Population Studies of Fermi LAT sources

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The Fermi Large Area Telescope (LAT) has been detecting hundreds of Galactic sources, most of which are pulsars. Many Galactic sources are still undetected or unresolved due to their low flux, below the Fermi LAT sensitivity, or because of foreground and source confusion. Moreover, among the many unassociated sources, which are one third of the detected sources, a large amount may have Galactic origin. We present our method of source population synthesis studies for characterizing the general properties of Fermi LAT Galactic gamma-ray sources and for estimating the number of Galactic sources below the Fermi LAT flux sensitivity threshold. Source density distribution and luminosity function of our Monte-Carlo simulation are constrained by the Galactic sources detected by Fermi LAT. Then, the number of unresolved sources and their contribution to the diffuse emission are estimated by our best model.

This is a long-term project on analyzing the point source catalog and performing theoretical studies of gamma-ray sources. Apart from being interesting on its own, characterizing the general properties of detected sources also allow us to estimate the contribution to the diffuse emission from undetected and unresolved sources. In turn this help their detection, impacting also other studies of diffuse gamma rays including studies of the interstellar emission and dark matter. Finally, it also help in the characterization of unassociated sources.

METHOD

Our analysis approach is based on the well-established method in [1,3, 6]. For each Galactic source population, we will perform a Monte Carlo study. A population is defined by three basic properties: spatial distribution, spectrum, and luminosity function. We test source space density distribution based on present models of source distributions derived from observations [1,4]. The space density of sources per unit luminosity ($L\gamma$) and position in the Galaxy (R, z) is defined as $\rho(R, z, L\gamma)$. This depends on a given luminosity function, as explained in [6]. Fluxes are then obtained from luminosities and distances. From the resulting simulated source list, we generate differential source counts defined as $N(F\gamma)$ (sources per unit flux over the sky-area considered), with the energy dependence given by the spectral information of the source population. The simulated catalogue extends below the detection threshold (flux limit). Above the detection threshold, the simulated source counts must reproduce the real source count as detected by LAT.

