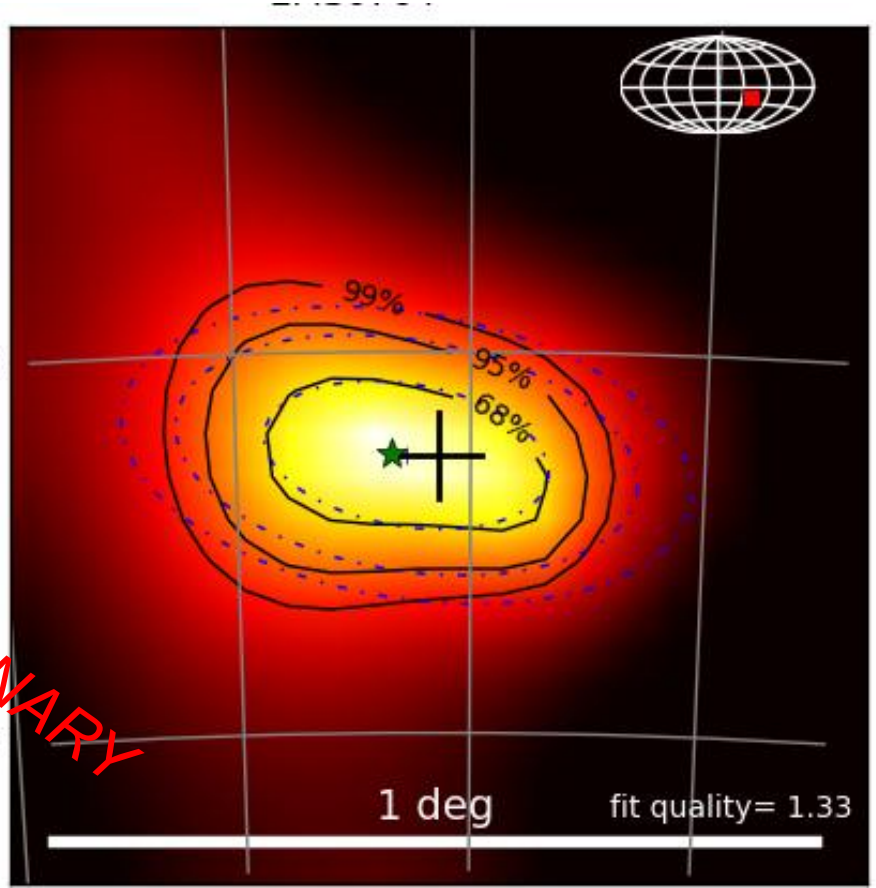
Flux > 100 MeV required to reach TS=25 for average $E^{-2.2}$ spectrum

Galactic coordinates, Aitoff projection

Source localization

- **Error ellipses adjusted on TS maps, on average close to circles**
- **Conservative 0.012° absolute limit based on bright pulsars**
- **A difficult example is below. Cross is 1σ 1D error from another localization method for comparison**

