Proceedings of ICRC 2001: 2566 © Copernicus Gesellschaft 2001

ICRC 2001

LogN–LogS studies of EGRET sources

O. Reimer[1,2] **and D.J. Thompson**[3]

[1]NRC/NASA/GSFC, Code 661, Greenbelt, MD 20771, USA
[2]Now at: Institut für Theoretische Physik, Lehrstuhl IV: Weltraum- & Astrophysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany
[3]NASA/GSFC, Code 661, Greenbelt, MD 20771, USA

Abstract. A comprehensive investigation of logN–logS distributions of gamma-ray sources discovered by EGRET has been performed for subsequent use in population studies. Existing models explaining the spatial arrangement of unidentified sources do not compare against an observed logN–logS distribution. However, viable population models not only have to reproduce the logN–logS distribution for different source classes globally, they have to correspond to apparent differences among their spatial, spectral and variability characteristics. Furthermore, it needs to be understood in which way results from selections among the unidentified sources like "persistent" (Grenier, 2000) or "steady" sources (Gehrels et al., 2000) are related to the overall picture regarding their logN–logS characteristics.

1 Introduction

A Log N–log S study of any class of astronomical object, if complete for a set of selection criteria, is a valid and useful tool for diagnoses of source properties. The completeness of the EGRET detected gamma-ray sources has been probed by analyzing gamma-ray excesses down to TS values of 9, i.e. below the detection criterion for inclusion of gamma-ray sources into the 3EG catalog (Hartman et al., 1999). On the condition that completeness for an investigation of 3EG catalog sources could be obtained this way, various questions concerning the properties of gamma-ray sources could be addressed. Spatial arrangements, source identification issues, source fluxes as well as selections of particular interest among the unidentified gamma-ray sources have been obtained and visualized in their logN–logS distribution. To date, logN–logS studies are not given in the full context of available gamma-ray observables : Özel & Thompson (1996) investigated high latitude AGN and unidentified sources on the basis of the 2EG catalog, just available at this time, Mücke & Pohl (2000) analyzed AGN and FSRQs in respect of their different contribution to the extragalactic diffuse gamma-ray background, and Gehrels et al. (2000) used the subset of "steady" unidentified sources to distinguish between faint mid-latitude sources and bright unidentified sources close to the Galactic disk. Here we want to study the relevant information concerning gamma-ray point source detections by EGRET in terms of logN–logS distributions. Scope of this investigation is the latter use in a source population model, where observed logN–logS distributions need to be adequately reproduced to reflect the reality and correspond to instrumental selection effects and detectability biases in population models as well.

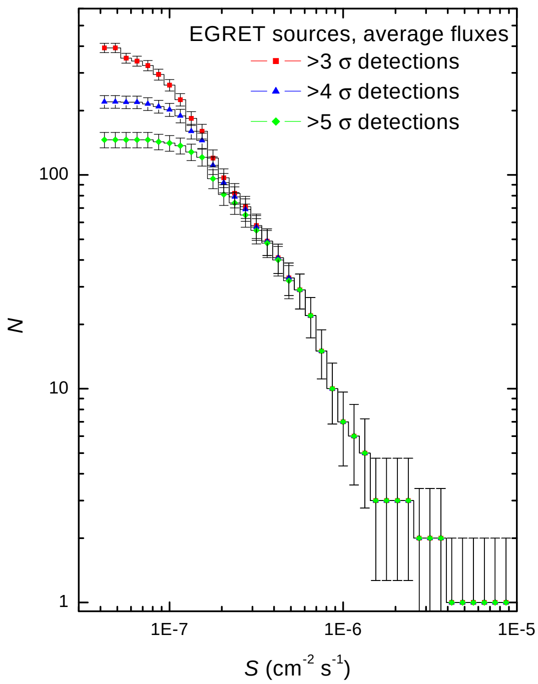

Fig. 1. LogN–logS distributions of gamma-ray sources at different detection significance thresholds.

