

PHOTOMETRY WITH THE NEW 1.5-METER TELESCOPE OF THE ROZHEN OBSERVATORY

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Abstract

The new 1.5-meter telescope (AZ1500) is operating at the National Astronomical Observatory Rozhen, Bulgaria. This paper gives an overview of the telescope and presents a snapshot of the current performance. Science observations are under way, and we give brief highlights from a number of programmes that have been enabled.

Key words: telescopes, instrumentation: photometers, stars: novae, cataclysmic variables, gamma-rays: stars

1. Introduction. The exploration of the space and the nature of celestial bodies, their motion, origin, and evolution are among the most current and pressing topics we face today. This necessitates a continuous process of refining techniques and instruments for observation. We observe and study the cosmos both with ground-based instruments and those deployed on space stations, as part of a global international collaboration. Our National Astronomical Observatory

We dedicate this paper to the memory of Prof. Evgeni Semkov (1961–2024), Corresponding Member of the Bulgarian Academy of Sciences, who was leading the project for the telescope. JM and RKZ acknowledge PID2022-136828NB-C42 grant funded by the Spanish MCIN/AEI/10.13039/501100011033 and “ERDF A way of making Europe”. The telescope is a part of the National Roadmap for Scientific Infrastructure [14], coordinated by the Ministry of Education and Science of Bulgaria.

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Rozhen is equipped with ground-based astronomical instruments designed for observing in the visible light range of the electromagnetic spectrum. The observatory is located on a mountain peak in the central part of the Rhodope Mountains. It is a complex that combines infrastructure and facilities for astronomical observations, scientific work and education.

2. AZ1500 telescope. The AZ1500 telescope made by ASA Astrosysteme GmbH is a 1.5-meter Ritchey–Chrétien telescope equipped with quartz optics that guarantees diffraction-limited performance. The focal length is 9 m, and the focal ratio is $f/6$. Ritchey–Chrétien system is a construction variant that has a hyperbolic primary mirror (in our case with diameter 150 cm) and a hyperbolic secondary mirror (with diameter 52 cm) designed to eliminate optical errors. During the last years, the majority of the large astronomical telescopes are of Ritchey–Chrétien system, e.g. the Hubble Space Telescope, the ESO Very Large Telescope, the Rozhen 2 m telescope. The mounting is Alt-Azimuth, which is a telescope mounting style that operates around a vertical azimuth axis and a horizontal altitude axis, requiring variable rates on both axes to track the celestial objects. These mounts are good for supporting heavy loads. The design of the telescope results in a compact system with a weight of 5500 kg that fits in a dome with diameter 6.0 m. The optical system is designed with two Nasmyth focus positions. First light for the telescope was achieved in the summer of 2023 [1]. For improvement of the telescope pointing and tracking capabilities is created and refined a T-Point model [2]. The model that works well is with 60 stars and provides a pointing accuracy of about 5 arc-seconds.

A new tower was constructed specifically for this telescope on the territory of NAO Rozhen. The tower and its dome were built by the Italian company Gambato Astronomical Building S.r.l. The dome is automated and synchronized with the telescope's pointing. The tower stands on a stable reinforced concrete foundation, weighing over 220 tons (see Fig. 1). The coordinates are $41^{\circ}41'48.4''$ N, $24^{\circ}44'18.4''$ E, altitude 1750 m.



Fig. 1. The new dome and AZ1500 telescope

3. Tracking accuracy. To give an estimation of the telescope guiding we measured the position of a few stars on the CCD during 1 hour continuous observations. The shifts in pixels were transformed into arc-seconds. The results for a few nights are:

