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OAUJ-CDK500: A NEW KRAKÓW ROBOTIC TELESCOPE

S. Zola[1], G. Stachowski[1], S. Kurowski[1], T. Kundera[1], W. Waniak[1], D. E. Reichart[2], V. Kouprianov[2], J. B. Haislip[2], Ł. Wyrzykowski[3], and P. J. Mikołajczyk[3,4]

RESUMEN

Describimos el pequeño telescopio óptico más nuevo de los pertenecientes al Observatorio Astronómico de la Universidad Jagellónica. Este telescopio está actualmente instalado en una cúpula Zeiss en el observatorio de Cracovia (Polonia). Damos detalles de la configuración del hardware, así como del software, lo que le permite funcionar de forma autónoma como telescopio asociado dentro de la Red de Telescopios Robóticos Skynet.

ABSTRACT

We describe the newest small optical telescope belonging to the Astronomical Observatory of the Jagiellonian University. This telescope is currently installed in a Zeiss dome at the observatory site in Kraków, Poland. We give details of the hardware configuration as well as the software which enables it to work autonomously as a partner telescope within the Skynet Robotic Telescope Network. The telescope working in this configuration is an efficient tool supporting the scientific, educational and outreach projects.

Key Words: telescopes — instrumentation: detectors — methods: observational — techniques: photometric

1. INTRODUCTION

Until nearly the end of the 20th century, observations with ground-based optical telescopes required the presence of an on-site observer, who decided if the weather conditions were suitable and who had to manually open the dome and point and operate the telescope. Subsequent progress in computing power and networking made remote observing possible, but still required continuous monitoring by the observer and a night assistant to be present on-site.

The decreasing costs and improving capabilities of computers, sensors and microcontrollers around the 1990s led to the development of hardware and software capable of controlling telescopes working autonomously from a target list. The first individual robotic telescopes were soon followed by the creation of robotic telescope networks, eventually spanning the entire globe (Woźniak 2013).

Several of these networks were initially created to facilitate rapid follow-up observations of the optical afterglows of γ-ray bursts (GRBs). Examples include the Bootes network created in 1998, with global coverage of seven telescopes completed in 2023 (Castro-Tirado et al. 1999; Castro-Tirado 2023), and the Skynet Robotic Telescope Network (Zola et al. 2021) created in 2004. The latter currently consists of a few dozen optical telescopes located on five continents and one radiotelescope (Greenbank–20) which has also been integrated into the network. A review of the ground based GRB follow-up facilities was published recently by Tsevtkova et al. (2022).

Until 2019, the Astronomical Observatory of the Jagiellonian University in Kraków, Poland, had three small telescopes used for photometry, all of which were originally manually operated. An attempt was made to automate the 1970s-era 50 cm Cassegrain telescope, however full automation turned out to not be economically viable and the telescope still requires remote operation by the observer and some manual setup. Therefore, the decision was made to purchase a more modern 50 cm telescope which could be used both for automated scientific observations and for teaching students at the astronomy department.

The new telescope, built by PlaneWave, arrived at the end of 2019 and was fully commissioned and collecting data at the Astronomical Observatory site in the suburbs of Kraków in early 2020.

In the next section of this paper we describe the hardware of the new telescope, followed by a description of the Skynet software on the client computer side. Next we present the performance of this telescope under typical Central European weather conditions.

[1]Astronomical Observatory of the Jagiellonian University, ul. Orla 171, PL 30-244 Kraków, Poland, (szola@oa.uj.edu.pl).
[2]University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, NC 27599, USA.
[3]Astronomical Observatory, University of Warsaw, Al. Ujazdowskie 4, 00-478 Warszawa, Poland.
[4]Astronomical Institute, University of Wrocław, Kopernika 11, 51-622 Wrocław, Poland.

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Fig. 1. The dome of the OAUJ-CDK500 telescope.

