Final Report

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This grant was composed of two separate Compton Observatory guest investigations (A and B below). The most effort was given to investigation A to reflect the allocated funding.

A) Compton GRO Cycle 7 Guest Investigation: *Probing the Small-Scale Angular Distribution of Gamma-Ray Bursts with Combined BATSE/Ulysses Burst Locations*

The goals of this project were to use the improved location accuracy of combined BATSE/Ulysses-IPN gamma-ray burst (GRB) data to search for small-angle clustering within the burst population and to search for possible correlations between bursts and catalogs of known astrophysical objects.

The research was completed in several phases, due to the length of time needed to process the basic BATSE/Ulysses data and to develop the appropriate analysis algorithms. In the first phase, BATSE/Ulysses data were gathered from their respective sources and processed to yield final BATSE burst catalog locations and final BATSE/Ulysses IPN timing annuli. The final data are published in [1] and [2]. In the next phase, traditional statistical analysis techniques were used to search a subset of the data for small-angle clustering and correlations, and to produce upper limits [3]. Next, the unique analysis techniques and software described in the proposal were developed and applied to the final set of data (corresponding to the 4B catalog). The final search [4] did not find any significant self-clustering or correlations with supernovae, AGN, or nearby galaxy clusters. The investigation ruled-out earlier findings that indicated (with marginal significance) such results, and provided stringent limits on the allowable fraction of bursts that are self-clustered and associated with selected known objects.

An added benefit of this research came in 1998, when it was suggested that some gamma-ray bursts may be associated with supernova (SN) explosions. We responded rapidly and applied the tools of this investigation to study this possibility [5]. Using combined BATSE/Ulysses data, we were able to completely rule out any association between bright bursts and known supernovae, thereby questioning the validity of any GRB/SN association. If a GRB/SN association exists, it must be only with a small fraction of weak bursts.

Published papers related to this investigation:

[1] Hurley, K., *et al.* 1998. "The *Ulysses* Supplement to the BATSE 4B Catalog of Cosmic Gamma-Ray Bursts." *Astrophys. J. Suppl. Ser.* **122**, 497.

[2] Hurley, K., *et al.* 1998. "The Ulysses Supplement to the BATSE 3B Catalog of Cosmic Gamma-Ray Bursts." *Astrophys. J. Suppl. Ser.* **120**, 399.

[3] Kippen, R. M., K. Hurley & G. N. Pendleton. 1998. "Preliminary Spatial Analysis of Combined BATSE/*Ulysses* Gamma-Ray Burst Locations." In AIP Conf. Proc. **428**, *Gamma-Ray Bursts: Fourth Huntsville Symposium*, eds. C. A. Meegan, R. D. Preece, & T. M. Koshut, (New York: AIP Press), 114.

[4] Kippen, R. M., Hurley, K., & Pendleton, G. N. 1999. "Probing the Small-Scale Angular Distribution of Gamma-Ray Bursts with Combined BATSE/Ulysses 4B Locations." *Astrophysical Lett. & Comm.* **38**, 729.

[5] Kippen, R. M., *et al.* 1998. "On the Association of Gamma-Ray Bursts with Supernovae." *Astrophys. J. Lett.* **506**, L27.

B) Compton GRO Cycle 7 Guest Investigation: *High-Energy Spectral and Temporal Constraints on Cosmological Gamma-Ray Bursts*

The goal of this project was to investigate the behavior of gamma-ray bursts at energies above 1 MeV, both in terms of average emission and time-resolved characteristics, using data from the Compton BATSE and COMPTEL instruments. While the allocated funding did not allow us to perform the full investigation, we were able, in combination with other efforts, to investigate the high-energy behavior through the analysis of burst spectral data from individual instruments.

The general findings of this research are that there is a smooth transition in burst spectra from the region measured by BATSE (<1 MeV), to that measured by COMPTEL (>1 MeV). However, the high-energy spectral indices measured with BATSE alone tend to be overly hard, compared with COMPTEL results. This effect appears to be purely instrumental in nature due to the fact that burst spectra often exhibit continuous roll over throughout the BATSE band-pass. Furthermore, the temporal evolution of high-energy photons appears to smoothly vary from low-energies to high energies, with the higher energies showing finer peaks. This behavior was successfully shown in the combined BATSE, COMPTEL, EGRET and OSSE analysis of GRB 990123 that was published in [5].

Published papers related to this investigation:

[1] Preece, R. D., *et al.* 1998. "BATSE Observations of Gamma-Ray Burst Spectra. IV. Time-resolved High-Energy Spectroscopy." *Astrophys. J.* **496**, 849.

[2] Schaefer, B. E., *et al.* 1998. "Gamma-Ray Burst Spectral Shapes from 2 keV to 500 MeV." *Astrophys. J.* **492**, 696.

[3] Connors, A., *et al.* 1998. "MeV Measurements of Gamma-Ray Bursts by CGRO-COMPTEL." In AIP Conf. Proc. **428**, *Gamma-Ray Bursts: Fourth Huntsville Symposium*, eds. C. A. Meegan, R. D. Preece, & T. M. Koshut, (New York: AIP Press), 344.

[4] Kippen, R. M., *et al.* 1998. "Characteristics of Gamma-Ray Bursts at MeV Energies Measured by COMPTEL." *Adv. Space Res.* **22** (7), 1097.

[5] Briggs, M. S., *et al.* 1999. "Observations of GRB 990123 by the Compton Gamma-Ray Observatory." *Astrophys. J.* **524**, 82.