28 Mar. 2024	UT21:19-22:19	T CrB	$s_1 = 14.6''$	$s_2 = 9.8''$
28 Mar. 2024	UT22:19-23:20	T CrB	$s_1 = 1.7''$	$s_2 = 1.1''$
15 Apr. 2024	UT01:09-02:09	4U1954+319	$s_1 = 7.7''$	$s_2 = 5.6''$
16 July 2024	UT22:32-23:33	T CrB	$s_1 = 0.9''$	$s_2 = 1.8''$
16 July 2024	UT23:20-00:20	T CrB	$s_1 = 8.9''$	$s_2 = 4.8''$
3 Sep. 2024	UT18:43-19:43	T CrB	$s_1 = 9.9''$	$s_2 = 4.4''$
5 Sep. 2024	UT20:09-21:09	SPICY 85657	$s_1 = 1.5''$	$s_2 = 4.4''$,

where s_1 is the shift along the Right Ascension, s_2 is the shift along the Declination, T CrB is a recurrent nova [3], 4U1954+319 is a symbiotic X-ray binary consisting of neutron star and a red supergiant [4], SPICY 85657 is a young stellar object candidate [5].

It is visible that the average shifts are $s_1 = 6.5$ arcsec hour⁻¹ along the Right Ascension and $s_2 = 4.6$ arcsec hour⁻¹ along the Declination. Removing the largest value, it is equivalent to $\sqrt{s_1^2 + s_2^2} = 6.5 \pm 4.1$ arcsec hour⁻¹. For a seeing of ~ 1 arcsec, a shift with half of the seeing (0.5 arcsec) takes typically 4 minutes. For a single star measurements shifts of about 1–2 arcsec would not make the photometry worse, which means that exposures up to 10 min will provide good results.

4. The accuracy of the photometry. The AZ1500 telescope is equipped with a filter wheel with optical filters in the UBVRI photometric system as well as narrow band filters. UBVRI is a set of well-defined pass-bands in the optical range from 3300 to 8800 Å. Roughly speaking, the B-band covers blue, the V-band covers green, and the R-band covers red. As a representation of the accuracy of the observations in the different bands, we calculated the standard deviation of ten consecutive measurements of ~ 30 stars with different brightness:

$$(1) \quad \sigma = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (m_i - \bar{m})^2},$$

where $m_1, m_2, \dots, m_N$ are the observed magnitudes, $\bar{m}$ is the average value of these observations, and N is the number of observations. We calculated σ for ten exposures in UBVR bands. The results are plotted in Fig. 2. The accuracy of the observations depends on the size of the primary mirror, the efficiency of the optics, filters, CCD detector, etc.

The V band has a mean wavelength $\lambda_{\text{mean}} = 5510$ Å and effective width $W_{\text{eff}} = 890$ Å. The brightness in V-band is referred to as the apparent visual magnitude. As can be seen in Fig. 2 for 1 s exposure time in V band we have good photometry for stars in the range $11.5 < V < 15$ mag. The increase of the

