1.0 INTRODUCTION

The X-Ray Transients (XRTs) represent a class of sources which flare up in brightness on a time scale of a few days and remain visible at hard X-ray energies for anywhere from several weeks to several months. They are generally believed to result from emission originating in an accreting black hole or neutron star system. Although observations with CGRO have provided a wealth of new information about the hard X-ray spectra of these sources, observations of spectra near 1 MeV are limited. Based on our experience with Cyg X-1, such observations would be valuable in our efforts to understand the high energy spectrum. Even one single significant datapoint near 1 MeV, when combined with lower energy data, could prove useful (as in the case of GRO J0422+32). COMPTEL is capable of providing such data. Unfortunately, past observations of XRTs with COMPTEL are limited in number, and individual observations have often been so limited in exposure that no detection was possible. *We propose to obtain long exposure observations with COMPTEL of any new XRT which becomes visible during cycle 7 and which is likely to be detected by COMPTEL.* Information provided by COMPTEL images may also be useful in the reduction of data from other instruments (such as BATSE and OSSE), especially at energies near 1 MeV.

Although X-Ray Transients (XRTs) were well-known before CGRO, the observations provided by CGRO has greatly improved our understanding of these sources. Several have been first detected by BATSE and there have been numerous ocassions in which a target-of-opportunity (ToO) has been declared to allow one or more of the other CGRO instruments to observe the source. Soft X-ray transients that have been observed by CGRO include GRS 1124-68 (e.g., Harmon et al. 1994b), GX 339-4 (e.g., Harmon et al. 1994a,b; Grabelsky et al. 1995), 4U 1543-47 (e.g., Levinson and Mattox 1996), GRS 1915+105 (e.g., Paciesas et al. 1996), 4U 1630-47 (e.g., Bloser et al. 1996), GRO J0422+32 (e.g., van Dijk et al. 1995; Levinson and Mattox 1996), GRS 1009-45 (e.g., Kroeger et al. 1993), GRS 1716-249 (e.g., Harmon et al. 1994b), and GRO J1655-40 (e.g., Kroeger et al. 1996; Levinson and Mattox 1996). At least five of these sources (4U 1543-47, GRO J0422+32, GRS 1009-45, GX 339-4, GRO J1655-40, and GRS 1915+105) were declared targets-of-opportunity (ToO), prompting a re-orientation of CGRO to permit observations by the pointed instruments on CGRO. Unfortunately, these re-orientations did not always result in the repositioning of the z-axis of CGRO (the pointing axis of COMPTEL). In many cases, CGRO was reoriented *about* the z-axis to permit observations by OSSE, leaving COMPTEL unable to observe the transient source.

2.0 SCIENTIFIC BACKGROUND

Here we are intersted in those sources involving accretion onto either a black hole or a low magnetic field neutron star. These objects are more likely to be observable with COMPTEL. High magnetic field neutron stars, for example, would contain disrupted accretion flows which may limit the amount of energy released from the system. Therefore, we shall not consider the class of objects (such as GRO J1744-28) commonly referred to as transient X-ray pulsars. This selection implies so-called soft X-ray transients (e.g., Tanaka and Shibazaki 1996), a characterization based on the spectrum of 1–10 keV X-rays. Since the outburst spectra of these sources closely resembles those from persistent LMXBs, these sources are usually associated with LMXBs. In a typical outburst, these sources increase in observed 1-10 keV luminosity by four orders of magnitude, with rise times on the order of a few days. This is followed by decay with time scales which vary from weeks to months. Secondary maxima are often seen.

Soft X-ray transients can be further sub-divided into neutron star and black hole systems. Definitive evidence for neutron star systems is the appearance of X-ray bursts, which are believed to result from thermonuclear flashes on the surface of the neutron star. The spectra of neutron star sources consists of a blackbody component (presumbaly originating in a neutron star envelope) and a soft component (presumably from an optically-thick accretion disk). Spectrally, black hole systems are usually distinguished by the lack of a blackbody component, a softer disk component (hence, the term “ultra-soft transient”) and a hard power-law component. Dynamical studies of XRTs have identified nine black hole candidates, seven of which exhibit spectra of the ultra-soft variety. Observations with OSSE have demonstrated evidence for two distinct spectral classes of black hole transients based on the form of the spectra at energies above ~50 keV (Grove, Kroeger and Strickman 1996). One class (corresponding to the traditional “X-ray high” state) exhibits a single continuous power law out to the limit of detectability (>200 keV), with peak luminosity below 10 keV. A second class (corresponding to the traditional “X-ray low” state) exhibits exponentially breaking spectra, with peak luminosity around 100 keV. These states have also been termed the γ-ray low and high states, respectively by Grove, Kroeger and Strickman (1996). It has been suggested that these two classes correspond to two distinct Comptonization mechanisms (Ebisawa, Titarchuk and

Chakrabarti 1996). Such bispectral forms are also exhibited by Cyg X-1. Of particular interest is the nature of the spectrum at energies near 1 MeV. COMPTEL observations of Cyg X-1 in the X-ray low state have demonstrated that standard thermal Comptonization models are not adequate to explain the emisson above several hundred keV. Several models have been proposed to explain this high energy tail, but so far the data are too limited to reach a final consensus as to its origin. Observations of other similar sources would certainly be useful in this regard.

