THE PHOTOELECTRIC PHOTOMETRY WITH A 60 CM REFLECTOR AT THE SKALNATÉ PLESO OBSERVATORY

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Abstract: A study of the colour and magnitude systems of a photoelectric photometer attached to the 60-cm reflector at the Skalnaté Pleso Observatory showed the colour system to depend on ambient temperature, while measurements of the atmospheric extinction revealed the presence of the azimuth effect which attained several hundredths of magnitude. An interpretation is given of the photoelectric observations of three RR Lyre type variable obtained recently at the Skalnate Pleso Observatory. New elements of light variations were derived and a secular change of the period of W CVn was found. On the basis of the photoelectric observations and using Fernie's method, the distance modulus of the investigated variable stars was derived.

1. *Introduction*

The Slovak Academy of Sciences Astronomical Observatory Skalnate Pleso is situated in the High Tatras 1783 m above sea-level. Its coordinates are $\lambda = 20°14'42''.0$ E and $\phi = 49°11'20''$ N. The main telescope of the observatory is the reflector 600/3300 with equivalent focus 10 m used from the year 1943 in the Skalnate Pleso Observatory. This telescope was produced by the firm Zeiss Jena and during the years 1928 to 1938 it was installed at the Astrophysical Observatory Hurbanovô (formerly Stará Ďala). To the year 1966 it was the only suitable instrument for astronomical observations at the Skalnaté Pleso Observatory and was used for various programs, primarily astrometrical. The first photoelectric photometer was installed in the year 1961, later it was modified and is now used for photometric programs. Since the year 1966 the telescope has been used for astrophysical programs only. During the years many thousand observations were made of which the main part was interpreted and published (Tremko and Sajtak 1964, Tremko 1964, Tremko and Vanysek 1964, Mrkos et al. 1968, Tremko 1968a, Tremko 1968b). This article contains the data which are cited in previously published papers or in the papers in press, and also the interpretation of new observations of the RR Lyrae type variables obtained recently, mainly at the Skalnaté Pleso Observatory.

2. *Photoelectric photometer*

a) *Optical and mechanical part*

The astrometrical programs were made in the Newtonian focus, however in the course of the night astrometric and photometric programs were switched several times and hence, it was necessary to construct a photoelectric photometer with regard to these facts. The general conception of the photoelectric photometer needed some special adjustments and, therefore, the individual parts have been solved not only from the point of view of their function but also of their assembly. The fast convergence of the beam of light in the Newtonian focus and the difficult manipulation with photoelectric photometer in the focus during observations in some parts of the sky, required an atypical adjustment of the operating elements.

The photoelectric photometer is composed of these functional parts: optical system, basic desk, revolving disk with focal diaphragms, revolving disk with colour filters, remote alignment of filters and photomultiplier tube housing. The arrangement of the individual parts is evident from Figs 1 and 2.

The optical arrangement is based on the exit pupil system, which enables one to measure objects of various structure and thus the performance of the photoelectric photometer is not dependent either on the position of objects in the focal diaphragm, or on its form.

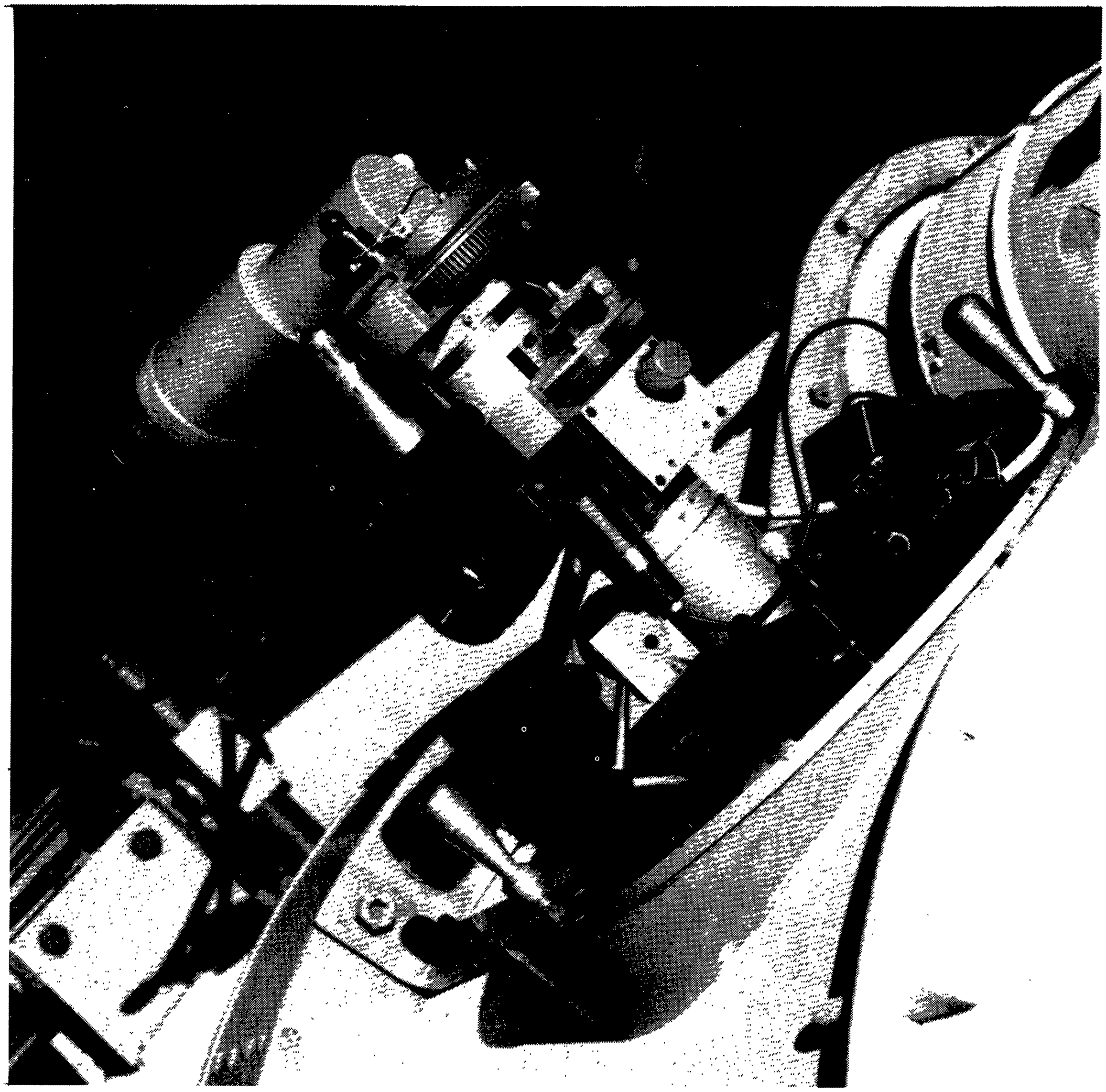

Fig. 1a. The photoelectric photometer of the Skalnaté Pleso Observatory.

The optical system is composed of a Fabry lens and control eyepieces. The quartz Fabry lens with a focal length $f = 23.753$ mm at 4860 Å and a cross magnification of – 0.00711 projects the entrance pupil of the telescope on the photocathode of the electron photomultiplier tube in the form of a small disk 4.27 mm in diameter (Hajda et al. 1961). The internal arrangement of the optical-mechanical part prevents any light refelection. The Kellner eyepiece of the viewing field with a focal lenght of 30 mm and a field of view of 30 minutes of arc is furnished with a crosswire and a prism, which can be pushed in and out from the optical axis in the perpendicular direction. For focusing the photoelectric photometer and for positioning a star in the diaphragm, a control microscope with a cross-wire is used. The control microscope consists of the microscope objective with a focal lenght of 15 mm and cross magnification – 1 and a symmetrical four-lens eyepiece (Hajda et al. 1961). The magnification of the control microscope is 20-times. The rectangular prism revolving about 100° in a plane perpendicular to the optical axis of the photometer and in another one, perpendicular to the optical axis of the control microscope is inserted in the optical axis during the check up of the position of the star in the diaphragm. The diaphragm in this position of the prism is illuminated by means of a small cystoscopic bulb and is switched on and off with the motion of the prism.

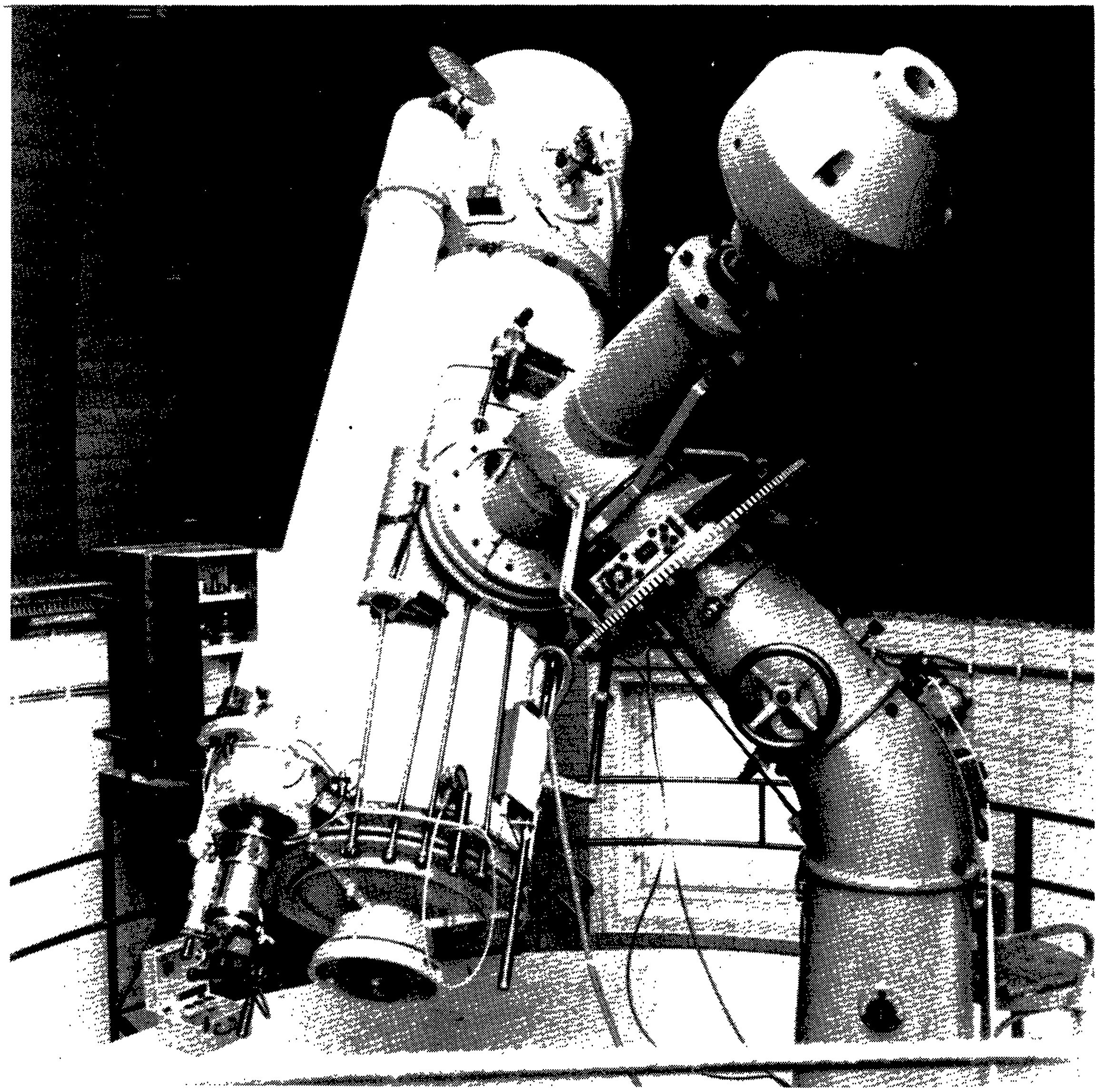

Fig. 1b. The 60 cm reflector of the Skalnaté Pleso Observatory with the photoelectric photometer.

The system of assembly of the base plate with the photoelectric photometer enables one to focus the optical system and to rotate the photometer in the position angle too. The last function is important when observing at the Newtonian focus near the zenith. The base board carries also an adjustable voltage source for the illumination of the cross-wires and the focal diaphragms.

The revolving disk with diaphragms is situated in the focal plane of the telescope and has 6 positions with 5 diaphragms. One of the positions is without a diaphragm as a prevention of illumination, outside observation. The data on focal diaphragms are found in Table 1.

