FIRST RESULTS OF THE BATSE/COMPTEL/NMSU RAPID BURST RESPONSE CAMPAIGN

R. M. Kippen, A. Connors, J. Macri, M. McConnell, J. Ryan
Space Science Center, University of New Hampshire, Durham, NH

W. Collmar, J. Greiner, V. Schönfelder, M. Varendorff
Max-Planck Institut für Extraterrische Physik, Garching, Germany

G. J. Fishman, C. Meegan
Space Sciences Laboratory, NASA/Marshall Space Flight Center, Huntsville, AL

C. Kouveliotou
Universities Space Research Association, Huntsville, AL

B. McNamara, T. Harrison
Astronomy Department, New Mexico State University, Las Cruces, NM

W. Hermsen, L. Kuiper
SRON-Leiden, Leiden, The Netherlands

K. Bennett, L. Hanlon, C. Winkler
Astrophysics Division, ESTEC, Noordwijk, The Netherlands

ABSTRACT

The Imaging Compton Telescope (COMPTEL) onboard the Compton Gamma Ray Observatory regularly observes gamma-ray bursts which occur inside the instrument's ~1 sr field-of-view. COMPTEL images bursts in the 0.75-30 MeV energy range with a typical location accuracy of 1-3 degrees, depending on burst strength, position, duration and spectrum. COMPTEL's imaging capability has been exploited in order to search for fading gamma-ray burst counterparts at other wavelengths through the establishment of a BATSE/COMPTEL/NMSU rapid burst response campaign. This campaign utilizes near real-time identification and preliminary burst location by BATSE, accelerated COMPTEL imaging, and a world-wide network of observers to search COMPTEL error boxes as quickly as possible. Timely, deep searches for lingering counterpart emission of several bursts per year are the realized goal of this campaign. During its first year of operation, the rapid response program has been successfully applied to two strong bursts: GRB 930131 and GRB 930309. These bursts were imaged in record time only hours after their occurrence. Subsequently, several observations were made at radio and optical observatories world-wide.

RAPID BURST RESPONSE

In response to the lack of identification of any gamma-ray burst (GRB) counterparts at other wavelengths, a unique search campaign has been implemented by a collaboration of optical and gamma-ray observers. This "Rapid

Burst Response Campaign" searches for fading GRB counterpart emission by performing deep scans of gamma-ray error boxes as soon after the burst occurrence as possible using existing instrumentation. This is realized only through the highly coordinated use of two instruments on the Compton Gamma Ray Observatory (BATSE and COMPTEL), and a world-wide network of wide-field, ground-based multiwavelength observers. By using BATSE to quickly identify bursts which COMPTEL can image, we are able to perform deep optical/radio scans of degree-sized GRB error boxes within hours. The Rapid Burst Response plan schematically illustrated in figure 1 has been explained in more detail elsewhere.[1]

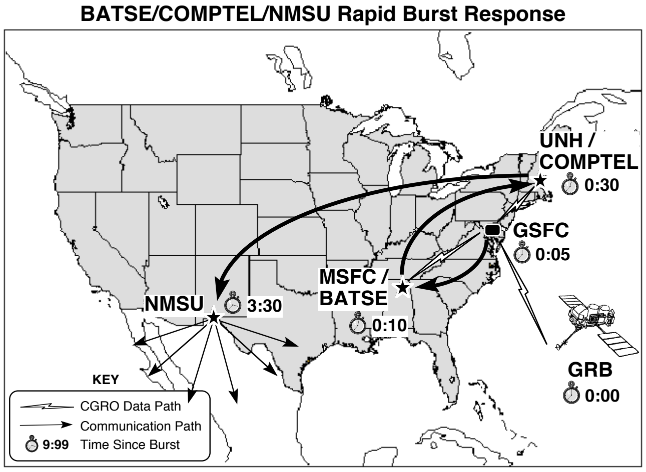

Figure 1. Schematic view of Rapid Burst Response operations.

Rapid response action is initiated when special BATSE count-rate thresholds are triggered at the onset of a burst. These thresholds have been set to indicate only those bursts which are of sufficient intensity to be detectable by COMPTEL. BATSE threshold data are continuously monitored in real-time at Goddard Space Flight Center (GSFC) and triggers are promptly communicated to the BATSE team at Marshall Space Flight Center (MSFC). The BATSE team provides a rough burst direction used to determine if the burst is in the $\sim$1 sr COMPTEL field of view and if it is of cosmic origin. Burst triggers satisfying these criteria are communicated to the University of New Hampshire (UNH) where readily available COMPTEL data are processed and analyzed in an accelerated manner. The result of this analysis is a COMPTEL image (0.75-30 MeV) of the burst. The burst direction information from the COMPTEL image (i.e. GRB error box) is then communicated to New Mexico State University (NMSU) where the counterpart search is coordinated using a world-wide network of wide-field radio and optical observatories. Under optimum circumstances, this entire plan can be executed in $\sim$3.5 hours from the time of the burst occurrence.

