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 8 and which is likely to be detected by COMPTEL.*

Although X-Ray Transients (XRTs) were well-known before CGRO, the observations provided by CGRO have 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), 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 et al. 1997, 1998). One class (corresponding to the traditional soft 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 soft 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 (Grove et al. 1997, 1998), respectively. 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, so far, the best case for the detection of an XRT 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 is 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; Crider et al. 1997; Moskalenko et al. 1998) *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.

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.

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. There remains several on-going efforts to analyze these data. Recently, Iyudin et al. (1998) have found evidence for emission from the superluminal sources GRO J1655-40 and GRS 1915+05, the emission being correlated with the radio outbursts. In addition, there is some evidence in the COMPTEL data for GX 339-4. All of these detections, however, are hampered by the presence of the galactic diffuse emision and the resulting complex spatial structure in these regions.

4.0 PROPOSED PLANS FOR CYCLE 8

During cycle 8 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 any ToO declared during cycle 8, a quick-look analysis of the COMPTEL data could be performed 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 addition to new observations, *we also propose to continue 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. Nonetheless, all three of these sources have shown at least some evidence for emission in the COMPTEL data (e.g., Iyudin et al. 1998). COMPTEL analysis methods continue to improve and there is potential for a corresponding improvement in the anlaysis of these sources.

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.

The proposed funding level of $15,000 will be used to support the analysis of COMPTEL data and to prepare publications resulting from these observations.

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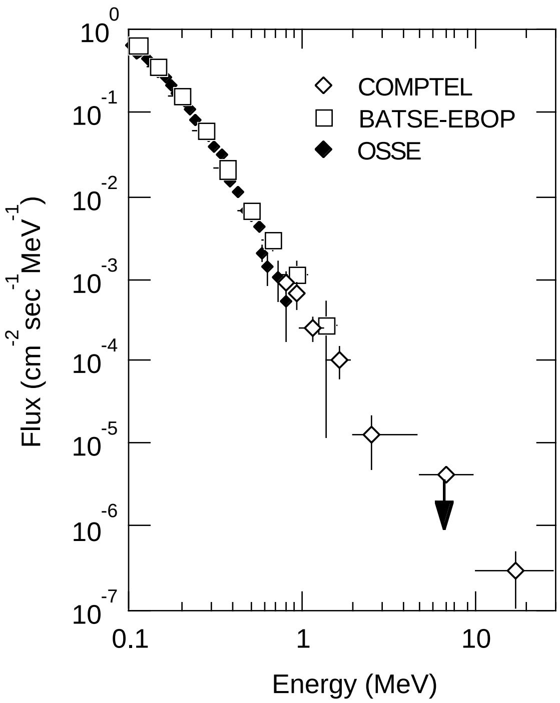

Figure 1 : Spectrum of Cyg X-1 as compiled from CGRO observations. OSSE data points above 900 keV (mostly upper limits) are excluded for clarity.

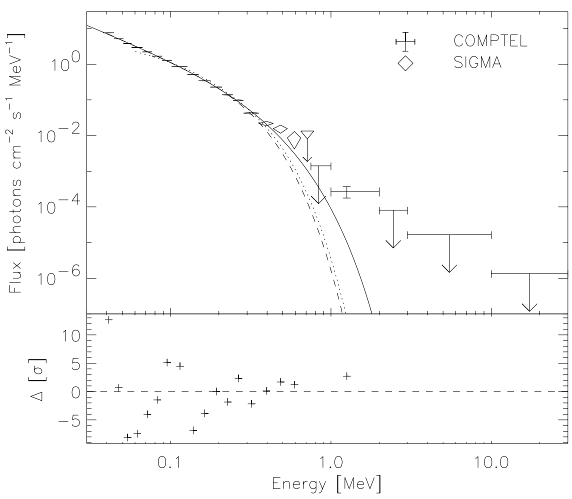

Figure 2. The COMPTEL spectrum of GRO J0422+32 as compared with SIGMA datapoints and with extrapolated fits to both SIGMA (dashedline) and OSSE (dotted line). The solid line represents a combined fit to the SIGMA and COMPTEL data.

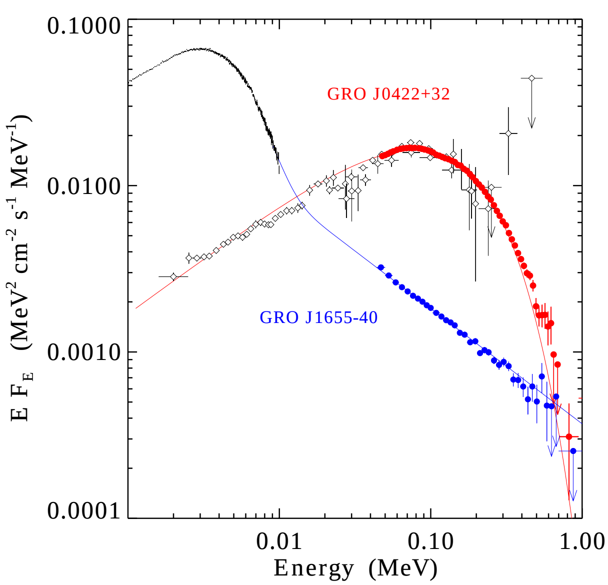

Figure 3: Spectra of GRO J0422+32 and J1655-40 showing the two different classes of black hole transient spectra. Note that the flux levels at 100 keV differ by an order of magnitude for the same flux level at 1 MeV.