Table 1

Number	Diameter mm	Diameter sec. of arc	Remarks
1	0,4	25.0	used during moonlight
2	0.7	43.8	most frequently used
3	1.2	75.0	used for measuring diffuse sources
4	1.9	118.8	used for measuring diffuse sources
5	3.0	187.5	used for measuring diffuse sources

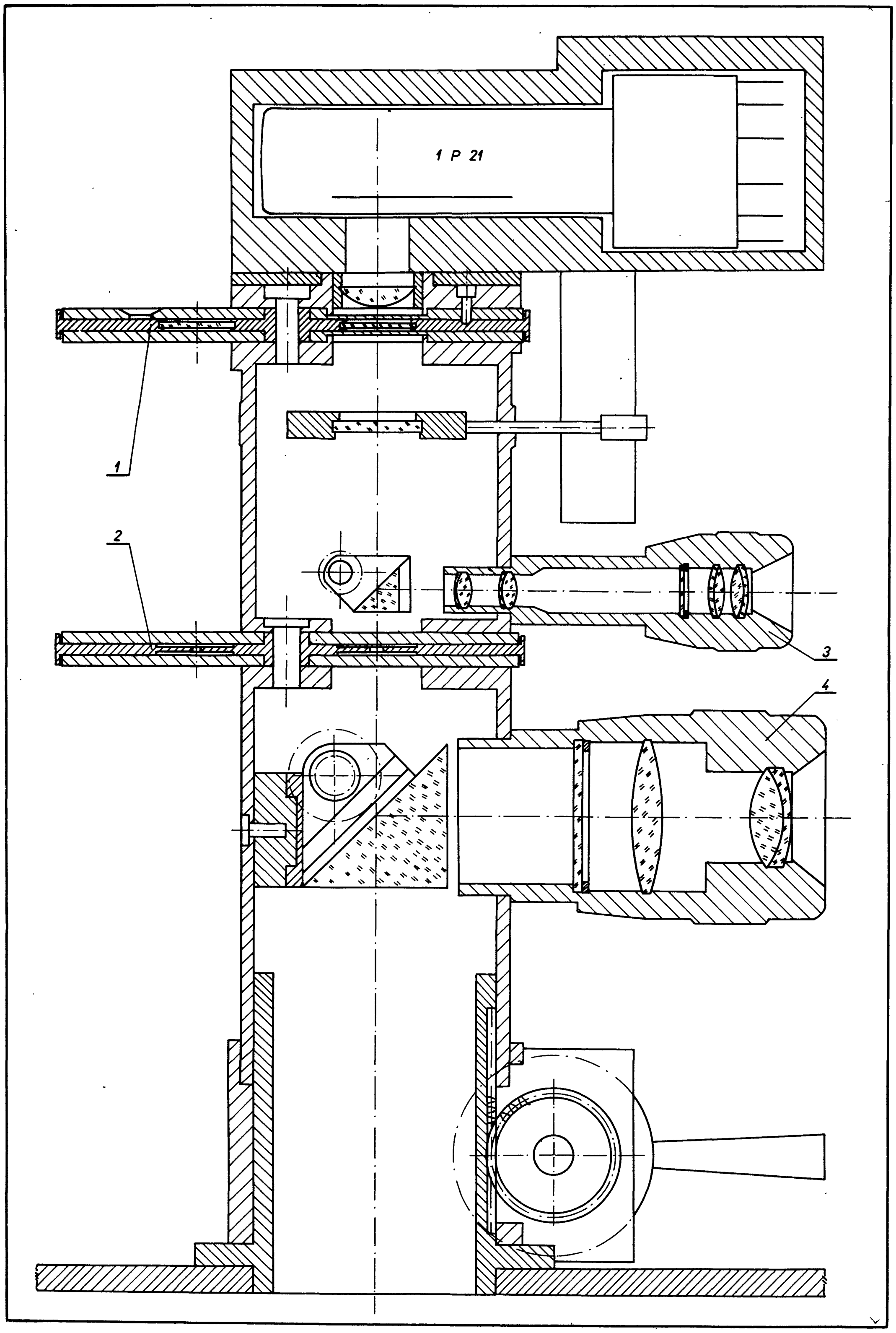

Fig. 2. The scheme of the optical part of the photoelectric photometer; 1 — the revolving disc with focal diaphragms, 2 — the revolving disc with colours filters, 3 — the control microscope, 4 — field eyepiece.

The focal diaphragms with a large diameter are used primarily to measure comets. The electron phototube is protected against illumination by the cystoscopic lamp with electric contacts, whose function is synchronized with the motions of prisms for the control eyepiece and the field eyepiece. The revolving disk contains the standard filters for UBV photometry and radioactive light sources, which are used for some photometric programs. The radioactive light sources are composed of a radioactive and luminescent mixture applied to a circular metallic base 14.5 mm in diameter. The luminescent material ZnSCu is irradiated by natural uranium (particles of Radium B, Radium C', Radium F). The light characteristic of the radioactive light sources, used by us, were published by Tremko (1969). Table 2 contains the data about the colour filters.

Table 2

Number	Filter	Eff. wavelength Å
1	UG 2 1 mm	3592
2	BG 12 1 mm+GG 13 2 mm	4318
3	GG 11 2 mm	5456
4	Radioactive light source	
5	Radioactive light source	

For the observation in the Newtonian focus the photoelectric photometer is equipped with a mechanical remote control on the base desk. The guiding around zenith is done by a guiding telescope, equipped with a micrometer head with motions in two coordinates. For observation in the Cassegrain focus this latter adaption is not necessary. The photomultiplier housing enables the electron photomultiplier adjustment in the axial and radial direction, and so, it is possible to project the entrance pupil on the most sensitive place of the photocathode. The electron photomultiplier is protected against external magnetic fields by a cylinder made of a treated mumetal. The space around the electron photomultiplier is kept dry with silicagel placed in easily exchangeable cartridges.

b) *Electronic components*

The electronic part of the photoelectric photometer is composed of the electron photomultiplier tube, voltage sources and equipment to measure the output signal. The electron photomultiplier tube was originally fed with a dry battery type AB 120, which keeping to the technical conditions of the operating regime, guaranteed a stability of the high voltage to 0.09 %. Later the stabilizer type NBZ 411 was used as a source of the high voltage. The divider of the stabilizer enables to adjust the output voltage in the limits from 400 V to 2000 V in steps of 10 V. The short-term stability of the output voltage is 0.05 % corresponding to a change of about 10 % of the input voltage.

Most observations were made with the electron photomultiplier tube type RCA 1 P 21 whose spectral characteristics was published by Tremko and Růžičková (1960). Since leads to the anode and to the cathode on the socket of the electron phototube RCA 1 P 21 are close to each other there is some leakage of the photocurrent present, which affects unfavourably observation of faint stars. In order to reduce the leakage the anode pin was isolated from the socket of the electron photomultiplier tube. Because the observatory is situated at 1783 m above sea-level, the mean yearly temperature is +0.9° C and as the best photometric nights occur during the fall and winter season, the electron photomultiplier tube does not require refrigeration.

During many years of work with the photoelectric photometer, several electronic diagrams were tested, all on the principle of the d.c. method. The last modification is a recording potentiometer type EZ 4, produced by the firm Laboratorní přístroje in Prague. The recorder enables to measure and

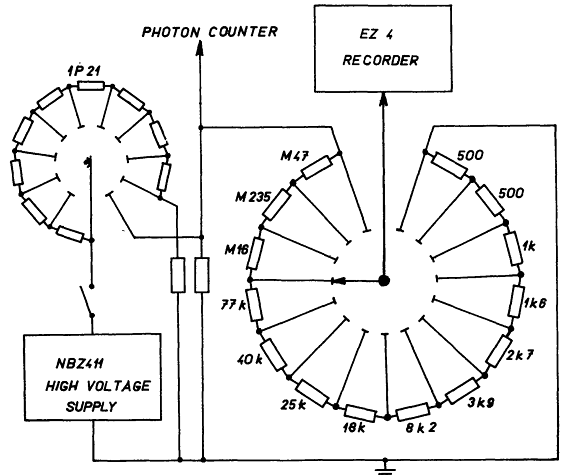

Fig. 3. The electronic diagram of the photoelectric photometer.

record signals with an accuracy of 0.2 %. Its limiting sensitivity is 100 μV for the full deflection of the pen. The stability of the zero point is 1 μV and the chart width is 280 mm. The speed of the registration can be regulated in the range from 1 cm to 1060 cm/h. The multipoint switch can adjust 16 different speeds of the registrating chart. The photoelectric photometer's electronic diagram is represented in Fig. 3.

The input to the recorder is formed by a set of the voltage divider resistors from 0.5 to 1043.4

kOhm. With the combination of voltage divider resistances and a change of the sensitivity of the electronic recorder EZ 4 it is possible to measure stars in the range of 12^m. The ratio of two neighbouring sensitivities is approximatly 0.5^m, which allows the measurements to be made at the maximum scale deflection of the measuring instrument. In this way the error of observation is not influenced by a lower resolving ability of reading of deflections if made in the second part of thescale. It is possible to choose the time constant of the measuring instrument by connecting a suitable capacity parallel with the input resistance. The previously mentioned electronic scheme was used in the earlier stages of the operation, later the input capacitor was eliminated. In the last case the apparatus time constant was determined by the dynamic properties of the electronic recorder, namely, by the time reguired by the pen to cross the entire scale, which is about 3 sec. Since the value of the input resistors changes with time due to various influences, it was necessary to check the ratio of sensitivities at different stages. For measurements of bright objects a mechanical diaphragm was used to reduce the effective mirror surface. The photoelectric photometer is connected by two coaxial cables with a recorder and a source of high voltage which are situated in a room with controlled temperature. The dome and the room where the electronic parts of the photoelectric photometer are situated, are connected by an intercommunication system.

3. *The colour and the magnitude system*

a) *Colour system*

By a suitable choice of the electron photomultiplier tube and the colour filters it is possible to make the instrumental colour system to approach the standard one so that the spectral range and the effective wavelengths of the two systems differ very little. In this way transition from the instrumental to the standard photometric system becomes easier. In order to preserve the photometric system stable all mirros of the reflector have been aluminized by a special technology so that the reflective qualities changed very little with time. As mentioned earlier for an electron photomultiplier the RCA 1 P 21 was chosen and the Schott colour filters listed in Table 2 were used. The transmission of the colour filters has been measured and the transmission curves and the spectral sensitivity of the electron photomultiplier tube have been plotted in Fig. 4. The curve *a* in the Fig. 4 shows the spectral sensitivity of the used electron photomultiplier tube. The maximum sensitivity at 4200 Å has been standardized as a unit value.

The effective wavelengths resulting from the transmissivity of the colour filters and the spectral sensitivity of the electron photomultiplier tube have been calculated and are listed in Table 2. The transmission of the colour filters used differs only a little from the catalogue data. The influence of the red leak of the colour filters UG 1 and BG 12 on the value of the effective wavelength is negligible.

The inaccuracy of transformation of the instrumental photometric system into the standard photometric system is one of the limiting factors of the accuracy of the measured colour indices. The aim of our program was not only to determine the transformation coefficients, but also to study the stability of our photometric system. The transformation equations for the black body radiation have a linear form, however, the general transformation equations for the stars do not have this form. On the other hand it is possible, under certain simplifying assumptions, for instance, with approximately the same value of effective wavelengths and spectral band windths, to apply the linear equations with sufficient accuracy. The transformation coefficients used in this treatment are as follows:

$$(B - V)^+ = A_1 + A_2\,(b - v),\qquad\qquad (1)$$
$$(U - B)^+ = A_5 + A_6\,(u - b).$$

Together 25 stars, mostly of luminosity class III and V located in different parts of the sky have been observed on 8 nights in order to determine the coefficients A_1, A_2, A_5, A_6 for transformation of the instrumental $b - v$, $u - b$ photometric system to the standard UBV system. Table 3 gives the following data about the observed stars: the

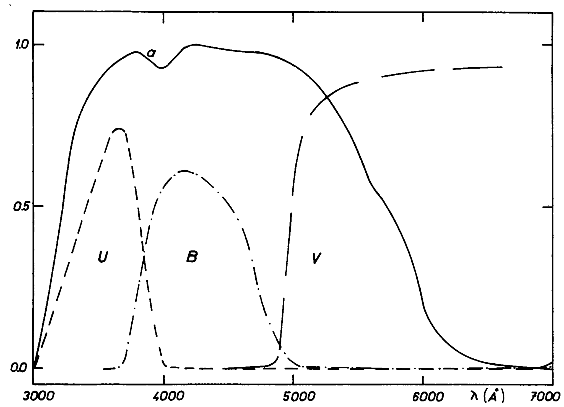

Fig. 4. The performance of the photoelectric photometer. The curve *a* denotes the spectral sensitivity of the photoelectric tube.

number of the stars according to HD catalogue, the name of the star, the spectral type, the values V, $B-V$, $U-B$ of Johnson and Harris (1954) and Johnson and Morgan (1953), our values of $(B-V)^+$ and $(U-B)^+$ and the number of observations.