Correspondence to: O. Reimer (lr@egret.gsfc.nasa.gov)

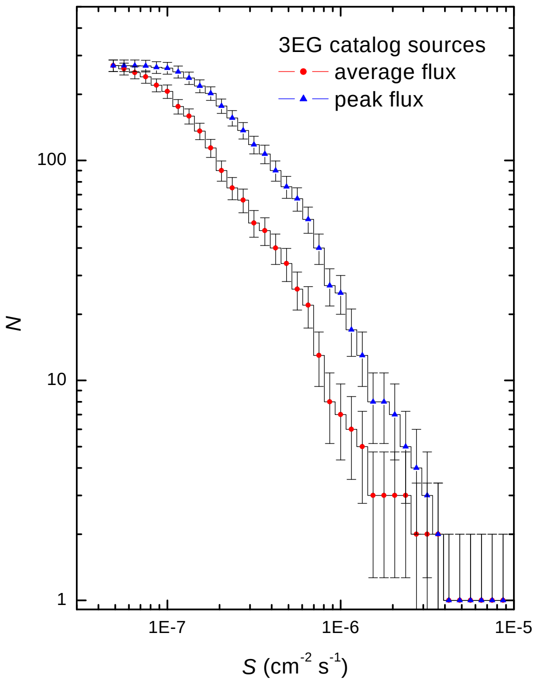

Fig. 2. LogN–logS distributions comparing 3EG catalog sources regarding peak flux and average flux values, respectively.

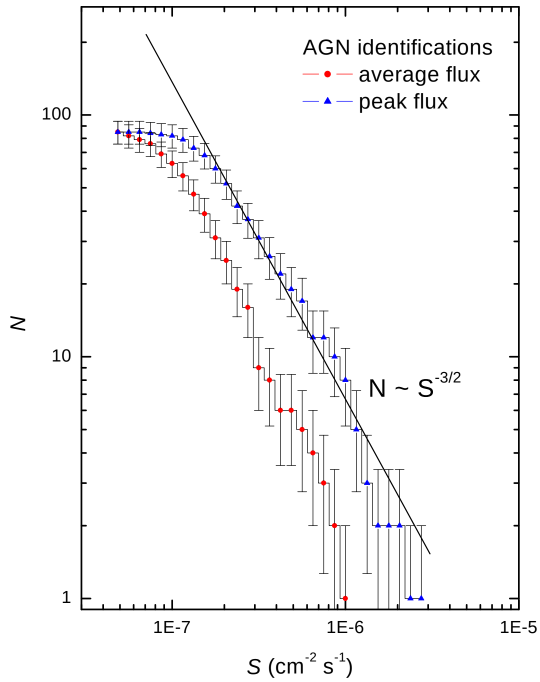

Fig. 3. LogN–logS distributions comparing identified AGN regarding peak flux and average flux values, respectively.

