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Spectroscopic and Photometric Observations of the Magnetic Cataclysmic Variable TX Col

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Abstract. Simultaneous photometry and spectroscopy of the Intermediate Polar TX Col were obtained in order to investigate its accretion mode and dynamics. The spectroscopic and photometric power spectra of TX Col are observed to change on relatively short timescales. Spectroscopy reveals a dominant periodicity at the orbital period (5.69 hr) and a spin period of 1909 s in radial velocities, while line equivalent widths show a strong periodicity at the beat period (2106 s). It is the first time that the orbital period has been detected in optical wavelengths.

Furthermore, the photometry shows a strong beat pulse and a relatively strong spin pulse. This is an indication of changes in the accretion mode. Large amplitude variations in photometry are also observed at low frequencies (roughly between 58 and 232 mHz). Here we report preliminary results and attempts we have made to explain our observations.

1. Introduction

It is generally accepted that in the majority of intermediate polars (IPs) accretion of material proceeds via an accretion disc (disc-fed accretion, Hellier 1991). X-ray and optical modulations at the white dwarf spin period and at the beat period have been realised as signatures for disc-fed and stream-fed accretion, respectively, a rule most systems have been observed to obey (Hellier 1991; Hellier 1996; Ferrario & Wickramasinghe 1999). There is, however, an ongoing debate as to whether accretion in TX Col, a non-eclipsing IP, occurs either via a disc, the accretion stream or some combination of both (known as disc-overflow accretion where both the spin and beat modulations arise, Norton, Hellier, Beardmore, Wheatley, Osborne & Taylor 1997). The reason why it is not easy to tell the exact accretion mode of this system is because of its varying behaviour over time.

In 1985, when TX Col was first optically identified, *EXOSAT* X-ray measurements and optical photometry revealed a dominant periodicity at 1920s which was interpreted as the spin period, an orbital period of 6.2 h and another period near 2100s (Tuohy, Buckley, Remillard, Bradt & Schwartz 1986). Later, Buckley & Tuohy (1989) reported detection of adominant modulation at a period of 2106 s which was adopted as the beat period, indicative of strong disc-overflow or stream-fed accretion. Optical photometry from 1989 (Buckley & Sullivan 1992) showed a persistent periodicity at ≈ 1054 s, exactly half the previously observed period of ≈ 2106 s. This 1054 s harmonic was not seen in the previously published photometry. Further optical photometry was obtained in 1994 (Buckley 1996) which no longer showed the beat period or its harmonic, but instead revealed a strong period near 6120 s and other quasi-periodic light variations at low frequencies. Further observations made with *ASCA* and *ROSAT* satellites show disc accretion in October of 1994 but disc-overflow in October of 1995 at which time a substantial amount of the accretion was directly via a stream (Norton, Hellier, Beardmore, Wheatley, Osborne & Taylor 1997).

The above observations together with those made at the South African Astronomical Observatory (SAAO), Cerro Tololo Inter-American Observatory (CTIO) and the Mt. John University Observatory (MJUO) (Buckley 1996) show that the strength of the beat and spin frequencies vary on a time-scale of at least a year, possibly much less, indicating changes in the accretion mode. The aim of this paper is to investigate and explain these changes and to explore possible modes of accretion of this system.

2. Spectroscopy

2.1. Observations and reductions

Spectra of TX Col were obtained during the period: 15 – 21 Jan 2002 using the Cassegrain grating spectrograph on the 1.9m telescope at the South African Astronomical Observatory(SAAO). The spectrograph uses a SITe CCD detector (266 × 1798 pixels) with pixel size of 15μm. Grating 4 (1200 mm^{-1}) was used at an angle of 4.8° giving a wavelength range covered of 4000 - 5200Å. The spectrograph slit width was 250μm (≈ 1.5 arcsecs) giving a resolution of 0.49Å. The exposure times during observations were 60s and a 1×2 binning scheme was employed (i.e. binning by 2× in spatial direction). Wavelength calibration exposures with integration times of 60s were taken using a CuAr arc lamp. Flat field frames were also taken at the beginning of the first two nights. Six nights of observations were obtained. During the first night there were episodes of clouds, but for the remaining nights conditions were clear. A total of 528 spectra was obtained. The data were reduced using the IRAF[1] package.

