BV photometric observations of the flickering of the dwarf nova RX And

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Abstract. We report photometry of the intranight variability of the dwarf nova RX And in two bands (B and V). The observations are carried out during three nights in November-December 2022 with the 50/70 cm Schmidt telescope of the Rozhen National Astronomical Observatory. The observations indicate that the amplitude of the flickering is about 0.5 mag in B band when the star is in faint state ($m_V \approx 13.5$), but it is considerably lower (less than 0.1 mag) when the star is bright ($m_V \approx 10.9$). The mass accretion rate in high state is estimated to be 1.2×10^{-9} M$_\odot$ yr^{-1}. Combining our data and GAIA distances we find for the mass donor in RX And spectral type K6V-K7V.
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 belongs to the subclass Dwarf Novae of the Cataclysmic Variable stars. The Cataclysmic Variables are compact close binaries (with orbital periods typically 1-12 hours) consisting of an white dwarf primary and a red dwarf secondary [e.g. Warner (1995), Sion & Godon(2022) and references therein]. In the most cases the secondary is on the main sequence, fills in its Roche lobe and its Roche lobe overflow supplies material for accretion disc around the white dwarf. The dwarf novae exhibit recurrent outbursts with amplitude of 2 to 5 mag on time-scale of weeks-months, caused by disc instability and increase in the mass accretion rate.

Following the AAVSO light curve generator, during the last three years (2020 - 2022), RX And varies in the range $10.9 < V \leq 14.3$ with many dwarf nova outbursts during this period (one outburst every ~ 30 days).

In this work, we present quasi-simultaneous observations of the intranight variability of RX And in the Johnson B and V bands.

2 Observations

The new observations of RX And are performed with the 50/70 cm Schmidt telescope of the Rozhen National Astronomical Observatory repeating B and V filters during three nights in November-December 2022. The telescope is equipped with a CCD camera 4096x4096 pixels. To reduce the readout time we binned the detector with a factor of 2x2 and windowed it down to 512x512 pixels, yielding $16' \times 16'$ field of view centered at RX And. As comparison stars we used: TYC 2807-1285-1 ($01^h03^m55^s$, $+41°15'22''$, B=11.151, V=10.568) and TYC 2803-1045-1 ($01^h05^m10^s$, $+41°14'07''$, B=11.938, V=11.431). The BV magnitudes are taken from the APASS DR10 (Henden et al. 2012).

The data reduction is carried out with IRAF (Tody 1993) following the standard recipes for processing of CCD images and aperture photometry. Our observations and results from the photometry are summarized in Table 1. We list the date and duration of the monitoring, the number of the exposures in each filter and the exposure times, the minimum (corresponding to the maximum apparent brightness), maximum and average magnitude of the target, the standard deviation during the monitoring, the typical observational errors and the peak-to-peak variability magnitude. Our new observations are presented in Fig. 1. The colour-magnitude diagram (V versus $B-V$) of RX And is presented in Fig. 2, where it is visible that the star becomes bluer as it gets brighter. In the next section we will analyse the new observations as well as the two runs 20191025 and 20200102 obtained with the same telescope setup and presented in Zamanov, Nikolov & Georgieva (2021).

Table 1. Log of RX And observations and photometric results. Columns: date (YYYY-MM-DD) and UT at start/end of the monitoring, filter, number of the frames and exposure times and light curve parameters (see Sec. 2).

date UT start-end	band	frames	min [mag]	max [mag]	average [mag]	stdev [mag]	merr [mag]	ampl. [mag]
2022-11-03	B	78 x 10 s	10.814	10.852	10.8339	0.009	0.007	0.038
20:43-23:17	V	78 x 7 s	10.829	10.888	10.8618	0.010	0.006	0.059
2022-11-14	B	111 x 10 s	13.459	14.018	13.7246	0.109	0.031	0.559
21:10-24:51	V	111 x 7 s	13.297	13.698	13.4890	0.092	0.026	0.401
2022-12-12	B	155 x 10 s	10.858	10.943	10.9053	0.018	0.006	0.085
18:46-20:46	V	155 x 10 s	10.882	10.983	10.9350	0.018	0.005	0.101

