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The long term optical behaviour of helium accreting AM CVn binaries

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ABSTRACT

We present the results of a two and a half year optical photometric monitoring programme covering 16 AM CVn binaries using the Liverpool Telescope on La Palma. We detected outbursts in seven systems, one of which (SDSS J0129) was seen in outburst for the first time. Our study coupled with existing data shows that ∼1/3 of these helium-rich accreting compact binaries show outbursts. The orbital period of the outbursting systems lie in the range 24–44 mins and is remarkably consistent with disk-instability predictions. The characteristics of the outbursts seem to be broadly correlated with their orbital period (and hence mass transfer rate). Systems which have short periods (<30 min) tend to exhibit outbursts lasting 1–2 weeks and often show a distinct 'dip' in flux shortly after the on-set of the burst. We explore the nature of these dips which are also seen in the near-UV. The longer period bursters show higher amplitude events (5 mag) that can last several months. We have made simulations to estimate how many outbursts we are likely to have missed.

Key words: Physical data and processes: accretion discs; Stars: binary - close; novae - cataclysmic variables

1 INTRODUCTION

AM CVn systems are accreting binaries consisting of a white dwarf accretor and a degenerate (or semi-degenerate) secondary. They are notable for at least two reasons: they have an extremely short orbital period ($P_{orb} < 70$ mins) and are almost entirely hydrogen deficient (see Solheim 2010 for a recent review). There are currently 27 known AM CVn systems of which half a dozen have been found to exhibit at least one outburst, where they increase in brightness typically by 3–4 magnitudes. Indeed, some systems were discovered through supernovae surveys (eg V406 Hya =2003aw, Wood-Vasey et al. 2003). It is thought that the origin of these outbursts is similar to those seen in hydrogen accreting dwarf novae (eg Osaki 1996). Much observational and theoretical work has been done in trying to understand the origin and nature of the outbursts in the hydrogen accreting systems (eg Lasota 2001). In contrast, our understanding of

the cause of the outbursts seen in AM CVn systems is much more limited.

On the observational side, this is largely due to the lack of information on their long term behaviour. On the theoretical side, progress has been more limited compared to the work on hydrogen accreting systems. However, the work of Smak (1983), who described a thermal instability model, Whitehurst (1988) and Tsugawa & Osaki (1997) who develop tidal instability models and Lasota, Dubus & Kruk (2008) and Kotko, Lasota & Dubus (2010) who take into account irradiation effects, are some notable advances in modelling hydrogen deficient accreting binaries.

Accretion discs in AM CVn binaries can be thermally stable in a hot state – the temperature of the disc is always greater than the ionisation temperature of helium – and can also be thermally stable in a low state – the temperature of the disc is always lower than the ionisation state of helium. Systems which lie between these states are expected to be unstable. It is thought that the longer period systems

Source	Period (mins)	LT Target?	LT Range g (mag)	LT mean g (mag)	LT rms g (mag)	Outbursting System?	Reference
HM Cnc	5.4	✗				N	[1]
V407 Vul	9.5	✗				N	[2]
ES Cet	10.4	✓	16.5–16.8	16.66	0.09	N	[3]
SDSS J190817.07+394036.4	15.6	✗				N	[4]
AM CVn	17.1	✗				N	[5]
HP Lib	18.4	✓	13.6–13.7	13.51	0.02	N	[6]
CR Boo	24.5	✓	13.8–17.0	15.00	1.00	Y	[7]
KL Dra	25.0	✓	16.0–19.6	17.68	1.19	Y	[8]
PTF1 J0719+4858	26.8	✗				Y	[25]
V803 Cen	26.9	✗				Y	[9]
SDSS J092638.71+362402.4	28.3	✓	16.6–19.6	19.31	0.52	Y	[10]
CP Eri	28.4	✓	16.2–20.2	19.30	1.33	Y	[11]
V406 Hya (2003aw)	33.8	✓	14.5–19.7	18.89	1.34	Y	[12]
2QZ J142701.6-012310	36.6	✓	20.0–20.5	20.35	0.18	Y	[13]
SDSS J012940.05+384210.4	:37	✓	14.5–20.0	19.31	1.31	Y	[14, 15, 16]
SDSS J124058.03-015919.2	37.4	✓	19.0–19.8	19.62	0.17	Y	[16, 17]
SDSS J080449.49+161624.8	44.5	✓	17.8–19.0	18.54	0.30	Y	[18]
SDSS J141118.31+481257.6	:46	✓	19.4–19.7	19.58	0.09	N	[14]
GP Com	46.6	✓	15.9–16.3	16.22	0.05	N	[19]
SDSS J090221.35+381941.9	48.3	✗				N	[20]
SDSS J155252.48+320150.9	56.3	✓	20.2–20.6	20.44	0.10	N	[21]
V396 Hya	65.1	✗				N	[22]
SDSS J120841.96+355025.2		✓	18.9–19.4	19.09	0.07	N	[23]
SDSS J152509.57+360054.5		✓	19.8–20.2	19.91	0.11	N	[20]
SDSS J164228.06+193410.0		✗				N	[20]
SDSS J172102.48+273301.2		✓	20.4–20.7	20.53	0.17	N	[20]
SDSS J204739.40+000840.1		✓	17.0–17.4	17.13	0.03	Y	[24]

