Baltic Astronomy, vol. 12, 555–560, 2003.

HIGH-PRECISION UBVRI PHOTOMETRY WITH A NEW 50 CM TELESCOPE AT STARÁ LESNÁ

T. Pribulla and D. Chochol
Astronomical Institute of the Slovak Academy of Sciences, 059 60 Tatranská Lomnica, Slovak Republic

Received November 5, 2003

Abstract. The paper presents the experience, observations and results obtained with the new 50 cm photometric telescope at the Stará Lesná Observatory equipped with an SBIG ST10MXE CCD camera. The telescope time is devoted to observations of variable stars of various types. Prospects for further improvement of the instrument, observational and reduction techniques are discussed.

Key words: telescopes – instrumentation: photometric, CCD cameras – stars: variables – methods: observational

1. INTRODUCTION

Photoelectric photometry at the Astronomical Institute of the SAS has a rather long tradition. The first observations were performed using the Newton focus of the 60 cm telescope at the Skalnaté Pleso Observatory in early 60-ties.

Until 2002 two telescopes were used for stellar photometry. The first is a 60/750 cm Cassegrain telescope at Skalnaté Pleso (49 13 18N, 20 14 42E, altitude 1783 m) equipped with a single-channel photometer with a Hamamatsu R4457P photomultiplier. The photometric observations are performed using the standard *UBVR* filters. The second instrument is a 60/750 cm Cassegrain telescope at Stará Lesná (49 09 10N, 20 17 28E, altitude 810 m) equipped with a single-channel photometer with an EMI 9789QB photomultiplier and using standard *UBV* filters. The photometer can operate in a fast mode: integration times of 0.1, 0.01 and 0.001 s can be selected. Both telescopes are guided using high-sensitivity night-vision cameras.

2. A NEW 50 CM TELESCOPE

In the autumn 2002 a new 50/250 cm Newtonian telescope was installed at the Stará Lesná site (close to the older 60 cm telescope). The telescope is equipped with a SBIG ST10 MXE CCD camera (KAF 3200ME chip 2174×1536 pixels, full-well capacity 77.000e$^-$, gain 1.3 e$^-$/ADU, 6.8 μm square pixels, USB interface). In spite of the front-lit chip the camera has quite good quantum efficiency: 40% in U, 65% in B, over 80% in V and R, 30% in I. Two filter sets: the standard *UBVRI* Johnson system and the medium-band Strömgren *uvby* system are available. Narrow-band H_α, H_β and [O III] filters are planned.

The first tests of the camera and the telescope performance started in February 2003. We found that the limiting magnitude of the instrument on clear night with 2–3" seeing is $V = 20$ for 3 minute integration time. The seeing at the observatory site is usually rather poor – usually 2–6". Simultaneous photoelectric observations of the test stars with the other telescope show that our CCD B and V magnitudes are close to the international photometric system: $\Delta < 0.03$ mag for solar-type stars. There are, however, problems with standardization of the U passband which according to the present observations reflects $\lambda \approx 3900$ Å. Extensive observations of M 67 (planned since beginning of November 2003) are necessary to determine the transformation coefficients to the standard *UBVRI* system (Mendoza 1967).

CCD frames are reduced using procedures written by the first author under the MIDAS environment. For each frame the appropriate dark, bias and flat are chosen automatically appropriate for the given integration time, temperature of the chip and filter. The instrumental magnitudes are determined by aperture photometry (PSF fitting is under preparation). The diameters of the apertures are determined according to the actual seeing. The precision of the resulting magnitudes depends mainly on the brightness of the object, telescope aperture, seeing and the sky-background level. During good sky conditions a typical precision of 0.003–0.004 mag can be attained for a $V = 10$ mag star. The output of the reduction produces instrumental magnitudes for as many as 50 stars. The coordinates of the measured stars relative to the first one, chosen to be a relatively bright and isolated object, are stored to the MIDAS table. The differential magnitudes are presently left in the instrumental system. Also no extinction correction is applied to the instrumental magnitudes. In spite of large amounts of data (thanks to fast

USB interface and electronics), all frames are archived on CDs. The interactive www form to search the frames is being prepared. The catalog of all observations (updated on a monthly basis) is available on-line at `http://www.ta3.sk/ pribulla/journalccd.txt`.

In spite of mostly good experience with the instrument, several problems are still being solved: (1) sky flat fields are negatively influenced by scattered light inside the telescope tube (presently rectified by a 2D polynomial fitting), (2) unreliable positioning of the filters in the CFW8 filter wheel, (3) problems with the connection of the camera to the computer USB port.

