BV Photometric Observations of the Dwarf Novae DX And and AR And

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Abstract. We report photometric observations of the intranight variability of the dwarf novae DX And and AR And in two bands (B and V) on a few nights in late October 2022. The observations are performed with the 50/70 cm Schmidt telescope of the National Astronomical Observatory Rozhen. The results indicate that both stars exhibit intranight variability with amplitude 0.15 mag in B and V bands on a time scale of $\sim$ few hours. Combining our data and GAIA distances we find for the mass donor in DX And spectral type K1V, and for the mass donor in AR And – K7V-M0V.
The data are available upon request from the authors and on Zenodo.
Key words: Stars: dwarf novae – novae, cataclysmic variables – stars: individual: DX And, AR And

Introduction

DX And and AR And belong to the subclass Dwarf Novae of the Cataclysmic Variable stars. The Cataclysmic Variables are short period binaries (with orbital periods typically 1-11 hours) consisting of a white dwarf primary and a red dwarf secondary (more details can be found in Warner (1995) and references therein). The secondary is in most cases on the main sequence, fills its Roche lobe and its Roche lobe overflow supplies material for accretion disc around the white dwarf. The dwarf novae are cataclysmic variables which exhibit recurrent outbursts with amplitude of 2 to 5 mag on a 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 DX And varies in the range $11 < V \leq 15.5$ with 3 dwarf nova outbursts during this period. During the same period AR And varies in the range $12 \leq V \leq 17.5$ mag.

In this work, we present quasi-simultaneous B-band and V-band observations of the intranight variability of DX And and AR And.

1. Observations

The observations are performed with the 50/70 cm Schmidt telescope of the National Astronomical Observatory Rozhen repeating B and V filters during three night in late October 2022. The telescope is equipped with a CCD camera 4096 x 4096 pixels, and the field of view is 1° x 1°. As comparison stars for DX And we used:
RA=352°.460324 Dec=43°.747296 V=13.316 B=13.892,
RA=352°.426632 Dec=43°.761698 V=12.684 B=13.389,
RA=352°.417791 Dec=43°.833855 V=11.009 B=12.206.
For AR And we used:
RA=26°.273237 Dec=37°.945584 V=14.663 B=15.130,

RA=26°.280894 Dec=37°.96159 V=14.955 B=15.590,
RA=26°.215691 Dec=37°.889346 V=13.397 B=13.931.
The coordinates and magnitudes are taken from the APASS DR10 (Henden et al. 2012).

The data reduction is done with IRAF (Tody 1993) following the standard recipes for processing of CCD images and aperture photometry. The results of our observations are summarized in Table 1 and Table 2, where we give date and duration of the observation, number of the exposures and the exposure times, 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. We note in passing that (1) the minimum magnitude corresponds to the maximum brightness and (2) the amplitude includes the variability and the observational errors. Our observations are presented on Fig. 1 and Fig. 2.

Table 1. Photometry of DX And. In the table are given: date of observation (in format YYYY-MM-DD), its duration (UT start - UT end), band, number of the frames and 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	frames	min [mag]	max [mag]	average [mag]	stdev [mag]	merr [mag]	ampl. [mag]
2022-10-28	17:52-01:41	B	41 x 200 s	15.706	15.859	15.8013	0.038	0.010	0.15
		V	39 x 120 s	14.878	14.993	14.9424	0.030	0.007	0.12
2022-10-29	16:39-00:51	B	71 x 200 s	15.711	15.900	15.8138	0.048	0.009	0.19
		V	72 x 120 s	14.873	15.007	14.9554	0.042	0.007	0.14
2022-10-30	16:41-23:59	B	61 x 200 s	15.714	15.858	15.7841	0.033	0.009	0.14
		V	61 x 120 s	14.877	15.014	14.9336	0.029	0.008	0.14

Table 2. Photometry of AR And. In the table are given: date of observation (in format YYYY-MM-DD), its duration (UT start - UT end), band, number of the frames and 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	frames	min [mag]	max [mag]	average [mag]	stdev [mag]	merr [mag]	ampl. [mag]
2022-10-30	01:10-03:29	B	21 x 200 s	16.998	17.168	17.1028	0.0415	0.028	0.17
		V	21 x 120 s	16.747	16.973	16.8430	0.0560	0.032	0.23
2022-10-31	00:48-02:41	B	17 x 200 s	16.946	17.153	17.0257	0.0519	0.027	0.21
		V	18 x 120 s	16.643	16.863	16.7483	0.0542	0.028	0.22