3 Results and discussion

RX And (2MASS J01043553+4117577) is a dwarf nova with orbital period 0.2098930 days = 5h02m = 302.2 min (Kaitchuck et al. 1988; Kaitchuck 1989). The underlying white dwarf component of RX And was first detected by Holm et al. (1991) using an International Ultraviolet Explorer (IUE) spectrum during RX And's quiescence. The spectrum is obtained when the star was V=13.8 and is consistent with the energy distribution of a 35000 K hydrogen-atmosphere white dwarf. The Hubble Space Telescope (HST) spectroscopy gives mass 1.14 $M_{\odot}$, temperature 34000 K, rotational velocity 600 km s^{-1} (Sepinsky et al. 2002; Sion et al. 2007; Sion & Godon 2012).

On the basis of GAIA eDR3 (Gaia Collaboration et al. 2021), the model by Bailer-Jones et al. (2021) provides a distance to RX And, d = 196 pc.

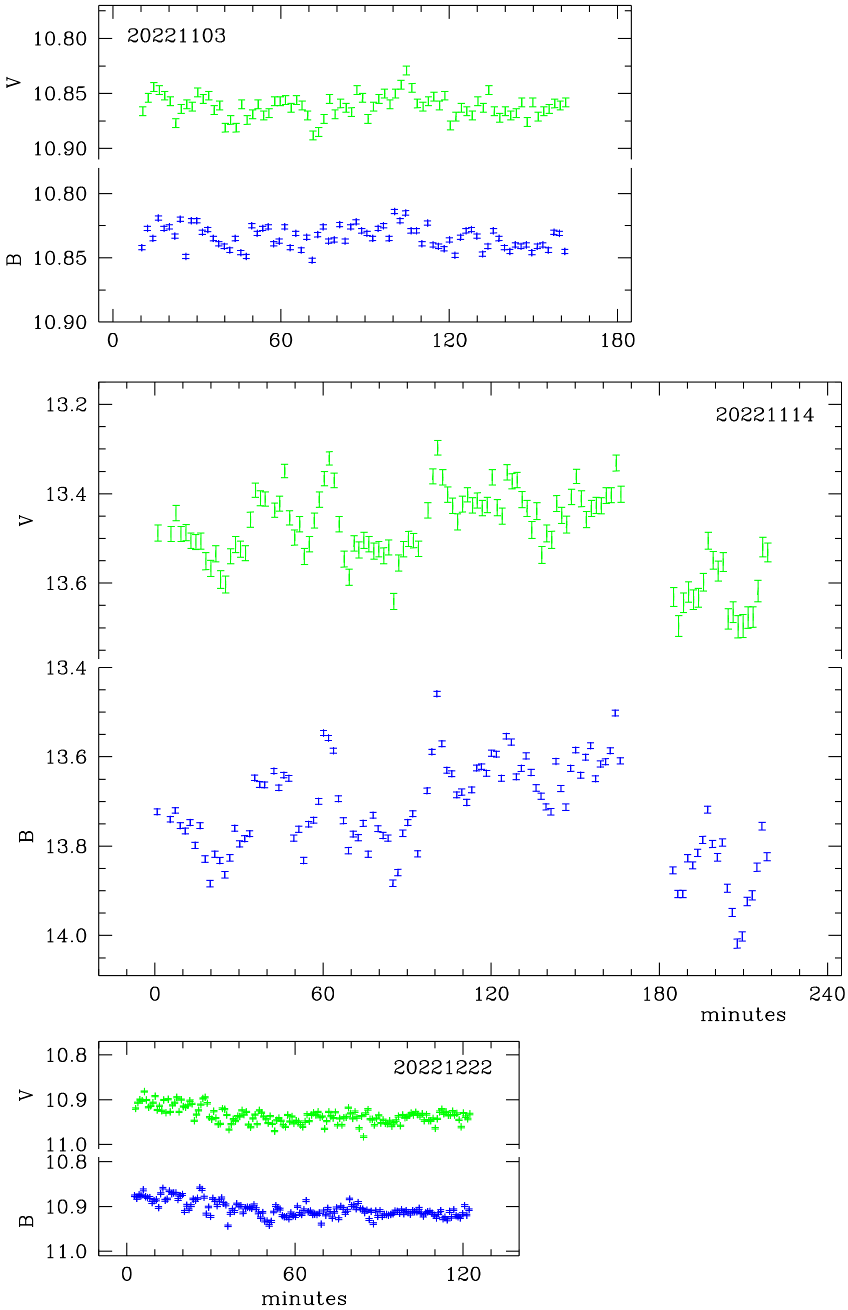

Fig. 1. Simultaneous observations of the dwarf nova RX And in *B* and *V* bands obtained on 3 November, 14 November, and 22 December 2022 with the 50/70 cm Schmidt telescope of Rozhen NAO. The X-axis is in minutes from start of the observation (1 hour = 60 min). Note that the scales of the axes are identical on all three panels. The amplitude of the flickering is higher when the star is fainter.

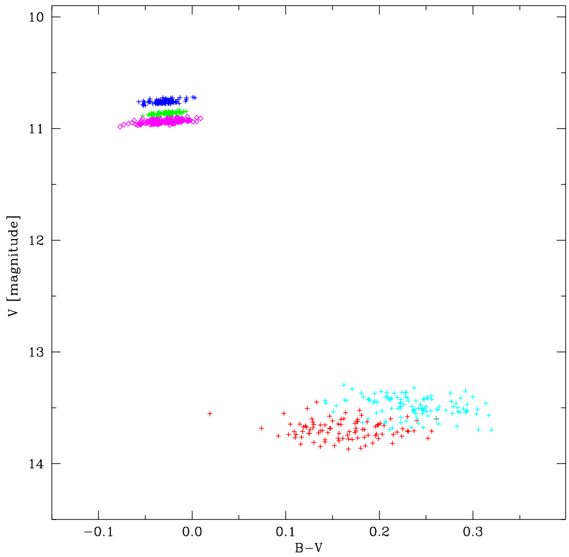

Fig. 2. Colour-magnitude diagram of RX And. Each night is plotted in different colour – 20191025 (red), 20200102 (blue), 20221103 (green), 20221114 (cyan), 20221222 (magenta). It is visible that the star becomes bluer as it gets brighter.

