UBVRI observations of the flickering of the dwarf nova RX And

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Abstract. We report observations of the flickering variability of the dwarf nova RX And in five bands (UBVRI) on two nights. On 25 October 2019 the brightness of the star was $B \approx 13.8$ mag, the amplitude of the flickering was 0.47 mag, and we estimate for the flickering source temperature $T_{fl} = 10700 \pm 400$ K, and radius $R_{fl} = 0.046 \pm 0.004$ $R_\odot$. On 2 January 2020, the star was about 3 magnitudes brighter ($B \approx 10.7$), the amplitude of the flickering was significantly lower (0.07 mag) and we derive for the flickering source $T_{fl} = 9600 \pm 700$ K, and radius $R_{fl} = 0.098 \pm 0.008$ $R_\odot$. The results indicate that 3 magnitudes brightening of the star doubled the radius of the flickering source.
The data are available upon request from the authors.
Key words: Stars: dwarf novae – novae, cataclysmic variables – stars: individual: RX And

1 Introduction

RX And (2MASS J01043553+4117577) is a cataclysmic variable of dwarf nova type with orbital period 0.2098930 day = 5h02m = 302 minutes (Kaitchuck 1989). The cataclysmic variables are short period binaries consisting of an white dwarf primary and a red dwarf as a mass donor.

The underlying white dwarf in RX And was first detected by Holm et al. (1991) using an IUE spectrum during RX And's quiescence. The infrared spectra identified that the mass donor is a K5V star (Dhillon & Marsh 1995).

The dwarf novae are cataclysmic variables which exhibit recurrent outbursts with amplitude of 2 to 5 mag on the time-scale of weeks, caused by an increase in the mass accretion rate. RX And shows regular dwarf nova outbursts every 15 days (e.g. Kato 2004) and flickering on time scale of minutes (e.g. Bennert et al. 1999).

Following the AAVSO light curve generator, during the last years RX And varies in the range $10.9 \leq V \leq 14.9$ and $9.5 \leq B \leq 15.0$. There was an extended faint state of RX And in 1996, when the brightness remained about 15 mag in V band for ≈ 100 days (Kato et al. 2002).

In this work, we present quasi-simultaneous UBVRI observations of the flickering variability of RX And and estimate the parameters of the flickering source.

2 Observations

The repeating U,B,V,R and I band observations are performed with the 50/70 cm Schmidt telescope of the National Astronomical Observatory Rozhen – on 25 October 2019 from UT 18:33 to 00:20, total duration 5h 47m, and on 2 January 2020 from UT 17:43 to 21:31, total duration 3h 48m. The telescope was equipped with a CCD camera and the field of view was 23 x 23 arcmin. The red bands correspond to the Cousins VRI system.

The comparison stars were TYC 2807-1285-1 (U=11.21, B=11.15, V=10.57, R=9.88, I=9.53) and TYC 2803-1045-1 (U=11.96, B=11.94, V=11.43, R=10.75, I=10.44). The data reduction is done with IRAF (Tody 1993) following the standard recipes for processing of CCD images and aperture photometry.

In Table 1 are given date of observation, its duration in seconds, number of the exposures (N_{pts}), the exposure times in seconds, minimum, maximum and average magnitude in the corresponding band, standard deviation of the run, typical observational error and peak-to-peak amplitude of the variability.

Our observations are presented in Fig. 1. What is immediately visible is that during the second night the star was brighter and the amplitude of the flickering was considerably lower.