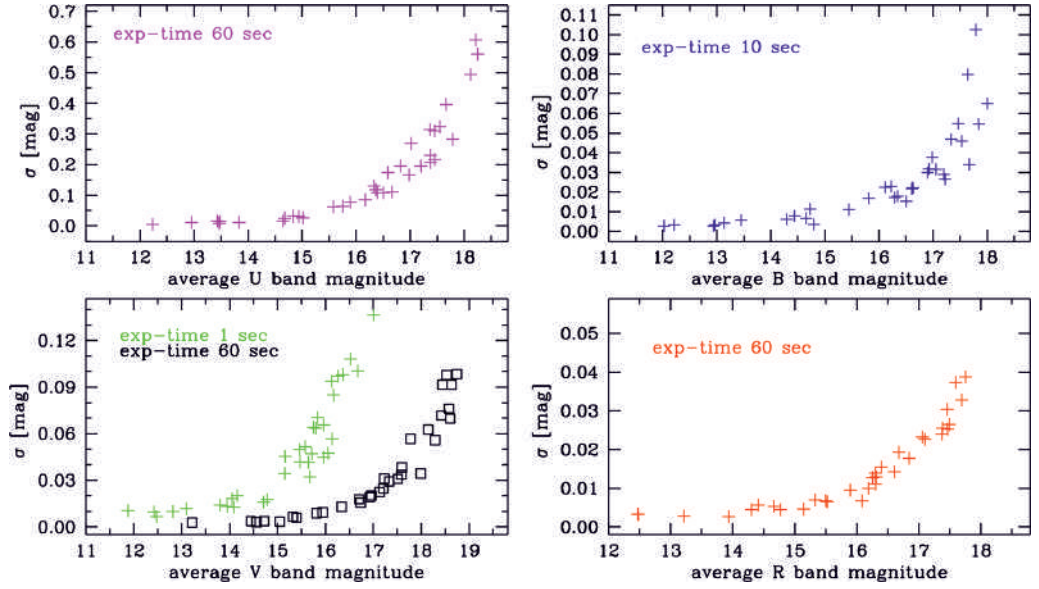


Fig. 2. Standard deviation (σ) versus the average magnitude in U, B, V, and R bands. σ represents the errors of the photometry. The colours are: U – magenta, B – blue, V – green (exposure 1 s), black (exposure 60 s), R – red. The exposure time (exp-time) is marked on each panel. For more details see Sect. 4

exposure to 60 s, provides good photometry (accuracy ± 0.02 mag) for stars in the range $13 < m_V < 17$ mag.

For U-band ($\lambda_{\text{mean}} = 3605 \text{ \AA}$, $W_{\text{eff}} = 640 \text{ \AA}$) for a 60 s exposure, measurements with photometric errors ± 0.05 mag can be done for stars in the range $12 \leq m_U \leq 15.5$. For B-band ($\lambda_{\text{mean}} = 4410 \text{ \AA}$, width $960 \text{ \AA}$) for a 10 s exposure photometry with errors ± 0.05 mag can be performed in the range $12 \leq m_B \leq 17.5$. For R-band ($\lambda_{\text{mean}} = 6580 \text{ \AA}$, width $1590 \text{ \AA}$) for a 60 s exposure photometry with accuracy ± 0.02 mag can be done for stars in the range $12 \leq m_B \leq 17$.

5. Science programmes with the telescope. 5.1. Accretion onto white dwarfs. UVB photometry of the recurrent nova T Coronae Borealis (NOVA CrB 1866, NOVA CrB 1946) has already been published in [6], where the observations with AZ1500 revealed a remarkable reddening of the system and decrease of the brightness and the temperature of the accretion disc in October 2023.

Here we present two light curves of the flickering behaviour obtained with AZ1500 telescope. Journal of observations is presented in Table 1 and the light curves are plotted in Fig. 3. Using the recipe of [7] we estimate for the maximum, dereddened $U - B_0$ colour of the flickering source -0.98 and -0.49 for 2024-04-14 and 2024-08-23, respectively. Using the method of [8], we estimate for the flickering source average dereddened $U - B_0$ colour -0.901 and -0.567 for 2024-04-14 and 2024-08-23, respectively. These colours correspond to temperature of the flickering source $T = 13675 \text{ K}$ and $T = 8085 \text{ K}$. The result indicates that when

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Observations of the intra-night variability of the recurrent nova T CrB. The first column presents the date (in format YYYY-MM-DD) and UT of start and end of the run (in format HH:MM). The second column presents the number of the exposures and the exposure time. The other columns present minimum, maximum and average magnitude, standard deviation, amplitude and the typical observational error

Date UT	Band		min [mag]	max [mag]	mean [mag]	stdev [mag]	Ampl. [mag]	merr [mag]
2024-04-14 20:41-20:52	U	90 × 60 s	11.977	12.309	12.1391	0.079	0.332	0.005
	B	90 × 10 s	11.547	11.633	11.5885	0.020	0.086	0.002
	V	90 × 2 s	—	—	10.1581	—	—	0.010
2024-08-23 18:20-20:14	U	80 × 60 s	11.354	11.699	11.5804	0.069	0.345	0.010
	B	80 × 5 s	11.119	11.293	11.2403	0.033	0.174	0.005
	V	80 × 1 s	—	—	9.9189	—	—	0.010

