STRONG GAMMA-RAY BURSTS OBSERVED BY COMPTEL DURING ITS SECOND YEAR OF OPERATION

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ABSTRACT

The imaging Compton telescope COMPTEL onboard the *Compton* Gamma Ray Observatory can localize gamma-ray bursts occurring inside its ~1 sr field-of-view in the energy range from 0.75 to 30 MeV with location accuracy of ~1°. Additional time-resolved spectral measurements in the energy range 0.1 to 10 MeV are made by individual COMPTEL 'burst' detectors. During its second year of operation, COMPTEL observed several gamma-ray bursts. Locations of five strong bursts (including the rapidly imaged events GRB 930131 and GRB 930309) are presented here along with the findings from preliminary spectral analysis.

COMPTEL BURST SEARCH

COMPTEL measures radiation from gamma-ray bursts (GRBs) with two independent operating modes /1/. To identify GRBs, COMPTEL utilizes the onboard transient event triggering system of the *Compton*-BATSE instrument. Upon receipt of a BATSE trigger signal, COMPTEL's 'burst' mode detectors automatically switch to shorter accumulation times, while normal 'telescope' operation continues. Since COMPTEL is only sensitive to bursts which occur at zenith angles $\lesssim 50°$ from its pointing axis /1/, not all BATSE bursts are candidates for COMPTEL.

During the period from April 1992 through April 1993 (*Compton's* second full year in orbit), there were more than 700 BATSE triggers; ~300 of which were due to GRBs. Of these, ~70 were localized by BATSE with zenith angles <60° and are thus potentially inside COMPTEL's FoV. Due to telemetry losses, COMPTEL data are available for only ~55 of these triggered events. We searched the telescope data at the times of each of these candidates (see below for detail) and have identified five significant detections. Preliminary results on some of these bursts have been published earlier /2,3/. Here we complement the earlier findings by presenting updated burst locations and preliminary spectral results.

BURST LOCATIONS

In its telescope mode, COMPTEL measures the energy and interaction location of photons which scatter in each of two separated detector-module layers. These time-tagged measurements (telescope "events") are used to determine the total energy (E_{TOT}), scatter direction (χ, ψ), and scatter angle ($\bar{\varphi}$) of incident photons, forming points in a four dimensional dataspace . Assuming the energy spectrum of the source, the dataspace dimensions are reduced to three. By statistically analyzing the distribution of observed events in this dataspace, with knowledge of point-source and background signatures, we are able to localize burst sources /1/.

Of the ~55 candidates, we identified five bursts in the telescope whose detection significance exceeds ~3.5σ using a maximum likelihood imaging technique /1/. The results of our analysis are listed in Table 1 where, for each significant detection, the most probable position along with the mean 1σ angular uncertainty radius are given. The localization maps of two of these bursts are shown in Figure 1.

TABLE 1 Locations of significant COMPTEL gamma-ray bursts observed from 4/92 - 4/93.

Burst Date	Telescope Zenith (deg)	Significance (No. σ)	Most Likely Location (RA, Dec., J2000.0)	Mean 1σ Error Radius (deg)
GRB 920622	46.0	13.5	$10^h50.0^m$, +49.2°	1.0
GRB 920830	16.6	5.3	$17^h16.0^m$, −74.5°	1.5
GRB 930118	15.7	3.9	$14^h47.2^m$, −34.8°	1.5
GRB 930131	27.9	5.1	$12^h24.8^m$, −07.9°	1.9
GRB 930309	29.9	5.9	$21^h30.8^m$, +55.2°	1.0

