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Observation of X-ray binary Cygnus X-3 by Indian X-ray Astronomy Experiment

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Abstract. The X-ray binary Cygnus X-3 was observed with the Indian X-ray Astronomy Experiment (IXAE) on Board the Indian Remote Sensing Satellite IRS-P3 during July 3-13, 1999 and October 11-24, 1999 with total useful exposure time of 31244.64 seconds in 1 sec integration mode. The short and long time variability of this X-ray source has been studied. We have found the orbital period to be 17254.273 ± 0.890 seconds.

Key words : Cygnus X-3, binary system, orbital period, light curve, cross-correlation

1. Introduction

In 1966, R. Giaconni et al. discovered the x-ray binary Cygnus X-3 during an x-ray survey which was sensitive in the energy range 2-5 KeV. This is a bright x-ray binary system which is located in the galactic plane of our galaxy at a distance of greater than 12 kiloparsecs from the Sun (Dickey et al. 1983), having right accession of $20^h\ 30^m\ 52^s$ (1950) and declination of $40^\circ\ 56'$ (1950) (Giaconni et al. 1967). The nature of Cygnus X-3 is cause for much debate (Schmutz et al. 1996; Mitra et al. 1998). It is not yet established whether it has an x-ray pulsar, a black hole or a low magnetic neutron star. There is also doubt about the mass and type of the companion star. The stable periodicity of 4.8 hrs. which is modulated in the light curve and believed to represent the orbital motion, was discovered by Parsignualt et al. 1976. Many attempts (Leach et al. 1975; Parsignault et al. 1976; Mason & Sanford 1979; Lamb, Dower & Fickle 1979; Elsner et al. 1980), van der Klis & Bonnet - Bidaud 1981, 1989; Kitamoto et al. 1987, 1992, 1995) have been made in the recent past to investigate whether there is any change in the orbital period of this x-ray source. In the present work, we report the observation of the Cygnus X-3 by the Indian X-ray Astronomy Experiment (IXAE) on board the Indian remote sensing satellite IRS-P3 and subsequent analysis of the x-ray data for determination of orbital period.

2. Instrument and observations

The X-ray source Cyg X-3 was observed by three co-aligned and identical, multiwire, multilayer proportional counters (PPC) of IXAE during the periods July 3 - 13, 1999 and October 11 - 24, 1999 for a total useful exposure time of 312444.64 seconds in 1 sec integration mode. The counters have a total effective area of 1200 cm^2 covering 2 to 18 KeV energy range with an average detection efficiency of about 60% at 6 keV. For a detailed description of the PPCs refer to Agrawal et al. (1998).

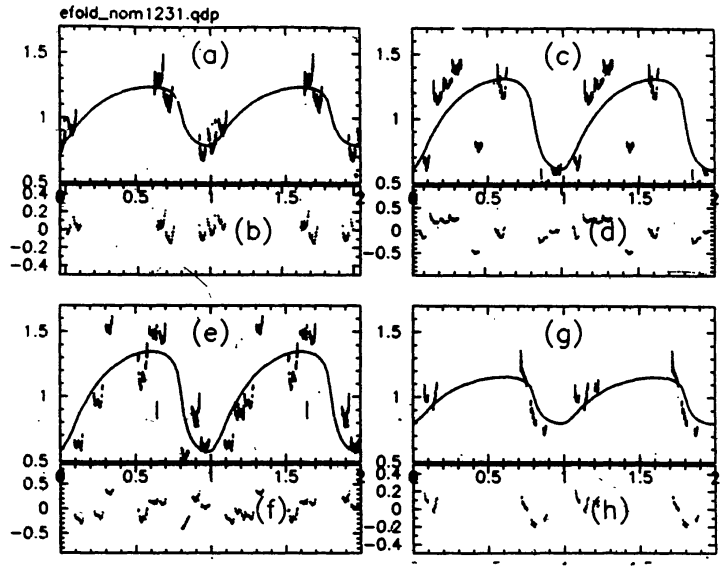

Figure 1. Folded light curves of PPCs' data for the observation during July 3-5, 1999 (a), July 7-10 1999 (c), July 11-13, 1999 (e) and October 11-12, 1999 (g). The solid lines are the normalised template data. The plots (b), (d), (f) and (h) are the residuals of (a), (c), (e) and (g) respectively.

