The Total Cosmic Diffuse Gamma-Ray Spectrum from 9 to 30 MeV Measured with COMPTEL

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Abstract. A preliminary COMPTEL Cosmic Diffuse Gamma-Ray (CDG) spectrum from 800 keV to 30 MeV was presented earlier at the 3rd Compton Symposium. The COMPTEL results represent the first significant detection of the CDG radiation in the 9 to 30 MeV range. Using high-latitude data from the first 5 years of the mission we have performed a new detailed measurement of the 9 to 30 MeV spectrum with finer energy binning. The new improved results are in good agreement with our previous estimates and are compatible with power-law extrapolations from higher energies. The measured 9–30 MeV spectra from the Virgo and South Galactic Pole observations are consistent with each other.

INTRODUCTION

One of the principle goals of the COMPTEL mission is the study of the Cosmic Diffuse Gamma (CDG) radiation. The COMPTEL instrument is ideally suited to measure the CDG radiation because of its large detection area, wide field-of-view and long exposure time. A *preliminary* COMPTEL CDG spectrum from 800 keV to 30 MeV has been presented earlier [1,2], see figure 1. The 2–10 MeV flux was lower than the pre-COMPTEL estimates [3–5] and showed no evidence for an MeV-bump, at least not at the levels claimed previously. The 2–30 MeV flux was compatible with power-law extrapolations from higher [6,7] and lower [8] energies. Only upper-limits were derived below $\sim$2 MeV due to the presence of uneliminated background. A word of caution is appropriate due to the *preliminary* nature of the earlier COMPTEL results [1,2].

We have continued our investigations since the earlier results [1,2]. We have analyzed more data, discovered additional radioactive isotopes [9,10], made improvements in our response calculations and begun investigations of the systematic errors. In this paper we present a new detailed measurement of the 9 to 30 MeV CDG spectrum with finer energy binning. We also present a comparison between the CDG spectra derived from Virgo and South Galactic Pole (SGP) observations. In this work the CDG flux refers to the total γ-ray flux from high galactic latitudes. A detailed description of the COMPTEL instrument can be found in the calibration paper [11].

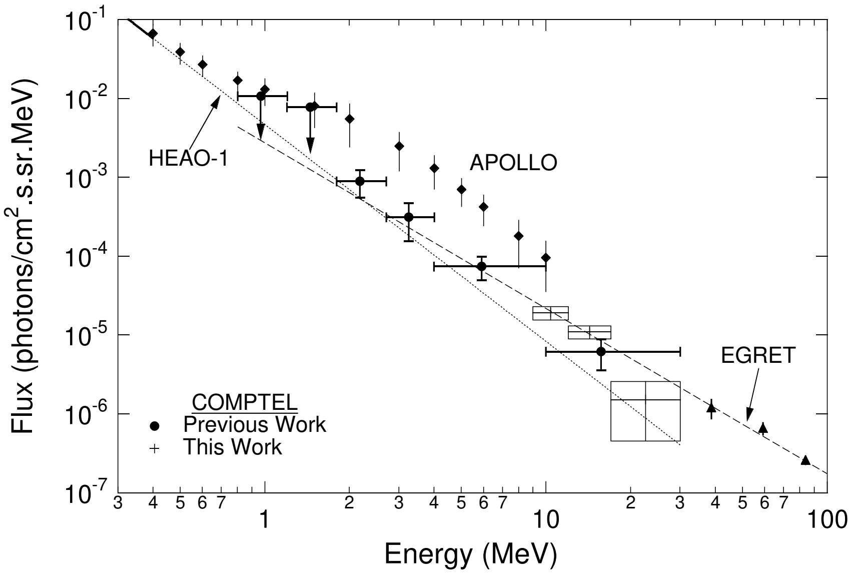

FIGURE 1. The latest (Virgo & SGP combined) 9–30 MeV CDG spectrum is shown together with the earlier COMPTEL results [1,2], the APOLLO measurements [5] and extrapolations from higher (EGRET) [6,7] and lower (HEAO-1) [8] energies.