Table 1. Photometry of RX And. In the table are given: date of observation, its duration, band, number of the data points obtained, exposure time [in seconds], minimum, maximum and average magnitudes in the corresponding band, standard deviation of the mean, typical observational error, peak-to-peak amplitude.

date duration	band	N_{pts}	exptime [sec]	min [mag]	max [mag]	average [mag]	stdev [mag]	merr [mag]	ampl. [mag]
2019-10-25	U	95	90, 60	12.741	13.161	12.9680	0.084	0.017	0.42
347 min	B	95	30, 20	13.571	14.040	13.8571	0.097	0.017	0.47
	V	95	20, 10	13.452	13.871	13.6971	0.084	0.020	0.42
	R	95	10	12.799	13.116	12.9934	0.065	0.015	0.32
	I	95	30, 10	12.301	12.550	12.4255	0.053	0.023	0.25
2020-01-02	U	90	60, 40, 30	9.992	10.100	10.0652	0.020	0.009	0.11
228 min	B	90	20, 10	10.687	10.759	10.7267	0.015	0.006	0.07
	V	90	10, 7	10.720	10.797	10.7598	0.016	0.005	0.08
	R	90	10, 7	10.316	10.383	10.3504	0.017	0.005	0.07
	I	90	10	10.208	10.286	10.2454	0.019	0.006	0.08

Table 2. Estimated colours of RX And and its flickering source. The colours of the star are the average colours during the night.

date	colour	star	average flickering	maximum flickering
20191025	(U-B)	0.89 ± 0.02	-0.94 ± 0.03	-0.73 ± 0.05
	(B-V)	0.16 ± 0.02	0.11 ± 0.03	0.02 ± 0.05
	(V-R)	0.70 ± 0.02	0.35 ± 0.04	0.40 ± 0.07
	(R-I)	0.57 ± 0.02	0.58 ± 0.06	0.27 ± 0.09
20200102	(U-B)	0.66 ± 0.01	-0.74 ± 0.09	-1.12 ± 0.09
	(B-V)	-0.03 ± 0.01	0.12 ± 0.05	0.04 ± 0.05
	(V-R)	0.41 ± 0.01	0.27 ± 0.04	0.26 ± 0.04
	(R-I)	0.11 ± 0.01	0.34 ± 0.03	0.27 ± 0.04

3 Flickering light source

Bruch (1992) proposed that the light curve of a white dwarf with flickering can be separated into two parts – constant light and variable (flickering) source. Following his recipe, we calculate the flux of the flickering light source as $F_{\rm fl} = F_{\rm av} - F_{\rm min}$, where $F_{\rm av}$ is the average flux during the run and $F_{\rm min}$ is the minimum flux during the run (corrected for the typical error of the observations). An expansion of the method is proposed by Nelson et al. (2011). They suggest to use the $F_{\rm fl.max} = F_{\rm max} - F_{\rm min}$, where $F_{\rm max}$ is the maximum flux during the run. In fact, the method of Bruch (1992) evaluates the average brightness of the flickering source, while that of Nelson et al. (2011) – its maximal brightness. $F_{\rm fl}$ and $F_{\rm fl.max}$ have been calculated for each band, using the values given in Table 1 and the calibration for a zero magnitude star (Bessell 1979).

Following the IRSA: Galactic Reddening and Extinction Calculator in NASA/IPAC Extragalactic Database, NED (which is operated by the Jet Propulsion Laboratory, California Institute of Technology), the extinction toward RX And is low, $E(B-V) \leq 0.06$. The IRSA calculator uses Galactic reddening maps to determine the total Galactic line-of-sight reddening (in front of RX And and behind it), and is based on the results by Schlegel, Finkbeiner & Davis (1998) and Schlafly & Finkbeiner (2011).

GAIA EDR3 (Lindegren et al. 2021) gives parallax 5.0510 ± 0.0269 mas. Hereafter, we assume no extinction, $E(B-V) = 0.0$ and distance 198 ± 1 pc. We calculate for the average flickering source of RX And its temperature and radius:
20191025 – $T_{fl} = 10700 \pm 400$ K, $R_{fl} = 0.046 \pm 0.004$ $R_\odot$,
20200102 – $T_{fl} = 9600 \pm 700$ K, $R_{fl} = 0.098 \pm 0.009$ $R_\odot$.
These values correspond to luminosity $L_{fl} = 0.025 \pm 0.004$ $L_\odot$ (for 20191025), and $L_{fl} = 0.074 \pm 0.008$ $L_\odot$ (for 20200102).