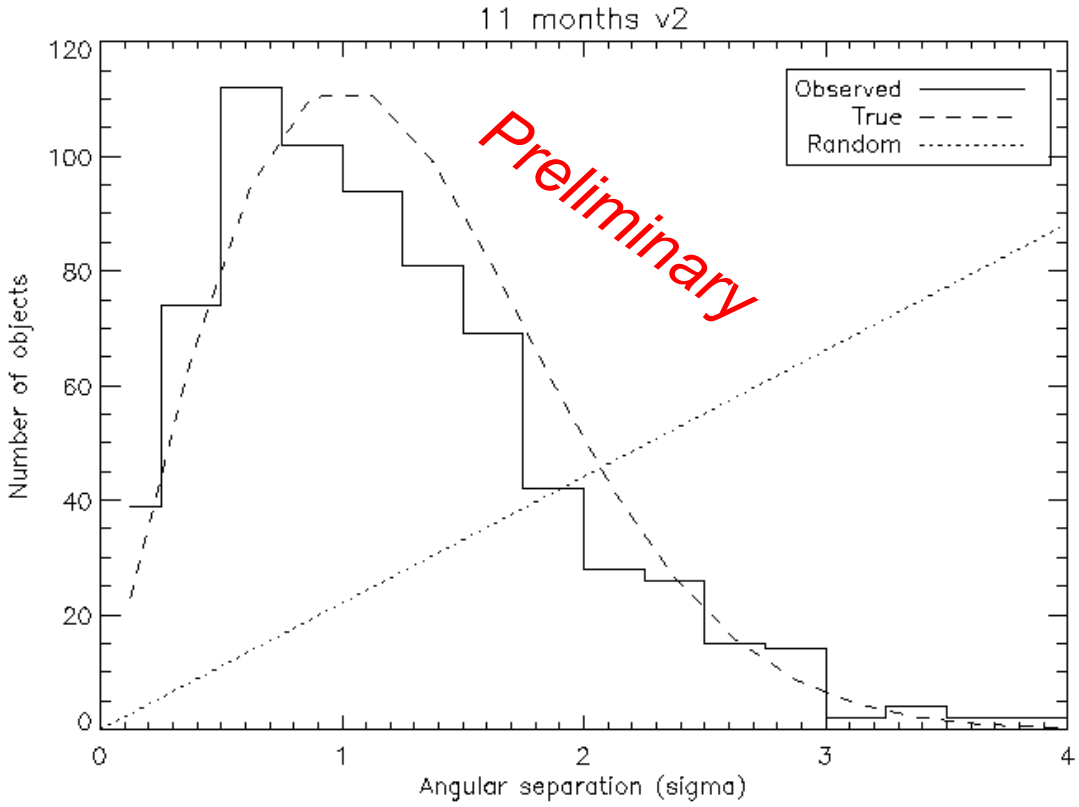




PRELIMINARY

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 to a plausible counterpart (radio blazar, pulsar, PWN, SNR, XRB), down from 2/3 at 0FGL (brighter)**