2.2. Radial Velocities and Equivalent widths

Analysis of emission lines (Hβ, Hγ and HeII) was done by fitting Gaussian profiles to the data in order to obtain line profile parameters such as radial velocities, widths and peak heights. The fitting procedure was achieved using the program Molly. Equivalent widths were also obtained using the Splot routine of the IRAF package.

2.3. Period Searches

The radial velocities and equivalent widths were put through a discrete Fourier Transform (hereafter refered to as DFT) algorithm, Eagle. The search interval was fixed between 0 and 2000 μHz.

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[1] IRAF is a software package distributed by NOAO and AURA

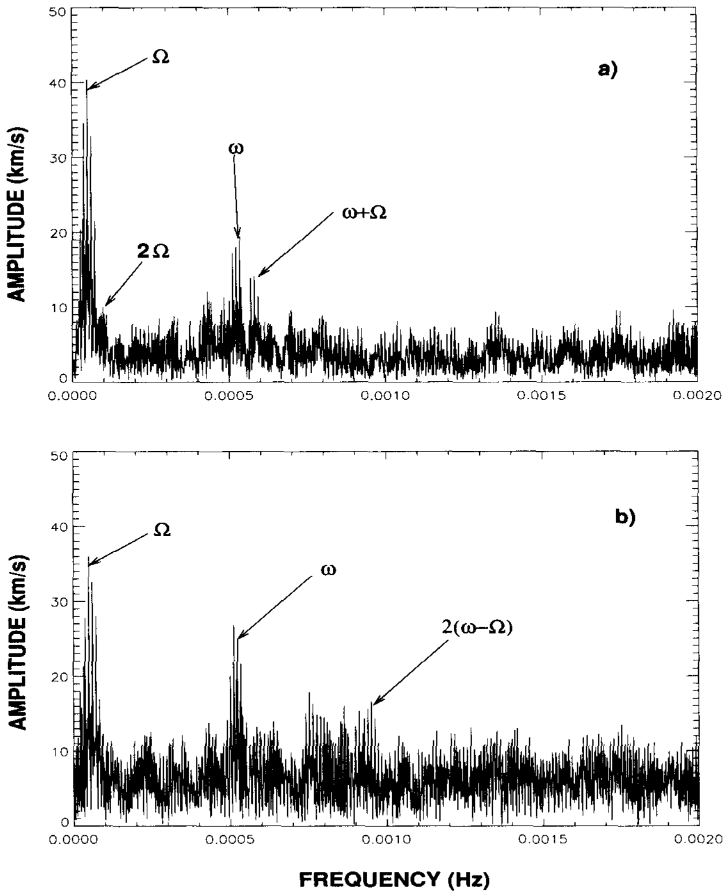

Figure 1. Radial velocity amplitude spectra for a) the Hβ and b) the HeII λ4686 emission lines.

In Fig. 1 periodograms are shown for the six nights of data. In radial velocities, for both the Hβ 4861 and HeII λ4686 lines, we see dominant peaks (at 5.69±0.08 h^{-1} and at 1910.10±0.45 s^{-1}) close to the previously determined periods, namely the orbital frequency, $\Omega = 1/P_o$ (5.72 h) and the spin frequency, $\omega = 1/P_s$ (1911 s). A weaker peak roughly coinciding with the lower period sidebands can also be seen at $\omega + \Omega$ (1754.56±0.79 s) for the 4861 in Fig. 1a. We have also detected the first harmonic of the beat period in radial velocities as shown in Fig. 1b.

Equivalent widths (Fig. 2), show a strong period at $\omega - \Omega$(2106.50±1.11 s) and at $\omega - \Omega$(2106.33±1.03 s) for the Hβ 4861 and HeII 4686 lines, respectively. There is no sign of the orbital period or the spin period.

