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Spectra of a recent bright burst measured by CGRO-COMPTEL: GRB 990123

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Spectra of a Recent Bright Burst Measured by CGRO-COMPTEL:GRB 990123

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Abstract. CGRO-COMPTEL measures gamma-ray burst positions, time-histories and spectra in the 0.1–30 MeV energy range, in both imaging "telescope" and single detector "burst spectroscopy" mode. GRB 990123, one of the most recent bright bursts seen by COMPTEL, was caught in the optical while the gamma-ray emission was ongoing. The burst spectral shape can be characterized by a peak in $\nu - F_\nu$ just below 1 MeV and a power-law tail above (photon index ~ -2.4), and flattening below. There is also spectral evolution by downward movement of the peak and/or softening of the power laws. We present light-curves, time resolved spectra and an image map for this burst.

INTRODUCTION

GRB 990123 is the only gamma-ray burst to be simultaneously observed in optical wavelengths. The Burst and Transient Source Experiment (BATSE) on CGRO triggered the Compton Telescope (COMPTEL) on CGRO at 35216.121 s UT on 23 January 1999 (BATSE trigger #7343). The burst was located at a zenith angle (w.r.t. CGRO and COMPTEL) pointing of 58.4°. The gamma-ray emission lasted for about 100 s with the > 1 MeV emission seen by COMPTEL most significant between 18 s and 46 s after the BATSE trigger. The Robotic Optical Transient Search Experiment (ROTSE) detected optical emission during and after the gamma-ray emission. ROTSE made 6 measurements starting 22.2 s after the BATSE trigger.

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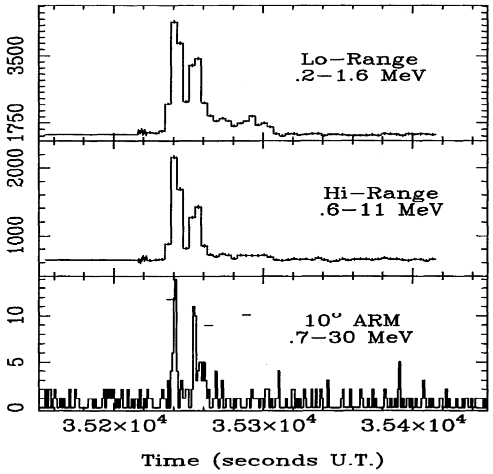

FIGURE 1. GRB 990123 (BATSE #7343) in the COMPTEL low (0.2–1.6 MeV) and high (0.6–11 MeV) range burst mode, plus the 0.7–30 MeV telescope mode light-curves. The ROTSE m_v are indicated with the telescope mode.

COMPTEL detected the second and third peaks of GRB 990123 in both its imaging telescope ("double scatter"; 0.75–30 MeV) and non-imaging burst-spectroscopy ("burst mode"; 0.3–1.5 MeV and 0.6–10 MeV; see Schönfelder et al. 1993) modes. Telescope position constraints were broadcast (via GCN/BACODINE) about 10 minutes after burst onset and preliminary light-curves were posted soon thereafter (Young et al. 1999; Connors et al. 1999).

In the imaging telescope mode, COMPTEL provides detailed information on individual time-tagged photons with $\frac{1}{8}$ ms time resolution. Because of the small effective area and limited telemetry of the telescope mode, however, only ~200 burst events were recorded. In spectroscopy mode the effective area was roughly two orders of magnitude greater, and the dead time was negligible. The COMPTEL light-curves are displayed in Fig. 1.

TELESCOPE MODE

The spectra from the two modes were handled differently. For the 0.75–30 MeV telescope data, one selects only events whose event circle falls within a certain angle of the source position ("angular resolution measure", or ARM; Schönfelder et al. 1993), both reducing background and providing a nearly diagonal response (e.g., Kippen et al. 1998). For the telescope spectrum displayed in Fig. 2, a 10° ARM limit was used. The 32.768 s integration interval of (35229.452 s, 35262.22 s) was chosen both to cover all the significant gamma-ray emission and to allow an accurate live time calculation. The background data were taken 15 orbits prior to the burst (see Kippen et al. 1998). The data were fit to a simple power-law via a forward folding technique. The best-fit is $2.0 \pm 0.4(E/1\,\mathrm{MeV})^{-3.33\pm0.4}$ photons/cm^2-s-MeV, giving a total fluence of $(0.98 \pm 0.5)\times10^{-4}$ ergs/cm^2 (0.75–30 MeV). However, a turnover at or below 1 MeV is also consistent with the telescope data.

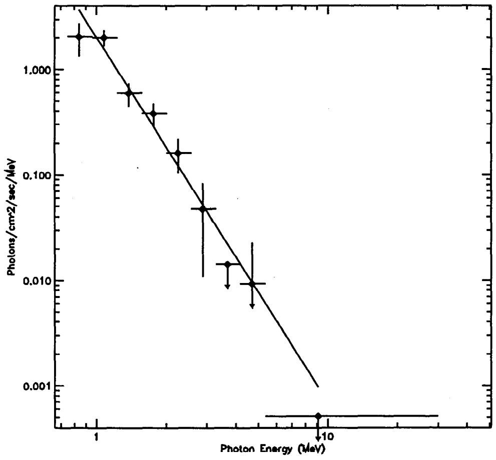

FIGURE 2. The best-fit power-law spectrum is $2.0\pm0.4(E/1\,\mathrm{MeV})^{-3.33\pm0.4}$ photons/cm^2-s-MeV, giving a total fluence of $(0.98 \pm 0.5)\times10^{-4}$ ergs/cm^2 (0.75–30 MeV). However, a turnover at or below 1 MeV is also consistent with these telescope data.