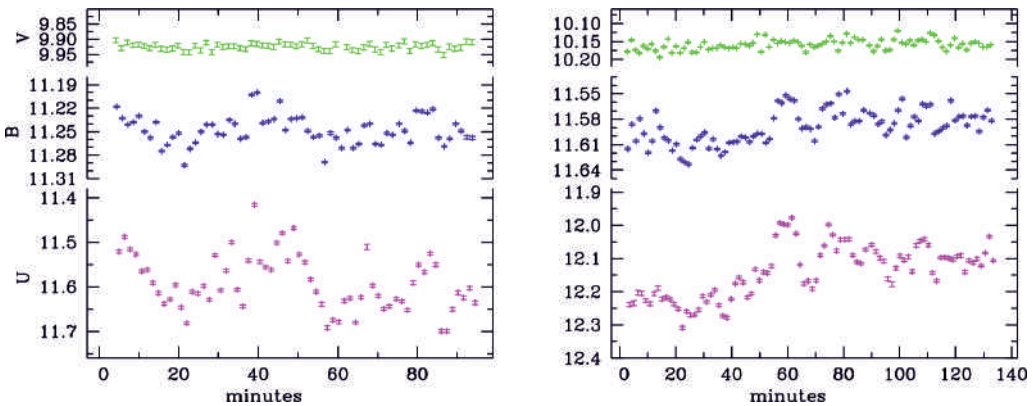


Fig. 3. Flickering of T CrB in U, B, V bands observed with the 1.5-meter telescope. The amplitude of the variability is of about 0.3 mag in *U*-band and 0.1 mag in *B*-band

the brightness increases, the flickering source becomes redder and its temperature decreases. A more detailed analysis will be given in a forthcoming paper.

5.2. Optical counterparts of high and very high energy sources.

Telescopes in the 1 to 2 meter class can play a very important support work in the golden era of highly sensitive gamma-ray observatories. The currently existing facilities, ranging from the *Fermi* gamma-ray space telescope to the growing family of Imaging Atmospheric Cherenkov Telescopes (IACTs), such as MAGIC, HESS, HAWC or LHAASO, will soon see their performances complemented, or surpassed, by upcoming projects such as the Cherenkov Telescope Array Observatory (CTAO). Many new unidentified gamma-ray sources, both transient or persistent, will certainly be discovered in a mid-term future. In this context, we will be facing the challenge of pinpointing their optical and/or near infrared counterparts out of the many objects often found inside the typically $\sim 0.1^\circ$ gamma-ray error boxes of IACTs. This task requires not only good astrometric

but also excellent photometric capabilities, as the gamma-ray emission responsible is often betrayed by related counterpart variability in other wavelength domains (including the optical window.)

In August 2024, the Rozhen 1.5-meter telescope participated in a campaign to acquire multi-epoch photometry of the high-mass X-ray binary candidate IRAS 18293-0941, originally identified by [9]. This was a good occasion to mimic the observational circumstances outlined in the previous paragraph. Although no short-term variability was detected, the performance of the telescope turned out to be remarkable. The target was immediately outstanding in combined VRI images owing to its extremely high reddening, thus rendering it the most peculiar object in the region. Both position and magnitude could be easily determined. Plate solutions based on a few hundreds of Gaia DR3 stars in the field of view were carried out using the IRAF software package, in particular with its `daofind`, `ccxymatch` and `ccmap` tasks. An excellent residual root mean square, amounting to 0.01 to 0.02 arc-second, was achieved both in right ascension and declination for reference stars in all filters (all of this despite a moderate 1.5 arc-second seeing). An accurate measurement of 0.1734 ± 0.0001 arc-second pixel⁻¹ also resulted for the CCD plate scale of the Rozhen telescope. Concerning photometry, a quick zero-point determination was conducted using a dozen reference stars in the field of view whose magnitudes were retrieved from the AAVSO Photometric All Sky Survey (and transformed from the Sloan to the Johnson–Cousins system when needed). The corresponding values were found to be $z_V = 5.5 \pm 0.1$ mag, $z_R = 4.29 \pm 0.05$ mag, and $z_I = 1.6 \pm 0.1$ mag, yielding $V = 21.9 \pm 0.3$ mag, $R = 16.4 \pm 0.1$ mag, and $I = 12.6 \pm 0.1$ mag for the target IRAS source. Comparison with numbers in the literature strengthens the suitability of the AZ1500 telescope for this kind of future research.

