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Astrophysics with the 60-cm telescope

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Abstract. Observational programs and selection from scientific results with the 60-cm telescope achieved at the Skalnaté Pleso Observatory since its putting into operation is reviewed: novae, eclipsing and interacting binaries, symbiotic stars, cataclysmic variables, chemically peculiar stars, comets. Possible targets among newly detected binaries are proposed for determining orbital parameters using the new spectrograph of the 60-cm telescope at the Stará Lesná Observatory.

Key words: History and philosophy of astronomy – Methods: observational – Techniques: photometric

1. Introduction

During the 70 years of the existence of the Skalnaté Pleso Observatory there have been two 60-cm telescopes, both manufactured by Carl Zeiss Jena, in operation in its eastern "big" dome. The first one was initially installed at the Stará Ďala Observatory, and in 1943 re-erected at a new observatory established by Dr. Antonín Bečvář near the mountain lake Skalnaté pleso in the High Tatras. The telescope was equipped with two foci – the Newton f/5.5 and the Cassegrain f/16.6. In 1978 it was replaced with a new one with the Cassegrain focus f/12.5.

From the plenty of papers published during that time I pick out a few that, I think, could well outline the field and topics of our interest. Many of the stars studied could be revisited once or more times, but I present the results as they were.

The beginning of astrophysical observations at the SP Observatory is connected with Dr. Tremko, who came with an idea to introduce photoelectric photometry. He succeeded.

2. Science

First works, however, applied the photographic method. Observations of a recurent nova RS Ophiuchi were such ones (Antal & Tremko, 1959). It was observed shortly after the outburst with a Tessar camera (and also visually) and, after the decline, 12 plates with a photographic camera attached to the Newton f/5.5 focus of the 60-cm reflector were exposed. Thanks to a systematic photographic survey carried out at the Observatory, one observation in the pre-outburst stage was made.

2.1. Shapes of light curves

The second work was on a short-period cepheid **YZ Bootis** (Tremko & Antal, 1959). One hundred and eighty photographic Agfa Astro plates covering 5 epochs of maxima and 4 epochs of minima were obtained. The period of the variable ($P = 0.104$ d), asymmetry (0.44) and amplitude (0.34 mag) of the light changes were determined.

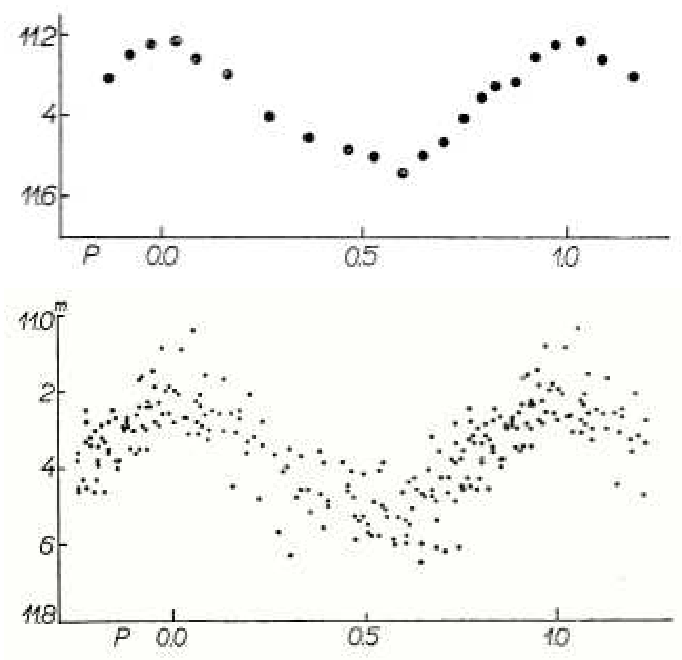

Figure 1. A light curve constructed from "normal" points (top) and individual points (bottom) of the cepheid YZ Boo (Tremko & Antal, 1959).

A short-period ($P = 0.197822$ d) pulsating variable **BS Aquarii** was the first one observed photoelectrically at the Skalnaté Pleso Observatory. Fourteen epochs of minima in V and 2 epochs of maxima in B were recorded. The shape of the light curve was found to change, however, smooth, and without deformations, Fig. 2. Depths of minima and heights of maxima periodically change in $P = 3.5$ d (Tremko & Sajták, 1964).

