

Tenth International Fermi Symposium

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Investigating the nature of the 4FGL soft Galactic unassociated sources

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Low- b unassociated sources in 4FGL-DR3



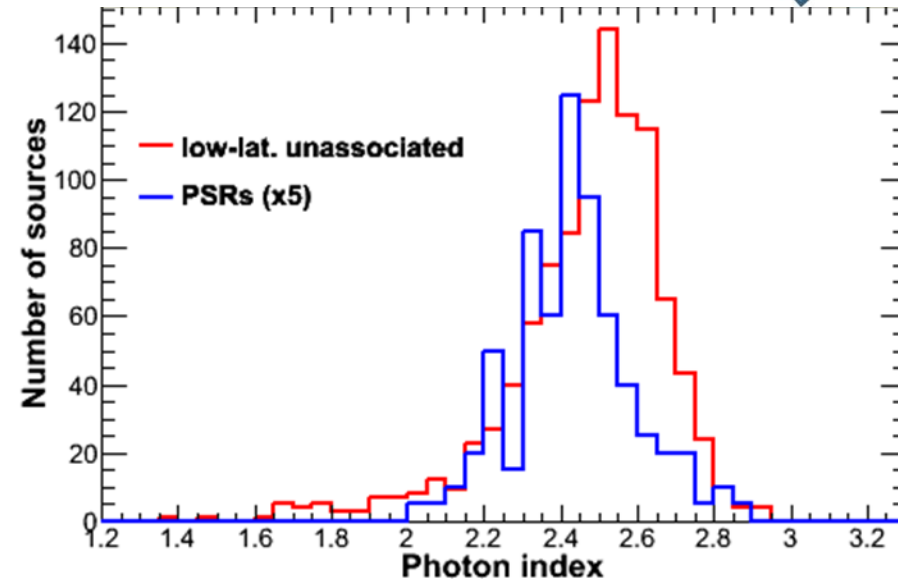
4FGL-DR3

- established with 12 years of data
- uses iem_v07 diffuse emission model
- 6659 entries (6658 sources)
- only point sources added relative to 4FGL
- no systematic test for source extension
- overall association fraction 68%

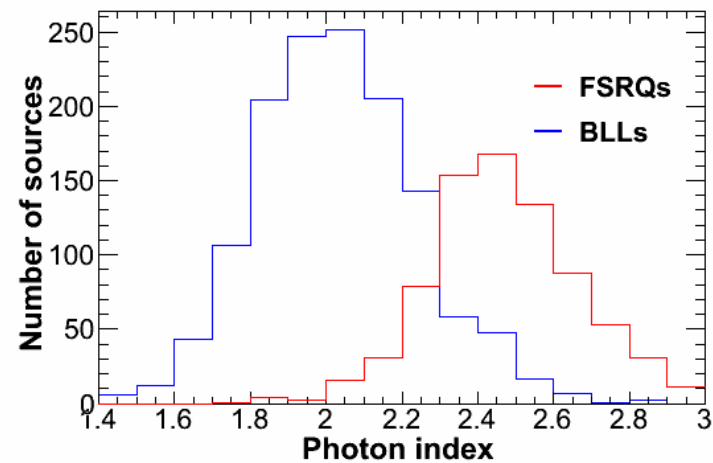
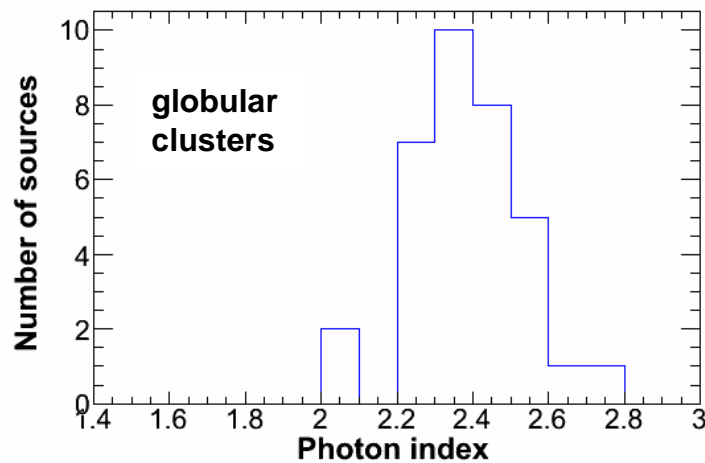
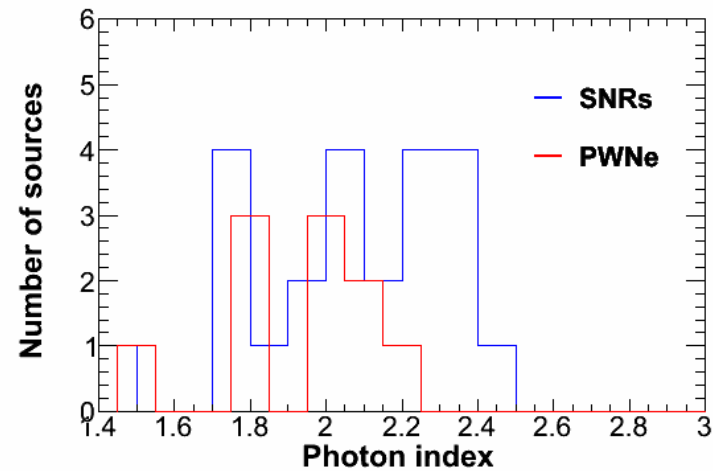
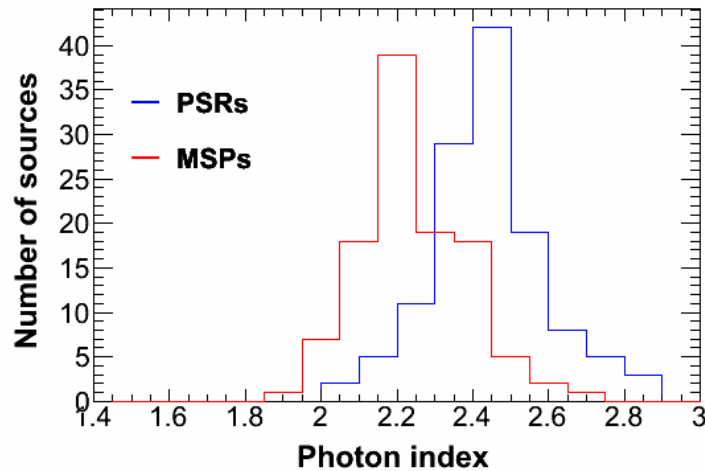
1018 $|b| < 10^\circ$ unassociated sources

