1.0 INTRODUCTION

We propose to analyse and interpret γ-ray burst (GRB) data using both telescope mode data and single detector burst mode data from COMPTEL. Collectively, these data span the energy range from 300 keV up to 30 MeV. The initial goal of our proposal will be to perform a standard analysis for each significant GRB event seen by COMPTEL. This includes GRBs that are registered by the telescope mode data as well as GRBs that are registered only in the burst mode data. (The latter category includes both GRBs that lie outside of the FoV as well as GRBs within the FoV that are too weak to be seen in the telescope mode.) We would also generate a set of data products (including deconvolved photon spectra) that, for each detected GRB event, would be made available via the COMPTEL GRB Web Page. The second important goal of our proposal will be to perform more detailed studies of selected GRB events, including joint analysis with other instruments, as was most recently carried out with GRB 990123 (Briggs et al. 1999). In general, the proposed effort represent a continuation of past GRB studies by the COMPTEL team.

A separate cycle 9 proposal (M. McConnell, PI) requests support to continue the COMPTEL Rapid Burst Response (RBR) program. That program is designed to provide rapid dissemination of burst *locations* (within minutes) to interested obsevers. The RBR program is not designed to provide spectral data products. *This proposal seeks support to provide a standard level of spectral analysis for each GRB detected by COMPTEL and to provide more detailed studies of selected events.*

2.0 PREVIOUS GRB RESULTS FROM COMPTEL

Although recent measurements of GRB afterglows and coincident optical emissions have revolutionized GRB research, most of our knowledge of GRBs comes from measurements made in the energy range from ~10 keV up to a few hundred keV. Measurements with COMPTEL have confirmed earlier SMM findings that MeV emission is a common and energetically important feature of GRB spectra (e.g., Hanlon et al. 1994; Kippen 1995). The study of GRBs at MeV energies has therefore been one of the important scientific objectives of COMPTEL (e.g., Winkler et al. 1986, Schönfelder et al. 1993). The shape of the emission above the νF_ν peak serves as a constraint on synchrotron and inverse Compton peaks in today's fledgling cosmological fireball models (e.g., Pilla & Loeb, 1998).

Data derived from COMPTEL's telescope mode (covering the 0.75–30 MeV energy band) can be used to derive time-histories, spectra and images for a GRB event. Using its unique ability to image MeV photons, COMPTEL can provide independent locations of GRBs with <1° accuracy (Kippen 1995, Kippen et al. 1995a, 1995b, 1998). This can provide important constraints on the burst locations within 10 minutes of the event. A total of 39 bursts have already been localized in this manner during the first 8 years of operation (through April, 1999). These independently obtained locations have been used to further constrain GRB error boxes obtained using the coarser BATSE locations (Fishman et al. 1994) and the interplanetary network (IPN) triangulation arcs. The COMPTEL experiment also uses two of its large D2 NaI detector modules to provide additional spectroscopic information in parallel with the telescope mode data. These data, referred to as the single-detector or burst mode data, span two separate but overlapping energy intervals. The low-range data covers 0.3–1.7 MeV. The high-range data covers 0.6-10.6 MeV. These data can be used to generate time-histories and spectra independent from those generated by telescope mode data. Whereas telemetry constraints limit the telescope event rate to $\sim 24\ \mathrm{s}^{-1}$, the burst mode detectors accumulate and transmit binned spectra and and can therefore handle much higher event rates.

The data collected from the COMPTEL telescope mode have shown that the time-averaged 0.75–30 MeV spectra tend to be best represented by a single power-law (Kippen et al. 1995a, 1995b; Connors et al. 1997). The distribution of power law indices for spectra > 1 MeV is shown in Figure 1. The mean spectral index for all such bursts observed by COMPTEL is 2.43. This power-law spectral shape is consistent both with earlier results from SMM and higher energy measurements from EGRET. For a few bright bursts, COMPTEL has measured curvature within its energy range, consistent with a peak νF_ν of ~1 MeV, rather than hundreds of keV. For example, both GRB 910814 (Hanlon et al. 1994) and GRB 940217 (Figures 2-5; Winkler et al. 1995) have clearly defined spectral breaks at energies above 300 keV. These COMPTEL results, together with lower energy results from OSSE and BATSE, shows that γ-ray burst spectra seem to have a canonical shape: a peak in νF_ν-space typically centered around ~hundreds of keV (but with a range of about a factor of 5 in either direction) with a power-law tail at higher energies extending out as far as it is measurable, sometimes to 100 MeV or more. Motivated by findings at lower energies of two classes of burst emission based on hardness, the COMPTEL data has been used to test the spectral index histogram for evidence of two populations. So far, the COMPTEL data does not require such a dual population (Connors et al. 1997). Only with a suitably large sample of events will a coherent picture be obtained to investigate in detail the frequency of occurrence of spectral breaks and the energies at which breaks occur. This may have important implications for models of burst sources.