Table 1. The currently known AM CVn binaries. We show their period which is either the orbital period (most reliably determined from spectroscopic observations) or the dominant photometric period which is typically within a few percent of the orbital period. A colon implies the period is approximate, while the lower five systems do not have known periods. We show by means of a tick or a cross whether the source is included our Liverpool Telescope survey and the observed range, the mean mag and the rms of the light curve in the g band magnitude. We also show through a 'Y' or a 'No' whether the source has been seen in outburst, either in these LT observations or through previous work. References: [1] Ramsay, Cropper & Hakala (2002), [2] Ramsay et al. (2000), [3] Espaillat et al. (2005), [4] Fontaine et al. (2011), [5] Nelemans, Steeghs & Groot (2001), [6] O'Donoghue et al. (1994) [7] Wood et al. (1987), [8] Wood et al. (2002), [9] Kato et al. (2004), [10] Copperwheat et al. (2011), [11] Abbott et al. (1992), [12] Wood-Vasey et al. (2003), [13] Woudt, Warner & Rykoff (2005), [14] Anderson et al (2005), [15] Barclay et al. (2009), [16] Shears et al. (2011), [17] Roelofs et al. (2005), [18] Roelofs et al. (2009), [19] Nather, Robinson & Stover (1981), [20] Rau et al. (2010), [21] Roelofs et al. (2007a), [22] Ruiz et al. (2001), [23] Anderson et al. (2008), [24] Prieto et al. (2006), [25] Levitan et al. (2011).

(40 min $< P_{orb} <$ 70 min) lie in the cool stable region and therefore do not show large optical photometric variations. Little is known about the long-term photometric behaviour of most AM CVn systems, in particular the fainter half of the sample which has been discovered in recent years. These systems are generally beyond the reach of amateur variable star networks (although see Shears et al. 2011), and coverage on larger telescopes has been patchy. To better characterise the properties of AM CVn systems and obtain a better understanding of the physics of the outbursts, we began a monitoring programme using the Liverpool Telescope in Feb 2009 and ended in June 2011.

2 LIVERPOOL TELESCOPE OBSERVATIONS

The Liverpool Telescope is a 2m robotic telescope sited on the island of La Palma in the Canaries and has a suite of instruments including the RATCAM imager (Steele 2004). Our goal was to obtain one g band image per source once per week for the first year and once every 5 days thereafter.

Our target list (see Table 1) include 18 out of the 27 known AM CVn systems.

Exposure times ranged from 5 sec in the brightest source (GP Com) to 140 sec in the faintest (eg SDSS J0129). Observations were made in a range of transparencies, lunar brightness and airmass. Images were typically downloaded within a few days of them being taken and have already been bias subtracted and flat-fielded in an automatic way. We selected two comparison stars and used the photometry analysis tool `autophotom` which is incorporated in the package `Gaia` to determine the relative brightness of our source with respect to the comparisons[1] . Some fields have low stellar density which meant that the comparison stars were as faint as $g \sim$19. We derived a differential light curve between the comparison stars used for each AM CVn system. The mean rms of these light curves was 0.04 mag when both

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[1] Both packages are part of the STARLINK suite of software which can be downloaded from http://starlink.jach.hawaii.edu/starlink
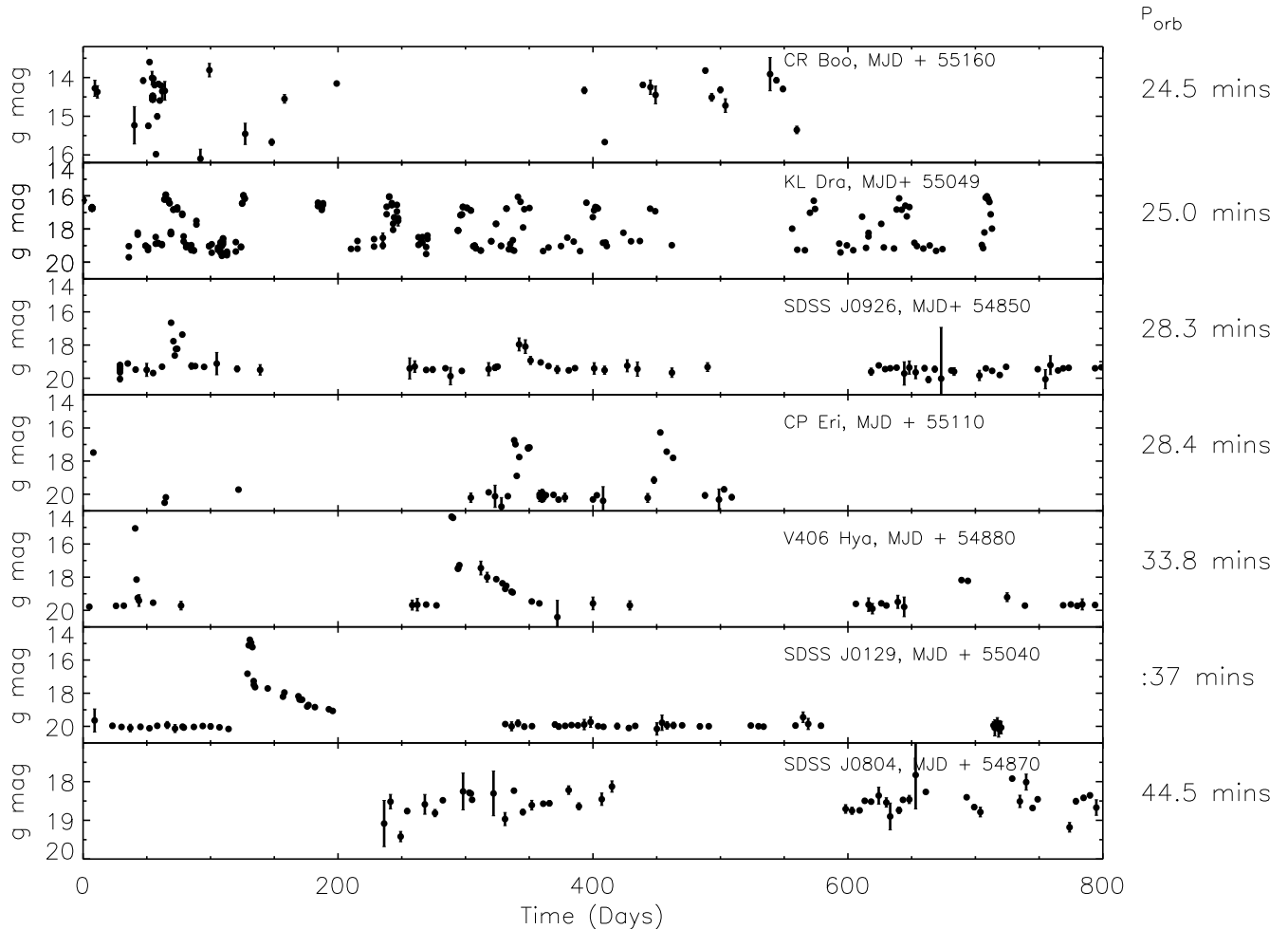
Figure 1. The light curves of AM CVn systems obtained using the Liverpool Telescope which showed an outburst. We show the start date of the observations in the top right of each panel and the orbital period of each system towards the right.

