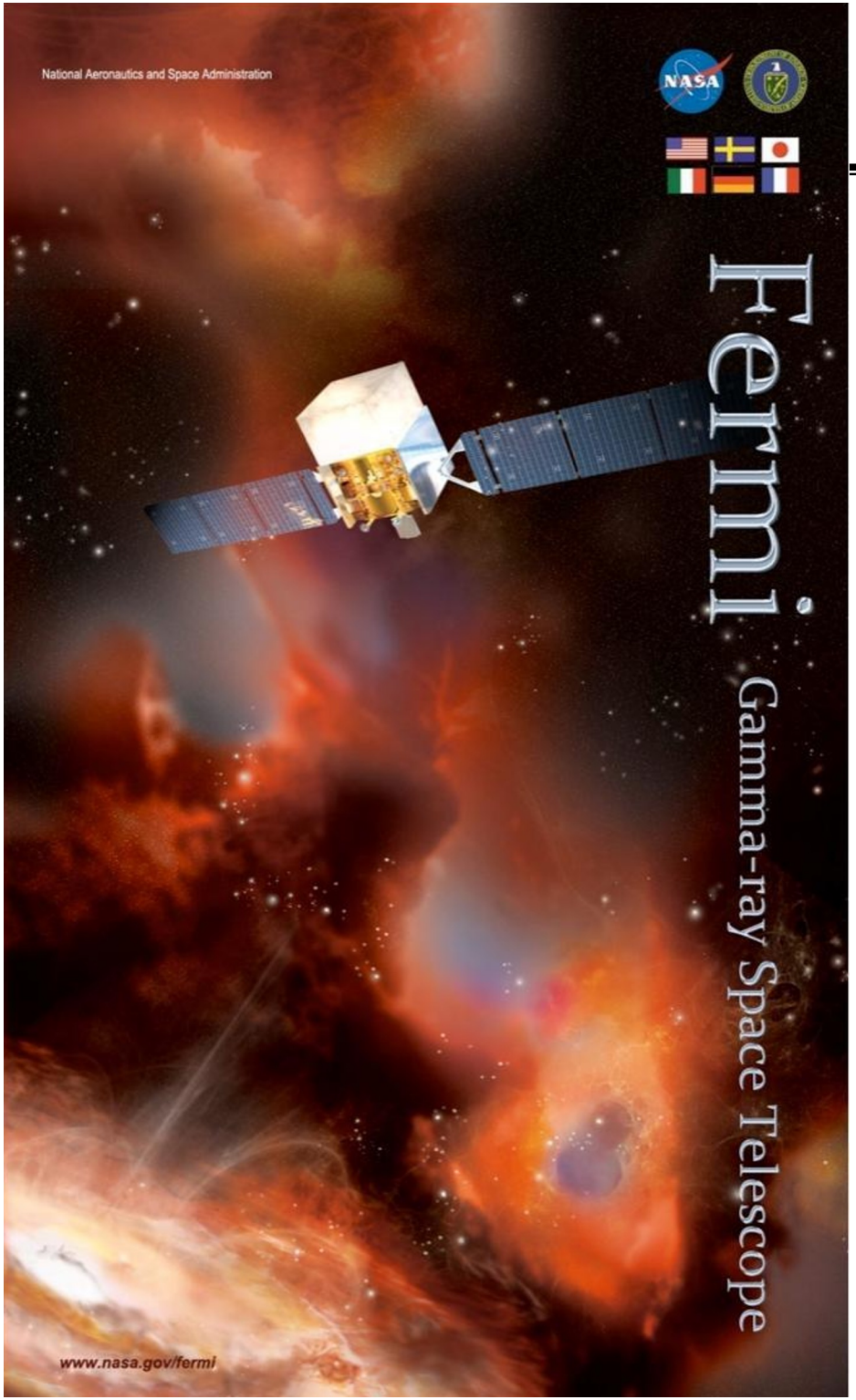


Low-latitude unassociated Fermi-LAT sources: a long-standing puzzle

Benoît Lott
(LP2IB)
on behalf of the Fermi-LAT collaboration

Census

4FGL-DR4

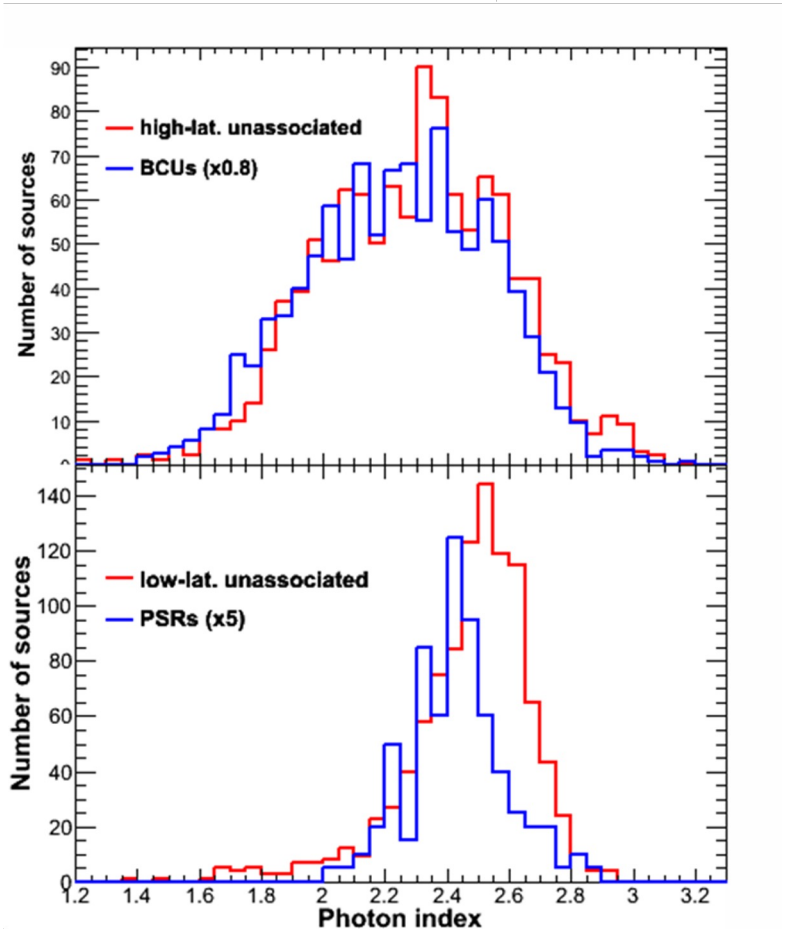
7114 gamma-ray point sources detected above 50 MeV over the first 14 years of operation