2 Analysis & Results

Originating from a source list of 416 gamma-ray excesses with test statistics (TS) greater than 9 (i.e. 3σ detections), source fluxes were determined using EGRET data from CGRO observation cycles 1 to 4. Identifications are taken from the 3EG catalog, which made use of a more strict source detection criterion. Hence, 263 gamma-ray point sources from the 3EG were used (neglecting 7 artifacts and a solar-flare detection). Individual source identifications beyond the 3EG catalog are consistently incorporated. Fig.1 gives the overall picture using different detection significances for the complete sample of gamma-ray sources. The different significance levels indicate the appearance of limitations in EGRETs source detectability, significantly flattening the distribution at lower fluxes than 2.5×10^{-7} photons $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$. We assume completeness for fluxes above this level within given statistical uncertainties. Fig.2 shows the 3EG catalog sources. Here we compare the discrepancy between the usage of average flux levels (P1234) and peak fluxes whenever the peak flux exceeds an average flux level. The instrumental detectability obviously lowered further to about 5×10^{-7} photons $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$, actually reflecting the way the 3EG catalog has been compiled using sources matching the detection threshold in either individual viewing periods or superpositions on timescales up to four years of CGRO operation, which is referenced by ”P1234”. It can bee seen, that the slope of the distribution above fluxes influenced by instrumental biases remains the same within the given statistical uncertainties. Before splitting the dataset into different categories in respect of their identification, a check has been done comparing the AGN identifications as given in the 3EG catalog (66 high-significance and 27 lower confidence identifications) and their subsequent quantitative evaluation by Mattox et al. (2001). As important the question of a correct identification of a gamma-ray source with an AGN is, individual discrepancies do not implicate a significant change in the shape of the logN–logS distribution. This is due to the fact that all high-confidence AGN identification have been confirmed by Mattox et al. (2001). Therefore misidentifications could only occur for low flux sources, simply resulting in a reduction in N. Fig.3 finally compared the identified AGN in average and peak flux, respectively. As also seen in Fig.2, the difference between both curves is significant, whereas the slope of a best-fitted power law not. The linear fit to the data down to the instrumental detectability bias appears to be consistent with the expected $\mathrm{S}^{3/2}$ dependence for an isotropic/spatial uniform distribution of underlying objects for a Euclidean universe A similar discrepancy could be noticed when comparing average and peak fluxes of unidentified gamma-ray sources. However, the right flank of the logN–logS distribution is heavily influenced from the degree of completeness of gamma-ray source identifications itself, which is essentially unknown as in the nature of a source being unidentified. Fig.4 is given here only as reference for the following latitudinal selections among unidentified sources. In Fig.5 high-latitude unidentified sources were selected ($|\mathrm{b}| > 30^{\circ}$). Two noticeable differences compared to Fig.3 can be seen: (1) AGN extend to higher flux levels compared to unidentified sources at high-galactic latitudes.

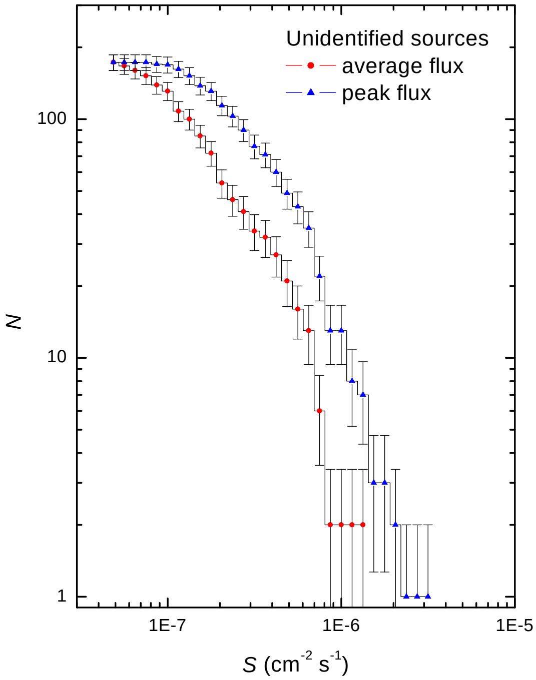

Fig. 4. LogN–logS distributions comparing unidentified gamma-ray sources from the 3EG catalog regarding peak flux and average flux values, respectively.

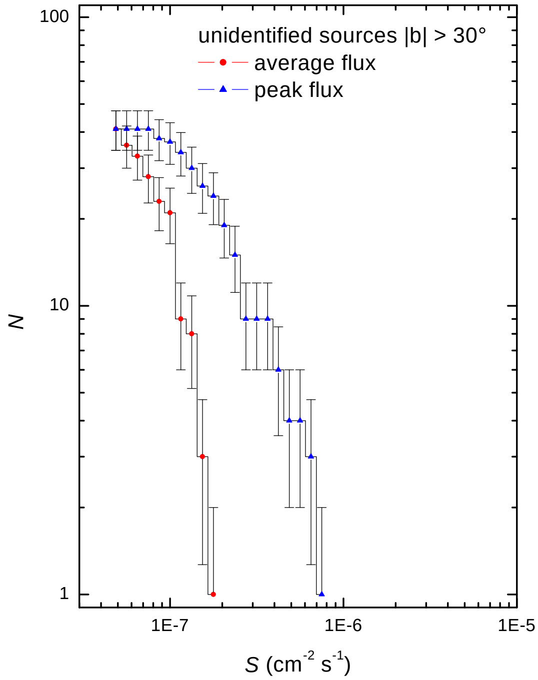

Fig. 5. LogN–logS distributions comparing high-galactic latitude unidentified sources regarding peak flux and average flux values, respectively.

