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COS-B X-RAY OBSERVATIONS OF CYG X-3; AN INDICATION FOR APSIDAL MOTION

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Results are presented of three ~ 40 d COS-B X-ray observations of Cyg X-3. The shape of the 4.8 h light curve showed variations on all observational time scales. An ~ 20 d periodicity was found in the arrival time of the minimum of the light curve, interpreted as apsidal motion of an orbit with an eccentricity of ~ 0.03 .

INTRODUCTION

The 4.8 h period of Cyg X-3 is slowly increasing (see van der Klis and Bonnet-Bidaud 1981 and references therein). Its X-ray light curve, smooth and asymmetric in shape, is probably mainly due to scattered radiation. Despite considerable cycle-to-cycle variability, it has shown no evidence of secular change during the ~ 10 years the source has been observed.

It has been proposed, that the asymmetric shape of the light curve is due to a highly eccentric orbit ($e \approx 0.1-0.6$). The suspected long term stability of the light curve shape would then imply an apsidal motion period of more than 22 y, which could explain part of the observed slow down as an apparent, long-periodic effect (Elsner et al. 1980).

The timing data obtained with the COS-B X-ray detector give an indication for a much shorter apsidal motion period, ~ 20 d, at an orbital eccentricity of ~ 0.03 . This would mean that the eccentricity is too small to cause the light curve asymmetry, and that the observed secular increase of the binary period is real.

RESULTS

The analysis of the COS-B data on Cyg X-3, consisting of three ~ 40 d observations, was discussed in Bonnet-Bidaud and van der Klis (1981). An example of the detected signal is given in Fig. 1. The shape of the light curve is quite variable; notice, however, that the minimum is relatively

Fig. 1. An example of the received signal. Time resolution ~ 200 s, one sigma counting statistics uncertainty per bin ~ 2 c/s. $1 \text{ COS-B c/s} \approx 2.9 \cdot 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}$ (2–12 keV, Crab spectrum).

undisturbed. Folding the data modulo the binary period, the shape of the resulting average light curve was not found to be invariable; in particular, during one ~ 30 d interval of high source intensity in 1980, the light curve was found to be systematically more symmetric than usual (Fig. 2). Again, the minimum was more constant in shape than the rest of the light curve.

Fig. 2. Folded light curves. Each curve is the average of ~ 100 binary cycles. Vertical scales are arbitrary, chosen to facilitate comparison of the shape of the curves. Notice the difference of curves with respect to template around maximum.

The relatively high shape stability of the light curve minimum made it possible to determine its arrival time to high accuracy. In this way a variation in the phase of the minimum was found, suggestive of a ~ 20 d periodicity (Fig. 3.). The phase shifts, with an amplitude of $\sim 2 \cdot 10^{-3}$ d, were not correlated to source intensity or light curve shape. They are compatible with a ~ 20 d apsidal motion of an orbit with $e \approx 0.03$ (see e.g. Batten 1973).

Fig. 3. Arrival times of the minimum of the light curve. Each point represents ~ 5 binary cycles. Drawn curve is best fit sinusoidal.

CONCLUSION

The light curve of Cyg X-3 has shown variations on all observational time scales. Therefore, care should be taken in determining detailed properties of the system from a specific observed light curve.

Clearly, further timing analysis of the light curve is essential. If the present results are confirmed, the detection of an apsidal motion effect in Cyg X-3 would:

- confirm the orbital nature of the 4.8 h period
- give tight constraints on the properties of the companion; an apsidal motion period as short as ~ 20 d implies a (nearly) Roche lobe filling companion star, i.e. a red dwarf, or maybe a helium star with an extended envelope
- supply a determination of the eccentricity of the binary orbit, of importance for the understanding of the (tidal) evolutionary history of the system
- establish the slow down of the orbital period as a real effect, containing information on the mass flow in the system; in particular, mass transfer from a red dwarf to a neutron star would be very difficult to reconcile with the magnitude of the observed slow down.

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