

Population studies of the unidentified EGRET sources

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Abstract. The third EGRET catalog contains a large number of unidentified sources. Current data allows the intriguing possibility that some of these objects may represent a new class of yet undiscovered gamma-ray sources. By assuming that galaxies similar to the Milky Way host comparable populations of objects, we constrain the allowed Galactic abundance and distribution of various classes of gamma-ray sources using the EGRET data set. Furthermore, regardless of the nature of the unidentified sources, faint unresolved objects of the same class contribute to the observed diffuse gamma-ray background. We investigate the potential contribution of these unresolved sources to the extragalactic gamma-ray background.

1. Introduction

This study statistically investigates the nature of the EGRET unidentified sources [1] under the simple assumption that if there exists a population of gamma-ray emitters commonly found in normal galaxies, then the Milky Way and M31 are likely to have similar such populations. We test whether the unidentified sources can be of Galactic origin by comparing the total luminosity of plausible Galactic distributions of these sources to the luminosity of M31.

In addition to detecting point sources, EGRET also measured diffuse background emission. The measured diffuse emission consists not only of truly diffuse emission, but also a contribution from unresolved point sources. Although the nature of the unidentified EGRET sources remains unknown, it is reasonable to believe that there are a number of fainter, unresolved objects of the same class which contribute to the observed diffuse emission. Taking the unidentified EGRET sources to be a single class of gamma-ray emitters and assuming in this case that this population is entirely extragalactic, we investigate the possible contribution of the unresolved members of this class to the extragalactic gamma-ray background (EGRB).

2. Constraining a Galactic population with M31

EGRET did not detect M31, determining only an upper limit to its flux. However, this observational bound limits the total flux both from point sources as well as from diffuse emission, and the expected flux of diffuse gamma-ray emission due to cosmic ray interactions in this energy range is almost two thirds of the EGRET upper limit [2]. Consequently, at a distance of 670 kpc, the expected luminosity of M31 due to point sources is constrained to less than $\sim 3.2 \times 10^{41} \text{ s}^{-1}$.

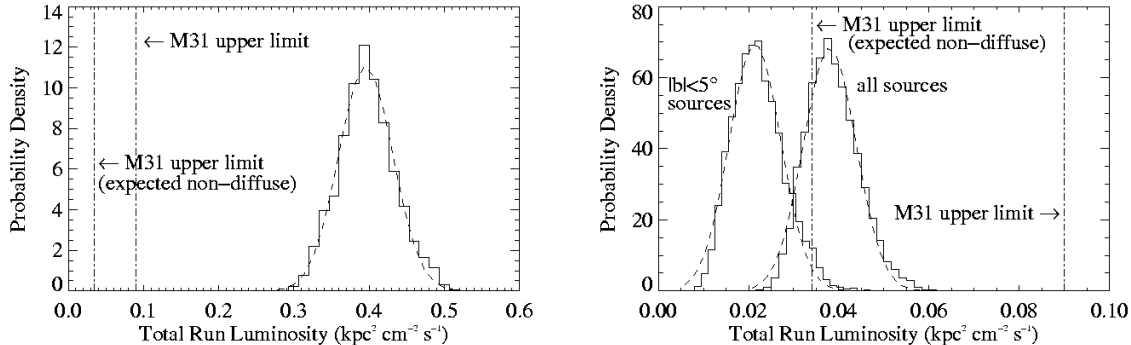


Figure 1. Probability density functions for the total luminosity of halo (*left*) and disk and bulge (*right*) distributions of the unidentified sources. The best-fit Gaussian distribution is plotted along with the histogram for each case. The observational and expected point source luminosity upper limits for M31 are shown for reference.

Using the flux and angular position measurements from the EGRET data, we evaluate the expected total luminosity of various Galactic distributions by assuming an underlying spatial distribution for the unidentified source population. Since proposed Galactic populations are generally associated with either the halo or the disk and bulge of the Galaxy, we use the mass distributions of these components to probabilistically assign distances for each source based on its angular position.