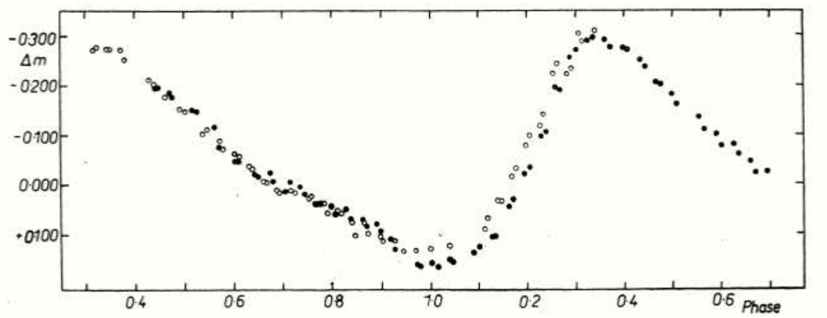

Figure 2. Two extreme light curves of the short-period variable BS Aquarii, (Tremko & Sajták, 1964).

2.2. Light-time effect and interacting binaries

Observations of minima of eclipsing binaries comprised a good deal of work with the telescope. The "$O-C$" diagram displays the difference between the times of the observed minima and the calculated ones from a given ephemeris. One of the binaries studied was **AR Auriga**, whose diagram had a sinusoidal shape, Fig. 3. The times of minima shifted periodically and, moreover, the secondary minimum remained in the phase 0.5. This is the "light-time effect" due to a third body which is present in the system and orbiting around the centre of gravity together with the eclipsing pair. The long period was between 24.75 and 27.09 years. The estimated minimum mass of the third body was $0.51 M_{\odot}$.

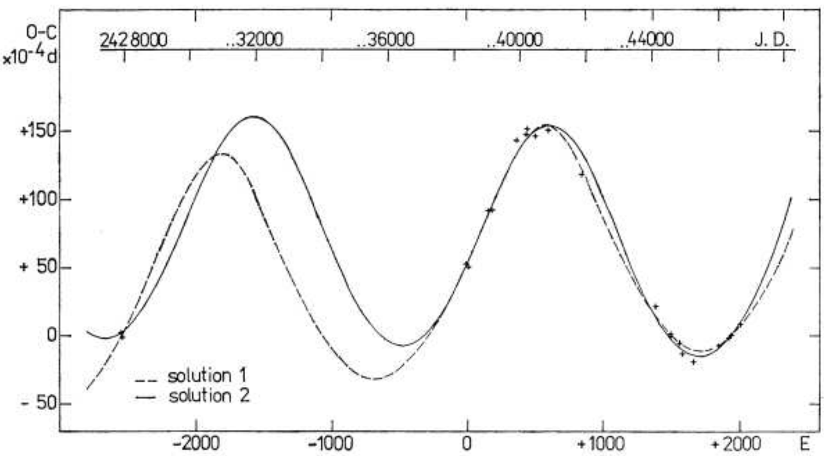

Figure 3. The $O-C$ diagram for the eclipsing binary AR Aur, Chochol et al. (1988).

U Coronae Borealis is an eclipsing binary showing the light-time effect, though this system is a bit more complicated than the previous one. Namely, weak evidence of a gradual shift of the secondary minima towards smaller phases existed in the literature. This would indicate the apsidal motion with a period of 38 years. However, a similar shift of the secondary minimum can be caused by other effects as, e. g., by a distortion of the light curve in the vicinity of the minimum due to clouds of gas in the system. Similar formations are frequently found in the eclipsing binaries which bear witness to existence of flows of mass of a various extent in the systems. These are the "interacting binaries". The clouds in U CrB could come from the secondary, which is a subgiant filling its Roche lobe and ejecting streams of mass from time to time. As this process would have to be reversible as the $O - C$ diagram showed the orbital period was alternately decreasing and increasing, the light-time effect was the most favoured explanation of the observations of U CrB (Bakos & Tremko, 1981).

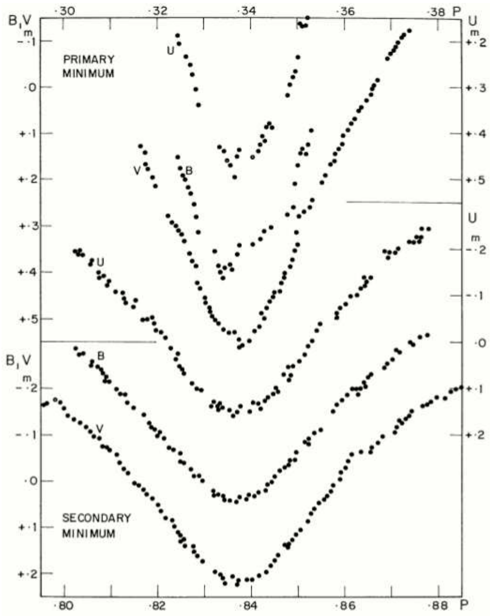

Figure 4. Primary (upper) and secondary (lower) minima of the eclipsing binary TX Her in various nights, Bakos & Tremko (1974)

