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CCD PHOTOMETRY OF THE MAY 2000 OUTBURST OF THE CATACLYSMIC VARIABLE RXJ 1450.5+6403

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RXJ 1450.5+6403 was detected as a cataclysmic variable (CV) of unknown type during the course of the ROSAT All-Sky Survey (Chisolm et al. 1999) and has a listed magnitude range of 16.3–17.1. Its USNO-A2.0 position is $\alpha = 14^{\rm h}50^{\rm m}38\overset{\rm s}{.}31$, $\delta = +64°03'28\overset{''}{.}6$ (J2000.0). The object is identical to FBS 1449+642 in the First Byurakan Spectral Sky Survey of blue stellar objects (Abrahamian & Mickaelian 1994), where it is listed with a spectral type of B1.

The May 2000 outburst of RXJ 1450.5+6403 was detected by Tonny Vanmunster on 2000 May 14 (Vanmunster 2000a) and was the first-ever since the discovery of the object. It was intensively monitored as part of an international observing campaign by the Center for Backyard Astrophysics (CBA). We report differential time-series photometry related to this outburst and the detection of superhumps with a period of 0.0601 ($\pm$ 0.0002) d, as well as quasi-periodic oscillations.

Upon notification of the outburst of RXJ 1450.5+6403, an international observing campaign was launched by the CBA. The CBA is a multi-longitude network of professional and amateur astronomers (Patterson 1998), who study periodic phenomena in cataclysmic variables. Since 1991, the CBA has been engaged in long-term photometric studies of CVs, primarily focusing on binary orbital periods, rotational periods, superhump periods and accretion disk precession periods. Target objects comprise SU UMa-type dwarf novae, intermediate polars (and DQ Her stars), permanent superhumpers (e.g., nova-like objects) and helium CVs, for which long, dense time-series differential photometry is performed. Target campaigns and results of the CBA are regularly reviewed on the CBA Web site (http://www.astro.bio2.edu/cba). The CBA campaign on RXJ 1450.5+6403 accumulated 92.5 hours of coverage over 12 nights and 6173 datapoints. Contributing stations are listed in Table 1.

Table 1: Log of photometry

May 2000 Date	JD Start[1]	Length (hr)	Telescope[2]	Points
14	5679.3776	5.72	1	240
15	5679.6578	6.99	2	460
15	5679.7072	3.17	3	353
15	5680.3439	6.06	5	398
15	5680.3916	5.29	1	207
16	5680.6039	5.11	3	621
18	5682.6774	4.09	2	49
19	5683.6619	7.10	2	130
19	5683.6780	5.71	4	997
21	5685.6475	7.37	2	136
21	5685.8230	3.87	4	1181
22	5687.4439	3.40	1	148
24	5688.8602	2.93	4	468
25	5689.8018	3.71	2	48
25	5689.8029	3.63	2	45
25	5689.8037	3.63	2	48
26	5690.6295	4.17	3	332
27	5691.6115	3.39	3	182
27	5691.6582	7.20	2	130

[1] 2,400,000 +
[2] (1) = CBA Belgium, 0.35-m; (2) = Braeside, 0.41-m;
(3) = CBA Maryland, 0.66-m; (4) = MDM, 1.3-m; (5) = Brno, 0.40-m

The outburst detection was made at CBA Belgium Observatory, one of the main contributing nodes in the CBA network. The observatory equipment and setup is quite characteristic for most CBA stations, and therefore is described in more detail below.

The CBA Belgium Observatory is located in Flanders, Belgium. The observatory building is a roll-off roof structure, measuring 3 m by 4 m. Its primary instrument for CCD photometry is a 0.35-m $f/6.3$ Schmidt–Cassegrain telescope, mounted on an AstroTechniek FM-98 German equatorial mount, and equipped with a SBIG ST-7 CCD camera (Kodak KAF-0400 CCD for imaging and Texas Instruments TC211 CCD for guiding). The observatory furthermore houses a laptop computer, that controls telescope and CCD operations. It is connected through a 10-Mb network connection with a desktop computer, located in the house of the observatory owner. The desktop computer allows full remote control of the telescope and CCD, and does instantaneous photometry reduction of acquired FITS images. Following software packages are used:

- Camera control, telescope guiding and unfiltered photometric imaging are all done using *MaxIm DL/CCD* (Cyanogen Productions Inc.). Images are stored as FITS files.
- All frames use 2×2 chip summation and are corrected for standard debiasing and flat-fielding. They are reduced using the profile fitting algorithm (PSF) of *MIPS* (Buil et al., 1993), immediately following their acquisition.
- Output files with differential magnitudes are produced by MIPS and are almost instantaneously post-processed, to allow the generation of quasi-real-time light curves. This is done using the software package *AfterMips*, written by Tonny Vanmunster.

- Sky conditions are monitored through a special software package, called *StarMon*, also written by Tonny Vanmunster. It generates an alarm sound if clouds enter the observing field.

The described set-up allows all-night long autonomous and unattended operation. The only human interaction required is for opening and closing of the observatory, and initialisation of the telescope, camera and computers.