The $B-V$ colour index is expressed in thousandths of magnitude and the $U-B$ colour index is given with an accuracy of hundredths of magnitude. The relationship of $B-V$ and $U-B$ values in the standard photometric system and in our system is shown in Fig. 5 and Fig. 6. There are no systematic differences between these two photometric system.

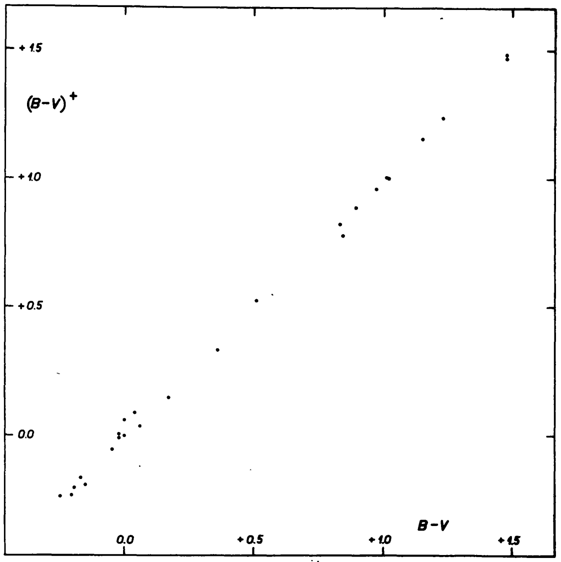

Fig. 5. The relationship of the $B-V$ and $(B-V)^+$ colour indices.

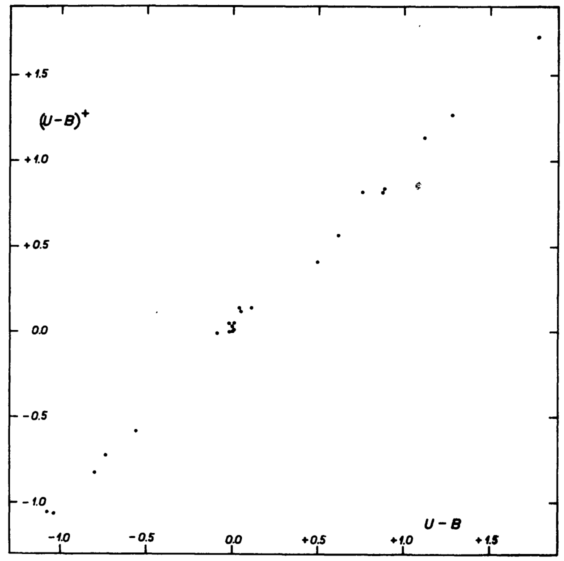

Fig. 6. The relationship of the $U-B$ and $(U-B)^+$ colour indices.

Table 3

HD Name	Sp	V	$B-V$	$U-B$	$(B-V)^+$	$(U-B)^+$	n
1280 ν And	A2V	4.61	+0.06	+0.04	+0.036	+0.14	13
6961 νCas	A7V	4.33	+0.17	+0.147	+0.14	+0.14	13
9570 η Psc	G8III	3.62	+0.97	+0.76	+0.961	+0.82	4
10476 107 Psc	K1V	5.23	+0.83	+0.50	+0.826	+0.41	5
12929 α Ari	K2III	2.00	+1.151	+1.12	+1.157	+1.14	5
18331 HR875	A1V	5.17	+0.084	+0.05	+0.78	+0.12	4
21120 σ Tau	G8III	3.59	+0.89	+0.62	+0.891	+0.57	3
28305 ϵ Tau	K0III	3.54	+1.02	+0.88	+1.005	+0.82	13
30836 π^4 Ori	B2III	3.69	−0.17	−0.80	−0.165	−0.82	4
37043 ι Ori	O9III	2.77	−0.25	−1.08	−0.236	−1.05	4
69267 β Cnc	K4III	3.52	+1.480	+1.78	+1.468	+1.72	3
71155 HR3314	A0V	3.90	−0.02	−0.02	+0.005	+0.00	1
74280 η Hya	B3V	4.30	−0.195	−0.74	−0.206	−0.72	3
103287 γ UMa	A0V	2.44	0.00	+0.01	−0.001	+0.05	3
113139 78 UMa	F2V	4.93	+0.36	+0.01	+0.332	+0.01	3
139006 α CrB	A0V	2.23	+0.02	−0.02	−0.010	+0.05	1
143107 ϵ CrB	K3III	4.15	+1.230	+1.28	+1.237	+1.27	1
147394 τ Her	B5IV	3.89	−0.152	−0.56	−0.193	−0.58	4
161868 γ Oph	A0V	3.75	+0.04	+0.04	+0.088	−	3
172167 α Lyr	A0V	0.04	0.00	−0.01	+0.060	+0.03	6
176437 γ Lyr	B9III	3.25	−0.05	−0.09	−0.055	−0.01	4
214680 10 Lac	O9V	4.88	−0.203	−1.04	−0.232	−1.06	17
219134 HR8832	K3V	5.57	+1.010	+0.89	+1.007	+0.84	10
222368 ι Psc	F7V	4.13	+0.51	0.00	+0.526	0.00	6
104774	M2V	8.98	+1.48	+1.09	+1.485	−	1

Fig. 7 and Fig. 8 show the relationship of the difference of the colour index values in the standard UBV system and our photometric system as function of stellar magnitudes. A small systematic difference reaching $0^m.03$, among the stars

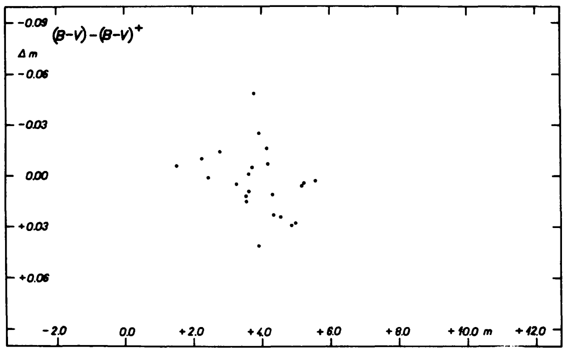

Fig. 7. The difference of the $B-V$ and $(B-V)^+$colour indices as function of the stellar magnitude.

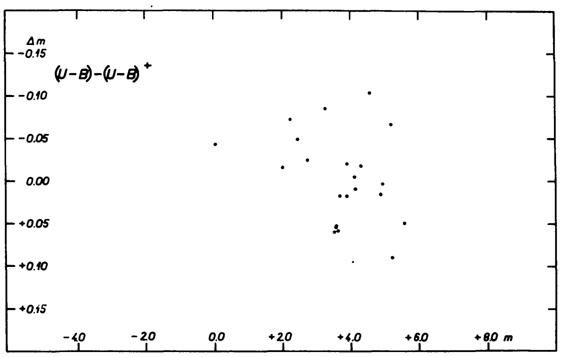

Fig. 8. The difference of the $U-B$ and $(U-B)^+$colour indices as function of the stellar magnitude.

brighter than the 2^m and stellar magnitude exists and may be due to fatigue of the photocathode when measuring bright stars.

The stability of the photometric system has been carefully investigated. From Table 4, which shows the transformation coefficients values and the data about the ambient temperature, it can be seen that the instrumental colour system has been changing in dependence on the temperature. As a matter of fact, there are several reasons for the colour system changes, and the effect can be either selective or nonselective. It is possible to detect the reasons for changes of the photometric system by a detailed analysis of values of the transformation coefficients.

The last column of Table 4. shows tne mean temperature during the observation.

The dependence of the transformation coefficients on the voltage of the electron photomultiplier tube 1 P 21 is negligible, since except for 2 nigths, the high voltage on the tube remained the same during observation (Tremko and Růžičková 1960). It is inadequate to explain the changes of the photometric system by slow changes of the detector, or optical system components. The transformation coefficients in dependence on time changed differently and perhaps only the A_6 coefficient could be expressed as a monotic function of time. On the other hand, it is evident that the transformation coefficients A_1, A_2, A_5, A_6 are function of the temperature. The coefficients A_1 and A_2 are increasing with temperature as follows $+0^m.0015$/deg. and $+0^m.0019$/deg. respectively. The trans-

Table 4

Temperature dependence of the transformation coefficients

Date	A_1	A_2	A_5	A_6	t° C
1963.IX.16/17	0.486	1.111	−2.122	1.036	+13.5
IX.17/18	0.516	1.095	−2.019	1.003	+14.5
IX.19/20	0.512	1.110	−2.034	1.028	+10.7
IX.22/23	0.469	1.088	−2.072	1.027	+10.0
X.29/30	0.440	1.044	−2.204	1.072	− 1.2
X.30/31	0.494	1.068	−2.008	1.004	+ 1.1
XII.2/3	0.480	1.074	−2.032	1.012	− 3.4
XII.3/4	0.487	1.121	−2.152	1.079	0.0

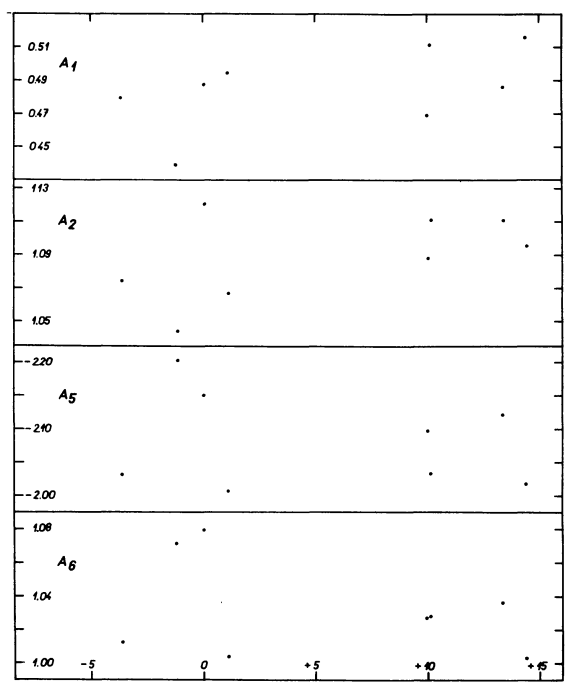

Fig. 9. The dependence of the transformation coefficients on temperature.

formation coefficients A_5 and A_6 are decreasing with temperature by $-0^m.0028$/deg. and $-0^m.0015$//deg. respectively.

After correction for temperature, the variation of the transformation coefficients could be due to a selection effect of stars of different luminosity classes on a given night or to observational erros. The dependence of the transformation coefficients on the luminosity class of stars is generaly known. This fact can be verified by comparing the values of colour indices of stars of different luminosity classes in the standard UBV system and in our photometric system. The mean error of the $(B - V)^+$ index after elimination of the star α Lyr from the observed group of stars is equal to $\pm 0^m.019$, the mean error of the $(U - B)^+$ colour index determination is approximately 2.5 times higher. These values refer to the external mean error as defined in the paper published by Johnson and Morgan (1953), i.e. not reduced to a unit air mass. The values of the mean error for some stars are influenced by unfavourable observing conditions, namely, that the stars have been observed over the whole sky and at zenith distance over 60°. Thus, the coefficients A_1 and A_2 were determined with an accuracy of 1.2 % and the coefficients A_5 and A_6 with an accuracy of 3.1 %.

b) *Magnitude system*

The transformation of the stars brightness has been made by using the relation:

$$V^+ = A + C.. V_i + D(B - V), \qquad (2)$$

where A, C, D – are constants,

V^+ – star brightness in the standard photometric system,

V_i – yellow magnitude in the instrumental photometric system.

The transformation coefficients A, C and D have been computed for stars of all luminosity classes together. Because in Table 3 there are only bright stars, observations of stars in the galactic star cluster M 45 have been made, on a total of 6 nights in order to define the scale of brightness in the instrumental system. Most stars were observed at least on two nights. The mean value of the constants are as follows:

$$A = +0^m.125, \ C = +0.976, \ D = -0.082.$$

The constants A and D, as well as the measuements of the spectral sensitivity of electron photomultiplier tube and of the spectral transmission of the filters used by us show, that the spectral response of our photoelectric photometer differs slightly from the characteristics of the instrument by means of which the V magnitude of the standard UBV photoelectric system has been defined.