4 Discussion

The light curve of RX And in 1972-1997 displays periods of frequent outbursts with amplitude ≈ 3 mag, low states and periods of stand still (Schreiber et al. 2002). The light curve of RX And in 2014-2015 was examined by Timar (2016), who found that the cycle of outbursts is short (< 15 days) due to the high accretion rate and every fourth outburst is a super-outburst. The period of the super-cycle was about 55.5 days.

The Hubble Space Telescope spectra revealed that the white dwarf in RX And has a temperature $T_{wd} \approx 34000$ K, and rotates with ≈ 600 km s^{-1} (Sion et al. 2001). Sepinsky et al. (2002), using HST observations during outburst rise and decline, found mass accretion rate 2×10^{-10} $M_\odot$ yr^{-1} onto a white dwarf of mass ~ 0.8 $M_\odot$ with effective temperature 40000 K. Godon & Sion (2003) found that it must be a massive white dwarf ~ 1.2 $M_\odot$.

The temperature of the flickering source estimated here is considerably lower than the white dwarf temperature. It is similar to the temperature of the bright spot of cataclysmic variables. For the bright spot of OY Car, Wood et al (1989) calculated black body temperature $T = 13800 \pm 1300$ K, and color

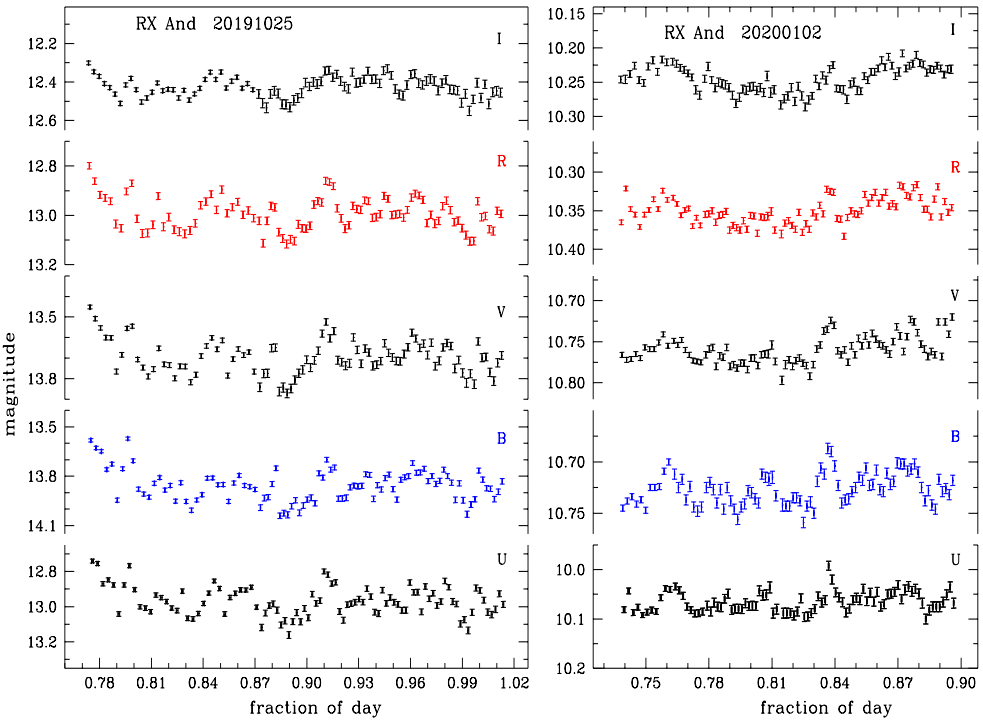

Fig. 1. UBVRI observations of the flickering dwarf nova RX And on 25 October 2019 and 2 January 2020 performed with the 50/70 cm Schmidt telescope of NAO Rozhen.