The BATSE Rapid Response thresholds were initiated in July 1992, however it was not until several months later that reliable procedures and communications pathways were defined and established between all the network participants. Since the Rapid Response Campaign was initiated only 5 bursts were intense enough to exceed the BATSE thresholds and trigger Rapid Response action, although subsequently an additional 6 bursts have been imaged from this same period. It was not until GRB 930131 that a fully reliable response plan was in place and could be exercised. Two months later, the plan was again successfully applied to GRB 930309. These two successful applications have resulted in degree-sized GRB locations in record time.

GRB 930131

The gamma-ray burst on 31 January 1993 (alias "The Super Bowl Burst") was the most intense burst yet observed by BATSE.[2] It was a unique event in terms of its intensity, short time-scale variation and hardness.[3,4,5] It was also the first successful application of the Rapid Response procedure. Upon notification of the burst by BATSE, COMPTEL data were used to determine the source of emission to an accuracy better than $2°(1\sigma$ error radius) within 6.5 hours of the burst onset. Being the first real trial of the Rapid Burst Response campaign, several minor problems were encountered, resulting in a less than optimum response time. Observations of the burst locale where made by several optical and radio observatories, the soonest being only 11 hours after the burst. Although no obvious fading counterparts were identified, several interesting objects were observed, prompting further study.[6]

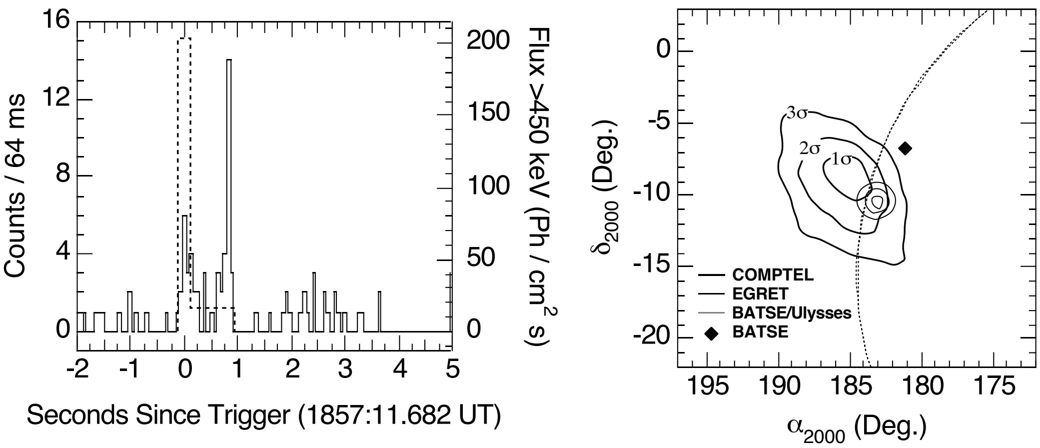

Figure 2. COMPTEL telescope lightcurve and image of GRB 930131.

In measuring bursts, COMPTEL uses two independent modes of operation: a single detector "burst" mode and a double scatter "telescope" mode.[7] Here, we are concerned primarily with the imaging "telescope" data. In the COMPTEL telescope data (0.75-30 MeV), GRB 930131 was intense and short-lived with the majority of significant emission occurring in a $\sim$1 s interval. The history of time-tagged telescope events in 64 ms bins is shown in figure 2. Because this burst was intense, the COMPTEL data suffers from severe deadtime effects ($\sim$12% live-time over the $\sim$1 s of intense emission). The complex evolution of the burst with time can be seen in the two-bin histogram (dashed line) in figure 2. This represents the burst emission as measured by a single COMPTEL detector, largely unaffected by deadtime effects. The single detector measurement shows that the telescope does not register much of the burst flux due to instrument deadtime.

To determine the location of GRB 930131, a maximum-likelihood technique was employed which places quantitative statistical constraints on the burst source position.[8] The maximum-likelihood ratio skymap for GRB 930131 (figure 2) was generated using only 28 events selected from the $\sim$1 s of significant burst emission. The high instrument deadtime and relatively short burst duration result in few telescope events for imaging, thus the statistical uncertainty in the location ($\pm 1.5°$ at the 1σ confidence level) is greater that of other strong bursts measured by COMPTEL (typically $\sim 1°$). From figure 2, it is clear that the COMPTEL-derived burst position is consistent with the BATSE[2] and EGRET[5] localizations as well as the BATSE/Ulysses IPN triangulation annulus.[9] The best COMPTEL position along this annulus is α_{2000}= 12h14m, δ_{2000}= -9°41′ (±48′ (1σ) along the annulus).