The manufactur of filters cannot guarantee a standard filter transmission such as is used in European countries to reproduce the V brightness in the UBV photometric system.

The photometric data obtained by observations of stars in the galactic cluster M 45 have been collected in Table 5. In the first column of Table 5 is the star number, further its V magnitude taken from the paper published by Johnson and Morgan (1953). V^+ indicates the brightness in the standard photometric system, derived from our observations and n is the number of observations. In the last column of Table 5 is the difference of the brightness obtained by Johnson and Morgan (1953) and of that derived from our observations. From the last column of the Table 5 it can be seen that the mean error of the star brightness determinations during at least the two night of observations is $\pm 0^m.02$.

Table 5

Hertzsprung No.	V	V^+	m.e.	$V - V^+$	n
542	2.86	2.84	±0.02	+0.02	3
870	3.62	3.63	±0.02	−0.01	4
126	3.69	3.70	±0.01	−0.01	4
156	4.29	4.24	±0.04	+0.05	3
117	5.45	5.47	±0.02	−0.02	4
150	5.64	5.68	±0.05	−0.04	3
255	5.75	5.79	±0.03	−0.04	4
265	6.41	6.38	±0.03	+0.03	3
436	6.80	6.81	±0.05	−0.01	3
540	6.80	6.77	±0.04	+0.03	3
569	7.68	7.68	±0.02	0.00	5
534	7.76	7.73	±0.02	+0.03	4
924	7.96	7.97	±0.03	−0.01	3
28	8.24	8.20	±0.04	+0.04	2
206	8.58	8.58	±0.06	0.00	2
597	8.77	8.77	±0.06	0.00	2
993	9.14	9.13		+0.01	1
108	9.82	9.88		−0.06	1
213	10.12	10.09		+0.03	1
385	10.20	10.19		+0.01	1

The observations of stars in M 45 extended over a scale of brightness $7^m.5$. Observations of variable stars show, that the accuracy of the determination of star brightness by the method of differential photometry, when the brightness of stars usually do es not exceed 2 magnitudes, is higher and for the best atmospheric conditions during good photometric nights it reaches $\pm 0^m.005$.

4. *The atmospheric extinction*

In general, the atmospheric conditions for photometry, in Central Europe are not favourable, and therefore they become the limiting factor for accuracy of observations and the main source of errors. For this reason special attention has been given to the atmospheric extincion and especially to its changes. Therefore, the autumn season, when the weather is relatively stable and photometric nights occur most frequently, was chosen for this sort of observation. The exinction coefficients have been computed for each night from the observations of the extinction stars at different zenith distances, In order to eliminate the influence of local transparency of the sky on the value of the extinction coefficients, a number of extinction stars with different colour indices and distributed in different parts of the sky have been measured each night. Because of the small air masses involved, the absorption coefficients have been computed under the following assumption:

a) The atmosphere is homogeneous in every horizontal layer. The validity of this assumption has been verified by a detailed study of the azimuth effect; b) The extinction coefficients are linear functions of the extra-atmospheric colour index of the stars.

The reduction equations are given by the following expression:

$$v = v_{\text{obs}} - k_3 . F(z),$$
$$b - v = (b - v)_{\text{obs}} - k_1 + k_2 (b - v)\, F(z), \qquad (3)$$
$$u - b = (u - b)_{\text{obs}} - k_5 . F(z),$$

where $F(z)$ is the air mass.

The notation of the symbols is taken partly from the paper of Mitchell (1960). Given the atmospheric conditions, the observations have been corrected for atmospheric extinction in two steps. The observed quantities have first been reduced by using relation (3). Because on every night several extinction stars were observed and we did not change them during the whole observation period, the second step of reduction involved then the application of the method of conditioned coefficients. This method is based on the assumption, that extra-atmospheric brightness and colour index of stars are constant during all nights and that during different nights they have the same numerical value (Weaver 1952). During the nights, when the extinction coefficients were determined with a lower accuracy, the observations were reduced by means of the mean extinction coefficients. In the reduction it was assumed, that the coefficients k_4 and k_6 are equal to zero. If this condition is not satisfied, the coefficient k_6 could cause, for stars of some spectral types, a systematic deviation of $0^{\text{m}}.02$ (Johnson 1963). The mean values of the extinction coefficients are as follows:

$$k_1 = 0^{\text{m}}.186,\ k_2 = -0^{\text{m}}.022,\ k_3 = 0^{\text{m}}.176,$$
$$k_5 = +0^{\text{m}}.334.$$

The accuracy of the determination of extinction coefficients on good photometric nights with sufficient number of observatiobs is a few thousandths of magnitude.

Despite the fact, that Skalnate Pleso Observatory is situated 1783 m above sea-level, and 900 m above the surrounding terrain, during some nights, the transparency in the azimuth from 180° to 360° at greater zenith distances was lower, due to a haze, which sometimes reached 2000 m above sea-level.

Before the beginning of the photoelectric observations program, the azimuth effect in the atmospheric extinction and the changes of the transparency during a night were thoroughly studies. It has been found that both effects are not negligible, and that it is becessary to eliminate their influence. The azimuth effect is obvious in the meridian south of the zenith. Fig. 10 shows, that the azimuth effect is clearly detectable at the zenith distance of Z = 60°. The azimuth effect was studied on either side of the meridian in the azimuth from 315° to 53° and in the zenith distance from 57°30' to 74°04'.

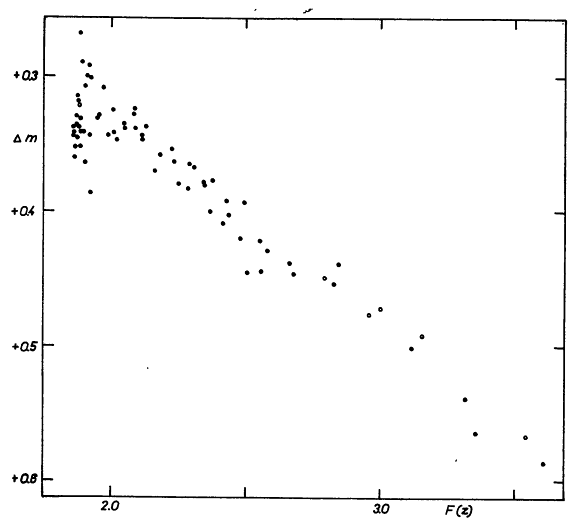

Fig. 10. The azimuth effect on the night 11/12 October 1961.

The azimuth effect is manifested only a few degrees on both sides of the meridian and it is caused by the central heating system of the nearby cableway station. The extent and the magnitude of the azimuth effect is given in Fig. 10, where the brightness of the comparison star during observation in the variable star program is shown as a function of the air mass. In the Fig. 10 the horizontal axis shows the air mass, the vertical one shows the star brightness diminishing in tenths of stellar magnitude, due to the atmospheric extinction during the night 11/12. October 1961. The zero point of the scale corresponds to the extra-atmospheric brightness of the star. The atmospheric extinction coefficient of the V spectral region after elimination of the azimuth effect was of the order of $0^{m}.163$, the azimuth effect reached a value of $0^{m}.019$. The scatter of the points in Fig. 10 is due to observing at large zenith distances. Observations before the meridian are indicated by open circles, and those obtained after the passage of the meridian are shown by full circles. The value of the azimuth effect changes not only from one night to another but also in the course of a night. In some meteorological situations it is possible to observe large changes of the transparency in the azimuth from 0° to 180° to an altitude of a few degrees above the mountains.

5. *The photometry of RR Lyres type stars*

a) *W Canum Venaticorum*

The visual and photographic observations of the variable star W Canum Venaticorum, carried out during more than three decades after its discovery, testify to considerable changes of the light curve. The question about the constancy or the variability of the period phase remained vague untill recently (Tremko 1968a). A comprehensive survey of the results and an interpretation of the most recent photoelectric observations were presented in a preceding paper (Tremko 1968a). Photoelectric observations of other autors are few in number and they were published by Geyer (1961), Sturch (1966), and Fitch et al. (1966). The most extensive observational material has been obtained with the 24-inch $f/6$ reflector of the Konkoly Observatory in Budapest and with the 24-inch $f/17$ telescope of the Skalnaté Pleso Observatory. The description of the former telescope and the photoelectric photometer has been published by Balasz and Detre (1954). The data about our equipment, our method and reduction of the observations are given in the preceding chapters of this paper. A detailed study of the results of the photoelectric observations carried out to 1967 at the Konkoly Observatory and at Skalnaté Pleso Observatory was published in our preceding paper (Tremko 1968a). Unlike the conclusions reached by Tsesevich (1868), Tremko indicated that during the whole interval of observation, the period of the light changes had shortened. Our next series of observations, carried out from 1968 to 1972, was made especially for the reason of a detailed study of the short-term and the long-term changes of the period.

From 1968 to 1972 we obtained 231 yellow and 17 blue photoelectric observations at the Skalnaté Pleso Observatory on the basis of which three new epochs of the maximum were derived. The observations in the blue colour have been carried out by means of an automatised photoelectric photometer, which will be described in one of the forth coming papers. Table 6 comprizes the data about time and the number of observations. The transformation of the instrumental system to the UBV photometric system has been made with the aid of our preceding observations (Tremko 1968a). The new derived epochs of the maximum, listed at the end of Table 6 together with other photoelectric epochs of maximum obtained by Detre, Tremko (this paper) and Fitch (1966), have been used for the computation of the period in the time interval J.D. 2435244 – J.D. 2441338.

Table 6

Date	J. D.$_{hel.}$	Colour	n	Notes
1968 Apr.23/24	2439970.5617 – .5814	*B*	17	
1971 May 25/26	2441097.3493 – .4314	*V*	104	1,2
July 1/2	2441134.3935 – .4235	*V*	26	1
1972 Jan.21/22	2441338.4578 – .5631	*V*	101	

Notes: 1 – Interfering fog. 2 – Interfering clouds.

The epoch of the maximum $\mathrm{Max}_{hel.}$ = J.D.2441134.3994 has been omitted from the calculation because it was derived from observations made under unfavourable atmospheric conditions. The elements derived by us have the following form:

$$\mathrm{Max}_{hel.} = \mathrm{J.D.}2435244.3881 + 0^{d}.551756786 . E \pm$$
$$\pm .0006 \pm 0.000000106. \quad (4)$$

Table 7 shaws the heliocentric photoelectric epochs of maxima, used for the computation of

Table 7

$Max_{hel.}$ 2400000+	E	$O-C$	Observer
1	2	3	4
35244.3875	0	$-0^d.0006$	Detre
36305.4155	1923	− .0011	Detre
36343.4895	1992	+ .0019	Detre
36348.4570	2001	+ .0036	Detre
36573.5685	2409	− .0017	Detre
36574.6705	2411	− .0032	Detre
36648.6094	2545	+ .0003	Detre
38085.3844	5149	+ .0006	Tremko
38448.4414	5807	+ .0016	Tremko
38450.6447	5811	− .0021	Tremko
38464.4427	5836	+ .0020	Tremko
38497.5455	5896	− .0006	Tremko
38789.977	6426	.000	Fitch
41097.4247	10608	+ .0006	Tremko
41338.5408	11045	− .0010	Tremko

the elements the $O-C$ values between the observed and the calculated epochs of maxima in accordance with the elements (4) as well as other data whose meaning is obvious, and which need no further explanation. The run of the $O-C$ in Fig. 11 shows that the deviations are randomly distributed, further, that it is possible to express the light changes well by the elements (4), and that the short-term period changes did not occur during the last years of observations.

For an explanation of the secular changes of the period all epochs of maxima given in Table 8, were used. The computation of the secular changes has been executed by means of high speed computer GIER of the Slovak Academy of Sciences in Bratislava. In Table 8 are listed the results of the calculation of the secular changes of the period. The values of $O-C$ in column 3 a refer to the elements (5) in which the term qE^2 has been applied. The elements have the following form:

$$Max_{hel.} = \text{J.D. } 2421402.4238 + 0^d.551759337 \cdot E$$
$$\pm\ 0019 \pm 0.000000232$$
$$- 368.10^{-13} \cdot E^2 \pm$$
$$\pm\ 66.10^{-13}. \qquad (5)$$

The observations exceeding the time interval of 45000 periods, are well approximated by the elements (5). Table 8 shows that the conclusions of Tsesevich (1966) about a constant period of the light changes of the variable W CVn are erroneous. Fig. 12 showing the difference in observation − calculation indicates that the elements (5) satisfy the observations, and that there are no deviations of a systematic character present.

