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DIFFERENTIAL PHOTOMETRY OF SUSPECTED CATACLYSMIC VARIABLES

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We here present differential photometry of the four suspected cataclysmic variables (CVs) HM Aur, FBS 0827+738, FBS 1614+711 and NSV 7956, and of the three known CVs HQ And, RX And and FO Per. The target objects were selected from the CV catalogue of Downes et al. (1997) (hereafter DWS 97), searching for not yet confirmed CVs and poorly observed systems with unknown orbital periods. Therefore the list of Ritter & Kolb (1998) was used to exclude objects with known periods. To evaluate the significance of our results, we included three systems with a certain CV classification.

The data were taken at Hoher List Observatory on March 9, 10, and 12, on October 8, 1998, and on March 10, 1999 in the framework of the *Astronomisches Beobachtungspraktikum* of the Ruhr–Universität Bochum. We used an astrograph ($D = 0.3$ m, $f = 1.5$ m) and a Cassegrain reflector ($D = 1.06$ m, $f = 3.68$ m) equipped with Ford Loral FA2048 CCDs and Johnson V-filters. In order to resolve the CV-typical short-term variation (flickering), the integration time was limited to 120 sec., thus constraining the accessible V-magnitude to 17.0. Table 1 lists the details of the observations.

Standard reduction was performed with IRAF[1] packages using overscan and dome- or skyflats for the 1.06 m telescope, biasframes and skyflats for the astrograph data. Aperture photometry was done with the DAOPHOT package. On each image frame we chose all non-saturated comparison stars comprising a S/N-ratio greater or equal to the S/N-ratio of the target object. For $j = 1, \ldots, n$ let $I_j(t)$ denote the instrumental intensity of comparison star j at time t. For $t_{\rm begin} \le t \le t_{\rm end}$ all differential lightcurves $I_k^j(t) := I_j(t) - I_k(t),\ j,k \in \{1,\ldots,n\},\ j \ne k$ were calculated. For $t_{\rm begin} \le t \le t_{\rm end}$ the average lightcurve $I_{\rm av}(t)$ was computed as the arithmetic mean of all comparison star intensities. Then, differential magnitudes were calculated according to $I_{\rm av}^j(t) := I_j(t) - I_{\rm av}(t)$. All comparison stars with brightness variations above the noise level were easily discriminated

[1] IRAF is distributed by the National Optical Astronomy Observatories.

Table 1: List of observations. The coordinates in columns 2 and 3 have been taken from DWS 97. Column 4 shows the instrument used, while columns 6 and 7 give the number of data points (lightcurves of observations marked with a * have been omitted in this paper) and the total time coverage per night, respectively.

Object	RA_{2000}	DEC_{2000}	Instrument	Date	$n_{\rm data}$	$t_{\rm obs}$ [h]
HM Aur	07 29 06.76	+40 40 57.2	astrograph	10.03.98	*19	0.5
				12.03.98	132	2.4
				10.03.99	*31	0.7
FBS 0827+738	08 32 45.57	+73 37 08	1.06 m telescope	09.03.98	*7	0.3
				12.03.98	76	2.4
FBS 1614+711	16 14 23.19	+70 58 18.6	1.06 m telescope	12.03.98	30	1.2
NSV 7956	16 29 24	+86 26 03	astrograph	09.03.98	224	3.6
				12.03.98	*52	0.8
HQ And	00 31 35.89	+43 49 05.1	1.06 m telescope	08.10.98	57	1.4
RX And	01 04 35.5	+41 17 58.6	astrograph	08.10.98	54	1.8
FO Per	04 08 35.03	+51 14 48.8	1.06 m telescope	08.10.98	151	2.5

and subsequently excluded from the average lightcurve. In an iterative process only comparison stars with constant brightness within the noise level contributed to the average lightcurve.

HM Aur: This system has been discovered by Geyer et al. (1955) who described it as a long-period variable showing irregular waves spanning over 50–100 days with an amplitude of 0.5–1.1 mag. However, Vogt (1989) suspected a quiescent nova, while DWS 97 list it as nova-like with photographic magnitudes 11.3–12.4. To our knowledge, no spectrum has been published.

FBS 0827+738 and FBS 1614+711: Both objects have been reported as possible CVs by Abramyan & Mikaelyan (1994, 1995) as discoveries of the First Byurakan Objective Prism Survey. The authors do not present finding charts. Therefore, charts published by DWS 97 are based on the published coordinates only. The reported magnitudes are $V = 15.9$ for FBS 0827+738 and $B = 16.4$ for FBS 1614+711, respectively. While for FBS 0827+738, a spectrum is not available, FBS 1614+711 has recently been studied by Liu et al. (1999) who classified it as a DAB type white dwarf.