Several questions related to these systems could be addressed by further observations with COMPTEL. Are high energy γ-ray tails a general feature of soft XRTs in the γ-ray high state? If so, what is the precise nature of this spectral form? How far does the power law spectrum extend for those sources in the low γ-ray state? Do the high energy spectra of superluminal XRTs (GRS 1915+105 and GRO J1655-40) differ significantly from other XRTs? In particular, do superluminal XRTs bear any spectral similarity at MeV energies to their big cousins, the AGN sources? Observations with COMPTEL can also address the issue of nuclear line emissions. Line emission may be expected from nuclear excitations in the accreting plasma (e.g., Higdon and Lingenfelter 1977), from nuclear reactions on a neutron star surface (e.g., Bildsten, Salpeter and Wasserman 1992), or from neutron capture processes (e.g., Guessom and Dermer 1988; Vestrand 1989).

3.0 PREVIOUS COMPTEL OBSERVATIONS

We use COMPTEL observations of Cyg X-1 and GRO J0422+32 as indicators of the type of spectra that may be observable from XRTs. Both of these are considered to be black hole candidates. Cyg X-1 is, however, a persistent HMXB source. GRO J0422+32 (Nova Persei) is the only XRT so far detected with certainty by COMPTEL. Both appear to exhibit similar spectra (i.e., both exhbit breaking spectra characteristic of the high γ-ray state).

Cygnus X-1. The COMPTEL results on Cyg X-1 (e.g., McConnell et al. 1997) show clear evidence for emission extending out to at least 2 MeV. The spectrum appears inconsistent with the extrapolation of thermal Comptonization models that can describe the lower energy continuum; it may be more consistent with models involving a Compton reflection component (Haardt et al. 1993; Wilms et al. 1996), thermal stratification (e.g., Skibo and Dermer 1995; Ling et al. 1997), or some type of stochastic acceleration process (e.g., Li et al. 1996) *Precise spectral measurements out to at least 1 MeV will be required to determine the nature of this γ-ray tail.* The latest COMPTEL spectrum is shown along with contemporaneous BATSE-EBOP and OSSE data in Figure 1. This comparison demonstrates an inherent difficulty in precisely determining the shape of the spectrum near 1 MeV. In particular, the BATSE-EBOP data shows a clear trend towards higher flux levels, while the OSSE spectrum shows a clear trend toward lower flux levels. We are presently investigating the possibility that both trends (especially near 1 MeV) may be due to the presence of additional sources of emission in the Cygnus region. The COMPTEL analysis, for example, requires spatial modeling of several features in order to obtain a reliable spectrum. The emission in the region can be modeled either as a collection of (two or three) point sources or as a distribution which follows the general gas distribution within the galaxy. In either case, such emissions may have an impact on the spectra derived from both BATSE and OSSE data. For example, the BATSE spectrum is derived without regard for the galactic diffuse emission. Any such emission, if present, would be included in the derived spectrum for Cyg X-1. Hence, the derived BATSE spectrum would tend to show *higher* flux levels. Likewise, the OSSE background subtraction process (on-source / off-

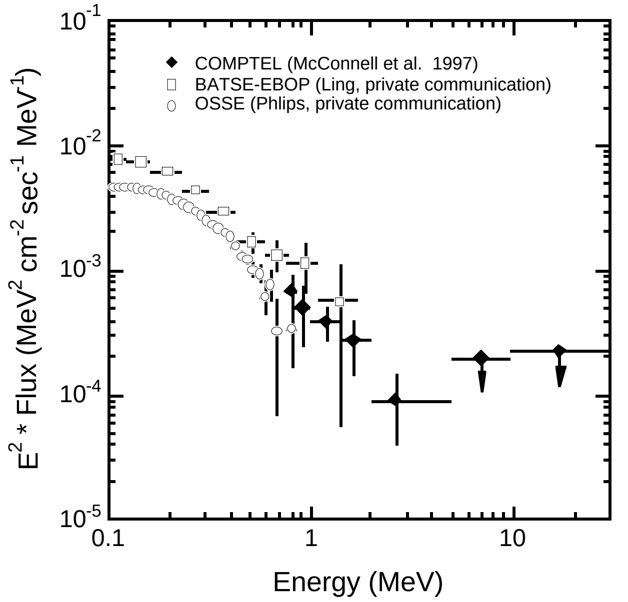

Figure 1. Contemporaneous spectra of Cyg X-1 obtained with COMPTEL, BATSE-EBOP and OSSE. Additional upper limits from OSSE data (at energies above 1 MeV) have been removed for the sake of clarity.