soft component unseen in any classes of Galactic sources :

« SGUs »: Soft Galactic Unassociated sources
Unassociated && Photon index > 2.4 && $|b| < 10^\circ$



Photon-index distributions

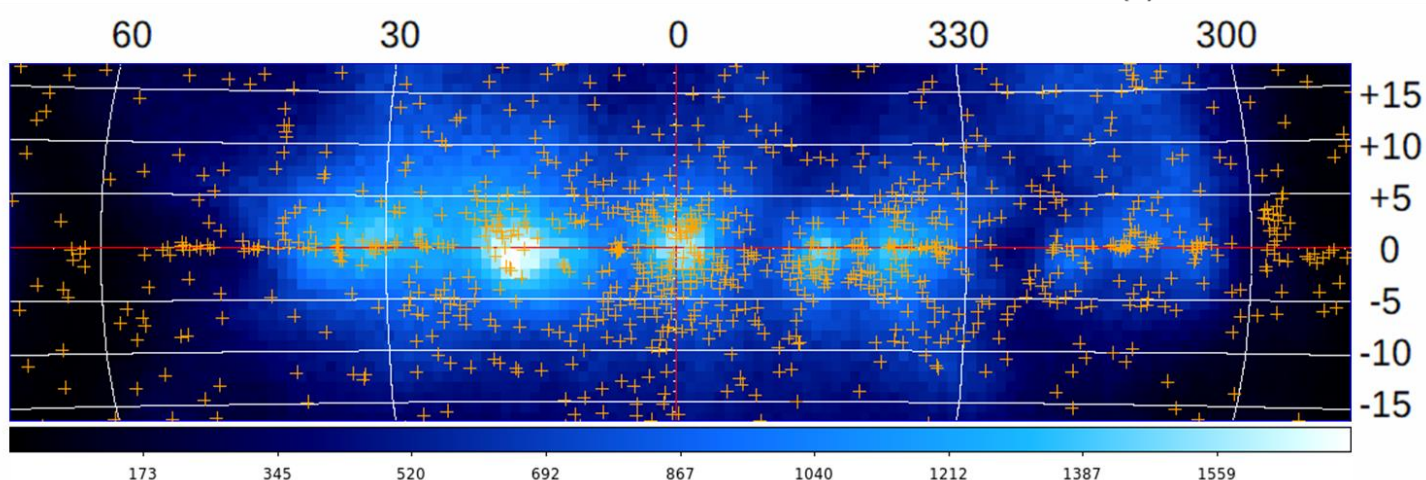
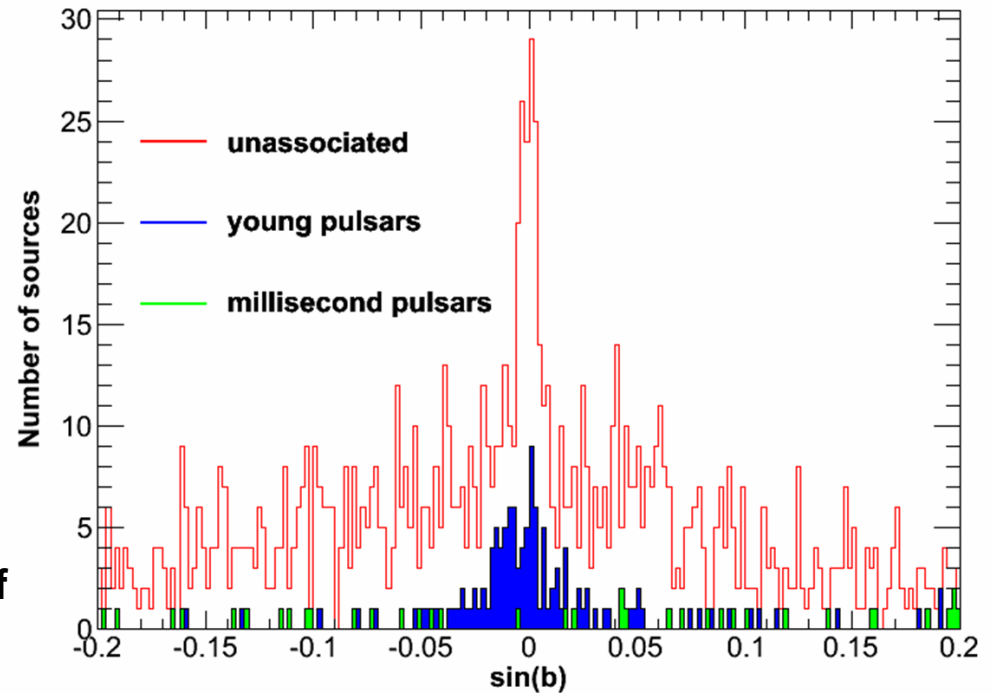