NSV 7956: NSV 7956 is listed in the NSV catalogue of Kholopov (1982) as a possible dwarf nova. No spectrum has been published so far and therefore this classification remains uncertain. DWS 97 give a magnitude range of $V = 9$–11.5.

HQ And: HQ And is listed as a CV in DWS 97 with a magnitude range of $m_{\rm phot} =$ 15.0–16.2. Meinunger (1975) first classified HQ And as a rapid irregular star and revised it later (1980) in favour of a CV classification. She already suspected a possible polar nature which was subsequently strengthened by the polarimetry of Andronov & Meinunger (1987).

RX And: RX And is a well-known dwarf nova of subtype Z Cam with a magnitude range of $V = 10.9$–12.6 (DWS 97). Spectroscopic studies were conducted e.g. by Kaitchuck et al. (1988) and Smith et al. (1995), while Verbunt et al. (1984) present a lightcurve. The orbital period has been determined to $P = 5.04$ hours by Kaitchuck (1989).

FO Per: According to Howarth (1976) and Gessner (1978) FO Per is a dwarf nova with a mean outburst cycle length of roughly 10 days. The spectrum published by Bruch (1989) shows the typical strong emission lines of such a system and thus supports this classification. DWS 97 give a maximum visual magnitude of 11.8 and a photographically

Table 2: Results of the differential photometry are given in this table. Column 3 shows the average magnitude of the differential lightcurve for the target and the comparison stars (CS1–CS7). Comparison stars marked with a * are used to calculate the average lightcurve.

HJD	Object	V_{diff}
2450882	HM Aur	-0.740 ± 0.073
	CS2*	–
	CS3	0.911 ± 0.075
	CS4	0.781 ± 0.048
	CS5	1.042 ± 0.095
2450884	HM Aur	-0.803 ± 0.011
	CS2*	–
	CS3	0.871 ± 0.024
	CS4	0.740 ± 0.023
	CS5	1.011 ± 0.024
2451248	HM Aur	-0.804 ± 0.006
	CS2*	–
	CS3	0.935 ± 0.006
	CS4	0.734 ± 0.006
	CS5	1.181 ± 0.005
2450881	FBS 0827+738	1.954 ± 0.020
	CS2	1.807 ± 0.027
	CS3	1.883 ± 0.024
	CS4*	–
2450884	FBS 0827+738	1.937 ± 0.036
	CS2	1.782 ± 0.036
	CS3	1.892 ± 0.037
	CS4*	–
2450884	FBS 1614+711	0.462 ± 0.047
	CS1*	-0.021 ± 0.031
	CS3*	-0.229 ± 0.030
	CS4*	0.035 ± 0.032
	CS5	0.216 ± 0.031

HJD	Object	V_{diff}
2450881	NSV 7956	-0.858 ± 0.009
	CS3*	0.402 ± 0.007
	CS4*	-0.402 ± 0.007
2450884	NSV 7956	-0.855 ± 0.010
	CS3*	0.403 ± 0.006
	CS4*	-0.403 ± 0.006

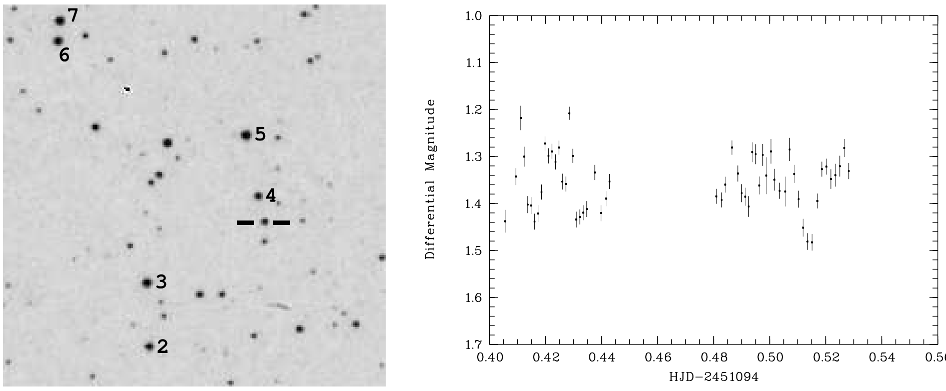
HJD	Object	V_{diff}
2451094	HQ And	1.354 ± 0.060
	CS2*	0.626 ± 0.009
	CS3*	-0.048 ± 0.005
	CS4	0.932 ± 0.014
	CS5*	-0.580 ± 0.007
	CS6*	0.248 ± 0.007
	CS7*	-0.245 ± 0.006
2451094	RX And	1.074 ± 0.135
	CS1*	-1.241 ± 0.038
	CS3*	1.241 ± 0.038
2451094	FO Per	0.771 ± 0.024
	CS2	-1.672 ± 0.010
	CS3*	0.528 ± 0.007
	CS4*	-1.034 ± 0.006
	CS5	-0.957 ± 0.011
	CS6	0.870 ± 0.014
	CS7*	0.507 ± 0.007

determined minimum value of 16.2.