BURST MODE

The single detector count spectra obtained in "spectroscopy mode" were processed as follows: the background was estimated from a spectrum of 140 s duration starting 202 s prior to the BATSE trigger (at 35216 s). Eight high range detector (0.6–10.0 MeV) spectra (4 s integration time each) covering a 32 s time interval (35230.2 s, 35262.3 s), were background subtracted and summed. The spectral fitting of these time-averaged data was performed by convolving a trial photon spectrum with the detector response matrix to produce a count spectrum. We used a χ^2 statistic to compare the model spectrum with the data. We first assumed a single power law for the spectrum between 0.9 and 5.0 MeV. As shown in Fig. 1 there is no significant signal above 4 MeV. The best fit parameters for the single power law in this energy range are: normalization = (1.37 ± 0.10) photons/[cm^2-sec-MeV] at 1 MeV; and index = (-2.63 ± 0.16). The fluence (0.9–5 MeV, 32 sec) is 7.86×10^{-5} erg/cm^2. We note a clear break (Briggs et al. 1999) in the spectrum below 0.9 MeV, where the spectrum becomes flatter. Also, preliminary analysis of the low range (0.3–1.5 MeV) spectroscopy data covering the same 32 s time interval indicates a single power law with index -2.0.

Due to evidence for spectral evolution (Briggs et al. 1999) with a break in COMPTEL's energy range, one goal of this analysis was to produce time resolved spectra of this burst. Traditional spectral analysis techniques (like those applied above) use a parametric approach assuming a particular model and approximately account for the Poisson nature of the data using χ^2 type approximations or data transformations. These techniques thus require high statistics and so don't allow for fine time binning of our data. We have begun the implementation of a newly developed technique that addresses some of these shortcomings enabling the use of finer time resolution. Nowak and Kolaczyk (1999) have presented a method for deconvolving spectra that is both non-parametric and explicitly handles Poisson data. We

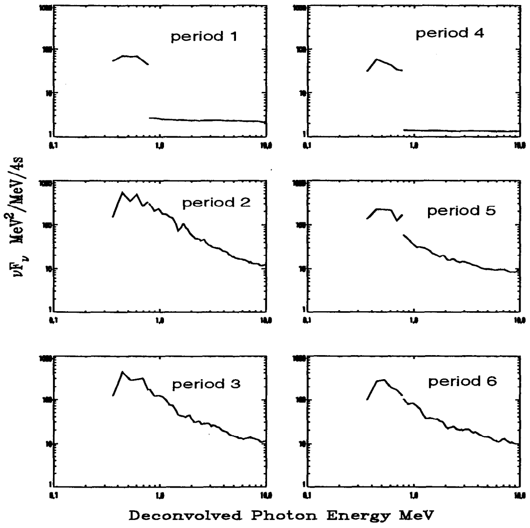

FIGURE 3. Time resolved $\nu - F_\nu$ spectra of 6 consecutive 4 s intervals of GRB 990123, showing qualitative evidence for spectral evolution. The deconvolution was performed using a non-parametric approach.

divided the low and high range burst data into seven 4 s time intervals. Using this non-parametric technique we deconvolved these spectra with the instrument response. Though only preliminary, Fig. 3 shows qualitative spectral structure consistent with the previous analysis with a spectral break below 1 MeV. The time periods displayed don't show any spectral evolution but they are consistent with the comparable times shown in Briggs et al. (1999).

IMAGE MAP

GRB 990123 was so bright in MeV gamma-rays that COMPTEL was able to image it in a 10 sigma detection. (The preliminary COMPTEL detection, broadcast about 11 minutes after the BATSE trigger, was 8.2 sigma.) Fig. 4 shows the combined COMPTEL and BATSE 1, 2, and 3 sigma location contours. The IPN, BeppoSAX X-ray, prompt Optical (ROTSE), fading optical, and radio counterpart locations are included on the map.

CONCLUSIONS

For GRB 990123, observed in the optical during the gamma-ray emission, one notes that the optical flux peaks after the brightest gamma-ray portion and is not a simple extrapolation of the MeV flux. Some have noted this may be a signature of self-absorption; while others suggest this shows the optical to have come from a separate component (Briggs et al. 1999). Traditional analysis techniques show consistent results for the burst and telescope data from COMPTEL. A preliminary non-parametric analysis is consistent with other methods and shows qualitative

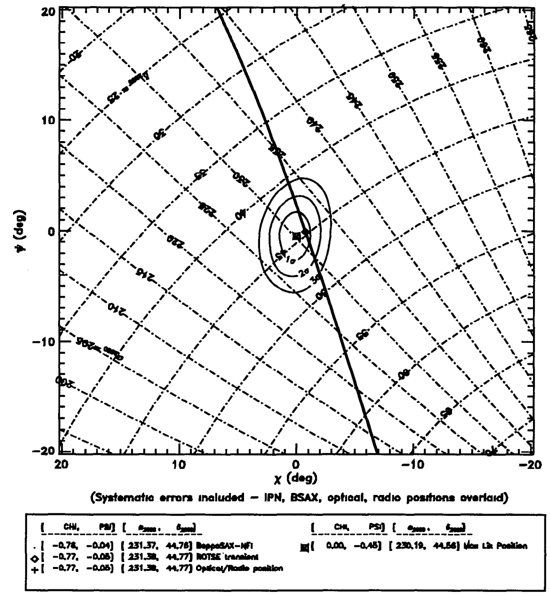

FIGURE 4. The combined COMPTEL and BATSE Huntsville 1, 2 and 3 sigma location contours (systematic uncertainties included), along with the IPN timing arc (Hurley, Feroci et al GCN 222), and indications of the BeppoSAX X-ray, prompt optical (ROTSE), fading optical, and radio counterparts.

evidence for a spectral break just under 1 MeV. Further investigation of this new technique will allow for quantitative results.

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