The spectral/temporal analysis of GRBs shows that most bursts demonstrate a significant spectral evolution during the burst event. An important aspect of spectral variability is the hard–to–soft evolution of the spectral slope during the burst event (Norris et al. 1986, Winkler et al. 1992, Hanlon et al. 1994, Winkler et al. 1995). Variability of continuum shapes and of spectral breaks (i.e. shifts of break energy as a function of time) have been discovered in COMPTEL data (GRB 910814, Hanlon et al. 1994) as well as in BATSE data (Ford et al. 1994, 1995). A large sample of burst data will be required to systematically study these phenomena in more detail. These processes can be expected to have important implications on the physical processes at the emission site (e.g., Baring 1994).

Another important objective of our ongoing GRB studies has been the examination of spectra for emission and/or absorption features. The primary candidates in the COMPTEL energy range are redshifted or blueshifted 511 keV annihilation features. Earlier reports are unconfirmed by other instruments. In the past, this has been complicated by various types of instrument bias and the fact that these features are reported to be time variable (Hurley 1988). All GRB photon spectra analysed by COMPTEL so far could be modelled using continuum spectra not requiring any additional component.

COMPTEL telescope mode events provide time histories showing structures with typically 100 ms resolution for stronger bursts within the FoV (Ryan et al. 1994, Winkler et al. 1995). An analysis of fine temporal structure in combination with positive detection of >1 MeV emission can be used to derive distance limits and to place realistic constraints on the nature of the burst process. Analysis of data from GRB 930131 and GRB 940217 were used to derive distance estimates assuming both isotropic and beamed emission (Ryan et al. 1994; Winkler et al. 1995). The data for GRB 930131, for example, suggests that, if the burst occured at cosmological distances, then the emission must have a bulk Lorentz factor of > 2800. Further analysis of a larger sample of GRB data is required to pursue this important issue.

The COMPTEL GRB location database has also been used to investigate the nature of potentially repeating sources. Spectra and lightcurves obtained from events with overlapping location error boxes can be analysed in detail to study whether these close events (separated in time) could be due to gravitational lensing effects of the same physical GRB event. This analysis so far has been applied on the two close events GRB 930704 and GRB 940301 although with a negative result (Kippen et al. 1995a, Hanlon et al. 1995a).

3.0 OBJECTIVES FOR CYCLE 9

As part of our cycle 8 activities, we have been working to set up a pipeline for processing and disseminating high-level spectral data products via the World Wide Web. This pipeline will be used to generate a COMPTEL catalog of burst spectra and to perform a standard analysis of new events as they occur. (This effort has included participation by a local high school student as part of a public outreach effort.) For cycle 9, we propose to continue this effort. In addition, we propose to continue our program of performing more detailed studies of selected events (as was the case, for example, with GRB 990123; Briggs et al., 1999).

For studies of γ-ray bursts, COMPTEL can actually be viewed as providing three independent sets of data: 1) the telescope mode data, covering the 0.75–30 MeV energy range with an event time resolution of 1/8 msec; 2) the low range burst mode data, covering the energy range of 300 keV to 1.7 MeV with a spectral resolution of 9.6% at 0.5 MeV; and 3) the high range burst mode data, covering the 600 keV to 10.6 MeV energy range with a spectral resolution of 7.0% at 1.5 MeV. The analysis of these three sets of data can either be performed independently or jointly. In either case, these data provide a nice complement to one another.