Fairly distinctive distributions

Low-b unassociated sources



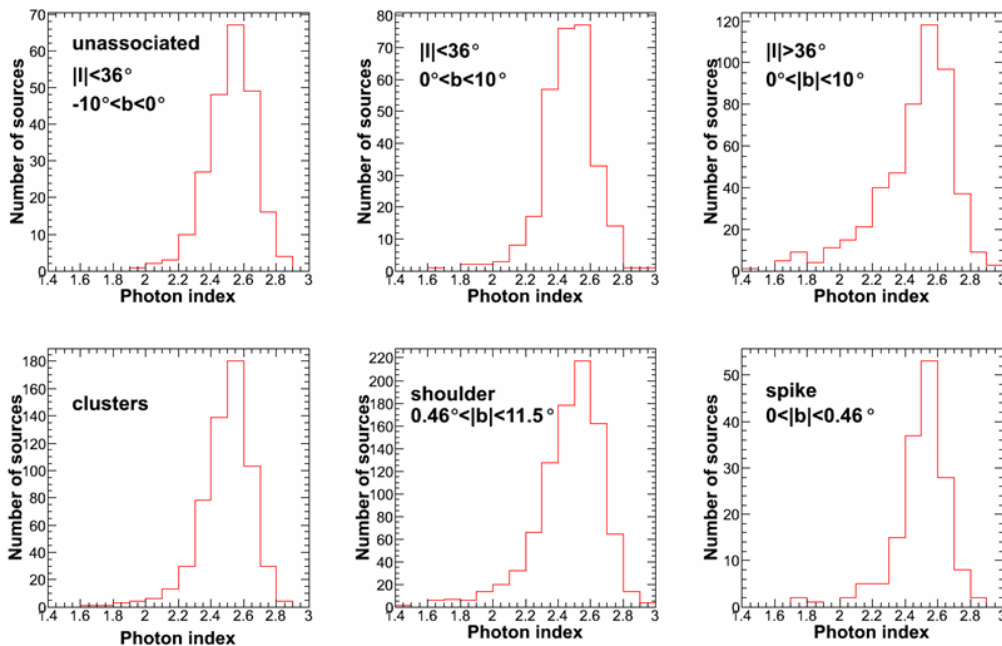
- Low contribution from background AGNs
- Specific latitude distribution:
« spike » and « shoulder »
- Notable clustering
- Indication for extension for some sources
- Correlation with patch component of Galactic diffuse emission model