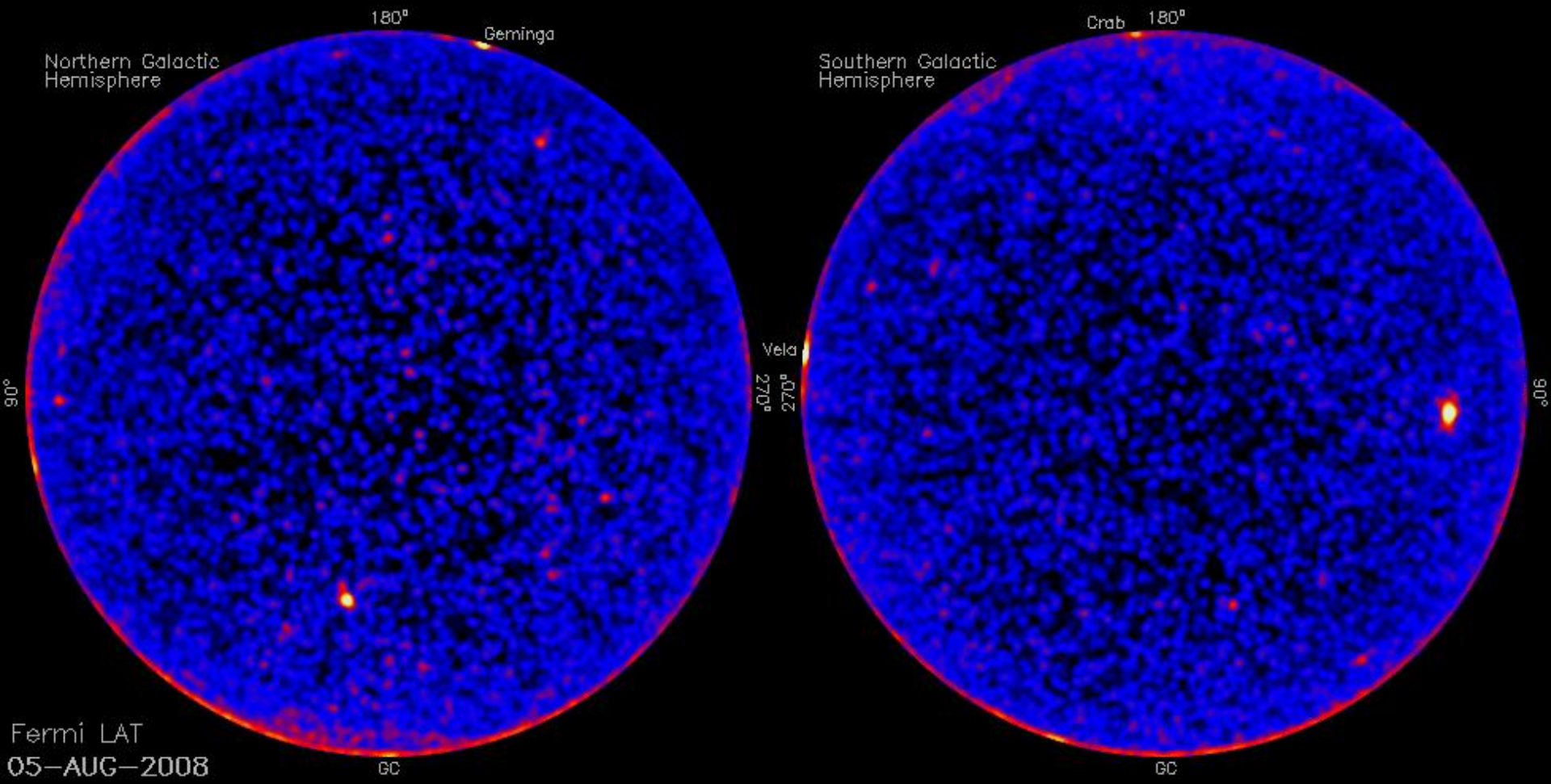
Point sources only

No doubt that most of these associations are true.

r_{95} was multiplied by 1.2 to cover the tail.

The distance distribution may be more complex than a simple gaussian

The variable Fermi sky

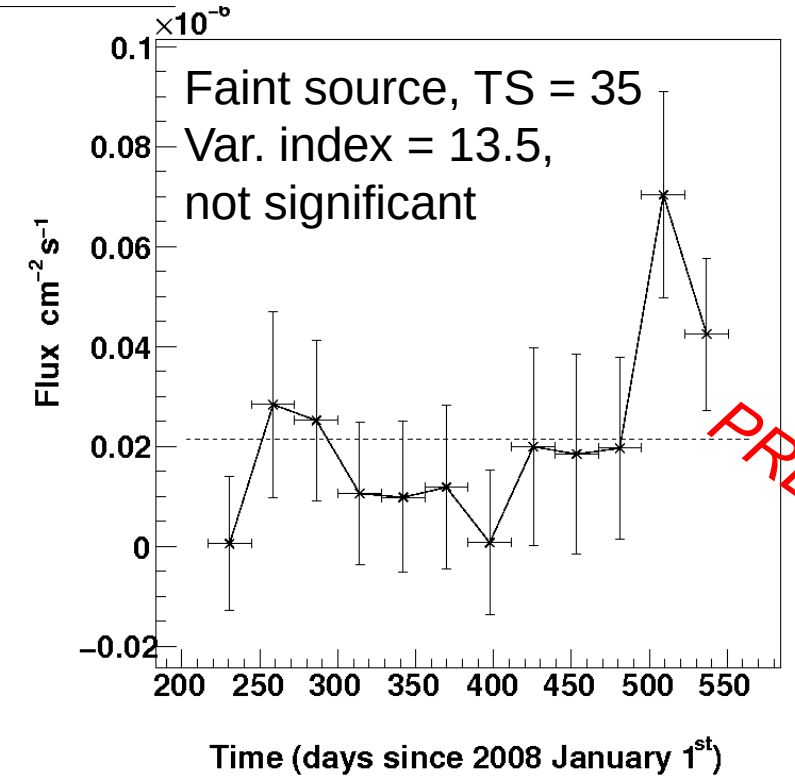


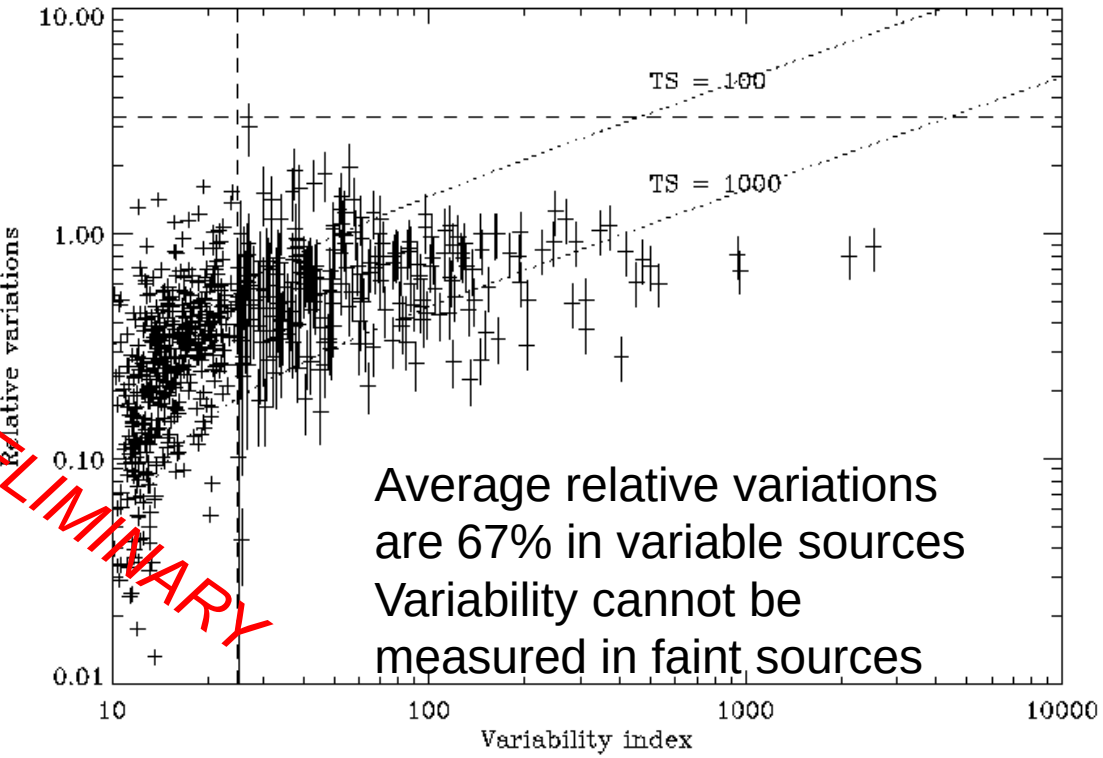
- **1-day snapshots, > 100 MeV, viewed from the poles (orthographic proj). Red is significant.**
- **The Sun is moving down right of North pole and up right of South pole**