The spectral analysis of each data type requires the generation of a suitable background-subtracted energy-loss spectrum accumulated over some appropriate time interval with respect to the GRB event. Once this is done, a spectral fitting is performed to extract a photon spectrum from the data. This step requires the availability of a suitable spectral response function for each of the three detector modes. The response of COMPTEL to a point source of radiation depends upon its position with respect to COMPTEL and the rest of the CGRO spacecraft. Since each GRB occurs at a different location, each GRB event must, in general, be treated separately. For COMPTEL, response functions are derived from Monte Carlo simulations (Stacy et al. 1996). Two such simulations are required for each GRB event – one for the telescope mode data and one for the burst mode data (a single response function is generated for both the low-range and high-range burst mode data). These simulations can often take several days to generate with the requisite statistics. In order to make maximal use of the full complement of COMPTEL data, a joint spectral analysis of all COMPTEL data is desirable. Figure 5, for example, shows the result of a joint analysis using both the low range and high range burst mode data.

For the last few years, the COMPTEL team has made available data derived from its Rapid Burst Response Program via the COMPTEL GRB Web page. These include time history data, image data and location contours. To date, spectral data (i.e., deconvolved photon spectra) have not been made available on a routine basis. The spectral analysis tools have now evolved to the point where the dissemination of these data becomes practical. During cycle 8 we have initiated an effort to provide, via our Web page, a more complete catalog (including spectral data) of not only COMPTEL telescope mode data, but also the COMPTEL burst mode data. *We propose, as a part of our cycle 9 program, to continue this effort of providing spectral data products via the Web. A more detailed analysis of individual events will include studies of the GRB spectrum and its variability during the course of the event, a search for spectral line features, and a study of variability at MeV energies.*

4.0 SUMMARY

We are requesting access to all burst data collected by COMPTEL during cycle 9 for the purposes of performing a standard data analysis and to continue with our ongoing studies of GRBs at MeV energies. We request data from the COMPTEL instrument only since, as members of the COMPTEL instrument team, we already have several years of experience in the analysis of the COMPTEL burst and telescope data. To fully exploit these data, it is also important to consider them together with data from the other CGRO instruments. As members of the instrument team we already benefit from existing contacts with members of the BATSE, OSSE and EGRET teams working on the joint analysis of GRB data (see e.g. COMPTEL/BATSE/OSSE analysis in Hanlon et al. 1995a, and COMPTEL/BATSE/EGRET analysis in Winkler et al. 1995, as well as Briggs et al. 1999: GRB990123; Hanlon et al. 1995b: GRB 940217, Share et al. 1994: GRB 910601, Schaefer et al. 1994: GRB 910503).

Data analysis will be carried out at one or more PI sites of the COMPTEL collaboration. The requested level of funding ($10,000) will be used to support activities at UNH. UNH, in conjunction with SSD, will be primarily responsible for the standard data analysis. UNH will assume sole responsibility for disseminating the data via the COMPTEL GRB Web Page.

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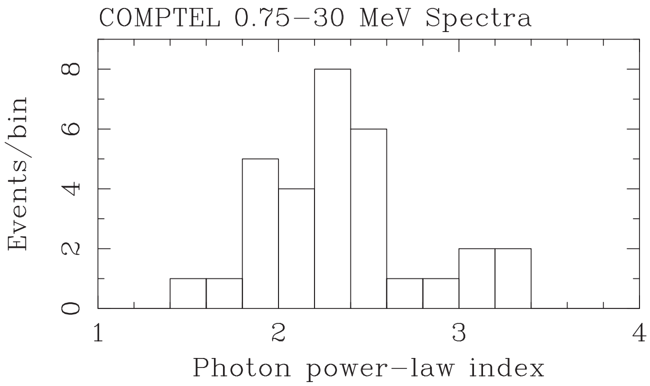

Figure 1: Histogram of photon power-law indices for bursts measured with COMPTEL telescope mode data.

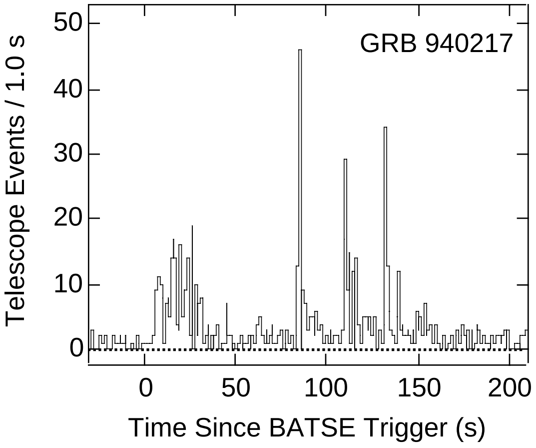

Figure 2: Time of history of GRB940217 based on telescope-mode data.