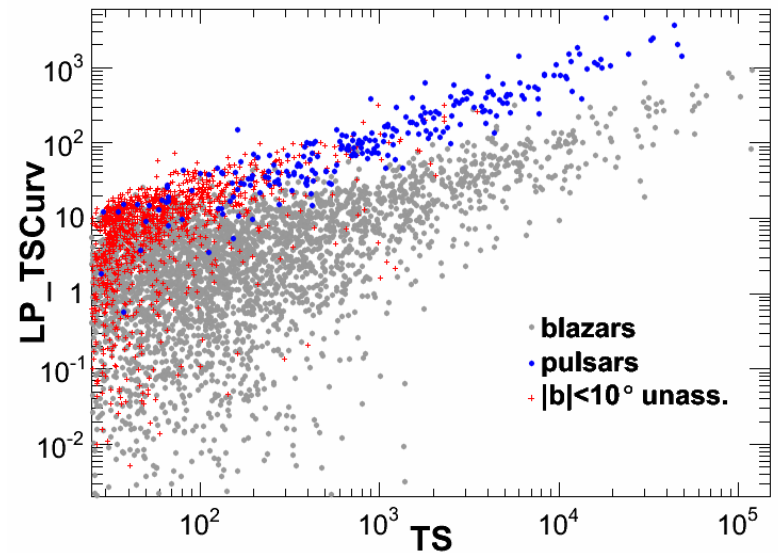
SGU spectral features



Similar SGU index distribution in different sky regions



Spectral curvature similar to that of pulsars

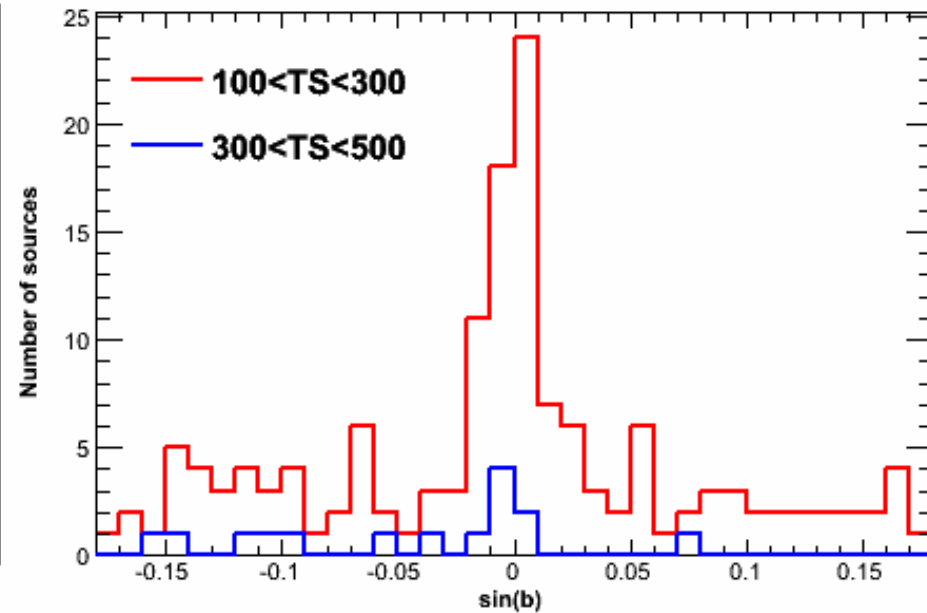
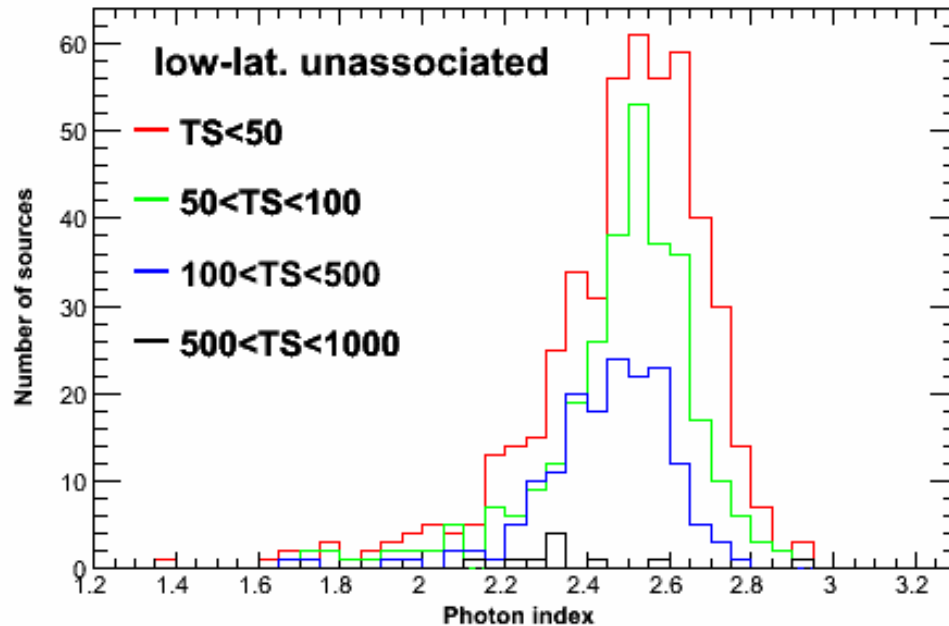


Flag 14 in DR3 devised to indicate SGUs (+SPPs+UNKs) in high-density regions (HEALpix tessellation)

Condition: within high-density pixels && $\Gamma > 2.4$ && $TS < 500$

446 SGUs, 45 SPPs and 49 UNKs

TS dependence



Relatively high TS ($100 < TS < 500$) sources retain similar properties as less significant ones.