source) would result in a background level that would be too high, leading to a *reduced* flux level in the derived Cyg X-1 spectrum. This type of trend is precisely what we observe. Whether or not it can explain the observed trends quantitatively (particularly near 1 MeV) is currently being investigated. The importance of this result for future observations of γ–ray transients (especially those near the galactic plane) is that observations with COMPTEL can be used to map out the spatial structure of emission near 1 MeV and to more precisely pin down the 1 MeV flux level. *It may be that accurate spectral measurements near 1 MeV will require knowledge of the spatial distribution of the emission, information which only COMPTEL can easily provide.*

GRO J0422+32 (Nova Persei 1992). This source was first discovered by BATSE on 5-Aug-1992. The 20–300 keV intensity reached a value of ~3 Crab within a few days, remaining at that level for 3 days, after which it decayed exponentially with a decay time of ~41 days. COMPTEL observations lasted from Aug 11–20 (VP 36.0 and VP 36.5) and then again from Sep 1–17 (VP 39.0), providing some of the best COMPTEL data on any X-ray transient to-date. Analysis of these data led to a positive detection in the 1–2 MeV energy band (van Dijk et al. 1995). Comparison with low energy data (Figure 2) shows that the COMPTEL flux measurement suggests a hardening of the spectrum near 1 MeV. This is very reminiscient of the spectrum of Cyg X-1, suggesting a high degree of similarity between these two black hole sources. Indeed, the observed flux levels at 100 keV and at 1 MeV were very similar to that of Cyg X-1.

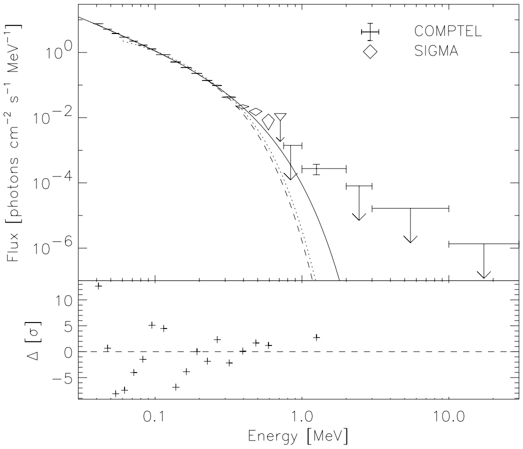

Figure 2. The COMPTEL spectrum of GRO J0422+32 as compared with SIGMA datapoints and with extrapolated fits to both SIGMA (dashedline) and OSSE (dotted line). The solid line represents a combined fit to the SIGMA and COMPTEL data.

Other Transient Sources. At least four other transient sources have been observed during outburst by COMPTEL. These include GX 339-4, GRO J1009-45, GRO J1655-40 and GRS 1915+05. In no case have significant fluxes been detected. However, these sources are generally located in regions where there is considerable spatial structure in the COMPTEL images and, in most cases, the COMPTEL exposures were limited. There remains several on-going efforts to analyze these data. (There is some limited evidence in the COMPTEL data for both GX 339-4 and GRO J1655-40, but these detections have so far been difficult to verify due to the complex spatial structure in these regions.)

4.0 PROPOSED PLANS FOR CYCLE 7

During cycle 7 we propose to obtain COMPTEL target-of-opportunity (ToO) observations of any transient source which, based on available hard X-ray data, is likely to be detected. In particular, we define a threshold of 1.0 Crab at 100 keV for a transient with an exponential-type spectrum and 0.5 Crab at 100 keV for a transient with a power-law-type spectrum. The spectra in Figure 3 demonstrate that a lower trigger threshold for power-law type sources is justified. *We further propose that such an observation last a minimum of 3 weeks, with the option of a longer observation based on whether the source remains above the corresponding threshold level.* In the past, competition for observatory time has prevented extended observations by COMPTEL. This is unfortunate, since a 1–2 week measurement of Cyg X-1 is usually required to obtain a significant spectral measurement. During cycle 7, COMPTEL sensitivity is expected to be reduced by the recent increase in instrumental background resulting from the recent orbital re-boost. Exposure time will therefore be an even more critical issue. During such a ToO, a copy of the COMPTEL data would be sent directly to UNH for quick-look analysis within 1-2 days of data acquisition. The results from such a quick-look analysis could then be used to judge the need for an extended observation.

