Identification of the Periodic Hard X-Ray Transient GRO J1849–03 with the X-Ray Pulsar GS 1843-02 = X1845-024 - a New Be/X-Ray Binary

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ABSTRACT

We identify the periodic transient hard X-ray source GRO J1849–03 with the transient x-ray pulsar GS 1843-02 = X1845–024 based on the detection of x-ray outbursts from X1845-024 coincident with hard x-ray outbursts of GRO J1849–03. Based on its spin period of 94.8 s and its orbital period of 241 days, we classify the system as a Be/X-ray binary.

Subject headings: stars: emission-line, Be — pulsars: individual (GS 1843-02) — stars: neutron — X-rays: stars

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1. Identification of GRO J1849-03

GRO J1849-03 is a periodic transient hard x-ray source in the direction of the 5-kpc arm (Zhang et al. 1996). The source was discovered using the Burst And Transient Source Experiment (BATSE) on the Compton Gamma-Ray Observatory and shows recurrent hard x-ray (20–100 keV) outbursts with a period of 241 ± 1 days (Zhang et al. 1996). The source produced a hard x-ray outburst detected with BATSE in September 1996 lasting from MJD 50340 to MJD 50358 (Barret et al. 1996). The maximum of the outburst occurred near MJD 50347.

In an effort to determine an accurate position for GRO J1849-03, an observation was made with the Wide Field Camera (WFC) on the *Satellite Italiano per Astronomia X* (BeppoSAX) on 17-18 September 1996 (MJD 50343-50344). The observation was scheduled to occur during the predicted hard x-ray outburst. An integration of 7712 s was obtained in two spacecraft orbits. The data were analyzed using the standard WFC software (version 101-104) and sources were extracted using the Iterative Removal of Sources (IROS) software (Hammerslay 1986; in't Zand 1992). We chose to use a relatively hard band (5–21 keV) for the analysis since the x-ray sources in the 5-kpc arm have high column densities (Koyama et al. 1990a) and also since the BATSE detection of the source extends down only to 20 keV. No sources were detected within the 1σ BATSE error box above a flux of $1.4 \times 10^{-10}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ for the 5-21 keV band at 3σ confidence. Eleven sources were detected at high confidence in the WFC field of view. The only source detected near GRO J1849-03 is X1845-024 (Doxsey et al. 1977). The WFC source is within 3' of the known position of X1845-024; this is consistent with the position uncertainty from the WFC. The source flux is $(2.1 \pm 0.5) \times 10^{-10}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ for the 5-21 keV band. X1845-024 lies within 2σ of the BATSE position for GRO J1849-03 (Zhang et al. 1996) as shown in Fig. 1.

We produced a light curve for X1845-024, shown in Fig. 2, using the All-Sky Monitor (ASM) on the *Rossi X-ray Timing Explorer* (RXTE) to search for transient behavior similar to that observed from GRO J1849-03. The light curve was produced from the "definitive data products" provided by the ASM/RXTE teams at MIT and at the RXTE SOF and GOF at NASA's GSFC. Each point represents the ASM counting rate in the 5–12 keV band averaged over 4 days. Points with errors larger than 0.3 c/s have been suppressed for clarity. Inspection of the light curve (Fig. 2) shows two outburst events. The first starts on MJD 50342 and lasts until approximately MJD 50366. The peak occurs near MJD 50350-50354. This x-ray outburst coincides with the September 1996 outburst of GRO J1849-03 detected by BATSE. The main parts of the X1845-024 and the GRO J1849-03 outbursts overlap. A second outburst in the x-ray light curve of X1845-024 occured during the interval MJD 50589-50598 with the peak near MJD 50591-50594. Hard x-ray emission was detected with BATSE from the direction of X1845-024 over the interval MJD 50585-50597. The second outburst found in the ASM is approximately 240-243 days after the first. The period between outbursts matches the known period of GRO J1849-03 (Zhang et al. 1996).