Worth investigating via dedicated MW studies

Nature of SGUs?



- Not pulsars (b distributions, too many, photon index distributions...)
- correlation with patch

Possibilities and avenues for exploring them

Mismodeled Galactic diffuse emission?

- *Try to reproduce spectral features via simulations*
- *Improve model*
- *Test other source-detection approaches*

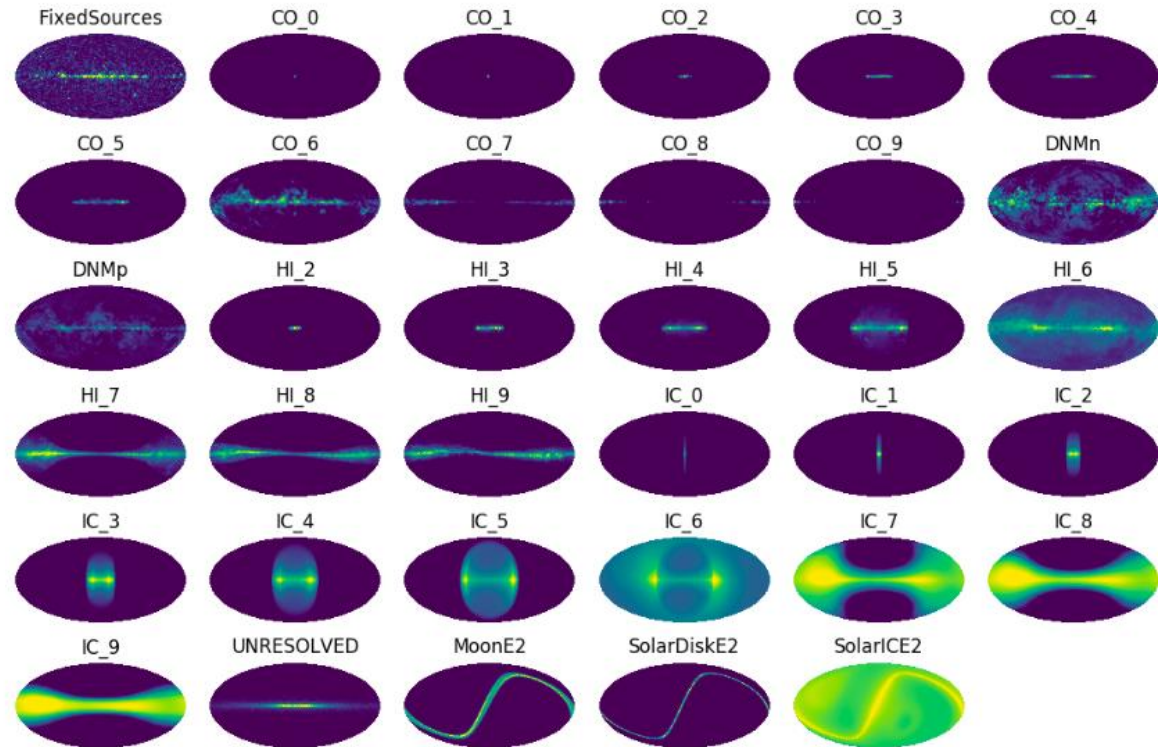
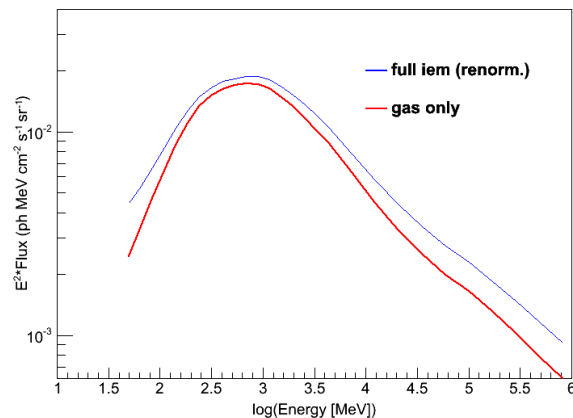
Existence of an abundant, entirely new class of sources?

