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UPDATES ON TWO NEW CATACLYSMIC VARIABLE SYSTEMS: 1RXS J173021.5-055933 AND 1RXS J180340.0+401214

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ABSTRACT

We report on two intermediate polar star systems, RX J1730-06 and RX J1803+40. We analyze a total of 97.4 hours of data for RX J1730-06 and 17.5 hours for the system RX J1803+40. We confirm previously reported spin periods (128 s and 25.4 min, respectively) and give a best-fit non-linear least-squares ephemeris for each.

Subject headings: stars: cataclysmic variables

1. INTRODUCTION

Cataclysmic variables (CVs) are binary star systems consisting of a primary white dwarf and a cool main-sequence secondary star with mass transfer between the two. The mass transfer occurs when the secondary fills its Roche lobe and matter begins to overflow through the inner Lagrangian point $L1$. In most cases the matter will form a disk around the primary, losing angular momentum through viscosity, and migrate inward to accrete onto the white dwarf. Most of the light from these systems is produced in the accretion disk (e.g., Hellier 2001).

Intermediate polars (IPs) are a subclass of CVs containing a white dwarf with a magnetic field strong enough to disrupt the Keplerian flow in the inner accretion disk, and to cause the plasma to then flow to the primary along the magnetic field lines. Unlike regular polars (also called AM Her stars), IPs do not have a strong enough field to obtain a synchronous spin period, and their white dwarfs have spin periods shorter than their orbital periods (Warner 1995). It is believed that the fluid attaches to the field roughly where the magnetic energy density is of order the kinetic energy density, and that the white dwarf spin period is thus the Keplerian orbital period at the radius at which this occurs. The systems with the shortest spin periods are called the DQ Her stars, and these have the weakest magnetic fields and only soft X-ray emission, in contrast to the stronger-field intermediate polars and polars (Warner 1995).

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The combined X-ray (ROSAT)/infrared (2MASS) target selection that discriminates against background active galactic nuclei has been utilized to search for short-period cataclysmic variables by exploiting the X-ray emission feature common to most low-mass-transfer systems. Gänsicke et al. (2005) were able to use spectroscopy and photometry to identify 4 stars as intermediate polars and to obtain their spin and orbital periods. Two systems of the 4 newly reported were of particular interest for further study, RX J1730–06 and RX J1803+40.

Disk-fed white dwarfs will tend to corotate with the disk material at the magnetosphere. White Dwarfs with shorter spin periods experience a negative torque on their magnetospheres due to the slower orbit of the disk material. In this case it is expected that the white dwarf spin will be slowing down. Another possible consequence of a faster than normal spin period is a propeller system, in which the material undergoing transfer is expelled by the spinning magnetosphere instead of accreting onto the white dwarf (Hellier 2001). AE Aqr is suspected as a possible propeller system due to the apparent mass transfer rate being 1000 times greater than the actual accretion rate. AE Aqr also exhibits a very long orbital period as compared to its spin period, and unusual flaring in its light curve (Hellier 2001). RX J1730–06 is an interesting IP system due to its long orbital period of $P_{\rm orb} = 925.27$ min, in conjunction with a short spin period of $P_{\rm spin} \approx 128$ s. This system is currently being compared to that of AE Aqr due to their similar discrepancy in orbital and spin periods. Any flaring has yet to be observed (Gänsicke et al. 2005).

As CVs evolve they must decrease their orbital separation in order to continue mass transfer. Above an orbital period of ∼3 hours magnetic braking is the main means by which this occurs. It is presumed that at orbital periods of around 3 hours magnetic braking shuts off, allowing the secondary to detach from it's Roche lobe until gravitational radiation brings it back in contact at a lower period. This causes the observed period gap. The few CVs found within the period gap likely made first contact within the gap. This means that higher mass transfer rates due to magnetic braking have not had the opportunity to drive the secondary out of equilibrium, and they can therefore continue mass transfer through the gap by gravitational radiation (Hellier 2001). RX J1803+40 is an intermediate polar found in the period gap, with a $P_{\rm orb} = 160.12$ min (Gänsicke et al. 2005).

