MeV Measurements of Gamma-Ray Bursts by CGRO-COMPTEL

A Connors[1], W Collmar[3], W Hermsen[4], S Kappadath[1], R M Kippen[5], L Kuiper[4], M McConnell[1], F Pelaez[2,6], J M Ryan[1], V Schönfelder[3], M Varendorff[3], O R Williams[2], C Winkler[2], and C A Young[1]

[1]*Space Science Center, University of New Hamphsire, Durham NH, USA*
[2]*Astrophysics Division, ESTEC, NL-2200 AG Noordwijk, NL*
[3]*Max-Planck-Institut fur Extraterrestrische Physik, D-85740 Garching, FRG*
[4]*SRON-Utrecht, Sorbonnelaan 2, NL-3584 Utrecht, NL*
[5]*C.S.P.A.R., University of Alabama in Huntsville, Huntsville AL, USA*
[6]*now at USRA, NASA/GSFC, Greenbelt, MD, USA*

Abstract. Since the launch of the Compton Gamma–Ray Observatory in April 1991, the imaging COMPTEL telescope has accumulated positions and 0.75–30 MeV spectra of more than thirty gamma-ray bursts within its $\sim \pi$ sr field of view. In an ongoing collaboration with BACODINE/GCN, COMPTEL positions are relayed to a global network of multiwavelength observers in near real time ($\sim$ 10 minutes). Here we summarize the MeV properties, and present spatial, spectral, and temporal data for the latest of these events, GRB 970807. In concurrence with earlier SMM and current BATSE, OSSE, and EGRET measurements, COMPTEL data add to the accumulating evidence that GRB spectra do seem to have a characteristic shape: a peak (in $E^2F(E)$) around several hundred keV; and a power law above (spectral index 1.5-3.5) extending beyond the COMPTEL energy range.

Introduction

The COMPTEL experiment on board the Compton Gamma-Ray Observatory (CGRO) has accumulated a sample of 33 gamma–ray bursts in its $\sim \pi$ sr field of view since its launch in April 1991. COMPTEL images these events in telescope or double–scatter mode (0.75–30 MeV); and measures burst spectra and light–curves both in telescope mode and in its burst, or spectroscopic single detector mode (0.1-11 MeV) [1]. These are preferentially bursts with

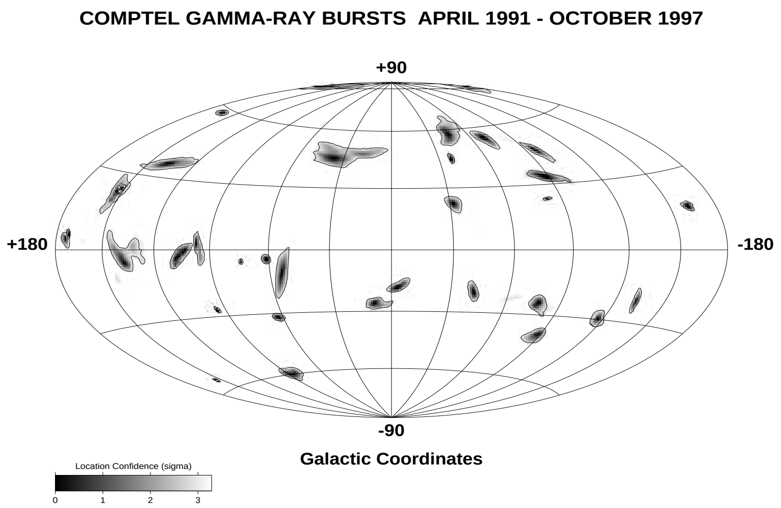

FIGURE 1. All-sky map of COMPTEL positions, in Galactic coordinates.

bright MeV emission. Here we describe some global properties of this sample, and report the details of the latest burst.

Locations

In Figure 1 we display an all–sky map of all COMPTEL bursts to date. COMPTEL relies on the BATSE trigger for preliminary start–time and position. We then localize each event that falls within $\sim 65°$ of telescope zenith, using a maximum–likelihood method [2], with on average $\sim$1.13° statistical and $\sim$0.5° systematic accuracy. The grayscale indicates confidence level, with the contours outlining the 3σ statistical limits, so the brightest bursts are actually the smallest. A detailed study of bursts during the first four years has so far confirmed that this map is consistent with isotropy [2].

Spectra

In Figure 2 we display a histogram of the photon power–law indices from fits to the 0.75–30 MeV telescope–mode spectra in the COMPTEL sample. Data from the first four years have shown that 0.75–30 MeV spectra tend to be best represented by a power–law, rather than by a form with more curvature [3,4]. Since then, we have added spectra from three more bursts. These are also consistent with power–law models, both in the 0.75–30 MeV telescope data and the $\sim$0.3-2 MeV burst mode data (GRBs 960808 and 961212: [5]; GRB 970807, this work). The mean burst spectrum in our energy range can be represented as:

$$< N_E(E) >= [0.91 \pm 1.9](E/\mathrm{MeV})^{-[2.43 \pm 0.56]} \text{ photons cm}^{-2}\mathrm{s}^{-1}\mathrm{MeV}^{-1}. \quad (1)$$

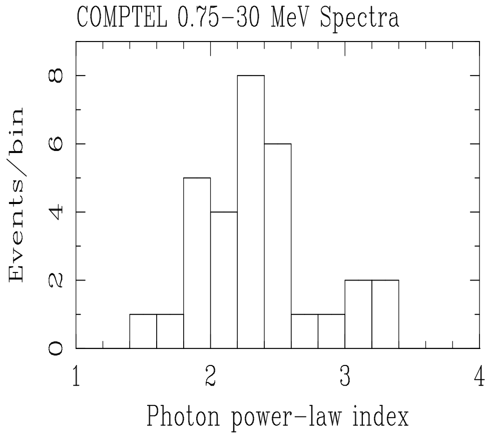

FIGURE 2. Histogram of photon power–law indices for COMPTEL bursts.