Source variability

- Build light curves on one-month time scale, assuming constant spectral index
- Pulsars are stable within 3%
- Bright blazars are very clearly variable
- Upper limit in intervals in which sources are not significant

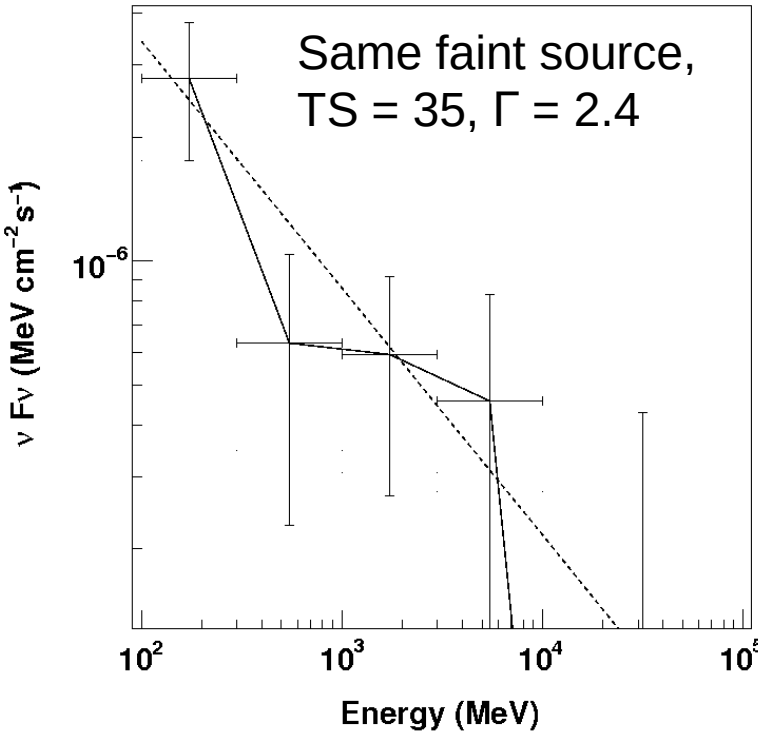
- **Variability index: χ^2 against constant hypothesis. 250 variable sources at 99% confidence level**
- **Relative variations: $\Delta F/F$ where ΔF^2 = measured variance minus Poisson variance**