RX J1730–06 and RX J1803+40 are also of interest to the Center for Backyard Astrophysics[1], an organization engaged in long term photometric studies of CVs. In collaboration with CBA we chose to devote the majority of our 4 nights observing in late May and early June to these two systems. In section 2 we discuss the observations. In section 3 we discuss our data reductions and analysis, and in section 4 we give our conclusions.

2. OBSERVATIONS

We give our Journal of Observations in Table 1. Observations conducted on the SARA 0.9-m telescope at Kitt Peak National Observatory were taken on the nights 2006 May 30 (UT) through 2006 June 2 (UT) and on 2006 July 23 (UT) with an Apogee U55, an Apogee U42, and a Finger Lakes Instruments IMG–1042s CCD camera. Observations on the night of 2453885 HJD (2006 May 30 UT) were taken with the U55 camera, a Custom Scientific infrared-blocking (IRB) filter, and a camera temperature of -25° C. Pixels were not binned, preserving the 22.5 μm pixel width. Observations on the evenings of 2453886 to 2453888 HJD (2006 May 31–June 2 UT) were taken with the Apogee U42 CCD camera without any filters, and at a camera temperature of -15° C. A 2×2 binning was utilized, giving an effective pixel with of 27 μm. The other 2 cameras being unavailable, we used our FLI camera on the night of 2453909 (2006 June 23 UT). Data from other sites were obtained with a variety of CCD systems, and reduced by the observers before being sent to the CBA archive.

3. DATA REDUCTION AND ANALYSIS

Preliminary processing of the raw CCD images and photometry were preformed with IRAF[2]routines. Data results were converted from ADUs to magnitudes. For ease of comparison, each observation run was offset by the median magnitude value in order to re-center oscillations about a common zero. With the exception of the runs performed by Kemp, all data were initially reported in Julian Date. A FORTRAN program was written using the procedure given by the Compendium of Practical Astronomy Vol.1 (1994) to convert the time to Heliocentric Julian Date (HJD). This routine was tested against IRAF and was found to agree within half a second for the two targets in question. We obtained a total of 97.4 hours of data on RX J1730–06 and 17.5 hours of data on RX J1830+40.

[1] http://cba.phys.columbia.edu/

[2] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

TABLE 1
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Start Time HJD 2453000+	Observer	Star	Filter	Exp. (s)	Length (h)	Frames
884.737...	Kemp[a]	1803+40	bg 38	10	3.2	643
885.742...	Kemp	1730-06	bg 38	10	1.5	297
885.746...	WTMG[b]	1803+40	IRB	120	5.6	158
886.701...	WTMG	1803+40	clear	30	6.6	1107
887.694...	WTMG	1730-06	clear	10	7.0	2167
888.666...	WTMG	1730-06	clear	10	7.6	2258
903.212...	Monard[c]	1730-06	clear	30	9.5	1030
904.298...	Monard	1730-06	clear	30	5.7	674
907.213...	Monard	1730-06	clear	30	8.2	894
908.271...	Monard	1730-06	clear	30	7.0	824
909.689...	Wood	1803+40	clear	30	2.1	161
910.291...	Monard	1730-06	clear	30	6.7	778
913.872...	Rea[d]	1730-06	clear	20	3.2	474

[a] Johnathan Kemp - MDM 1.3m - Hilo, Hawaii
[b] Wood, Teichgraeber, Mirada, Ge - SARA 0.9-m - KittPeak, Arizona
[c] Berto Monard - Meade LX-200 12" - Pretoria, South Africa
[d] Robert Rea - Celestron 14" - Nelson, New Zealand

