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Study of Photometric Variability of Selected SU UMa Dwarf Novae

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Abstract

In this work we present time-resolved photometry of several poorly-studied dwarf novae during recent superoutbursts. Observations were made with a CCD, mounted on 50- and 60-cm telescopes of the Sternberg Astronomical Institute in Crimea in April - May and October 2012 and June - July 2013. Superhumps were detected in light curves of all the dwarf novae. The amplitudes and periods of detected light variations were calculated. Superhumps evolution was also followed up for all systems and classification is improved.

Keywords: cataclysmic variables - dwarf novae - SU UMa stars - outbursts - photometry - light curves - periods.

1 Introduction

SU UMa stars represent one of the three sub-types of dwarf novae. Besides the frequent normal outbursts, they could show outbursts of larger amplitudes and much longer duration than the normal ones,- **superoutbursts**. During superoutbursts they exhibit so-called superhumps,- an increase of system brightness on the small part of the orbital light curve, that repeats with a period a few percents longer than the orbital one. The amplitudes of superhumps are around - $0^m.3$. The orbital periods of SU UMa stars are about 80-180 min. There are two small subtypes of dwarf novae inside of this group: ***WZ Sge*** stars with short superhumps period and very long time of outburst recurrence and ***ER UMa*** stars with very short intervals between superoutbursts. It was found from observations that evolution of the superhumps period consists of 3 stages: early evolutionary stage with a longer period of superhumps (**stage A**), middle stage with systematically varying superhumps period (**stage B**) and the last stage with a shorter, stable period of superhumps (**stage C**). All stages are most distinct in WZ Sge systems. The superhumps, seen during the early stages of WZ Sge dwarf novae, are double-wave humps and their periods are close to the orbital ones (Kato, 2002), the ordinary superhumps are one-wave humps. They have the largest amplitude of periodicity and period slightly longer than the orbital period. According to the tidal-thermal model of Osaki (1996) superhumps arise as a result of accretion disk precession triggered by gravitational disturbances from the secondary component. The period of superhumps is beat period between the precession period P_{prec} and orbital period P_{orb}.

The present paper is aimed at investigating of superhumps phenomenon in selected SU UMa stars.

2 Program Stars

The stars for our study were chosen from the VSNet list of dwarf novae undergoing superoutbursts during our observational sets. The criteria for our choice were, first of all, the brightness of an object limited by telescope power and relatively rare superoutbursts (and therefore poorly studied). They are: CSS 121004: 205146-035827 (J2051), V844 Her, PNV J19150199+0719471 (J1915), SDSS J150240.98+3334239 (J1502).

3 Observations

The main part of our observations was obtained at the 60-cm telescope with CCD Apogee 47 (528 × 512 pxl, pixel size $12\times12\mu$m) in V, R and R_c bands and partly at the 50-cm telescope with a new CCD Apogee Alta-8300 (3326×2504 pxl, pixel size - $5.4 \times 5.4\mu$m) in V band in Crimea. The duration of observational sets varied from 3 to 6 h. The accuracy is $2-3\%$ for R band, but is less for V band $4-5\%$. The reference stars were taken mostly from AAVSO list. If we used the local standard star from the vicinity of a program star special high precision observations with UBV photometer at the 60-cm telescope were conducted during the nights with good weather conditions for the standard calibration. CCD data were reduced using the MAXIM DL standard package, UBV data - with software developed by V. Lyuty.

3.1 V844 Her

The dwarf nova V844 Her underwent a superoutburst in May, 2012 (vsnet-alert 14525). This object showed frequent outbursts during 2009–2011, but was relatively inactive next year. The superoutburst that we followed up occurred 370 days after the last superoutburst of 2011. Our first observation of V844 Her was conducted on April 22 when this nova was in quiescence ($\sim 18^m$) but restarted later after receiving information about the outburst and lasted practically until the end of the outburst when V844 Her returned to its pre-outburst brightness. Figure 1 show the evolution of superhumps in V844 Her.