(2) The contrast between average and peak flux representation in a logN–logS diagram between unidentified gamma-ray sources and AGN is even more pronounced. This is due to the fact, that sources at high-galactic latitude are preferential identified by its peak flux, therefore leaving the average flux distribution in a random shape in respect of its completeness in identification. The similarity between the peak-flux distribution for unidentified high-latitude sources and AGN confirms that AGN are the obvious potential identification for these unidentified gamma-ray sources. Fig.6 shows unidentified sources at mid-galactic latitudes. Here we have chosen three different latitudinal selections matching previously studied mid-latitude unidentified sources ($10^o > |b| > 30^o$ reflecting the threshold between two different detection criteria as present in the 3EG catalog at 10^o, $5^o > |b| > 30^o$) to compare with ”steady” unidentified sources (Gehrels et al., 2000), and $2.5^o > |b| > 30^o$ reflecting a cut for ”persistent” unidentified sources as used by Grenier (2000). In fact, the difference in the shape of the distributions between these mid-latitude selections are within the statistics of the sample itself, therefore it does not matter which cut has been chosen in order to draw conclusion from logN–logS distributions. In Fig. 7 we compare unidentified sources close to the Galactic Plane in average and peak flux, respectively. Here one clearly sees the suppression from EGRETs inability to discriminate sources in the Galactic Plane at a similar level against the dominant galactic diffuse background compared to sources outside the Plane. Furthermore, the slope of the logN–logS distribution appears to be rather different for high source fluxes compared to Fig.4. It remains to be investigates whether this is due to a different class of objects responsible for this steeper slope as suggested by Gehrels et al. (2000) or it is a result from selection effects due to a different level of completeness in source identifications within the Galactic Plane. Differences between unidentified sources and samples like ”steady” unidentified sources and ”persistent” unidentified sources have been looked at, too. When comparing its particular logN–logS distribution, the way these selections are compiled is apparent. They basically resemble the logN–logS distribution for unidentified gamma-ray sources using average flux values, sorting out unidentified sources which have been included in the 3EG catalog because of their peak flux instead of cumulative added source significance (in other words: sources matching the 3EG catalog criteria with its P1234 average flux). Therefore, a comparison with these samples is meaningful only considering average flux values in logN–logS distributions. Finally, Fig.8 compares ”steady” unidentified sources in respect of its photon spectral index. A separation in γ= -2.25 has been made and the difference in the logN–logS distributions is clearly seen. Unidentified sources with hard power law spectrum show a distinct steeper logN–logS distribution than softer unidentified sources. However, in this case we also have to consider an apparent selection effect: In regions of dominant Galactic diffuse emission hard sources are easier detectable compared to soft spectrum gamma-ray emitters, but only to a flux level significantly higher than achievable at high-galactic latitudes. Therefore differences in the logN–logS distribution

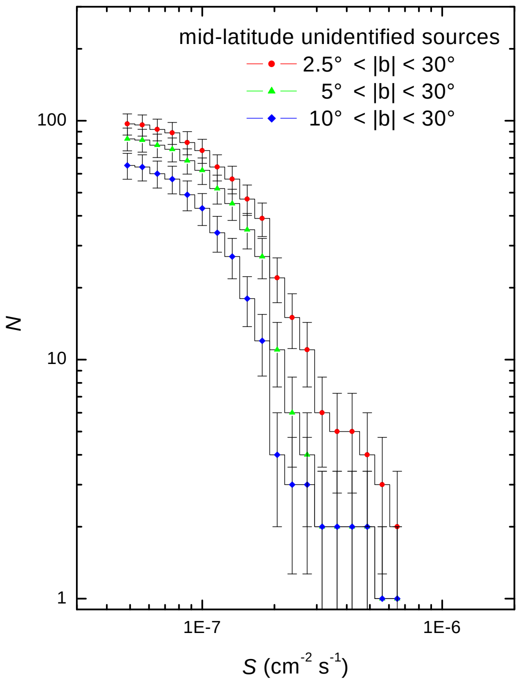

Fig. 6. LogN–logS distributions comparing different latitudinal cuts describing mid-latitude unidentified sources (”steady” sources, ”persistent” sources).