comparison stars were brighter than g=18, and 0.11 mag when both stars were fainter than g=18. Since our aim is to detect variations greater than 1 mag, this is sufficient for our purposes. To place our results on to the standard g band system, we used SDSS photometry of stars in the immediate field when available. For other sources we obtained images of the field (along with standard star fields) using the INT on La Palma.

We show the light curve of each system in Figure 1 (for those showing outbursts) and in Figure 2 (for those which did not). The mean magnitude and range in brightness of our sources as derived using LT data is shown in Table 1, along with the rms of the light curve (see also Figure 3).

3 RESULTS

3.1 Overview

Outbursts from hydrogen accreting cataclysmic variables (CVs) show amplitudes of at least one mag (eg Koto, Lasota & Dubus 2010). We therefore define an AM CVn system in outburst as that which shows light curve variations greater than 1 mag. Of the 18 AM CVn systems in our LT survey,

seven were found to show at least one outburst (CR Boo, KL Dra, SDSS J0926, CP Eri, V406 Hya, SDSS J0129 and SDSS J0804). The LT data of SDSS J0129 were the first to show this system in outburst (Barclay et al. 2009). The other sources all had rms variations less than 0.2 mag (Figure 3). Two systems which have previously been seen in outburst, (2QZ J1427 and SDSS J1240) were not seen in outburst in our LT data (although it is possible we have detected a decline from outburst in SDSS J1240 at MJD~55170). Combining our results with those in the literature, we find that out of the 27 AM CVn systems currently known, 10 show outbursts, and they fall into a narrow range of orbital periods, covering 24.5–44.5 min.

To get an overview of the outburst characteristics of each source we show in Figure 4 the outburst profile of each source (with the exception of CR Boo and SDSS J0804 which show erratic outbursts). For sources which have shown more than one outburst we over-lay data from different outbursts. The shape of the outburst light curves can be split into three broad classes: relatively long duration events such as those seen in V406 Hya and SDSS J0129; shorter duration bursts such as SDSS J0926, CP Eri and KL Dra (Ramsay et al. 2010), and rapid transitions from bright to faint states as seen in CR Boo and SDSS J0804. We show the typical dura-
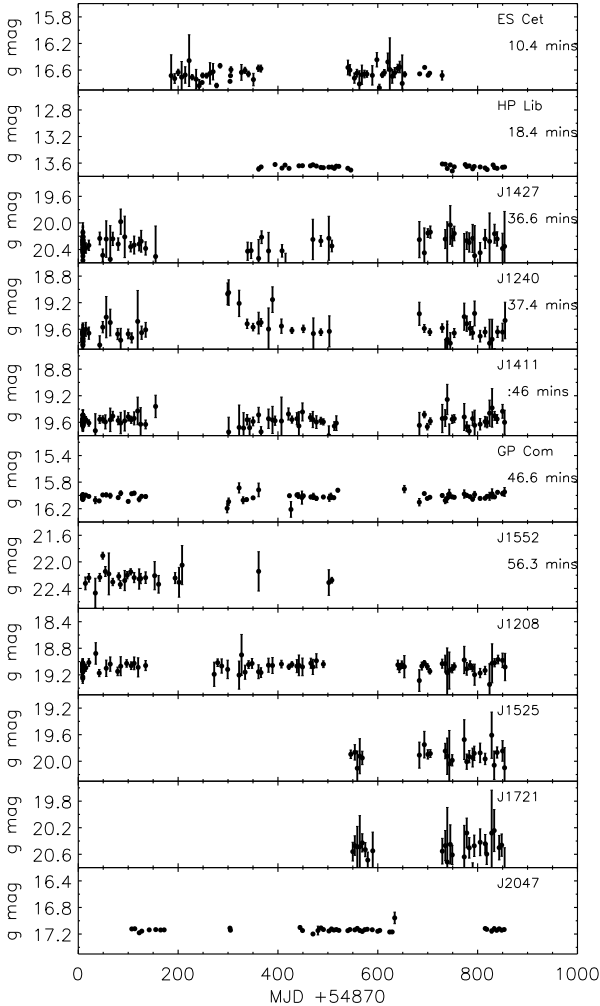
Figure 2. The light curves obtained using the Liverpool Telescope of those systems which did not show an outburst. We show the orbital period of each system towards the right hand side of each panel. The orbital period is not known for the lower four systems.

