COMPTEL Observation of GRB 930131

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ABSTRACT

On 1993 January 31 at 18:57:11 UT, COMPTEL detected high energy (0.7-30 MeV) emission from the intense cosmic gamma-ray burst GRB 930131. Upon rapid notification of this burst by the BATSE experiment on CGRO, COMPTEL's gamma-ray imaging capability was utilized to locate the source of emission to within ~2 degrees sooner than seven hours after the start of the burst. This early source position was later found to be consistent with independent BATSE and CGRO-EGRET locations as well as triangulation between BATSE and Ulysses. GRB 930131 is the most successful application to date of a rapid response program established between BATSE and COMPTEL to quickly and accurately locate gamma-ray bursts. The duration of this burst in COMPTEL's energy range was short; consisting of two separate peaks both occurring within a ~1 second interval. Spectral analysis of the limited number of COMPTEL telescope events indicate hard, power-law emission extending to greater than 10 MeV.

1. INTRODUCTION

The Imaging Compton Telescope (COMPTEL), one of four complementary experiments on the *Compton Gamma Ray Observatory,* covers the energy range 0.75-30 MeV within a nominal field of view of about 1 steradian. COMPTEL's good sensitivity over this relatively large field allows it to image gamma-rays from several cosmic gamma-ray bursts per year. In observing bursts, COMPTEL gathers data in two separate modes of operation. In the normal "Double Scatter" or "Telescope" mode, COMPTEL directly images gamma-rays with a location accuracy of better than 1 degree and spectral resolution better than 10% FWHM. A "Single Detector" or "Burst" mode is also employed which acquires time resolved energy spectra from two of the fourteen lower NaI detectors. A detailed description of the instrument and its operating modes may be found in Schönfelder *et al.* (1984, 1993). Here we present results from "Telescope" mode observations of the intense, short duration gamma-ray burst GRB 930131. This event had the highest peak flux of any burst detected thus far by BATSE (BATSE trigger number 2151) making it a truly unique event. GRB 930131 is a good candidate for counterpart searches since it was detected and located by at least four different instruments, including the independent COMPTEL localization.

2. OBSERVED DATA AND RESULTS

2.1 Rapid Response

COMPTEL has no on board transient detection system, so we rely on the BATSE experiment for burst notification. An accelerated burst notification and response scheme has been developed which uses limited real-time BATSE data to quickly identify bursts within the COMPTEL field of view. Such rapid notification allows timely COMPTEL response to strong bursts. The details of this "Rapid Response" plan are described by Kippen *et al.* (1992). The goal of this plan is to provide accurate gamma-ray burst error boxes in a timely manner to multiwavelength observers in order to search for lingering counterparts. The rapid response scheme was successfully applied to GRB 930131, producing a preliminary COMPTEL-source-location within 6 1/2 hours of the initial burst detection by BATSE. Follow-up observations were made at several multiwavelength observatories; the soonest being within 11 hours of the burst. These observations are reviewed by Schaefer *et al.* (1993). Although several interesting objects were identified, no obvious fading counterparts were detected.

2.2 Time History

The lightcurve of GRB 930131 in selected time-tagged COMPTEL telescope events is shown in Fig. 1. The events are combined into 50 ms bins using the BATSE burst trigger time as a reference. The rapid onset and short duration of the burst result in a high signal to noise ratio which has allowed us to improve detection efficiency by relaxing standard energy deposit and time of flight windows normally applied to reduce background. Only loose time of flight and pulse shape restrictions have been applied to the data in this lightcurve. The resulting events span from below 0.7 MeV to a maximum recorded energy of near 30 MeV. Two significant features are clearly evident in the COMPTEL lightcurve: a relatively small pulse of ~300 ms duration starting ~100 ms *before* the BATSE trigger time, followed nearly 800 ms later by a seemingly more intense pulse lasting for ~100 ms. Finer binning reveals that the second feature is narrower than 40 ms at peak emission. No other *obvious* features are seen in the data, however we are currently investigating the possibility of extended emission beyond the intense features. The limitations of COMPTEL's on-board electronics produce severe dead time for the intense portions of this burst. We have used on-board rate counters in two of the lower detectors to estimate the relative burst flux (> [~400] keV) at different times during the burst -- thus estimating the relative dead time effects between the two emission peaks. The dashed line in Fig. 1 shows that the first peak is actually more intense than the rest of the burst, and it is the higher dead time during this period making the first peak appear less intense than the second.

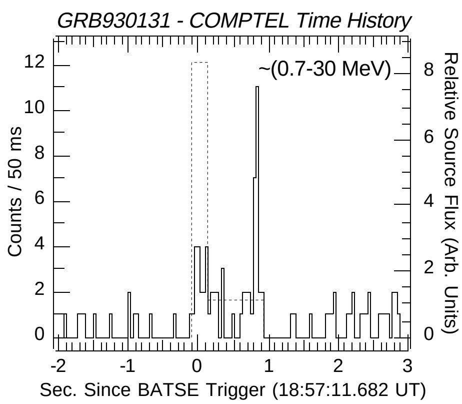
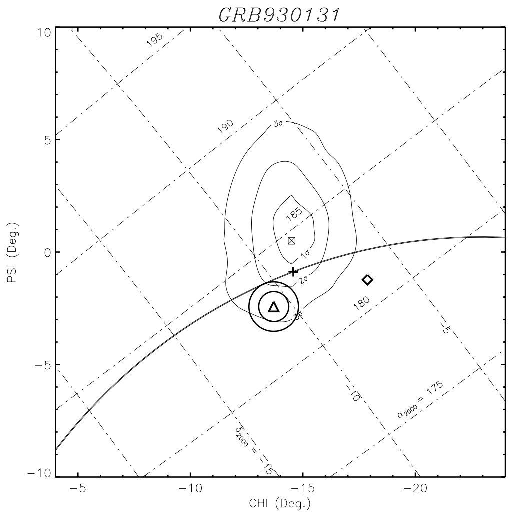


Fig. 1: The time history of GRB 930131 as observed by COMPTEL. Solid line: observed events; dashed line: estimate of the relative dead-time for the two main emission regions.

