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SDSS J102146.44+234926.3: NEW WZ SGE-TYPE DWARF NOVA

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The cataclysmic variable SDSS J102146.44+234926.3 (SDSS J1021 hereafter; $\alpha_{2000} = 10^{\rm h}21^{\rm m}46\overset{\rm s}{.}44$; $\delta_{2000} = +23^\circ49'26\overset{''}{.}3$) was discovered in outburst having a V magnitude of $13\overset{\rm m}{.}9$ by Christensen on CCD images obtained in the course of the Catalina Sky Survey on October 28.503 UT 2006. In an archival image there is a star with $V \sim 21^{\rm m}$ at this position (Christensen, 2006) and there is an object in the database of the *Sloan Digital Sky Survey* Data Release 5 (Adelman-McCarthy et al., 2007; SDSS DR5 hereafter) with the following magnitudes, measured on January 17.455 UT, 2005: $u = 20.83, g = 20.74, r = 20.63, i = 20.84, z = 20.45$. In the USNO-B1.0 catalog this object is listed as USNO-B1.0 1138-0175054 with magnitudes $B_{\rm 2mag} = 20.79$ and $R_{\rm 2mag} = 20.35$. The large amplitude and the blue color imply that the object could be a dwarf nova of SU UMa or WZ Sge type (Waagen, 2006).

Fig. 1 (left) shows the $8' \times 8'$ image of the SDSS J1021 vicinity, generated from SDSS DR5 Finding Chart Tool (`http://cas.sdss.org/astrodr5/en/tools/chart/chart.asp`).

Time resolved CCD photometry has been carried out from different sites by the authors since November 21, 2006 (the first night after the discovery was reported) until 2006 December 06 (Data available for download at `http://www.aavso.org/data/download` and from IBVS server; See Table 1 for log of observations). The photometry was done in the V and R_c bands as well as unfiltered; this did not affect the following period analysis. The error of a single measurement can be typically assumed to be $\pm0\overset{\rm m}{.}02$. Fig. 1 (right) shows the overall light curve of the object. Here we assume $m_R = m_{\rm unfiltered}$. The light curve could be divided into three parts, denoting the plateau stage, dip and long-lasting echo-outburst (rebrightening).

Before carrying out Fourier analysis for the presence of short-periodic signal in the light curve (superhumps), each observer's data set was individually transformed to a uniform zero-point by subtracting a linear fit from each night's observations. This was done to remove the overall trend of the outburst and to combine all observations into a single data set.

From the periodogram analysis (Fig. 2, left) the value of the superhump period $P_{\rm sh} = 0^{\rm d}.05633 \pm 0.00003$ was determined. Such a value is typical for the WZ Sge-type systems and is just 58.7 seconds shorter than $P_{\rm sh}$ of another WZ Sge-like system: ASAS 002511+1217.2 (Golovin et al., 2005).

The superhump light curve (with 15-point binning used) folded with $0^{\rm d}.05633$ period is shown on Fig. 2 (right). It is plotted for two cycles for clarity. Only JD 2454061.0-2454063.6 data was included. Note the $0^{\rm m}.1$ amplitude of variations and the double-humped profile of the light curve. There remain many questions concerning the nature of a double-humped superhumps in the WZ Sge-type stars. The explanation of a double-humped light curve could lie in a formation of a two-armed precessional spiral density wave in the accretion disk (Osaki, 2003) or a one-armed *optically thick* spiral wave, but with the occurrence of a self-eclipse of the energy emitting source in the wave (Bisikalo, 2006).

Other theories concerning a double-peaked superhumps can be found in Lasota et al. (1995), Osaki & Meyer (2002), Kato (2002), Patterson et al. (2002), Osaki & Meyer (2003).

Applying the method of "sliding parabolas" (Marsakova & Andronov, 1996) we deter-

