Temporal and Spectral Studies of Unidentified EGRET High Latitude Sources

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Abstract.
Source distribution studies only provide meaningful information if the basic populations are carefully determined, especially if the statistics are limited. This necessitates restrictions from the approach of using the complete EGRET source catalog data. Considering various peculiarities of the catalogs a more uniform data set is defined for further source distribution studies. Here we focus on the temporal and spectral characteristic of the unidentified EGRET high latitude sources ($|b| > 10°$). Variability is addressed on the basis of flux histories with timescales of individual viewing periods, and spectra are determined for all sources based on the enhanced statistics from EGRET observations of Phase 1 to 4. The derived features are used to discuss whether the unidentified high latitude sources show similarities or differences from classes of already identified objects, or if no conclusive answer can be given.

THE EGRET POINT SOURCE CATALOGS

The most popular approach to population and correlation studies of EGRET point sources has been to use the EGRET point source catalogs. The study of the 2EG-catalog and its supplement (Thompson et al. [1], [2]) has become a

common procedure for attempts to understand the nature of the unidentified EGRET sources by comparison with properties of known objects or object classes [3], [4], [5], [6], [7], [8]. The approach here is basically to take all catalog sources and divide them into subclasses by identifications, coordinates, physical properties etc. But various aspects from the compilation of the 2EG- and 2EGS-catalogs have to be taken into account in order to get an almost unbiased sample of sources as the fundamental starting point for source population studies. This becomes even more important and essential if corrections for the instrument response (exposure, detection sensitivity etc.) are introduced.

First, the 2EG- and 2EGS-catalogs consist of two different significance thresholds for detection, for $|b| < 10°$ of $\geq 5\sigma$ and for $|b| < 10°$ of $\geq 4\sigma$. If a separation study in galactic latitudes does not take this nonuniformity ("step") in the detectibility function into account, classes with different statistical significances and sensitivities for being a source will smear the characteristics of source distributions, e.g. Grenier 1997 [8]. It is difficult to balance this effect afterwards in order to conclude if source excesses are present or not.

Second, the criterion for including a source in the 2EG- and 2EGS-catalogs as detected is, if the significance criterion mentioned above is fulfilled in either a single viewing period, a combination of single viewing periods or the total superposition of all viewing periods. This means a source will be listed as detection if it fulfills the detectibility criterion in one single viewing period, even if it is well beneath that criterion in an analysis of the superposition of all viewing periods from phase 1+2 or phase 1+2+3. This becomes an essential point if one attempt to introduce an instrumental exposure correction in order to balance the uneven sky coverage of EGRET, e.g. Grenier 1997 [8]. Any use of the *total* exposure regarding sources in the catalogs below the sensitivity criterion for the appropriate *total* observation time is improper and will not correct for the nonuniformity.

HIGH LATITUDE SOURCE DISTRIBUTIONS

Noticing these peculiarities of the 2EG- and 2EGS-catalogs, a suitable subset of sources was extracted. It includes only sources above the $\geq 4\sigma$ significance criterion for the *total* superpositioned observations from phase 1 and 2. This is currently the only common available base for an appropriate exposure correction, because the 2EGS-catalog does not include the statistical significances of detections for the 2EG-sources for phase 1+2+3. The nonuniform sensitivity across $|b| = 10°$ for catalog sources is handled by setting the histogram bin size of the latitude distributions to 10° and restricting the interpretation of objects to either $|b| > 10°$ or $|b| < 10°$. A total of 66 sources will be used here as high latitude sources, 47 AGN, the LMC, and 18 unidentified sources. The 35 sources $|b| < 10°$ are only sketched for qualitative

consideration.
The latitude distributions of different source classes meeting these selection criteria are shown in Fig. 1. In order to get a comparable visual impression the sources are always normalized to sources per steradian. No significant excess of unidentified sources at intermediate galactic latitudes $10° < |b| < 30°$ is indicated, although the enhancement in the Galactic plane is obvious.

