Contrib. Astron. Obs. Skalnaté Pleso **49**, 484 – 487, (2019)

Science with Global Astrophysical Telescope System

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Received: November 27, 2018; Accepted: January 24, 2019

Abstract. We present the Global Astrophysical Telescope System project arranged by the Astronomical Observatory Institute of Adam Mickiewicz University in Poznań (Poland) and exemplary results obtained from it, including asteroids, eclipsing binary stars, and artificial satellites.

Key words: telescopes – spectroscopy – photometry – stars – asteroids

1. About GATS

The Global Astrophysical Telescope System (GATS[1]) operates as a global network of robotic telescopes and consists of two telescopes: PST1 (the Poznan Spectroscopic Telescope) (Baranowski et al., 2009) located near Poznań (Poland), and RBT/PST2 (the Roman Baranowski Telescope) in Winer Observatory in Arizona (USA). Both telescopes are equipped with fibre-fed echelle spectrographs, which are based on a modified MUSICOS design with a rotating carousel removed and only one fixed prism being used (Baudrand & Bohm, 1992) of resolution R$\sim$35000 (PST1) and R$\sim$40000 (RBT/PST2). PST1 consists of: a Binary 2 x 0.5 m Newtonian telescope, a low noise back-illuminated 2k x 2k Andor DZ 436 CCD camera and it is equipped with an equatorial, robotic mount capable to work in a remotely controlled mode. RBT/PST2 telescope is: 0.7 m f/6.6 Planewave CDK700 on an alt-az robotic direct-drive mount (Corrected Dall-Kirkham, dual Nasmyth focus), a spectroscopic CCD camera Andor iKon-L 936 back-illuminated, and a photometric CCD camera Andor iXon3 back-illuminated.

GATS main research topics are: eclipsing binary stars, asteroseismology of pulsating stars, stellar rotation and dynamical evolution in binary eclipsing stars, cataclysmic variables, photometric observations of Main Belt asteroids and Near Earth Objects, artificial satellites and space debris, and "targets of opportunity" (Gamma Ray Burst or Gaia alerts). Telescopes also participate in research programs of the BRITE consortium.

[1] www.astro.amu.edu.pl/GATS

1.1. Asteroids – example of (737) Arequipa

RBT/PST2 participates in a project of photometric asteroid studies to find their rotation periods, spins, and 3D shapes. As one of the nodes of the network consisting of 20 stations worldwide, it participates in round-the-globe campaigns to observe slowly rotating main belt asteroids (Marciniak et al., 2018). In summer months, when most asteroids are on the southern sky hemisphere, it helps to reach low-declination targets. Fig. 1.A shows a lightcurve of asteroid Arequipa, where the observations from RBT/PST2 helped to find the rotation period of 7.0259±0.0001 hours.

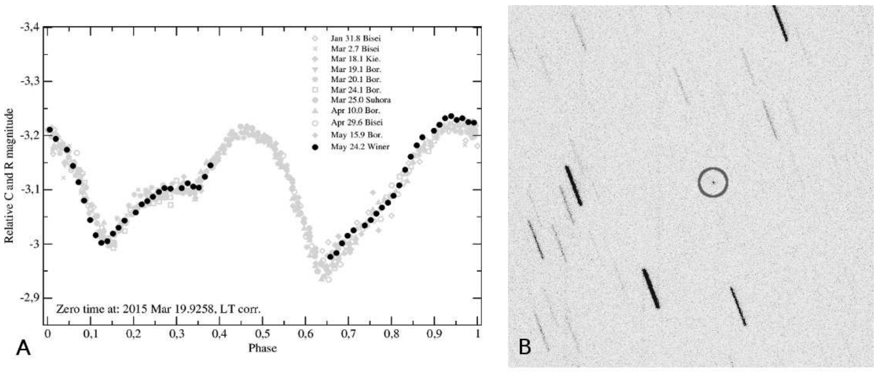

Figure 1. A. Composite lightcurve of (737) Arequipa observed in 2015 during 1 night with RBT/PST2. **B**. UKube-1 satellite tracking - RBT/PST2, exp. time 0.05 s, observed brightness ∼14 mag.