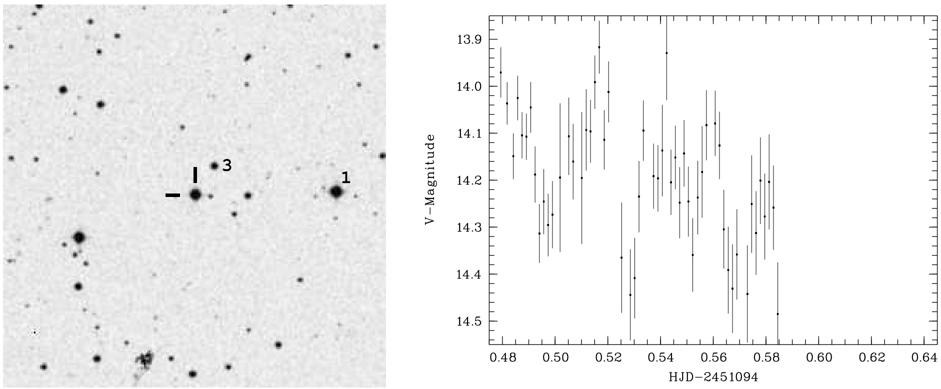
In Table 2 we give the mean differential magnitudes together with their standard deviation over the night. Figure 1 shows the lightcurves of the program stars as plots of the differential magnitude (except for FO Per and RX And, where the calibrated V-magnitude was available) against time in units of the Heliocentric Julian Date (HJD). All magnitude-axes cover a range of 0.7 mag, while all HJD-axes cover a time of 0.17 d, thus rendering all lightcurves directly comparable. The finding charts on the left side of Figure 1 give the location of the objects as well as of all comparison stars referred to in Table 2 for which differential lightcurves were computed.

Known CVs: HQ And, RX And and FO Per

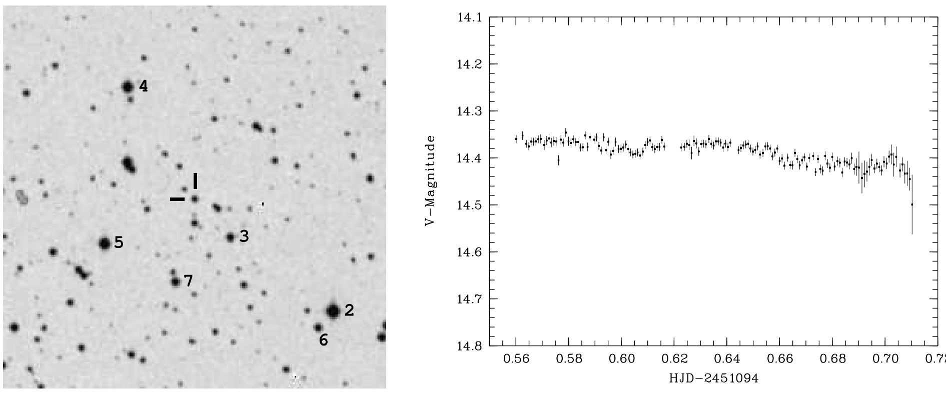
It is evident from Table 2 that the standard deviation of the differential lightcurve is much higher than those of the comparison stars. The differential lightcurves of HQ And and RX And show the characteristic flickering while the lightcurve of FO Per shows a slow descent. Furthermore, we can derive a calibrated magnitude for FO Per and RX And, as several comparison stars have been measured as secondary standards by Misselt (1996).