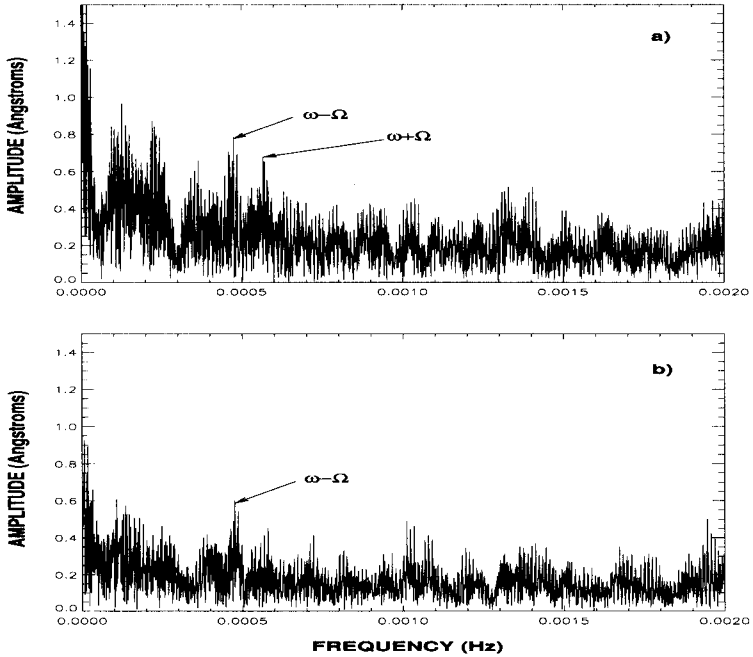

Figure 2. Equivalent width amplitude spectra for a) the Hβ and b) the HeII λ4686 emission lines.

2.4. Radial Velocity Curves

The Radial velocities were fit with a sine curve using least squares fitting and the results are shown for the $H\beta$ 4861 line in Fig. 3.

Table 1 shows the radial velocity curve parameters obtained from the fits. The orbital frequency of 4.88×10^{-5} Hz obtained from the DFT – see previous section – was used as an input parameter.

Table 1. Radial velocity curve parameters

Parameter	**Hβ**	**HeII**
$\gamma(kms^{-1})$	1.52±2.16	10.14(7)±3.53
K(kms^{-1})	41.84±3.05	38.20(8)±5.01(9)
Φ	1.04±0.07	1.09(8)±0.12(9)

3. Photometry

Optical photometry was obtained during the period: 15 Jan – 06 Feb 2002 using the UCT CCD photometer on the SAAO 1.0m telescope at Sutherland. The photometer was used in frame transfer mode in order to eliminate dead-time. B and I filters were used alternatingly. The integration times were 20s in both filters. Sky flatfields were taken at various points through the observation week.

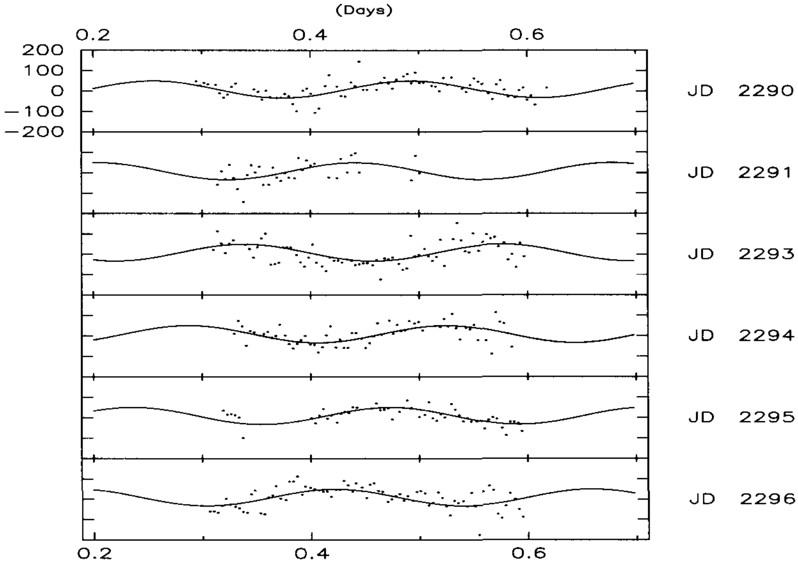

Figure 3. Radial velocity plots for $H\beta$ 4861 obtained by fitting a Gaussian to the emission line. The least-squares sin fit is overploted.

The observation period was three weeks and a total of 6349 images was taken. The data was reduced using the DuPhot program. Additional photometric data were obtained from Centre for Backyard Astrophysics group(CBA). This data were acquired during the period: 02 Jan – 06 Feb 2002. The CBA data was combined with the SAAO data (B filter) before analyses.

3.1. Period Searches

The SAAO and the combined photometric data (SAAO plus CBA) were subject to a DFT algorithm and Fig. 4a and 4b shows the results. The combined data set (Fig. 4b) shows a strong beat pulse (≈ 17% bigger in amplitude than the spin pulse) and quasi periodic variations which are also detectable in (Fig. 4a).