Refresher on diffuse emission model



Components

- CO (10 rings)
- HI (10 rings)
- IC (10 rings)
- Dark Neutral Medium (DMNp+DMNn)
- unresolved
- Patch (residuals smoothed out over a spatial scale of 4°)
- isotropic

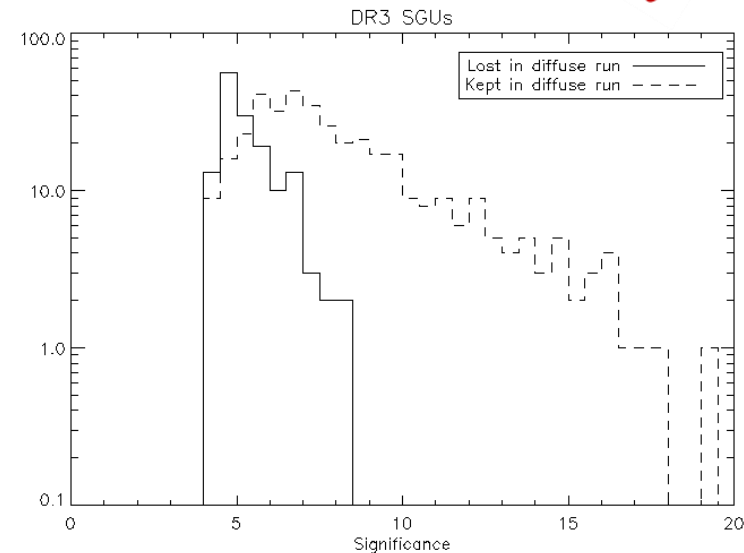
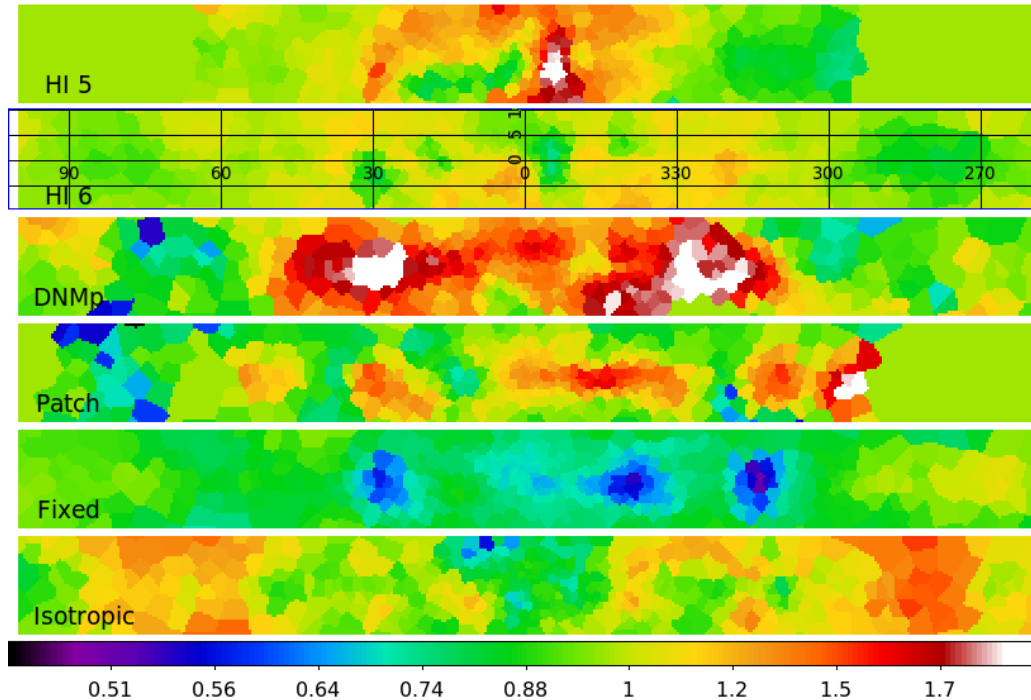


https://fermi.gsfc.nasa.gov/ssc/data/analysis/software/aux/4fgl/Galactic_Diffuse_Emission_Model_for_the_4FGL_Catalog_Analysis.pdf

Freeing IEM components



Preliminary



A total of 14 IEM components (including isotropic) were left free for each Rol. More than 70% of the SGUs remain.

A simple renormalization of the diffuse components at the Rol scale by itself does not allow suppressing the SGUs.