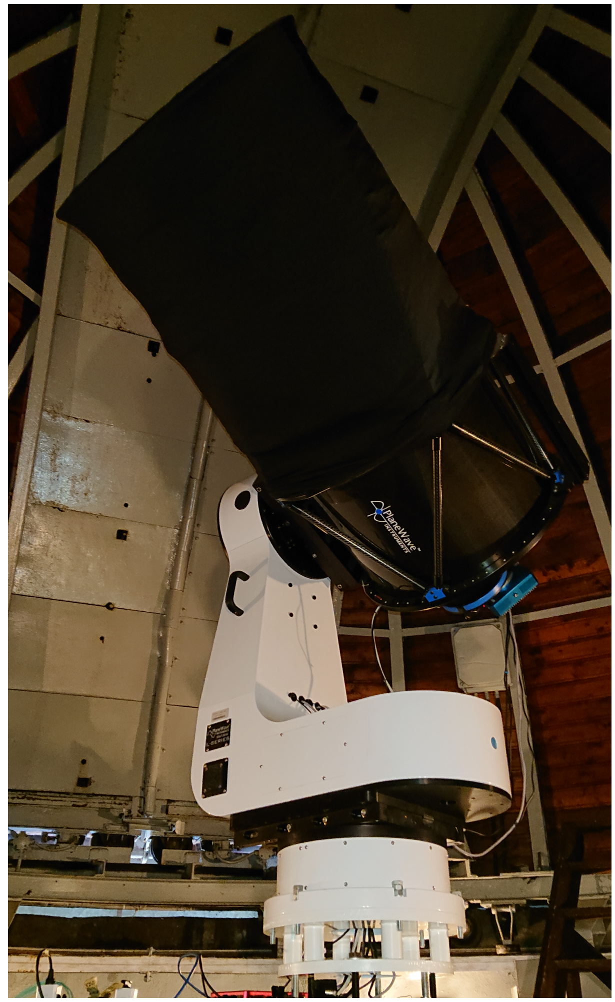

Fig. 2. The OAUJ-CDK500 telescope inside the Zeiss dome.

2. OBSERVATORY HARDWARE

2.1. *Weather Sensors*

Two crucial pieces of hardware must be present for a fully autonomous telescope to operate safely and be aware of changing weather conditions: a cloud sensor and a weather station providing rainfall, wind, temperature and humidity measurements. Our observatory is equipped with the AAG cloud sensor [5] and a Davis WeatherPro station [6] which provide continuous monitoring of weather status at the site. Current weather conditions and the dome position can be visually checked with a SBIG Allsky-340C camera mounted next to the dome and a nearby security camera.

2.2. *Telescope and Dome Hardware*

The telescope is a 20 inch (50.8 cm) diameter f/6.8 Corrected Dall-Kirkham (CDK), manufactured by PlaneWave[7]. The CDK optical design consists of an ellipsoidal primary mirror, spherical secondary and additional lenses to correct off-axis aberrations. The telescope works on the PlaneWave L-500 direct-drive mount, ensuring high pointing precision and fast slewing speeds up to 50° per second. The alt-azimuth type mount necessitates a field derotator, which in our case is integrated with the focuser (PlaneWave IRF90). Due to the low expansion coefficient of the carbon-fiber truss tube, the focus position only needs to be corrected a few times a year when the temperature changes very significantly.

The telescope is installed in the 6-meter Zeiss dome formerly housing an astrograph, which has been automated with a Technical Innovations Digital Dome Works (DDW) system[8]. This consists of a set of sensors and relays for both azimuthal rotation and shutter control. The DDW software interface includes some safety features, such as the control software querying the DDW processor every few

[5] https://eu.lunaticoastro.com/product/aag-cloudwatcher-cloud-detector
[6] https://www.davisinstruments.com/
[7] https://planewave.com/product/cdk500-telescope-system/
[8] https://www.homedome.com/

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minutes and automatically parking and closing the dome if the connection to the computer is lost.

2.3. *CCD and Filters*

Two CCD cameras are currently configured for, and can be installed on, the OAUJ-CDK500 telescope: an Apogee Alta U47 and Apogee Alta F42. Both cameras have CCD chips with 13 μm pixels, however the Alta U47 has a 1k×1k chip, while the chip of the Alta F42 is twice as large, providing a field view of $27.7' \times 27.7'$. A Finger Lakes Instrumentation (FLI) seven-position filter wheel is mounted in front of the camera. It accomodates 3 filters in the Strömgren system (Sv, Sb and Sy) and 4 wide band (B, V, R, I) ones manufactured according to Bessell's specification (Bessell 1990, 2005).

