On the role of short period Cataclysmic Variables from Catalina Sky Survey

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Abstract

We report time-resolved photometry of three new CVs during superoutburst: CSS130105:105026+332813 (CSS130105), CSS130122:154310+045531 (CSS130122), CSS131026:024354-160314 (CSS131026), discovery by Catalina Real-Time Transient Survey (CRTS). The observations have been carried out at a 2.4 m Thai National Telescope, two 0.6 m PROMPT5, and PROMPT8 telescopes, and a 0.43 m PROMPT-SSO-3 telescope. Time-series analysis was used to determine superhump periods of these three CVs, resulting P_{sh} = 97.7 min, P_{sh} = 98.5 min, and P_{sh} = 86.7 min, for CSS130105, CSS130122, and CSS131026, respectively. Based on outburst properties, we have classified all three CVs as SU Uma-type dwarf novae with orbital periods P_{orb} < 2h. In addition, we have updated the recent status of all known CVs and all known dwarf novae discovered by various means.

***Keywords*:** Cataclysmic Variables, Binary Star System, Catalina Real-Time Transient Survey

Introduction

Cataclysmic variables (CVs) are semi-detached close binary systems comprising an accreting white dwarf, and a late-type main-sequence donor with the orbital period ranging between ~ 80 min and ~ 10 h. Angular momentum loss drives CVs to evolve toward shorter period, reaching its minimum period at P_{orb} ~ 65 min (Kolb & Baraffe 1999; Howell et al. 2001) and finally evolve back towards longer orbital period. Population syntheses estimated that ~ 99% of the entire CV population should have short orbital periods (P_{orb} < 2 h), and of these, 70% should have passed the period minimum (Kolb 1993; Howell et al. 1997). As the evolution of the orbital period slows down at the shortest periods, this should lead to a significant accumulation of systems near the minimum period. From observational side, however, the predicted 'spike-like' feature near the period minimum was not observed (e.g. Kolb & Baraffe 1999; Willems et al. 2005). Until recently, Gänsicke et al. (2009) have shown that the period distribution of CVs discovery by the Sloan Digital Sky Survey (Szkody et al. 2002, 2003, 2004, 2005, 2006, 2007, 2009, 2011)) differs dramatically from all previously samples. In particular, a clear accumulation of systems in the period range 80-86 min is observed. However the problem of the location of the period minimum remains. Also the observed ratio of short to long-period CVs still disagrees with the model predictions (Aungwerojwit et al. 2006; Pretorius et al. 2007; Pretorius & Knigge 2008).

In order to solve these problems, we have initiated to identify intrinsically faint CVs in the Catalina Real-time Transient Survey (CRTS; Drake et al. 2009) using their outburst properties with the aim to establish the faintest CV sample to date. Here, we present time-resolved photometry of three new CRTS CVs, CSS130105:105026+332813 (CSS130105), CSS130122:154310+045531 (CSS130122), CSS131026:024354-160314 (CSS131026) during their superoutbursts. CSS130105, CSS130122, and CSS130122 are CVs with 22.3, 21.9, and 20.2 magnitudes during quiescence, respectively. On 5th January, 22nd January, and 26th October, 2013, the CRTS detected the outbursts of these systems with outburst magnitudes of 5.30, 4.31, and 5.90, turning the systems as bright objects with 17.0, 17.59, and 14.0 magnitudes which are accessible to small/intermediate telescopes. The details of observations and data analysis are presented in following sections.

Observations and data reduction

In January 2013 we obtained time-resolved CCD photometry of CSS130105, and CSS130122 using a 2.4-m Thai National Telescope (TNT) located at Doi Inthanon. The telescope was mounted with a 2k x 2k ALTA U42 CCD and 3k x 3k ALTA U9000 CCD, respectively (see Table 1 for log of observations).

Data reduction was carried out in the standard manner using the pipeline described by Gänsicke et al. (2004), which uses the Sextractor (Bertin & Arnouts 1996) to calculate aperture photometry for all objects in the field of view. For CSS131026, the observations were obtained in November 2013 with a 0.6 m PROMPT5 (P5) telescope and a 0.6 m PROMPT8 (P8) telescope, located at Cerro Tololo Inter-American Observatory, Chile and a 0.43-m PROMPT-SSO-3 (SSO-3) located at Siding Springs Observatory, Coonabarabran, Australia as shown in Table 1. All PROMPT data were automatically reduced via PROMPT pipeline.