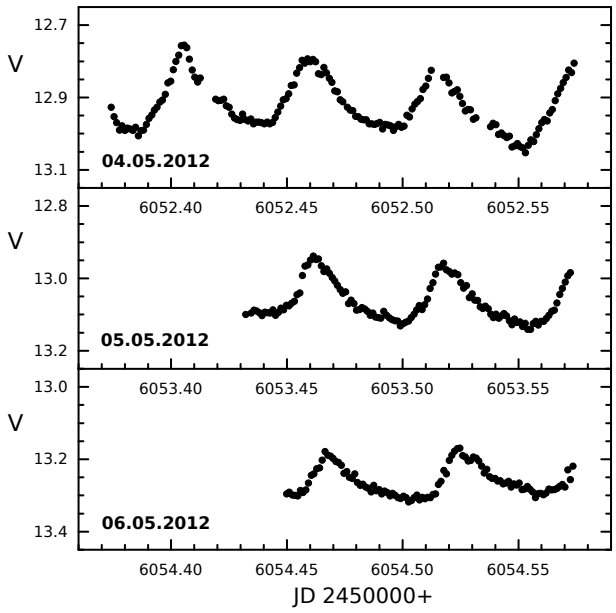

Figure 1: V844 Her light curves obtained at the beginning of the outburst. Decreasing of superhumps which is clearly seen on the light curve at the bottom indicates that a new stage is approaching.

3.2 SDSS J150240.98+3334239

The discovery of outburst of this dwarf nova was reported by VSNet on April 2, 2012. Its optical magnitude ranges from $13^m.7$ to $19^m.6$ during quiescent and outburst phases, respectively. USNO photometry reveals a deep (2.5 mag) eclipse occurring at a period of 84.24 minutes (Szkody et al., 2006) which evidence that it is a high inclination system. Our observations of J1502 cover 6 nights from April 23 to June 2, 2012. Observational light curves for three of them are presented in Figure 2. They show deep eclipses besides superhumps. Our analysis was restricted by consideration of superhumps phenomenon in this system.

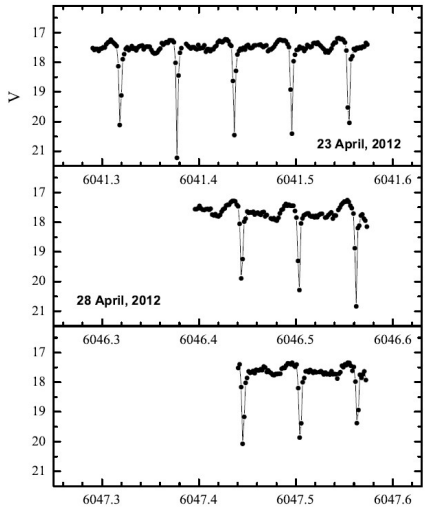

Figure 2: Light curves of high inclination system J1502 showing both superhumps and eclipses.

3.3 CSS 121004: 205146-035827

The object was discovered by CRTS on October 4, 2012. Observations provided by Dr. Maehara on October 8 (vsnet-outburst 14685) demonstrate superhumps with

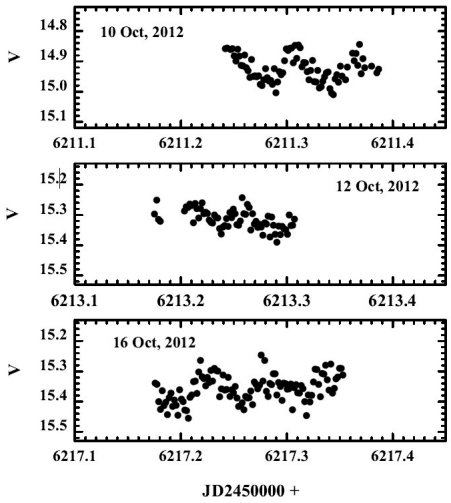

Figure 3: Stage B superhumps in the light curves of dwarf nova J2051.

an amplitude of $0^m.2$ and with a short period of $0^d.056$ in the light curves of this object. We started our observations later, on October 10 because of the bad sky conditions before this date. At this moment the brightness of J2051 was $14^m.9$. The object started to fade rapidly on October 20 with rate $0.37m \cdot d^{-1}$ and became too faint for observations on October 22 ($\sim 18^m$). Our observations of dwarf nova J2051 in V band are shown in Figure 3.

