Gamma-ray point sources below the Fermi detection limit

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Abstract

An analytic relation between the statistics of photons in pixels and the number counts of multi-photon point sources is used to constrain the distribution of gamma-ray point sources below the *Fermi* detection limit at energies above 1 GeV and at latitudes below and above $30°$. The derived source-count distribution is consistent with the distribution found by the *Fermi* collaboration [1] based on the first *Fermi* point source catalogue [2]. In particular, we find that the contribution of resolved and unresolved active galactic nuclei (AGN) to the total gamma-ray flux is below 20 to 25%.

1. Introduction

Faint gamma-ray point sources cannot be detected individually, however their presence affects the statistics of photons across the sky. One can use the observed statistics of photons to infer some general properties about the population of point sources below the *Fermi* detection limit.

In this work we distinguish three sources of gamma-rays at high latitudes based on their statistical properties. The first source is a diffuse source that varies over large angles. The main contribution to this source comes from the Galactic diffuse emission. We will call it non-isotropic Galactic diffuse emission.

The second source corresponds to an isotropic distribution of gamma-rays, i.e., the statistics of photons across the sky is consistent with the Poisson distribution for this source. The isotropic flux has contributions from the homogeneous part of the Galactic diffuse emission and from diffuse intergalactic emission.

The third source is a population of point sources modeled by a broken power-law source count distribution. We assume that the point sources are distributed homogeneously over the sky. The statistics of photons coming from these point sources has a non-trivial form different from the Poisson statistics. These sources model a population of AGN-like point sources.

2. Model

We consider a pixelation of the sphere with pixels of equal size and denote by n_k the number of pixels that contain k photons. If the total number of pixels is $N_{\rm pix}$, then the probability to observe k photons inside a pixel can be estimated from the data as $p_k = \frac{n_k}{N_{\rm pix}}$. For large $N_{\rm pix}$, the statistical uncertainty of n_k is approximately $\sqrt{n_k}$.

Let x_m denote the average number of sources inside a pixel that emit exactly m photons during the time of observation. In [3] we derive the following relation between the probability generating function $P(t) \equiv \Sigma_k p_k t^k$ and the expected numbers x_m of m-photon sources

$$P(t) = \exp\left(\sum_{m=1}^{\infty} (x_m t^m - x_m)\right). \quad (1)$$

The probabilities to observe k photons are determined by expanding the right hand side of this equation and picking the coefficient in front of t^k. We model the source count distribution for point sources by a broken power-law

$$\frac{dN}{dS} \sim \begin{cases} S^{-n_1}, & S > S_{\rm break}; \\ S^{-n_2}, & S < S_{\rm break}. \end{cases} \quad (2)$$

The expected number of m-photon sources is

$$x_m \sim \int_0^\infty dS \frac{dN}{dS}(S) \frac{S^m}{m!} e^{-S}. \quad (3)$$

The generating function for the isotropic emission is given the the generating function for Poisson probabilities

$$I(t) = e^{x_{\rm isotr} t - x_{\rm isotr}}. \quad (4)$$

The variable part of Galactic diffuse emission $x^{\rm p}_{\rm Gal} \geq 0$ is modeled by $\ell < 20$ spherical harmonics. The corresponding generating function is

$$G(t) = \frac{1}{N_{\rm pix}} \sum_{\rm p=1}^{N_{\rm pix}} e^{x^{\rm p}_{\rm Gal} t - x^{\rm p}_{\rm Gal}} \quad (5)$$

The generating function for a sum of three independent sources is a product of the corresponding generating functions

$$\sum_{k=0}^{\infty} p_k t^k = P(t) \cdot I(t) \cdot G(t). \quad (6)$$

3. Results

We consider 11 months of *Fermi* data (August 4, 2008 - July 4, 2009). For pixelation, we use HEALPix [4] with the pixelation parameter nside = 32, which corresponds to pixel size about $2°$. The best fit of the model defined in Eq. (6) is presented in Figures 1 and 2.