Table 8

1	2	3	4	5
$Max_{hel.}$ J.D.2400000+	E	$O-C$	Observer	Notes
15804.828	− 10145	+ 0.006	Payne-Gaposchkin	pg
20251.450	− 2086	− 0.003	Zinner	v
21077.980	− 588	− 0.009	Robinson	pg
21402.427	0	+ 0.003	Blažko	v
22081.6350	+ 1231	− 0.0044	Jordan	pg
22839.7576	+ 2605	+ 0.0010	Jordan	pg
24621.380	+ 5834	− 0.007	Parenago	pg
26477.504	+ 9198	+ 0.001	Detre	phm
26483.575	+ 9209	+ 0.003	Detre	phm
26488.542	+ 9218	+ 0.004	Detre	phm
26509.508	+ 9256	+ 0.003	Detre	phm
26520.545	+ 9276	+ 0.005	Detre	phm
26540.406	+ 9312	+ 0.003	Detre	phm
26556.407	+ 9341	+ 0.002	Detre	phm
26908.437	+ 9979	+ 0.011	Detre	phm
27260.457	+ 10617	+ 0.009	Detre	phm
27281.426	+ 10655	+ 0.011	Detre	phm
27311.200	+ 10709	− 0.010	Radlova	v
27543.4939	+ 11130	− 0.0067	Kleissen	pg
27558.390	+ 11157	− 0.008	Soloviev	v
27628.468	+ 11284	− 0.004	Soloviev	v
27927.516	+ 11826	− 0.009	Soloviev	v
27955.663	+ 11877	− 0.001	Soloviev	v
28305.4779	+ 12511	− 0.0012	Kleissen	pg
29360.431	+ 14423	− 0.010	Nachapkin	v
29456.447	+ 14597	0.000	Tremko	pg
29461.422	+ 14606	+ 0.009	Tremko	pg
33453.391	+ 21841	+ 0.009	Tremko	pg
34130.377	+ 23068	− 0.012	Alania	pg
34457.580	+ 23661	− 0.001	Tremko	pg
35244.3875	+ 25087	+ 0.0004	Detre	pe
35601.394	+ 25734	+ 0.020	Geyer	pg
36232.5813	+ 26878	− 0.0034	Geyer	pe
36305.4155	+ 27010	− 0.0011	Detre	pe
36343.4895	+ 27079	+ 0.0016	Detre	pe
36348.4570	+ 27088	+ 0.0034	Detre	pe
36573.5685	+ 27496	− 0.0021	Detre	pe
36574.6705	+ 27498	− 0.0036	Detre	pe
36648.6094	+ 27632	− 0.0002	Detre	pe
36877.601	+ 28047	+ 0.002	Satanova	pg
37025.458	+ 28315	− 0.002	Ahnert	v
38085.3844	+ 30236	− 0.0010	Tremko	pe
38448.4414	+ 30894	− 0.0003	Tremko	pe
38450.6447	+ 30898	− 0.0038	Tremko	pe
38464.4427	+ 30923	+ 0.0002	Tremko	pe
38497.5455	+ 30983	− 0.0024	Tremko	pe
38789.977	+ 31513	− 0.0022	Fitch	pe
41097.4247	+ 35695	− 0.0016	Tremko	pe
41134.3994	+ 35762	+ 0.0053	Tremko	pe
41338.5408	+ 36132	− 0.0033	Tremko	pe

It seems that there is some printing error, in Geyer's paper (1961) because such a large deviation of the observed epoch of maximum from the calculated one is unikely. Table 9 and 10 list the recent observations obtained at the Skalnate Pleso Observatory.

Table 9
Blue observations

J.D.$_{hel.}$	B
2439970.5617	11.145
5625	11.138
.5630	11.155
.5642	11.167
,5652	11.149
.5660	11.156
.5668	11.174
.5679	11.184
.5689	11.155
.5697	11.147
.5749	11.170
.5760	11.098
.5768	11.082
.5776	11.203
.5796	11.192
.5805	11.078
.5814	11.094

Table 10
Yellow observations

J.D.$_{hel.}$	V		
2441097.3493	10.902	2441097.3757	10.512
3500	10.895	.3764	10.456
3507	10.881	.3771	10.483
3514	10.884	.3778	10.464
3521	10.888	.3785	10.428
3528	10.864	.3792	10.423
.3535	10.884	.3794	10.433
.3542	10.871	.3806	10.419
.3549	10.865	.3813	10.411
.3556	10.872	.3820	10.367
.3564	10.826	.3827	10.387
.3571	10.798	.3834	10.376
.3578	10.846	.3841	10.374
.3585	10.819	.3848	10.399
.3612	10.748	.3855	10.389
.3619	10.748	.3862	10.371
.3626	10.772	.3889	10.347
.3633	10.813	.3896	10.346
.3640	10.778	.3903	10.317
.3647	10.752	.3910	10.314
.3654	10.722	.3917	10.319
.3661	10.697	.3924	10.294
.3668	10.691	.3931	10.279
.3675	10.724	.3938	10.287
.3682	10.621	.3945	10.297
.3689	10.619	.3952	10.271
.3696	10.654	.3959	10.229
.3703	10.610	.3965	10.244
.3710	10.607	.3972	10.224
.3717	10.621	.3979	10.234
.3743	10.491	.3986	10.236
.3750	10.499	.3993	10.239

Continuation Table 10

2441097 4000	10.203	2441338 .4648	10.923
.4007	10.192	.4656	10.911
.4036	10.188	.4664	10.939
.4043	10.191	.4673	10.898
.4050	10.173	.4683	10.924
.4057	10.182	.4724	10.828
.4064	10.151	.4731	10.845
.4071	10.172	.4738	10.841
.4078	10.131	.4745	10.829
.4085	10.124	.4753	10.829
.4092	10.162	.4761	10.835
.4098	10.126	.4770	10.804
.4105	10.103	.4777	10.811
.4112	10.098	.4784	10.806
.4119	10.067	.4792	10.798
.4126	10.071	.4800	10.785
.4133	10.077	.4807	10.763
.4140	10.095	.4828	10.732
.4147	10.084	.4840	10.693
.4154	10.096	.4848	10.689
.4161	10.097	.4857	10.658
.4168	10.084	.4864	10.626
.4175	10.073	.4874	10.623
.4182	10.087	.4882	10.599
.4189	10.065	.4889	10.584
.4196	10.081	.4901	10.556
.4223	10.068	.4910	10.530
.4230	10.049	.4918	10.463
.4237	10.026	.4947	10.438
.4244	10.072	.4956	10.415
,4251	10,081	.4963	10.407
.4258	10.043	.4970	10.389
.4265	10.047	.4977	10.406
.4272	10.030	.4989	10.401
.4279	10.049	.5000	10.382
.4285	10.059	.5008	10.385
.4291	10.052	.5016	10.391
.4297	10.096	.5025	10.389
.4307	10.081	.5057	10.356
.4314	10.070	.5064	10.342
2441134.3935	10.085	.5084	10.341
.3945	10.091	.5094	10.330
.3953	10.084	.5101	10.329
.3963	10.076	.5109	10.315
.3973	10.079	.5117	10.315
.3982	10.061	.5125	10.320
.3991	10.074	.5131	10.284
.4003	10.056	.5141	10.274
.4012	10.112	.5154	10.257
.4023	10.080	.5162	10.247
.4068	10.093	.5168	10.248
.4077	10.139	.5192	10.223
.4086	10.150	.5199	10.211
2441338.4578	10.958	.5205	10.196
.4587	10.964	.5211	10.202
.4595	10.956	.5221	10.182
.4604	10.949	.5230	10.165
.4613	10.927	.5238	10.158
.4622	10.921	.5248	10.157
.4633	10.922	.5255	10.146
.4641	10.922	.5262	10.142
		.5272	10.138

Continuation Table 10

-2441338 .5302	10.122	2441338 .5470	10.105
.5308	10.110	.5478	10.083
.5314	10.124	.5488	10.090
.5321	10.099	.5502	10.118
.5326	10.110	.5516	10.133
.5335	10.103	.5529	10.136
.5344	10.101	.5539	10.157
.5353	10.092	.5560	10.173
.5361	10.079	.5579	10.175
.5369	10.081	.5586	10.150
.5407	10.080	.5598	10.160
.5418	10.052	.5606	10.147
.5430	10.088	.5612	10.126
.5440	10.094	.5622	10.218
.5448	10.098	.5631	10.148
.5458	10.087		

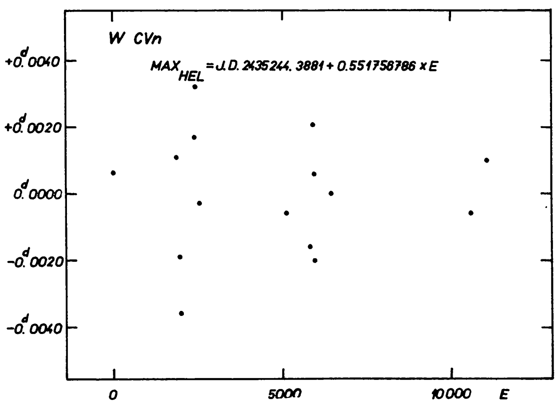

Fig. 1. The deviation of the observed epochs of maxima from the elements (4).

b) *TT Lyncis*

Despite the fact, that it is a bright, short period cepheid variable, TT Lyn has been discovered only in 1949. It was observed very sporadicaly and insufficiently. The first photoelectric observations were obtained by Jones (1966) and Sturch (1966). The most extensive observing material has been obtained at Skalnaté Pleso Observatory. The discussion of our material, obtained before 1967, and equally, of other visual and photographic observations, is published in the preceding paper (Tremko 1968b).

The earlier visual and photographic observations have an unusually great dispersion. Because the photoelectric epochs of maxima, interpreted in the preceding paper (Tremko 1968b), have been obtained on a short time scale of 3025 periods only, it was not possible to determine these elements reliably. For this reason the observational material has continuosly been collected until the present time, making the period of photoelectric observations 2.5 times the original. The colour characteristics, the form of the light curve, the interstellar absorption, and the distance of the variable were discussed in the variable were discussed in the preceding paper (Tremko 1968b). Therefore, have we confined ourselves, first of all, to the computation of new elements and to a study of possible secular changes of the period.

During the years 1970–1972, 277 photoelectric observations were made, by means of 60 cm re-

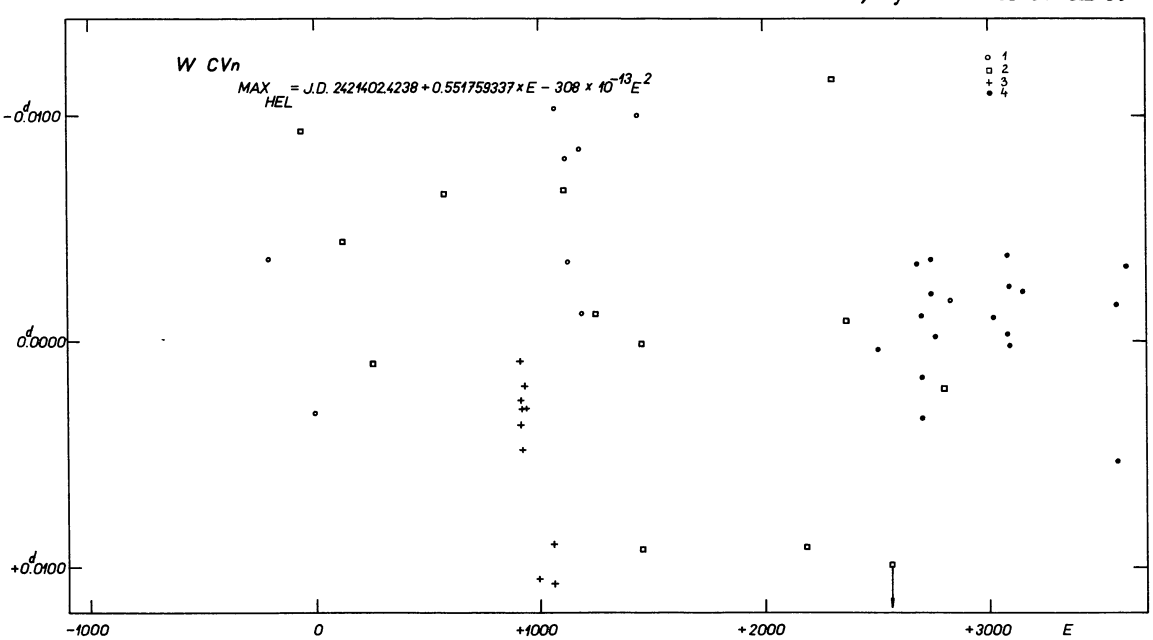

Fig. 12. The deviation of the observed epochs of maxima from the elements (5). 1 – visual observations, 2 – photographic observations, 3 – photometric observations, 4 – photoelectric observations.

flector at Skalnaté Pleso Observatory, in the V region, using the photoelectric photometer, described in the preceding chapters of this paper, or by the automated photoelectric photometer, which will be described later. The list of the times of observations and the numbers of observations is summarised in Table 11.

