IL NUOVO CIMENTO Vol. 28 C, N. 4-5 Luglio-Ottobre 2005
DOI 10.1393/ncc/i2005-10165-6

The MeV spectra of gamma-ray bursts measured with COMPTEL(*)

A. S. Hoover(1), R. M. Kippen(1) and M. L. McConnell(2)

(1) *Los Alamos National Laboratory - Los Alamos, NM 87545, USA*
(2) *University of New Hampshire - Durham, NH 03824, USA*

(ricevuto il 23 Maggio 2005; pubblicato online il 28 Ottobre 2005)

Summary. — The past decade has produced a wealth of observational data on the energy spectra of prompt emission from gamma-ray bursts. Most of the data cover the energy range from a few to several hundred keV. One set of higher energy observations comes from the Imaging Compton Telescope COMPTEL on the Compton Observatory, which measured in the energy range from 0.75 to 30 MeV. We analyzed the full 9.2 years COMPTEL data to reveal the significant detection of 44 gamma-ray bursts. We present preliminary results obtained in the process of preparing a final catalog of the spectral analysis of these events. In addition, we compare the COMPTEL spectra to simultaneous BATSE measurements for purposes of cross-calibration.

PACS `98.70.Rz` – γ-ray sources; γ-ray bursts.
PACS `01.30.Cc` – Conference proceedings.

1. – Introduction

The Compton Gamma-Ray Observatory (CGRO) was launched in April 1991, and made observations until June, 2000. CGRO was comprised of four detector subsytems, including the Burst and Transient Source Experiment (BATSE) and the Compton Telescope (COMPTEL). BATSE was the all-sky burst monitor, and covered the 20 keV–1 MeV range. COMPTEL consisted of a layer of liquid-scintillator scattering detectors and a second layer of NaI absorbing detectors, and covered the 0.8–30 MeV range. When COMPTEL was operated in “telescope mode”, gamma-rays Compton scattered in the first layer and were completely absorbed in the second layer. This paper discusses results obtained from telescope mode observations, where the use of imaging information leads to nearly background-free data, and a strongly diagonal instrument response function.

2. – COMPTEL Gamma-ray Bursts

COMPTEL observed 44 significant gamma-ray bursts during its nine year lifetime. Bursts were identified by searching for excess numbers of measured photons at the times

---

(*) Paper presented at the “4th Workshop on Gamma-Ray Burst in the Afterglow Era”, Rome, October 18-22, 2004.

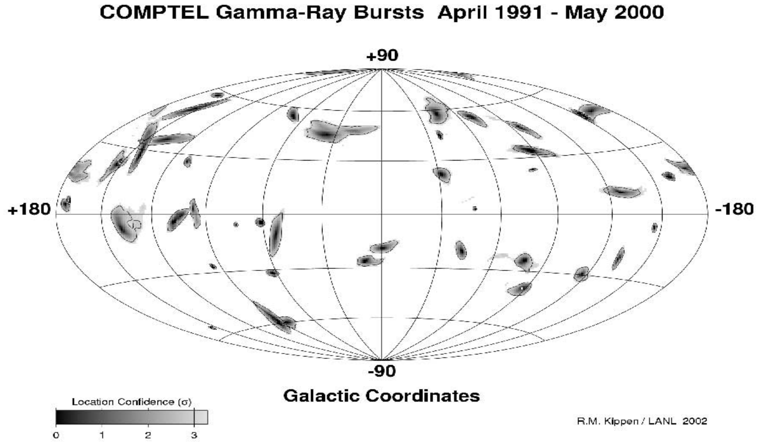

Fig. 1. – Statistical location contours in galactic coordinates for the 44 observed COMPTEL bursts.

of known BATSE bursts using a maximum-likelihood imaging technique [1]. From the BATSE catalog of 2703 bursts, 828 were within the COMPTEL field of view (direction angle $< 65^o$), 633 had COMPTEL data available with no gaps, and 44 had a significant point source in the image with a likelihood ratio > 20 (formally corresponding to 3.8σ detection significance). Figure 1 shows the COMPTEL statistical (1σ, 2σ, and 3σ) location contours in Galactic coordinates for the 44 observed bursts. Within statistical uncertainties, there are no significant deviations from large-scale isotropy of burst locations in either galactic or celestial coordinates [2].