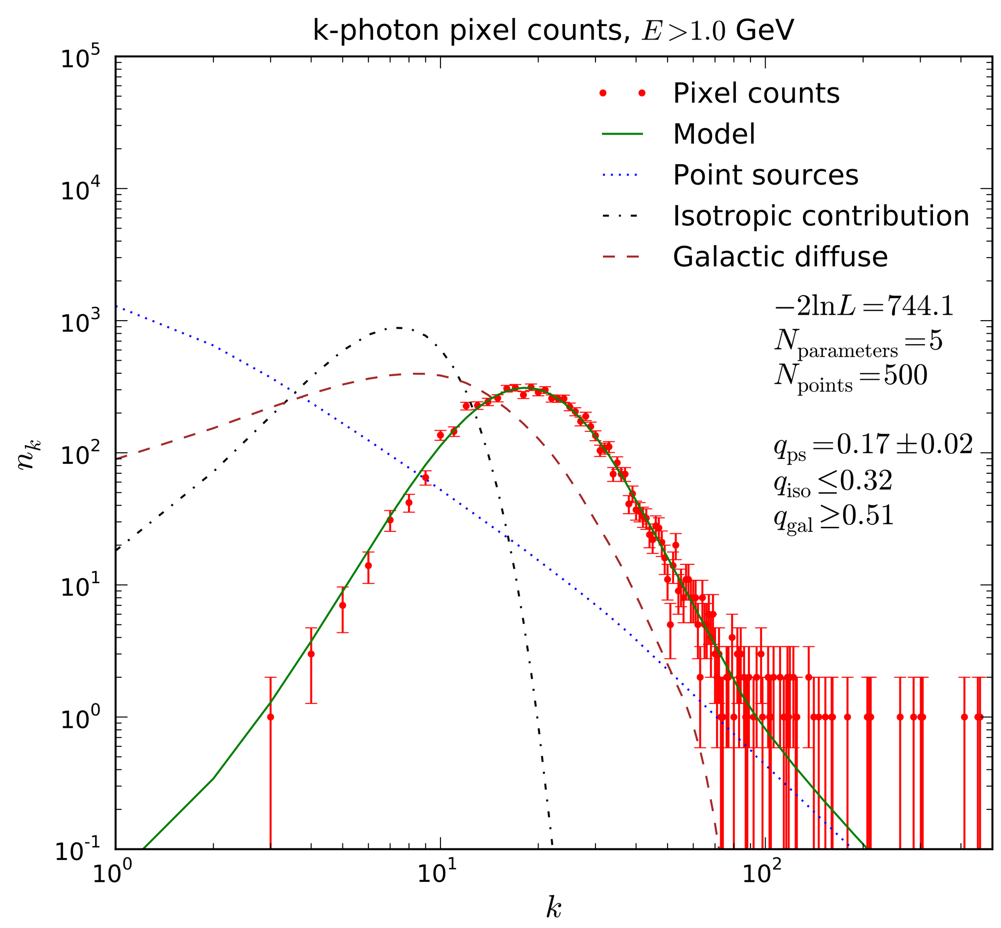

Figure 1: *Fit of the three components in Eq. (6) to the photon counts in pixels.*

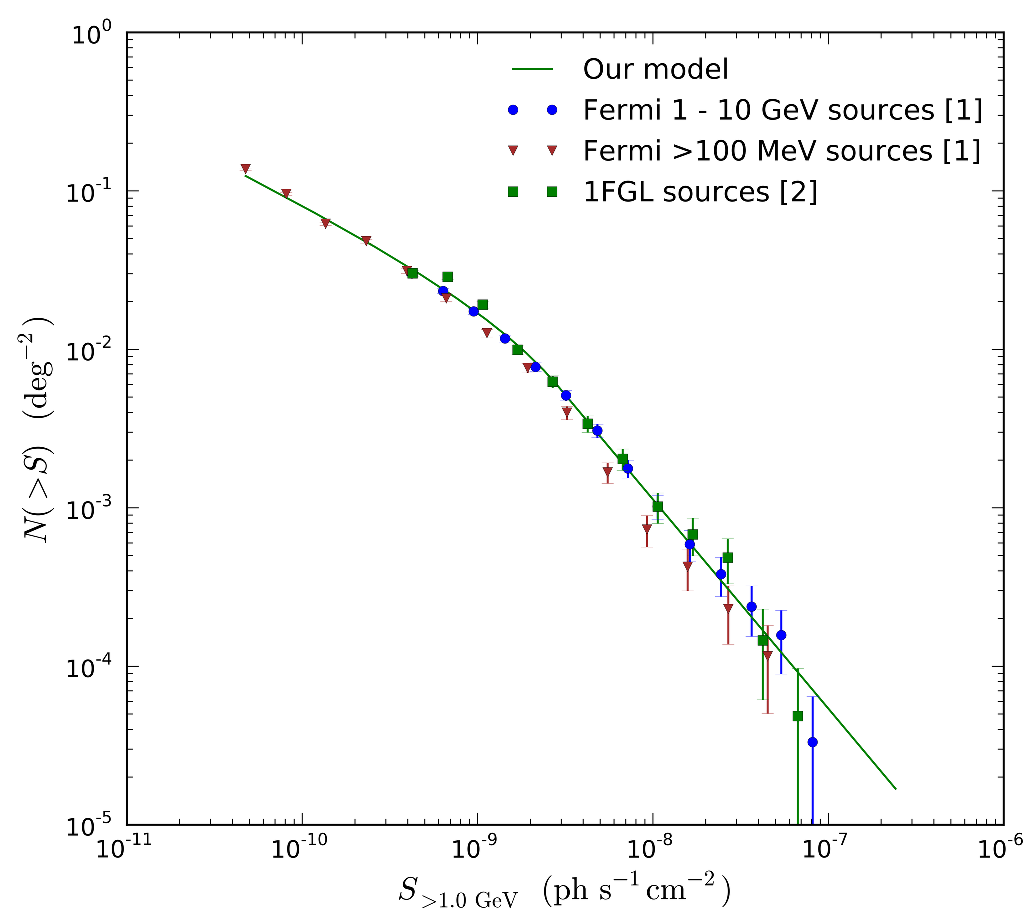

Figure 2: *Comparison of the best fit model to the source count distributions derived in [1, 2].*

References

[1] Abdo, A. A., et al. 2010, ApJ, 720, 435
[2] Abdo, A. A., et al. 2010, ApJS, 188, 405
[3] Malyshev D., & Hogg D. W. 2011 arXiv:1104.0010
[4] Górski, K. M., et al. 2005, ApJ, 622, 759

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