Table 1. Log of observations

JD (mid of obs. run)	Duration of observational run [minutes]	Observatory	Telescope	CCD	Filter
2454060.9	214	Rolling Hills, FL, USA	Meade LX200-10	SBIG ST-9	V
2454061.0	158	Cloudcroft, NM, USA	C-11	SBIG ST-7	none
2454062.0	259	Cloudcroft, NM, USA	C-11	SBIG ST-7	none
2454062.9	288	Cloudcroft, NM, USA	C-11	SBIG ST-7	none
2454063.6	115	CrAO, Ukraine	K-380	SBIG ST-9	R
2454064.6	222	CrAO, Ukraine	K-380	SBIG ST-9	R
2454066.7	S.D.P. *	Pic du Midi, France	T-60	Mx516	None
2454067.6	90	CrAO, Ukraine	K-380	Apogee 47p	R
2454067.9	S.D.P.	Las Cruses, NM, USA	Meade LX200	SBIG ST-7	V
2454069.0	S.D.P.	Arch Cape, USA	SCT-30	SBIG ST-9	V
2454069.0	S.D.P.	Las Cruses, NM, USA	Meade LX200	SBIG ST-7	V
2454069.6	63	CrAO, Ukraine	K-380	Apogee 47p	R
2454071.9	S.D.P.	Las Cruses, NM, USA	Meade LX200	SBIG ST-7	V
2454072.9	S.D.P.	Las Cruses, NM, USA	Meade LX200	SBIG ST-7	V
2454073.9	S.D.P.	Las Cruses, NM, USA	Meade LX200	SBIG ST-7	V
2454074.9	S.D.P.	Las Cruses, NM, USA	Meade LX200	SBIG ST-7	V
2454075.9	S.D.P.	Las Cruses, NM, USA	Meade LX200	SBIG ST-7	V
2454166.8	S.D.P.	Sonoita Observatory, USA	0.35 m telescope	SBIG STL-1001XE	V
2454167.7	S.D.P.	Sonoita Observatory, USA	0.35 m telescope	SBIG STL-1001XE	V

* S.D.P. - Single Data Point

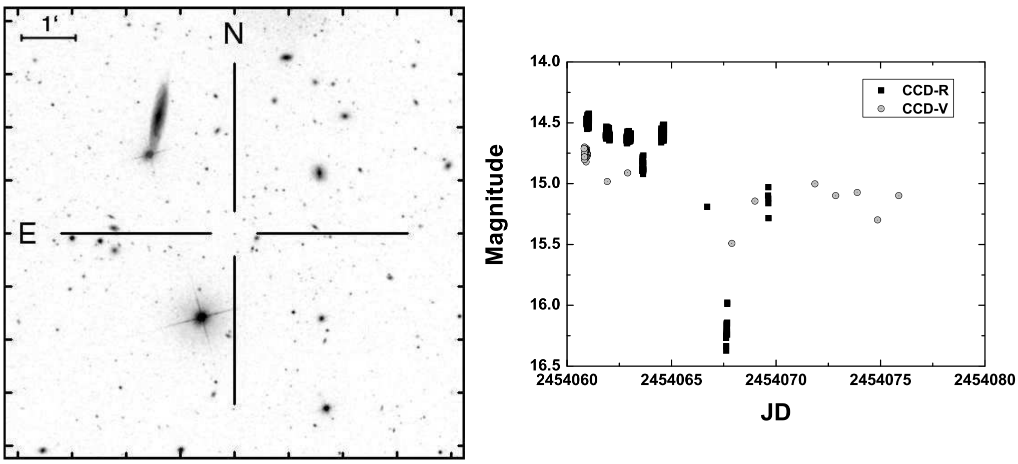

Figure 1. Left: SDSS image of the SDSS J1021 vicinity. Right: Light curve of SDSS J1021 during the outburst

mined, when it was possible (JD 2454061.0–2454063.6), the times of maxima of superhumps (with mean 1σ error of $0\overset{\rm d}{.}0021$) and calculated $O-C$ residuals based on founded period. The moments of superhump maximua are given in Table 2. No period variations reaching the 3σ level were found during the time of observations.

Another prominent feature of the SDSS J1021 light curve is the echo-outburst (or *rebrightening* — another term for this event) that occurs during the declining stage of the superoutburst. On Nov. 27/28 2006 (i.e. JD 2454067.61-2454067.68) a rapid brightening with the rate of $0\overset{\rm m}{.}13$ per hour was detected at Crimean Astrophysical Observatory (Ukraine; CrAO hereafter), that most probably was the early beginning of the echo-outburst. Judging from our light curve, we conclude that rebrightening phase lasted at least 8 days. Similar echo-outbursts are classified as "type-A" echo-outburst according to classification system proposed by Imada et al. (2006) as observed in the 2005 superoutburst of TSS J022216.4+412259.9 and the 1995 superoutburst of AL Com (Imada et al., 2006; Patterson et al., 1996).