HQ And

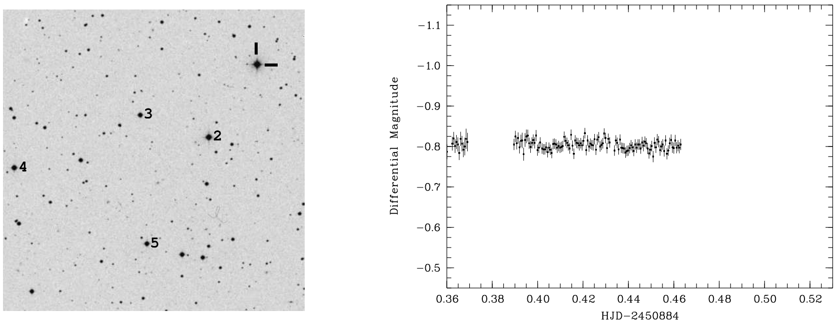


RX And

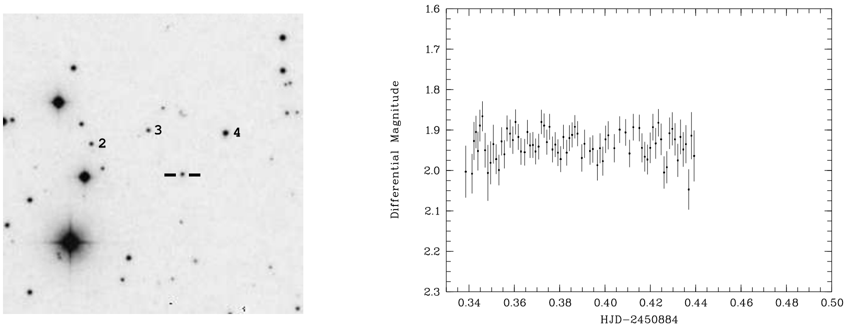


FO Per

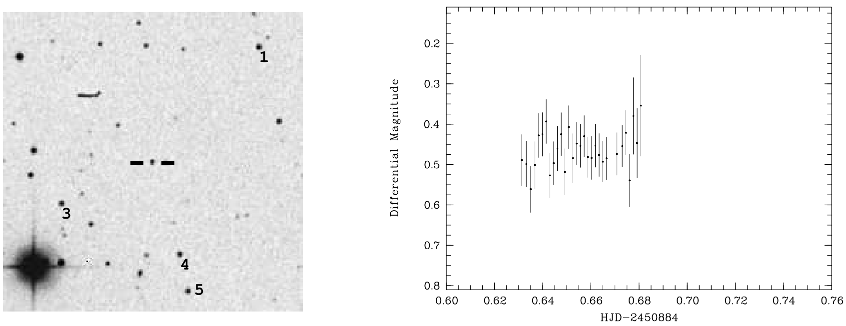
Figure 1. On the left side, we present the finding charts for the analyzed stars. On the right side, the corresponding lightcurves (Magnitude vs. HJD) are displayed. Scales were chosen to be directly comparable. Finding charts: HM Aur (dimensions: $13' \times 13'$), FBS 0827+738 ($7' \times 7'$), FBS 1614 ($6' \times 6'$), NSV 7956 ($13' \times 13'$), HQ And ($6' \times 6'$), RX And ($7' \times 7'$), and FO Per ($7' \times 7'$). North is up, East is to the left. Numbers correspond to the comparison stars.



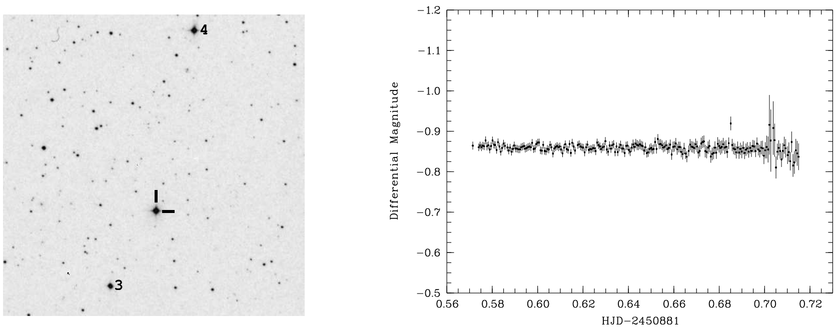
HM Aur



FBS 0827+738



FBS 1614+711



NSV 7956

Figure 1. (cont.)

For RX And, we thus obtain a visual magnitude of $V = 13.92(6)$–$14.48(11)$ and for FO Per $V = 14.35(1)$–$14.50(6)$. The latter value lies almost exactly in the middle of the above mentioned magnitude range. We therefore conclude that our observation must have taken place shortly after an outburst while the CV was still in its decline.

Candidate CVs: HM Aur, FBS 0827+738, FBS 1614+711, and NSV 7956
In the cases of HM Aur, FBS 0827+738, and NSV 7956 the resulting lightcurves show a straight line at a constant magnitude. None of the targets shows a standard deviation significantly higher than those of the comparison stars. Furthermore, all objects which could be observed in more than one night always show the same average magnitudes within the errors. We therefore conclude that a CV nature seems unlikely for these objects. As for FBS 1614+711, due to the large uncertainties and the short time interval we do not consider our lightcurve to provide sufficient information to speak in favour or against a CV classification. However, the very recently published spectrum by Liu et al. (1999) clearly lacks any CV characteristic. We thus take the fact that the most doubtful lightcurve was obtained from an object which was proven afterwards not to be a CV to strengthen our conclusions on the other three candidates, although spectroscopic observations will be required to finally clarify their status.

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