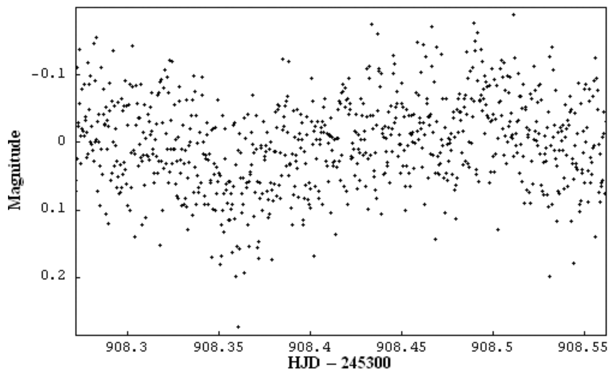

FIG. 1.— Data set taken by B. Monard of RX J1730-06.

3.1. *1RXS J173021.5-055933*

Most of the observations obtained were of RX J1730. Figure 1 shows one such data set. Given the short spin period of 128 s – the second fastest IP to date – it is not possible to visibly pick out a periodic curve. We shall leave that to the phase plot.

A Fourier transform of each data set revealed a strong peak at about 675 c/d, and where the sampling interval was short enough, the harmonic at 1350 c/d is strongly seen (Figure 2). All the data sets with long enough run length reflected a strong signal in the lower frequency region from 2.8 – 5.8 c/d, yet these signals were not nearly as consistent. These findings are in accordance with the reported spin period of 127.999 909 s, and the lower frequency power is reflected in previous photometry observations as being related to the long orbital period of 925.27 min (Gänsicke et al. 2005).

We made individual fits of the two frequencies using the method of non-linear least squares. The best results for the combined nights of data are reported in Table 2. A phase plot was constructed in Mathematica showing the combined data for the system folded over the fundamental frequency along with the sum of the best fit curves (Figure 3).

Due to the presence of two simultaneous frequencies it is

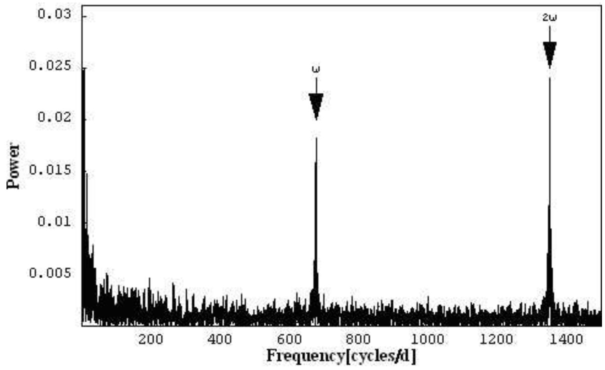

FIG. 2.— Fourier transform of RX J1730-06 data.

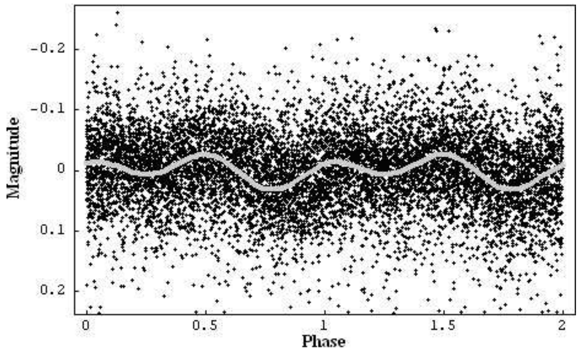

FIG. 3.— Phase plot of data for RX J1730-06 folded over the fundamental frequency along with the sum of the two best fit curves.

TABLE 2
BEST FIT SINE CURVE VALUES FOR SPIN PERIODS

System	Spin Period (d)	Amplitude	T_0 (d)
RX J1730–06	$1.481018(1) \times 10^{-3}$	0.0142(4)	887.69996(1)
(Harmonic)	$7.407536(2) \times 10^{-4}$	0.0191(4)	887.699946(4)
RX J1803+40	$1.764120(3) \times 10^{-2}$	0.134(3)	886.78298(2)

best to report the minima for the ephemeris. Equation 1 states our ephemeris for the system.

$$\text{HJD } T_{\text{min}} = 887.6995797455 + 0.001481018(1) \times E \quad (1)$$

3.2. *1RXS J180340.0+401214*

Data analysis was carried out much the same way as with RX J1730. The longer spin period is clearly seen in the data as shown in Figure 4, which makes this a more visually rewarding data set.