3. OBSERVATIONAL PROGRAM

The observational program on the telescope is a continuation of the long-term campaigns and programs at the institute. The objects of interest are: (1) active, spotted RS CVn (preferably short period systems like SV Cam, XY UMa, CG Cyg, WY Cnc, etc.) and W UMa stars (e.g., V857 Her, DU Boo, EQ Tau, YY CrB, EF Dra, AH Tau, etc.), (2) symbiotic stars (e.g., Z And, AX Per, BF Cyg, AG Dra, QW Sge, etc.) and symbiotic novae (V1016 Cyg, V1329 Cyg, HM Sge, PU Vul), (3) classical novae (V723 Cas and V475 Sct) and dwarf novae (e.g., SS Cyg), (4) chemically peculiar Ap and Am stars, and (5) open and globular clusters (aimed at the search of variable stars). In future we plan to extend the observational program to an extrasolar planet search. This will require a higher degree of automatizing of the telescope and camera.

4. NEW MULTICOLOR CCD LIGHT CURVES

Eclipsing active binaries of the RS CVn or W UMa types require high-precision multi-color observations to determine reliably their temperatures and the positions of surface spots. Precision better than 0.003 mag is usually needed to perform eclipse mapping (see, e.g., Lister et al. 2001). Since most RS CVn systems change their maximum brightness due to presence of spots and magnetic activity, it is necessary to determine the brightness of all historically used comparison stars. In this case, the accurate transformation of the observations to the international photometric system is important. In Figure 1 we present B and I light curves of XY UMa ($V \approx 9.6$, sp. type G5 V + K2 V, $P = 0.47899$ days), probably the most active member of the short-period RS CVn group (see, e.g., Pribulla et al. 2001).

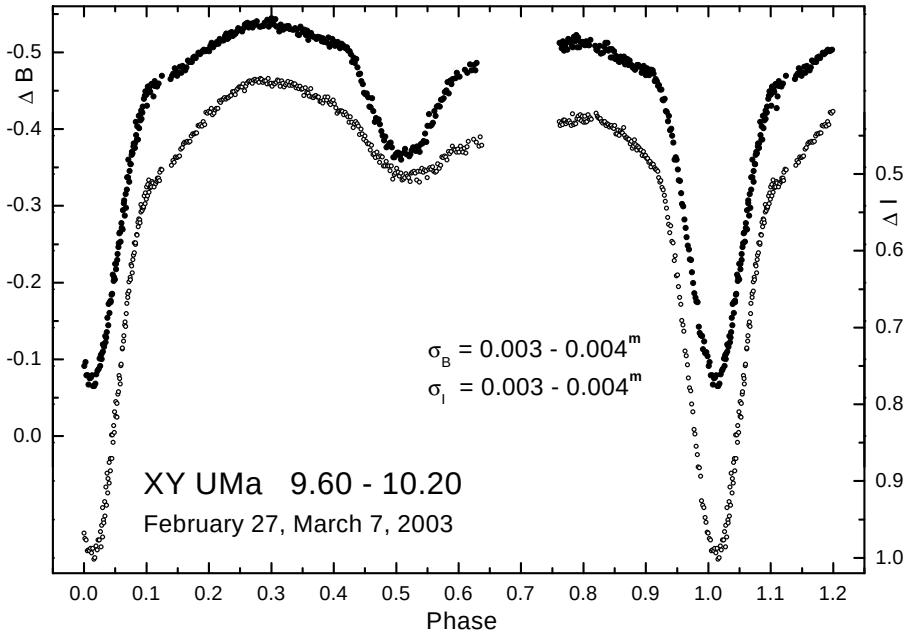

Fig. 1. *B* and *I* CCD light curves of the short-period active binary XY UMa.

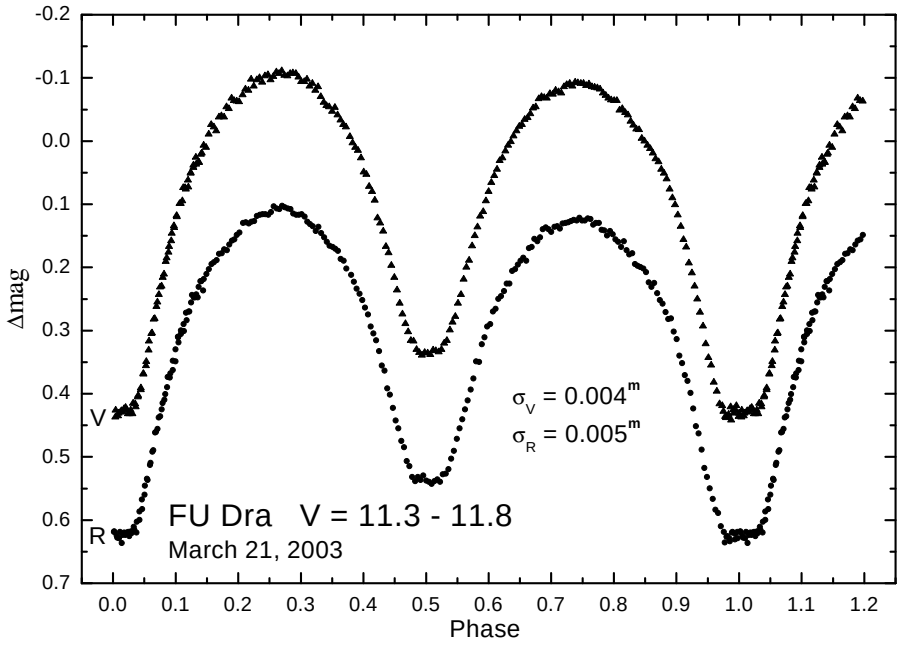

Fig. 2. *V* and *R* CCD light curves of the contact binary FU Dra.

