A New Estimate of the Extragalactic Gamma-Ray Background from EGRET Data

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Abstract

We use the GALPROP model for cosmic-ray (CR) propagation to obtain our best prediction of the Galactic component of gamma rays, and show that away from the Galactic plane it gives an accurate prediction of the observed EGRET intensities. On this basis we re-evaluate the isotropic extragalactic gamma-ray background (EGRB). We find that for some energies previous work underestimated the Galactic contribution and hence overestimated the background. Our new EGRB spectrum shows a positive curvature similar to that expected for models of the extragalactic emission based on the blazar population.

1. Introduction

The GALPROP model for CR propagation produces explicit predictions for the angular distribution of diffuse Galactic γ-rays. In a companion paper [4] we describe a comparison of a model for Galactic diffuse continuum γ-rays with EGRET data. In this paper we use this model to determine the EGRB.

2. Data and method

Given the success of the model [4] in reproducing the γ-ray sky, we can use it to make improved estimates of the EGRB. Since the model is nevertheless not exact the best approach is to fit the observed intensities with a free scaling factor; in this way the EGRB is determined as the intercept, thus removing any residual uncertainty in the absolute level of the Galactic components. (This is the same method as in [2], the difference lies in the model). To reduce the effects of Galactic structure, point sources etc. the fits are made excluding the plane, using the region $360° < l < 0°, 10° < |b| < 90°$ ("region G"); ideally both IC and gas-related components would be left free but they are difficult to separate statistically at high latitudes, so we make a linear fit to the total IC+π^0-decay+bremsstrahlung, with the scaling factor and EGRB as parameters. The fit and errors are based

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on a simple χ^2 analysis, with (l, b) bins $360^\circ \times 2^\circ$ to obtain sufficient statistics (at least 10 counts per bin were required). For comparison we also made fits to the entire sky; in this case IC and gas-related contributions are easily separated; the two fit regions then give some indication of the model-dependent systematic error in our EGRB estimates.

The scaling factors determined for the region G fits reflect the deviations from the model and are shown in Table 1. They are typically between 0.8 and 1.2 which is satisfactory. (Only statistical errors are shown in Table 1.) For 30–50 MeV, 1–2 and 2–4 GeV the scaling factors deviate further from 1 reflecting the discrepancy in the spectrum so that these are the least reliable ranges of our EGRB determination. The EGRB is however not very sensitive to the scaling factor.

Table 2 summarizes the fitted EGRB values. The two fitted regions (region G and all sky) give consistent results, indicating that there is no large systematic effect; it shows a model-dependent systematic uncertainty of 5–30%, comparable to the formal statistical errors. This is comparable to the $\sim$ 15% systematic uncertainty on EGRET data so we adopt 30% for our total error estimate.

Fig. 1 shows the extragalactic X- and γ-ray background, using the compilation by [2] but with our new EGRET values, and also updated COMPTEL results ([5] and references therein). Our estimates lie significantly below those of [2], in each energy range. The positive curvature in our EGRB spectrum is interesting and not unexpected [1] but in view of the systematic uncertainties should not be taken too literally; a similar, less pronounced effect is present in the Sreekmar spectrum. A power-law is a poor fit to our spectrum. Although the 50 MeV – 2 GeV range can be fit satisfactorily by a power law, it is clearly inconsistent with the points above 2 GeV.

The reason for the difference between our spectrum and that given in [2] is the improved modelling of high-latitude γ-rays based on inverse Compton emission from the halo. An indication of this effect is already apparent in Table 1 of [2] which requires scaling factors up to 1.8 above 1 GeV. Detailed comparisons of our model with the EGRET data will be given in a forthcoming publication.

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3. References

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Table 1. Scaling factors of components of Galactic diffuse emission

Energy, MeV	Total, $\|b\| > 10°$	All-sky IC	All-sky Gas
30 − 50	1.43 ± 0.05	1.54 ± 0.12	1.20 ± 0.14
50 − 70	1.15 ± 0.03	1.10 ± 0.065	1.03 ± 0.05
70 − 100	1.07 ± 0.02	1.20 ± 0.04	0.82 ± 0.02
100 − 150	0.97 ± 0.01	1.14 ± 0.03	0.76 ± 0.01
150 − 300	0.93 ± 0.01	1.16 ± 0.03	0.76 ± 0.01
300 − 500	1.07 ± 0.01	1.26 ± 0.04	0.90 ± 0.01
500 − 1000	1.17 ± 0.015	1.31 ± 0.04	1.06 ± 0.01
1000 − 2000	1.34 ± 0.025	1.21 ± 0.06	1.37 ± 0.03
2000 − 4000	1.48 ± 0.05	1.14 ± 0.08	1.67 ± 0.06
4000 − 10000	0.83 ± 0.06	0.58 ± 0.09	1.40 ± 0.11

