COMPTEL observations of gamma-ray bursts

M. Varendorff[1,3], A. Connors[3], W. Collmar[1], L. Hanlon[4], W. Hermsen[2], R. M. Kippen[3] L. Kuiper[2], M. McConnell[3], J. Ryan[3], V. Schönfelder[1], O.R. Williams[4], C. Winkler[4]

1. Max-Planck Institut für extraterrestrische Physik, D-8046 Garching, FRG
2. SRON-Leiden, P.B. 9504, NL-2300 RA Leiden, The Netherlands
3. University of New Hampshire, Institute for the Study of Earth, Oceans and Space, Durham NH 03824, USA
4. Astrophysics Division, Space Science Department of ESA, ESTEC, 2200 AG Noordwijk, The Netherlands

ABSTRACT

The COMPTEL experiment on GRO images 0.75 – 30 MeV celestial gamma radiation that falls within its 1 steradian field of view. During the first 22 months in orbit, direct images of 14 bursts have been produced, using COMPTEL's primary mode of operation (the telescope mode). The bursts of the first year of observation are summarized in Hanlon et al. 1993. We present images and time profiles of the latest bursts.

1. INTRODUCTION

The imaging Compton Telescope, COMPTEL, is one of four instruments on board the Compton Gamma Ray Observatory (CGRO). Since shortly after its launch in April 1991, COMPTEL has been accumulating measurements of the positions, time profiles, and spectra of gamma–ray bursts in the MeV range. In COMPTEL's imaging telescope or 'double scatter' mode (0.75 – 30 MeV), it measures both positions and spectra of cosmic γ-ray bursts that fall within its 1 steradian field of view. In addition, in burst or 'single detector' mode COMPTEL accumulates independent 0.1 – 1.1 MeV and 1 – 10 MeV spectra in two of its lower NaI detectors. A full description of the instrument is given in Schönfelder et al. 1992.

In COMPTEL's imaging or 'double scatter' mode, a photon which Compton–scatters in one of the seven upper D1 detectors, is then detected in one of the lower fourteen high–Z D2 detectors. In the simplest case of a single Compton scatter in D1 and complete photo–absorption in D2, the possible γ-ray source positions lie on a circle of radius $\bar{\varphi}$ around the direction of the scattered photon, with

$$\cos\bar{\varphi} = 1 - \frac{1}{\epsilon_2} + \frac{1}{\epsilon_1 + \epsilon_2}, \qquad (1)$$

where ϵ_1 and ϵ_2 are the energy deposits measured in the upper (D1) and lower (D2) detectors, respectively, in units of the electron rest–mass. The intersection of these circles would produce an image.

Initial spectral results and positions of the first bursts are given in Connors et al. 1993, Collmar et al. 1992, Winkler et al. 1992, Connors et al. 1992 and Varendorff et al. 1992. A summary of all positions and spectral results for the bursts which occured in the first 15 months of observation will be published in Hanlon et al. 1993. In this paper we add to this sample positions and time profiles for 6 new bursts.

2. DATA and ANALYSIS

Most of the BATSE burst trigger messages contain preliminary positions, with typical error radii of about 5°. Of these, about 16% had been given BATSE positions within 45° of COMPTEL's telescope zenith, and were potential candidates for imaging. For each of those bursts, light–curves are produced, using the BATSE trigger time and event duration to select an appropriate time window. Only telescope events which satisfy the optimum event selection criteria are used. Images are produced, if the time profile shows evidence for the presence of a burst signal. In Figure 1 we display the time profiles of the recently analyzed bursts.

COMPTEL uses several imaging methods. One is a maximum entropy technique, which directly estimates the count–rate per angular bin on the sky. This general method is described in Strong et al. 1991; and its application to imaging γ-ray bursts in Varendorff et al. 1992. In this paper we present quantitative constraints on source positions, using a maximum–likelihood fit to a model of a point source plus a flat background, convolved with the COMPTEL instrument response (de Boer et al. 1991; Kuiper et al. 1992).