3.2. Quasi Periodic Variations

In addition to the spin and beat frequencies, the amplitude spectra is dominated by frequencies roughly between 58 and 232 mHz as shown in Fig. 4a and Fig. 4b. These can be seen in both the SAAO and the combined SAAO and CBA data and appear to have no fixed periods. In the SAAO data the maximum period peak occurs at 6287.72 s (1.59×10^{-4} Hz) while in the combined data the maximum period peak occurs at 5897.62 s (1.6956×10^{-4} Hz).

To check whether or not these periods are consistent, the data was divided into four parts and put through the DFT. We could not find any consistency, indicating that the oscillations are quasi-periodic in nature. Their origin is not fully understood at this stage.

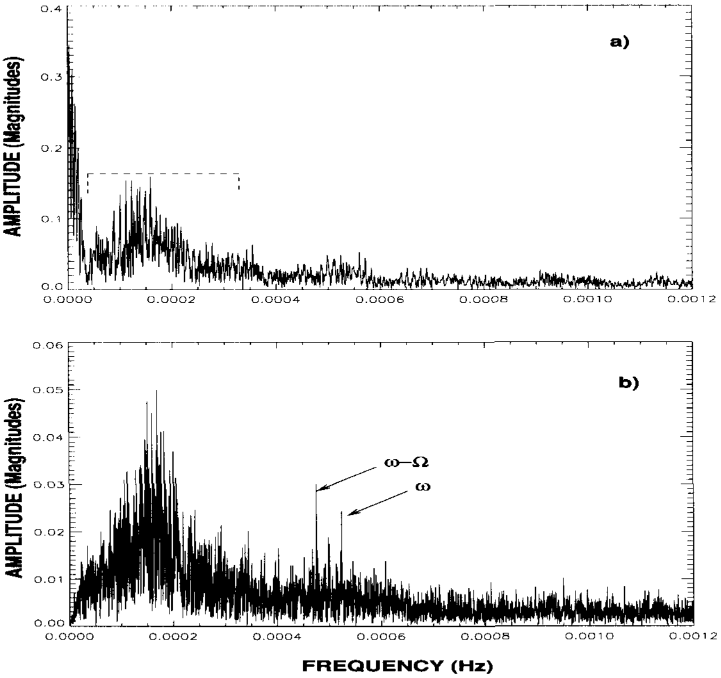

Figure 4. Photometric amplitude spectra for a) SAAO and b) CBA data.

4. Summary and Conclusion

Our observations of TX Col confirmed and refined a number of periods including the orbital period (5.69±0.08 h), the spin period (1910.10±0.45 s) and the beat period (2106.50±1.11). Radial velocities have revealed a strong orbital modulation (with an amplitude of $\approx$ 40 kms^{-1} for the Hβ 4861 and of $\approx$ 36 kms^{-1} for the HeII λ4686 lines). Since TX Col is known to be a low inclination system, this period may arise due to accretion sites' visibility changing over the orbital cycle as the stream flips between the two accretion sites at the magnetic poles (Hellier 1991). The spin pulse (with the amplitude of $\approx$ 20 kms^{-1} for the Hβ 4861 and $\approx$ 26 kms^{-1} for the HeII λ4686 lines) has also been detected as a second dominant peak. This pulsation could be emitted from the white dwarf accretion curtain (Hellier 1992), indicating the presence of some disc.

We have also detected the first harmonic of the beat period at 1051.84±0.34 s in radial velocities (HeII λ4686) with an amplitude of 16 kms^{-1}. Unlike the beat pulse in photometry, a beat pulse in radial velocities cannot arise from the secondary or any fixed component in the binary frame but can occur due to some kind of modulated accretion at the magnetosphere. This needs some thorough investigation.

The beat pulse in equivalent widths can be clearly seen while the spin pulse is not detectable. A strong beat pulse and a relatively strong spin pulse with an amplitude of 83% of the beat pulse are revealed in photometry. Though our results point more to stream accretion than disc accretion, it may be sensible to suspect the presence of a disc due to the presence of a strong spin pulse in photometry and in radial velocities. The large variation amplitudes seen in photometry could be due to random variations in the accretion rate. Not much elaboration can be done on this matter at this stage as more detailed analysis still needs to be done.

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