Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 2 (OG part 1), pages 517–520

30TH INTERNATIONAL COSMIC RAY CONFERENCE

A Monte Carlo Study of the Irreducible Background in the EGRET Instrument

T. A. PORTER, W. B. ATWOOD, B. BAUGHMAN, AND R. P. JOHNSON
Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA 95064, U.S.A.
tporter@scipp.ucsc.edu

Abstract: The diffuse extragalactic γ-ray background (EGRB) has been derived by various groups from observations by the Energetic Gamma Ray Experiment Telescope (EGRET) instrument on the Compton Gamma Ray Observatory (CGRO). The derived EGRB consists of γ-rays that may come from astrophysical components, such as from unresolved extragalactic point sources (blazars, normal galaxies, etc.), true extragalactic diffuse emission, misattributed diffuse signals from the Galaxy and other celestial sources, and an irreducible instrumental background due to γ-rays produced by cosmic-ray (CR) interactions in the EGRET instrument. Using the Gamma Ray Large Area Space Telescope (GLAST) simulation and reconstruction software, we have investigated the magnitude of the irreducible instrumental background in the GLAST Large Area Telescope (LAT). We re-scale our results to the EGRET and present preliminary results of our study and its effect on current estimates of the EGRB.

Introduction

The diffuse extragalactic γ-ray background (EGRB) is a superposition of all unresolved sources and true diffuse high energy γ-ray emission in the Universe. The EGRB is a weak component which is difficult to disentangle from the intense Galactic foreground. The isotropic, presumably extragalactic component of the diffuse γ-ray flux was first discovered by the SAS-2 satellite [1]. Analysis of the data from the EGRET instrument on CGRO appears to confirm this discovery [2].

The extraction of the EGRB is difficult because its derivation relies on modelling foregrounds that are uncertain to some degree, as well as a good understanding of the instrumental background. Extensive work has been done [2] to derive the spectrum of the EGRB based on the EGRET data. The relation of modelled Galactic diffuse emission to total measured diffuse emission was used to determine the EGRB as the extrapolation to zero Galactic contribution. A new detailed model of the Galactic diffuse emission [3] lead to a new estimate of the EGRB which is lower and steeper than found by [2]. Analysis of the same data by Grenier et al. [4] found similar results; they make the important point that the overall intensity and spectrum depend within 50% on the choice of foreground model.

Understanding of the instrumental background is also crucial for extraction of the EGRB. Gamma-ray telescopes, such as the EGRET and the upcoming GLAST-LAT, employ a sensitive anti-coincidence shield (ACS) to veto charged particles entering the instrument field of view (FoV). Surrounding the ACS there is additional material, such as the thermal blanket and micrometeor shield. Charged particles interacting in this inert material can produce neutral secondaries and not trigger the ACS. Similarly, if a charged particle interacts in the scintillator in the ACS without causing a veto, the neutral secondaries will enter the instrument in the FoV. In either case, the secondaries contaminate the celestial signal and are an irreducible background that is a systematic uncertainty in determining the level of the EGRB.

In this paper, we report on a study of the irreducible background in the GLAST-LAT, and its application to estimate the systematic uncertainty in the EGRB derived from the EGRET data.

Monte Carlo Simulations and Analysis

The GLAST-LAT is a pair-conversion telescope in which the tracker-converter uses silicon microstrip technology to track the electron-positron pairs resulting from γ-ray conversion in thin tungsten foils. A cesium iodide calorimeter below the tracker is used to measure the γ-ray energy, and the tracker is surrounded on the other 5 sides by plastic scintillators forming the ACS for charged-particle rejection.

As part of the pre-launch analysis, simulation studies of data collected by the LAT are performed. These include a complete detector simulation with realistic orbit and attitude profile, full CR background model, and a detailed model of the γ-ray sky including time variable sources. The resulting simulation data are pushed through an analysis chain which includes direction and energy reconstruction, background rejection and event classification algorithms allowing the identification of well-reconstructed γ-ray events.