Our WFC observation shows that X1845-024 is the only bright source within the 2σ error box for GRO J1849-03 near the time of the September outburst. The detection of two x-ray outbursts from X1845-024 simultaneous with hard x-ray outbursts detected by BATSE from GRO J1849-03 lead us to conclude that GRO J1849-03 and X1845-024 are the same object. The outburst of GS 1843-02 detected by Ginga (Koyama et al. 1990b) occurred at a time only 1σ away from the extrapolation of the BATSE ephemeris for GRO J1849-03 (Zhang et al. 1996). It is likely that GS 1843-02 is also X1845-024 (Makino et al. 1988).

The composite BATSE/ASM spectrum for the interval MJD 50331.5-50358.5 is adequately fit by a exponentially cutoff power law with a photon index of -1.4 ± 0.4, a cutoff energy of $42 \pm 25\,\mathrm{keV}$, and a column density of $2.5 \pm 1.0 \times 10^{23}\,\mathrm{cm^{-2}}$. These are consistent with the spectral parameters and column density found for GS 1843-02 (Koyama et al. 1990b). This lends support to the identification of GS 1843-02 and X1845-024.

We searched for pulsations with periods near 94.8 s in the WFC data. However, the results were inconclusive due to the weakness of the source and the presence of the bright and highly variable source GRS 1915+105 in the WFC field of view. We did not search for pulsations in the ASM data as the 94.8 s period is nearly commensurate with the 90 s duration of individual ASM dwells. Pulsations at the 94.8 s period of X1845-024 have not been detected from GRO J1849-03 except for a marginal detection during the latter part of one outburst (Zhang et al.

1996). However, the upper limit of 35% pulsed fraction in the 20–50 keV band is not strongly inconsistent with the 40% pulsed fraction observed by Ginga at lower energies (Koyama et al. 1990b).

2. The nature of X1845-024

GS 1843-02 is an x-ray pulsar with a pulse period of 94.8 s (Koyama et al. 1990a). Given the association of GRO J1849-03, GS 1843-02, and X1845-024, we can classify the system based on its pulse and orbital period via the method of Corbet (1986). We assume that the 241 day outburst recurrence time is the orbital period. Fig. 3 shows a plot of pulse versus orbital period for high-mass x-ray binaries, a 'Corbet diagram', indicating the position of X1845-024. The object clearly lies in the region of the diagram occupied by Be-star systems. The location of the source, coincident with the 5 kpc arm, lends some support to the Be-star binary identification, as IR observations of the region show that it contains a population of young stars (Hayakawa et al. 1981) with ages consistent with those estimated for Be/X-ray binaries (van den Heuvel & Rappaport 1987). If the source lies within the 5-kpc arm, at a distance of 10 kpc, the unabsorbed luminosity of the source during outburst is $6 \times 10^{36}\,\mathrm{erg\,s^{-1}}$. This is consistent with luminosities observed from long orbital period Be/X-ray binaries.

X1845-024 lies slightly below the main track of Be systems on the Corbet diagram. The observed correlation between spin and orbital periods of x-ray pulsars in Be-star binaries is believed to depend on the interaction between the neutron star magnetic field and the Be-star outflow. X1845-024 may have a relatively small value of the density vs. radius index (n between 3 and 3.25) and/or a low initial outflow velocity ($v_0 \leq 5\,\mathrm{km\,s^{-1}}$) compared to other Be systems (Waters & van Kerkwijk 1989). Since no centrifugal barrier is expected for a neutron star with a spin period of 94.8 s, the duration of x-ray outbursts should be directly related to the size or width of the Be-star equatorial outflow. Identification of the optical or IR companion of X1845-024 and a study of its mass outflow may help provide a better understanding of the spin and orbital period correlation.