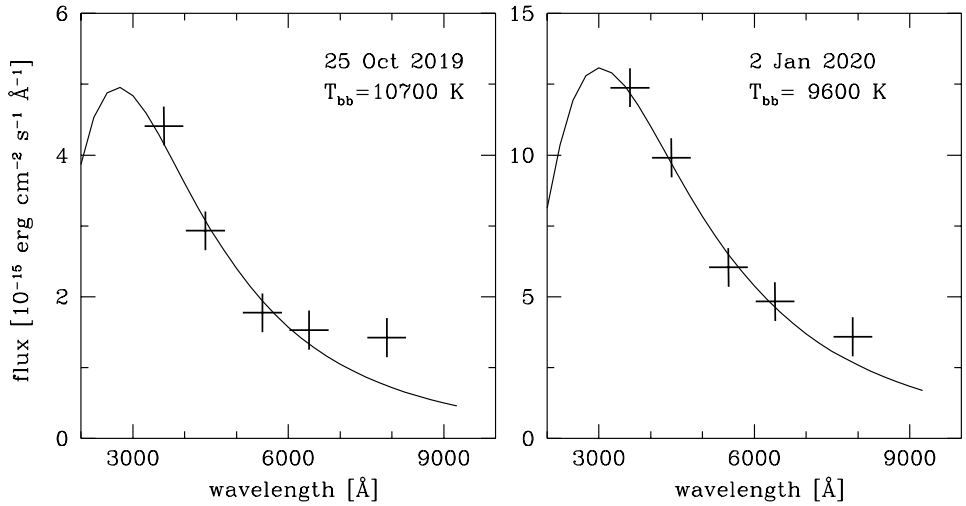

Fig. 2. Black body fits to the flickering source of RX And.

temperature $T = 9000$ K. For IP Peg Marsh (1988) give $T = 11200$ K, for U Gem Zhang & Robinson (1987) give $T = 11600 \pm 500$ K, and for the bright spot in WZ Sge Robinson et al. (1978) give $T = 16000$ K. The colours of the flickering source of RX And on 10 August 1983 were estimated by Bruch (1992): $U - B = -1.14$, $B - V = 0.46$, assuming E(B-V)=0.06. The value of U-B is bluer than our and B-V is more red. The differences can be connected with real changes in the flickering and/or with the used different calibrations for a zero magnitude star.

In dwarf novae, the flickering amplitude is high during quiescence, drops quickly at an intermediate magnitude when the system enters into (or returns from) an outburst and, on average, remains constant above a given brightness threshold (Bruch 2021). In future it will be interesting to search for a correlation between the flickering source parameters and brightness as done for the recurrent nova RS Oph (Zamanov et al. 2018) and the jet-ejecting symbiotic MWC 560 (Zamanov et al. 2020).

Conclusions: We report quasi-simultaneous observations in 5 bands (UBVRI) of the flickering of the cataclysmic variable RX And during two nights.

For 25 October 2019 the brightness of the star was $13.57 \leq B \leq 14.04$, the amplitude of the flickering in B band was $\Delta B = 0.47$ mag. For the optical flickering source we obtained colour $(B - V)_0 = 0.11$, temperature $T_{fl} = 10700 \pm 400$ K, and radius $R_{fl} = 0.046\ R_{\odot}$.

For 2 January 2020, the star was about 3 magnitudes brighter in B band $10.69 \leq B \leq 10.76$ and the amplitude of the flickering decreased considerably $\Delta B = 0.07$ mag. For the optical flickering source we derived colour $(B-V)_0 = 0.12$, temperature $T_{fl} = 9600 \pm 700$ K, and radius $R_{fl} = 0.098\ R_{\odot}$.

The results indicate that when the star is 3 magnitudes brighter the radius of the flickering source is twice larger.

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