Is TW Pictoris really an intermediate polar?

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Accepted 1997 Month ??; Received 1997 Month ??; in original form 1997 Month ??

ABSTRACT

We present the results of a long ROSAT HRI observation of the candidate intermediate polar TW Pic. The power spectrum shows no sign of either the previously proposed white dwarf spin period or the proposed binary orbital period (1.996 hr and 6.06 hr respectively). The limits to the X-ray modulation are less than 0.3% in each case. In the absence of a coherent X-ray pulsation, the credentials of TW Pic for membership of the intermediate polar subclass must be suspect. We further suggest that the true orbital period of the binary may be the shorter of the two previously suggested, and that the longer period may represent a quasi-periodic phenomenon associated with the accretion disc.

Key words: novae, cataclysmic variables – X-rays: stars – stars: individual: TW Pic

1 INTRODUCTION

TW Pic is a 14th magnitude cataclysmic variable which was identified by Tuohy et al (1986) as the optical counterpart to the HEAO-1 X-ray source H0534–581. Although Tuohy et al (1986) failed to detect any periodicities in either optical photometry or EXOSAT X-ray observations, they suggested that TW Pic may be an intermediate polar based on its X-ray to optical flux ratio and its strong He I 4686Å emission line (for a review of intermediate polars, see Patterson 1994). Subsequently, Buckley & Tuohy (1990) reported an optical spectroscopic study of the system and determined periods of 2.1 ± 0.1 hr and 6.5 ± 1.0 hr from radial velocity measurements, which they took to represent the spin period of the white dwarf and the orbital period of the binary, respectively. A re-analysis of the EXOSAT data by Buckley & Tuohy (1990) this time revealed the 2.1 hr proposed spin period, and new optical photometry also showed the 6.5 hr proposed orbital period. A later optical photometric study of TW Pic by Patterson & Moulden (1993) revealed periods of 6.06 ± 0.03 hr and 1.996 ± 0.001 hr which they interpreted as more accurate determinations of the orbital and spin periods found by Buckley & Tuohy (1990). They noted, however, that the 6.06 hr period appeared to drift throughout their 3 weeks of observations, and that the supposed orbital profile varied greatly from cycle to cycle.

2 A ROSAT HRI OBSERVATION OF TW PIC

Here we report details of a long X-ray observation of TW Pic, made with the ROSAT High Resolution Imager (Zombeck et al 1995). The observation comprises 47.9 ksec on source between 1995 Nov 15 17:39 UT and 1995 Nov 24 19:59 UT, and was performed in ‘time critical’ mode, observing the source for about five hours per day, over ten days. Using the Starlink Asterix software (Allen & Vallance 1995), data were optimally extracted from a region about an arc min in radius, centred on the source, and background subtraction was carried out using the data from a concentric annulus. A binned light curve with 10 s time resolution was created, and a lower resolution version of this is shown in Figure 1. Each block of data represents one satellite orbit, and each panel contains one day of observations. The mean count rate is 0.20 c s⁻¹.

To analyse the light-curve we used the 1-dimensional clean algorithm in the implementation of H.J. Lehto. This period searching algorithm is ideal for searching for multiply periodic signals in unevenly spaced data and we have shown in the past that it is particularly suited to analysing X-ray light curves of intermediate polars (see for example Norton et al 1997, Beardmore et al 1998, and references in both). The results of clean are shown in Figure 2.

The top panel simply shows the window function of the time series – it reflects the 96 min satellite orbit (large scale ‘envelope’ structure) and the daily observation slots (small scale ‘spike’ structure). The second panel is the raw or ‘dirty’ power spectrum of the time series. The fact that this looks essentially the same as the window function is a good indication that there are no periodicities in the data which result from TW Pic itself. The third panel is another ‘dirty’ power spectrum of the time series, but this time with the mean value of the data removed prior to calculation of the Fourier transform. This effectively removes the ‘first order’ window function from the data allowing any weak signals to be seen
more clearly. Note that the vertical scale of this power spectrum is 100 times greater than in the second panel. Some residual structure appears to be present in this power spectrum, but close inspection again reveals that all the peaks are at window function frequencies.

The bottom panel shows the cleaned power spectrum, with the same vertical scale as the third panel. The two largest spikes in the cleaned power spectrum, near to $3.5 \times 10^{-4}$ Hz, are at window function frequencies and so are unlikely to represent real signals. (In fact, their frequencies correspond to half the orbital period of the satellite and its one day alias.) The cleaned X-ray power spectra of confirmed intermediate polars generally show clear signals at the system periods (see for example Norton et al 1997, Beardmore et al 1998), and that is not the case here. There are no significant signals at either of the previously reported periods of this object. At periods of both 6.06 hr and 1.996 hr, the power is less than about $10^{-7} \text{ c}^2 \text{ s}^{-2}$, corresponding to a limiting amplitude in the light curve of $< 6 \times 10^{-4} \text{ c s}^{-1}$. (Nb. The amplitude is equal to twice

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**Figure 1.** The ROSAT HRI lightcurve of TW Pic at a time resolution of 100 s. Each panel represents one day of observations and contains between three and five satellite orbits of data.
Figure 2. The power spectrum of the ROSAT HRI lightcurve of TW Pic. The top panel shows the window function of the data; the second panel shows the ‘dirty’ power spectrum; the third panel shows the ‘dirty’ power spectrum after the mean has been subtracted from the data (note the scale change by a factor of 100 between the second and third panels); and the bottom panel shows the cleaned power spectrum. Tick marks show the locations of the previously reported periods for this system.