Figure 3. Using our LT data we show the mean g band brightness of our sources as a function of the root mean squared of the light curve.

Source	Orbital Period (mins)	Duration (days)	Amplitude (mag)	Duty Cycle
CR Boo	24.5		2.3	70%
KL Dra	25.0	10	3.3	15%
J0929	28.3	10	2.6	8%
CP Eri	28.4	15	4.0	27%
V406 Hya	33.8	50	5.2	27%
J0129	:37	50	4.2	22%
J0804	44.5		1.2	8%

Table 2. The typical duration, amplitude and duty cycle (the percentage of observations for which the source was seen in outburst) of those AM CVn systems seen in outburst in our LT data. CR Boo and SDSS J0804 showed erratic rather than regular outbursts.

tion, amplitude and duty cycle (the fraction of observations which showed the source in outburst) of each source in Table 2. For systems with orbital periods between 33–37 mins, there is a tendancy for the outbursts to have longer durations and higher amplitude than the shorter period systems.

3.2 Likelihood of missing outbursts

We have carried out simulations in order to estimate characteristic probabilities for missing an outburst given the typical data sampling. In particular, we have created synthetic light curves with a range of outburst lenghts and separation intervals. This was done by assuming an exponential distribution for inter-outburst times and a uniform distibution for outburst lengths. A range of different means were used for the inter-outburst exponential distributions. Figure 5 shows two representative cases. We have plotted a 2D probability distribution of missing outbursts from GP Com (top) and J2047 (bottom) as a function of mean inter-outburst duration versus the outburst length. GP Com and J2047 represent two cases where we did not detect an outburst.
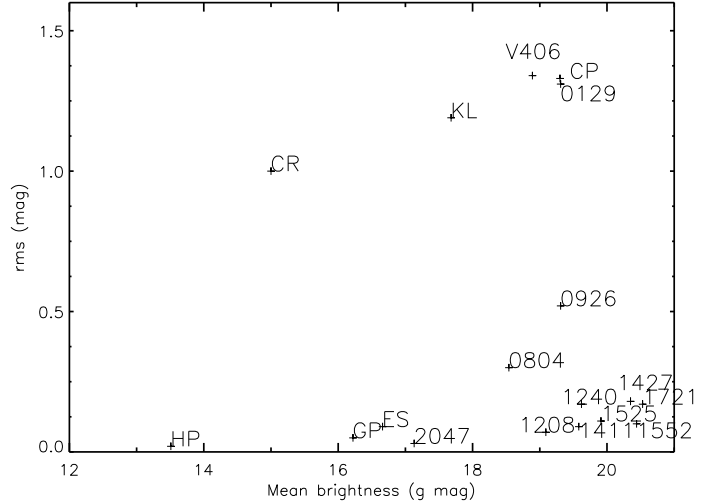
For both systems, the probability of us missing an outburst is less than 10 percent when the burst is interval is less than 150 days. For longer burst intervals the probability of us missing a burst reaches 30 percent in the case of J2047 when the burst length is shorter than 2 weeks.

We also examined the light curve of J0926 which shows two outbursts although we may well have missed additional bursts. We performed a similar set of simulations although on this occasion we define the outburst length as being 10 days. We find the number of missed outbursts does not depend on the outburst frequency - we expect to miss 47 percent of outbursts if the outburst frequency is between 60 and 400 days. Our data of J0926 unevenly cover 800 days and our similations predict three outbursts over this timescale where we detected two.

