The Preliminary Cosmic Diffuse γ-Ray Spectrum from 800 keV to 30 MeV Measured with COMPTEL

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Abstract

A preliminary Cosmic Diffuse γ-ray (CDG) spectrum from 800 keV to 30 MeV is presented, using the COMPTEL instrument, the Imaging Compton Telescope on-board the Compton Gamma Ray Observatory. The spectrum is constructed by measuring the count rate of γ rays at high galactic latitudes and extrapolating this rate to infinite geomagnetic cutoff rigidity to eliminate the prompt background. This rate is then corrected for the effects of delayed internal radioactivity. The preliminary measurements of the CDG flux in the 2–10 MeV range is 5–10 times lower than previous estimates. The 10–30 MeV flux is consistent with other measurements. The 'MeV bump', if present, is restricted to energies less than $\sim$ 2 MeV.

1 Introduction

The origin of the Cosmic Diffuse γ-radiation (CDG) is of fundamental importance. Previous measurements of the CDG radiation in the 0.5–30 MeV range have been made with satellite-borne spectrometers [2,3] and balloon-borne Compton-telescopes [4,6]. However, uncertainties in the CDG spectral shape and isotropy still exist. The COMPTEL instrument is ideally suited to measure the CDG flux with its large detection area, low background and wide field of view $\sim$ 1 sr. We report preliminary results of the COMPTEL measurements of the CDG energy spectrum from 0.8–30 MeV.

2 Instrumentation and Observation

A detailed description of the COMPTEL instrument can be found in Schönfelder *et al.* [5]. Each 'telescope' event is defined by a coincident signal in the upper (D1) and lower (D2) detectors with the proper time-of-flight and with no signal from the charged-particle shields. For each event, COMPTEL measures the following: energy deposit in D1 and D2, interaction position in D1 and D2, pulse-shape in D1 (to discriminate between γ-ray and neutron-induced events), time-of-flight (TOF) between D1 and D2 and absolute time of the event. The data used in this analysis are from observations of the Virgo

Figure 1: *(A) A typical Time-of-Flight spectrum. (B) Downward-Scattered count rate from 4–10 MeV versus the vertical cutoff rigidity.*

region ($l{\sim}270\,^\circ$, $b{\sim}65\,^\circ$) during the periods when the Earth was outside the COMPTEL field-of-view. The high latitude observations minimize any contribution from the Galaxy.

3 Data Analysis

The CDG radiation is considered to be isotropic in space and constant in time. Hence, we expect no unique spatial or temporal variations to separate the CDG radiation from the background radiation. The CDG measurement is made by first subtracting every instrumental background source, measured and calculated and then attributing the residual flux to the CDG radiation.

'Telescope' events are produced by cosmic (external) γ rays and background (internal) γ rays. The background γ rays are produced primarily by the interaction of cosmic rays and neutrons with the spacecraft material. The different γ-ray sources exhibit different TOF behavior. The TOF spectrum can be accurately described by a gaussian peak superimposed over a smooth continuum. A typical TOF spectrum is shown in Figure 1(A). The continuum is due to the background γ rays, while the peak is due to the cosmic and background γ rays produced in the upper part of the instrument (i.e. D1 platform). Background events are suppressed by rejecting events with very small and very large scatter-angles.

Neutrons interact inelastically through (n, n' γ) or (n, x γ) type reactions with the carbon in the D1 scintillators. When the n' or x produces a signal in D1 and the γ ray produces a signal in D2 a 'telescope' event is produced. Such background events are suppressed by selections on the pulse-shape signal in the D1-detector. Thermal neutron-capture by hydrogen produces 2.223 MeV photons that are not affected by selections on the pulse-shape.

The prompt background component ($\tau_{1/2} < 1$ minute) in the downward-scattered TOF peak can be calculated by ordering the fitted TOF peak rates by the local geomagnetic vertical cutoff rigidity. The typical behavior of the fitted rates with rigidity is shown in Figure 1(B). The fitted TOF peak event rates are extrapolated to infinite rigidity to estimate the steady-state event rate. The steady-state events are due to cosmic γ rays and quasi-steady-state background γ rays (i.e. beta decays). The 2.223 MeV line flux is prompt and rigidity dependent and hence its contribution is eliminated in the infinite rigidity extrapolation. The prompt background is seen to be negligible compared to the steady state background for energies below 2 MeV.

