

# First observations with the 25 cm telescope of the Shumen Astronomical Observatory

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**Abstract.** The first observations with the 25 cm telescope of the Shumen Astronomical Observatory led to the following conclusions: (a) Intra-night observations of variable stars with an amplitude larger than 0.1 mag are possible down to 14 mag with an acceptable quality with this setup; (b) The equipment is suitable for observations of bright extended objects with sizes up to 30 arcmin (planets, comets, clusters, nebulae, galaxies) with resolution 0.88 arcsec/pix; (c) The guiding of telescope is very good which makes the equipment appropriate for prolonged patrols; (d) The observations with the 25 cm are already fully remote-controlled; (e) The determined transformation coefficients allow transfer from instrumental to standard photometric system  $BVR_cI_c$  and realization of differential photometry.

**Key words:** Telescopes techniques: photometric – stars: individual (V568 Peg)

## Introduction

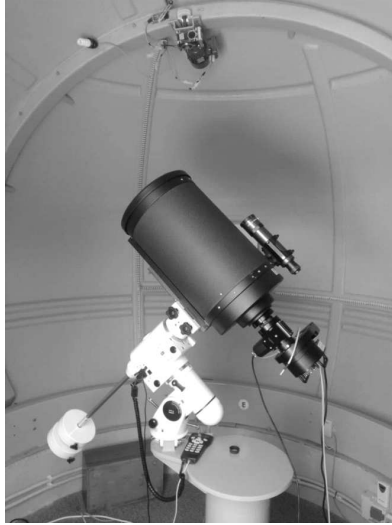
The invention of remote controlled telescopes at the end of the 20-th century increased the role of small telescopes in the observational astronomy and efficiency of usage of observational time (Iliev 2014).

The small telescopes have an invaluable role in the discovery of variable stars of different type by ground-based wide-field surveys: ASAS (Pojmanski 1997), ROTSE (Akerlof et al. 2005), SuperWASP (Pollacco et al. 2006), CRTS (Drake et al. 2014), etc. The detailed investigation of these stars is also appropriate task for small telescopes. The main goal of this paper is to demonstrate the possibilities of the 25 cm telescope of Shumen Astronomical Observatory (ShAO) for observations of objects of different type, mainly variable stars.

## 1. Equipment

The 25 cm Schmidt-Cassegrain telescope *MEADE 10 LX80 SC* (focal length 2540 mm) is driven by mounting *Sky-Watcher NEQ6 PRO* fixed on a special column. It is designed to provide not only stability but also free movement of the telescope in all directions. The optical equipment is situated inside a 3 m automated telescope dome (Fig. 1) in the ShAO, whose coordinates are: longitude  $26^{\circ}55'23''$  E, latitude  $+43^{\circ}15'2''$ , altitude 493 m.

The telescope is equipped with a detector *SBIG ST-10XME* ( $2184 \times 1472$  pixels,  $6.8\mu\text{m}/\text{pixel}$ ) and a SBIG CFW10 filter wheel with circle 1.25-inch Johnson-Cousins mounted filters  $BVR_cI_c$ . This telescope-detector system provided field of view (FoV) of  $20 \times 14$  arcmin with resolution 0.55



**Fig. 1.** The 25 cm telescope inside the 3 m dome

arcsec/pix. The FoV was increased by focal reducer *TS Optics* f/6.3 to  $32 \times 22$  arcmin with resolution 0.88 arcsec/pix. The remote focusing is performed by focuser *Optec Temperature Compensating Focuser*.

Generator *ProTech P12000* and *ATG* system (Fig. 2) can provide electricity supply of the equipment during 5 hours in case of accidental events.



**Fig. 2.** Generator *ProTech P12000* and *ATG* system

The components of the whole equipment were connected to a computer controlled power switch *Expert Power Control 8210* (Fig. 3). A remote-control videocamera inside the 3 m dome allows us to see the telescope and shutter positions.

Cloud detector *AAG CloudWatcher* provides full information of sky conditions: (i) Its light sensor allows to estimate the sky glow; (ii) An infrared sensor measures the outside temperature while an electronic thermometer measures the internal temperature. Both data determine the existence of clouds; (iii) A variable capacitor determines the existence of rain.



