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The photometric observations of new WZ Sge-type systems with small telescopes

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Abstract. The last few years have been marked by discoveries and studies of the powerful outbursts of the WZ Sge-type dwarf novae with small telescopes. These objects are characterized by very short orbital periods (mostly 80–90 min), strong and rare superoutbursts and very specific light curve features – superhumps. We carried out the multicolour observations of some WZ Sge-type systems during their superoutbursts, fadings, rebrightenings (if they were detected) and in quiescence using small telescopes (60-, 125-cm) of the Crimean station of Moscow State University and the Astromonical Institute of the Slovak Academy of Sciences. A short review of the WZ Sge-type objects, having been observed in these observatories, is presented. Possibility of good investigation of CVs with small telescopes, equipped with CCD-cameras, is very relevant.

Key words: cataclysmic variables – dwarf novae – WZ Sge-stars– superoutbursts – superhumps – photometry

1. Introduction

Cataclysmic variables (CVs) are close binaries consisting of a white dwarf accreting a matter from his companion – a red dwarf, filling its Roche-lobe. This matter creates an accretion disk around the white dwarf. CVs are subdivided into some subclasses, including dwarf novae (DNe) and nova-likes variables. DNe are usually in quiescent state but sometimes they exhibit outbursts, lasting a few days and caused by accumulation of matter in the accretion disk and possibly a sudden increase of a mass transfer rate. The SU UMa-type is one of the subclasses of DNe with short lasting outbursts and more prolongated superoutbursts with very special features on the light curves – superhumps – with periods exceeding the orbital periods by 1–3%. Most of the orbital periods of SU UMa-type DNe are below two hours. Majority of WZ Sge-type (subclass of SU UMa-type) DNe have orbital periods in the range 80-90 min. They show strong and rare superoutbursts (with several years of recurrent time between superoutbursts) and modulations of their light cuves known as early, ordinary and late-stage superhumps. Some of them exhibit a complex post-superoutburst rise of brightness called rebrightening(s), or echo-outburst(s), whose nature is unclear till now. The presence of early superhumps during the earliest stages of superoutbursts is one of the most remarkable signatures of WZ Sge-type objects not detected in other DNe. Most of the WZ Sge-type objects have been discovered in the last few years and their number is approximately equal to 60. Characterization of these systems and a large observational and statistical bulk of information was collected in the "Pdot-Survey of SU UMa and WZ Sge-stars" by Kato et al. (2009, 2010, 2012, 2013). The orbital periods of WZ Sge-type DNe are close to the so called period minimum of CVs, which has to be near 78 min (observational) (Hellier, 2001) and 65-70 min (theoretical) (Rappaport et al., 1982; Kolb, Baraffe, 1999). Thus the WZ Sge-type objects are very important for an investigation of evolution binary systems in the region of "the period minimum" and as the candidates for period bouncers.

2. Photometric observations of the WZ Sge-type DNe

In recent years we have observed and investigated next WZ Sge-type DNe (some of them in collaboration with the colleagues from SAO RAS, Ukraine, Japan etc). Some of our data were included in Kato et al. (2009, 2010, 2012, 2013). We offer a short description of a few interesting objects, listed in Table 1.

2.1. DN Draconis 2011

DN Draconis = PNV J18422792+4837425 (J1842+48) experienced a superoutburst on September, 5, 2011. It was described in Kato et al. (2013) and Katysheva et al. (2012). The decline from the brightness maximum was replaced by a wide brightness minimum followed by a very long first rebrightening, detected on October 6, 2011 (JD 2455841). Its plateau lasted 14 days. Usual duration of the rebrightening is about 2-3 days. Kato et al. (2013) described this feature as a double outburst. During the first outburst the early superhumps were detected and no ordinary superhumps were observed. Ordinary superhumps only appeared in the second outburst (the first rebrightening according to Katysheva et al., 2012). Such behaviour is very unusual for WZ Sge-type DNe. In Fig. 1 the overall light curves in $UBVRI$-bands are presented. We also found the mean period of the ordinary superhumps $0.^{d}07275$ during the plateau of the first rebrightening and detected the second rebrightening, narrower than the first one. Now the system is in quiescence, but the variability is clearly seen in the R_C-band (see Fig. 1, right).