NASA-IPAC extinction calculator gives interstellar reddening $E_{B-V} < 0.06$ for RX And. This upper limit refers to the extinction through the entire Milky Way in the direction of the object (in front of the object and behind it). The calculator uses Galactic reddening maps to determine the total Galactic line-of-sight reddening, and is based on the results by Schlegel, Finkbeiner & Davis (1998) and Schlafly & Finkbeiner (2011). Because the object is close to the Sun, it is very likely that there is no extinction, $E_{B-V} \approx 0$.

3.1 Spectral type of the secondary

The infrared observations show that many secondary stars in Cataclysmic variables have mid-K spectral type (Howell 2005). For RX And, Dhillon & Marsh (1995) found that the mass donor is a K5V star using infrared spectra. To verify this result with our data, we use standard formula $M = m - 2.5 \log[(d/10)^2]$, and the minimum brightness in V band. In our data set the minimum brightness in V band is in the run 20191025, $V = 13.871$ (see also Fig. 2). We find absolute V magnitude of the secondary in the range $7.4 < M_V \leq 8.2$. The limits are calculated adopting fractional contribution of the secondary star to the total V band flux in the range 100% – 50%, respectively. It should be noted that the uncertainty in this fractional contribution dominates the uncertainty in the spectral type, because it greatly exceeds the observational errors. The calibration of spectral types in absolute magnitudes (Sraizys & Kuriliene 1981) gives $M_V = 7.3$ for K5V star, and $M_V = 8.1$ for K7V star.

More recently, Pecaut & Mamajek (2013)[1] lists similar values for the absolute magnites: M_V = 7.28 for K5V star, M_V = 7.64 for K6V, and M_V = 8.16 for K7V.

The range inferred from our observations indicates that the secondary component in RX And is most probably of spectral type K6V - K7V, which is similar but a bit later than the spectral type given in Dhillon & Marsh (1995).