**Fig. 3.** Computer controlled power switch *Expert Power Control 8210*

## 2. Software and remote control

The remote-control observations by the 25 cm telescope require the following software: (i) *C2A* realizes telescope remote control; (ii) *FocusMax V4* allows remote focusing; (iii) *MaxIm DL Version 6* controls the CCD camera, filter wheel and focuser; (iv) *CCDAutoPilot 5.0 Professional* connects and manages the software and drivers in a single complex; (v) *ScopeDome* drives the 3 m dome.

The *Sky-Watcher NEQ6 PRO* mounting is designed for manual control of the telescope by a special console. Such a mode requires an alignment of the telescope every night before observations by 2-3 stars. Our mounting does not accept time information from a computer but only from the console that caused a huge problem for the realization of remote-control observations. After many tests, we managed to overcome the difficulties by using *Astrometry.net*. Currently the 25 cm telescope is remote-controlled and further we present results of the first observations.

## 3. Images of extended objects

The investigation of extended objects requires adequate background estimation. The image reduction techniques aim to diminish the impact of both instrumental and non-instrumental offsets, which may lead to erroneous flux estimation (Popowicz & Smolka 2015). The instrumental sources of background variations are related to the CCD detectors and the most of them are mitigated recently by novel CCD structures, proper CCD calibration and strong cooling.

The main source of non-instrumental background variations is the sky glow, which is dependent on the altitude above the horizon and the observed wavelength range. It originates from the local light pollution and is time-dependent. The contribution of the sky glow is bigger in the infrared. There are techniques to subtract the background bias frames in real-time (Bertero et al. 2000; Fiorucci et al. 2003) but the scattered light in the instrument from nearby very bright object is still difficult to remove.

Figures 4–8 illustrate the image quality of extended objects (planets, comets, nebulae, etc.) observed by our 25 cm telescope and different detectors. They reveal that the city lights have not noticeable negative contribution to the image quality. Surprisingly, the lights of the moving cars alongside the observatory also do not hinder the image quality considerably. Hence, the 25 cm telescope might be used for study of extended objects with size up to 30 arcmin (planets, comets, clusters, nebulae, galaxies) with resolution 0.88 arcsec/pix. Images of objects with a larger angular size might be obtained by mosaic observations.



**Fig. 4.** Jupiter with three Galilean satellites (Io, Ganymede and Europa), exposure 1 sec, 2017 April 10, detector *NexImage 5*



**Fig. 5.** Transit of Mercury, 2016 May 9, detector *NexImage 5*



**Fig. 6.** Planetary nebula M57, 2018 Aug 3, detector *SBIG ST-10XME*, exposure 180 s, R filter



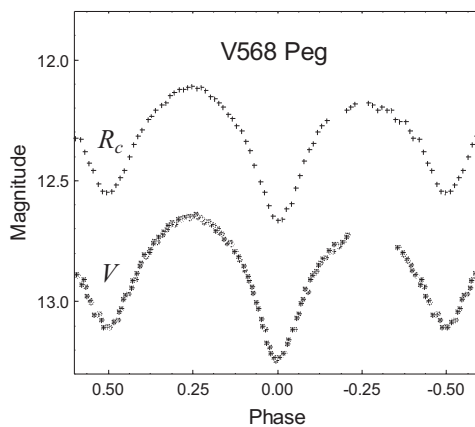
**Fig. 7.** The Moon, 2018 Aug 30, detector *SBIG ST-10XME*, exposure 0.1 s, B filter



**Fig. 8.** The comet 21P/Giacobini-Zinner, 2018 Aug 30, detector *SBIG ST-10XME*, exposure 30 s, R filter

#### 4. Investigation of stellar variability

We chose to test the possibilities of the 25 cm telescope and its equipment for study of stellar variability by observations of the W UMa star V568 Peg. The reasons for this choice were: (i) The target has been observed earlier also by small telescope (Kjurkchieva et al. 2015) which gives an opportunity for comparison of the results; (ii) The target V magnitude is 13.5 which was the expected highest value, at which our photometric precision would be acceptable; (iii) The short-period of around 6 hrs of the binary was important to obtain observations covering the whole cycle during a night taking into account the very bad atmospheric conditions in the last seasons of 2018.