Interpretation of the observed spatial features still lacking

Spurious sources from IEM excess



Preliminary

Simulations with boosted (x2)
CO, DNMP or patch components

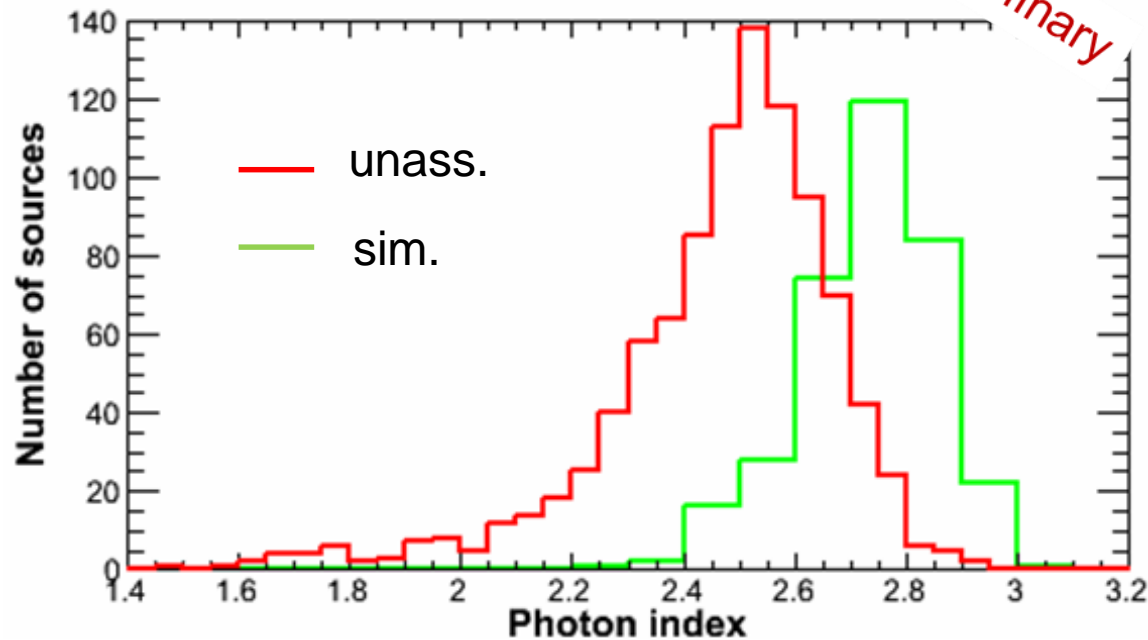
Detection of resulting sources
with fermipy's *find_src* tool

Analysis with standard pipeline

Results

Spurious sources considerably
softer (mean photon index=2.71)
than the data.

Excess photons analyzed as point sources: measured spectra softer than real ones
because of the energy-dependent PSF (downplaying high-energy photons)



Effect of possible extension



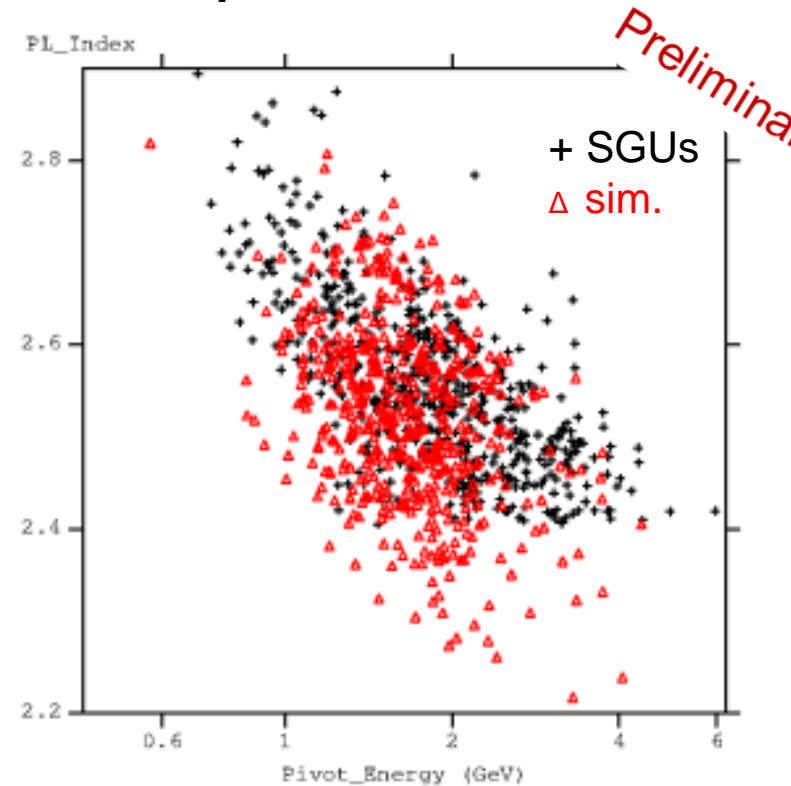
Simulations of *sources* with:

- spectra matching that of the Galactic diffuse emission
- similar locations as SGUs
- slight extension ($\sigma=0.1^\circ$), to mimic the spatial granularity of the diffuse emission.

Some of the SGU spectral features reproduced under these ad-hoc conditions.

The spectra are harder than those in simulations presented in the previous slide because the spatial scale (0.1°) is much less than that of features present in the IEM.