3.2 Amplitude of the flickering

Bruch (2021, 2022) noted that in some 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. Our observations of RX And give a similar result. In low state ($V \approx 13.5$), the peak-to-peak amplitude of the flickering in B band is large: 0.56 mag (run 20221114) and 0.47 mag (run 20191025). In high state ($V \approx 10.8$), the amplitude of the flickering in B band is small: 0.07 mag (run 20200102), 0.04 mag (run 20221103), 0.09 mag (run 20221212).

3.3 Mass accretion rate

For dwarf novae in high state, the main source of radiation in the optical bands is the accretion disc. In our observations (Fig. 2) the highest brightness is B=10.687 and V=10.720 in our run 20200201. The lowest brightness of RX And is B=14.040 and V=13.871 in our run 20191025. We transformed these magnitudes into fluxes using the calibrations for a zero magnitude star (Rodrigo et al. 2012). We subtracted the minimum from the maximum flux, and the residuals should represent the contribution of the accretion disc. In this way we find that the contribution of the accretion disc to the energy emitted in the optical B and V bands (in high state), is equivalent to B = 10.738, V = 10.781, and colour $(B-V) = -0.044$. For distance 196 pc, this corresponds to a black body with temperature T = 14220 K, radius 0.305 $R_\odot$, and luminosity 3.4 $L_\odot$.

The white dwarfs are objects in which the electron degeneracy pressure is equal to the gravitational pressure, and a remarkable property is that the more massive white dwarfs are smaller. To estimate the radius of the white dwarf in RX And, we use the Eggleton's formula as given in Verbunt & Rappaport (1988):

$$\frac{R_{wd}}{R_\odot} = 0.0114 \left[\left(\frac{M_{wd}}{M_{Ch}}\right)^{-2/3} - \left(\frac{M_{wd}}{M_{Ch}}\right)^{2/3} \right]^{1/2} \times \left[1 + 3.5 \left(\frac{M_{wd}}{M_p}\right)^{-2/3} + \left(\frac{M_{wd}}{M_p}\right)^{-1} \right]^{-2/3}, \quad (1)$$

[1] The values are from version 2022.04.16 as given at www.pas.rochester.edu/∼emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt

where M_{Ch} =1.44 $M_\odot$ is the Chandrasekhar limit mass for the white dwarfs, M_p is a constant $M_p = 0.00057$ $M_\odot$. We note in passing that the masses and radii estimated for white dwarfs in detached eclipsing binaries agree with this formula (e.g. Parsons et al. 2017). This mass-radius relation gives radius $R_{wd} = 4370$ km for a $M_{wd} = 1.14$ $M_\odot$.

The luminosity of the accretion disc is connected with the mass accretion rate:

$$L_{disc} = \frac{G\, M_{wd}\, \dot{M}_a}{2\, R_{wd}}, \quad (2)$$

where $\dot{M}_a$ is the mass accretion rate, M_{wd} is the mass of the white dwarf, R_{wd} is the radius of the white dwarf. The underlying assumption in this equation is that the disc luminosity is half of the total accretion luminosity. The other half is emitted in UV/X-rays by the boundary layer between the accretion disc and white dwarf (more details can be found in Chapter 6 of Frank et al. 2012). We find mass accretion rate for RX And in high state 1.2×10^{-9} $M_\odot$ yr^{-1} (7.5×10^{16} g s^{-1}). The error is about $\pm 20\%$, estimated from the inaccuracy of the parameters and the assumptions. This value is typical for the dwarf novae in high state and it is inside (in the upper part of) the range $1 \times 10^{14} - 2 \times 10^{17}$ g s^{-1} discussed in the theoretical models of dwarf novae accretion discs (e.g. Dubus et al. 2018).

4 Conclusions

We report observations of the intranight variability of the dwarf novae RX And obtained in November-December 2022. The observations are performed quasi-simultaneously in two optical bands (B and V) with the 50/70 cm Schmidt telescope of the Rozhen National Astronomical Observatory.

We find for the mass donor of RX And absolute V band magnitude in the range $7.4 < M_V < 8.2$ corresponding to spectral type K6-K7V. We observed a large amplitude (≈ 0.5 mag) flickering in low state. In high state the amplitude of the flickering is small ≈ 0.07 mag. We estimate that in high state, the mass accretion rate onto the white dwarf is of about 1.2×10^{-9} $M_\odot$ yr^{-1}.

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