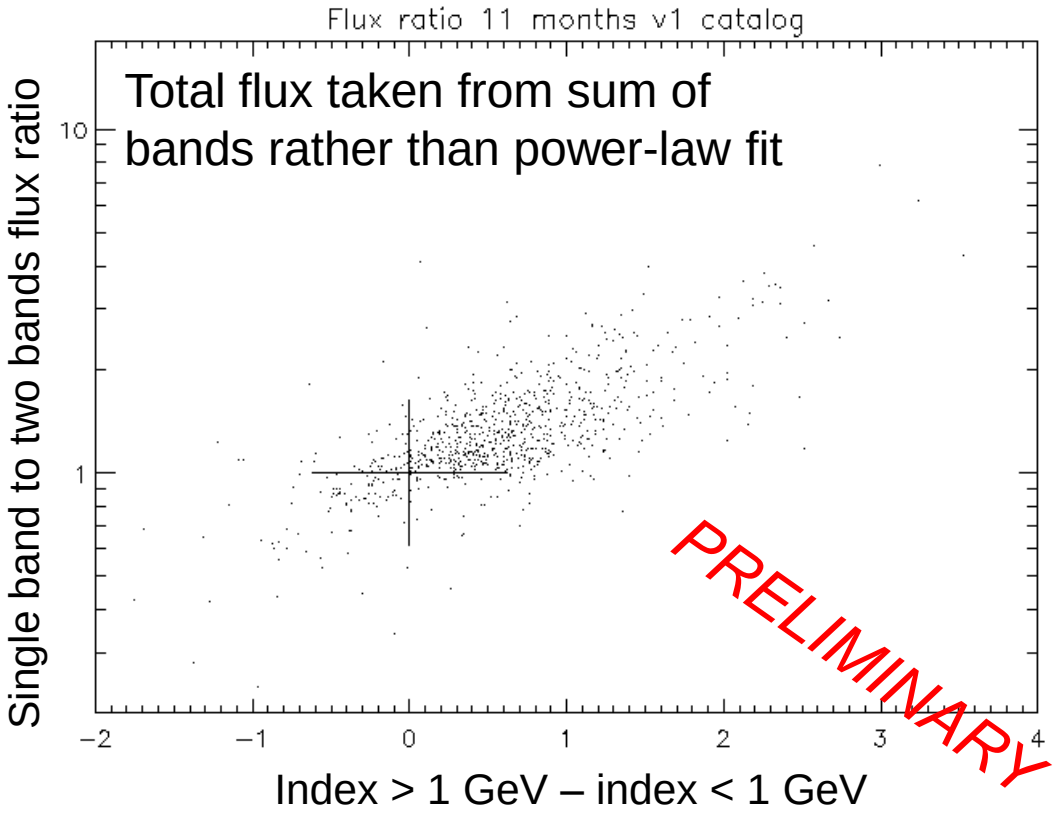




Source spectra

- **Extract flux in 5 bands from 100 to 300 MeV, 300 MeV to 1 GeV, 1 to 3 GeV, 3 to 10 GeV, 10 to 100 GeV**
- **Upper limit in bands in which sources are not significant**
- **Sources not significant in all bands, total flux not well measured**
- **Average spectrum is broken, power-law estimate is too high**



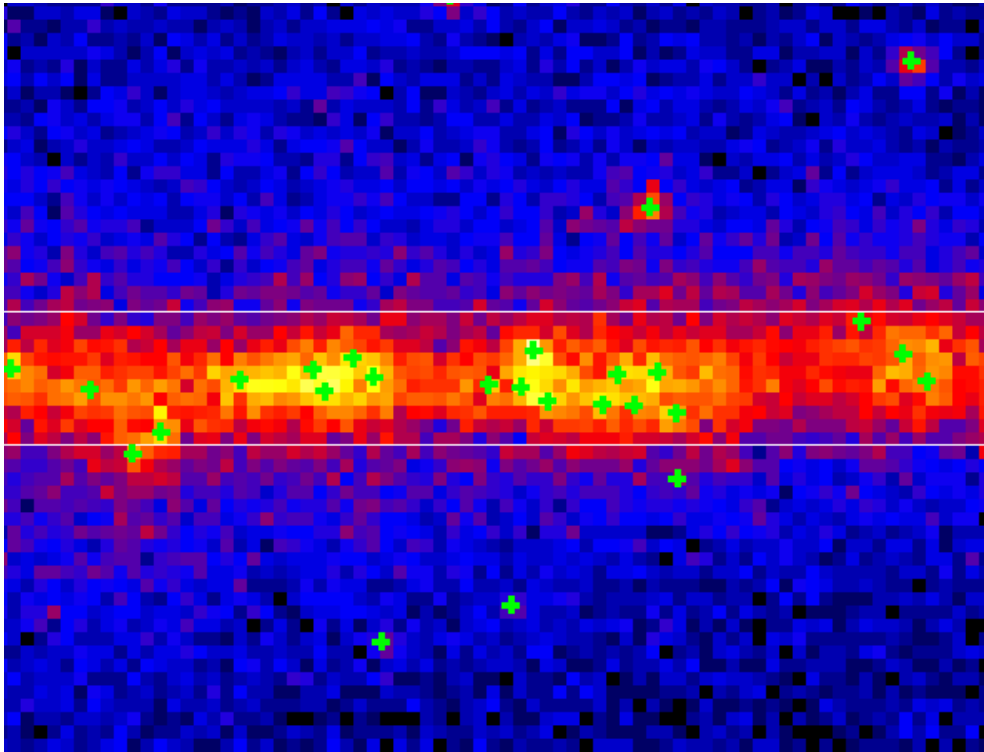


Source confusion

- Average distance between sources outside the plane is about 3˚
- More than r_{68} at typical detection energy (0.8˚ at 1 GeV)
- Important for soft sources, and introduces strong additional bias against very soft sources ($\Gamma \geq 3$)