Figures 2 and 3 show how the 44 COMPTEL bursts fit into the larger sample of BATSE bursts. Figure 2 plots burst hardness *versus* duration, and fig. 3 plots burst hardness *versus* fluence. The COMPTEL events tend to have large fluence and populate the harder region of long bursts. These selection biases are expected because the COMPTEL burst detection sensitivity depends strongly on the total number of $> 700\,\text{keV}$ photons.

3. – COMPTEL/BATSE joint fit spectral analysis

It is possible that our understanding of the high-energy behavior of burst spectra obtained using only BATSE data could be improved by considering a joint analysis of the low-energy BATSE data combined with the high-energy COMPTEL data. BATSE and COMPTEL data were combined for the 44 bursts and jointly fitted with Band's GRB function [3]. In addition to the four Band function parameters, a fifth parameter was used in the fit to account for an effective area correction between the BATSE and COMPTEL detectors. Seven of the bursts could not be fit without imposing a lower limit on the β parameter, and these bursts were not used in the analysis, leaving us with a sample of 37 bursts. All results are time-averaged over the full burst duration, using 16-channel continuous BATSE LAD data and telescope mode binned COMPTEL data. An example of how the COMPTEL data complement the BATSE data at higher energies is shown for GRB 990728 in fig. 4. Figure 5 shows the time history of GRB 990728 as measured jointly by BATSE and COMPTEL. For each of the 37 bursts, the data were fit once using BATSE data alone, and again using the joint BATSE plus COMPTEL data. We are interested to see if the addition of the high-energy COMPTEL data will significantly change the results obtained from the low-energy BATSE data,

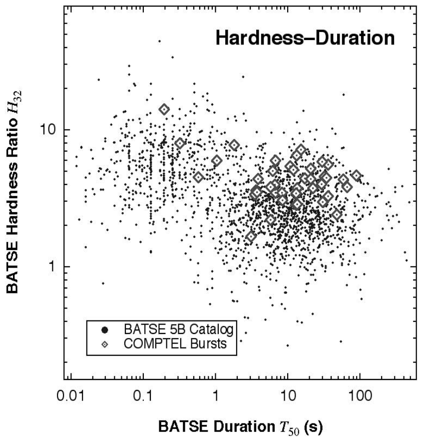

Fig. 2

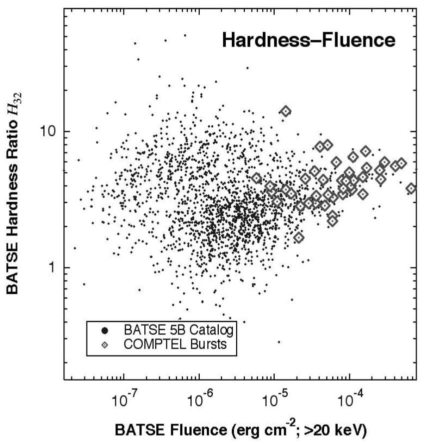

Fig. 3

Fig. 2. – Hardness *versus* duration for BATSE and COMPTEL bursts.

Fig. 3. – Hardness *versus* fluence for BATSE and COMPTEL bursts.

particularly the β parameter which describes the high-energy tail. In the case of the α parameter, there was no change in the distribution when COMPTEL data was added to BATSE data, as expected. The β (fig. 6) and E_{peak} distributions changed slightly, and the χ^2/DOF values for the fits improved. A Kolmogorov-Smirnov (KS) statistical test indicates that the significance level for the null hypothesis that the BATSE-only and BATSE+COMPTEL data sets are drawn from the same distribution is 1.0 for α and

