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Technical performance and first light of the new 1.5-meter telescope at the National Astronomical Observatory Rozhen

M. Minev, N. Petrov and E. Semkov

Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Science, 72 Tsarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria (E-mail: msminev13@gmail.com)

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Abstract. A new 1.5-meter Ritchey-Chretien telescope has been inaugurated as part of the observational equipment of the Institute of Astronomy and the National Astronomical Observatory Rozhen (IANAO) at the Bulgarian Academy of Science (BAS). The telescope, designed with advanced optical and mechanical components, aims to enhance observational capabilities from NAO Rozhen. Here, we present the initial tests and setup procedures conducted for the new telescope and we describe the assembly process, alignment procedures, and calibration techniques implemented to ensure optimal performance. The tests involved nighttime observations and preliminary results highlight the successful alignment of the telescope's optics, the stability of its tracking mechanism, and the establishment of an efficient data acquisition workflow. The findings from these initial tests provide valuable insights into the telescope's capabilities and help us to set up a fully robotic telescope for observational campaigns and scientific research. This new observational instrument will primarily perform photometric and astrometric tasks. However, there is also the possibility of conducting low-dispersion spectral observations.

Key words: telescopes – instrumentation: miscellaneous – site testing

1. Introduction

In the middle of the last century, there was significant global interest in astronomy, both among scientists and the general population. Bulgaria was no exception to this trend, and there was a growing appreciation for this scientific discipline in the country. This led to the construction of numerous public observatories with planetariums throughout Bulgaria. Additionally, important decisions were made in the country that laid the groundwork for the development of modern astronomical observatories. On March 13, 1981, the Bulgarian National Astronomical Observatory (NAO) Rozhen was officially opened. It was the final result in the long sequence of dreams, ideas, projects, decisions, and actions of many people and institutions which placed Bulgaria among the modern nations possessing their own resources to investigate the Cosmos (Petrov et al., 2018). NAO Rozhen is the main observatory of the Institute of Astronomy, BAS. From the beginning, the observatory has featured several optical telescopes for photometric and spectral observations in the visible part of the electromagnetic spectrum. The primary instrument is the 2-meter RCC telescope, complemented by the 50/70 cm Schmidt telescope and the 60 cm Cassegrain telescope, all produced by the Carl Zeiss factories in Jena. Since 2005 NAO Rozhen has also had a 15 cm Lyot coronagraph with Ha filter, designed for observations of prominences on the solar limb. In 2021, this telescope was replaced by a 30 cm chromospheric telescope for observing and researching active formations on the solar disk (Tsvetkov & Petrov, 2020).

In addition to its strictly scientific observational and research activities, the National Astronomical Observatory Rozhen has, in the past decade, provided opportunities for collaborative work with amateur astronomers from both Bulgaria and abroad. The observatory grounds smaller optical telescopes with remote access capabilities for observations. An excellent example of such collaborative work is the IRIDA observatory, which includes two separate telescopes for night observations (https://www.irida-observatory.org/). The results of this joint effort have led to numerous scientific publications in reputable journals (Popov & Petrov (2022) and Kjurkchieva et al. (2018)).

NAO Rozhen is continually evolving, striving for improvement by incorporating new light detectors and technologies. This commitment to progress led to the realization and operation of a new telescope for observations. In the summer of 2023, the observatory achieved first light with its new 1.5-meter Alt-Azimuth telescope. This telescope allows remote control access or can execute fully robotic observational programs. All the tests and adjustments described in this work are made in remote control mode but our goal is to use fully robotic mode when everything adjusted.