Table 1: Log of the observations

Date	UT	Tel.	Filter	Exp.	Frames
CSS130105:105026+332813					
20130106	19:02:37-23:20:39	TNT	Clear	30	429
CSS130122:154310+045531					
20130124	20:44:41-23:16:46	TNT	V	70	116
20130125	20:20:12-23:15:49	TNT	V	85	118
20130126	20:11:06-23:22:51	TNT	V	90	122
CSS131026:024354-160314					
20131102	10:13:30-11:52:47	SSO-3	V	40	88
20131103	10:00:36-13:13:50	SSO-3	V	40,60	168
20131104	03:24:57-04:03:10	P5	V	60	35
20131105	00:36:51-05:04:08	P8	V	40	150
20131106	01:02:59-04:34:45	P8	V	40	216

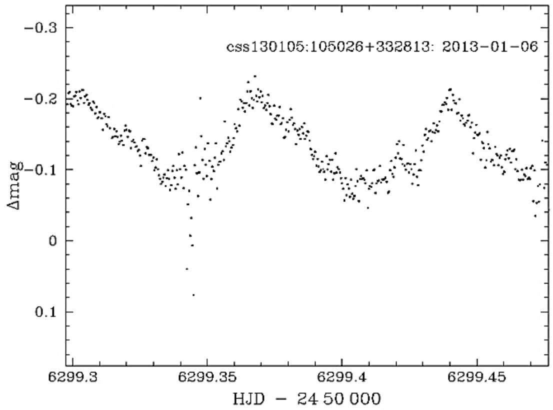

Figure 1. Light curve of CSS130105 obtained with the TNT.

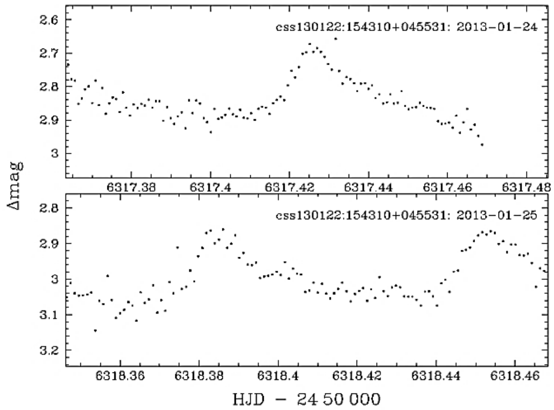

Figure 2. Sample light curves of CSS130122 obtained with the TNT.

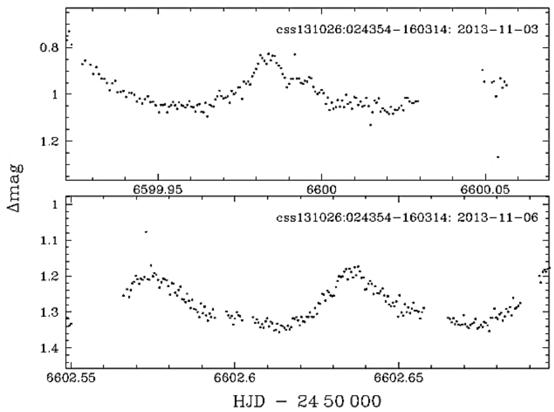

Figure 3. Sample light curves of CSS131026 obtained with the PROMPT8, and PROMPT-SSO-3.

Data Analysis and Results

Sample light curves of CSS130105, CSS130122, and CSS131026 are illustrated in Figure 1-3. Superhump structures are clearly seen in all light curves. In order to estimate superhump periods (P_{sh}) of these systems, Scargle (1982) periodograms and analysis-of-variance (AOV; Schwarzenberg-Czerny 1996) periodograms were computed within the MIDAS/TSA context. The Scargle periodogram of CSS130105 is presented in Figure 3 (top panel) with the strongest peaks at f = 14.7 d^{-1}. We computed the Scargle periodogram for CSS131022, resulting in two equally peaks at f = 13.5 d^{-1} and f = 14.5 d^{-1}. The AOV periodogram, however, gives a clean signal at f = 14.5 d^{-1} (Figure 3, middle panel). For CSS131026, the computed Scargle periodogram shows the strongest peak at f = 16.6 d^{-1} (Figure 3, bottom panel). Figure 4 shows all photometric data of CSS130105 folded on P_{sh} = 97.7 min, CSS130122 folded on P_{sh} = 98.5 min, and CSS131026 folded on P_{sh} = 86.7 min, respectively.

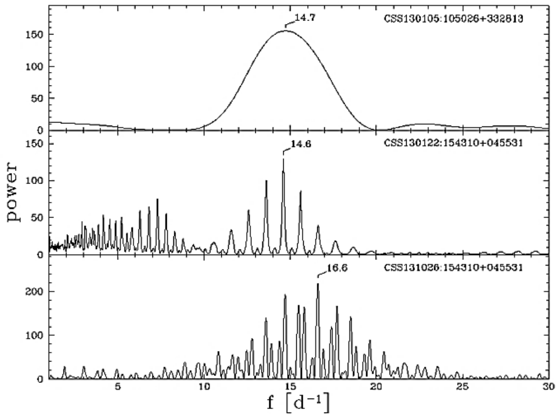

Figure 4. Scargle (top panel: CSS130105 and bottom panel: CSS131026) and AOV (middle panel: CSS130122) periodograms computed from the combined photometric data of the three CVs.