Rebrightenings during the decline stage are observed in the WZ Sge-type dwarf novae (as well as in some of the WZ Sge-type candidate systems). However, their physical mechanism is still poorly understood. In most cases, just one rebrightening occurs (also observed sometimes in typical SU UMa systems), though a series of rebrightenings are also possible, as it was manifested by WZ Sge itself (12 rebrightenings), SDSS J0804 (11) and EG Cnc (6) (Pavlenko et al., 2007). There are several competing theories concerning what causes an echo-outburst(s) in such systems, though all of them predict that the disk must be heated over the thermal instability limit for a rebrightening to occur. See papers by Patterson et al. (1998), Buat-Menard & Hameury (2002), Schreiber & Gansicke (2001), Osaki, Meyer & Meyer-Hofmeister (2001) and Matthews et al. (2005) for a discussion of the physical reasons for echo-outbursts.

Recent CCD-V photometry manifests that SDSS J1021 has a magnitude of $19\overset{\rm m}{.}72\pm0.07$ and $19\overset{\rm m}{.}59\pm0.07$ as of 06 March and 07 March, 2007 (HJD = 2454165.80 and HJD = 2454167.74) respectively, at Sonoita Research Observatory (Sonoita, Arizona, USA) using a robotic 0.35 meter telescope equipped with an SBIG STL-1001XE CCD camera.

Spectroscopic observations were carried out on November 21.8 UT with the CCD spectrograph mounted on the 1.01-m telescope of Bisei Astronomical Observatory (Japan).

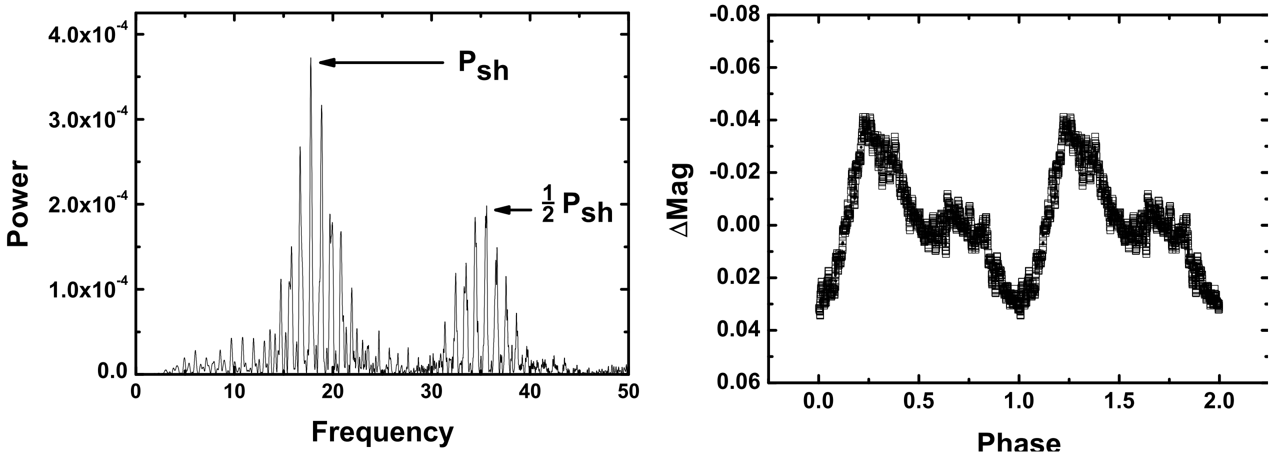

Figure 2. Left: Power spectrum, revealing the $P_{\rm sh}$ of SDSS J1021. Right: Superhump profile of SDSS J1021

Table 2. Times of superhump maximums

HJD	E	$O-C$	$\sigma_{(O-C)}$
2454061.03380	0	0	0.00120
2454061.88103	15	0.00228	0.00130
2454061.93507	16	−0.00001	0.00368
2454061.99121	17	−0.00020	0.00099
2454062.89325	33	0.00056	0.00179
2454062.94709	34	−0.00193	0.00214
2454063.00533	35	−0.00002	0.00156
2454063.62385	46	−0.00113	0.00464

The preliminary discussion of the spectra can be found in (Ayani & Kato, 2006). The spectral range is 400–800 nm, and the resolution is 0.5 nm at H_α. HR 3454 ($\alpha_{2000} = 08^{\rm h}43^{\rm m}13\overset{\rm s}{.}475; \delta_{2000} = +03^\circ 23' 55\overset{''}{.}18$) was observed for flux calibration of the spectra. Standard IRAF routines were used for data reduction.