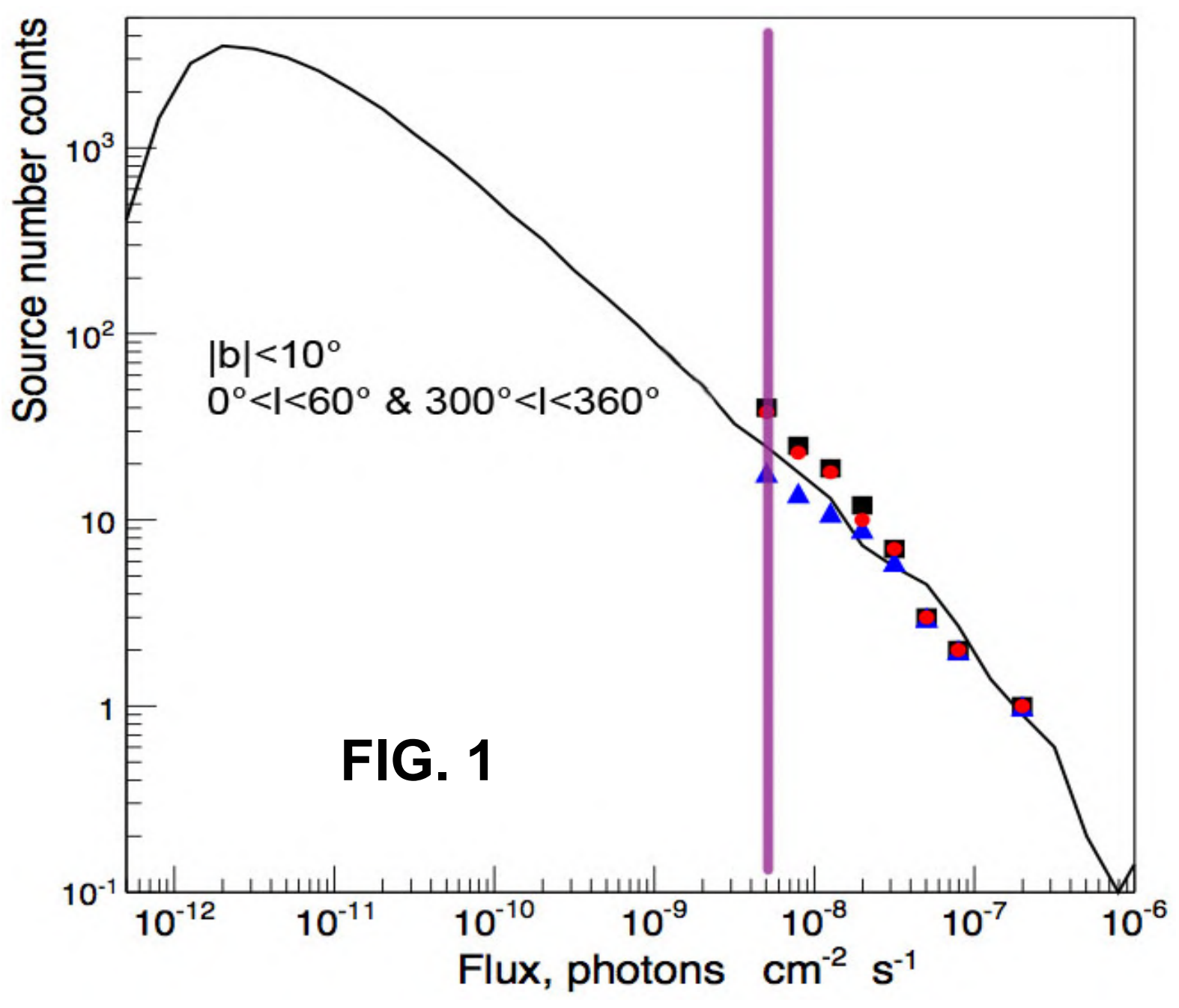
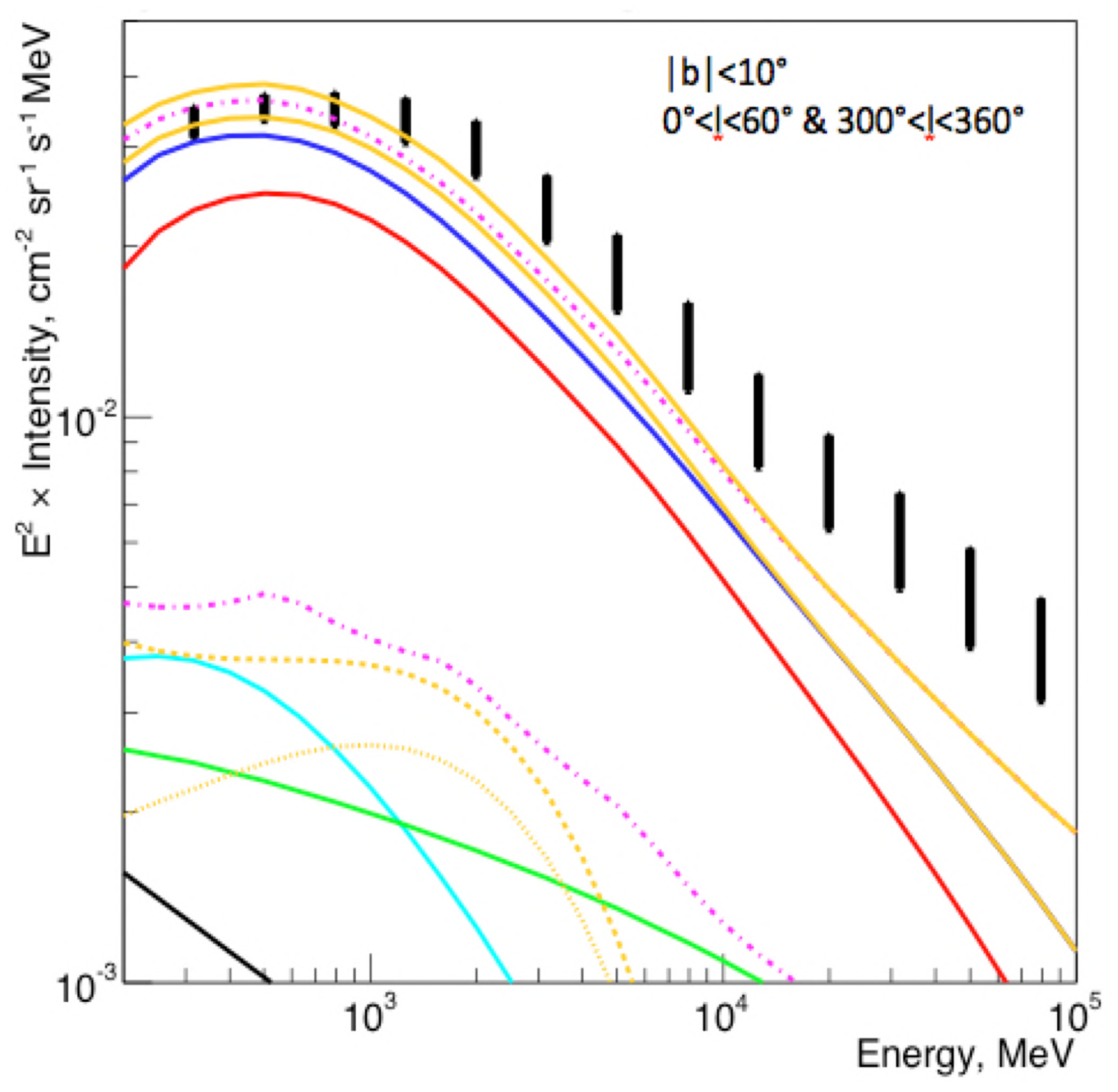