Following the detection of a bright outburst of RXJ 1450.5+6403 at CBA Belgium Observatory on 2000 May 14/15, time-resolved and differential (variable – comparison) CCD photometry was started at this CBA node. Using the AfterMips software package, incoming observations were monitored in a quasi-real-time mode and soon revealed the development of superhumps in the system (Figure 1). This allowed the immediate classification of the object as an SU UMa-type cataclysmic variable (Vanmunster 2000b).

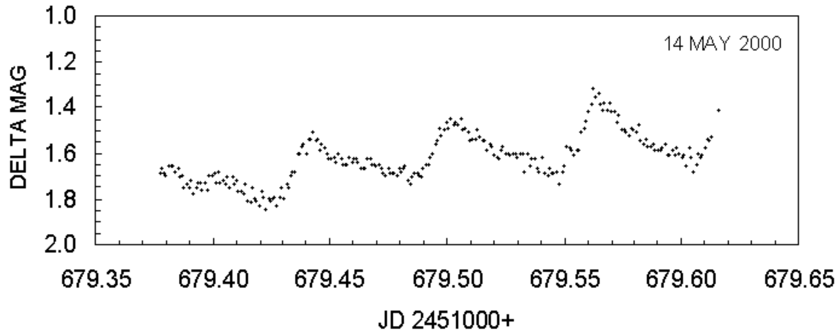

Figure 1. Light curve of RXJ 1450.5+6403 on 2000, May 14

The object was intensively monitored by additional observatories of the CBA network (see Table 1). The outburst continued till May 28th, 2000, after which the object returned to quiescence. The May 2000 light curve revealed a fairly constant superhump profile between JD 2451679.3 and 2451680.8. The superhump period slightly increased between JD 2451682.7 and 2451692.0, and showed a somewhat different profile as well. Below, we discuss these two light curve portions separately. A short, normal outburst of RXJ 1450.5+6403 was furthermore observed on June 25, 2000 (Pavlenko 2000).

Observations between JD 2451679.3 and JD 2451680.8. After removing linear trends in the light curve, we performed a period analysis using the Phase Dispersion Minimization (PDM) method (Stellingwerf 1978). The resulting theta diagram is shown in Figure 2. The best superhump period is 0.0601 (±0.0002) d. This is one of the shortest superhump periods among SU UMa-type dwarf novae. The phase-averaged superhump profile folded by this period is shown in Figure 3. The profile is that of a typical, well-developed "common superhump". The full amplitude is 0.30 mag.

These findings are consistent with radial velocity results obtained by J. Thorstensen from spectroscopic observations in April 2000 (Thorstensen 2000), when the object was at quiescence. His orbital period determination was not conclusive, but showed leading candidates at $0^{d}.0588$ and $0^{d}.0599$. Assuming the $0^{d}.0588$ value is the most accurate one, then the superhump excess value ε is 2.2 percent, where $\varepsilon = (P_{\rm sh} - P_{\rm orb})/P_{\rm orb}$, with $P_{\rm sh}$ and $P_{\rm orb}$ denoting the superhump and orbital period respectively. Thorstensen further commented that the RXJ 1450.5+6403 spectrum at minimum light appeared typical of SU UMa-type dwarf novae.

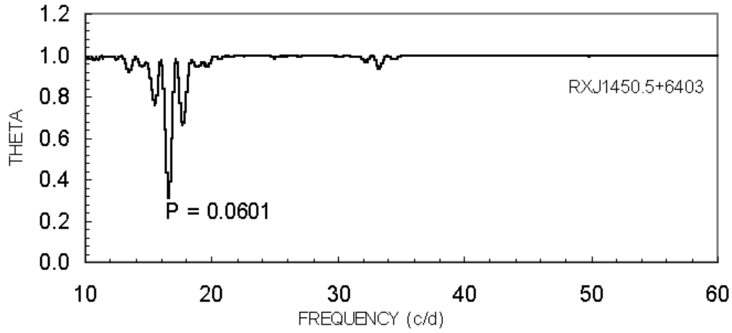

Figure 2. Period analysis of RXJ 1450.5+6403 between JD 2451679.3 and JD 2451680.8

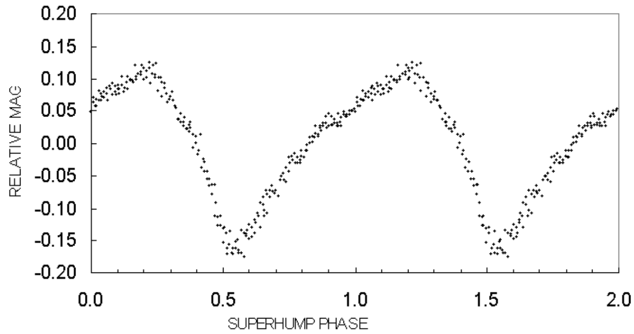

Figure 3. Common superhump profile of RXJ 1450.5+6403 between JD 2451679.3 and JD 2451680.8

Other photometric observations at quiescence were reported by D. Nogami, on behalf of the Goettingen-HS Survey Collaboration Team (Nogami 2000). Their period analysis yielded a period estimation of $0\overset{d}{.}056$ with a large error due to short coverage, and a $0\overset{m}{.}35$ orbital hump with a $0\overset{m}{.}1$ mag secondary hump.