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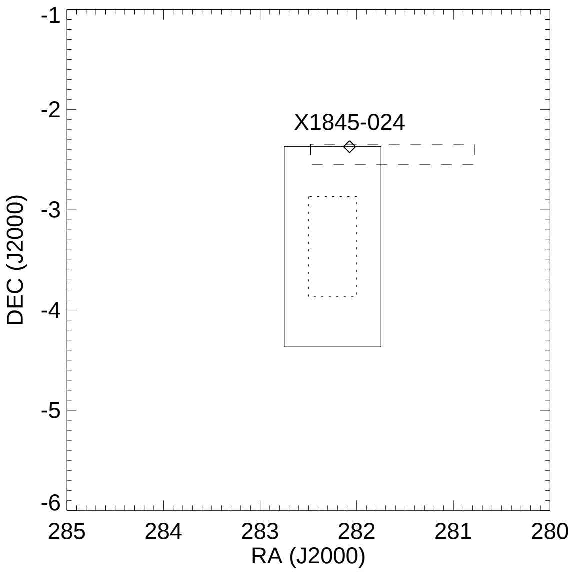

Fig. 1.— Sources near GRO J1849-03. The only source in this region detected with the WFC is X1845-024, shown as a diamond. The dotted square is the 1σ confidence error box for GRO J1849-03 and the solid square is the 2σ confidence error box (Zhang et al. 1996). The dashed square is the error box for GS 1843-02 (Koyama et al. 1990b).

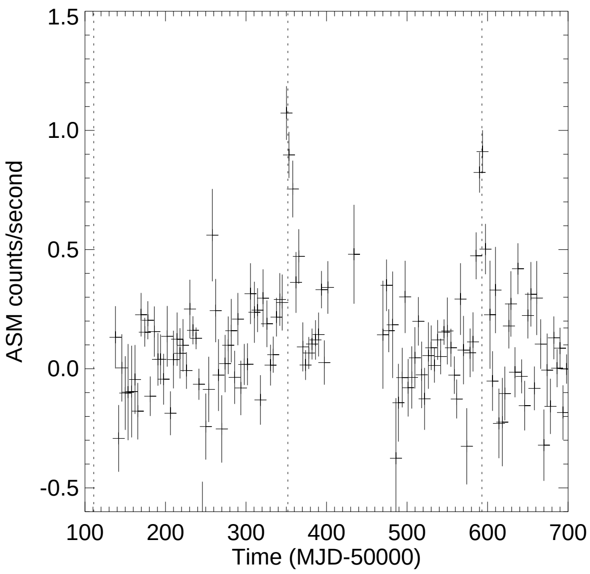

Fig. 2.— The x-ray (5–12 keV) light curve for X1845-024 from the ASM/RXTE. Each point represents an average over 4 days and points with errors larger than 0.3 c/s have been suppressed. The dotted lines show 241 day intervals and are drawn at MJD 50111, 50352, and 50593.

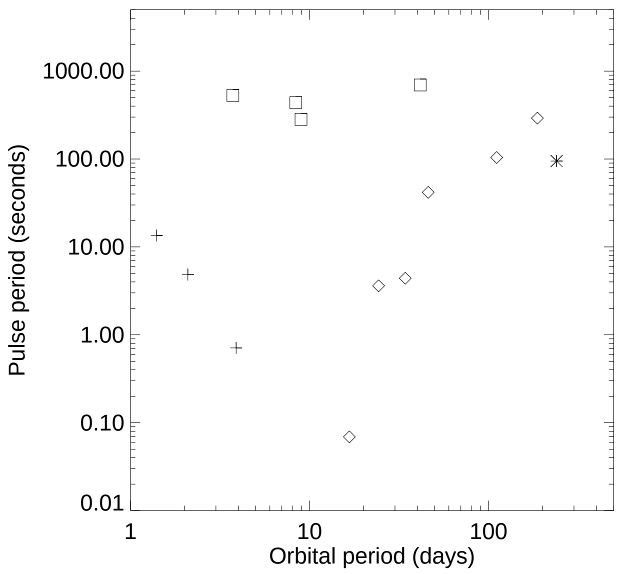

Fig. 3.— Spin period versus orbital period for various high mass x-ray pulsars (following Corbet 1986). Diamonds indicate Be primaries, boxes indicate supergiant primaries, crosses indicate likely Roche lobe filling primaries, and the asterisk is for X1845-024.