33% unassociated (2408 sources)

- **25% for the |b|>10° sources**
- **54% (1132) for the |b|<10° sources outnumber detected pulsars by a factor ~4**

Spectral distributions very different for the two sky regions

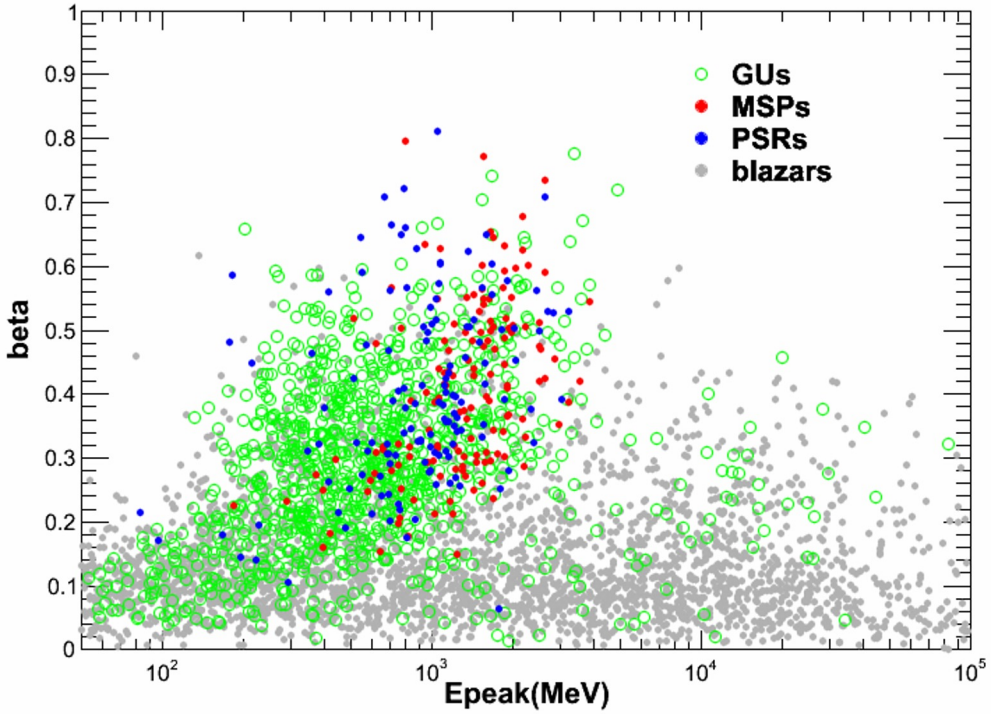
High-b ones are probably mostly blazars, with a few MSPs.



SGUs: soft population of GUs

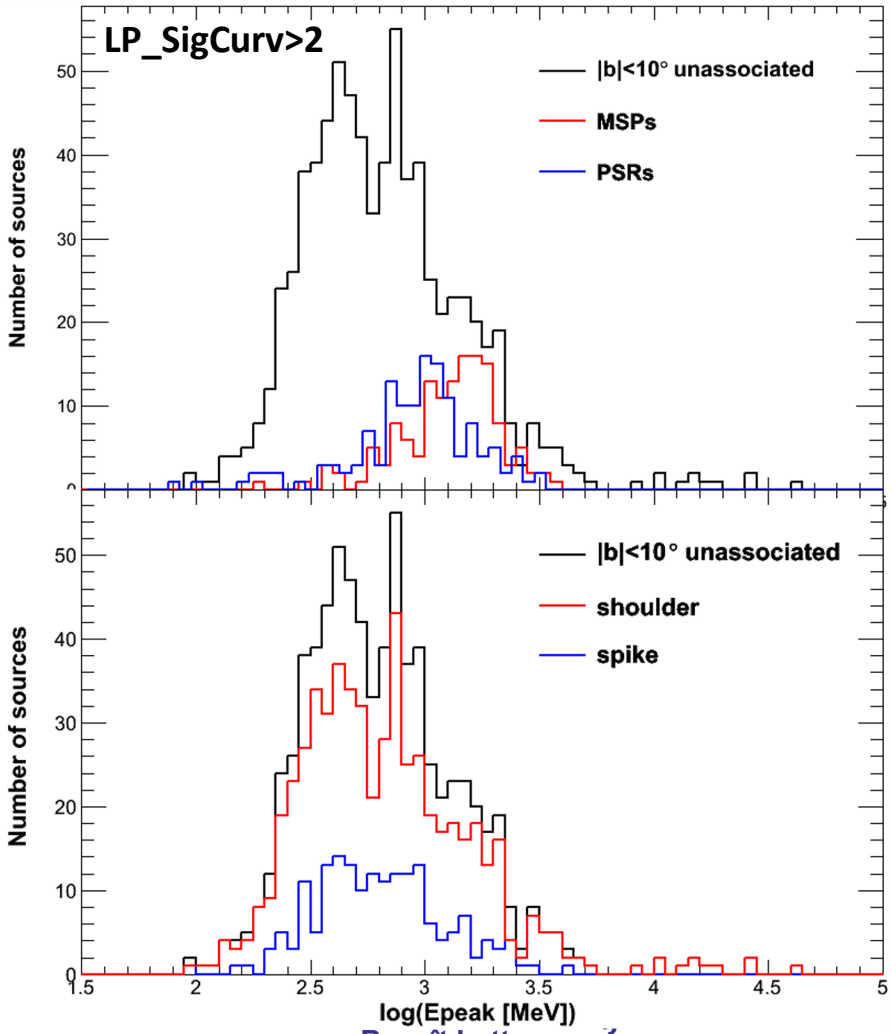
Nature of SGUs? *most important open problem* regarding LAT data

Energy Spectra



Fitting a logParabola to the SED, GUs show pronounced spectral curvatures, similar to what is observed in young (PSR) and millisecond (MSP) pulsars.