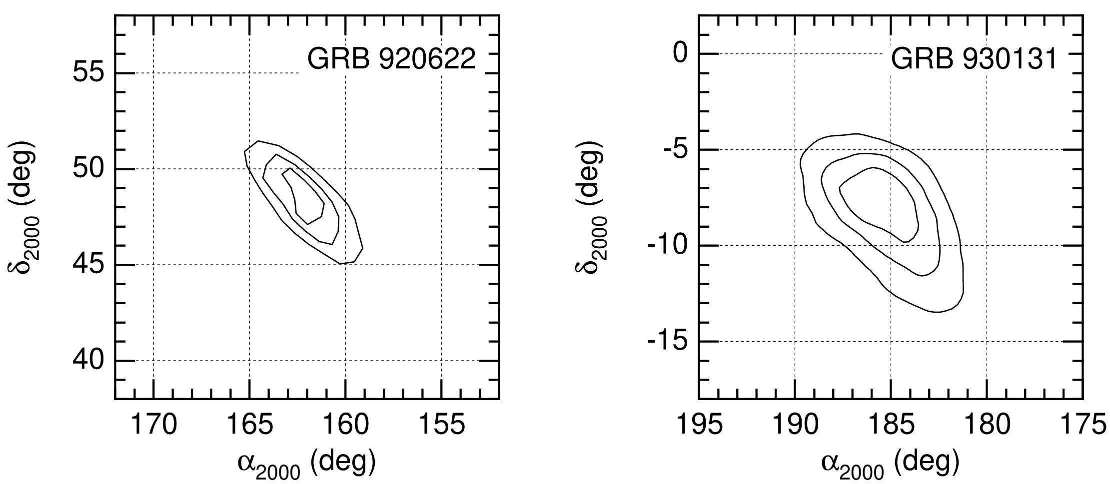

Fig. 1. COMPTEL maximum likelihood localizations of GRB 920622 and GRB 930131. For each burst, 1, 2, and 3σ confidence contours are plotted in celestial coordinates (α, δ).

Our burst localization analysis accounts only for statistical uncertainty, which is the dominant source of location error in these bursts. Simulations, along with the study of solar flares and independently localized bursts, indicate that the systematic error in burst location caused by inadequacies in the instrument response and background model is ~0.5°. Both statistical and systematic errors are strongly dependent on the zenith angle of the burst. Those bursts near the edge of the FoV have the greatest location uncertainty. GRB 920622, GRB 930131 and GRB 930309, have been independently constrained to lie on thin (typically << 1°) annuli by the Interplanetary Network (IPN) using timing differences between BATSE and *Ulysses* detectors /4/. The COMPTEL locations are consistent with the IPN annuli and their intersections provide sufficiently small regions to search for counterparts at other wavelengths.

In addition to providing relatively small error boxes, COMPTEL burst localization is valuable because it can be performed quickly. Starting with GRB 930131, this ability has been utilized in rapid searches for fading and/or delayed emission from optical/radio counterparts. GRB 930131 was localized within 6.5 hours of the burst onset, prompting world-wide multiwavelength observations which began as soon as 11 hours after the GRB. Although no obvious counterparts were identified, several interesting objects were observed and continue to be studied (/5/ and references therein). The COMPTEL image of GRB 930309 was obtained in less than 4.5 hours, however its relatively poor localization and proximity to the Sun made observations problematic. Radio observations within several days of this burst revealed no obvious counterpart emission. The lack of observed counterparts this soon after bursts will help to constrain the nature of fading or delayed counterpart emission (/6/ and references therein). We continue to improve this effort such that COMPTEL localizations of newly occurring bursts can now be obtained within ~1 hour of the burst.

ENERGY SPECTRA

Spectral analysis of COMPTEL telescope and burst detector data is performed separately using different analysis techniques. This is due to the completely independent operation of the two detection modes, each with separate instrument response, background and statistical requirements. Model testing is performed using a standard forward-folding technique where model photon spectra are convolved with the instrument response and compared to the observed source and background data in count-space using the appropriate statistical test /1/.

When the COMPTEL data are analyzed in this manner, the five bursts listed in Table 1 are all well fit by a simple power-law model of the form A (photons cm^{-2} s^{-1} MeV^{-1}) $\cdot$ E (MeV)$^{-\alpha}$ with spectral slope α in the range 2-3. As a group, the high energy behavior of these events is consistent with that seen in previous COMPTEL and *Compton*-EGRET bursts /1/ and agrees with an extension of more complicated models used to describe BATSE data at lower energies /6/. The results of full spectral analysis of all these bursts will be presented in a later paper. Here we summarize the results from two interesting cases: GRB 920622 and GRB 930131.