GRB 930309

The second successful application of the Rapid Response campaign occurred on 9 March 1993. This burst was weaker, softer and of longer duration than the Super Bowl Burst, however it was of sufficient intensity to trigger the BATSE thresholds initiating Rapid Response. Following prompt notification from BATSE, a COMPTEL image was obtained less than 4.5 hours after the start of the burst. Unfortunately, the burst location was close to the sun, making the field poorly observable to optical instruments. Radio observations were made over the next several days by Westerbork, Owens Valley and the VLA observatories.[10,11]

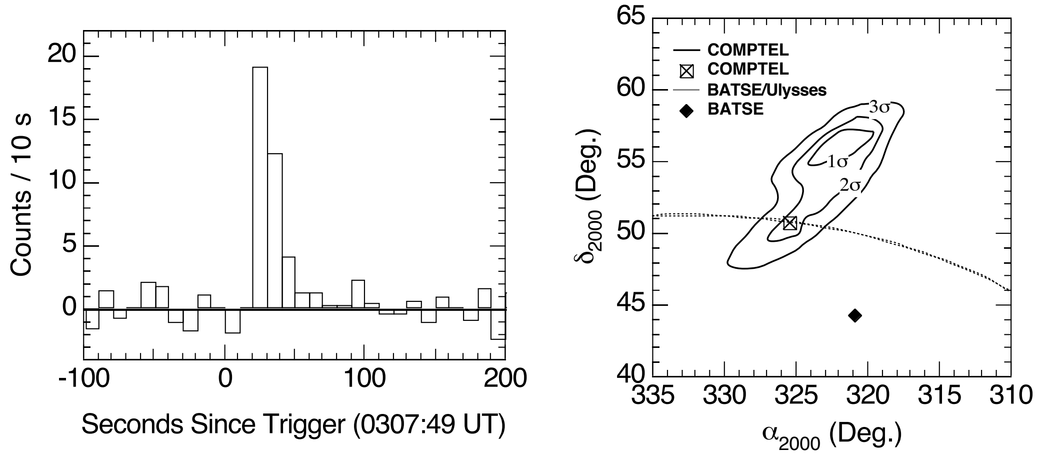

Figure 3. COMPTEL telescope lightcurve and image of GRB 930309.

An interesting candidate object was identified by Westerbork very close to the most likely COMPTEL-derived position[12]. It exhibited a declining flux over time as might be expected from a fading GRB counterpart. Unfortunately, the position of this radio source was inconsistent with the BATSE/Ulysses IPN triangulation annulus[13] as revealed several days later. The source candidate was later determined to be a variable double lobed radio galaxy.

Since GRB 930309 was of moderate intensity, the COMPTEL data does not suffer from significant deadtime effects ($\sim$95% live-time for the duration of the burst), however the background during this burst cannot be neglected. To improve the signal to noise ratio (S/N), the intensity-time profile of telescope data shown in figure 3 includes only events from within 6°of the derived burst position. This data selection effectively removes background while retaining source events. To correct data for the remaining background, binned events from 15 orbits prior to the burst were used as a background estimate. COMPTEL measures significant emission starting well after the BATSE trigger and lasting for $\sim$25 seconds before returning to background level.

The maximum-likelihood ratio skymap of GRB 930309 (figure 3) was calculated using 69 events (source plus background) from the most intense 22 seconds of the burst. Since this burst was quite far from the COMPTEL pointing axis ($\sim 30°$), the location contours are azimuthally elongated. This is an artifact of COMPTEL's off-axis response. Thus, the systematic and statistical location uncertainties combine to yield a burst position accurate only to about 5° RMS. The BATSE/Ulysses IPN triangulation annulus[13] falls within the 2σ confidence contour of the COMPTEL skymap. The best COMPTEL position along this annulus is α_{2000}= 21h42m, δ_{2000}= $50°47'$ ($\pm 30'$ (1σ) along the annulus).

CONCLUSION

GRB 930131 and GRB 930309 have been imaged by COMPTEL in record time, prompting rapid optical and radio follow-up observations. With two successful applications of the Rapid Burst Response Campaign, we have shown that deep, time-correlated searches for gamma-ray burst counterparts are possible using existing instrumentation. It is our intent to continue to improve this campaign, resulting in burst locations distributed to the observer network as quickly as $\sim$1 hour after the BATSE trigger. This will be accomplished through improved COMPTEL processing and analysis, and the use of the BACODINE[14] system for faster burst notification.

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