The SED peak energy is found lower than in PSRs and MSPs.

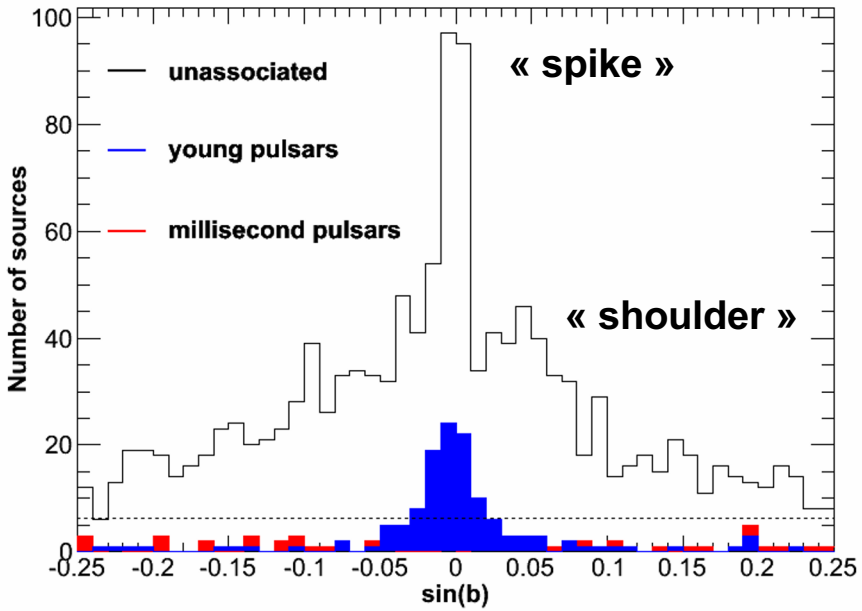


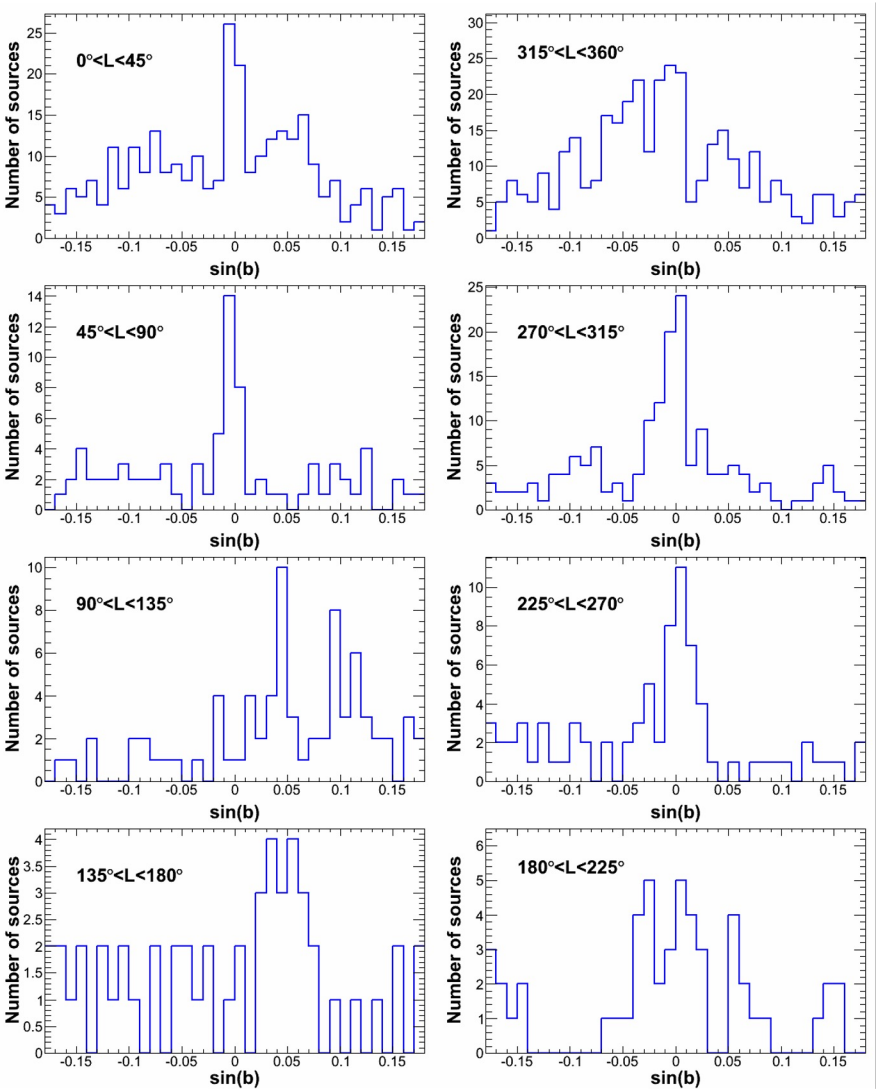
Galactic latitudes

Very specific, two-component distribution

- the spike, narrower than PSRs
- the shoulder, broader than PSRs

Currently no clear explanation for these features





