GAMMA-RAY BURST STUDIES BY COMPTEL DURING ITS FIRST YEAR OF OPERATION

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ABSTRACT

During the first year of Compton GRO operations, more than 20 cosmic gamma-ray bursts - detected by the BATSE instrument - occurred inside the 1 sr field of view of the imaging gamma-ray telescope COMPTEL[1]. Using COMPTEL's primary mode of operation (the telescope mode) direct images (with ~ 1° GRB location accuracy) and event spectra (0.7 MeV - 30 MeV) with spectral resolution better than 10% FWHM have been obtained. In its secondary mode of burst operations, COMPTEL has recorded time resolved spectra (0.1 MeV - 10 MeV) from its large NaI detectors. This paper summarises the results on cosmic GRB sources obtained by COMPTEL during its first year of operation.

INSTRUMENT AND OPERATING MODES

Gamma-ray bursts can be observed by COMPTEL[1] using two independent operating modes, the "Double Scatter Mode" and the "Single Detector Mode". These modes are described in detail elsewhere[2,3]. Summarizing, the "Double Scatter Mode", which is the normal imaging mode, is used to obtain direct locations of gamma-ray bursts within a field of view of ~ 1 sr and to obtain telescope spectra with an energy resolution of better than 10% FWHM. The operating range in this mode is 0.7 MeV to 30 MeV.

In the "Single Detector Mode"(see[2,3] for detailed description) COMPTEL uses 2 of the lower 14 NaI detectors to accumulate burst spectra upon receipt of a trigger signal from BATSE. The detectors are, in principle, 4π sensitive. However, their on-axis field of view is largely obstructed by the upper D1 detector array. At larger zenith angles (> 45°), obstruction is due to other CGRO instruments, electronics boxes, spacecraft structure etc. The two detectors measure different energy regions: a low range (apx. 0.1 MeV - 1.1 MeV, binwidth ~ 9.8 keV) and a high range (apx. 1 MeV - 10 MeV, binwidth ~ 84.7 keV).

GAMMA-RAY BURST OBSERVATIONS

During its first year of operation, beginning on 25 April 1991, COMPTEL received in total 1358 trigger messages from BATSE identifying 305 cosmic gamma-ray bursts, 432 solar flares, 456 particle events, 81 triggers on SAA entry/exit, and 84 others. Out of the 305 isotropically distributed[4] cosmic gamma-ray bursts, 29 events occurred inside or close to the COMPTEL field-of-view and they are therefore candidate objects for direct imaging and spectral analysis (Table I). The data include the strong bursts GRB 910425, GRB 910503, GRB 910601 and GRB 910814. Six bursts could not be observed due to instrument switch-off and telemetry gaps. The low range burst detector D2-14 was out of commission from 25 May 1991 until 13 May 1992.

Bursts detected by COMPTEL				
BATSE	Burst ID		COMPTEL	
Trigger	Date	Seconds	gal. long.	gal. lat.
109	910425	2268	228.1	-21.1
143	910503	25455	172.6	5.2
249	910601	69737	74.4	-5.0
298	910609	2909		
451	910627	16160	314.2	58.4
503	910709	41604		
537	910714	74779		
678	910814	69275	93.7	-25.9
692	910818	49487		
856	911002	31974		
1051	911113	49306		
1073	911117	16543		
1085	911118	68260	271.4	33.1
1125	911127	83316		
1154	911209	3410		
1197	911219	79040		
1211	911224	21946		
1221	911225	61720		
1297	920113	75141		
1298	920114	62628		
1318	920127	77219		
1365	920207	6263		
1551	920413	82534		

Bursts not detected by COMPTEL			
BATSE	Burst ID		COMPTEL
Trigger	Date	Seconds	Status
829	910927	84415	COMPTEL off
1469	920308	63226	Bit error gaps
1493	920318	54420	Bit error gaps
1510	920321	84902	Telemetry gap
1517	920324	75269	Telemetry gap
1550	920412	72126	Telemetry gap

Table I. Journal of gamma-ray burst observations by COMPTEL during one year following 25 April 1991.