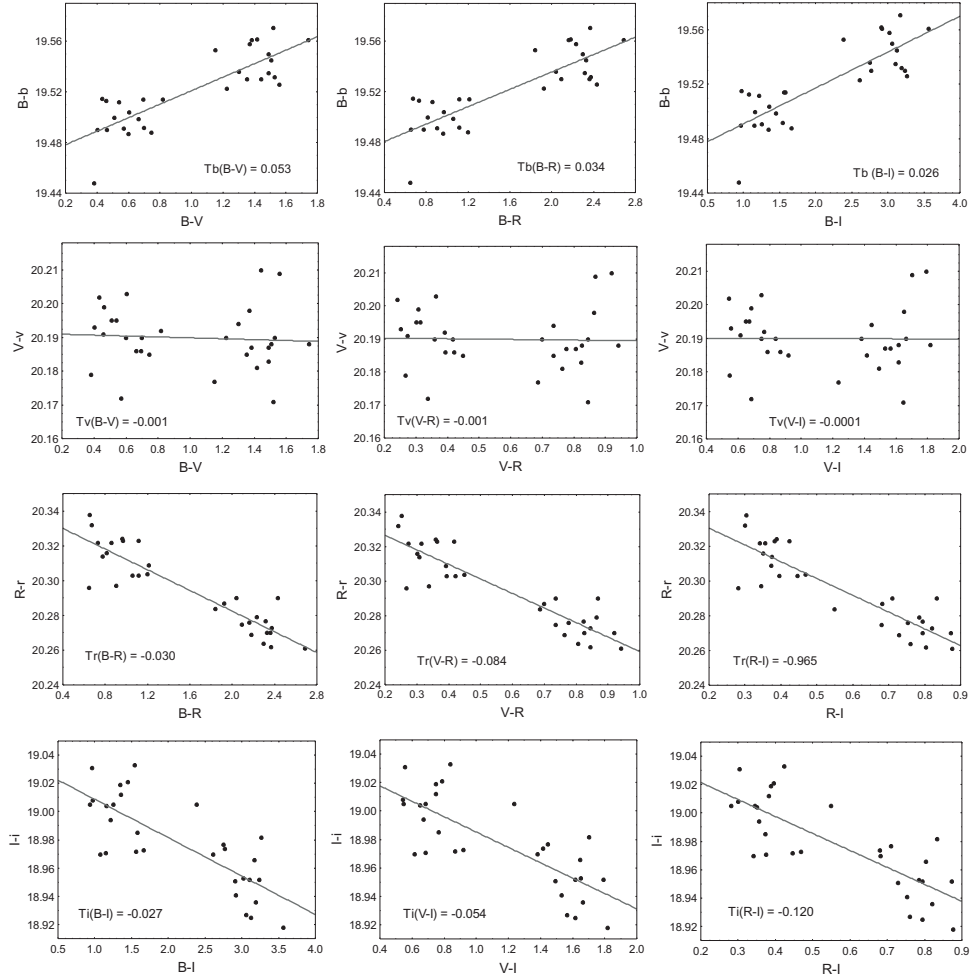
**Fig. 9.** The folded  $V, R_c$  light curves of V568 Peg from 2018 Aug 13 obtained by the 25 cm telescope and CCD detector *SBIG ST-10XME*

V568 Peg was observed on 13 Aug 2018. The atmospheric conditions at the beginning of the night (UT = 19 h) were good: clear sky, temperature 25 C, humidity 50 %. The CCD was cooled to -10 C. There was no wind and Moon (night after new Moon). The exposures in V and R filter were respectively 90 s and 60 s. The initial FWHM of the target images were around 4 pix in V and 5.5 pix in R. After the midnight the target images became considerably better with FWHM up to 2.4 pix in V and 4.5 pix in R. Unfortunately 2 hrs later the outside temperature decreased and humidity rapidly increased. The FWHM of the target images did not change considerably but the signal rapidly decreased. We stopped the observations when the humidity reached 90 %.

It should be pointed out that there was not any need to make corrections in the telescope guiding during the 7-hr observations.

Standard procedure was used for reduction of the photometric data. We performed differential photometry using nearby standard stars. The

obtained folded  $V, R_c$  light curves of V568 Peg are shown in Fig. 9. The average photometric accuracy is 0.029 in both filters.