Spectrum (Fig. 3) shows blue continuum and Balmer absorption lines (from H_ϵ to H_α) together with K CaII 3934 in absorption. Very weak HeI 4471, Fe 5169, NII 5767 absorption lines may be present. H_ϵ 3970 is probably blended by H Ca II 3968. The FeIII 5461 line resembles weak P-Cygni profile. Noteworthy, FeIII 5461 and NII 5767 may be artifacts caused by imperfect subtraction of city lights: HgI 5461 and 5770 (spectrum of the sky background which was subtracted, is available upon request). The HeI 5876 line (mentioned for this object in Rau et al., 2006) is not detectable on our spectrum. It is remarkable that H_α manifests a "W-like" profile: an emission component embedded in the absorption component of the line.

Table 3 represents EWs (equivalent widths) of detected spectral lines. EW was calculated by direct numerical integration over the area under the line profile.

The archive photographic plates from the Main Astronomical Observatory Wide Field Plate Archive (Kyiv, Ukraine; MAO hereafter) and Plate Archive of Sternberg Astronomical Institute of Moscow State University (Moscow, Russia; SAI hereafter) and plate from Crimean Astrophysical Observatory archive (Ukraine) were carefully scanned and inspected for previous outbursts on the plates dating from 1978 to 1992 from MAO, 1913–1973 from SAI and 1948 from CrAO archives. The number of plates from each archive

Table 3. Equivalent widths of spectral lines

Line	EW [Å]
K CaII 3934	−5.8
H_ϵ 3970 / H CaII 3968	−8.7
H_δ 4101	−6.4
H_γ 4340	−8.5
H_β 4861	−6.4
H_α 6563	−7.7
H_α 6563 (emission)	2.3
HeI 4471	−0.95
FeII 5169	−0.65
NII 5767	−0.7

is 22 for SAI, 6 for MAO and 1 for CrAO archives. For all plates the magnitude limit was determined (this data as well as scans of plates are available upon request). The selection of plates from MAO archive was done with the help of the database developed by L.K. Pakuliak, which is accessible at *http://mao.kiev.ua/ardb/* (Sergeeva et al., 2004; Pakuliak, L.K. & Sergeeva, T.P., 2006;). No outbursts on the selected plates from the MAO, SAI and CrAO archives were detected. This implies that outbursts in SDDS J1021 are rather rare, which is typical for the WZ Sge-type stars.

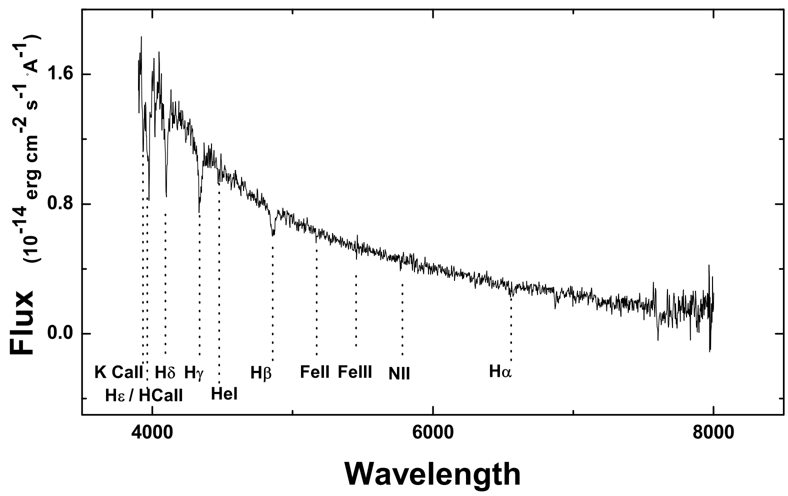

Figure 3. Spectra of SDSS J1021 obtained on November 21.8 UT on 1.01-m telescope of Bisei Astronomical Observatory (Japan)

Table 4 (available only electronically from IBVS server or via AAVSO ftp-server at `ftp://ftp.aavso.org/public/calib/varleo06.dat`) represents BVR_cI_c photometric calibration of 52 stars in SDSS J1021 vicinity, which have a V-magnitude in the range of $11^{\rm m}_{.}21$–$17^{\rm m}_{.}23$ and can serve as a comparison stars. Calibration (by AH[8]) was done at Sonoita Research Observatory (Arizona, USA).

The large amplitude of the SDSS J1021 outburst of $7^{\rm m}$, superhumps with a period below the "period gap", rebrightening during the declining stage of superoutburst, rarity of outbursts and obtained spectrum allow to classify this object as a WZ Sge type dwarf nova.

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