In order to maximize the return of data at low energies, we propose to investigate placing COMPTEL in a ‘low-threshold’ mode during XRT observations. The XRT spectra tend to be quite soft and we would therefore like to extend the COMPTEL detection efficiencies to as low an energy as is practical (while retaining reasonable sensitivity to possible line emission). For standard COMPTEL data analysis, we specify a uniform set of software thresholds in both the upper and lower detector layers (70 keV and 650 keV, respectively) and for the sum energy (750 keV). In many cases, however, the hardware thresholds are actually much lower. *Additional data at lower energies would be available if both the software and hardware thresholds were to be lowered.* Specially generated

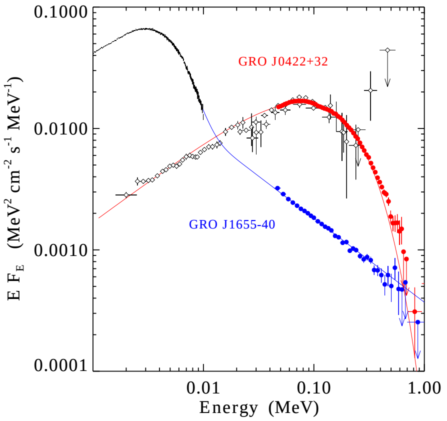

Figure 3: Spectra of GRO J0422+32 and J1655-40 showing the two different classes of black hole transient spectra. Note that the flux levels at 100 keV differ by an order of magnitude for the same flux level at 1 MeV.

PSFs would be required due to the wide range of thresholds, but these can be generated using available software (COMPASS). Despite the fact that the COMPTEL efficiency falls off at low energies, a preliminary study suggests that significant sensitivity would still be available at energies down to 620 keV (see GI proposal by R. van Dijk). The exact nature of this low threshold mode may depend on the outcome of an on-going reconfiguration of COMPTEL resulting from the higher orbital background introduced by the recent CGRO re-boost.

In addition to new observations, *we also propose to revisit the analysis of archival data of XRTs*. Of particular interest are the data for GX 339-4, GRO J1655-40 and GRS 1915+105. All of these sources lie in the galactic plane, in regions where there is considerable spatial structure in the emission. COMPTEL analysis methods have now improved to the point where a re-analysis of these data may prove fruitful and where we can expect more efficient analysis of future events.

The experience to-date has also made clear that contemporaneous data from other CGRO experiments can be very valuable. Joint OSSE-COMPTEL observations permit high sensitivity observations of select sources from about 50 keV up to well beyond 1 MeV. We therefore propose joint interpretation of COMPTEL and OSSE results should the opportunity for such interpretation arise and be judged advantageous by both teams.

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SUMMARY OF PREVIOUS CGRO WORK (M. McConnell)

The PI has been an active co-investigator on the CGRO-COMPTEL instrument team since 1987. He has participated in the pre-flight calibration activities, the analysis of the pre-flight calibration data, and the development of software (with the COMPTEL-COMPASS analysis system) for COMPTEL data analysis. His scientific activities with COMPTEL data have been focused largely on X-ray binary systems (especially Cygnus X-1) and solar studies. On-going CGRO-related activities in which he plays a significant role include:

- Continued analysis of Cyg X-1 data from COMPTEL and comparison with other CGRO instruments. The latest results were recently presented at the 4th Compton Symposium and are being prepared for publication in the conference proceedings. A journal publication regarding the full set of Cygnus data from phases 1-3 currently in preparation.

- Mapping of the full sky at 2.2 MeV using data from COMPTEL. This includes efforts to improve the modeling of the COMPTEL background. Evidence has recently emerged for a potential point source of emission at this energy. The latest results were recently presented at the 4th Compton Symposium and are being prepared for publication in the conference proceedings. A proceedings paper has also been submitted for the upcoming ICRC. A journal publication is currently in preparation.

- Analysis of COMPTEL solar data, integrating over all available observations to search for emission from the quiet-time sun. This work has established upper limits for several different energy bands, some of which place constraints on certain models for coronal heating. The latest results were presented at a recent meeting of the AGU and will also be presented at the upcoming meeting of the AAS Solar Physics Division. A proceedings paper has also been submitted for the upcoming ICRC. This work is related to a GI program proposed for Cycle 6.

- Analysis of COMPTEL data pertaining to X-ray transients. Quick-look analysis of COMPTEL ToO data is performed at UNH for any declared targets-of-opportunity. This represents part of a CGRO-wide effort related to past GI proposals (PI - R. Kroeger).

- A study involving an effort to search for evidence of polarization in solar flares and in gamma-ray bursts using data from BATSE. Simulations of the albedo flux from such events have been used to estimate the BATSE sensitivity to polarization. Two related proceedings papers (one for the High Energy Solar Workshop and one for the most recent Huntsville Gamma Ray Burst Workshop) have been published within the past year. This is related to GI programs funded in Phase 3 and Cycle 5.

Approved CGRO Guest Investigations (PI - M. McConnell)

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”

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