All bursts listed in Table I are in the process of being analysed, i.e. for the stronger bursts, locations by direct imaging and telescope spectra in the 0.7 MeV to 30 MeV range, as well as single detector spectra up to 10 MeV are obtained. Some of the bursts listed in Table I are either too weak or too soft for direct imaging. The final results of the spectral analysis for all of these bursts will be given in a separate paper in preparation. Preliminary results have been reported earlier [3,5,6,7,8]. Here we concentrate on updated results obtained for GRB 910503, GRB 910601 and GRB 910814.

LOCATIONS

Locations of strong gamma-ray bursts (S ($>$ 1 MeV) $> 10^{-6}$ erg cm^{-2}) can be obtained using the Maximum Likelihood and the Maximum Entropy methods. The former is used in this paper because it yields accurate error estimates on the source location. The locations of 6 bursts are listed in Table I. Location maps of two bursts are shown in Figure 1 together with a triangulation annulus using independent timing information from the ULYSSES spacecraft. All bursts localized by COMPTEL have a source origin consistent with the position derived from the independent triangulation method. The statistical error on source location depends on the burst fluence and the inclination angle (relative to the instrument line of sight). A strong burst like GRB 910503 (S (> 1 MeV) = 1.2 × 10^{-4} erg cm^{-2}) has an error radius of 1° for the 2σ confidence interval, whereas the weaker event GRB 910425 (with a flux 3 times less than GRB 910503) has a 2σ error radius of $\sim 3°$. Systematic errors are estimated to be of the order of 0.5°.

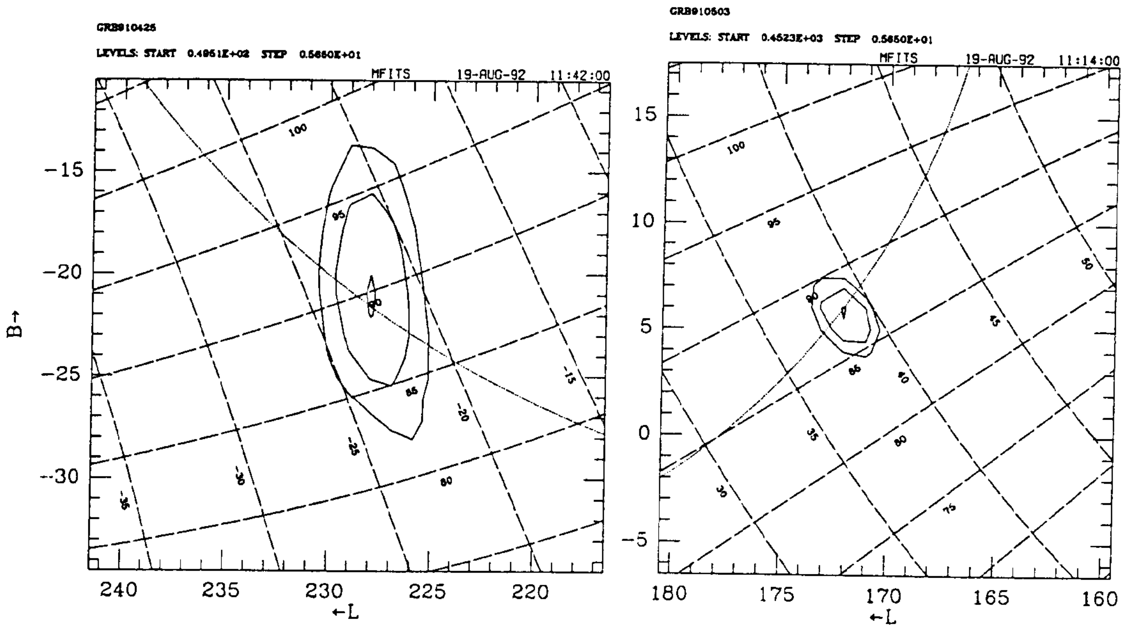

Figure 1. Gamma-ray burst locations obtained by COMPTEL using the Maximum Likelihood method for GRB 910425 (left panel) and GRB 910503 (right panel). A (R.A., Decl.) grid for epoch 2000.0 is shown. Inner contour: most likely source position; two outer contours: 2σ and 3σ confidence intervals; dotted line: triangulation annulus using ULYSSES timing information.