2. Specifications and science programs of the new telescope

The AZ1500 is a 1.5 m f/6 Ritchey-Chrétien Alt-Az telescope equipped with quartz optics from ASA (Astro Systeme Austria) GmbH that guarantees diffraction-limited performance and best micro-roughness values with higher contrast and less obstruction[1]. The optical system is designed with two Nasmyth focus positions (configurable up to four) with an image field of 200 mm or 1.27°. This design results in a more compact system with a weight of only 5.5 tons that fits perfectly in a 6 m diameter dome. All drives are direct drives and they are equipped with high-resolution absolute encoders. To improve the accuracy of a telescope's pointing and tracking capabilities first we had to create and refine a T-Point model (Wallace, 1994). The best model with 60 points brings us good results with a pointing accuracy of less than $5''$ RMS (<60 pixels) and a tracking accuracy of $0.07''$ RMS/min.

[1] https://www.astrosysteme.com/products/asa-az1500/

The telescope is equipped with a Moravian C3-61000 Pro camera with a back-illuminated Sony IMX455 CMOS sensor, offering very low dark current, full-well capacity over 50 ke$^-$ and quantum efficiency of about 90%. The sensor format is 9576×6388 pixels (36×24 mm) with a square pixel size of 3.76 μm. With a corresponding optical system that results in an image scale of 0.086$''$/pixel and a field of view 13.75$'$×9.17$'$.

The telescopes at NAO Rozhen conduct a wide range of astronomical observations (photometric and spectral) on various celestial objects from the night sky, as well as research in the field of heliophysics and space weather (Tsvetkov (2020); Myshyakov & Tsvetkov (2020) and Bogomolov et al. (2018)). Objects observed from the night sky include small bodies from the Solar System, primarily asteroids and comets (Borisov et al. (2023) and Bebekovska et al. (2023)). Objects from our galaxy include young stars and star-forming regions (Ibryamov et al., 2023), binary and symbiotic stars (Zamanov et al. (2022) and Stoyanov et al. (2020)), supernovae remnants (SNR) (Vučetić et al. (2023) and Vučetić et al. (2019)); star clusters and exoplanets. Additionally, extragalactic objects such as galaxies and quasars are observed (Bachev et al. (2023) and Agarwal et al. (2021)). The new telescope will complement these observations and enhance efficiency in terms of observational time. This undoubtedly provides greater opportunities for new collaborative observations by astronomers in Bulgaria and the potential for new projects with international participation. In addition, due to the fast pointing and robotic mode, the telescope can join international networks for transient observations, such as supernova explosions, gravitational microlensing events, gamma-ray burst (GRB) afterglows, and gravitational wave events follow-ups. Currently, only photometric observations will be conducted, but we plan to install a low-dispersion spectrograph in a few years to significantly expand the scientific capabilities.

3. Photometry tests

We performed the first photometry tests on globular cluster M92 (NGC6341). It is one of the Stetson targets with standard stars[2]. During a good photometric night with seeing ∼0.7$''$, we obtained 3×3 min exposures in Johnson-Cousinns photometric BVR filters. For data reduction (dark current subtraction and flat fielding normalization) and aperture photometry, we used standard procedures in IRAF[3] (Image Reduction and Analysis Facility). Images in each filter were combined median. The results of photometry in the R filter show a perfect linear

[2]This research used the Canadian Advanced Network For Astronomy Research (CANFAR) operated in partnership with the Canadian Astronomy Data Centre and The Digital Research Alliance of Canada with support from the National Research Council of Canada the Canadian Space Agency, CANARIE and the Canadian Foundation for Innovation.

[3]IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy under a cooperative agreement with the National Science Foundation.

trend between instrumental and Stetson standard magnitudes for the whole range of magnitudes with constant value $R_{\text{Stetson}} - R_{\text{inst}} = 3.994 \pm 0.004$ mag (Fig.1, left). The photometric error for $R < 17$ mag is about $R_{\text{err}} \approx 3$ mmag, shown on the right panel of Fig.1. Radial flux variation in the field of view was not found. We also construct a color-magnitude diagram for M92 to compare the results with others in the literature and the results are indistinguishable down to 22 mag (Fig.2).