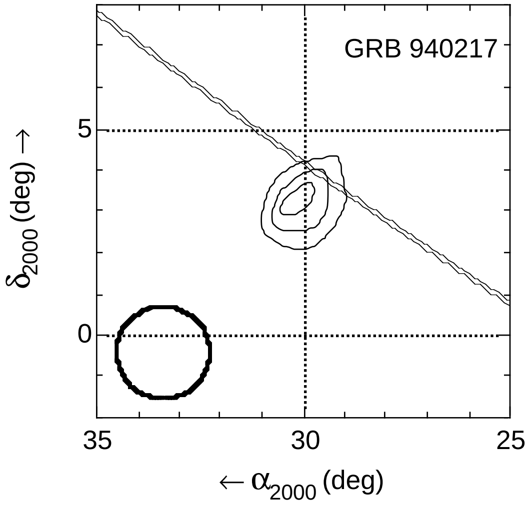

Figure 3: Location contours for GRB940217 derived from telescope-mode data with IPN localization.

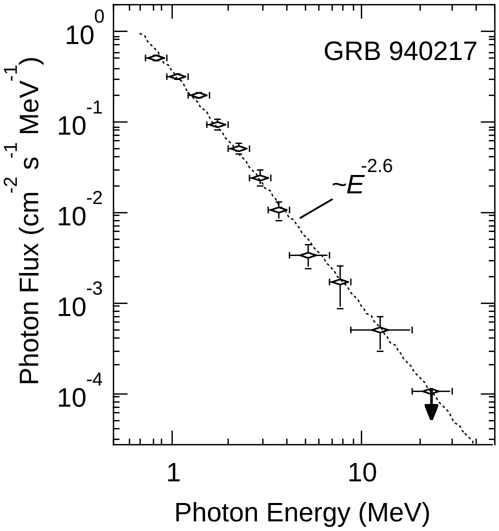

Figure 4: Photon spectrum of GRB 940217 derived from telescope mode data.

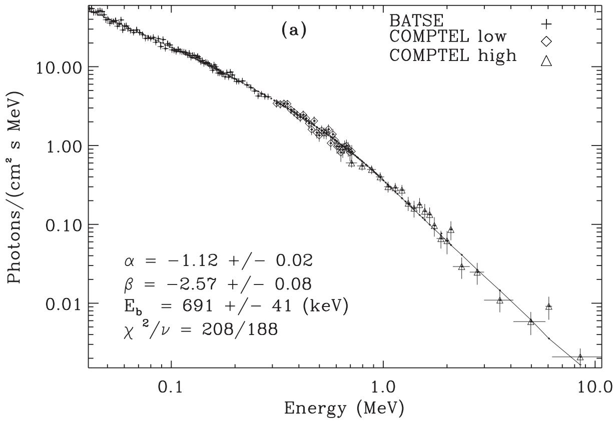

Figure5: Photon spectrum of GRB 940217 derived from low- and high-range burst mode data.

SUMMARY OF PREVIOUS CGRO WORK

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University of New Hampshire

Approved CGRO Guest Investigations

Phase 3	"COMPTEL Observations of X-Ray Binaries"
Phase 3	"Investigation of BATSE Sensitivity to Polarized Radiation"
Cycle 4	"COMPTEL Observations of X-Ray Binaries"
Cycle 5	"COMPTEL Observations of Cygnus X-1"
Cycle 5	"Search for Nuclear Line Emission from Accreting Binaries"
Cycle 5	"BATSE Albedo Polarimetry of Gamma-Ray Bursts and Solar Flares"
Cycle 6	"Quiescent Solar Gamma-Ray and Neutron Emission"
Cycle 7	"Exploring the Gamma-Ray Sky at 2.2 MeV"
Cycle 7	"COMPTEL Observations of Soft X-Ray Transients"
Cycle 8	"Broad Band Gamma-Ray Spectra of Cygnus X-1"
Cycle 8	"COMPTEL Studies of Gamma-Ray Bursts at MeV Energies"
Cycle 8	"COMPTEL Observations of X-Ray Transients"
Cycle 8	"CGRO Observations of the 2.2 MeV Source Candidate RE J0317-853"

Partial list of CGRO-Related Publications :

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