The scatter-angle selections eliminate most of the single-photon-scatter background events. Hence, the steady-state background γ rays are primarily due to multiple-photon cascade events from long-lived radioactive isotopes. These long-lived beta sources can often be identified by characteristic decay lines measured in the individual detector spectra. Above 4 MeV there is no evidence of any steady-state γ-ray background. Below 4 MeV, we have identified the ^{24}Na isotope to be the dominant source of quasi-steady background γ rays. ^{24}Na decays ($\tau_{1/2} \simeq 15$ hours) emit two simultaneous photons (1.368 and 2.754 MeV). When one photon hits D1 and the other hits D2 a 'telescope' event is registered. We measure directly the intensity of the ^{24}Na activity and through simulations predict the full telescope response. At least two other unidentified sources of steady state background are seen below 2 MeV. One of these is eliminated through tighter event selections on the scatter- angle while the other remains. We are working to identify and estimate these background sources.

4 Results and Discussion

The CDG flux (Figure 2) was determined by deconvolving the resultant count spectrum with the response due to a $E^{-2.3}$ power-law diffuse source, as determined by Monte Carlo simulations. Only upper-limits are plotted for energies < 2 MeV due to the presence of uncorrected background events. The errors are statistical and do not include systematic errors of the ^{24}Na cascade event corrections and effective area calculations. It is important to note that although the results are high latitude measurements, they include flux contributions from the Galactic diffuse γ-radiation ($< 5\%$ at 1 MeV to $< 50\%$ at 15 MeV) and γ-ray point sources in the field-of-view, specifically 3C 273 and 3C 279 ($< 1\%$ at 1 MeV to $< 4\%$ at 15 MeV).

The preliminary COMPTEL measurements of the CDG flux in the 2–10 MeV range are a factor of 5–10 lower than previous measurements. The 10–30 MeV flux is not in disagreement with the extrapolated power-laws from the lower [2] and higher [1] energies. The observed 2–30 MeV flux is compatible with the low energy extrapolated power-law spectrum [2]. COMPTEL measurements show no evidence of a 'MeV bump' for energies above ~ 2 MeV. We have plotted conservative upper-limits in the 0.8–1.8 MeV range due to the remaining uncorrected background. The 1.2–1.8 MeV flux must be re-

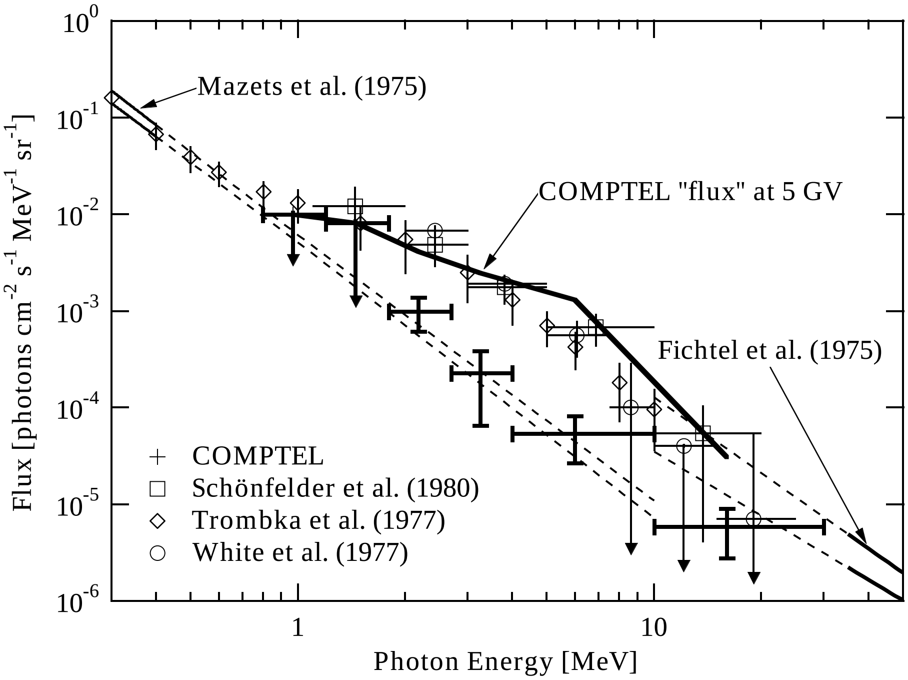

Figure 2: *The Cosmic Diffuse γ-ray spectrum. COMPTEL measurements are shown with other experiments [3,4,6] and the power-law extrapolations from lower [2] and higher [1] energies.*

duced by $\sim$ 75% and the 0.8–1.2 MeV flux by $\sim$ 30% if they are to lie on the extrapolated power-law. The 'MeV bump', if present, is confined to the 0.8–2 MeV energy range. Adding the CDG flux reported here to the 5 GV (typical balloon environment) rigidity dependent background measured with COMPTEL gives flux values (COMPTEL "flux" at 5 GV, Figure 2) that agree well with earlier measurements [3,4,6]. Hence, the ability to extrapolate COMPTEL data to infinite rigidity and correct for cosmic-ray and neutron-induced prompt background lowers the COMPTEL CDG flux values with respect to earlier measurements.

5 References

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