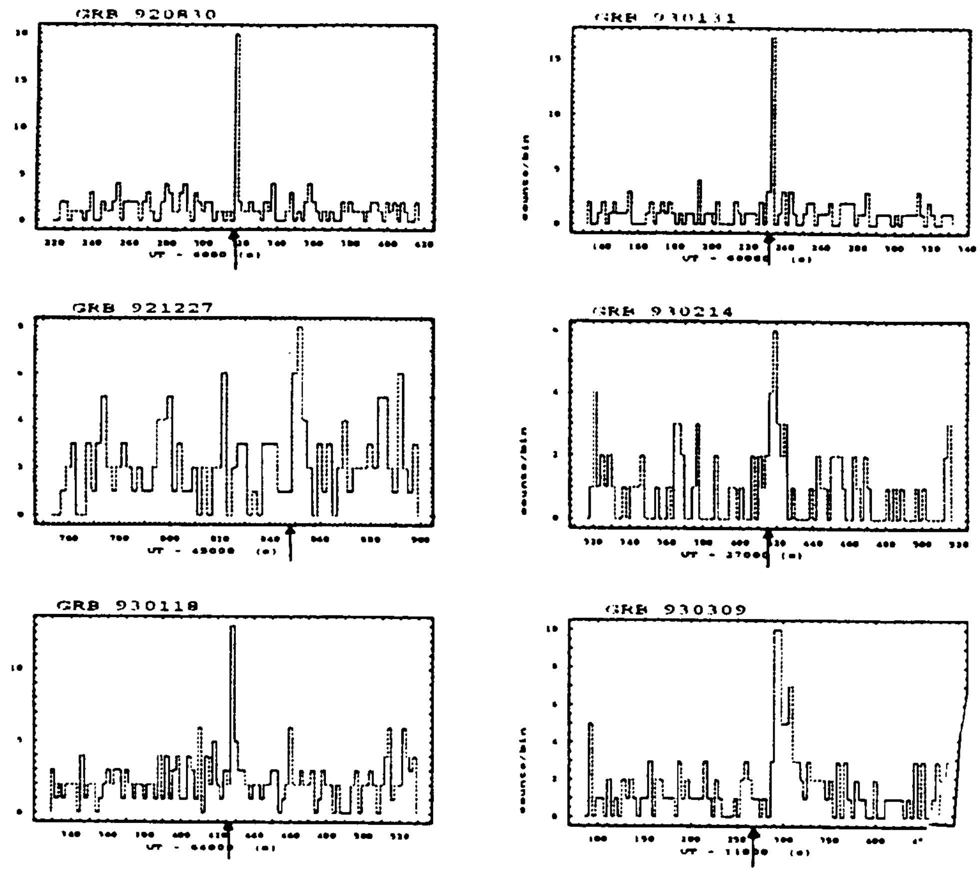

Figure 1. Time profiles of gamma-rays detected in COMPTEL telescope mode. (BATSE trigger time is indicated with an arrow).

In practice the full instrument response is substantially complicated by multiple scatters and partial energy absorption (Diehl et al. 1991). To simplify, one first transforms to the coordinates $\chi, \psi, \bar{\varphi}$ and E_{TOT}, where $\bar{\varphi}$ is defined in Eq. 1, E_{TOT} is the total energy deposited in both D1 and D2, and (χ, ψ) represent convenient telescope coordinates for the scattered photon direction. For a single energy interval, COMPTEL's complex instrument response is factored into an instrument geometry and exposure, which incorprates all information on the absolute telescope pointing direction; and a point spread function, which depends only on the relative coordinates $\chi, \psi, \bar{\varphi}$ (see Diehl et al. 1991 and references therein). This is then integrated over an assumed input energy spectrum. For this analysis a spectrum $\sim E^{-2}$ was used.

For each gamma-ray burst, a point source is convolved with this instrument response, and added to a simple background. This model is compared to the data-counts in each $\chi, \psi, \bar{\varphi}$-bin, using the standard maximum-likelihood statistic appropriate for Poisson counts per bin (de Boer et al. 1991). The source flux and background level are allowed to vary, as contours of constant probability are mapped out in (χ, ψ) space, at the equivalent of 1, 2, and 3σ significance for the case of two parameters (Lampton et al. 1976; Cash et al. 1976).

3. RESULTS

We display these maximum-likelihood ratio contours, which incorporate statistical errors only, in Figure 2. The varying widths of the contours reflect the number of telescope events available for imaging. The signal of GRB 921227 was too weak, therefore we could not produce a consistent image of this burst. The signal from GRB 930214 is just strong enough for imaging, but only 1σ and 2σ contour lines can be given.