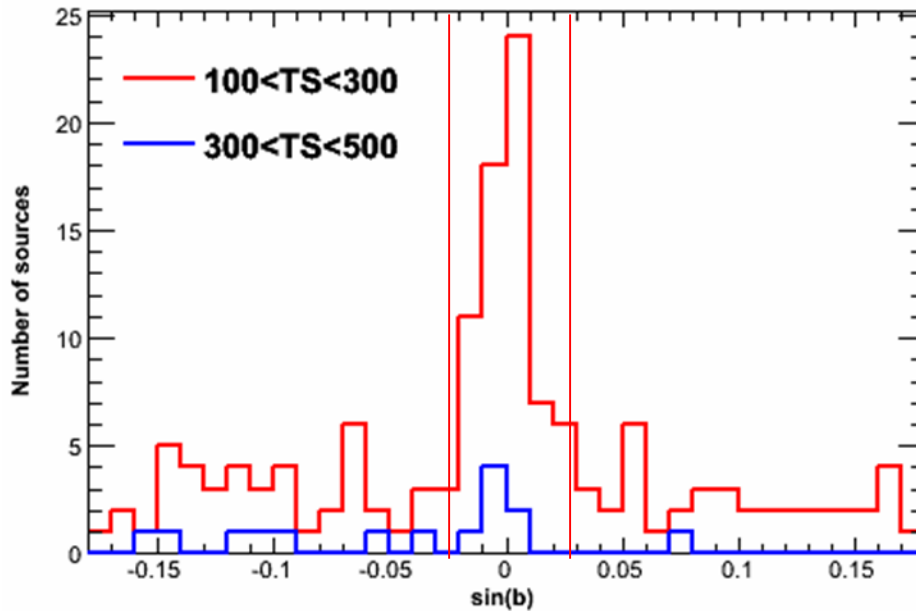
SGU positions, TS=55



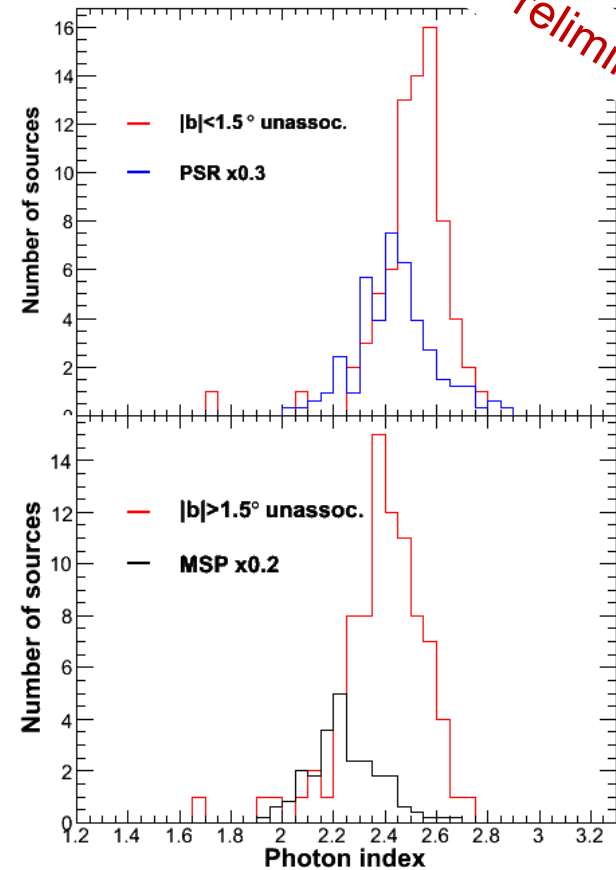
High-TS sample



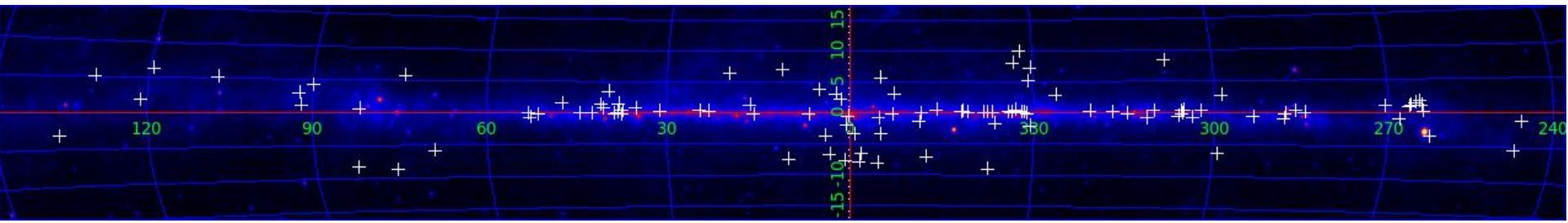
$100 < TS < 500$ && $|b| < 10^\circ$ && $PL_Index > 2.4$
108 unassociated sources



MW investigation of regions surrounding these bright SGUs is in progress.



Preliminary



Conclusion



- **SGUs constitute an important population of the current catalogs, not fitting in any known classes;**
- **Attempting to break down the unassociated sources solely into « AGN-like » and « pulsar-like » classes is not appropriate;**
- **Some SGUs are possibly related to small-scale structures of the diffuse emission.**
- **The MW investigation of the brightest SGUs is underway.**