OBSERVATIONS

In this work we have analyzed high-latitude observations from the first 5 years of the mission (~266 days of observations). Specifically, the data are all the Virgo observations ($b^{II} \sim 60^o$) and most observations towards the SGP ($b^{II} < -50^o$). The observed Virgo and SGP regions represent large areas towards the North and South Galactic Polar directions because of the wide COMPTEL field-of-view (~1.5 steradians) and the addition of data from adjacent pointings. The high-latitude observations minimize the γ ray contribution from the Galaxy. Also, the data are accumulated only during the periods when the Earth is outside the COMPTEL field-of-view. This eliminates any contamination from atmospheric γ rays.

DATA ANALYSIS

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

In general the instrumental background can be decomposed into 'prompt' and 'long-lived' components. The prompt background is instantaneously produced by proton and neutron interactions in the spacecraft. Hence, it refers to the component that modulates with the instantaneous local cosmic-ray flux. The prompt background is assumed to vary linearly with the veto-scalar rates. The veto-scalar-rates are trigger-rates of the charge-particle shields (veto-domes) surrounding the main detectors and used in anti-coincidence [11]. Thermal neutron capture by the hydrogen in the upper detector produces a prompt 2.223 MeV photon ($\tau_{1/2}$ ~100 μs) which is well described by a linear function in veto-rate, hence we expect all prompt background to behave linearly with the measured veto-rate.

The long-lived background events are due to de-excitation photons from activated radioactive isotopes with long half-lives ($\tau_{1/2}$ >30 sec). Their decay rate is not directly related to the instantaneous cosmic-ray flux because of the long half-lives. The energy spectrum is used to determine the absolute contribution of each of the long-lived background isotopes [1].

In constructing the CDG spectrum, the first step is to determine the scattered γ-ray (forward-peak) count rates by explicitly fitting the Time-of-Flight (ToF) spectrum [1]. However, there are some additional background events in the forward-peak that originate in the upper part of the detector (both prompt and long-lived) that need to be accounted for. For each bin in total energy, the ToF-fitted count rates are ordered with the instantaneous veto-rates to construct veto-growth-curves (VGCs). In the absence of long-lived background (above ~4.2 MeV), the VGCs are fitted with a straight line to determine the count rate at zero veto-rate. Under the assumption that zero veto-rate corresponds to zero cosmic ray flux, the extrapolated flux at zero veto-rate is the desired CDG count rate. Below ~4.2 MeV, there are numerous long-lived activation lines whose behaviors are not accurately described by a linear VGC. Each of the radioactive isotopes must be accounted for individually. This includes identifying the isotopes, estimating their activities and subtracting their contributions to the VGC prior to correcting the prompt background. This is part of on-going work and results will be reported in future publications.

The CDG flux is then determined by deconvolving the resultant CDG count spectrum with the computed instrument response. The instrument response is determined from Monte Carlo simulations of a diffuse isotropic power-law source propagated through a detailed COMPTEL mass model.

RESULTS

Here we present the improved 9 to 30 MeV CDG spectrum. The 9–30 MeV range represents one of the optimum COMPTEL energy bands due to the high S/N ratio (>30%). The S/N decreases below 9 MeV, due to the prompt background dominating the 4–9 MeV band and due to the addition of the long-lived background component below ∼4 MeV. Below 9 MeV, we presently feel the need for further investigations (especially of the systematic errors) before presenting the improved CDG spectrum.

The 9 to 30 MeV spectrum for the combined and separate Virgo and SGP observations are plotted in figures 1 and 2 respectively. The latest 9–30 MeV spectrum is consistent with our earlier results [1,2] and is compatible with power-law extrapolation from higher (EGRET) energies [6,7]. The COMPTEL results represent the first significant detection (7σ) of the 9–30 MeV CDG flux.