For COMPTEL locations of strong γ-ray bursts, since the background is negligible, any systematic uncertainty would come from uncertainties in the instrument response, which for imaging is primarily represented by the point-spread function. Preliminary investigations from imaging high signal-to-noise sources such as solar flares and the Crab indicate any

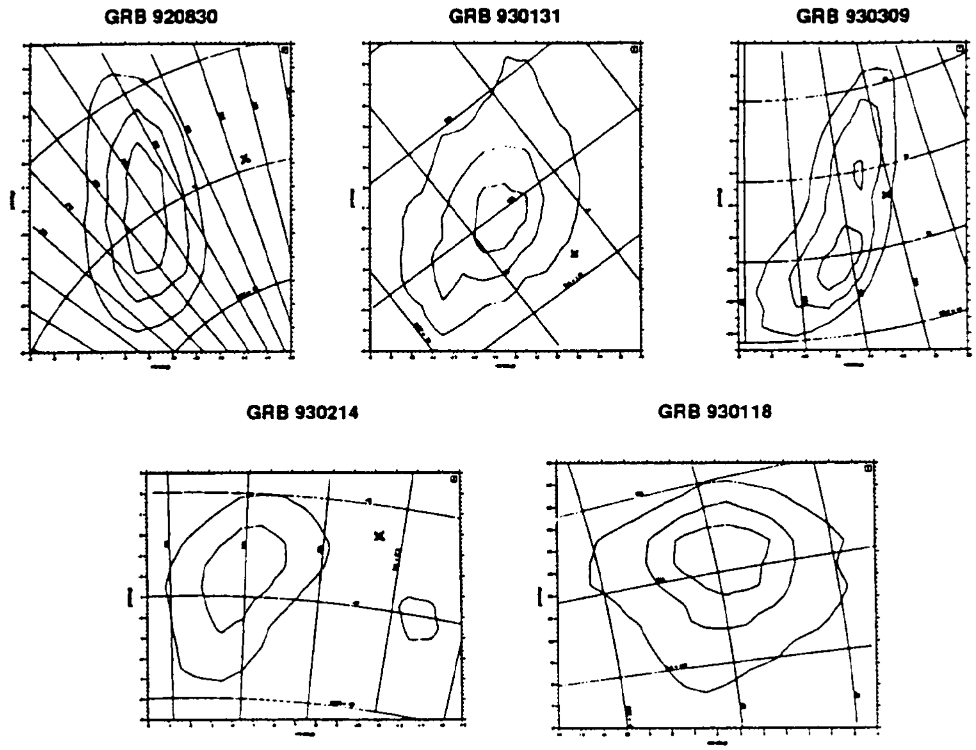

Figure 2. Maximum Likelihood images showing 1, 2, and 3σ contours of the maximum likelihood ratio, with α, δ (epoch 2000) grid superposed.

systematic uncertainties to be no larger than ~0.5–1°(Connors et al. 1993). We expect additional work will allow us to constrain these systematic uncertainties further.

Table 1. Summary of COMPTEL burst positions (epoch 2000)

GRB ID (date)	Telescope Zenith	Equatorial $\alpha \pm \sigma$	Coordinates $\delta \pm \sigma$
920830	14.8°	$17^h30^m \pm 26.4^m$	$-74.8° \pm 2.7°$
921227	32.7°	—	—
930118	21. °	$14^h43^m \pm 8.8^m$	$-34.7° \pm 2.8°$
930131	28. °	$12^h19^m \pm 6.8^m$	$-8.6° \pm 1.7°$
930214	21.5°	$19^h\ 2^m \pm 21.^m$	$-44.0° \pm 2.7°$
930309	32. °	$21^h36^m \pm 12.^m$	$53.0° \pm 4.0°$

We summarize our results in Table 1. To the 1σ statistical errors, we have added ~ 1° systematic uncertainties in quadrature. The positions given reflect the middle of the 1 σ contour line on the images. For GRB 930903, which shows two separate 1σ regions, the center of the 2σ contour line is given.

4. SUMMARY

This paper reports positions and time profiles of 6 new bursts observed during the first half of Observation Phase II within the COMPTEL field of view, bringing the total number located so far to 14. Energy spectra of these bursts and the fast location of GRB 930131 is covered by two other papers in these proceedings. COMPTEL continues to accumulate measurements of light-curves, positions, and energy spectra of cosmic gamma-ray bursts in its 0.75 – 30 MeV (telescope mode) and 0.1 – 10 MeV (burst mode) energy windows.

5. REFERENCES

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