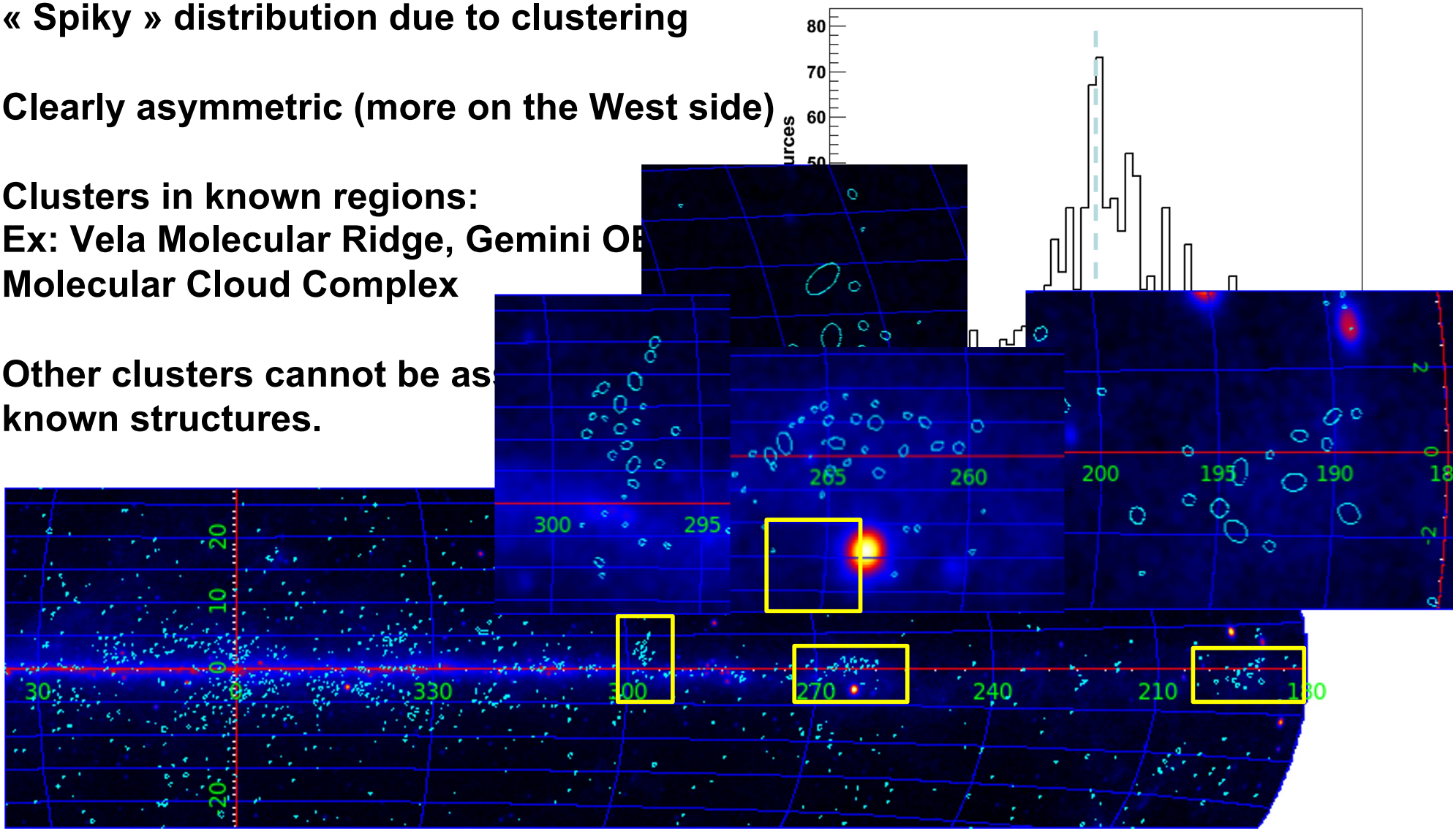
Galactic longitudes/clustering

« Spiky » distribution due to clustering

Clearly asymmetric (more on the West side)

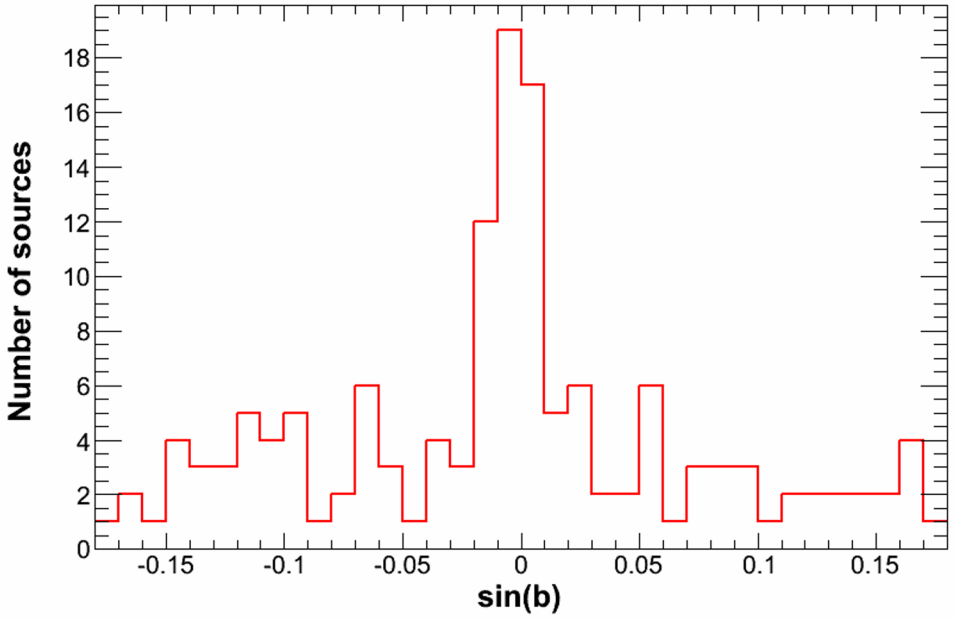
Clusters in known regions:
Ex: Vela Molecular Ridge, Gemini OB
Molecular Cloud Complex