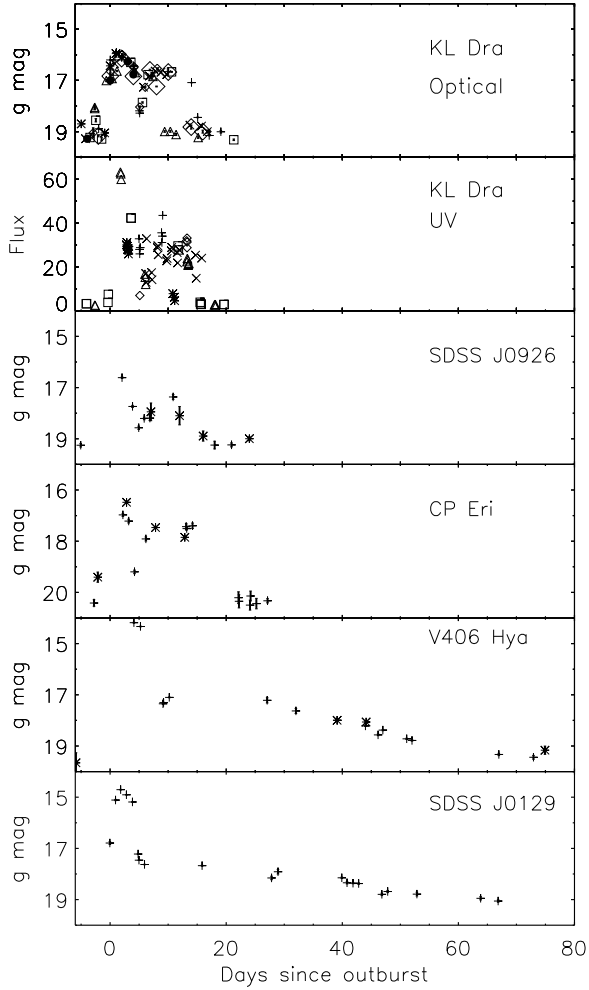We now proceed and discuss individual outbursting systems in more detail.

Figure 4. We show typical outburst profile of outbursting AM CVn systems. Different symbols have been used for different outbursts. The UV data from KL Dra has been obtained using the *Swift* satellite.

3.3 CR Boo

CR Boo shows marked changes in its intensity with an amplitude of 3 mag. It is either brighter than g=14.5, or fainter than g=16.5 for 90 percent of time and is brighter than g=14.5 for 70 percent of the epochs it was observed using the LT. However, our sampling is not frequent enough to determine if there is an underlying periodic or quasi-periodic signal. However, observations covering a timescale of 3 years show evidence for a quasi periodic transition between bright and faint states of 46.3 days (Kato et al. 2001). On the other hand, Patterson et al. (1997) found a prominent modulation ($\sim$1 mag) on a period of $\sim$19–22 hrs (which our data are unable to sample).

3.4 KL Dra

The first nine months of our LT observations of KL Dra have been reported in Ramsay et al. (2010). They showed an outburst every $\sim$60 days (or roughly six per year), making KL Dra the best example of a helium accreting dwarf nova. Since then KL Dra has continued to show regular out-
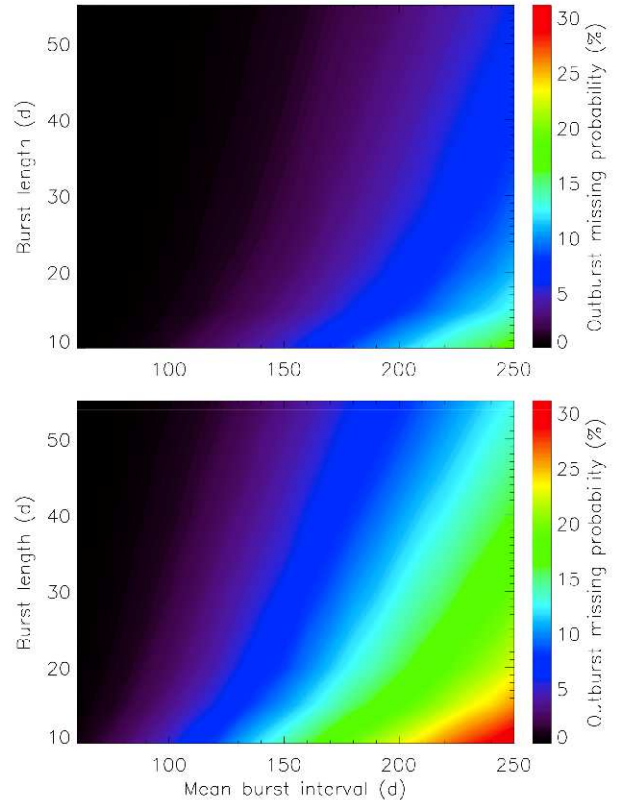

Figure 5. We show the probability of missing an outburst as a function of mean outburst interval and outburst length. In the top panel we derive the probability for GP Com and in the lower panel J2047.

bursts. We have determined the recurrence time between successive outbursts and their peak brightness. Although there is some uncertainty in determining both parameters since the cadence of our observations is variable, it is clear that the recurrence time shortened from 60 days at the beginning of our observations, to $\sim$45 days after a further five outbursts (Figure 6). When KL Dra became visible again the recurrence time had increased to $\sim$65 days. There is a hint that the peak brightness in the optical band followed the trend seen in the recurrence time.