5.3. Quasars, Novae, Star formation. Observations of Active Galactic Nuclei, quasars [10], and blazars [11] with different timescales optical variability, in narrow and broad photometric bands are a critical aspect of modern astrophysics, providing insights into some of the most energetic phenomena in the Universe. The precise observations will be used to apply reverberation mapping and study the structures and physical processes around the super-massive black hole ($10^6 - 10^9 M_\odot$) at the centre.

The classical novae in the galaxy M31 have a characteristic strong and broad H-alpha emission line. With fast and precise observations in H-alpha filter, novae candidates in M31 can be confirmed or rejected.

The AZ1500 telescope also collects observations of young star clusters [12], by which star formation, Herbig’s Ae/Be and T Tauri stars, collimated jets, nebulous filaments, embedded infrared sources, and other young objects can be studied.

In the future a low-resolution spectrograph might be installed in the second Nasmyth focus for observations of transient objects, novae, supernovae, tidal disruption events [13], relativistic explosions, etc.

Conclusions. The new 1.5-meter telescope (AZ1500) is in operation at the National Astronomical Observatory Rozhen, Bulgaria. Its design and performance are suitable for precise observations of various astrophysical objects – from proto-stars in the star-forming regions, accreting white dwarfs, nova outbursts to the blazars and the quasars.

REFERENCES

- [1] MINEV M., N. PETROV, E. SEMKOV (2024) Technical performance and first light of the new 1.5-meter telescope at the National Astronomical Observatory Rozhen, Contributions of the Astronomical Observatory Skalnat Pleso, **54**(2), 15–21.
- [2] WALLACE P. T. (2002) A rigorous algorithm for telescope pointing, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, **4848**, 125.
- [3] PLANQUART L., A. JORISSEN, H. VAN WINCKEL (2025) Resolving the mass transfer in the symbiotic recurrent nova T Coronae Borealis, Astron. Astrophys., **694**, A85.
- [4] BOZZO E., C. FERRIGNO, L. OSKINOVA, L. DUCCI (2022) Accretion of a clumped wind from a red supergiant donor on to a magnetar is suggested by the analysis of the XMM-Newton and NuSTAR observations of the X-ray binary 3A1954+319, MNRAS, **510**, 4645.
- [5] KUHN M. A., R. S. DE SOUZA, A. KRONE-MARTINS et al. (2021) SPICY: the Spitzer/IRAC candidate YSO catalog for the inner galactic midplane, Astrophys. J. Suppl. Ser., **254**, 33.
- [6] ZAMANOV R., S. BOEVA, G. Y. LATEV et al. (2023) Accretion in the recurrent nova T CrB: Linking the superactive state to the predicted outburst, Astron. Astrophys., **680**, L18.
- [7] NELSON T., K. MUKAI, M. ORIO et al. (2011) X-Ray and ultraviolet emission from the recurrent Nova RS Ophiuchi in quiescence: Signatures of accretion and shocked gas, Astrophys. J., **737**, 7.
- [8] BRUCH A. (1992) Flickering in cataclysmic variables: its properties and origins, Astron. Astrophys., **266**, 237.
- [9] MOTCH C., P. WARWICK, M. S. CROPPER et al. (2010) The X-ray source content of the XMM-Newton Galactic plane survey, Astron. Astrophys., **523**, A92.
- [10] OVCHAROV E. P., P. L. NEDIALKOV, A. T. VALCHEVA et al. (2008) Optical monitoring of the $z = 4.40$ quasar Q2203+292, MNRAS, **386**, 819.
- [11] BACHEV R., T. TRIPATHI, A. C. GUPTA et al. (2023) Intra-night optical flux and polarization variability of BL Lacertae during its 2020–2021 high state, MNRAS, **522**, 3018.
- [12] IBRYAMOV S., G. ZIDAROVA, E. SEMKOV, S. PENEVA (2023) Study of the long-term BVRI photometric variability of eight PMS stars in the young open cluster Trumpler 37, Res. Astron. Astrophys., **23**, 085006.
- [13] JANKOVIC T., C. BONNEROT, A. GOMBOC (2024) Spin-induced offset stream self-crossing shocks in tidal disruption events, MNRAS, **529**, 673.
- [14] BONEV T. (2011) National roadmap for research infrastructure, Bulgarian Astron. J., **17**, 3.

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