The presence of so-called irreducible γ-ray events became apparent upon scanning the residual background events after their statistical rejection in the analysis. Gamma-rays in this event class are produced in the inert material located outside of the sensitive portion of the ACS scintillation tiles (this includes ~ 1 mm of the plastic scintillator since it is possible for particles to interact in the scintillator producing all neutral secondaries without sufficient light production to cause a reliable veto). The incident charged particles responsible for these γ-rays were: positrons (60%), protons producing π^0s (30%), and electrons/positrons producing γ-rays via Bremsstrahlung (10%). Our handscan of the residual events resulted in a sample of 751 irreducible background events. Using these events, a live-time of 2×10^4 seconds and an effective area-solid angle product of 2.2×10^4 cm^2 sr, the irreducible γ-ray intensity was computed in the LAT. Figure 1 shows the result of our analysis for the irreducible γ-ray component in the GLAST-LAT. The error bars are statistical only.

There is a systematic uncertainty on the irreducible component due to the uncertainty in the incident charged particle fluxes. The details of the particle flux model are outlined in [5]. Albedo electrons, positrons, and protons are included, as well as Galactic CRs. Included in the albedo component are splash particles produced by CR interactions with the atmosphere and re-entrant particles trapped by the Earth's magnetic field. The albedo electron/positron component is dominant below $\sim 400 - 500$ MeV while the albedo proton component is the main contributor up to ~ 3 GeV; above this Galactic CRs are the dominant component of the charged particle flux. The major uncertainties associated with orbit-averaged components of the flux model are:

- $\pm 50\%$ for albedo electrons/positrons; $\pm 30\%$ for albedo electrons/positrons with energies ≥ 30 MeV
- $\pm 30\%$ for albedo protons
- $\pm 10\%$ for the Galactic CR component.

Furthermore, there is an additional significant systematic error due to the hadronic physics modelling for protons producing π^0s without causing a veto in the ACS. Hadronic interactions are less well-modelled compared with electromagnetic interactions and we have taken a conservative additional 20% uncertainty for the proton induced irreducible component. We combine these uncertainties and show them as the hatched band in Fig. 1.

To re-scale our results for the EGRET we need to account for the difference in orbital altitude between the GLAST and the CGRO. The GLAST-LAT study was done for an orbital altitude 565 km, whereas the the nominal orbital altitude for the CGRO when deployed was 450 km. However, the CGRO's orbital altitude decreased by ~ 100 km requiring subsequent reboosts to regain the initial deployed altitude. The uncertainty in the charged particle flux model for lower orbital altitudes is:

- 20% increase in the albedo component as orbital altitude decreases from 615-430 km
- 10% decrease in the Galactic CR component as orbital altitude decreases from 615-430 km.

We adopt a simple 20% increase in the albedo component and 10% decrease in the Galactic CR component. We do not consider the decrease in orbital altitude that the CGRO experienced; this would add further systematic uncertainty. The irreducible intensity from our analysis of the GLAST-LAT re-scaled to the nominal CGRO orbital altitude is shown in Fig. 1 as the shaded region.

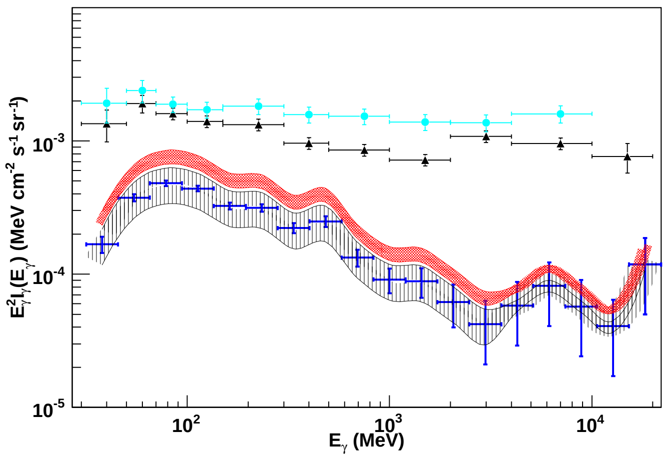

Figure 1: Extragalactic γ-ray and irreducible background in the GLAST-LAT based on our Monte Carlo study. Data points: cyan-circle from [2]; black-triangle from [3]. Blue points with error bars: irreducible intensity from our analysis. Black-lines show the uncertainty on the irreducible intensity due to uncertainties in the charged particle flux model. Black-hatched region shows the combined uncertainty from the charged particle flux model and hadronic physics modelling. Red-shaded region shows the hatched region re-scaled to the nominal CGRO orbital altitude of 450 km.