Although our coverage is such that the duration of the outbursts is not well defined, the outburst with the best coverage reported by Ramsay et al. (2010) lasted 17 days. However, for the cycle which had a recurrence time of 44 days, the duration of the outburst prior to this lasted only 9 days. The typical duty cycle for the system being in the outburst state is 15 percent. The fact that there is a significant spread in the outburst recurrence time is entirely consistent with that seen in the hydrogen accreting dwarf novae, which can show a spread of up to a factor of 4 (cf Cannizzo, Shafter & Wheeler 1988). We note that the *Kepler* observations of the dwarf nova V344 Lyr shows a shortening in the recurrence time of the outbursts immediately after a super-outburst, which then appears to lengthen and shorten in the lead up to the next super-outburst (Cannizzo et al. 2010).
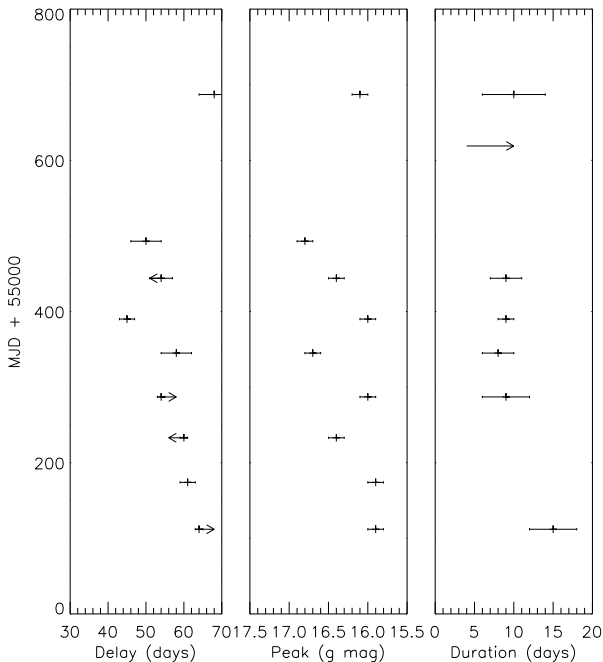
Figure 6. KL Dra: In the left hand panel we show the delay between the burst peaking at the date shown on the y-axis (MJD-55000) and the previous one. In the middle panel we show the g mag peak brightness of the burst, while in the right hand panel we show the duration of the burst.

3.5 SDSS J0926

Observations made using the Catalina Real-Time Transient Survey showed five outbursts (of amplitude ∼3 mag) of SDSS J0926 over nearly 6 years of observations (Copperwheat et al. 2011). (Our simulations suggest that roughly eight outbursts would be expected over 6 years). The sampling is such that the source was observed, at best, once every 20 days or so. Our observations made using the LT show one clear outburst with an amplitude of ∼2.5 mag and a duration ∼16 days, with a second outburst for which we caught the decline phase (at MJD∼55192, cf Figure 1). Our data show SDSS J0926 was brighter than g=18.4 mag for 8 percent of our observations. We note the presence of a brightening 8 days after the initial outburst – this maybe related to the dip seen in both CP Eri and KL Dra (Figure 4. We will discuss these dips further in §4.

3.6 CP Eri

We have detected CP Eri in outburst on three occasions (although in the first there is only one data point where our sampling was rather sparse). The amplitude of the outbursts is ∼4 mag, while the rise time from the faint state to the high state was less than 5 days in the second outburst and less than 10 in the third. Our data show CP Eri was brighter than g=18.0 mag for 27 percent of our observations. We note a short duration drop in the intensity of CP Eri 2 days after the on-set of the second burst (cf Figure 4 and §4). The third outburst took place ∼114 days after the second. The only other recorded instances of CP Eri showing outbursts is Luyten & Haro (1959) who found it ∼2.5 mag brighter

than on the POSS images and Abbot et al. (1992) observed it at one epoch when it was brighter still.

3.7 V406 Hya

V406 Hya was originally thought to be a supernova (2003aw) but subsequent spectroscopic observations showed it was an AM CVn system. Followup photometric observations showed that V406 Hya exhibits outbursts which can be up to 5 mag in amplitude and have durations lasting two or three months (Woudt & Warner 2003, Nogami et al 2004). Our observations using the LT showed one long duration outburst, which lasted more than 60 days and had an amplitude of 4 mag. We also observed an increase in brightness at MJD∼56170 which could be the decline from an outburst which was not detected (Figure 1). Although our observations did not have high cadence, they indicate that the rise to maximum took place on a timescale <12 days, and showed a very rapid initial decline from maximum (4 days) followed by a lengthy decline phase. Our data show V406 Hya was brighter than g=18.5 mag for 27 percent of our observations. The characteristics of this outburst are very similar to that found in Nogami et al. (2004). Our observations also show a very short duration (less than 10 days), high amplitude outburst (maximum at MJD=54920).

3.8 SDSS J0129

SDSS J0129 was seen in outburst on Dec 3rd 2009 when it was seen 3 mag brighter than it was 14 days earlier. It went on to reach maximum brightness after a further two days when it was 5 mag brighter than found in quiescence (Barclay et al. 2009). The shape of the light curve is very similar to V406 Hya, showing a very rapid initial decline from maximum brightness (less than a day) and an extended tail. Our data show SDSS J0129 was brighter than g=18.5 mag for 22 percent of our observations.

Shears et al. (2011) have recently reported the detection of the same outburst as reported here. Moreover they detected super-humps during the outburst which had a period of 38 min. Since the super-hump period is typically longer than the orbital period by a few percent at most, the likely orbital period is 37–38 min.

3.9 SDSS J0804

Of all our 'outbursting' AM CVn systems, SDSS J0804 shows the lowest amplitude variations (1.2 mag) and has the longest orbital period. It does not show obvious outbursts such as KL Dra or SDSS J0129, but shows a light curve more similar to CR Boo (which has the shortest orbital period of our outbursting systems). However, in contrast to CR Boo there are no clear low/high states, with 90 percent of our datapoints in the range 18.2< g <18.8 and only 8 percent brighter than g=18.2. It is therefore not clear whether SDSS J0804 shows genuine outbursts but rather is just more active than systems which do not show outbursts.