Still more complicated is **TX Herculis**, an eclipsing detached system with a period of $P = 2.059808$ d . If the $O - C$ diagram constructed only of the photoelectric observations was extended back to the photograpic ones the curve would become sinusoidal with a period of 48 years. Then the mass of the third body would amount to $0.31 M_{\odot}$ if the light-time effect was considered as an explanation. However, here the change of the orbital period went along with irregularities in the primary minima, Fig. 4. The primary minimum exhibited a considerable distortion at the bottom and the ascending branch on some nights, while in others the minima appeared regular. A third body of the mentioned mass, however, could not account for the distortion of the light curve, so mass transfer was a more plausible explanation. According to the $O-C$ diagram the orbital period was increasing at a rate of $\Delta P/P = 1.5 \times 10^{-9}$, and the corresponding mass transfer from the less massive component was $4 \times 10^{-7} M_{\odot}\,\mathrm{yr}^{-1}$. The mass transfer form the seondary need not to be continuous and could be due to a chromospheric activity of the F-type star, Bakos & Tremko (1974).

A well known eclipsing binary **U Cep** was observed in 7 nights with primary minima between September 26, 1968 and August 6, 1969 in the B filter. During 80 periods between December 1968 an July 1969 lengthening of the orbital period by 18 seconds per a period was recorded. Besides this enormous increase, also the depth of the primary minimum significantly varied, Fig. 5. The explanation was that a luminous ring or a gas cloud originating from the G-type secondary trailed around a B-type primary and the extent or brightness of the circumstellar material change (Bakos & Tremko, 1973).

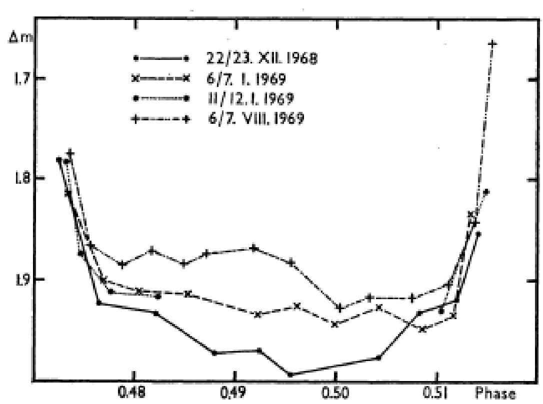

Figure 5. The bottom part of the primary minimum of U Cep in B, Bakos & Tremko (1973).

2.3. Symbiotic stars and cataclysmic variables

Symbiotic stars create wide pairs consisting of a small blue and a big red star. In some phases of their orbits they demostrate strong activity visible in a remarkable spectroscopic and photometric variability. **CH Cygni** was systematically, with a long-lasting effort, observed photometrically. As a result, a third body in the system was discovered orbiting once in 14.5 years as it obscured the inner binary, in which a red giant eclipses a hot small primary with a period of

$P = 756$ days (see a figure in the article by A. Skopal elsewhere in this Proceedings), Skopal et al.(1996). Other kind of irregular variability is the "flickering" observed on light curves of cataclysmic variables. It is aperiodic short-time variability observed on the light curve in a "quiet phase" between the cataclysmic events. Dorotka et al. (2010) adopted an idea that the aperiodic activity is initiated by the angular momentum transport in the inner parts of accretion discs and were able to simulate such variations as those observed in a known cataclysmic variable **T Coronae Borealis**, Fig. 6.