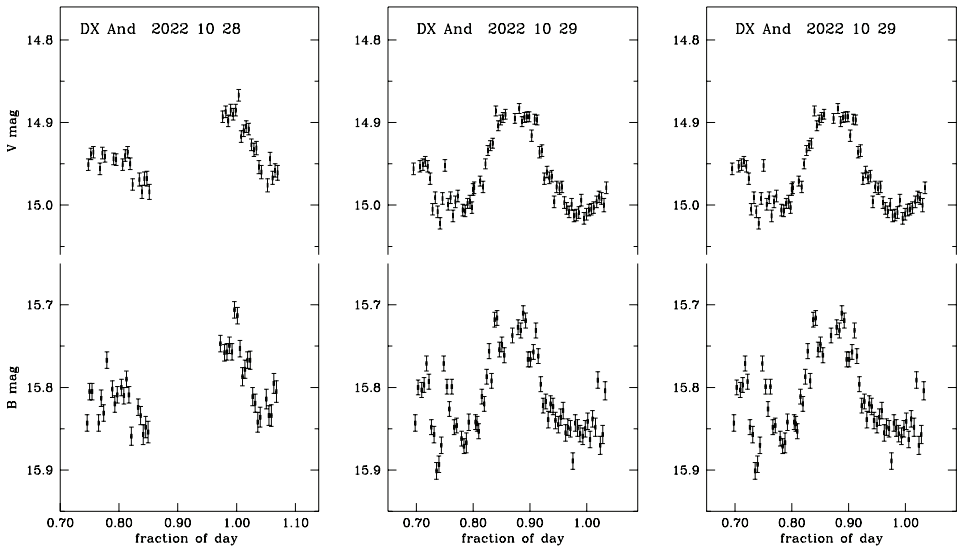

Fig. 1. Simultaneous B-band and V-band observations of the dwarf nova DX And obtained on 28, 29 and 30 October 2022 with the 50/70 cm Schmidt telescope of NAO Rozhen. The Y-axes are identical on the all three panels.

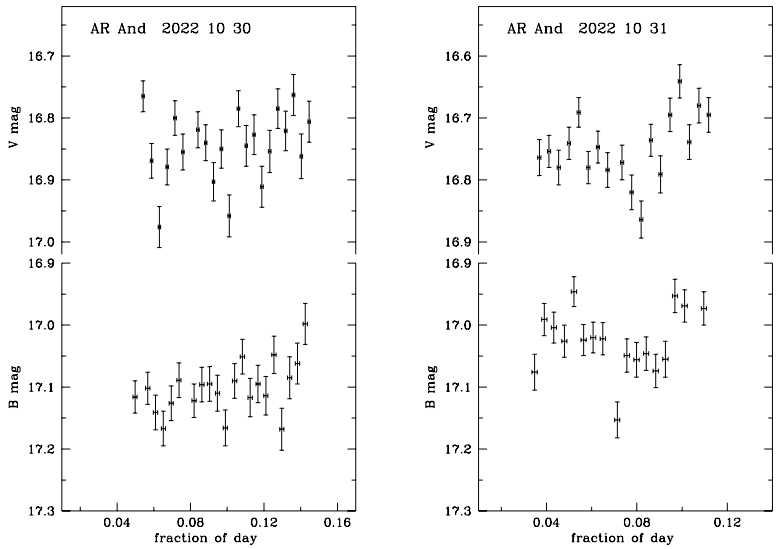

Fig. 2. Simultaneous B-band and V-band observations of the dwarf nova AR And performed on 30 and 31 October 2022 with the 50/70 cm Schmidt telescope of NAO Rozhen.

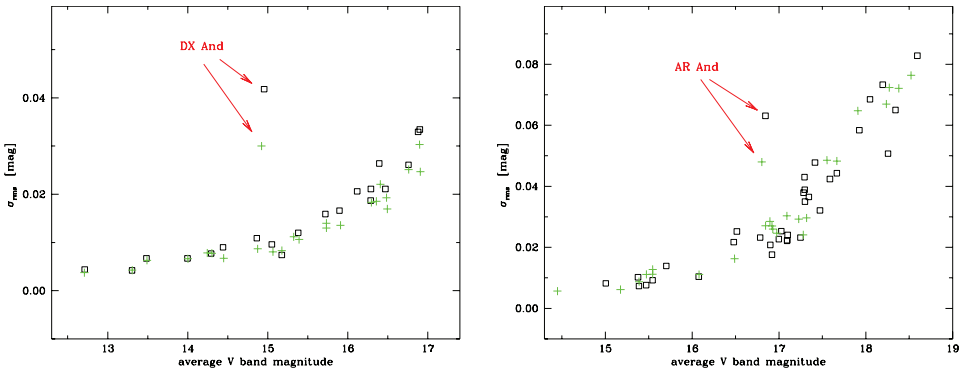

Fig. 3. Root mean square versus the average V-band magnitude. Left panel: DX And - the black squares refer to the night 2022-10-29 and the green plus signs to 2022-10-30. Right panel: AR And - the black squares refer to the night 2022-10-30 and the green pluses to 2022-10-31. The σ_{rms} of DX And and AR And deviates from the behaviour of the other stars, which indicates that they exhibit intranight variability during our observations.