could only be discussed meaningfully if they are determined within regions of comparable diffuse background level. Unfortunately, the EGRET data do not allow statistically significant results at this depths of investigation. These distinctions could only be made when next-generation gamma-ray instruments like GLAST will provide much more source detections and subsequently more source identifications, too.

Acknowledgements. O.R. acknowledges a National Research Council Associateship Award taken at NASA Goddard Space Flight Center.

References

Hartman, R.C. et al., ApJS 123, 79
Özel, M.E. & Thompson, D.J., ApJ 463, 105
Müecke, A. & Pohl, M., 2000, MNRAS 312, 177
Gehrels, N. et. al., 2000, Nature 404, 363
Mattox, J.R., Hartman, R.C., & Reimer, O., 2001, ApJS 135
Grenier, I.A., 2000, A&A 362, L93

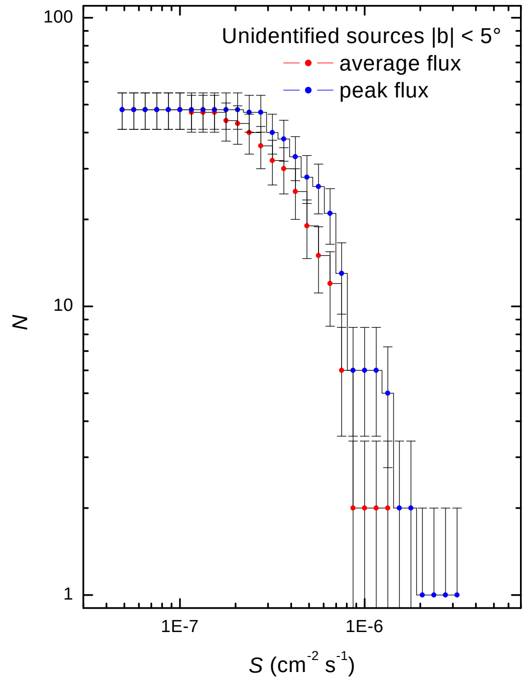

Fig. 7. LogN–logS distributions comparing unidentified EGRET sources close to the Galactic Plane regarding peak flux and average flux values, respectively.

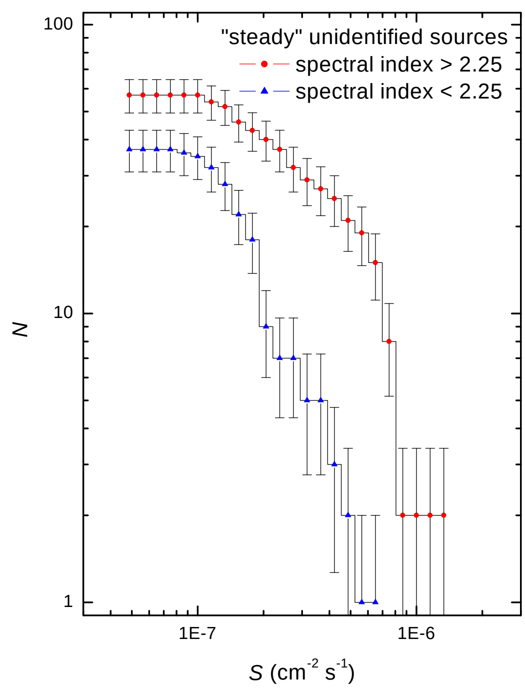

Fig. 8. LogN–logS distributions comparing unidentified EGERT sources regarding different spectral hardness.