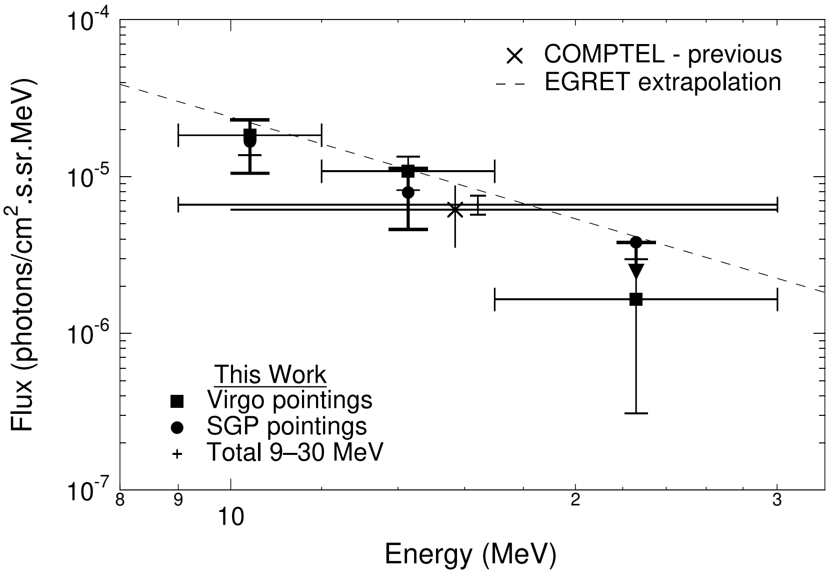

FIGURE 2. The CDG spectrum for the separate Virgo and SGP observations along with the total 9–30 MeV flux and the previous COMPTEL 10–30 MeV measurement [1].

The 9-30 MeV flux was computed for time- and pointing-separated subsets of the data (figure 3). They are consistent with a constant CDG flux (the null hypothesis of a constant CDG is rejected at the 68% level). Although the total 9–30 MeV flux from SGP is ∼ 31% lower than the flux from Virgo pointings (figure 3), the null hypothesis of a uniform CDG is rejected only at the 71% level. The CDG spectra from the Virgo and the SGP observations (figure 2 and 3) are consistent with one another, even though the COMPTEL fluxes have not been corrected for the Galactic or point-source contribution.

Only *statistical* errors are plotted in the COMPTEL CDG measurements (figures 1, 2 and 3). Three major sources of *systematic* errors are: 1) the ToF-fit function, since the ToF-continuum [1] can be modeled with a quadratic or an exponential function, 2) the choice of veto-dome rates to generate the VGCs, since there are four independent veto-domes and 3) the COMPTEL effective-area calculations. We compute a total systematic error of ~15% for the 9–30 MeV flux result.

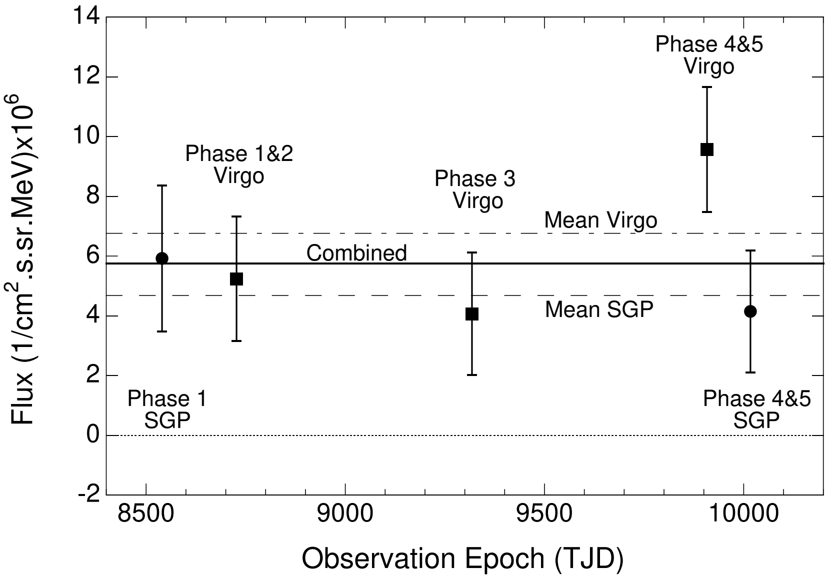

FIGURE 3. The time- and pointing-separated 9–30 MeV CDG flux together with the mean Virgo, mean SGP and combined 9–30 MeV flux.

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