Table 11

Observing intervals

Date	J.D.$_{hel.}$	n	Notes
1970 March 10/11	2440656.3567 – .4268	44	
March 16/17	2440662.4842 – .5927	79	1
1971 May 12/13	2441084.3311 – .4020	44	2
1972 Jan. 13/14	2441330.3975 – .5035	110	

Notes: 1 – Interfering fog. 2 – Bad transparency.

For the computation of the period all published epochs of the maxima have been used with the exception $E = -1758$ and $E = -1555$. These visual epochs of the maxima differ from those calculated with the elements (6) by more than $0^{d}.12$. Thus a total of 38 epochs of the maxima for the calculation of the period has been used. The resulting elements are as follows:

$$\mathrm{Max._{hel.}} = \mathrm{J.D.}2436651.3479 + 0^{d}.59742688 \cdot E \pm \pm .0037 \pm 0.00000175. \quad (6)$$

Table 12 contains the heliocentric epochs of the maxima and the $O - C$ data. In column 3 of Table 12 there are the differences in observation - calculation obtained with the elements (6). The data marked by an asterisk have not been used for the calculation of the elements (7). Those marked by the symbol + + have not been used for the calculation of the elements (6).

Table 12

Max.$_{hel.}$	E	$(O - C)_6$	$(O - C)_7$		Notes
1	2	3	4	5	6
2400000 +					
35599.33	– 1761 +	+ 0.03	+ 0.06	Tsesevich	v
35601.25	– 1758 + +	+ .16	+ .18	Tsesevich	v
35608.31	– 1746 +	+ .04	+ .07	Tsesevich	v
35626.774	– 1715 +	– .012	+ .018	Ahnert	v
35722.50	– 1555 + +	+ .13	+ .15	Tsesevich	v
35747.54	– 1513 +	+ .07	+ .10	Tsesevich	v
35753.45	– 1503 +	+ .01	+ .04	Tsesevich	v
36229.60	– 706 +	+ .01	+ .03	Ahnert	pg
36232.58	– 701 +	+ .00	+ .03	Ahnert	pg
36274.40	– 631 +	+ .00	+ .03	Ahnert	pg
36287.53	– 609 +	– .01	+ .01	Ahnert	pg
36609.5275	– 70 +	– .0275	– .0081	Tremko	pg
36611.32	– 67 +	– .03	– .01	Ahnert	v
36611.3307	– 67 +	– .0165	+ .0028	Tremko	pg
36626.30	– 42 +	+ .02	+ .04	Ahnert	v
36630.44	– 35 +	– .03	– .01	Ahnert	v
36651.3586	0	– .0163	+ .0026	Detre	pe
36663.32	+ 20 +	– 0.00	+ 0.02	Ahnert	v
36679.4361	+ 47	– .0179	+ .0007	Detre	pe
36961.4210	+ 519 +	– .0189	– .0034	Tremko	pg
37016.404	+ 611 +	+ .001	– .016	Ahnert	v
37017.567	+ 613 +	– .031	– .016	Ahnert	v
37026.553	+ 628 +	– .007	+ .008	Ahnert	v
37028.353	+ 631 +	+ .001	+ .016	Ahnert	v
37321.6797	+ 1122	– .0091	+ .0024	Tremko	pe
37327.6496	+ 1132	– .0134	– .0021	Tremko	pe
37669.3825	+ 1704	– .0092	– .0016	Tremko	pe
37673.5664	+ 1711	– .0073	+ .0002	Tremko	pe
37696.2665	+ 1749	– .0094	– .0022	Tremko	pe
38378.5371	+ 2891	– .0012	– .0016	Tremko	pe
38381.5247	+ 2896	– .0008	– .0012	Tremko	pe
38400.6420	+ 2928	– .0012	– .0018	Tremko	pe
38406.6288	+ 2938	+ .0014	+ .0007	Tremko	pe
38408.4113	+ 2941	+ .0016	+ .0009	Tremko	pe
38414.3861	+ 2951	+ .0021	+ .0013	Tremko	pe
38415.5800	+ 2953	+ .0011	+ .0004	Tremko	pe
38418.5668	+ 2958	+ .0008	+ .0000	Tremko	pe
38458.5951	+ 3025	+ .0014	+ .0002	Tremko	pe
40662.5330	+ 6714	+ .0287	+ .0027	Tremko	pe
41330.4609	+ 7832	+ .0323	– .0010	Tremko	pe

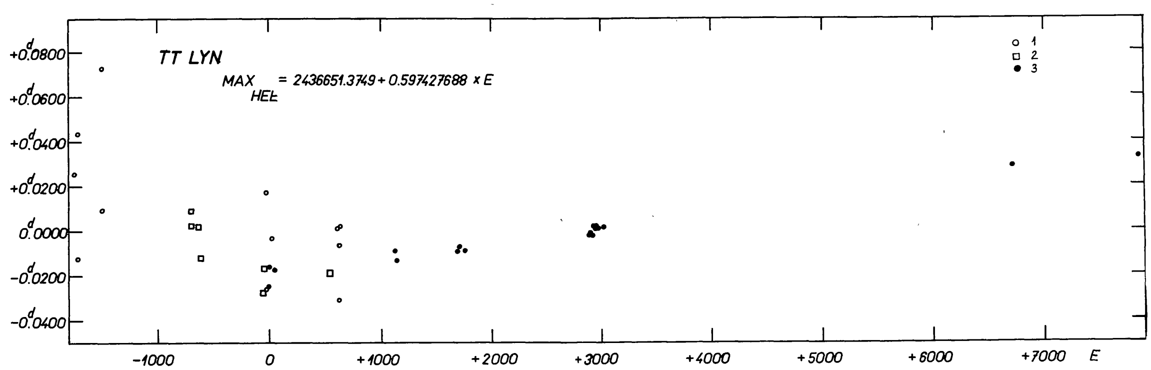

Fig. 13. The deviation of the observed epochs of maxima from the elements (6). 1 – visual observations, 2 – photographic observations, 3 – photoelectric observations.

From the analysis of the data in column 3 of Table it is evident that the visual and photographic observations show too large a dispersion. Fig. 13 in which the deviation of the observed epochs from the elements (6) has been represented, testifies to the secular change of the period, namely, to its increase.

In order to clarify the question of variability or constancy of the period of the light changes, all epochs of the maxima obtained from visual and photographic observations, which show a considerably larger scatter than the photoelectric epochs, were excluded from the treatment. For computation only the photoelectric epochs of the maxima, obtained at the Konkoly Observatory and Skalnate Pleso Observatory have been used. The time interval of observation has thus been shortened by leaving out all epochs of maxima whit $E < O$. The shortening of the time of observation, as seen from Table 12, is not considerable. From the photoelectric epochs of maxima with $E < O$ we have derived the following elements:

$$\text{Max}_{\text{hel.}} = \text{J.D.}2436651.3560 + 0^{d}.597434355 . E \pm \pm .0007 \pm 0.000000198. \quad (7)$$

Comparing elements (6) and (7), it can be seen, that the mean error of the determination of the period in the second case is smaller by an order of magnitude, despite the fact that the number of epochs of maximum in this latter case is only half that of the former. The accuracy of the computation of the elements (6) decreased on account of the large scatter of the epochs of maxima with $E < -1503$. Column 4 of Table 12 contains the $O - C$ deviations of the observed epochs using the elements (7). In Fig. 14 the $O - C$' s resulting from the elements (7) have been represented graphically. Table 13 contains the photoelectric observations carried out at the Skalnaté Pleso Observatory during the years 1970–1972.

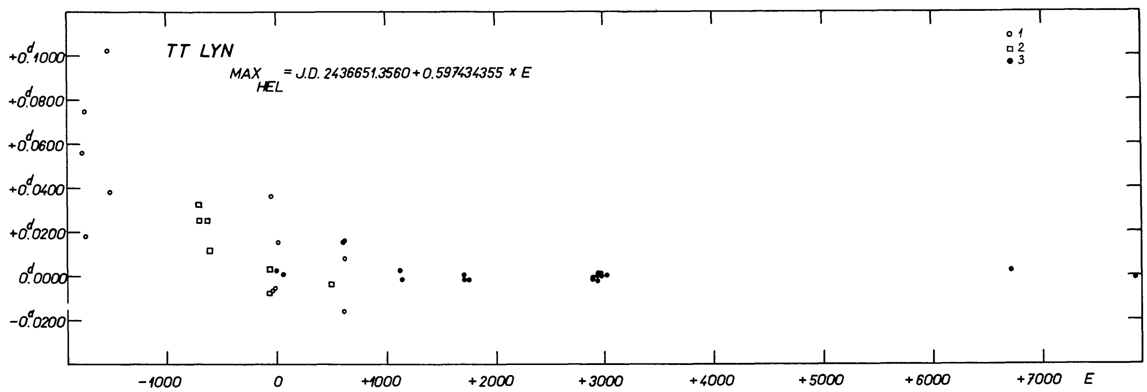

Fig. 14. The deviation of the observed epochs of maxima from the elements (7). 1 – visual observations, 2 – photographic observations, 3 – photoelectric observations.

Table 13

Yellow observations

J.D.hel.	V	J.D.hel.	V
2440656.3567	10.134	2440656.3807	10.116
.3577	10.134	.3816	10.136
.3586	10.131	.3828	10.125
.3598	10.134	.3836	10.107
.3607	10.134	.3847	10.095
.3617	10.140	.3856	10.086
.3626	10.137	.3868	10.093
.3637	10.135	.3877	10.118
.3667	10.147	.3890	10.137
.3675	10.142	.3997	10.183
.3685	10.153	.4008	10.188
.3696	10.150	.4017	10.171
.3707	10.156	.4046	10.166
.3716	10.155	.4058	10.173
.3786	10.128	.4066	10.159
.3797	10.126	.4078	10.168

2440656.4087	10.181	2440662.4904	9.634
.4097	10.184	.4939	9.610
.4107	10.195	.4947	9.611
.4165	10.186	.4953	9.617
.4188	10.185	.4961	9.639
.4197	10.187	.4967	9.618
.4206	10.168	.4974	9.631
.4226	10.146	.4982	9.658
.4237	10.139	.4988	9.634
.4248	10.148	.4995	9.640
.4257	10.160	.5001	9.622
.4268	10.169	.5142	9.501
2440662.4842	9.698	.5149	9.501
.4849	9.651	.5156	9.511
.4855	9.695	.5163	9.496
.4863	9.742	.5170	9.490
.4870	9.727	.5177	9.502
.4876	9.684	.5183	9.501
.4884	9.671	.5191	9.487
.4891	9.660	.5198	9.491
.4897	9.642	.5205	9.500
		.5294	9.469

Continuation Table 13

2440662.5301	9.487	2441084.3659	9.546
.5336	9.453	.3669	9.538
.5343	9.479	.3679	9.666
.5350	9.460	.3687	9.692
.5357	9.458	.3694	9.694
.5364	9.464	.3706	9.712
.5371	9.450	.3714	9.660
.5377	9.454	.3724	9.703
.5384	9.450	.3762	9.724
.5391	9.459	.3769	9.724
.5398	9.465	.3779	9.603
.5483	9.480	.3787	9.591
.5489	9.481	.3798	9.632
.5503	9.484	.3810	9.666
.5510	9.501	.3827	9.761
.5517	9.505	.3838	9.681
.5524	9.485	.3849	9.691
.5551	9.509	.3860	9.661
.5558	9.534	.3871	9.697
.5566	9.532	.3881	9.694
.5572	9.501	.3889	9.693
.5579	9.492	.3941	9.757
.5586	9.503	.3949	9.727
.5593	9.519	.3957	9.790
.5600	9.538	.3965	9.775
.5607	9.552	.3972	9.792
.5614	9.551	.3981	9.740
.5669	9.547	.3990	9.773
.5675	9.543	.4013	9.802
.5682	9.528	.4020	9.879
.5689	9.520	2441330.3975	9.900
.5697	9.536	.3982	9.877
.5704	9.536	.3990	9.869
.5711	9.547	.3997	9.860
.5718	9.558	.4004	9.856
.5809	9.571	.4013	9.851
.5816	9.587	.4058	9.742
.5823	9.608	.4068	9.753
.5864	9.596	.4075	9.748
.5871	9.593	.4081	9.737
.5878	9.618	.4090	9.731
.5885	9.583	.4097	9.731
.5892	9.608	.4104	9.728
.5899	9.592	.4111	9.726
.5906	9.567	.4118	9.712
.5913	9.581	.4125	9.711
.5920	9.611	.4180	9.704
.5927	9.526	.4187	9.712
2441084.3311	9.512	.4195	9.699
.3325	9.495	.4202	9.700
.3428	9.492	.4209	9.697
.3435	9.517	.4216	9.692
.3444	9.495	.4223	9.686
.3528	9.473	.4230	9.685
.3543	9.545	.4237	9.672
.3550	9.504	.4243	9.682
.3558	9.566	.4250	9.670
.3567	9.589	.4257	9.669
.3617	9.574	.4264	9.669
.3626	9.563	.4295	9.641
.3634	9.558	.4303	9.641
.3642	9.545	.4309	9.630