the square root of the cleaned power.) The upper limit to any modulation in the X-ray light curve at these periods is therefore 0.3%. Furthermore, there are no other significant periods detected either – the Nyquist frequency of the time series is around $3 \times 10^{-3}$ Hz and there are no significant signals detected out to this frequency. (The power spectra in Figure 2 are only plotted out to $10^{-3}$ Hz to emphasize the structure at lower frequencies.) We therefore conclude that the light curve of TW Pic from this ROSAT HRI observation displays no intrinsic periodic signals, with a period greater than about 300 s, down to a limiting modulation of less than 1%.
3 DISCUSSION

The ROSAT HRI count rate from TW Pic (0.20 c s\(^{-1}\)) is comparable to that of confirmed intermediate polars with similar optical fluxes. For instance AO Psc and V1223 Sgr are both 13th magnitude intermediate polars and exhibit HRI count rates of 0.22 c s\(^{-1}\) and 0.41 c s\(^{-1}\) respectively (Taylor et al 1997), whilst the 15th magnitude TX Col has an HRI count rate of 0.07 c s\(^{-1}\) (Norton et al 1997). On the basis of its X-ray to optical flux ratio therefore, TW Pic would seem to be a good candidate for intermediate polar status, as Tuohy et al (1986) originally suggested. However, the one unambiguous signature of an intermediate polar is a coherent X-ray pulsation at a period significantly less than the binary orbital period. Based on this most sensitive X-ray observation yet of TW Pic, no such pulsation exists and so we have no evidence to support the proposed classification of the system. TW Pic may still be an intermediate polar, but one seen at a relatively low inclination angle such that a roughly constant X-ray flux is seen from the upper magnetic pole, and the lower one is permanently hidden. In this case, we would not expect the spin period of the white dwarf to be apparent in optical photometry or spectroscopy either. So, whether or not TW Pic is an intermediate polar, we must therefore suggest some other explanation for the periods previously reported in this system.

The ∼2 hr period cannot represent the spin period of an accreting magnetic white dwarf, otherwise we would have seen evidence for it in our ROSAT HRI data. The original detection of this period was in the optical spectroscopic data of Buckley & Tuohy (1990). However, their subsequent detection of a similar period in the EXOSAT X-ray data is barely significant, and indeed went un-noticed in their earlier analysis of the same data (Tuohy et al 1986). It is doubtful whether the X-ray detection of the period would have been claimed without the prior discovery of the ∼2 hr optical period. Nonetheless, a ∼2 hr period has been clearly detected in both optical spectroscopy (Buckley & Tuohy 1990) and in optical photometry (Patterson & Moulden 1993), and is undoubtedly real. We suggest, therefore, that 1.996 hr represents the orbital period of the system and as such we would not necessarily expect to detect it in an X-ray observation, unless the system were at a relatively high inclination.

The reasons for disbelieving that the ∼6 hr period represents the orbital motion have already been discussed by Patterson & Moulden (1993). In their photometric data, this period was observed to drift over the course of 3 weeks by up to 0.3 cycles. Moreover, they note that the profile of the ∼6 hr modulation simply does not look stable, and varies significantly from cycle to cycle. The spectroscopic and photometric observations reported by Buckley & Tuohy (1990) both detected a ∼6 hr period, but again the constancy of the period is not convincing, and in their case could merely be a second harmonic of the ∼2 hr period, as neither of the periods are determined very accurately. We suggest instead that this quasi-periodic 6 hr modulation may arise from a phenomenon associated with the accretion disc.

A comparable system may be the intermediate polar TV Col (Hutchings et al 1981), which exhibits a spectroscopic (orbital) period of 5.49 hr but a photometric period of 5.19 hr (in addition to the white dwarf spin period of 1911 s). The additional presence of a ∼4 d 'beat' period (such that 1/5.49 hr + 1/4 d = 1/5.19 hr) led Barrett, O'Donoghue and Warner (1988) to interpret these multiple periodicities in terms of a retrogradely precessing accretion disc. The disc is assumed to precess with a 4 d period, and the 5.19 hr period may then arise due to tidal interactions with the secondary (Hewett 1993). Augusteijn et al (1994) noted that both the 5.19 hr and 4 d periods in TV Col are unstable and may vary monotonically. Given the similarly unstable ∼6 hr period in TW Pic, disc precession may be the explanation for the long period seen in this system also.

Finally, we note that if TW Pic really were a magnetic system, and if the spin period of the white dwarf really were around two hours, it would represent the slowest rotator amongst all the intermediate polars. The only confirmed intermediate polar coming close to this is EX Hya, with a spin period of 67 min. However, EX Hya is unusual in that its spin and orbital periods are in a ∼2:3 ratio. G. Wynn (private communication) has shown that high magnetic field intermediate polars will indeed evolve such that their periods end up in a ∼2:3 ratio, not the apparent ∼1:3 ratio which the previously proposed periods of TW Pic might indicate.

In conclusion, we find that there is no convincing evidence for regarding TW Pic as an intermediate polar, and we suggest that the true orbital period of the binary is the shorter of the two previously identified periods.

ACKNOWLEDGMENTS

The data analysis reported here was carried out using facilities provided by PPARC, Starlink and the Open University Research Committee.

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