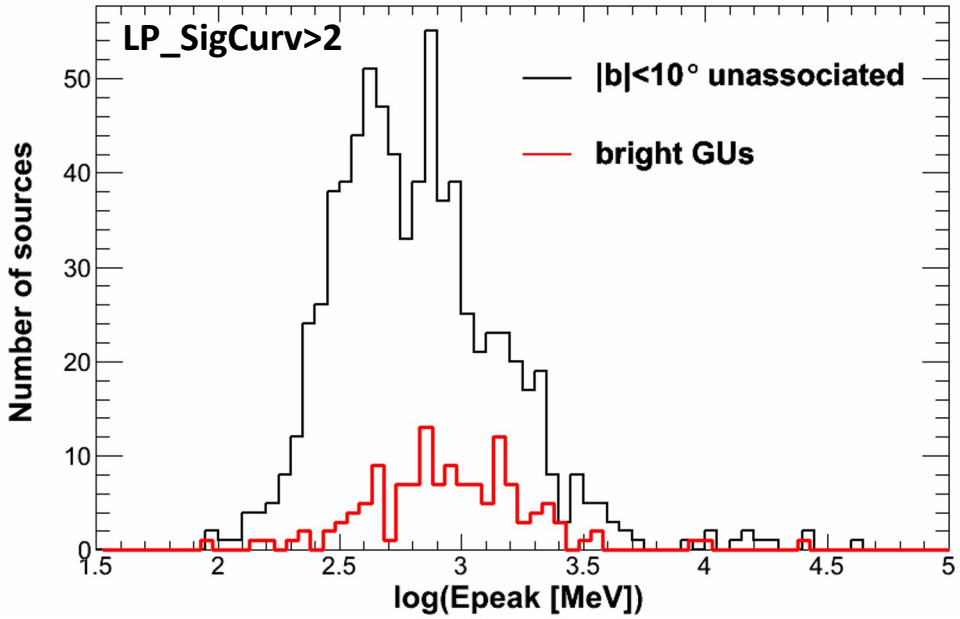
Other clusters cannot be as
known structures.

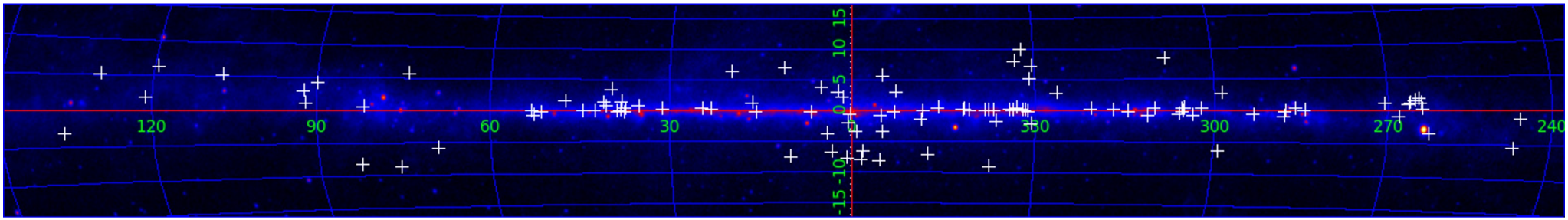


Highly-significant sources

160 unassociated sources with TS>100, |b|<10°
Share common features with the bulk of the GUs
« Tip of the iceberg »







Highly significant sources

160 sources, 106 with very soft spectra (SGUs)

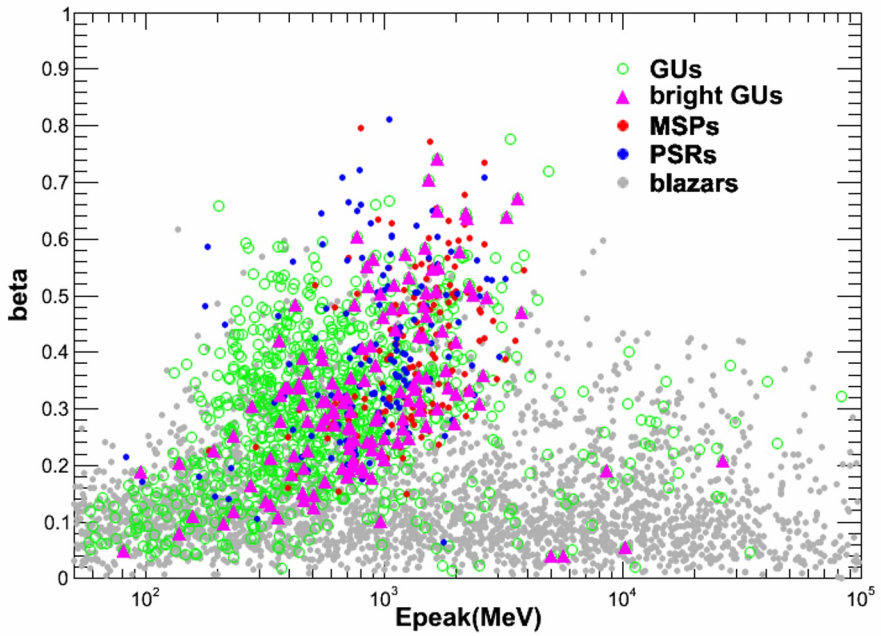
~40 sources searched for pulsations by the Fermi-pulsar consortium

32 in the Swift catalog, 6 more (with P>0.5) in the eRosita catalog, 6 in third EGRET catalog, 7 overlapping with extended TeV sources

5 possible AGNs (low spectral curvature, hard spectrum, X-ray associations with Swift/eRosita)

Associations with HII regions or young star clusters: RCW38, RCW 36, RCW 41 (Peron24), NGC 3603 (Yang17), NGC 6216

One discovered as a pulsar (Clark et al.)