Figure 1 shows distributions of the total luminosity of the unidentified sources as a halo population (using sources with $|b| > 5^\circ$) and as a population residing in the disk and bulge (first considering sources with $|b| < 5^\circ$, then using all sources), each generated by 5000 realizations using a Monte Carlo algorithm. For the halo population, the central value of the total luminosity distribution is more than a factor of 4 greater than the observational limit for M31, and more than an order of magnitude greater than the expected upper limit for point sources, ruling out a halo population at high confidence. In the case of the population associated with the disk and bulge, we find that for both sets of sources the total luminosity distributions lie well below the observational upper limit, and a significant fraction of realizations are also below the expected limit for point sources. Taking into account reasonable variations between the Milky Way and M31, our luminosity test is consistent with all unidentified sources being members of a Galactic population distributed in the disk and bulge.

3. Contribution to the extragalactic gamma-ray background

Here we consider the case in which all unidentified sources are members of a single extragalactic population. We calculate the spectrum of fainter, unresolved members of the same class as the unidentified sources under this assumption and examine the implications for the EGRB.

The cumulative flux distribution (number of sources with flux greater than F as a function of F) of the detected unidentified sources is well-described by a power-law at high fluxes, but flattens out due to the finite telescope sensitivity at lower fluxes. Thus it is plausible that the true underlying distribution can be described by a continuation of the power-law fit, at least for modest extrapolations to lower fluxes. We take the spectral index distribution of the unresolved unidentified sources to be the same as that of their resolved counterparts, and use a maximum likelihood analysis taking into account individual measurement errors to extract their spectral index distribution (see [3] for a similar analysis). Using the extrapolated cumulative flux distribution and this spectral index distribution, we calculate the collective diffuse emission

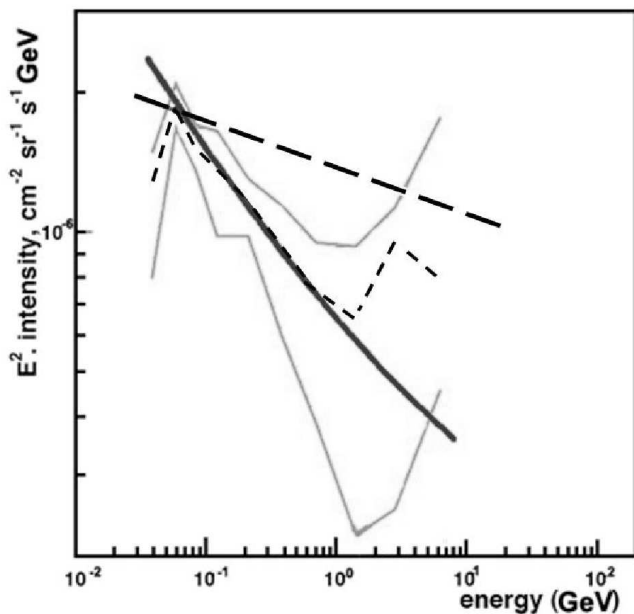


Figure 2. Predicted contribution of unresolved sources of the same class as the unidentified sources to the EGRB. Thick dashed line: Sreekumar *et al.* determination of the EGRB. Thin dashed line: SMR determination of the EGRB (best guess). Light solid lines: Systematics-based limits from SMR. Dark solid line: collective spectrum of unresolved unidentified sources (this work).

of the unresolved unidentified sources.

Figure 2 presents our calculated spectrum of these sources, along with the EGRET determination of the EGRB by Sreekumar *et al.* [4], and the redetermination of the EGRB by Strong, Moskalenko, and Reimer (hereafter SMR) [5]. The spectrum of the unresolved unidentified sources follows the SMR determination of the EGRB remarkably well over most of the energy range considered, suggesting that this source class may in fact be an important contributor to the EGRB. We also find that if the power-law description of the underlying cumulative flux distribution is accurate for fluxes down to roughly an order of magnitude lower than the observed turnover, this emission would dominate the EGRB at low energies.

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