1.2. Eclipsing binary star - example of BD-00 2862 (component A)

Spectroscopic PST1 observations of the BD-00 2862 system show that it is a triple star, consisting of an eclipsing binary (component A), and a visual third object (component B) (Dimitrov et al., 2018). Spectra of BD-00 2862 (component A) are dominated by the lines of the main component, thus we treat them in analysis as single-lined spectra. We used twelve selected spectra with the best signal-to-noise ratio to create an averaged spectrum. To obtain atmospheric parameters (effective temperature, $T_{\rm eff}$ (from Balmer lines); surface gravity, $\log g$; metallicity [M/H]; and projected rotational velocity, $v \sin i$) the spectrum synthesis method implemented in the iSpec code was used (Blanco-Cuaresma et al., 2014). Fig. 2 shows the comparison of the average spectrum (Mg b I region) of BD-00 2862 (component A), and the calculated synthetic spectrum.

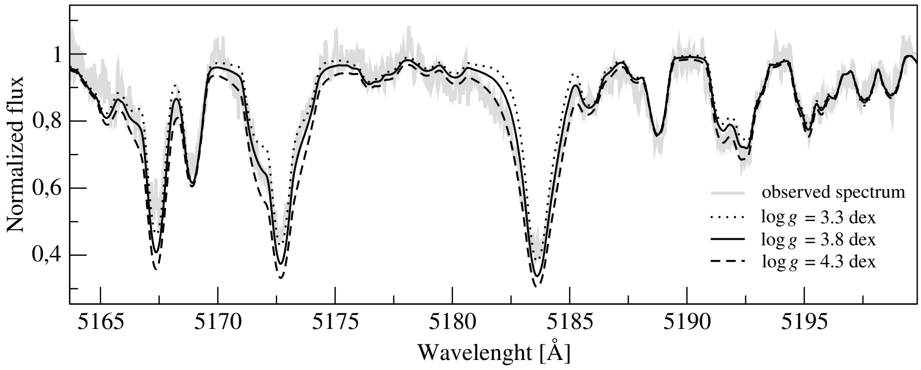

Figure 2. The combined spectrum (gray) with the fitted spectrum (black, different line style corresponds to various $\log g$ within the error limits) for Mg b I line regions for parameters: $T_{\rm eff} = 5600 \pm 400\,{\rm K}$, $\log g = 3.8 \pm 0.5$, [M/H]$= -0.30 \pm 0.20$, $v \sin i = 30 \pm 4\,{\rm km\,s^{-1}}$.

1.3. Satellites and space debris

Both GATS telescopes are capable of observing artificial Earth satellites. PST1 is mainly a survey telescope with its 1×1 deg field of view. RBT/PST2 is mainly a tracking (follow up) telescope. RBT/PST2 is equipped with a sensitive Andor EMCCD camera, and can detect all TLE (Two-Line Elements) catalog objects, even the smallest cubesats ($10 \times 10 \times 10\,{\rm cm}^3$) on low Earth orbits (LEO) (Kamiński et al., 2017). It can follow all satellites down to about 14.5 mag (with 0.05 sec exposure time) moving on the sky with proper motion up to 2° per sec (Fig. 1.B.). Both telescopes are equipped with our custom designed GPS based timing devices, allowing us to measure shutter opening and closing time with 1ms accuracy. We are involved in several ESA and European Space Surveillance and Tracking (EU SST) consortium projects. Based on gathered experience we are currently building an innovative cluster of 5 satellite surveillance and tracking telescopes - Poznań SST Telescope 3 (PST3). Its first light is expected in 2019.

Acknowledgements. This work has been supported by the Polish National Science Centre through grants no. 2014/13/B/ST9/00902 and 2014/13/D/ST9/01818.

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