2.3 Image and Location

Several different imaging techniques are currently used with COMPTEL data. We employ a maximum-likelihood technique which places quantitative constraints on the derived source position and significance. The maximum-likelihood technique performs a fit of a model consisting of a point source plus a simple background, convolved with the COMPTEL point spread function to the observed counts. The best-fit for each position in the sky results in a maximum-likelihood ratio skymap in which contours of constant probability define positional constraints for a given significance level. The application of this technique to COMPTEL data is described in de Boer *et al.* (1992) and its application to several gamma-ray bursts in Connors *et al.* (1993a, 1993b) and Winkler *et al.* (1992, 1993). The maximum-likelihood ratio skymap for GRB 930131 was generated using 40 events from 0.72-30 MeV selected from the first ~1 second following the BATSE trigger, including both pulses of the main emission. The 1, 2 and 3σ confidence contours are displayed in Fig. 2 in a



GRB930131
PSI (Deg.)
CHI (Deg.)
10
5
0
−5
−10
−5
−10
−15
−20
195
190
185
180
α2000 = 175
δ2000 = 15
10
5
3σ
2σ
1σ

The procedure proceeds as follows: Monte Carlo simulation is used to determine the COMPTEL response to a trial photon spectrum at the proper burst location (as determined from maximum likelihood fitting (Sect. 2.3)). This diagonal response is relatively insensitive to the choice of trial spectrum so long as energy bins significantly larger than COMPTEL's resolution are used. Identical data selections are imposed on the simulated and observed events (corrected for dead time). The simulated response is then used to determine the burst photon spectrum from the observed count spectrum by direct scalar inversion. No background subtraction was required due to the high signal to noise ratio of this burst. When the resulting photon spectrum differs significantly from the trial spectrum used in simulation, a new response is generated using an updated trial spectrum. Model testing is performed by fitting a model photon spectrum, folded through the simulated response, to the observed count spectrum. Maximum-likelihood statistics (Cash 1979) are used rather than χ^2 due to the low number of observed counts per energy bin.

We selected 32 events originating from within 15° of the burst position from the first ~1 second of burst emission for our analysis. These events were selected from 0.75 MeV to a maximum energy of near 30 MeV. The raw count and deconvolved photon spectra derived from these events are shown in Fig. 3. We found a single power law model gave an acceptable fit with power law index of -1.9 ± 0.4 (1σ confidence). The power law fit photon and count spectra are superposed on the plots in Fig. 3. The largest uncertainty in our preliminary photon spectrum is the absolute flux normalization level due to severe dead time effects present during this intense event. We have attempted to account for dead time due to telemetry and electronics limitations by using available data from on board rate meters. The estimated dead time during the ~1 s chosen for study is higher than 87%. This estimate has been used to scale our photon flux shown in Fig. 3.

Because dead time during the first emission peak is much more severe than for the rest of the burst (see Fig. 1) our integrated spectrum is weighted more by photons from the second pulse, which may conceal spectral evolution. We have too few counts to perform spectral analysis of the individual features, however as a simple test for evolution we have computed the mean photon energy for each pulse separately. For the first pulse $\langle E \rangle = 5.8 \pm 4.2 (1\sigma)$ MeV, while the second pulse yields 4.0 ± 2.7 MeV. These values are consistent with the value of 4.5 ± 2.2 MeV obtained for the full ~1 s of the burst. Thus, within the limits of our large statistical uncertainty, we see no obvious evidence for spectral evolution in this time period.

3. CONCLUSIONS

The intense, short duration gamma-ray burst GRB 930131 was directly imaged in the MeV range by COMPTEL sooner than 7 hours after its initial detection. The COMPTEL localization was found to be consistent with independent BATSE and EGRET locations, as well as triangulation between BATSE and Ulysses. Multiwavelength observations of the COMPTEL source region have been performed in record time. The analysis of these observations may help to place new limits on current theories of extended fading counterpart emission. Preliminary spectral analysis indicates that GRB 930131 is a hard transient event with power law emission extending throughout the COMPTEL energy range. The unique nature of this gamma-ray burst, combined

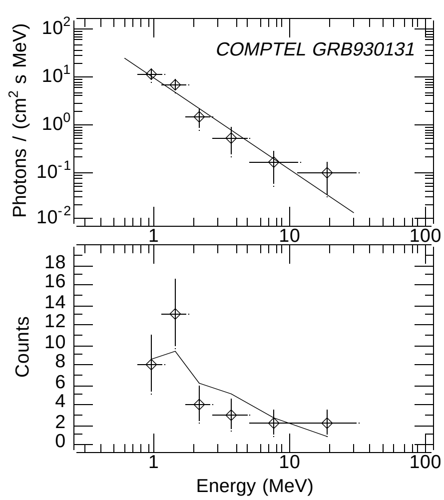


Fig. 3: The energy spectrum of GRB930131 integrated over the first ~1 s following the BATSE trigger. The best fit power law is indicated with a solid line plotted over count and photon spectra.

with the fact that it was observed by many different instruments operating in different energy ranges, make it a good candidate for further investigation.

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