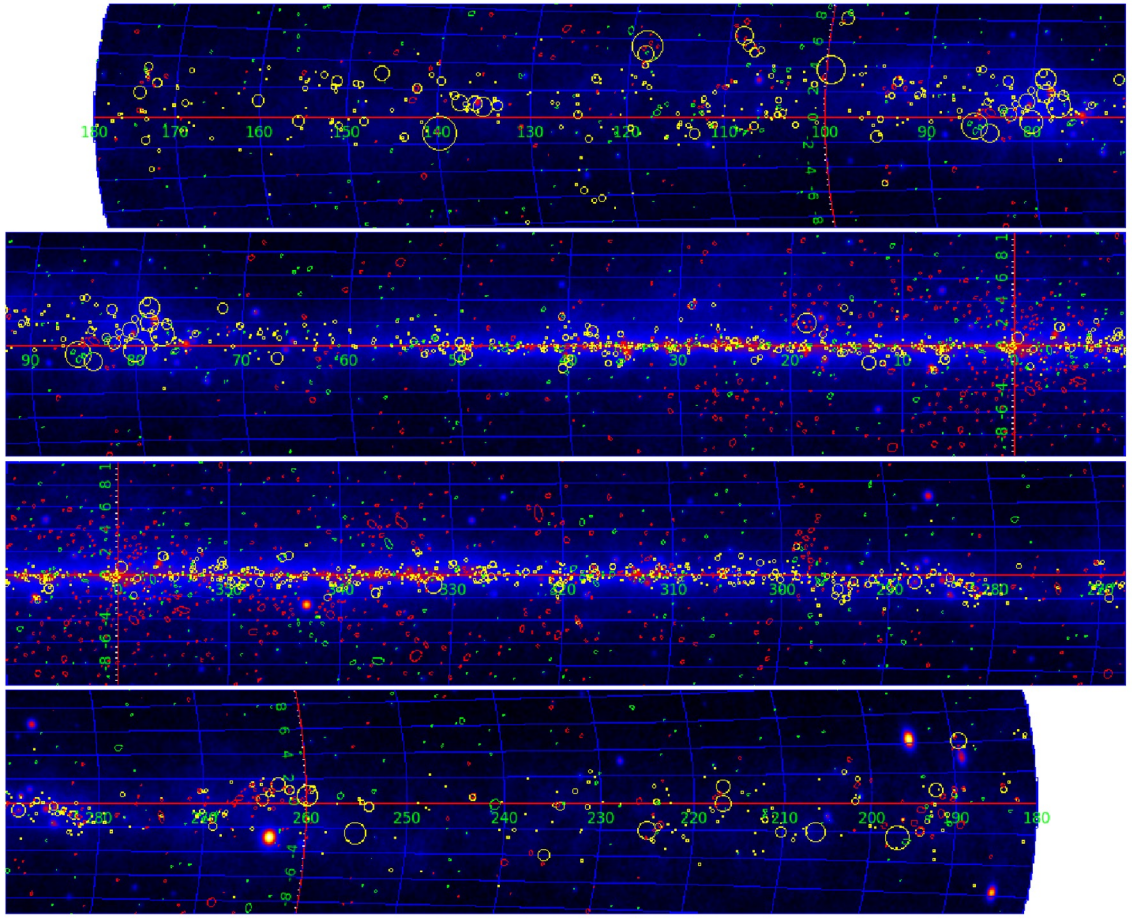


Searched for MW counterparts from radio to TeV:
~70 have no plausible counterparts at other wavelengths

Search for new classes

- **Bright stars**
  Yale Bright Star Catalog
- **OB stars**
  BESS survey
- **Wolf-Rayet stars**
  van der Hucht01
- **Colliding Wind Binaries**
  de Becker+13
- **Open Clusters**
  COCD, (Kharchenko+05)
- **Star forming regions**
  RCW (Rodgers+60)
  H-alpha (Avedisova 02)
- **HII regions**
  WISE, (Anderson+14)
  130 associations, for an estimated background of 50 (Peron+24, arXiv:2408.04973)

WISE, HII regions

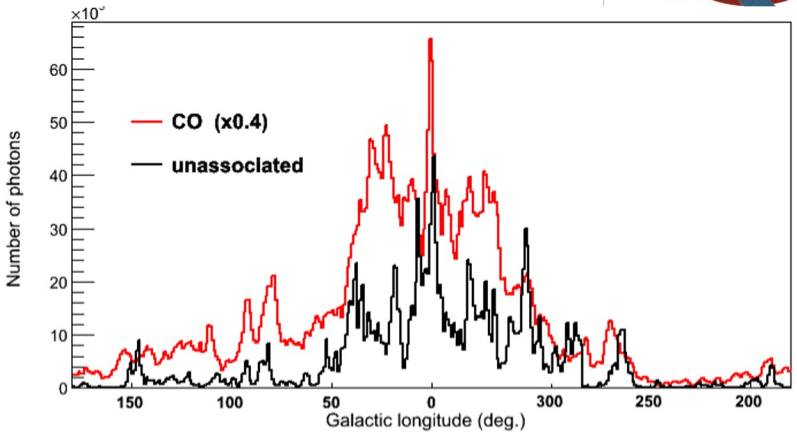


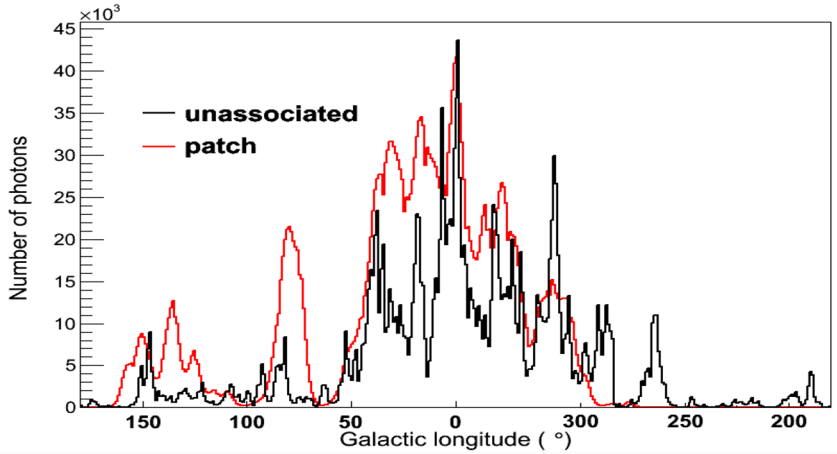
eRosita mostly provides counterparts for AGN-like sources