4   THE 'DIP' FEATURE

Ramsay et al. (2010) found clear evidence for a short duration decrease in the optical flux of KL Dra around five days after the start of the outburst. With our more extended dataset, we have identified a total of five such dips in KL Dra suggesting they are not transient. Moreover, similar dips are seen in our LT optical light curves of SDSS J0926 and CP Eri (Figure 4) and in the recently discovered system PTF1 J0719+4858 (Levitan et al. 2011).

We show in Figure 4 the outburst light curve of KL Dra in the optical and UV bands. Given the relatively sparse cadence of our data, this is accurate only to within a few days. However, the dip lasts 2–3 days and has a depth of a factor of ∼5 compared to the pre-dip light curve. Although the UV data are more scattered compared to the optical data, the UV flux tends to be weaker at the time of the optical dip. (We have included *Swift* UV data which were taken in April 2010 – after the paper by Ramsay et al. 2010 was accepted). Our data do not have high enough cadence to determine whether a dip is seen in *every* outburst of KL Dra.

A dip-like feature has also been reported in the AM CVn system V803 Cen by Kato et al. (2004) who noted its similarity to the 2001 super-outburst of WZ Sge. This dip has been interpreted as a re-brightening due to a recurring thermal instability (eg Osaki et al. 2001). However, compared to KL Dra the dip occurs much longer after the on-set of the outburst. We note that dips have also been seen in some hydrogen accreting CVs, eg T Leo, (Kato 1997), which are thought to due to a normal outburst triggering a superoutburst (van der Woerd & van Paradijs 1987).

5   OUTBURSTING SYSTEMS AS A FUNCTION OF ORBITAL PERIOD

One of the main motivations for our study was to test the prediction of Smak (1983), and later elaborated by Tsugawa & Osaki (1997), who suggested that systems with orbital periods in the range ∼20–40 min would experience outbursts. For AM CVn systems with $P_{orb} \gtrsim 40$ mins, the accretion disc is predicted to be cooler than the ionisation state of helium. For binaries with $P_{orb} \lesssim 20$ mins, the disc is predicted to be hotter than the ionisation state of helium. Since these discs were expected to be stable it was predicted that systems would not show photometric outbursts.

Tsugawa & Osaki (1997) indicated (their Figure 3) the predicted location of these thermally stable and unstable regions in the P_{orb}, $\dot{M}$ plane for AM CVn binaries. Depending on whether the donor star is fully or partially degenerate may shift a particular source to the stable or unstable region. We have taken Figure 3 of Tsugawa & Osaki (1997) as a starting point, but employed the predicted relationship between P_{orb} and $\dot{M}$ from Deloye et al. (2007) which is more physical than that of the earlier work.

In the top of Figure 7 we place a 'Y' or a 'N' indicating whether a source shows outbursts or not (Table 1). We find that all the systems with orbital periods between 24–44 mins show outbursts and are located in the unstable region (Figure 7). However, taking into account the period of the systems which do not show outbursts, the unstable
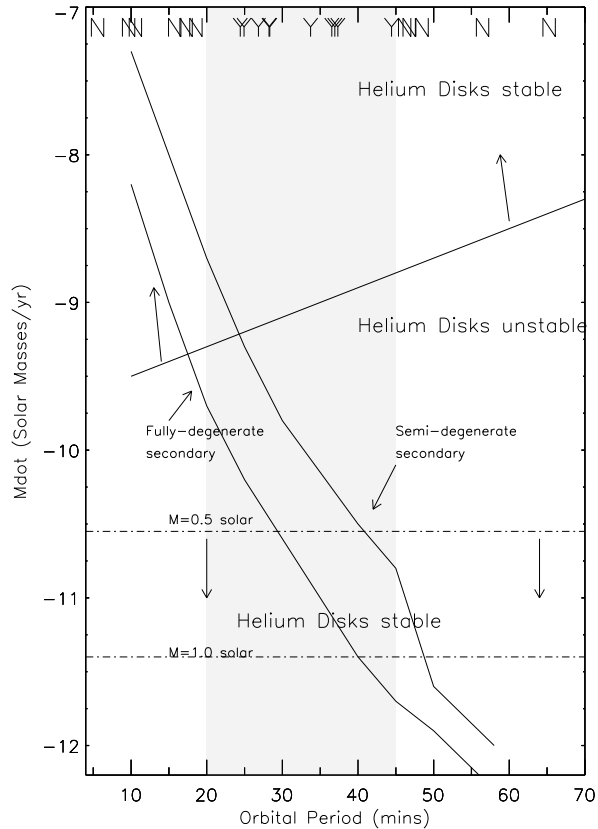

Figure 7. We show the stable and unstable regions for AM CVn systems as a function of orbital period and mass transfer rate where we have taken the general outline from Tsugawa & Osaki (1997) as a starting point but annotated and updated it. Unstable accretion disks are predicted to lie between the hot and the cool stable regions (top and bottom). The horizontal dashed-dotted lines give the location of the cool stable region depending on the mass of the accreting star. The lines travelling from the lower right to the upper left are the predicted mass-transfer rate as a function of orbital period (taken from Figure 15 of Deloye et al. 2007). We have added a 'Y' or a 'N' at the appropriate orbital period depending on whether the AM CVn binary goes into outbursts or not.

region potentially extends between 19–46 mins (cf Table 1). At the lower end of the unstable range, CR Boo (which is thought to have a semi-degenerate donor star Roelofs et al. 2007b) is just inside the unstable regime. In the case of KL Dra, which has a virtually identical orbital period, it is unknown whether its donor star is semi or fully degenerate. At the shortest orbital periods, these systems would be stable whether their donor star was fully or semi degenerate. At longer periods (J0804, GP Com, J1411) these stars would be more likely to be unstable if their donor star was semi-degenerate and/or their accreting white dwarf was relatively low mass. This result indicates a remarkable agreement between the prediction of Smak (1983), Tsugawa & Osaki (1997) and observation.