Table 2. Estimates of EGRB[1] obtained by fitting optimized model to EGRET data

Energy, MeV	Total,[2] $\|b\| > 10°$	All-sky,[2] IC+Gas	[2][3]
30 − 50	16.4 ± 0.67	16.2 ± 0.8	24.0 ± 7.0
50 − 70	10.2 ± 0.19	10.6 ± 0.2	13.3 ± 2.6
70 − 100	6.33 ± 0.10	6.42 ± 0.1	7.83 ± 1.05
100 − 150	4.26 ± 0.07	4.3 ± 0.07	5.5 ± 0.75
150 − 300	3.76 ± 0.06	3.76 ± 0.07	5.4 ± 0.72
300 − 500	1.08 ± 0.04	1.1 ± 0.04	1.97 ± 0.27
500 − 1000	0.65 ± 0.04	0.67 ± 0.04	1.36 ± 0.19
1000 − 2000	0.265 ± 0.03	0.33 ± 0.03	0.617 ± 0.084
2000 − 4000	0.203 ± 0.02	0.28 ± 0.02	0.30 ± 0.044
4000 − 10000	0.117 ± 0.02	0.125 ± 0.02	0.196 ± 0.029

[1]Units: 10^{-6} cm^{-2} sr^{-1} s^{-1}.
[2]For our fits only statistical errors are given, for systematic errors see text.
[3]The values [2] are from their Table 1 which includes systematic errors.

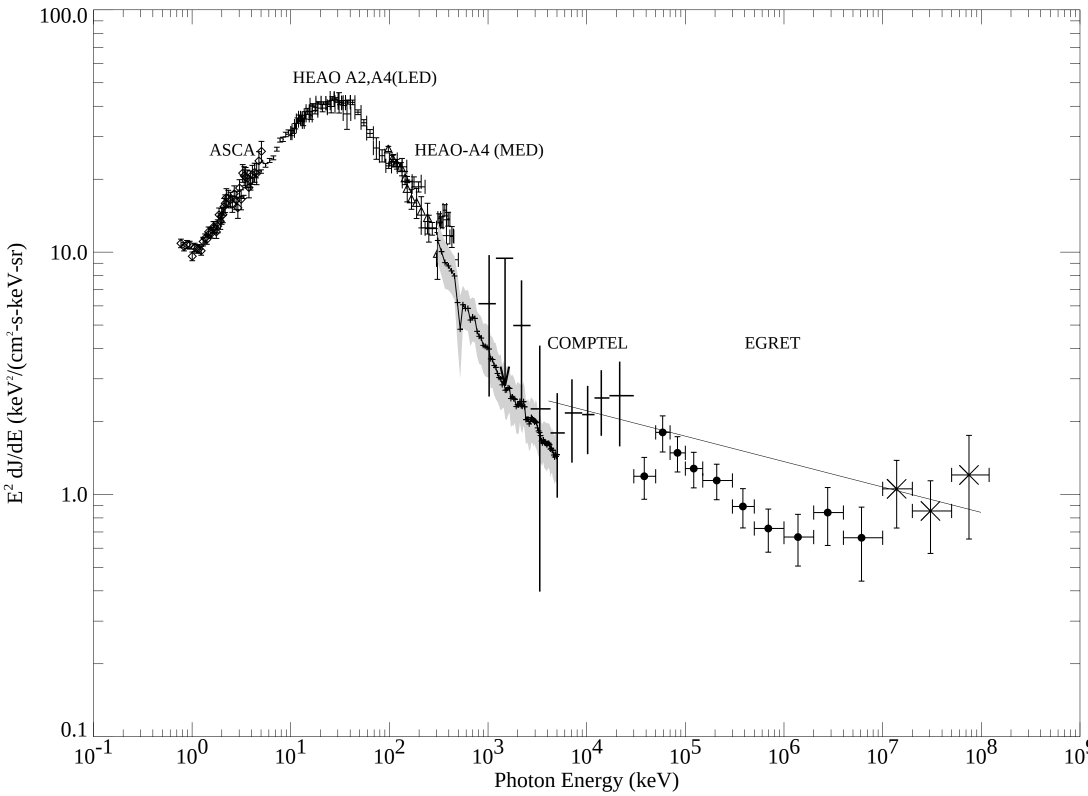

Fig. 1. Extragalactic X-ray and γ-ray spectrum. Data compilation from [2] except for COMPTEL [5] and EGRET 30 MeV – 10 GeV (this work). The power-law in the EGRET range and the 3 data points above 10 GeV represent the spectrum derived by [2].