Observations between JD 2451682.7 and JD 2451692.0. During this stage of the outburst, we noticed a slight increase in the superhump period value. Using again the PDM method, after having removed linear trends, the resulting theta diagram of Figure 4 is characterised by a superhump period of 0.0603 ($\pm$ 0.0002) d. The phase profile also changed during this stage of the outburst, with the superhump still dominating. Although most SU UMa-type dwarf novae show waveform changes, RXJ 1450.5+6403 has spent remarkably short time with its maximum light waveform, and quickly changed to a much more complex waveform. Figure 5 depicts the phase-averaged superhump profile folded by a period of $0\overset{d}{.}0603$.

Quasi-periodic oscillations (QPO's) are brightness variations on a short time scale (1–30 min), with a very low amplitude, appearing as a noisy, broad band in the power spectrum, that typically is overlooked were it not for the prominence of the oscillations in the light curve (Warner 1995).

QPO's first became apparent in the RXJ 1450.5+6403 light curve on May 15th, 2000 (Figure 6), being most explicit on the descending branch of the superhumps. They were present in the light curves obtained at CBA Belgium, CBA East and Brno Observatory. Their power spectrum showed a main signal at 95 s, and a mean amplitude of $0\overset{m}{.}04$. Though they continued to exist in the following night, the QPO's became more difficult to detect and finally disappeared in overall light curve noise.

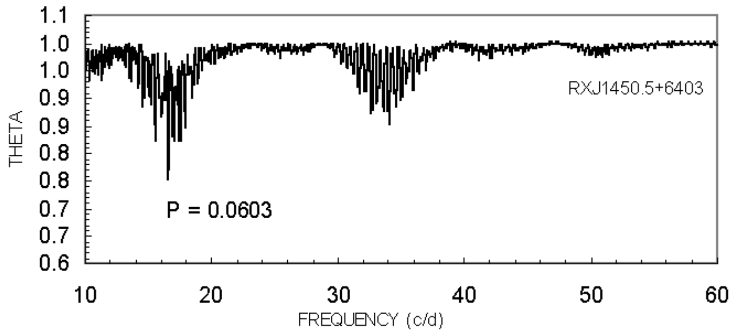

Figure 4. Period analysis of RXJ 1450.5+6403 between JD 2451682.7 and JD 2451692.0

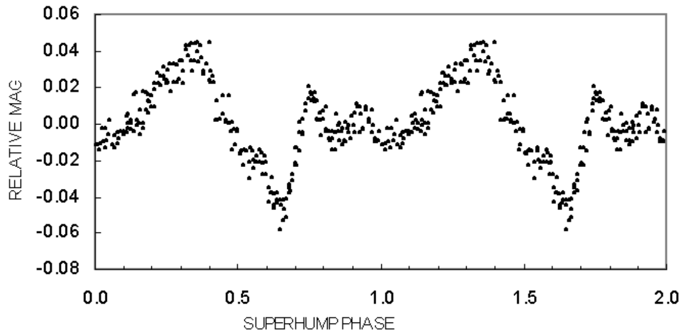

Figure 5. Common superhump profile of RXJ 1450.5+6403 between JD 2451682.7 and JD 2451692.0

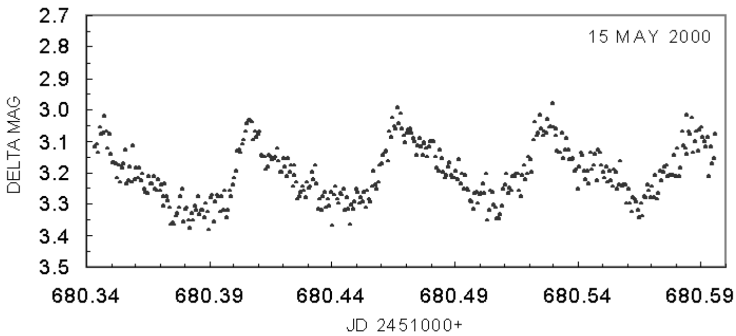

Figure 6. Light curve by Nicholas Copernicus Observatory on 2000, May 15

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References:

Abrahamian H.V., Mickaelian A.M., 1994, *Astrofizika*, **37**, 43
Buil, C., Klotz, A. et al., 1993, *Manual for the Microcomputer Image Processing System*, V2.0
Chisholm, J.R., Harnden, F.R. Jr., Schachter, J., Micela, G., Sciortino, S., Favata, F., 1999, *AJ*, **117**, 1845
Nogami, D., 2000, *vsnet-alert* No. 4868
Patterson, J., 1998, *Sky and Telescope*, October 1998, 77
Pavlenko, E., 2000, *vsnet-outburst* No. 196
Stellingwerf R.F., 1978, *ApJ*, **224**, 953
Thorstensen 2000, private communication
Vanmunster, T., 2000a, *vsnet-alert* No. 4834
Vanmunster, T., 2000b, *vsnet-alert* No. 4838
Warner, B., 1995, *Cataclysmic Variable Stars*, Cambridge University Press