3. SOFTWARE

The Skynet Robotic Telescope Network consists of two parts: the server side which is hosted at the University of North Carolina (UNC) at Chapel Hill (USA), and software running on a data gathering computer at each site. The former was described in more detail by Zola et al. (2021). The server is responsible for submission of observation requests, their prioritization and scheduling, and dispatch to one or more telescopes for execution. After the observations are completed, the client computers transfer images to the server for calibration. Once calibration is completed, the images are ready for download by the user in both JPEG and FITS formats. The Skynet client computer software for the OAUJ-CDK500 runs under the Windows 10 operating system on a PrimaLuce Labs Eagle computer. In the following subsections, we describe the software modules needed to operate the telescope in robotic mode within the Skynet Network.

3.1. *Weather control programs*

To enable fully autonomous and unsupervised operation, OAUJ-CDK500 uses weather monitoring software to retrieve information from the sensors described in section 2.1. The central part of this software is WeatherMan, a custom weather data collection service created by the Skynet team at UNC. It talks to the AAG cloud sensor driver via the Component Object Model (COM) server built into the AAG cloud sensor driver and to the Davis weather station via the freely available Cumulus software, using its ability to log current sensor readings to a text file. WeatherMan has configurable thresholds and wait times for all available weather parameters, most important of which are humidity, precipitation, wind speed and sky temperature. This data is analyzed to determine whether the conditions are safe; failure to retrieve data from a particular sensor is also considered an unsafe situation. WeatherMan communicates this safe/unsafe decision to the telescope control software described below by means of a custom HTTP-based application programming interface (API).

3.2. *Telescope control software*

The current Skynet telescope software architecture is built around the ASCOM ecosystem[9]. All hardware components, including the mount, dome, imaging camera, focuser, filter wheel, and field derotator, are controlled either directly via their ASCOM drivers or through MaxIm DL (from Diffraction Limited) using its COM API. Terminator is a custom Skynet telescope client LabView application which is responsible for integrating all other software components and communicating with the Skynet servers at UNC. It 1) reports the current state of the telescope to Skynet, including the weather safety flag and the status of all telescope subsystems, 2) receives calibration and science observation requests from Skynet, 3) commands the hardware components via ASCOM and MaxIm DL to perform their respective tasks running the job from opening the dome, through pointing the telescope, to obtaining the images from the CCD camera, and 4) transfers the resulting images to the UNC data storage servers. Terminator is responsible for coordinating the work of all hardware components and for maintaining the safety of the observatory by closing the dome and suspending observations if the weather becomes unsafe. As an additional safety measure, telescope administrators have the ability to flag the telescope as "locked" via the Skynet website to prevent the dome from opening and all observations (excluding bias and dark calibration tasks which are performed with a closed dome) from running in the (unlikely) event that the weather is wrongly reported as safe by WeatherMan, or there are other issues that Terminator cannot detect such as mechanical damage to the dome.

From the users' perspective, observations within the Skynet network are submitted via a web-based interface[10]. This is suitable for users with all levels of experience, from school pupils, through students to professional astronomers. The interface allows for target objects to be chosen via map, name search or by directly entering coordinates. Restrictions such as altitude or lunar phase and separation