- **15˚ region of the Galactic ridge above 1 GeV**
- **Crosses are sources, pixel is 0.2˚**
- **Sources not clearly separated**
- **Could be unmodeled diffuse emission**

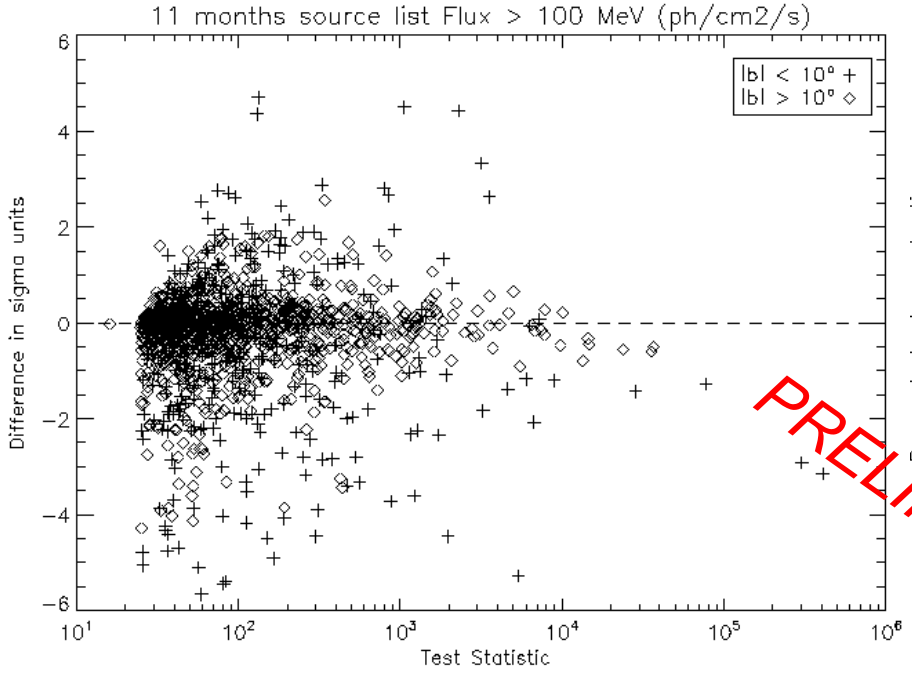
PRELIMINARY

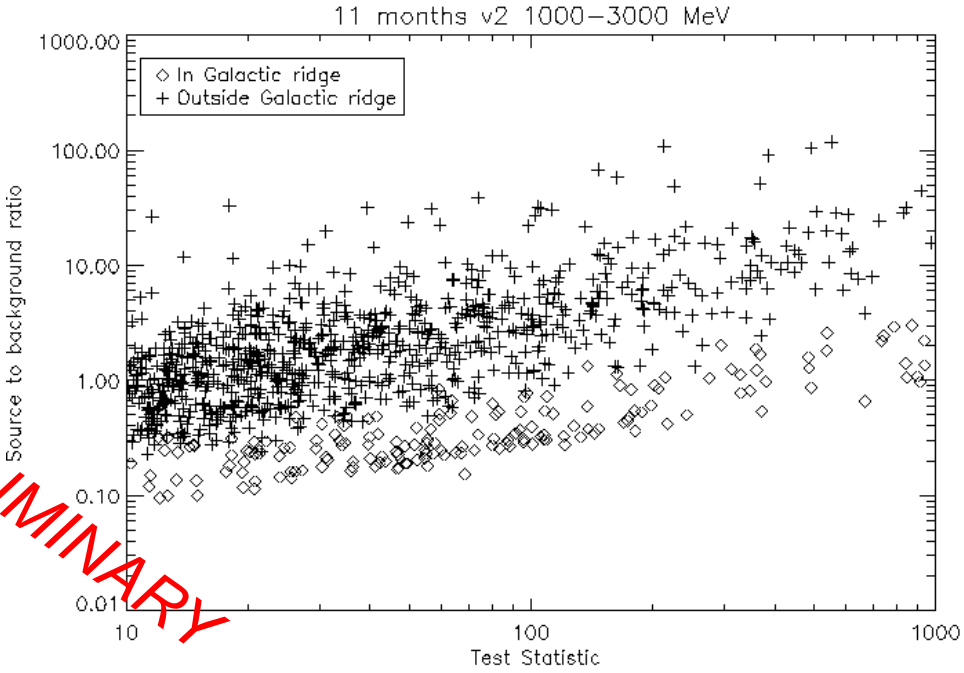


Diffuse emission uncertainties

- Use two different diffuse models to assess sensitivity of sources
- Inside Galactic plane, flux dispersion due to diffuse model is 1.8 sigma
- Outside plane, dispersion is 0.7 sigma