2441330.4318	9.632	2441330.4723	9.508
.4325	9.621	.4734	9.506
.4333	9.614	.4742	9.507
.4340	9.614	.4749	9.510
.4349	9.613	.4755	9.511
.4356	9.591	.4762	9.513
.4363	9.596	.4769	9.521
.4371	9.585	.4776	9.518
.4379	9.588	.4783	9.520
.4387	9.585	.4790	9.516
.4395	9.581	.4797	9.526
.4402	9.571	.4804	9.524
.4410	9.565	.4811	9.527
.4456	9.538	.4817	9.539
.4463	9.539	.4848	9.533
.4471	9.533	.4855	9.540
.4480	9.531	.4861	9.544
.4487	9.523	.4868	9.561
.4495	9.525	.4875	9.550
.4501	9.505	.4882	9.547
.4508	9.510	.4889	9.551
.4513	9.507	.4896	9.555
.4522	9.498	.4903	9.551
.4529	9.505	.4910	9.551
.4536	9.503	.4917	9.550
.4542	9.495	.4923	9.552
.4549	9.499	.4930	9.557
.4591	9.490	.4973	9.578
.4599	9.487	.4980	9.586
.4606	9.480	.4987	9.580
.4613	9.488	.4994	9.588
.4621	9.492	.5001	9.595
.4629	9.489	.5008	9.590
.4636	9.493	.5014	9.589
.4642	9.490	.5021	9.596
.4649	9.490	.5028	9.611
.4656	9.490	.5035	9.611
.4662	9.482		
.4669	9.484		
.4676	9.497		
.4682	9.490		

We have confirmed the conclusion reached about the variable TT Lyn, published in the precedent paper (Tremko 1968c), and we have derived more accurate elements on the basis of the new photoelectric observations made by us.

c) *VY Serpentis*

Despite the fact, that VY Serpentis was discovered 40 years ago and that it is a relatively bright variable star, it received no attention for a long time. An interpretation of the visual observation made by Tsesevich in 1944 and Ustinov in 1949, has shown that the period of the light changes, $P = 0\overset{d}{.}416$ as published in General Catalogue of

Variable Stars (Kukarkin and Parenago 1948), is wrong (Ustinov and Odynskaya 1952). In accordance with the calculation of Ustinov and Odynskaya, the correct epriod is $P = 0^d.71409384$. The photoelectric observations in the V region have been obtained by means of 24-inch reflector the at the Skalnate Pleso Observatory. A total of 104 photoelectric observations during four nights were obtained. The photoelectric observations were transformed to the standard photometric system Johnson and Morgan (1953) and they are given in Table 16. Table 14 also contains the basic data about the intervals of observation.

Table 14

Observing intervals

Data	$J.D._{hel.}$	n
1961 Apr. 21/22	2437411.3818-.5971	47
June /July 30/1	2437481.3848-.4792	31
1961 July 2/3	2437483.4013-.4575	22
July 11/12	2437492.3791-.3867	4

The three colour photoelectric observations of a portion of the light curve, including the regions of the maximum and the minimum of the brightness have been published by Fitch et al. (1966). From his and our observations (this paper) it was possible to derive two epochs of the maximum which have extended the interval of observation. For calculation of a new period of light changes, the epochs of maxima, published by Ustinov and Odynskaya (1952), Karetnikov (1962), Fitch et al. (1966) and one derived from our photoelectric observations (this paper) have been used. From the interpretation two epochs of maximum, namely $Max_{hel.}$= J.D. 2431248.252, which differs from the calculated value by about $+0^d.064$ and $Max_{hel.}$= = J.D. 2437192.2465, which differs from the calculated epoch of macimum by about $-0^d.055$ have been eliminated. The deviations of these observed epochs of maximum from the calculated epochs are twice as large as the deviations of the remaining epochs od maxima of this variable. The calculation based on 22 epochs of the maximum gives the following elements:

$$Max_{hel.} = J.D.\ 2431225.3375 + 0^d.71409338 \cdot E \pm \pm .0035 \pm 0.00000069. \quad (8)$$

Table 15 contains all epochs of maximum published, up to this time and other data and the results of the computations, which are all self-explanatory. The epochs eliminated from this work have been marked by an asterisk. The values $O - C$ from Table 15 column 3 have been represented graphically in Fig. 15.

Table 15

$Max_{hel.}$ 2400000+	E	$O-C$	Observer	Notes
1	2	3	4	5
26826.503	-6160	-0.019	Lause	v
26834.400	-6149	- .023	Lause	v
26841.494	-6139	- .024	Lause	v
26851.503	-6125	- .013	Lause	v
26861.527	-6111	+ .014	Lause	v
26889.380	-6072	+ .018	Lause	v
26894.371	-6065	+ .010	Lause	v
26919.360	-6030	+ .006	Lause	v
31225.338	0	+ .001	Tsesevich	v
31230.368	+ 7	+ .032	Tsesevich	v
31232.450	+ 10	- .028	Tsesevich	v
31235.328	+ 14	- .007	Tsesevich	v
31242.450	+ 24	- .026	Tsesevich	v
31245.320	+ 28	- 012	Tsesevich	v
31248.252	+ 32	+ .064	Tsesevich	v
31260.324	+ 49	- .004	Tsesevich	v
31265.338	+ 56	+ .011	Tsesevich	v
31270.335	+ 63	+ .010	Tsesevich	v
33003.422	+2490	- .008	Ustinov	v
33058.427	+2567	+ .012	Ustinov	v
37172.3112	+8328	+ .0040	Karetnikov	v
37192.2465+	+8356	- .0553	Karetnikov	v
37411.5310	+8663	+ .0025	Tremko	pe
39213.901	+11187	+ .001	Fitch	pe

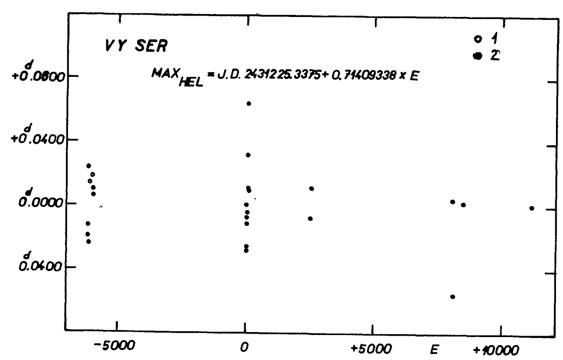

Fig. 15. The deviation of the observed epochs of maxima from the elements (8). 1 – visual observations, 2 – photoelectric observations.

An analysis of the $O - C$ values from the elements (8) shows that the period of VY Ser remained constant during the whole interval of observations. The large values of $O - C$ and the errors in the elements are due to errors of the epochs, derived from visual observations.

Table 16
Yellow observations

J.D.$_{hel.}$	V	J.D.$_{hel.}$	V
2437411.3818	10.517	2437481.4403	10.020
.3853	10.486	.4424	9.992
.3908	10.470	.4445	9.981
.3971	10.501	.4473	10.001
.3998	10.474	.4493	10.009
.4026	10.471	.4514	9.976
.4061	10.465	.4542	9.981
.4096	10.505	.4556	10.018
.4130	10.437	.4591	9.949
.4172	10.386	.4612	9.954
.4207	10.408	.4632	9.952
.4248	10.407	.4646	9.947
.4297	10.373	.4674	9.923
.4325	10.371	.4685	9.922
.4360	10.325	.4723	9.940
.4401	10.256	.4743	9.848
.4436	10.226	.4771	9.806
.4471	10.173	.4792	9.783
.4505	10.125	2437483.4013	10.380
.4547	10.102	.4027	10.417
.4587	10.023	.4055	10.393
.4624	10.023	.4076	10.391
.4860	9.946	.4110	10.394
.4894	9.935	.4131	10.386
.4929	9.918	.4157	10.394
.4964	9.879	.4180	10.408
.4998	9.878	.4208	10.391
.5033	9.856	.4235	10.415
.5068	9.830	.4263	10.425
.5144	9.832	.4291	10.408
.5186	9.797	.4319	10.408
.5290	9.808	.4333	10.434
.5325	9.822	.4395	10.382
.5415	9.831	.4416	10.437
.5450	9.828	.4451	10.397
.5512	9.827	.4472	10.467
.5544	9.851	.4506	10.430
.5589	9.857	.4531	10.483
.5623	9.866	.4554	10.504
.5658	9.865	.4575	10.487
.5693	9.876	2437492.3791	10.038
.5728	9.863	.3812	10.038
.5762	9.878	.3846	10.124
.5797	9.887	.3867	10.176
.5832	9.938		
.5950	9.904		
.5971	9.852		
2437481.3848	10.465		
.3875	10.463		
.3896	10.454		
.3924	10.454		
.4181	10.454		
.4236	10.192		
.4257	10.181		
.4278	10.119		
.4299	10.123		
.4320	10.061		
.4341	10.058		
.4361	10.046		
.4375	10.034		

d) *The distance modulus of W CVn, TT Lyn and VY Ser.*

The observed stars are situated at different galactic longitudes, the star VY Ser being in the direction to the galactic centre, and TT Lyn in the direction to the galactic anticentre. The galactic latitude of these three stars are greater than 40°. A visual inspection of the Palomar Observatory Sky Survey charts of those region where the observed stars are situated, showed that in the direction of the above reported stars, or in their nearest surroundings, there is no obvious great accumulation of interstellar matter and for this reason, the interstellar absorption is very small. For a calculation of a distance modulus the modified period-luminosity-colour relation for variable stars of the RR Lyr type, derived by Fernie (1965) was used:

$$(m - M)_0 = V + 0.83 + 2.50 \log P - K\,(B - V) - - (R - K)\,E_{B-V}. \qquad (9)$$

The symbols in the equation (9) are as follows: R – the ratio of the total to the selection absorbtion and K numerical factor, which characterises the light and colour variation. The other symbols are self-explanatory. On the basis of this relation, from a set of photometric observations of V and $(B - V)$, and from the well known length of the of the period of light changes, it is possible to compute the distance of the variable star. The numerical factor K in the relation (9) has a mean value of 2.96 derived from a sample of 32 RR Lyr stars, and for different stars it could reach the extreme values from 2.1 to 5.1 (Fernie 1965). In the cases when the slope of the dependence V and $(B - V)$ differs substantially from the value of R, the last term in the equation (9) cannot be neglected and the factor of the term $(B - V)$ will also change. Consequently, we have constructed a dependence between the quantities V and $(B - V)$ for each star on the basis of our observations (Tremko 1968b, Tremko 1968c, this paper) and the observations published by Fitch et al. (1966) were utilized for VY Ser. Figures 16, 17 and 18 show the relation between the V and $(B - V)$ values.

Since the Blažko effect has not been found in case of the observed stars and the light curves appear to be stable for all practical purposes, in view of the large number of observations needed for calculating the relation between V and $(B - V)$, have utilized data derived from mean light curves instead of individual observations. Table 17 contains basic data on three studied variable stars.

It is assumed that the stars which are more than 100 pc above the galactic plane and have a great

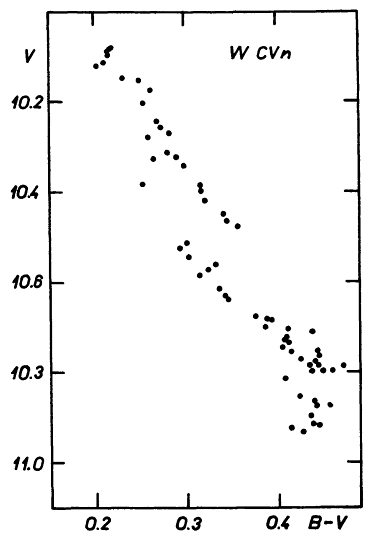

Fig. 16. The V and $B - V$ relation of W CVn.