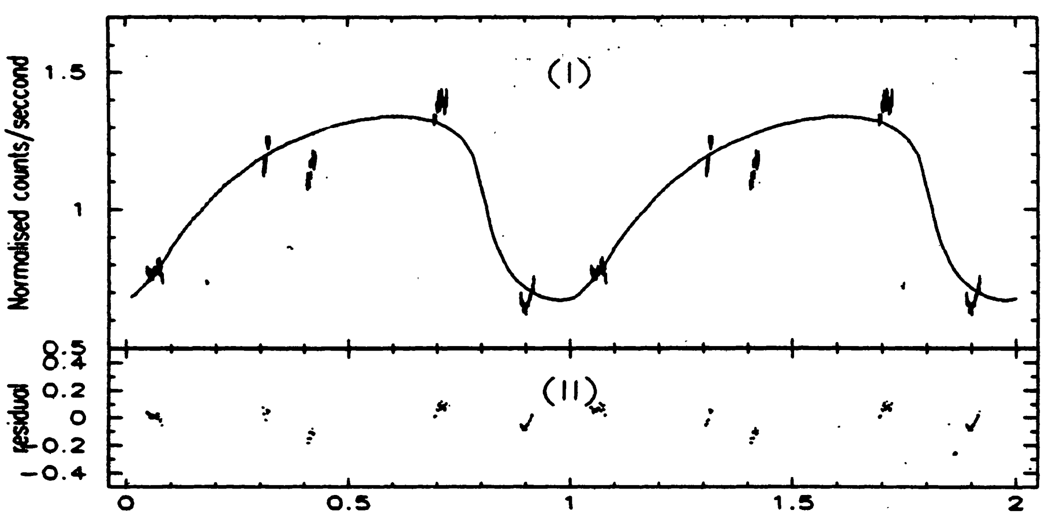

Figure 2. Panel (I) : Folded light curve of PPC data for the observation during october 13-14, 1999. The solid line is the normalised template data. Panel (II) is the residual between the folded data and normalised template.

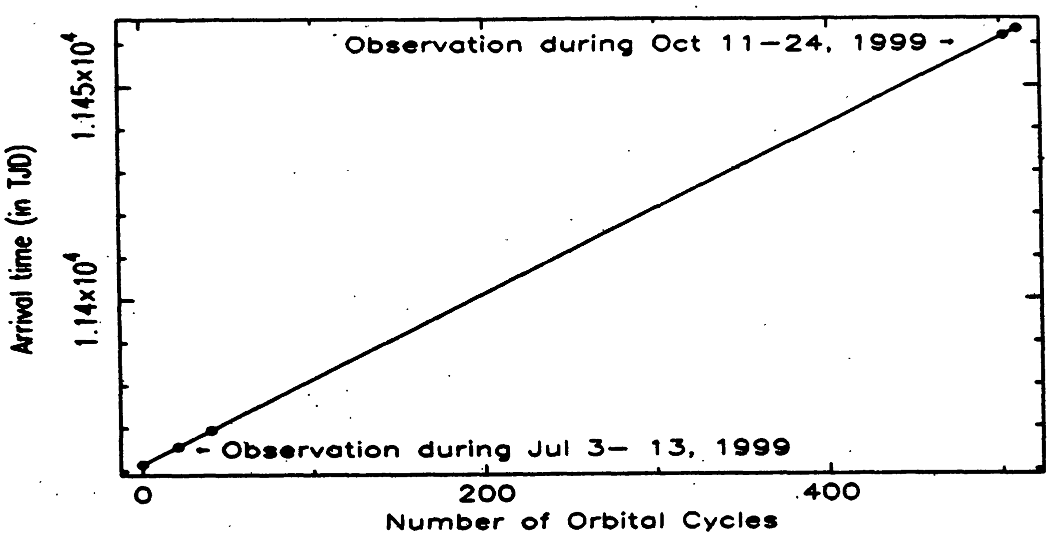

Figure 3. The plot of arrival time in TJD versus numbers of orbital cycles. The slope of this plot gives the value of orbital period.

3. Analysis and results

The Barycenter correction for sun-earth system, was accomplished with the help of the JPL DE 200 solar system ephemeris described by Standish 1982. The correction for off-pointing was done by using pointing information from the star tracker. There were many discontinuities in the light curve due to inherent physical constraints during observation. Consequently, the sinusoidal fitting which was performed first by Parsignault, 1976 with the period of 4.8 hrs. for the same binary star Cygnus X-3, could not be done for the x-ray data. We divided the whole x-ray light curve of Cygnus X-3 for the entire data observed by IXAE into 5 segments each with an interval of slightly more than 2 days and thus, we obtained three data segments from the July 1999 observation and two from the October, 1999 observation. We created time averaged orbital modulation profile by folding the light curves for each segment with a period of 17253 seconds ($\cong$ 4.8 Hrs). In all cases, the shape of the folded light curve is similar to the shape of the template function which represents the long term average of the orbital modulation curve obtained with the Copernicus satellite (Mason & Sanford, 1979).

To determine the arrival times of the minimum of the folded light curves, we used the normalized template of the same (van der Kliss et al., 1989). Ths folded data were cross-correlated with the template to note down the phase value of the maximum cross-correlation and finally, the epoch time was shifted in order that the maximum cross-correlation occurs at zero phase. The shifted epoch time thus found was taken as the arrival time of photon corresponding to the minima of the X-ray light curve. In order to determine the error of the arrival time cross-correlation data (calculated between folded data and normalized template) were plotted versus phase, followed by fitting of the Gaussian model. Error in the centroid parameter of Gaussian model was multiplied by the period of the light curve to get the required error in the value of arrival time. The upper panels is figures 1 and 2 show the folded light curves along with the normalized template data. The residuals which are differences between folded points and normalized template are also displayed in the lower panels (b), (d), (f), (g) of figure 1 and panel (II) of figure 2. The arrival times are plotted with respect to numbers of orbital cycles. The slope of the graph (figure 3) gives the orbital period directly. Following this procedure the orbital period of Cygnus X-3 was found to be 17254.273 ± 0.890 seconds.

4. Discussion

Because of the stability of the period 4.8 hrs. which is found to be modulated in the X-ray light curve of Cygnus X-3, the cause of this periodicity would be regarded as being due to orbital motion of its binary system. The study of the orbital dynamics with high resolution spectroscopy of Cygnus X-3 will give the mass range (Hanson et al. 2000) and other parameters (Paperels et al. 2000) of the system. The implications of these findings will be useful for discussing the nature, size and structure of the binary system.

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