In the case of contact systems we performed first ground-based photometric observations of V921 Her and HH UMa (Pribulla et al. 2003) discovered by *Hipparcos*. The contact binaries are easy to observe (orbital periods 0.22–1 days) but, due to the low information content of the photometry, it is hard to interpret them without spectroscopy. The B and V differential light curves of the contact binary FU Dra ($V_{\max} = 10.55$, sp. type F8 V, $P = 0.30672$ days) are presented in Figure 2.

Symbiotic stars, classical and dwarf novae require long-term multicolor monitoring. While U and B passbands reflect the radiation of the hot component and the accretion disk (flare and outburst activity), R and I observations reflect the cool component – in some symbiotic novae it is a Mira variable. Due to strong emission lines in their spectra the transformation of magnitudes to the standard system is very difficult and unreliable (Skopal 2003). This complicates proper combining of the data from different observatories or telescopes.

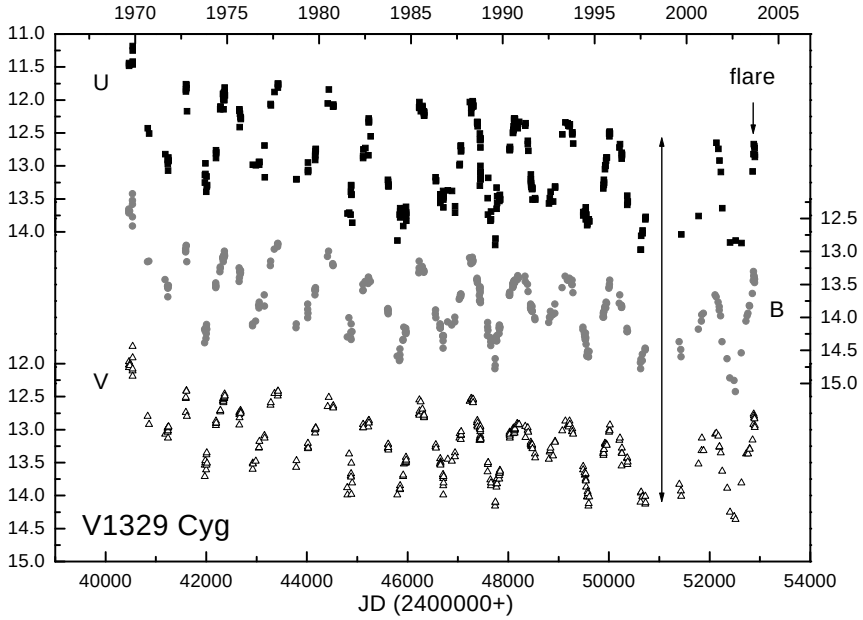

Fig. 3. *UBV* light curves of the symbiotic nova V1329 Cyg.

As an example, *UBV* observations of the symbiotic nova V1329 Cyg (ephemeris $\mathrm{JD}_{\min} = 2\,446\,771 + 956.5 \times E$, Chochol et al. 1999) are presented in Figure 3. Photoelectric and CCD observations were carried out at the Stará Lesná Observatory after JD 2 451 000 (de-

noted by the arrow). The most recent CCD observations recorded a flare best visible in the B passband ($\Delta B \approx 0.4$ mag), which occurred about 110 days before the expected maximum of the wave-like variation of brightness.

5. PROSPECTS FOR FURTHER IMPROVEMENTS

Since there is a long-term shortage of observers at Stará Lesná Observatory, the most important goal is automatizing of the observations. Unfortunately, the present Zeiss 7 mount requires substantial changes in the declination axis to enable full robotizing. Automatizing of the dome movement according to the hour angle, declination and east-west position of the telescope is under preparation. The extension of the present program to variable-star or extrasolar planet searches will require step motors on both axes to scan larger portions of sky (FOV of the camera is $13.8' \times 21.5'$). The remote control of the telescope and camera from the main observational building (via fast LAN connection) will be available in 2004. The camera will require additional cooling during summer months, when the night temperature at the site reaches 15–20°C.

And finally... a larger telescope is needed. The present 5 m dome would house a rapid (1:3.5–1:4) 80 cm Newtonian.

ACKNOWLEDGMENTS. This work was supported by Science and Technology Assistance Agency under the contract No. APVT-20-014402.

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