6 A HELIUM-RICH DWARF-NOVA SEQUENCE?

Our survey to characterise the long term behaviour of AM CVn binaries has found that 10 out of the 27 systems has shown at least one outburst. Moreover, the outbursting systems have periods between 24 and 44 mins – a result which is remarkably consistent with theoretical predictions. It appears that systems with $P_{orb} \lesssim 24$ mins have an accretion disc which has a mean temperature always above the ionisation state of helium, while systems with $P_{orb} \gtrsim 44$ mins have a disc with a mean temperature below the ionisation state of helium.

Of the seven systems which showed at least one outburst in our LT data, there is some evidence that the outbursts fall into three rather distinct characteristics, the nature of which may be related (at least partly) to their orbital period. KL Dra (25.0 min), J0926 (28.3 min) and CP Eri (28.4 min) all show outbursts lasting a week or two with a distinctive dip in the outburst profile. The recently discovered system PTF1 J0719 (26.8 min, Levitan et al. 2011) also shows outbursts lasting several weeks, but in addition exhibits bursts lasting several days (which is very similar to what we observe in KL Dra, although they are not well sampled). Given our low cadence it is possible that the 50–60 day outbursts seen in KL Dra are super-outbursts, and the short duration bursts are normal outbursts.

CR Boo which has a period just shorter than KL Dra (24.5 min) shows a rapid change between high and low states. In addition it has shown a peculiar 'cycling' state when it shows a prominent modulation (~ 1 mag) on a period of $\sim$19-22 hrs (Patterson et al. 1997). This photometric feature has also been seen in V803 Cen (26.9 min) (Patterson et al. 2000). At the longer period boundary, SDSS J0804 (44.5 mins) also shows enhanced levels of activity, but not regular outbursts. This may hint that systems on the boundary between having a stable or a non-stable accretion disc are likely to be unstable. On the other hand, given KL Dra and CR Boo have practically identical periods it is likely that factors other than the orbital period (for instance, the nature and metallicity of the donor star) affects the long term photometric behaviour.

In complete contrast, V406 Hya (33.8 min) and J0129 (~ 37 min) show outbursts which are up to 5–6 mag in amplitude and which last several months. Evidence exists that J1240 (37.4 mins) also shows high amplitude and long duration outbursts (Shears et al. 2011). The similar period of these systems makes observations of J1427 (which has a photometric period – probably a superhump – of 36.6 min, Shears et al 2011) particularly interesting. Does it also show similar long outbursts? In the case of SDSS J2047+0008, which currently does not have a known orbital period, the fact that it has been found to go into outburst, strongly suggests that it has an orbital period between 24–44 mins.

7 SUMMARY

Our survey of AM CVn binaries using the Liverpool Telescope coupled with existing published data shows that $\sim 1/3$ of these helium accreting compact binaries undergo outbursts. These outbursting systems have orbital periods within the range 24–44 mins. This result is in excellent agreement with theoretical predictions. Moreover, we find tentative evidence for the characteristics of these outbursts to be dependent on orbital period. Systems at the lower end of this period range show outbursts which last a week or two and tend to show a characteristic dip a handful of days after the start of the outburst. At longer periods, the outbursts have greater amplitude and last for several months. Systems at the edge of this period range, whether the disc is close to being in a stable hot state or a stable cool state, show rapid changes in brightness.

This sequence can be seen in the context of the rapidly diminishing mass transfer rate between 20–40 mins. At shorter periods the higher mass transfer rate enables the disc to achieve a critical mass on a shorter timescale than for longer period systems where the mass transfer rate is significantly lower. Based on our survey we predict that J1427 will also exhibit large amplitude long duration outbursts. Indeed we encourage observations of J1427, V406 Hya and J0129 to detect further outbursts so that they can be studied in much greater detail, and at different wavelengths, and determine how similar they are to the hydrogen accreting WZ Sge stars.

Using the models of Nelemans et al. (2001, 2004), Roelofs, Nelemans & Groot (2007c) predict the population surface density of AM CVn systems as a function of Galactic latitude. For $|b| < 30°$ they predict that around half of all AM CVn binaries are expected to have orbital periods in the range 20–40 mins (irrespective of whether one assumes 'optimistic' or 'pessimistic' assumptions for their space density), although this fraction is lower for higher Galactic latitudes. Although we find the duty cycle is quite variable from source to source (and indeed, not especially well constrained), our results indicate that a duty cycle of $\sim 1/4$ is not untypical, which may be due to the small disks in AM CVn systems. Given this reasonably high duty cycle, surveys which followup blue transient systems may provide the best method with which to discover AM CVn systems. The recent discovery of PTF1 J0719 using the Palomar Transient Factory confirms such a view (Levitan et al. 2011).

8 ACKNOWLEDGEMENTS

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