2.2. DN Pegasi 2010

DN Pegasi 2010 (J213806.6+261957 = J2138+26) was discovered as a bright optical transient on May 6, 2010. Our early $UBVR_CI_C$ CCD observations of the J2138+26 were taken with the 0.35–0.6m telescopes. We started our observations after the early stage of superoutburst, so the early LCs are missing. The results of our observations were presented in the paper by Chochol et al. (2012). The

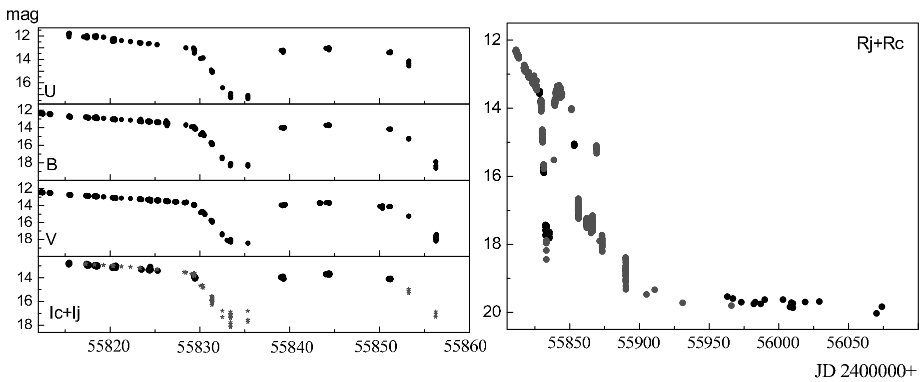

Figure 1. The overall light curves of J1842792+4837425 in *UBVI*-bands (left) and R_J+R_C-band (right).

Table 1. A few observed WZ Sge-type DNe.

Name	year SO	Ref.
V455 And	2007	Katysheva, Shugarov, 2009
V466 And	2008	Chochol et al., 2010
PR Her	2008	in preparation
EZ Lyn=J0804+5103	2006, 2010	Pavlenko et al., 2007
CT Tri	2008	Chochol et al., 2009
J102146+234926	2006	Uemura et al., 2008
J104411+211307	2009	in press
V355 UMa=J1339+4847	2011	in preparation
J174033+414756	2013	Chochol et al., 2014
J184227+483742	2011	Katysheva et al., 2013
J1915019+071947	2013	Golysheva, Shugarov, 2014
J203749+552210	2012	in preparation
J213806+261957	2010	Chochol et al., 2012
SBS 1108+57	2012	Kato et al., 2013; Littlefield et al., 2013 Carter et al., 2013; Pavlenko et al., - - in preparation

outburst light curve is drawn in Fig. 2. It is seen that the object is brightest in the *U*-band.

An analysis of our data revealed the presence of ordinary superhumps with the mean period of $0.^d055106$ and late-stage superhumps with the period of $0.^d05490$. The orbital period of the J2138+26 was calculated as $0.^d0542\pm 0.^d005$ and the mass of the red dwarf was estimated as $0.090 \pm 0.01 M_{sun}$. According to Kato et al. (2009), during the stage B, the period of superhumps increased as $Pdot = dP/dt/P = +6.2 \times 10^{-5}$. The night-to-night brightness variations as well as a flickering with an amplitude of 0.2 mag on a time scale of minutes were detected in quiescence.

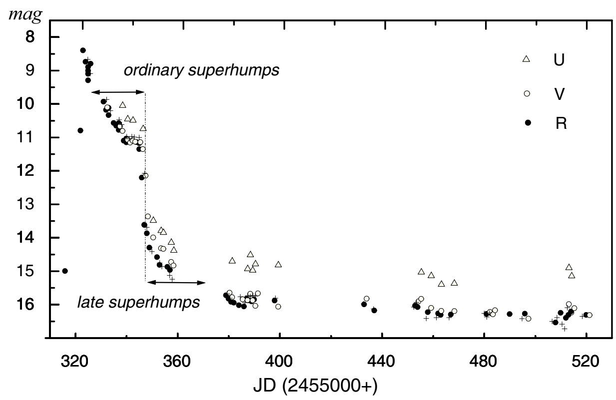

Figure 2. The UVR_C LCs of the J2138+26. The superhumps' stages are denoted by arrows.