**Fig. 10.** Diagrams for determination of the first set of transformation coefficients

## 5. Transformation coefficients

The measurements of star brightness need to be transformed from instrumental to standard photometric systems. For this purpose, we followed the procedure given in the CCD Photometry Guide of the American Associ-

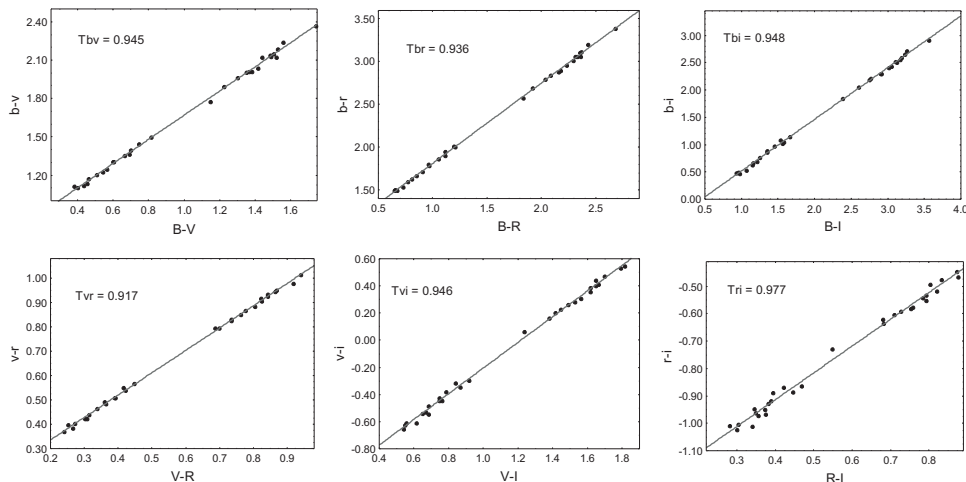


Fig. 11. Diagrams for determination of the second set of transformation coefficients

Table 1. Transformation coefficients

coefficient value		coefficient value		coefficient value	
Tbv	0.945	Tb(B-V)	0.053	Tr(B-R)	-0.030
Tbr	0.936	Tb(B-R)	0.034	Tr(V-R)	-0.084
Tbi	0.948	Tb(B-I)	0.026	Tr(R-I)	-0.965
Tvr	0.917	Tv(B-V)	-0.001	Ti(B-I)	-0.027
Tvi	0.946	Tv(V-R)	-0.001	Ti(V-I)	-0.054
Tri	0.977	Tv(V-I)	-0.0001	Ti(R-I)	-0.120

ation of Variable Star Observers (<https://www.aavso.org/ccd-photometry-guide>).

The determination of the transformation coefficients requires observing as many as possible standard stars with a wide range of colors. In order to obtain the transformation coefficients of our equipment we carried out observations of the open cluster NGC 7790 in  $BVR_cI_c$  filters with exposures of 60 s on 27 Sept 2018. The atmospheric conditions were excellent. We measured 30 stars in the field and the results are shown in Figs. 10–11 and Table 1.

The transformation coefficients allow to perform differential photometry if the calibrated magnitudes of suitable comparison stars in the field have been previously determined. Then only the color and magnitude differences between the target and the comparison stars are important because all they have the same airmass.

Future observations will allow to assess the stability of the transformation coefficients of our equipment on long time scales.



## Conclusions

The first observations with the 25 cm telescope of Shumen Astronomical Observatory led to the following conclusions.

(1) The equipment is suitable for observations of bright extended objects with sizes up to 30 arcmin (planets, comets, clusters, nebulae, galaxies) with resolution 0.88 arcsec/pix.

(2) Intra-night observations of variable stars with an amplitude larger than 0.1 mag are possible down to 14 mag with an acceptable quality with this setup.

(3) The guiding of telescope is very good which makes the equipment appropriate for prolonged patrols.

(4) The sky glow doesn't have any noticeable negative contribution to the image quality.

(5) The observations with the 25 cm are already fully remote-controlled.

The determined transformation coefficients allow transfer from instrumental to standard photometric system  $BVR_cI_c$  and realization of differential photometry.

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