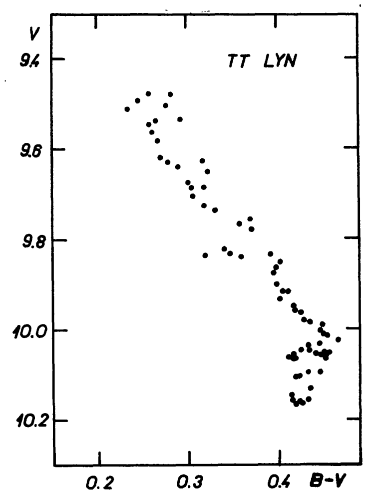

Fig. 17. The V and $B - V$ relation of TT Lyn.

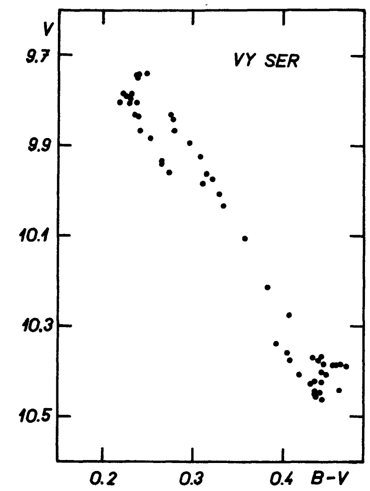

Fig. 18. The V and $B - V$ relation of VY Ser.

galactic latitude, are reddened by 0.05 x cosec b (Woolley and al. 1965). The investigation performed by Sturch (1966) has shown that the value for the reddening term for the stars with $b > 56^\circ$

Table 17

Star	log P	K	$(m-M)_0$	E_{B-V}
W CVn	0.74175 − 1	2.830	9.717	0.034
TT Lyn	0.77629 − 1	3.015	9.025	0.075
VY Ser	0.85375 − 1	3.146	9.486	0.073

is 0.02 x cosec b if the excesively reddened regions in Taurus and Ophiuchus are omitted, but the stars with $b > 70^\circ$ are kept. The latter relation was used for the calculation of the reddening of W CVn. The numerical value 3.03 for the ratio of total to selective absorption derived by Wickramasinghe (1967) was accepted.

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REFERENCES

Balasz, J., Detre, L., 1954: Mitt. der Sternw. der UAdW, Budapest, No. 33.

Fernie, J.D., 1965: Astrophys. J., *141*, 1411.

Fitch, W.S., Wisniewski, W.Z., Johnson, H.L., 1966: Commun. Lunar and Planet. Lab., No. 71.

Geyer, E., 1961: Z. Astrophys., *52*, 229.

Hajda, J., Tischler, J., 1961: Final Report on the Instrument for the Observation of the light changes of Variable Stars.

Johnson, H.L., 1963: Stars and Stellar Systems 3, Basic Astronomical Data K. Aa. Strand Ed., Univ. Chicago Press.

Johnson, H.L., Harris, III D.L., 1954: Astrophys, J., *120*, 196.

Johnson, H.L., Morgan, W.W., 1953: Astrophys. J., *117*, 313.

Johnson, D.H.P., 1966: Roy. Observ. Greenwich – Cape Bull., No. 112.

Karetnikov, V.G., 1962: VS Bull., *111*, 238.

Kukarkin, B.V., Parenago, P.P., 1948: General Catalogue of Variable Stars, Izd. Akad. Nauk, Moskva 1948.

Mitchell, R.I., 1960: Astrophys. J., *132*, 68.

Mrkos, A., Tremko, J., Vanysek, V., 1968: Bull. Astron. Inst. Czechoslov. *19*, 43.

Sturch, C., 1966: Astrophys. J., *143*, 774.

Tremko, J., 1964: Mitt. der Sternw. der 7'd2, Budapest, No. 55.

Tremko, J., 1968a: Mitt. der Sternw. der UAdW, Budapest, in press.

Tremko, J., 1969: Bull.Astron.Inst.Czechoslov., *20*, 81.

Tremko, J., Růžičková, B., 1960: Bull. Astron. Inst. Czechoslov. *11*, 75.
Tremko, J., Sajtak, D., 1964: Bull. Astron. Inst. Czechoslov. *15*, 91.
Tremko, J., Vanýsek, V., 1964: Bull. Astron. Inst. Czechoslov., *15*, 233.
Tsesevich, V.P., 1966: Zvezdy Tipa RR Liry, Naukova dumka, Kijev.
Ustinov, B.A., Odynskaya, O.K., 1952: Izv. Astron. Observ. Odessa, Tom V., Vypusk II., 87.
Weaver, H.F. 1952: Astrophys. J., *116*, 612.
Wickramasinghe, N.C., 1967: Interstellar Grains, Chapman and Hall, London.
Woolley, Sir. R., Harding, G.A., Gassels, A.I., Saunders, J., 1965: Roy. Observ. Bull., 97.

FOTOELEKTRICKÁ FOTOMETRIA SO 60 CM REFLEKTOROM ASTRONOMICKÉHO ÚSTAVU NA SKALNATOM PLESE

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Resumé

V práci sa skúmajú vlastnosti fotoelektrického fotometra inštalovaného na 60 cm reflektore Astronomického observatória na Skalnatom Plese, jeho fotometrický systém a atmosferická extinkcia. Fotometer pracuje na princípe jednosmernej metódy, je osadený násobičom elektrónov 1 P 21 a pre záznam signálu sa používa elektronický líniový zapisovač EZ 4. Merania štandardných hviezd internacionálneho fotometrického UBV systému ukázali, že náš fotometrický systém je veľmi blízky systému UBV. Podrobná analýza hodnot transformačných koeficientov ukázala, že fotometrický systém sa nepatrne mení s teplotou.

Atmosferické podmienky v našich krajinách nie sú vynikajúce a sú limitujúcim faktorom presnosti. Z toho dovodu sledovaniu atmosferickej extinkcie, najma jej zmenám, venovala sa veľká pozornosť. Stredné hodnoty extinkčných koeficientov sú nasledujúce $k_1 = 0^m\!.186$, $k_2 = -0^m\!.022$, $k_3 = 0^m\!.176$, $k_5 = 0^m\!.334$. Azimutálny efekt v meridiáne na juh od zenitu dosahuje hodnotu približne $0^m\!.02$, pričom jeho hodnota sa mení od noci k noci.

Práca obsahuje interpretáciu fotoelektrických pozorovaní troch krátkoperiodických cefeíd: W CVn, TT Lyn a VY Ser. V rokoch 1968–1972 sa získalo 248 pozorovaní, z ktorých sa odvodili 2 epochy maxima. Z intervalu viac ako 45 000 epoch sa zistili sekulárne zmeny periódy premennej hviezdy W CVn. Nami odvodené elementy so sekulárnym členom majú nasledujúci tvar:

$$\begin{aligned} \mathrm{Max}_{\mathrm{hel.}} = \mathrm{J.D.}\ 2421402.4238 &+ 0.551759337 \,.\, E - 368 \,.\, 10^{-13} \,.\, E^2 \pm \\ \pm .0019 &\pm 0.000000232 \qquad \pm 66 \,.\, 10^{-13}. \end{aligned}$$

V rokoch 1970–1972 sa získalo 277 nových fotoelektrických pozorovaní, z ktorých sa odvodili 2 epochy maxima, čím sa interval fotoelektrických pozorovaní zvačšil 2,5 násobne. Tejto premennej hviezde sa v minulosti venovala na Skalnatom Plese veľká pozornosť, získal sa rozsiahly pozorovací materiál, z ktorého sa odvodili 3 fotografické a 16 fotoelektrických epoch maxima. Zistilo sa, že perióda svetelných zmien je konštantná a elementy odvodené z fotoelektrických epoch maxima, ktoré získali Detre a Tremko, majú tvar:

$$\begin{aligned} \mathrm{Max}_{\mathrm{hel.}} = \mathrm{J.D.}\ 2436651.3560 &+ 0^d\!.597434355 \,.\, E \pm . \\ \pm .0007 &\pm 0.000000198. \end{aligned}$$

Získalo sa 107 fotoelektrických pozorovaní premennej hviezdy VY Ser a odvodila sa jedna epocha maxima. Perióda svetelných zmien je konštantná a elementy majú tvar:

$$\begin{aligned} \mathrm{Max}_{\mathrm{hel.}} = \mathrm{J.D.}\ 2431225.3375 &+ 0.71409338 \,.\, E \pm . \\ \pm .0035 &\pm 0.00000069. \end{aligned}$$

Z fotoelektrických pozorovaní sa odvodila pre všetky tri premenné hviezdy funkcionálna závislosť medzi V a $B-V$, ktorá sa použila na výpočet modulu vzdialenosti pomocou vzťahu, ktorý odvodil Fernie. Hodnoty modulov vzdialenosti sú nasledujúce: W CVn 9.717, TT Lyn 9.025, VY Ser 9.486.

ФОТОЕЛЕКТРИЧЕСКАЯ ФОТОМЕТРИЯ С 60 СМ ЗЕРКАЛЬНЫМ ТЕЛЕСКОПОМ АСТРОНОМИЧЕСКОЙ ОБСЕРВАТОРИИ СКАЛНАТЕ ПЛЕСО

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Резюме·

В работе исследовались характеристики фотоэлектрического фотометра установленного на 60 cm зеркальном телескопе Астрономической Обсерватории Скалнате Плесо, его фотометрическая система и атмосферная экстинкция. фотоелектрический фотометр работает на принципе постоянного тока. В виде детектора используется электронный умножитель 1 P 21 и для регистрации сигнала используется самописец типа EZ 4. Наблюдения стандардных звезд международной фотометрической UBV системы показали, что наша фотометрическая система близка международной фотометрической системе UBV. Подробный анализ величин трансформационных коеффициентов показал, что фотометрическая система немножко меняется с температурой.

Атмосферные условия в районе обсерватории не выдающиеся и являются ограничивающим фактором точности наблюдений. По этим причинам уделялось большое внимание исследованию атмосферной экстинкции, особенно ее изменениям. Средние величины коеффициентов экстинкции следующие: $\varkappa_1 = 0^m.186$, $\varkappa_2 = -0^m.022$, $\varkappa_3 = 0^m.176$, $\varkappa_5 = 0^m.334$. Азимутальный эффект в меридиане на юг от зенита достигает около $0^m.02$, причем величина азимутального эффекта меняется от ночи к ночи.

Работа содержит интерпретацию фотоэлектрических наблюдений трех короткопериодических цефеид: W CVn, TT Lyn, VY Ser. В течении 1968—1972 г. мы получили 248 наблюдений W CVn, на основе которых мы получили две эпохи максимума. В промежутке времени, большем, чем 45000 периодов, мы обнаружили вековые изменения периода переменной звезды W CVn. Нами полученные элементы с вековым членом имеют следующую форму:

$$\text{Max}_{\text{hel.}} = \text{J.D. } 2421402.4238 + 0^d.551759337 \cdot E - 368 \cdot 10^{-13} \cdot E^2 \pm$$
$$\pm .0019 \pm 0.000000232 \quad \pm \quad 66 \cdot 10^{-13}.$$

В течение лет 1970—1972 мы получили 277 фотоэлектрических наблюдений переменной звезды TT Lyn, с помошю которых мы получили две эпохи максимума и таким образом интервал новые фотоэлектрических наблюдений увеличился с половины в два раза. В Астрономической обсерватории Скалнате Плесо этой переменной звезды уделялось большое внимание и было получено большое количество наблюдательного материала, с помошю которого мы получили 3 фотографических и 16 фотоэлектрических эпох максимума. Мы установили, ято период изменений света постоянный и элементы полученные на основе фотоэлектрических эпох максимума, которые получили Petre и Tremko имеют следующий вид:

$$\text{Max}_{\text{hel.}} = \text{J.D. } 2436651.3560 + 0^d.597434355 \cdot E \pm$$
$$\pm .0007 \pm 0.000000198.$$

Мы получили 107 фотоэлектрических наблюдений переменной звезды VY Ser, на основе которых мы получили одну эпоху максимума. Период изменений света постоянной и форма элементов следующая:

$$\text{Max}_{\text{hel.}} = \text{J.D. } 2431225.3375 + 0^d.71409338 \cdot E \pm$$
$$\pm 0035 \pm 0.00000069.$$

На основе фотоэлектрических наблюдений мы получили функциональную зависимость между величинами V и $B - V$ для всех трех переменных звезд. Эту зависимость мы использовали для вычисления модуля расстояния методом Fernie. Величины модулей расстояний следующие:
W CVn 9.717, TT Lyn 9.025, VY Ser 9.486.