[9] https://www.ascom-standards.org
[10] https://skynet.unc.edu

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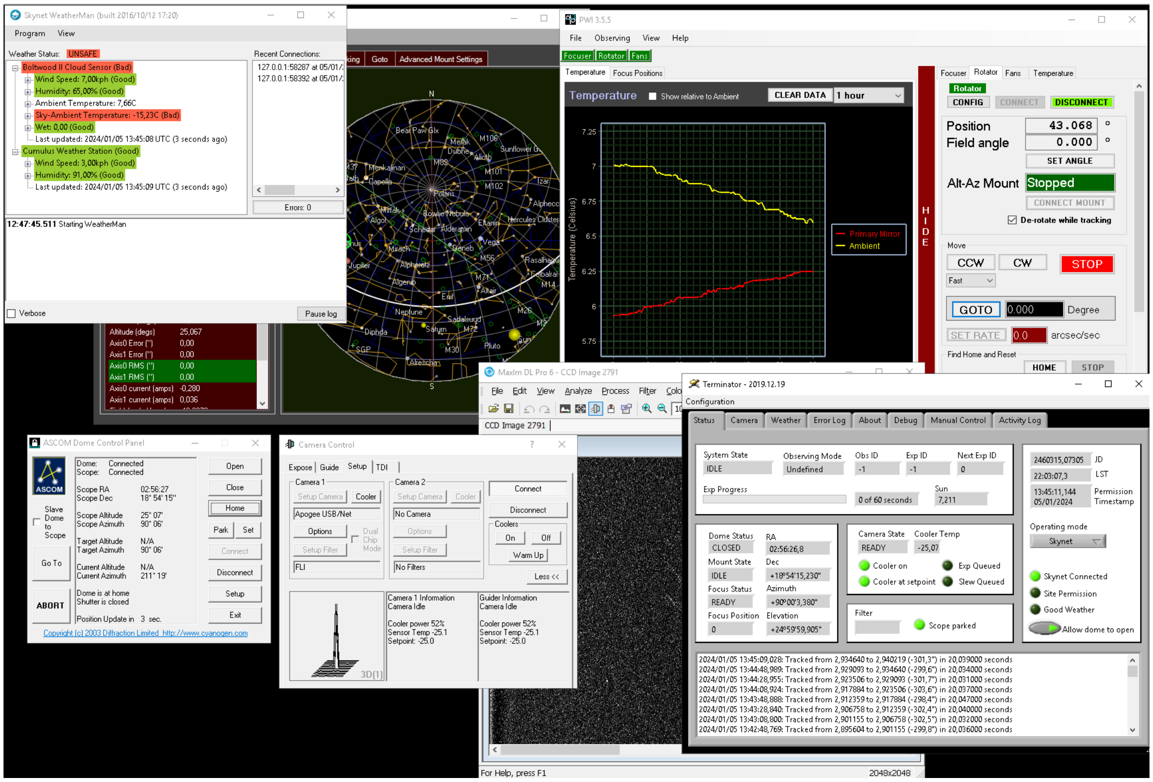

Fig. 3. Programs running on the data gathering computer.

can be set, and for exposure sequences and intervals (both within one night and over multiple nights) to be defined. Filters can be set for each exposure (depending on their availability on the given telescope). The interface can easily and conveniently be used to set up observations ranging from 'pretty pictures' to carefully-planned long-duration photometric studies. Once submitted the process is fully automated. The Skynet server will allocate time on the certain telescope or a subset of telescopes until the desired observation sequence is completed. Users of the Skynet network do not have to take bias, dark and flatfield calibration images themselves, as this task is automatically scheduled by the Skynet server and image calibration is performed automatically. When the observations are done, the calibrated images appear in the user's account ready for downloading, typically within a few days but sometimes in almost real time, depending on weather and number of jobs submitted.

4. TELESCOPE PERFORMANCE AND EFFICIENCY

Since commissioning at the beginning of 2020, the telescope has operated in the robotic mode continuously with just few small glitches, most of which were due to mechanical issues with the old dome. It has collected several thousand images and was used for a combination of scientific programs, teaching and outreach. The scientific programs mostly consisted of long term monitoring of extragalactic targets, as these are most suitable for unpredictable weather conditions.

Here we present data taken during 2023 of the supernova SN2023ixf, discovered in the nearby galaxy Messier 101 in May (Perley et al. 2023). Soon after its discovery, a long observing run request was submitted through Skynet and data were collected over the entire summer vacation without any human supervision. In early October all the obtained images were tentatively reduced using the BHTOM project led by L. Wyrzykowski[11] (Zieliński at al. 2019, 2020). The result is shown in Fig. 4.

