Long Term Hard X-ray Monitoring of X-ray Bursters
Final Report (2/1/97 - 1/31/98)

submitted by:

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on behalf of:

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1 Introduction

This grant supported our analysis of BATSE occultation data on x-ray bursters and neutron star low mass x-ray binaries (LMXBs) from the Compton Gamma-ray Observatory carried out under observing cycle 6. The work carried out under this grant was closely related to our separate investigation (NAG5-3808) to develop a prototype BATSE imaging survey for faint transients. In this Final Report, we summarize the Scientific Objectives of this investigation of hard x-ray studies of bursters and the Results Achieved; and finally the Papers Published.

2 Scientific Objectives of the Research

Our objectives in the study of hard emission from bursters, which we have conducted jointly with MSFC and Columbia, have been to study:

1. *What is the relation between hard x-ray emission and spectral state for bursters ?.* Prior to BATSE, Ginga observations showed that the spectra of sources like 4U1608-52 became very hard with a power law type spectrum if the source was in a low state. Our objective was to followup on SIGMA studies which indicated this hard tail extended out to ~100 keV.

2. *What is the spectral break energy and is it different from that for black hole systems ?.* The presence of a hard x-ray spectral component could no longer be regarded as a unique signature of a black hole (BH)

3 Results Achieved

Considerable progress was achieved over the duration of this grant in our continuing study of hard x-ray emission from x-ray bursters and from faint x-ray transients. Our investigation makes use of occultation data from the BATSE experiment on the Compton Gamma Ray Observatory and is being carried out in collaboration with the BATSE team at the MSFC as well as (for this burster study) a group (Ford, Kaaret and Tavani) at Columbia.

We have shown that x-ray burst sources, or low mass x-ray binaries (LMXBs) containing a neutron star accreting from a low mass companion, can be relatively intense hard x-ray (20-200 keV) sources when their accretion rate is relatively low. This work follows up, and extends significantly, earlier work conducted with the French/Russian SIGMA telescope on the GRANAT Observatory by Didier Barret, the post-doctoral fellow supported (in part) on this grant at Harvard. Our analysis of BATSE data on x-ray bursters has been carried out primarily by Barret and also by graduate student Peter Bloser, who has also received partial support from this grant.

We have achieved a number of our original objectives, although of course considerable followup work remains:

1. We have shown that x-ray bursters do indeed have significant hard x-ray emission, thereby confirming and greatly extending the SIGMA results. In particular we have demonstrated that the bursters 4U1608-52 and 4U0614+09 have hard x-ray spectra extending out to break energies of $\sim$50-70 keV and flux significantly (anti-)correlated with their soft x-ray emission.

2. We have shown that ultra-compact systems, 4U1820-30 (11 min binary) and 4U1916-05 (50 min binary) are not strong hard x-ray emitters. They were not detected in either our BATSE or OSSE studies, whereas particularly for 4U1916-05 the luminosity similarity to 4U0614+09 would suggest it should have been. The implications for the hard x-ray source emission region in bursters is an interesting project for followup investigation.

Our burster studies have been conducted in collaboration with the Columbia group (E. Ford, P. Kaaret and M. Tavani). The collaborative effort carried out under this grant has focussed on the study of the 4U0614+09 system, for which we found the BATSE hard x-ray emission was significantly anti-correlated with the RXTE medium x-ray flux. Later work on this source (cycle 6) has focussed on QPOs and will be described in reports for the activity carried out in cycle 6 under the new grant.

4 Papers Published

Although much of the work from this grant is being carried on into cycle 6 under the followup grant, and more is proposed for cycle 7, the NAG5-2763 grant activity for cycles 4-5 (and

part of 6) has resulted in a number of publications. Below we list the papers published, all in refereed publications, for the burster work and then the faint transients survey work.

Following are papers on our study of x-ray bursters which report results achieved in this study:

1. "BATSE Observations of Hard X-ray Emission from X-ray Bursters", D. Barret, J. Grindlay, P. Bloser, S. Zhang, G. Fishman, B. Harmon, W. Paciesas, P. Kaaret, M. Tavani, and E. Ford, *Astronomy and Astrophysics, Supplement Series*, 120:121-127 (1996).

2. "BATSE Observations of Two X-ray Bursters: 4U1820-30 and 4U1915-05", P. Bloser, D. Barret, J. Grindlay, S. Zhang, B. Harmon, G. Fishman, W. Paciesas, E. Ford, P. Kaaret, M. Tavani *Astronomy and Astrophysics, Supplement Series*, 120: 275-278 (1996).

3. "Low State Hard X-ray Outburst from the X-ray Burster 4U1608-522 Observed by BATSE/CGRO", S. Zhang, B. Harmon, W. Paciesas, G. Fishman, J. Grindlay, D. Barret, M. Tavani, P. Kaaret, P. Bloser, E. Ford and L. Titarchuk, *Astronomy and Astrophysics, Supplement Series*, 120: 279-282 (1996).

4. "Anticorrelated hard/soft x-ray emission from the x-ray burster 4u 0614+091", E. Ford, P. Kaaret, M. Tavani, B. A. Harmon, S. N. Zhang, D. Barret, J. Grindlay, P. Bloser, and R. A. Remillard, *Astrophysical Journal Letters*, 469:L37–+, (1996).

5. "Luminosity Differences Between Black Holes and Neutron Stars", D. Barret, J.E. McClintock and J.E. Grindlay, *Astrophysical Journal*, volume 463, pages 963-990 (1996).

6. "Energy Spectra and High-Frequency Oscillations in 4U0614+091", E. Ford, P. Kaaret, K. Chen, M. Tavani, D. Barret, P. Bloser, J. Grindlay, B. Harmon, W. Paciesas, and S. Zhang, *Astrophysical Journal Letters*, volume 486, pages L47-L51 (1997).

7. "KHZ QPO and X-ray Bursts in 4U1608-52 in Low Intensity State", W. Yu, S. Zhang, B. Harmon, W. Paciesas, C. Robinson, J. Grindlay, P. Bloser, D. Barret, E. Ford, M. Tavani, and P. Kaaret, *Proc. 4th Compton Symposium*, in press (1997).