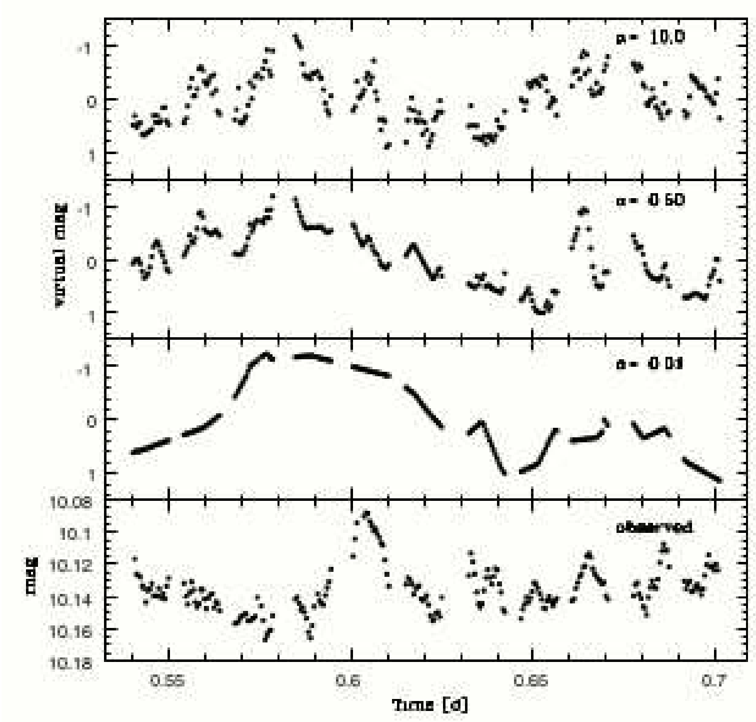

Figure 6. Examples of synthetic data compared to the observed light curve of T CrB (lower panel).

2.4. Chemically peculiar stars

Chemically peculiar (CP) stars, by contrast to those discussed above, show photometric variability only a few hundredths of magnitude. Their variability is inherent in the rotation of a star whose surface is covered with patches of anomalous chemical composition. Their light curves are in the long term stable in the shape and in the period. A magnetic CP star **56 Arietis** with $P = 0.728$ d, however, is an exception (Žižňovský et al., 2000). Its light curve exhibits

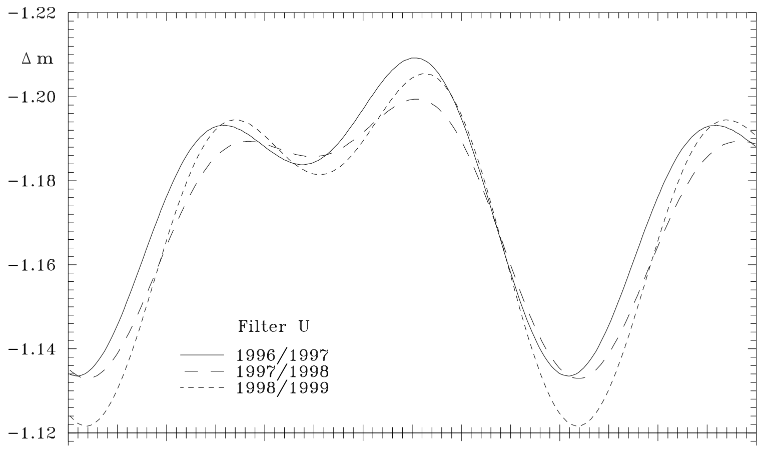

Figure 7. Seasonal changes of the light curve of the CP star 53 Ari in U, Žižňovský et al. (2000). For clarity only the fits through the individual observations are shown.

seasonal changes of its shape, Fig. 7, which can be explained due to precession of the rotational axis.

2.5. Comets

A special challenge for the astrophysicists at the SP Observatory was represented by comets. Vanýsek & Tremko (1964) observed comets 1961e (Humason), 1961f (Seki) and 1963b (Alcock). Using focal diaphragmas of different diameters, and for 1963b transversal tracings through the head of the comet, they measured the surface brightness depending on the distance from the nucleus.

3. Technology

The first photoelectric photometer at the SP Observatory was installed in 1961. Equipped with a 1P21 photomultiplier and U, B and V filters, it was attached to the Newton f/5.5 focus of the 60 cm reflector. The signal was measured with a microammeter which was soon replaced with a strip chart recorder. This instrumentation enabled observation of stars up to 12th magnitude, Tremko (1975).

In 1964 a new automated system was introduced. It consisted of a new photometer harbouring a photomultiplier EMI 6256B, UBV filters, three filters for medium-band photometry and three narrow-band filters centered on the Balmer α, β and γ lines. The photometer designed by Dr. P. Mayer, Charles University, Prague, was attached to the Cassegrain focus f/16.6. The A/D conversion was used and the data were recorded simultaneously by a typewriter and a punching machine, Horák et al. (1976). The control and measuring system was designed and completed in cooperation with Metra Blansko, n. p. The electronics was decommissioned in 1974, and next few years a standby analog system was used. In 1977 a new semiautomatic system based on the photon-counting technology, a programmable control unit and a printer was introduced, Klocok et al. (1986). In 1978 the telescope was decommissioned and replaced with a new 60 cm telescope. Since then the photometer has been installed in the Cassegrain f/12.5. In 1984 the specialized control unit was replaced with a programmable desk-top calculator EMG 666 which was used for recording as well as reducing the data, Klocok et al. (1986). From 1990 a new photometer OPTEC controlled by a PC was in operation until 1996, when a new control and measuring system with P. Mayer's photometer was inroduced, Kollár & Komžík (1997).