3.4 PNV J19150199+0719471

On June 1, 2013 E.de Miguel (vsnet-outburst 15466) reported discovery of an outburst of this transient with magnitude $\sim 10^m.8$. The next day he reported about detection of early superhumps in the light curve of this object with a possible period of $0^d.0641(2)$ (probably stage A). On June 9 the double-peaked superhumps with an average amplitude of $0^m.1$ and $P_{sh} \sim 0^d.0569$, were detected by several observers. Spectroscopic observations provided by Echevarria et al.(2013) suggested the high inclination and low massive component,- brown dwarf.

Our observations of this nova started on June 4, 2013 and lasted until the middle of July 2013. During our observations the brightness of J1915 dropped from $11^m.47$ at the beginning to 18^m (V) at the end of the superoutburst. The light curves of J1915 obtained at the different moments of 2013 superoutburst as an example are shown in Figure 4.

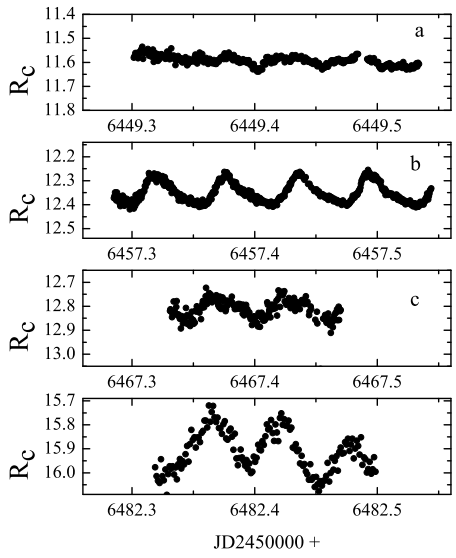

Figure 4: Evolution of superhumps in dwarf nova J1915: a - beginning of stage A superhumps; b - stage B superhumps; c - transition from B to C stage; d - post-fading stage superhumps. Scale is the same for all panels.

4 Results

For data analysis and search of periodicities we used a special code period98 (Sperl, 1998) and period04 (Lenz & Breger, 2004). The analysis was firstly done for every observational night and later the mean values for different stages of each star were calculated. For V844 Her although stages A-C were observed, the period of stage A superhumps was not determined, due to limited observations during this stage. P_{dot} for stage B was positive, as seen in other superoutbursts of this object. In the light curves of dwarf nova J2051 the stages B and C can be distinguished. The superhumps period variations suggests that the object more resemble ordinary SU UMa-dwarf novae than WZ Sge-stars. The numerous observations obtained for J1915 (about 6000 images at all) permitted us to follow up superhumps evolution in detail beginning from the first night of our observations, June 4. No superhumps were detected in the light curve of J1915 on this particular night. Subsequent observations provided on the next night, June 5, recorded a periodic variation in the light curve of J1915. We suggest that it could be beginning of the stage A. The superhumps period for different stages was determined. The absence of recorded outburst in the past, large amplitude of present outburst, values of parameters (like ϵ, P_{dot} and other) and the pattern of superhumps period variation are typical for WZ Sge-stars. So we conclude that the recently discovered dwarf nova J1915 belongs to the WZ Sge-subtype. Some of the power spectra calculated for each star as an example are shown in Figures 5–8.

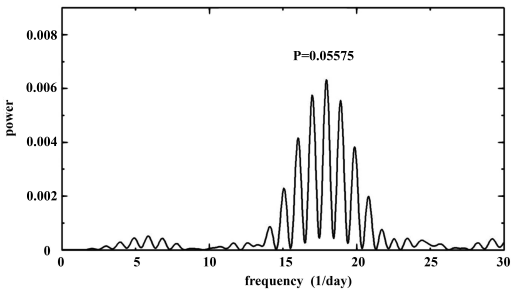

Figure 5: One of the V844 Her power spectra as an example.