2. Results and discussion

Form Fig. 1 and Table 1, it is visible that DX And varies on a time scale of hours with peak-to-peak amplitude ΔV larger then 0.1 mag. However, there are practically no changes of the average brightness from night to night, it remains $V \approx 14.94 \pm 0.02$ for all three runs.

For four V band runs we measure the standard deviation of our targets and 20 other stars in the field and plot it in Fig. 3. The standard deviation is calculated as

$$\sigma_{rms} = \sqrt{\frac{1}{N_{pts} - 1} \sum_{i} (m_i - \overline{m})^2}, \quad (1)$$

where $\overline{m}$ is the average magnitude in the run, N_{pts} is the number of the data points. σ_{rms} calculated in this way includes the variability of the star (if it exists) and the measurement errors. For non-variable stars it represents the accuracy of the photometry. σ_{rms} of DX And and AR And deviates from the behaviour of the field stars. σ_{rms} of DX And is 3.5 - 4.3 times larger than what is expected from stars with similar brightness. σ_{rms} of AR And is 2.0 - 2.8 times larger than what is expected for non-variable field stars.

Using the GAIA eDR3 (Gaia Collaboration et al. 2021) parallaxes, the model by Bailer-Jones et al. (2021) provides a distance d=591 pc to DX And, and d=585 pc to AR And. NASA-IPAC extinction calculator gives $E_{B-V} < 0.14$ for DX And, and $E_{B-V} < 0.05$ for AR And. These upper limits refer to the extinction through the entire Milky Way in the direction of the objects (in front of the object and behind it). The IRSA 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 objects are close to Earth, likely the extinction is ≈ 0.

2.1. DX And

DX And is a cataclysmic variable of dwarf nova type with orbital period 10.57 hours (see Bruch et al. 1997, Hilditch 1995, Drew et al. 1993). The time of the inferior conjunction of the secondary has ephemeris HJD = 2447800.2935 + 0.4405019 × E. The secondary is classified as K1V spectral type. The fractional contribution of the primary to the total light is determined as a function of wavelength – it is 19% at Hβ (4861.3 Å) and drops to 5% at Hα (6562.8 Å). The effective wavelength of the V band is 5445.4 Å (Spanish Virtual Observatory Filter profile Service, Rodrigo et al. 2012). We estimate a fractional contribution of the primary in V band 14%, and a fractional contribution of the secondary in V band 86% .

Using the standard formula $M = m - 2.5\log[(d/10)^2]$, we find the absolute V magnitude of the secondary in the range $6.15 < M_V \leq 6.32$ (where the limits are calculated adopting fractional contribution of the secondary star to the maximum V band magnitude (i.e. the minimal V band brightness) in the range 100% - 86%. The obtained value is in excellent agreement with the absolute V band magnitude of a K1V star $M_V = 6.2$ (Sraizys & Kuriliene 1981). For comparison, they give for a K0V star $M_V = 6.0$, and for a K2V star $M_V = 6.5$. Result does not confirm the supposition of Smith & Dhillon (1998) that DX And almost certainly has an evolved secondary star and points that it is an "normal" K1V star.

Time series observations on two nights for DX And, on 06 February 2019 (in R_c band) and 08 February 2019 (in V band) are reported by Spogli et al. (2020). The oscillations in V are between magnitudes 14.95 and 15.20, while in R_c they are between 14.40 and 14.63. Our observations in V band shows variability in the range 14.88-14.99, 14.87-15.01, and 14.88-15.01, for the three nights (see Table 1), with peak-to-peak amplitude 0.12-0.14 mag, which is similar to but lower than the amplitude of 0.25 mag observed by Spogli et al. (2020).

2.2. AR And

Using the standard formula, we find the absolute V magnitude of the secondary in the range $8.1 < M_V \leq 8.9$, where the limits are calculated adopting fractional contribution of the secondary star to the maximum V band magnitude (i.e. the minimal V band brightness) in the range 100% - 50%. Sraizys & Kuriliene (1981) give for K7V $M_V = 8.1$ and for M0V $M_V = 8.9$. Our observations point to a spectral class of the secondary K7V - M0V.

2.3. Future observational plans

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. In the future it will be interesting to obtain more data (also with the forthcoming 1.5 m photometric telescope of NAO Rozhen) to study the evolution of the colors of the intranight variability of the dwarf nova during the quiescence and outbursts.

3. Conclusions

We report observations of the intranight variability of the dwarf novae DX And and AR And during the period 28 - 31 October 2022. The obsevations are performed quasi-simultaneously in B and V bands with the 50/70 cm Schmidt telescope of the National Astronomical Observatory Rozhen. The results indicate that both stars exhibit intranight variability with amplitude 0.15 mag in B and V bands on a time scale of $\sim$ few hours. We find for the mass donor of DX And absolute V band magnitude $M_V = 6.2 \pm 0.1$ corresponding to spectral type K1V, and for AR And $M_V = 8.5 \pm 0.3$ and spectral type in the range K7V-M0V.

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