SPECTRA

We obtain gamma-ray burst spectra using telescope event data ("Double Scatter Mode") and single detector data (" Single Detector Mode"). In fact, theses constitute two independent instruments using different response information and deconvolution techniques. Photon spectra have been constructed using the traditional method by assuming a model photon spectrum which is folded by the response after which comparison is performed with the observed data in count space. Best fit results are obtained using χ^2 or similar statistics. Detailed results obtained on all bursts (Table I) will be published in a forthcoming paper. For the purpose of this workshop it is of benefit to compare our results with those from other CGRO experiments. We report therefore updated spectral analysis results for GRB 910503, GRB 910601 and GRB 910814.

GRB 910503: One of the strongest bursts observed so far resulting in significant deadtime effects in the COMPTEL event data stream. So far it is the only event with a significant spectral hard-to-soft evolution. Preliminary results for this event are published elsewhere[9]. Figure 2 shows a spectrum accumulated during a 2-second period starting 1 second after the onset of the burst. The COMPTEL best fit photon spectrum can be described by a hard single power-law $a{\cdot}E^{\alpha} = (7.92 \pm 0.42){\cdot}\,(E/\mathrm{MeV})^{(-2.03\pm0.08)}$ ph/(cm^2 s MeV). Comparison with EGRET[10] and BATSE[11] results shows good agreement across the CGRO instruments in both normalization and slope. The EGRET photon spectrum has been determined using data from 1 MeV up to 150 MeV[10].

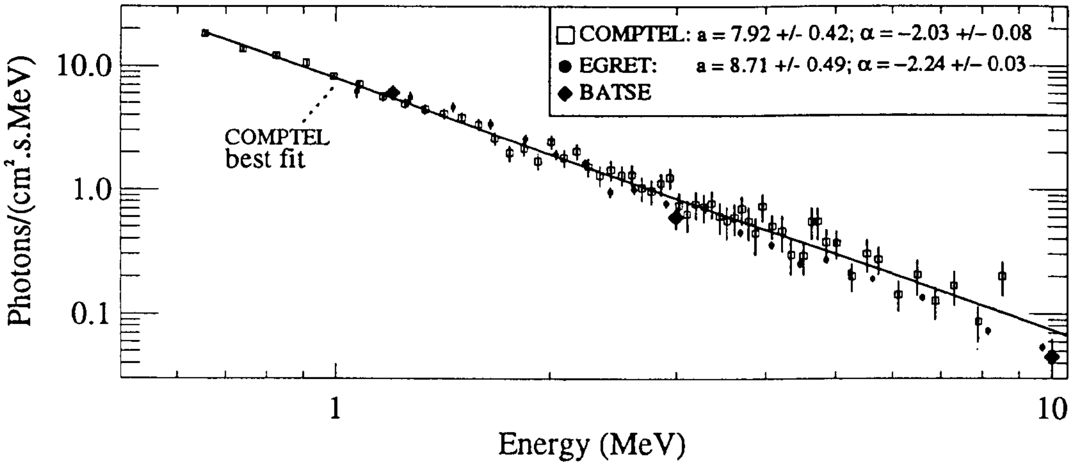

Figure 2. Photon spectrum of GRB 910503 during 2 seconds starting one second after the BATSE trigger.

We note that at the end of the first pulse of this event (i.e. during a 6 second time interval starting 3 seconds after burst onset) we have to reject a single power-law for the input spectrum and favour a broken power-law similar to findings by EGRET[10].