The difference between the GLAST-LAT and the EGRET inert material audit must also be taken into account. However, it is the most uncertain step of a process that already involves considerable uncertainties. For the LAT, the micrometeor shield and thermal blanket have a total column density of 0.38 g cm^{-2}, with the $\sim$ 1 mm of inert scintillator contributing a further 0.15 g cm^{-2} giving a total of 0.53 g cm^{-2}. For the EGRET, the micrometeor shield, thermal blanket, and light shield amount to a column density of 0.20 g cm^{-2}. For the EGRET ACS we can only estimate the column density of inert material by examining the veto threshold energy. The veto threshold energy was measured during the EGRET calibration but was known to have significant systematic errors. Thus, we are only able to give a range of the charged particle penetration depth before which a veto would be triggered in the ACS. From examining internal EGRET documents [6], we find that the penetration depth can range from as little as 0.15 mm up to 2.5 mm for the apex of the ACS. This yields a range of total column densities of inert material in the EGRET of 0.215 g cm^{-2} to 0.45 g cm^{-2}. A simple scaling of the derived irreducible intensity by the relative column densities between the LAT and the EGRET is not possible due to the uncertainties associated with the charged particle rejection from hadronic interactions in the inert material. Therefore, we do not attempt to further re-scale the derived irreducible intensity, but simply mention that there will be a further systematic error from the uncertainty in the amount of inert material.

Discussion

We have made a study of the irreducible background in the GLAST-LAT and have extended this, using simple re-scalings of the particle flux model and an estimate of the EGRET inert material audit, to estimate the irreducible background in the EGRET.

From this analysis, the importance of accurately determining the irreducible component is clear. To enable this, additional information derived from the MC truth has been added to the GLAST-LAT data sets.This includes the location that the incident particle intersects the surface of the LAT, the energy it deposits in the ACS tile it hits, and a count of the number of hits registering in the silicon strip tracker caused by particles other than electrons/positrons and photons. With this information the signature of an irreducible event becomes its direction within the FoV, its intersection point within the fiducial volume of the tracker, and the lack of any hits caused by anything other than electrons/positrons, and photons.

We have attempted to re-scale the results of our analysis to estimate the irreducible background in the EGRET. Our estimate is not exact given the considerable uncertainties associated with the charged particle flux model, the variation in the orbital altitude of CGRO over its mission, the amount of inert material in the EGRET, and the hadronic physics in the Monte Carlo model. However, it is a non-negligible fraction of current estimates of the EGRB.

The EGRB, as inferred from the EGRET data, is affected by large systematic errors. The data are strongly affected by the Galactic foreground subtraction, as well as uncertainties in the irreducible instrumental background. Taken together, these uncertainties imply that current estimates of the EGRB should realistically be viewed as upper limits only.

Acknowledgements

This work was done under US Department of Energy grant DE-FG02-04ER41286 and NASA contract PY-1775.

References

[1] Thompson, D. J., & Fichtel, C. E., *Astron. Astrophys.* **109**, 352 (1982).
[2] Sreekumar, P., et al., *ApJ* **494**, 523 (1998).
[3] Strong, A. W., Moskalenko, I. V., & Reimer, O., *ApJ* **613**, 956 (2004).
[4] Grenier, I. A., Casandjian, J. M., & Terrier, R., *Int. Cosmic Ray Conf.* **4**, 13 (2005).
[5] Ormes, J. F., et al., to appear in *Proc. 1st Int. GLAST Symp.* (Stanford, Feb. 5-8, 2007), eds. Ritz, S., Michelson, P. F., & Meegan, C., *AIP Conf. Proc.*, astro-ph/0704.0462.
[6] Kanbach, G., *private communication*.