FIG. 1

DETECTED SOURCES

Characterization of the source population properties and identify unidentified sources as Galactic or extragalactic source classes through statistical analyses

Example of number of simulated sources for a given source density and luminosity function compared with the number of detected sources above 1 GeV and for the inner Galaxy. Simulated sources for this example are pulsar-like objects with a spatial distribution based on [4]. The plot shows source number counts above 1 GeV in the inner Galaxy. Triangles are source counts from the 3FGL above a detection limit set at 5×10^{-9} photons cm^{-2}s^{-1} above 1 GeV. Blue triangles: Galactic identified sources. Red triangles: Galactic identified and unassociated sources. Black squares: all sources with extragalactic. Black line: simulated sources.



UNDETECTED SOURCES

Estimate of the number of sources below the LAT threshold and their contribution to the diffuse emission

Example of diffuse spectral components, including the unresolved sources calculated for the model in Fig. 1 (solid line), compared to 3-year LAT data. At >8 GeV At >8 GeV, the total component fails to account for all the data, enforcing the idea enforcing the idea that the proposed study is needed for understanding the complete picture. We note that this model is for illustration only and it was not fit to data. The plot shows spectra of the inner Galaxy. Magenta dash line: 3FGL, Galactic identified and unassociated sources. Vertical black bars: Fermi-LAT data: Pass 7 Rep Clean with systematic and statistical errors included. Blue line: total interstellar emission as sum of πo-decay (red), inverse Compton (green), bremsstrahlung (cyan). Black solid line: isotropic component. Yellow lines: population contributions above (dashed upper) and below (dotted lower) threshold; total including interstellar and population contributions (solid). The interstellar model is taken from [2].

Density (pulsars/kpc^3)	Min. Luminosity (photons/s)	Index of Luminosity	Log-likelihood
4	1 x 10^36	-2.4	6
10	1 x 10^35	-1.8	66
20	1 x 10^34	-1.6	129
50	1 x 10^34	-1.8	152
100	1 x 10^33	-1.6	154
200	1 x 10^33	-1.8	141

PARAMETER SCAN

Preliminary results of the best-fit parameters given the likelihood function

As a first trial a set of models created by varying model parameters (density, minimum luminosity, luminosity index) are generated and their Log-Likelihood is obtained by fitting the pulsars sources in the 4FGL-DR2. The best-fit parameters for this preliminary run are underlined [5].

UNDETECTED SOURCE TEMPLATE

Skymap of the model sources below the detection threshold

Zoom in the inner Galaxy of simulated sources below threshold for the same model as in Fig 1 (solid line). It shows clearly the glow from weak sources. Colours refer to different fluxes.

REFERENCES

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