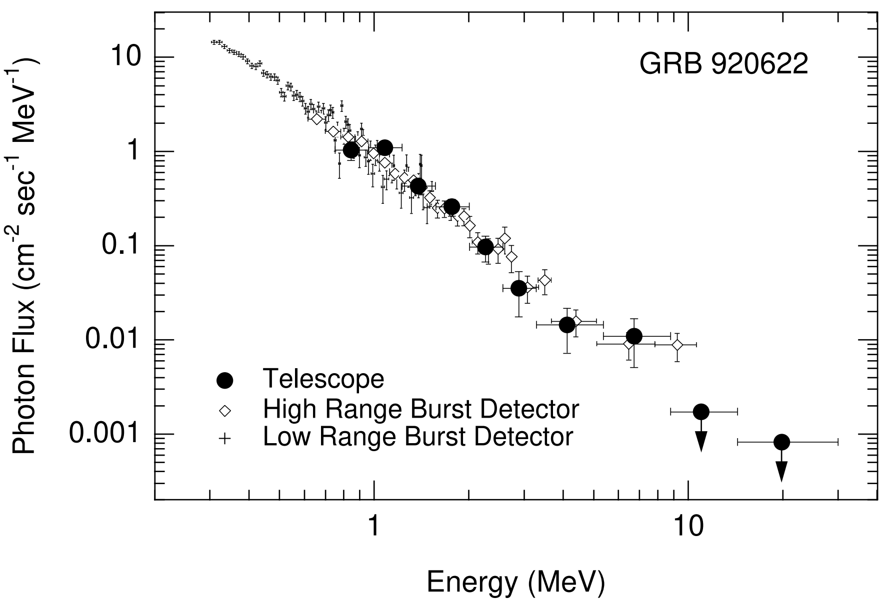

Fig. 2. COMPTEL energy spectra of GRB 920622 integrated over the full burst duration.

Significant emission from GRB 920622, (the strongest COMPTEL burst of this group) was observed over nearly two decades in energy up to ~10 MeV when integrated over its full ~24 s duration (Figure 2). Spectra of the individual observing modes are each well fit by simple power-law models and all give consistent results in the overlap region near 1 MeV. There is no significant change in the spectral slope over the entire COMPTEL energy range -- each power-law fit being consistent with $\alpha \approx 2.5$. However, time resolved spectra from the first ~6 seconds of this burst show that there is significant hard-to-soft evolution. Such behavior is a common feature in many GRBs (/3/ and references therein).

The most intense burst of the group, GRB 930131, exhibited hard power-law emission with $\alpha \approx 1.8$ throughout the COMPTEL energy range. This spectrum was observed to extend above 10 MeV with no significant break or cut-off at the highest energies. The bulk of the burst was contained in a short ~1 s interval. Within this interval, temporal structure on time-scales of ~50 ms was observed with a peak intensity of ~42 photons cm^{-2} s^{-1} (@ 1 MeV). The great intensity and rapid fluctuations of the high energy (>10 MeV) flux observed by COMPTEL from this burst constrains the source to lie *within* the Galaxy assuming that the radiation is not relativistically beamed. Conversely, if the source is at extragalactic distances, these COMPTEL observations require that the radiation be highly beamed /3/.

CONCLUSIONS

In its second year of operation COMPTEL has detected five significant gamma-ray bursts which have been well-localized. Two of these events were rapidly located, initiating multiwavelength observations in record time. Spectral analysis indicates that all of these bursts are consistent with simple power-law emission in the COMPTEL energy range. Unique results from individual bursts like GRB 920622 and GRB 930131 help to constrain the nature of all bursts by providing new clues about high energy emission mechanisms.

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