During the operation of the 60-cm telescopes the atmospheric extinction over the site of the Skalnaté Pleso observatory was permanently checked up and evaluated, Papoušek et al. (1984), Mikulášek et al. (2000), Mikulášek et al. (2001).

4. What could be observed - my offer

The 60-cm telescope at the SP Observatory was decommissioned, and after re-installation at the Stará Lesná Observatory it was equipped with a spectrograph giving a good resolution, $R = 12000$. Below I propose stars suitable for observations with such instrument.

In the recent few years I have been dealing with stars demonstrating controversial spectra. I compiled a list of 24 stars for which the values of the projected rotational velocity derived from various spectral line differ. By now a dozen of them have been analyzed from which 6 turned out to be double. Radial velocities are needed to determine the orbital parameters of the systems, and to refine the physical parameters of the components.

HD 2913 (51 Psc). *A double or multiple star, a third component doubtful.* We disclosed the HD 2913A to be an SB2 binary. The composite spectrum of the HD 2913A consists of a B9.5V (HD 2913Aa, $v \sin i = 170 \mathrm{km\,s^{-1}}$) and a mid F (HD 2913Ab, $v \sin i = 50$ $\mathrm{km\,s^{-1}}$) spectrum. Radial velocity of the primary varies from -2 to 11 km $\mathrm{s^{-1}}$, Zverko et al.(2011).

HD 47152 (53 Aur). *A speckle interferometric double.* The interferometric observations allow periods $P = 13.7$ or $P = 22.39$ years. The spectrum was disentangled to be composed from spectra of B9V-Mn and F0V stars that contribute to the total light in the ratio 0.9:0.1. The hot component rotates with $v \sin i = 25$ $\mathrm{km\,s^{-1}}$, while for the cool one $v \sin i \approx 0$ $\mathrm{km\,s^{-1}}$. The strong Ca II-line at 3933 Å in the F spectrum with its width mimics a high rotational velocity in the composite spectrum, Zverko et al. (2008).

HD 47964 (HR 2461). *Discovered by HIPPARCOS as a double.* No evidence of spectral lines of the other star has been found. Based on the HIP-

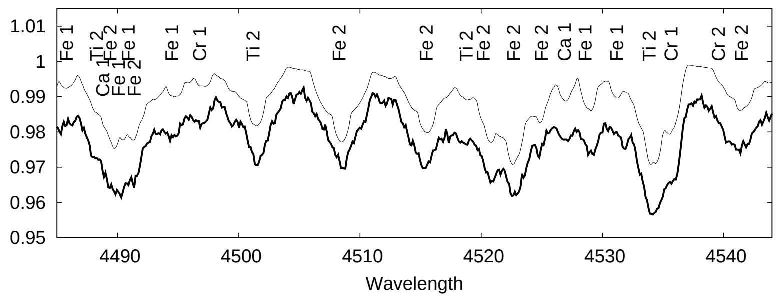

Figure 8. Comparison of the observed spectrum (lower) with the theoretical composite one (upper) of HD 2913. The spectra are shifted vertically for clarity.

PARCOS data we derived that the secondary is a main sequence A4 star with a high rotational velocity. Radial velocity varies from 0 to 20 km s^{-1}, Zverko et al. (2013b).

HD 90569 (CX Leo). An SB1 binary with a long period ($P = 12658.4$ d) shows low velocity variations, which should be confirmed by further observations. Although discovered as an occultation double of two equally bright components, no evidence of two systems of spectral lines in the spectrum has been found. Moreover, three observations by the speckle interferometry did not confirm the existence of the second component. Radial velocity varies from 0 to -13 km s^{-1}, Zverko et al. (2012).

HD 138527 (τ^2 Ser). Although not detected as a double by speckle interferometry, we found additional light contributing by 15% to the total brigthness. Spectral lines of the contributing component have not been detected. Radial velocity varies from -6 to -23 km s^{-1}, Zverko et al. (2013a).

HD 183986 (HR 7419). *A visual triple star.* We have discovered that the brightest component, HD 183986A itself, is a spectroscopic SB2 binary. The secondary is a main sequence A5 star rotating with $v \sin i = 150$ km s^{-1}. Radial velocity varies from -6 to 22 km s^{-1}, Zverko et al. (2013b).

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