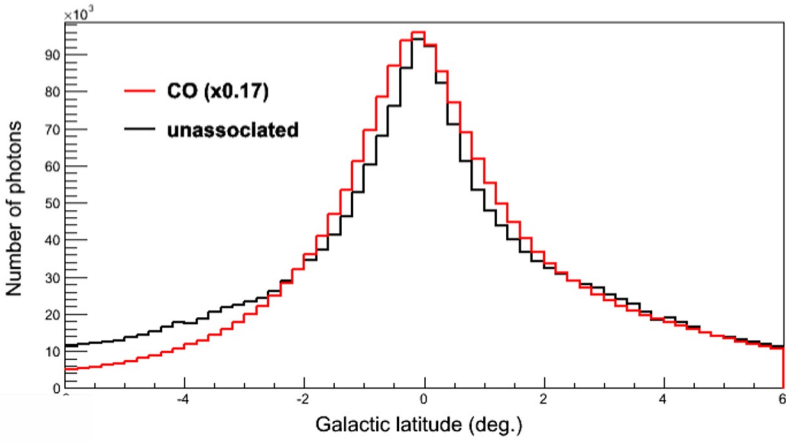
Mismodeled diffuse emission?

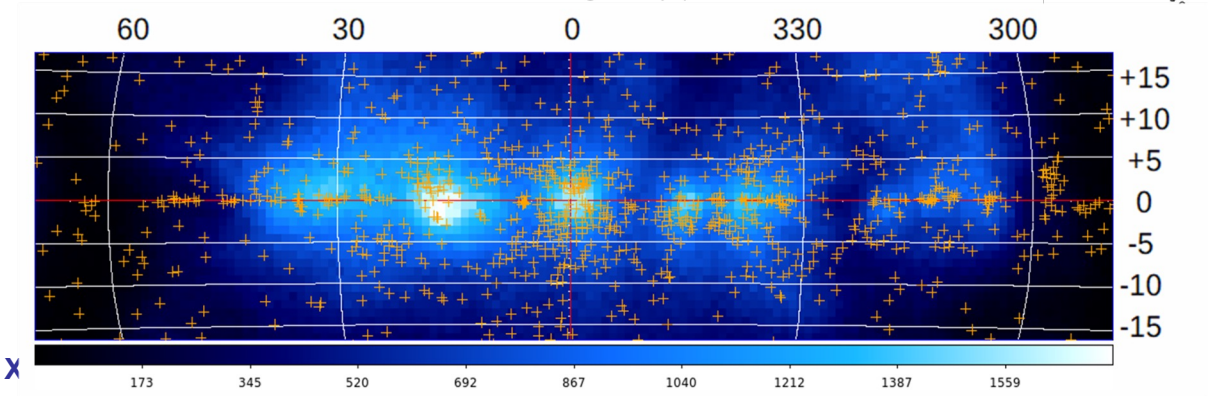
Interstellar Emission Model (IEM) includes 9 components, e.g., CO, HI, IC, Patch.
The GU photons represent a minor fraction of those in CO and a comparable amount to those in the patch. They are distributed in a similar fashion, making a connection plausible.

Can one reproduce the SGU spectral features?









Mismodeled diffuse emission?

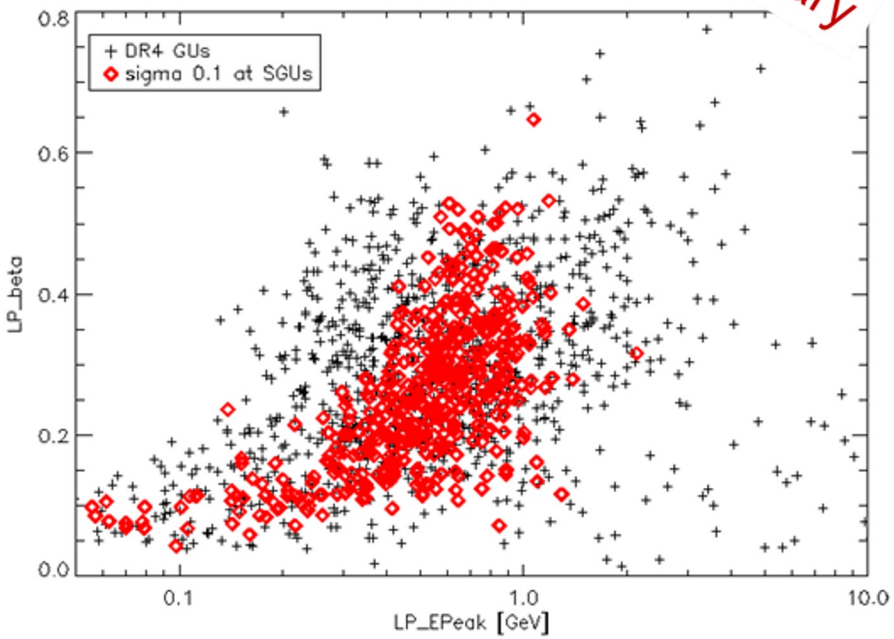
Different avenues followed to address this possibility:

- **leaving more freedom to the interstellar emission model when fitting the data,**
- **simulating the effect of additional interstellar gas,**
- **simulating slightly extended interstellar clumps, and looking for similar extension in the actual unassociated sources**

Simulations of *sources* with:

- **spectra matching that of the Galactic diffuse emission**
- **similar locations and fluxes as SGUs**
- **slight extension (σ=0.1°) , to mimic possible spatial granularity of the diffuse emission.**

Preliminary



The SGU spectral features can be reproduced under ad-hoc conditions. Some evidence for extension in the brightest SGUs have been found.