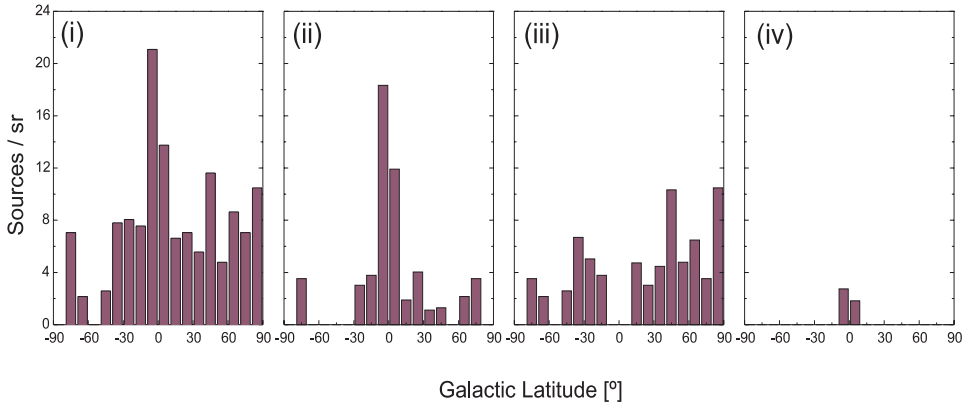

FIGURE 1. Latitude distributions of different source classes (i) all sources (ii) unidentified sources (iii) AGN (iv) PSR.

But this figure has to be completed by including the uneven instrument exposure and the structured galactic diffuse background. Mattox et al. [10] determined that the significance of detection s for an isolated EGRET point source could be expressed by $s \sim f\sqrt{e/bg}$, where f is the flux, e the exposure and bg the diffuse gamma ray background. Fig. 2 shows the latitude distribution of e, bg, and $\sqrt{e/bg}$, which is proportional to the detection significance for equally luminous sources .

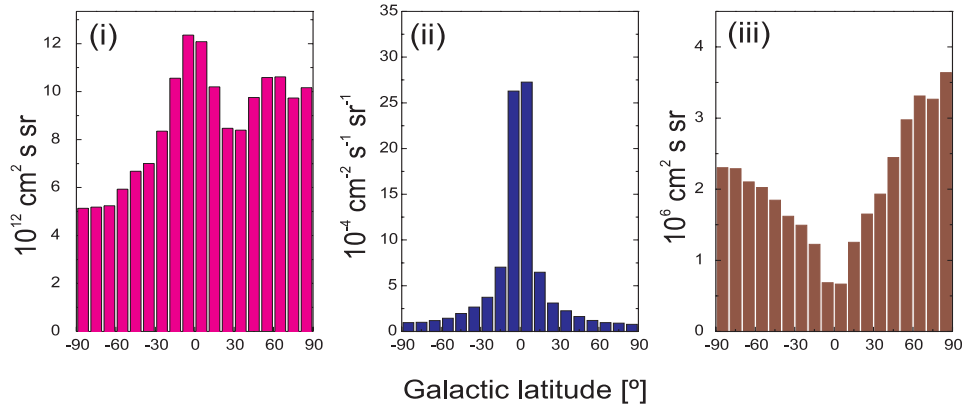

FIGURE 2. Latitude distributions of (i) exposure, (ii) diffuse background, (iii) $\sqrt{exposure/background}$, see text.

This picture suggests even more that one has to be careful in assessing source exesses in latitude profiles. The detection sensitivity is certainly lower in regions of enhanced diffuse emission, although longer sky coverage counteracts partly for the Galactic plane. For the high latitude sources rising gradients for the detectability are seen, with obviously better detection sensitivity at positive Galactic latitudes. This means an equally luminous point source would be more easily detected at high galactic latitudes, especially at *positive* high latitudes. Considering the slightly lower detection sensitivity at intermediate Galactic latitudes, limited evidence for an enhancement of unidentified sources is indicated.

VARIABILITY STUDIES

The Variability index V introduced by McLaughlin et al. [9] is used additionally for deciding if the unidentified high latitude sources show a specific feature with respect to other source classes. The unidentified high latitude sources tend to show a more non-variable behavior than AGNs, although a clear separation of source classes by only their variability seems impossible. Fig. 3 shows the Variability V for selected source classes.