Fourier transforms showed only one strong peak in this system, so a single sine fit was used. The orbital period is once again not directly visible in the transform, but given the previously reported value of $P_{\text{orb}} = 160.21$ min, evidence of it can be found (Figure 5). Unfortunately, the lack of multiple spin frequencies leads to a somewhat dull phase plot in comparison to that of RX J1730. The observations for the night of 2453886 HJD and best fit frequency were used for the phase plot (Figure 6).

Table 2 shows the best fit sine curve period, amplitude, and time of zero. The constructed ephemeris for this system is

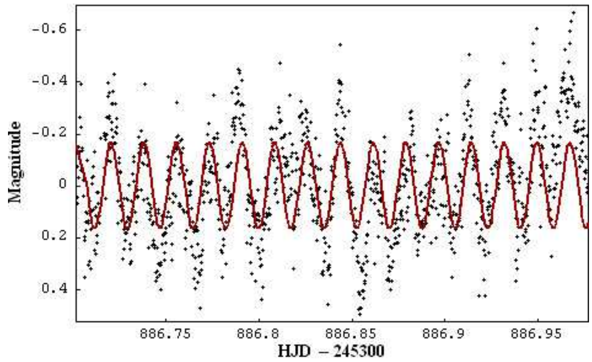

FIG. 4.— Data plot of RX J1803 as taken with the SARA 0.9-m telescope on the night of HJD 2453886 with best fit curve.

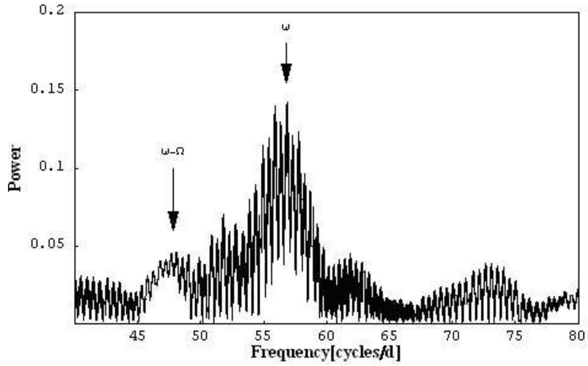

FIG. 5.— Fourier transform of RXJ1803+40 data. Spin period shown with the previously reported $\omega - \Omega$. The spin frequency is ω, and the orbital period is Ω.

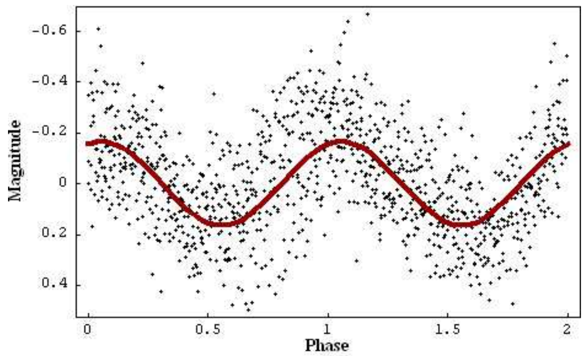

FIG. 6.— Phase plot of data taken on HJD 2453886 with the SARA 0.9-m telescope along with the best fit curve.

given in Equation 2.

$$\text{HJD } T_{\text{max}} = 886.782979(2) + 0.01764120(3) \times E \quad (2)$$

4. CONCLUSIONS

With data from the CBA and the SARA Observatory, we were able to confirm the reported spin periods for the IP systems RX J1730–06 and RX J1803+40. The new data are in accordance with the originally reported data to within the stated errors, and we were also able to update the ephemeris for each of the star systems, giving time of minimum for RX J1730–06 in Equation 1 and time of maximum for RX J1803+40 in Equation 2.

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