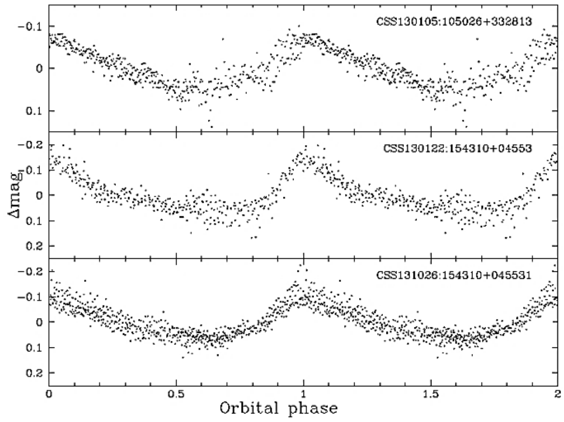

Figure 5: The combined photometric data of CSS130105 (top panel), CSS130122 (middle panel), and CSS131026 (bottom panel) folded on their superhump periods.

Discussion

We update the orbital period distribution of all known CVs and all known dwarf novae presented in Figure 17 of Aungwerojwit et.al. 2005 by adding new CVs listed in Ritter & Kolb catalogue (2003, version 7.20, July 2013) within the orbital period between ~1 h to ~10 h, excluding AM CVn systems. Figure 6 (top panel) presents the orbital period distribution of all known CVs (1,124 systems) of which 542 (48%) are short-period systems (P_{orb} < 2 h), 142 systems (13%) are found in the 2-3 h period gap, and 440 (39%) are long-period systems (P_{orb} > 3 h). We found that more than half of all known CVs (58%, 657 systems out of 1124) are dwarf novae of which 439 (67%) have P_{orb} < 2 h, 75 systems (11%) are located in the period gap, and 143 (22%) have P_{orb} > 3h. The bottom panel of Figure 6 shows all known dwarf novae classified by their subtypes which are 446 SU UMa (including 8 ER UMa stars, and 78 WZ Sge stars), 70 U Gem, 29 Z Cam, and 92 unclassified subtypes. The trend of the updated period distribution of all known dwarf novae is similar to the original version presented by Aungwerojwit et. al. 2005 i.e., all confirmed U Gem and Z Cam stars lie above the period gap and most of SU UMa (86%) lie below the period gap and only a small number (14%) inhabits the 2-3 period range. In addition, the orbital period distribution of dwarf novae does not represent the large number of short-period systems predicted by the standard CV evolution. Furthermore, the minimum period is close to 74-78 min instead of the predicted value of 65 min (Paczyński & Sienkiewicz 1983). It is noted that our three CVs will be added into SU UMa-type dwarf novae with the orbital period P_{orb} < 2 h.

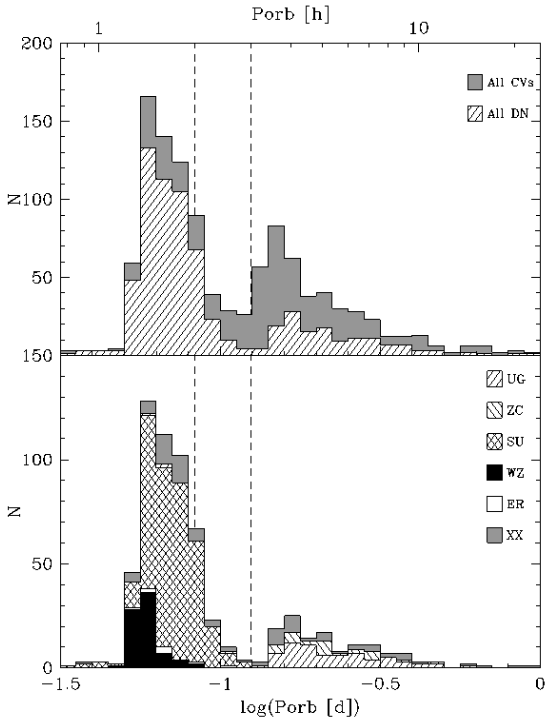

Figure 6: Top panel: the updated orbital period distribution of known CVs (gray) and dwarf novae (shade) from Ritter & Kolb (2003, version 7.20, July 2013). Bottom panel: the period distribution of all known dwarf novae according to their subtypes, U Gem (UG), Z Cam (ZC), SU UMa (SU), WZ Sge (WZ), ER UMa (ER), and unclassified subtype (XX). The dashed lines are the 2-3 h period gap.

Conclusions

We have identified three new SU UMa-type dwarf novae with P_{sh} = 97.7 min for CSS130105, P_{sh} = 98.5 min for CSS130122, and P_{sh} = 86.7 min for CSS131026. Overall the period distribution of all known CVs and all known dwarf novae do not agree with the predictions made by the standard models of CV evolution in particular the number of short-period systems and the value of the minimum period.

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