GRB 910601: We have performed a spectral analysis covering the full burst duration (33 s). The data can be described by a single power-law with, however, a much softer spectral index (α = - 2.82) compared to GRB 910503. No spectral (hard-to-soft) evolution has been found. The photon spectrum which was derived using the high range COMPTEL burst detector data is shown in Figure 3, together with the photon spectrum obtained from COMPTEL telescope double scatter events. The comparison shows excellent agreement between these two datasets which have been derived using different deconvolution techniques and response matrices.

GRB 910814: Using single detector data, spectral analysis of this event which is characterized by a sharp rise followed by an exponential decay with a total duration of about 40 seconds indicates, that the individual burst spectra and time integrated spectra cannot be fitted by single power-law models. A broken power-law provides acceptable fit results. Break energies are found between 1 MeV and 3 MeV with power-law indices α in the range of - 1 to - 2 below, and - 2.5 to - 3.5 above the break energy. Independent spectral analysis of the COMPTEL telescope data accumulated over the full burst duration confirm both the single detector results and BATSE observations published recently[13]. In addition, EGRET data analysis[14] shows a clear break at around 2 MeV. The break at high energies may indicate the presence of photon annihilation processes, e.g. due to interaction of single photons with strong magnetic fields[12].

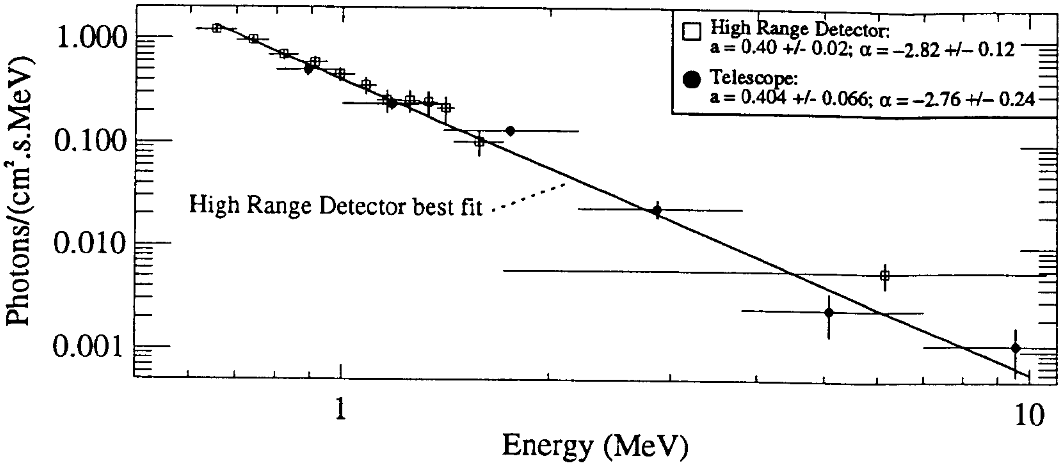

Figure 3. GRB 910601 photon spectrum of (full burst, 33 s).

CONCLUSIONS

COMPTEL can locate gamma-ray bursts (by direct imaging) to an accuracy of typically 1° (error radius of the statistical 2σ confidence interval) for 10^{-4} erg cm^{-2} bursts with correspondingly larger radii for weaker events. Systematic errors are estimated to be of the order of 0.5°. All locations derived so far are fully consistent with independent methods using triangulation with other spacecraft. Spectral analysis of COMPTEL burst data shows that many bursts have photon spectra which can be described by single power-laws with slopes in the range of $\alpha \sim -1.8$ to ~ -3. Only GRB 910503 shows significant spectral evolution (hard-to-soft). GRB 910814 and the last 6 s of the first main pulse (9 s) of GRB 910503 deviate from single power-law and need a broken power-law model. Comparison of data from EGRET and BATSE with the COMPTEL burst detector and the COMPTEL telescope shows a good agreement across the instruments using different deconvolution methods and response matrices. Up to now we have not detected any lines, periodicities or any pre- or post-cursors in the COMPTEL data.

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