2.3. EZ Lyn = SDSS J080434.20+510349.2

EZ Lyn = SDSS J080434.2+510349.2 was first discovered as a CV and considered as a potential DN in quiescence (Szkody et al., 2006). Its first superoutburst was detected by Pavlenko et al. (2007) in 2006. Its $0.^d060$ superhump period and $0.^d059005$ orbital period suggested EZ Lyn as a period bouncer, which passed the period minimum (Zharikov et al., 2008). Pavlenko (2009) discovered the non-radial pulsations of the WD that appeared 8 months after the 2006 outburst and lasted for 2 years. EZ Lyn experienced the next superoutburst in 2010. It should be noted that the number of rebrightenings in the first and second superoutburst were different (11 and 6, respectively). Nakata et al. (2013) considered the WZ Sge-type DNe with multiple echo-outbursts as the good candidates for period bouncers. The outbursts light curves and the rebrightening phases of the superoutburst are presented in Fig. 3, using the data of Pavlenko (2013). It could be noted that several "minioutbursts" were detected a few months after the superoutburst EZ Lyn (Zharikov et al., 2008). They repeated after 16–17 days (Pavlenko, Malanushenko, 2009). It is probable that such behavior is typical for quiescence stage of some WZ Sge-type DNe.

2.4. CT Tri = Dwarf nova Trianguli 2008

The *UBV (RI)$_c$* photometry of CT Tri = OT J023839.1+355648 was obtained during its superoutburst started on October 25, 2008. The object can be classified as the WZ Sge-type DN. The early superhumps with the period of $0.^d05307$ and ordinary superhumps with the period of $0.^d0537$ were discovered by Shugarov et al. (2008). The period of ordinary superhumps $0.^d053663$, detected during the plateau stage, was the shortest one among WZ Sge-type DNe in 2008. A sudden increase of activity of the object during quiescence was detected on January 11, 2009, when the brightness of the object increased for about 1 mag in the R_C-band. The overall LCs of the superoutburst are similar to the LCs of the J2138+26.

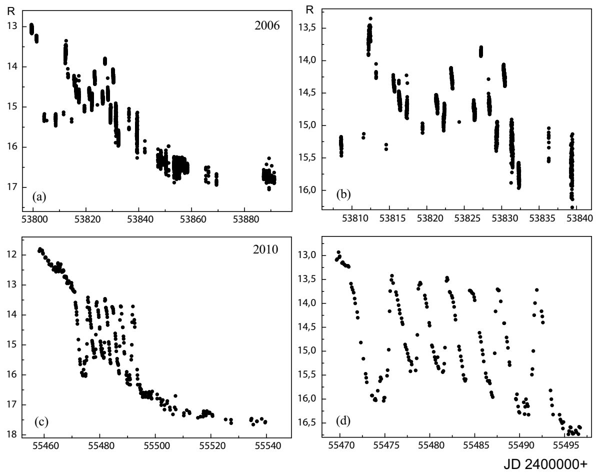

Figure 3. Two light curves of EZ Lyn in 2006 and 2010 (a, c) and rebrightening phases of 2006 and 2010 outbursts (b, d).

2.5. SBS 1108+57 and J174033.5+414756

The superoutburst of SBS 1108+57 = CSS120422:111127+571239 took place in May 2012. This system is unique because of its 55-min orbital period, well below the period minimum of CVs and a high helium abundance (Kato et al., 2013, Littlefield et al., 2013; Carter et al., 2013; Pavlenko et al., 2014). The object cannot be classified as an AM CVn star, because of presence of hydrogen lines in its spectrum. The high accretion rate and large mass ratio suggest that the object is still evolving towards its period minimum. New sub-period-minimum cataclysmic variable CSS130418: 174033.5+414756 underwent its superoutburst on April 18, 2013. Multicolour photometry and detection of early and ordinary superhumps enable us to determine its orbital period 64.84 minutes and classified it as a WZ Sge-type DN (Chochol et al., 2014). Our quiescent spectrum show that it is rich in helium, showing double peaked emission lines of H I and He I from the accretion disk. We got the value of the mass ratio, applying the relation $\epsilon = 0.18q + 0.29q^2$ (Patterson et al., 2005): $q = 0.0565 \pm 0.020$.

3. Conclusion

An investigation of WZ Sge-type systems and analysis of their observational data at a wide range of wavelengths is very important for understanding their evolution. The special interest requires the study of strongly evolved short period close binaries with higher abundance of helium, because they could be progenitors of AM CVn stars. Their orbital periods are below the period minimum of CVs. Although the number of these objects at present is small, an improvement of the small telescopes' equipments will enable to increase their number by expected new discoveries.

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