Here the uncertainties are from the square root of the sample variance, summed in quadrature with the mean statistical error, and so indicate the wide variety of burst spectra measured by COMPTEL. This power–law shape >1 MeV is consistent both with earlier results from SMM [10] and higher energy measurements from CGRO–EGRET, when they are available [11–13]. For a few bright bursts, COMPTEL has measured curvature in its energy range, consistent with a peak in νF_ν of $\sim$ 1 MeV rather than hundreds of keV [6–9]. No significant line features have been detected in any individual burst. This, together with lower energy OSSE and BATSE results, [14–16], shows that gamma-ray burst spectra seem to have a canonical shape: a peak in νF_ν space typically centered around $\sim$ hundreds of keV (but with a range of about a factor of 5 in either direction); at higher energies, a power-law tail extending out as far as it is measureable, sometimes to 100 MeV or more; and indications of flattening or turnovers at X–ray energies [17].

Motivated by findings at lower energies of two classes of burst emission based on hardness [20,21] we tested the spectral index histogram for evidence of two populations: one with ($< \alpha >= 2.2$); and one softer ($< \alpha_2 >= 3.2$). However the drop in 2*log-likelihood was only 7.5 for an addition of 3 degrees of freedom, so this was not significant.

The dramatic detections of optical counterparts for two recent bright bursts, one associated with a galaxy [18] and one consistent with a redshift $z \sim 0.83$ [19], have focused attention on cosmological "fireball" models, and in particular on relativistic shocks. In these scenarios, the canonical break at several hundred keV is attributed either to inverse Compton, or synchrotron processes [22–24]. However others emphasize the difficulties of realistically producing gamma–rays with complex time–histories this way, one alternative being pulsar–like emission from the debris of a collapsed neutron star [25,26]. As these various models mature, the variability, break energy and power–law high energy emission remain strong constraints on the physics of realistic emission mechanisms.

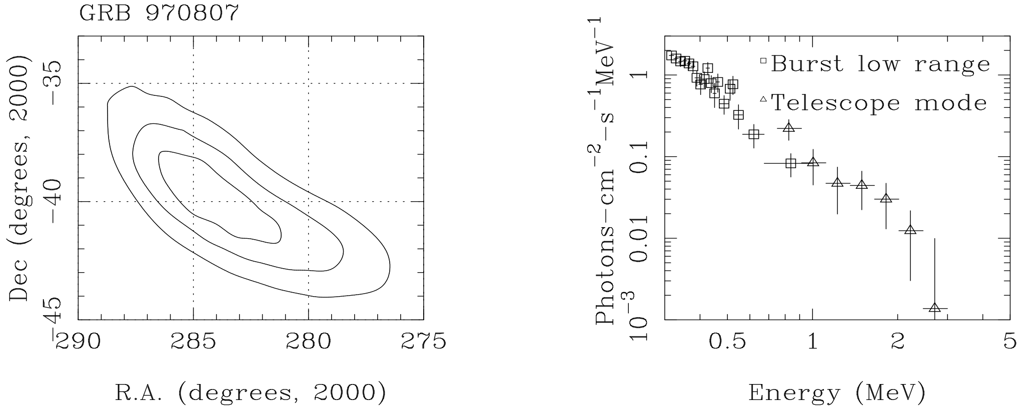

FIGURE 3. COMPTEL 1, 2, and 3σ position contours (left) and low-range burst detector plus telescope spectra (right) for GRB 970807.

Rapid Burst Response

In a joint project with BACODINE/GCN, COMPTEL automatically processes any burst (defined by a BATSE burst trigger) within 65° of telescope zenith. If the burst is localized, an initial ~1–2° position can be sent to a world–wide network of ground–based observers within ~7.5 minutes of burst onset. These error boxes are considerably larger than those available from BeppoSAX or RXTE, but the response time is minutes rather than hours. Our ground–based observers include several with large field of view Schmidt cameras, capable of rapid response [27]. Out of, on average, ~70 BATSE triggers per year in our field of view, we successfully localize ~5. We are now upgrading the automated burst response, both to at least halve the response time, and to make the system more robust.

The Most Recent COMPTEL Telescope Burst

The most recent burst (GRB 970807) was quite soft, so intervention by the duty scientists was necessary. This position did not get broadcast until ~45 minutes after burst onset. On the left in Figure 3, we display the (statistical) burst location contours. The COMPTEL 2σ contours overlap the BATSE and IPN positions. On the right are the best–fit telescope mode plus low–range burst–mode spectra, assuming a 48 s integration time. The best fit to the burst–mode was $N_E(E) \sim (0.05 \pm 0.01)E^{-3.2\pm0.2}$, while for the telescope data it was $N_E(E) \sim (0.1 \pm 0.03)E^{-3.3\pm1.1}$ Although it is soft, it is consistent with the range of spectra previously measured by COMPTEL.

Conclusion

COMPTEL continues to measure MeV spectra and locations of bursts in its field of view, at an average rate of $\sim$5 per year. We are in the process of upgrading our rapid response, bringing with it the possibility, for particularly well-suited bursts, of broadcasting $\sim$1–2° localizations while the intense portion of the burst is still underway.

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