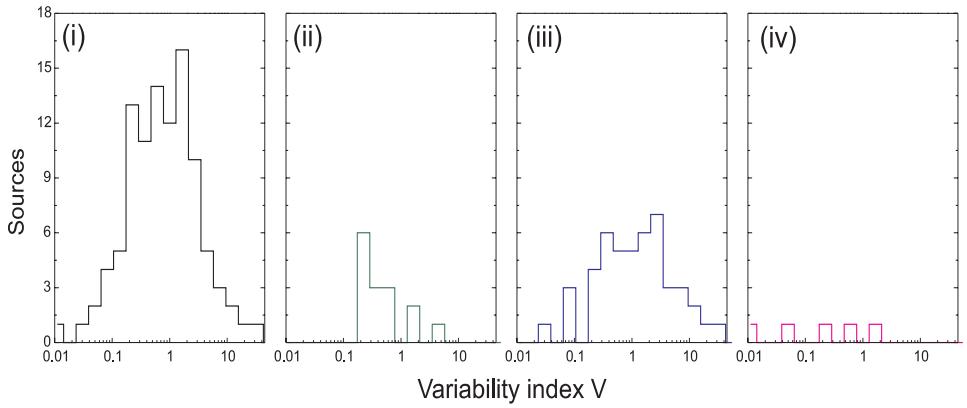

FIGURE 3. Variability index V for the following source classes (i) all sources (ii) all high latitude unidentified sources (iii) AGN (iv) PSR.

SPECTRAL STUDIES

A source spectrum is derived for all sources matching the selection criteria here based on the enhanced statistics of EGRET observations from phase 1 to 4. Flux values or upper limits for each of 10 energy intervals were determined.

These values were used to fit power law models to the energy spectra. The explicit spectra will be published in conjunction with the announced 3EG-catalog [11]; therefore here spectral indices were used only to investigate whether the unidentified high latitude sources show a characteristic feature with respect to other sources classes. In general, a range in the spectral indices as seen previously for high-energy γ-ray emitting objects is present. But in contrast to the distribution of the AGN, which show a nonuniform distribution centered near an index of -2, the distribution appears more equalized for the unidentified high latitude sources. The spectra of the few known γ-ray pulsars are harder compared to AGN. But as mentioned in Merck et al. for the Galactic sources [12], many of the unidentified high latitude sources have softer spectra than the known γ-ray pulsars. Fig. 4 shows the distribution of the spectral indices.

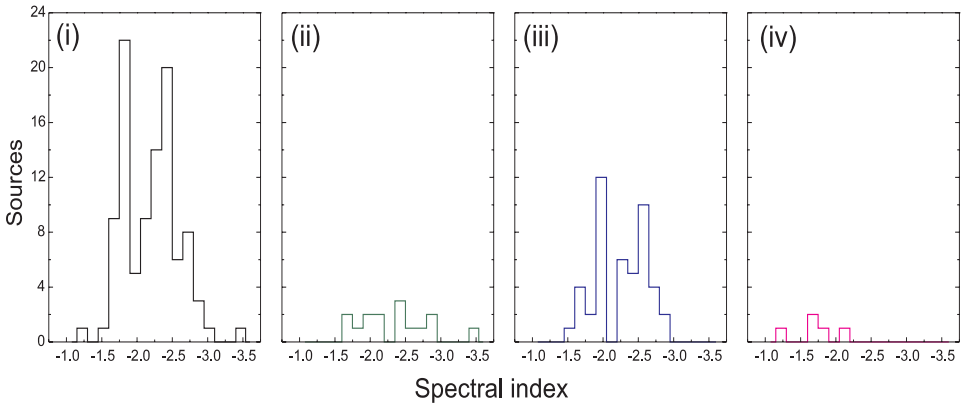

FIGURE 4. Spectral index α for the following source classes (i) all sources (ii) all high latitude unidentified sources (iii) AGN (iv) PSR.

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