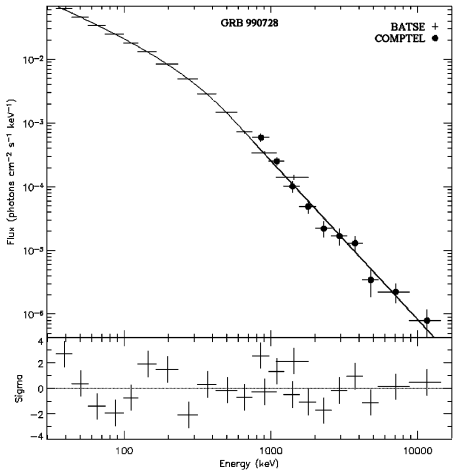

Fig. 4

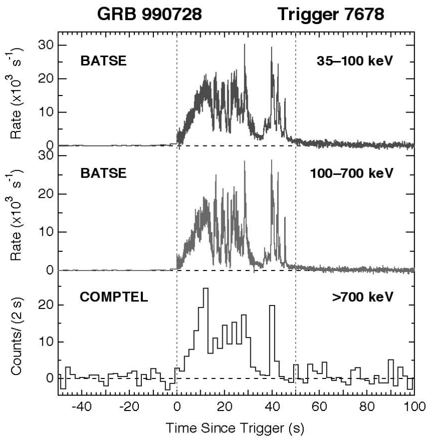

Fig. 5

Fig. 4. – GRB 990728 joint fit using BATSE and COMPTEL data.

Fig. 5. – Time history of GRB 990728 as measured jointly by BATSE and COMPTEL (dashed lines indicate the interval used for spectral fitting).

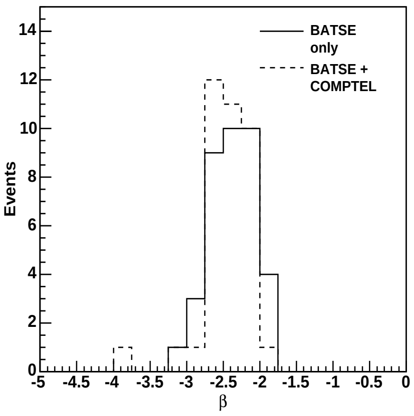

Fig. 6

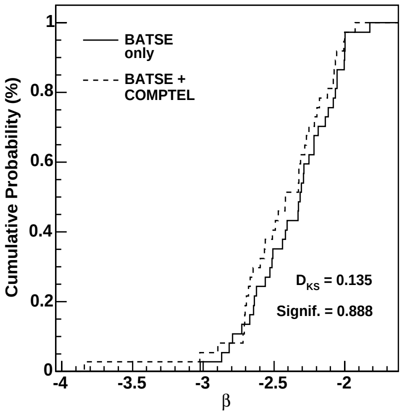

Fig. 7

Fig. 6. – β parameter for BATSE data only fit (line) and BATSE+COMPTEL data joint fit (dash).

Fig. 7. – Cumulative probability distribution for the β parameter. D_{KS} is the KS test statistic.

E_{peak}, and 0.89 for β (fig. 7). Since β describes the high-energy tail, it seems reasonable that addition of the high-energy COMPTEL data might change the results obtained from the BATSE-only data, although it appears the change is not statistically significant. An identical analysis was performed using a broken power law spectrum instead of the Band function, and the results were consistent, giving a significance level of 1.0 for the low-energy index, 1.0 for the break energy, and 0.81 for the high-energy index.

4. – Conclusions

The COMPTEL experiment detected 44 gamma-ray bursts during its operational lifetime. It is found that COMPTEL bursts tend to occupy the large hardness ratio/high fluence regions of the BATSE burst dataspace. The BATSE spectral data were extended to higher energies by combining them with the corresponding COMPTEL data for 37 bursts. Kolmogorov-Smirnov tests show that the α, β, and E_{peak} parameters had no significant change due to the addition of COMPTEL data. These results indicate that for this sample of 37 detected COMPTEL bursts, BATSE data alone provide a fair representation of the MeV spectral properties. Future work to strengthen this argument includes examining whether BATSE spectral data are consistent with the more numerous COMPTEL non-detections.

* * *

This work was supported in part through a grant from the NASA Astrophysics Data Program.

REFERENCES

[1] deBoer H. *et al.*, *Data Analysis in Astronomy - IV*, **59** (1992) 241.
[2] Kippen R. M. *et al.*, *ApJ*, **492** (1998) 246.
[3] Band D. *et al.*, *ApJ*, **413** (1993) 281.