5. CONCLUSIONS

After several attempts at automating the Zeiss 50 cm Cassegrain telescope, originally installed in 1970, we were only able to make it partially remotely operable. Full automation turned out to be extremely costly and therefore, after being granted

[11]https://bh-tom2.astrolabs.pl

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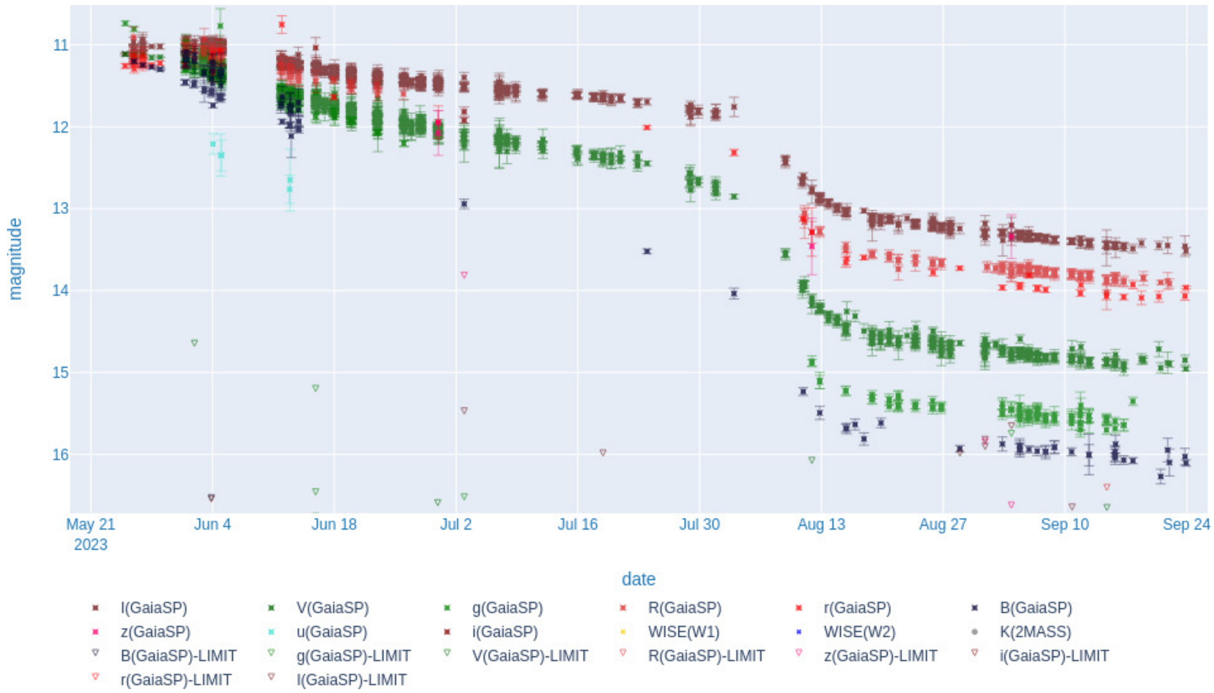

Fig. 4. Photometric observations of the supernova SN2023ixf in M101. Data were taken in four filters. The vast majority of the points represent observations taken with the OAUJ-CDK500 robotic telescope.

funds, it was instead decided to buy a new automatic telescope. A PlaneWave CDK-500 telescope and mount system was chosen and arrived at the site in Kraków at the end of 2019. We considered several possibilities for operating it autonomously, and eventually joined the Skynet Robotic Telescope Network as a partner telescope. Using the mature Skynet software we were able to start observing in the robotic mode from early 2020. This proved extremely fortuitous as it allowed students and pupils to carry on observations from their homes during the subsequent COVID-19 pandemic lockdown, using the convenient and intuitive Skynet web interface. Long-term photometric monitoring programs could also be continued without interruption.

The ability to observe autonomously whenever the weather was clear turned out to be very efficient in our prevailing weather patterns. The telescope often automatically opened, collected data and closed during short windows of good weather which appeared during the night, when a manually-operated telescope would have remained closed and missed the opportunity. Compared to fully manual operation, we estimate the gain in efficiency was twofold, and especially suitable for very long term brightness monitoring of targets for which just a short series of images is needed every clear night. This can be seen in the case of the observations of the recent supernova SN2023ixf (see Fig. 4), with many data points being obtained despite the absence of on-site observing staff during the summer vacation.

In summary, since installation in 2020, the OAUJ CDK500 operating within the Skynet network has proven itself to be a reliable and efficient tool supporting the scientific, educational and outreach missions of the Jagiellonian University Astronomical Observatory.

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