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LATEST COMPTEL RESULTS ON GALACTIC BLACK HOLE CANDIDATES

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ABSTRACT

Since its launch in April of 1991, the *COMPTEL* experiment on the *Compton Gamma-Ray Observatory* has surveyed the entire sky in the energy range of 0.75 – 30.0 MeV. Here we survey the latest results obtained from the *COMPTEL* data with respect to galactic black hole candidates. The most prominent such object, Cygnus X-1, is also one of the brightest sources observed by *COMPTEL*. In addition, we report on the progress of a full survey of the sky, searching for evidence of MeV emission from other black hole candidates.

INTRODUCTION

The *COMPTEL* instrument was designed to image celestial γ -rays in the energy range of 0.75 – 30.0 MeV. With a field-of-view of ~ 1 steradian, *COMPTEL* is capable of imaging a large part of the γ -ray sky at any given time with a point source location accuracy of typically $\sim 1^\circ$. A more detailed description of the experiment can be found in Schönfelder et al. /1/.

CYGNUS X-1

The black hole candidate Cygnus X-1 is one of the strongest sources observed by *COMPTEL*. During the 3 years of the *CGRO* mission, it has been observed several times within the field-of-view of *COMPTEL*. Previously we have reported on the results of the analysis of data obtained during the first year of the *CGRO* mission /2/. These data indicated that: 1) there was no evidence for any hardening of the spectrum in the region near 1 MeV; and 2) the plasma temperature suggested by a Wien spectral model (the high energy limit of the Sunyaev-Titarchuk Comptonization model) was much higher than that generally implied by hard X-ray observations. This latter conclusion seems to require a revision in the standard spectral model for Cygnus X-1. In particular, it would suggest either a limitation in the standard Comptonization model or the need to incorporate a backscatter component resulting from the scattering of hard X-rays off a cooler (optically-thick) component of the accretion flow.

We have continued our analysis of Cygnus X-1, incorporating new observations as they become available. The latest analysis of Cygnus X-1 now incorporates all observations through February, 1994. The most recent of these observations (Viewing Period 318.1) was a target-of-opportunity observation of Cygnus X-1, prompted by an extremely low state of hard X-ray emission /3/. No positive detection was made by *COMPTEL* during this observation, despite a favorable exposure.

A summary of the observations used in the present analysis is given in Table 1, which also includes the average 0.75 – 2.0 MeV flux for each observation period. These data show that, although there are variations in the measured flux near 1 MeV (by more than a factor of two), these variations are not statistically significant. (We note that this is contrary to an earlier analysis, which had

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Viewing Period	Start Date	End Date	Viewing Angle	0.75-2.0 MeV Flux ($\text{cm}^{-2}\text{s}^{-1}\text{MeV}^{-1}$)
2.0	30-May-1991	8-Jun-1991	2°	$3.3(\pm 1.0) \times 10^{-4}$
7.0	8-Aug-1991	15-Aug-1991	11°	$5.1(\pm 1.4) \times 10^{-4}$
203	1-Dec-1992	22-Dec-1992	7°	$2.7(\pm 0.7) \times 10^{-4}$
212.0	9-Mar-1993	23-Mar-1993	15°	$2.9(\pm 0.9) \times 10^{-4}$
302.0	7-Sep-1993	9-Sep-1993	18°	
303.2	22-Sep-1993	1-Oct-1993	18°	
303.7	17-Oct-1993	19-Oct-1993	18°	
302-303				$2.3(\pm 1.2) \times 10^{-4}$
318.1	1-Feb-1994	8-Feb-1994	5°	$2.9(\pm 1.7) \times 10^{-4}$

Table 1: Summary of Cygnus X-1 observations used in the present analysis.

indicated that the variations were significant [2/.]