Conclusions/outlook

The bulk of the unassociated sources close to the Galactic plane show properties that set them apart from known classes of gamma-ray emitters.

The Galactic latitude distribution exhibits a narrow (the « spike») and a broad (the « shoulder ») components, whose relative intensities are longitude dependent. The origin of these components is unclear.

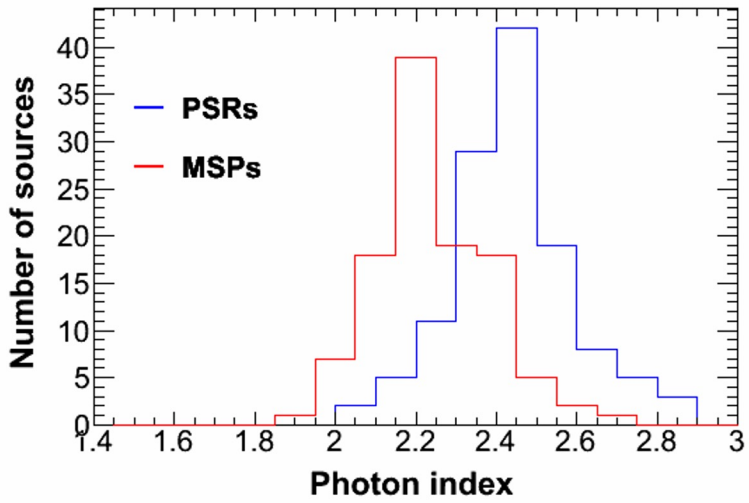
Several extended clusters of sources have been found.

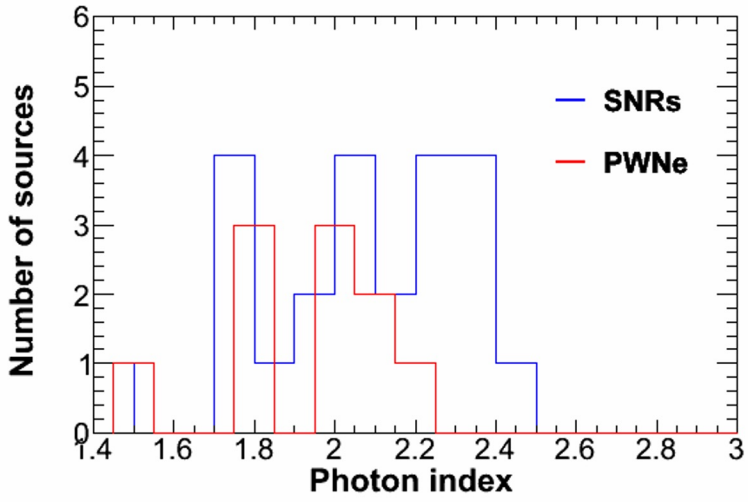
Indications for new classes (e.g., star clusters, star-forming regions) exist, but so far fail to account for the large population of GUs.

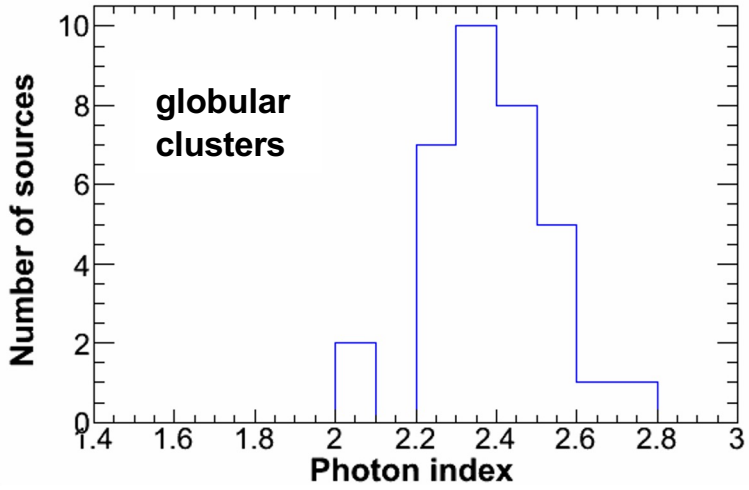
An origin related to mismodeled diffuse emission remains plausible, as evidenced via simulations.

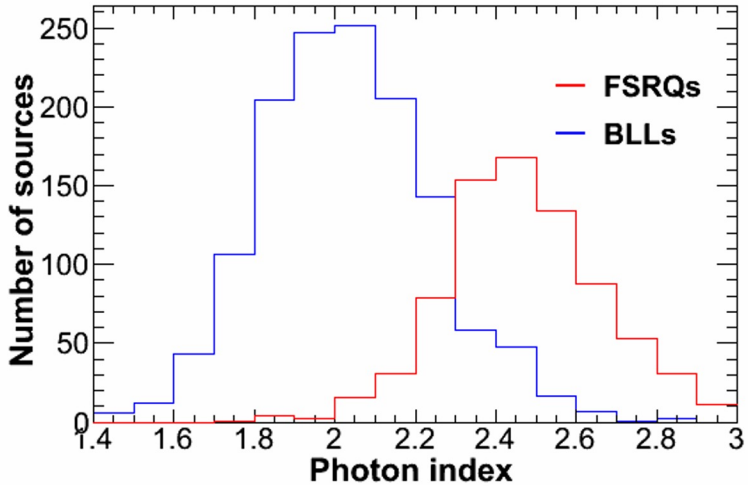
A new diffuse emission model is in preparation for 5FGL, which should shed new light on this issue.

Photon-index distributions









Fairly distinctive distributions