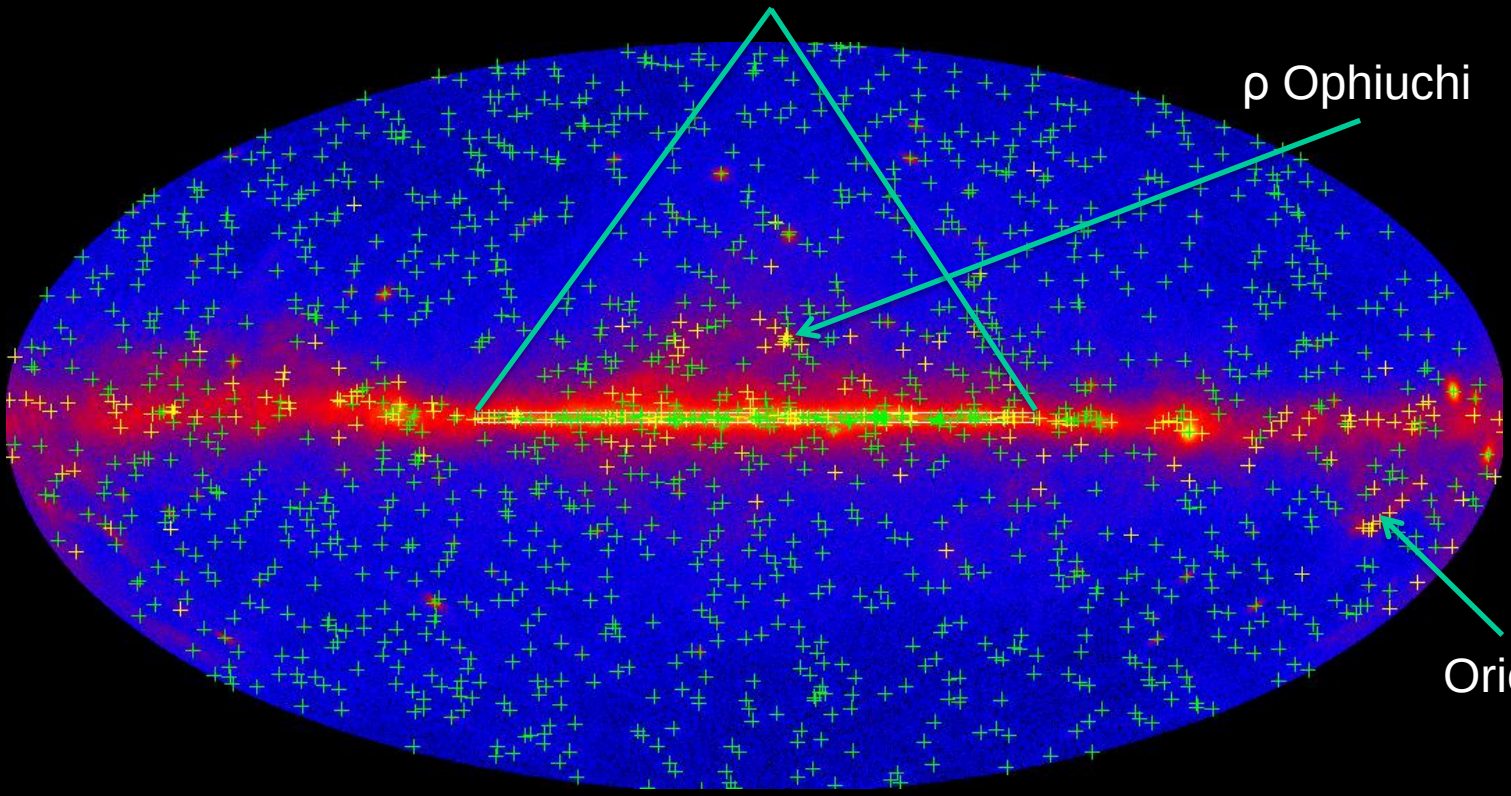
- Source to background ratio within r_{68} is not very large in the Galactic plane even above 1 GeV.
- Has to go above 3 GeV to be above 50%