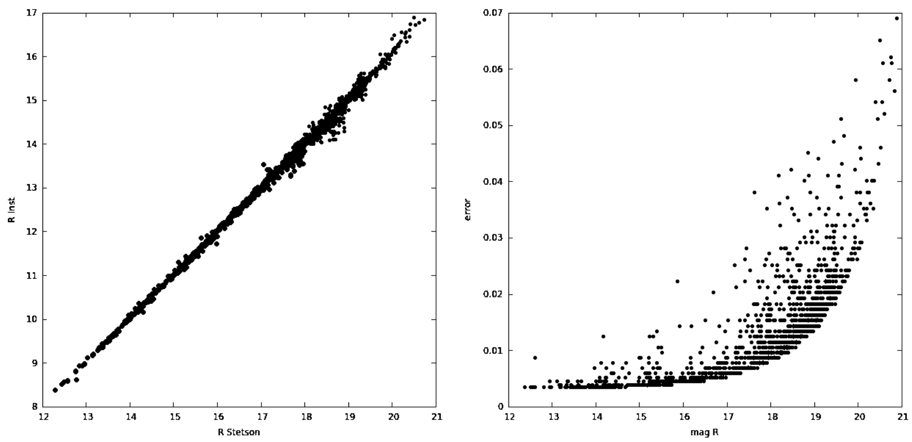

Figure 1. Photometry of a few thousand stars in the field of M92 cluster. On the left panel are shown instrumental versus Stetson standard magnitudes and photometric error on the right panel.

4. Conclusion

Nearly half a century after opening the doors of our NAO Rozhen, we now have another new, modern optical telescope for night observations. The initial observations and results demonstrate the telescope's precise performance. The AZ1500 has a fast pointing speed (up to 6°/sec). After creating a pointing model, we achieved a pointing deviation of less than 5″, which is up to 60 pixels of the currently used digital camera. Under favorable meteorological conditions, our new telescope achieved a resolution of 0.4″.

Photometric evaluations were conducted on star clusters (such as M92 presented here), galaxies, variable stars, and exoplanet transits. The results are entirely consistent with our expectations for accuracy and are scientifically justified. The initial results from the new telescope serve as the basis for presentation at scientific forums and as publications in scientific journals.

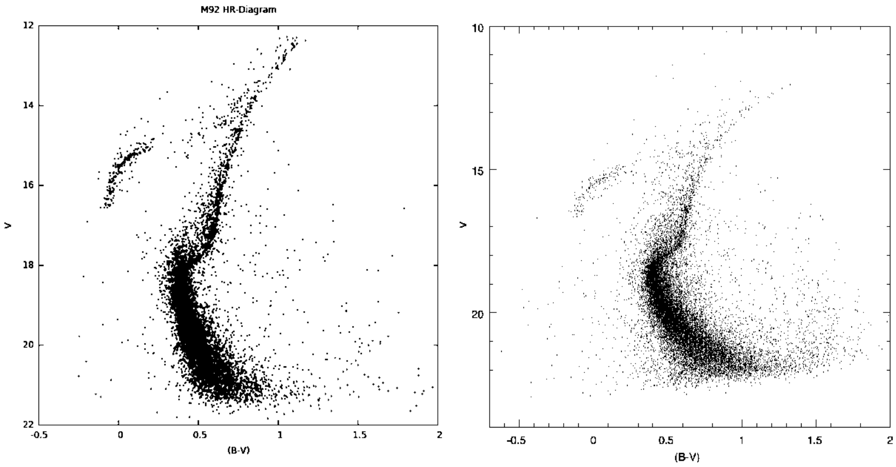

Figure 2. Colour-magnitude diagram for M92 – comparison between our photometry (left) and photometry from Ruelas-Mayorga & Sánchez (2008) (right).

Figure 3. M16 – Pillars of Creation in Ha filter. Stack of 15 images with 5 min exposure.

Automated observing programs with the new telescope are in progress. We believe that this can enhance our observational efficiency.

One of the first images taken with the AZ1500 telescope is shown in Fig.3.

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