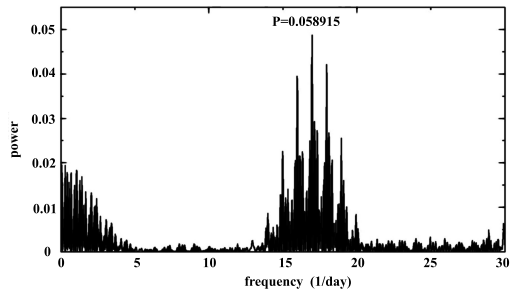

Figure 6: The power spectrum of J1502, calculated for all 6 nights of our observations.

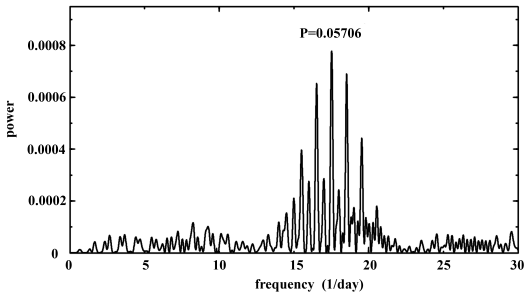

Figure 7: The power spectrum of J2051.

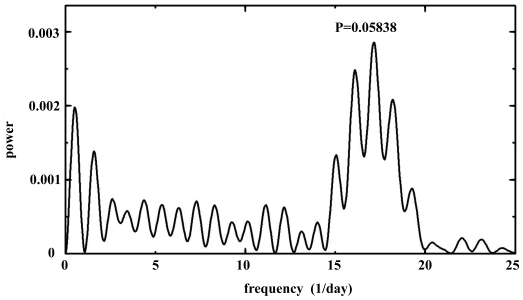

Figure 8: The power spectrum of J1915.

The periods which were determined in frame of this study are collected in Table 1. The orbital periods were taken from the literature.

Table 1: Determined periods.

Object	P_{sh}(stage B)	P_{sh}(stage C)	P_{orb}
V844 Her	0.05590 ± 2	0.05587 ± 3	0.054643
J2051	0.05715 ± 5	0.05680 ± 6	—
J1502	0.05891 ± 2	—	0.06944
J1915	0.05833 ± 2	0.05800 ± 3*	0.06164

* For J1915 the period in the second column represent the post-fading superhumps period.

5 Summary

The main results of our study of SU UMa dwarf nova photometric variability can be summarized as follows:

- The time-resolved photometry in V and R bands was obtained for several SU UMa-type dwarf novae whose superoutbursts were observed during the 2012–2013 season:
  - for V844 Her - 10 nights, $\sim$ 1400 images in V and R_c bands;
  - for CSS 120004: 205146-03582 - 8 nights, $\sim$ 1000 images in V and R bands;
  - for PNVJ19150199+0719471 - 13 nights, about 6000 images both in V and R_c bands;
  - for SDSS J150240.98+3334239 - 6 nights, $\sim$ 750 images in V band.
- The individual light curves of all program stars were constructed on the base of these numerous observations. Superhumps were detected in the light curves all of them and their evolution during the outbursts was followed up.
- The superhumps periods and amplitudes were determined from our data and mean superhumps periods were obtained for each nova (see Table 1).
- The amplitude of outburst, phase-averaged profile of superhumps and superhumps period variations for CSS 121004: 205146-035827 suggest that this object more resemble ordinary SU UMa-stars than WZ Sge-dwarf nova.
- On the base of its outburst properties, the recently discovered NV J19150199+0719471 was classified as a dwarf nova of WZ Sge subtype.

The obtained results are preliminary and reflect the work in progress. They may be slightly improved by using more sophisticated methods and thorough subsequent analysis.

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