Galactic ridge and dense clouds

- 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 (hear Troy Porter and Seth Digel). This even affects sources statistically very significant (TS > 100).
- We now plan to set Galactic ridge sources apart entirely (some 120 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

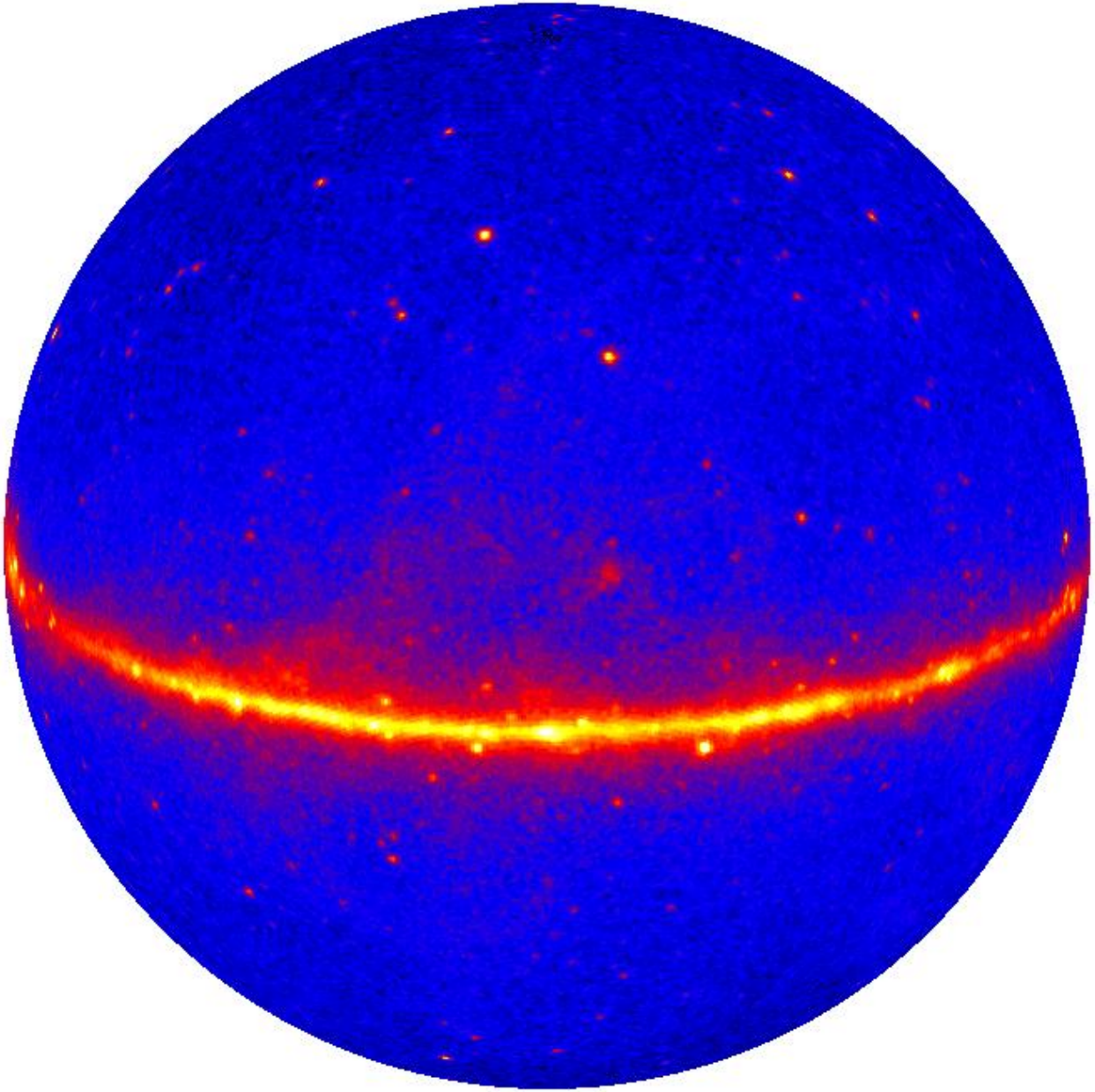
Sources outside the Gal. ridge can be flagged individually

First LAT source catalog

- Extends 0FGL to much fainter sources
- Typical 95% error radius is 10'. Absolute accuracy is better than 1'
- About 250 sources show evidence of variability
- 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
- Detailed results on many of these sources at this meeting
- Catalog will be available before the end of November

The sky viewed from above

Fermi-LAT
11 months
E > 1 GeV



Orthographic projection