Figure 1 shows the average photon spectrum derived from all observations up through February, 1994. There is evidence for significant emission extending well above 2 MeV, with a data point in the 2-5 MeV range at a significance level of 4.4σ . (However, the observed flux near 1 MeV is still well below that reported by HEAO-3 and several other balloon observations [2/.] A fit to the *COMPTEL* data using a Wien spectrum gives an electron temperature value of $kT \sim 190$ keV. This is consistent with the temperature values which were derived from an earlier analysis of the *COMPTEL* data [4/]. Continuing observations (e.g., three more weeks of data collected in June, 1994) should permit an ever more accurate determination of the time-averaged spectrum near 1 MeV.

Figure 1: Average spectrum of Cygnus X-1 derived from all *COMPTEL* data collected through February, 1994 (Viewing Period 318.1). Also shown are representative spectra from both *HEAO-3* and *OSSE*.

OBSERVATIONS OF X-RAY TRANSIENTS

In order for sources to be observed by *COMPTEL*, they must lie within $\sim 30^\circ$ of the *CGRO* pointing direction. Therefore, unless a given X-ray transient happens to lie within the *COMPTEL* field-of-view, a Target-of-Opportunity is usually required in order for *COMPTEL* to obtain useful data. To date, only two such Targets-of-Opportunity have been declared. The first was for Nova Persei (GRO J0422+32), which was discovered by *BATSE* in August of 1991. More than 3 weeks of data was obtained by *COMPTEL* within two months of the onset of the event. Preliminary results have been previously reported /4/. These data show evidence for emission in both the 0.75-1.0 MeV and 1-2 MeV energy intervals with some evidence for a hardening in the spectrum above 1 MeV. The second Target-of-Opportunity was that of GRO J1009-45. However, this observation lasted only about one day, so the *COMPTEL* exposure is quite poor. No emission was detected; the 2σ upper limits in the 0.75 – 1.0 MeV and the 1 – 3 MeV energy intervals are $1.5 \times 10^{-3} \text{ cm}^{-2} \text{ s}^{-1} \text{ MeV}^{-1}$ and $3.1 \times 10^{-4} \text{ cm}^{-2} \text{ s}^{-1} \text{ MeV}^{-1}$, respectively.

SYSTEMATIC SEARCH FOR OTHER BLACK HOLE CANDIDATES

The *COMPTEL* database (which covers the entire sky) affords the opportunity to search for emission from all known objects of a given class. We have therefore undertaken an effort to search for point sources which may be coincident with the known (or suspected) black hole candidates. For this purpose, we have generated a list of candidates based, in part, on that of Cowley [5].

Our initial work has concentrated on a search for time-averaged continuum emission using all of the data from phases 1 and 2 (the first 28 months) of the *CGRO* mission. Since this work is not yet completed, the results of this survey will be presented elsewhere. Here, in order to demonstrate the kind of results which are coming out of this study, we present two separate images of a wide field centered near Cygnus X-1. In both cases, we have plotted the locations of the known black-hole candidates within this field-of-view. (The plot symbols for each source are as follows: '+' = SS 433; '◇' = 1957+11; '△' = 2000+25; '□' = 2023+34.) The first image (Figure 2) shows the results we derive using a standard background analysis which is derived via a smoothing of the 3-dimensional *COMPTEL* dataspace /6/. The second image (Figure 3) incorporates a model which corresponds to the spatial distribution of molecular and atomic hydrogen (H_2 and HI , respectively) in the galaxy. The importance of modeling this diffuse galactic component at these energies is clear. Typical (2σ) upper limits for derived source fluxes in the 1 – 30 MeV interval are on the order of a few times $10^{-6} \text{ cm}^{-2} \text{ s}^{-1} \text{ MeV}^{-1}$.

Our future work will include the use of data from phase 3 and the search for phase-dependent emission from selected candidates. We have also begun a systematic search for 2.2 MeV line emission from X-ray binary systems. This is a bit more problematic due to a strong internally-generated 2.2 MeV background in *COMPTEL*. However, the origin of this background is well-known (neutron capture in the D1 detectors), and our recent efforts to model this background component appear quite promising.

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Figure 2: Image of the Cygnus region derived for 1-30 MeV energy range using a standard background analysis.

Figure 3: Same as in Figure 2, but with an additional background component which corresponds to the spatial distribution of diffuse emission in the galaxy.

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