A MAGYAR
TUDOMÁNYOS AKADÉMIA
CSILLAGVIZSGÁLÓ
INTÉZETÉNEK
KÖZLEMÉNYEI

MITTEILUNGEN
DER
STERNWARTE
DER UNGARISCHEN AKADEMIE
DER WISSENSCHAFTEN

BUDAPEST-SZABADSÁGHEGY

Nr. 67.

J. TREMKO
(Astronomical Institute of the Slovak Academy of Sciences,
Skalnate Pleso, Czechoslovakia)

THREE COLOUR PHOTOMETRY OF W CVn, LIGHT CURVE AND PERIOD

BUDAPEST, 1974

ABSTRACT

Three colour photoelectric observations of the variable W CVn obtained at Konkoly Observatory and at Skalnaté Pleso Observatory were interpreted. The investigation shows secular change of the period and a stable light curve. The interstellar absorption in the direction of the variable is discussed and the absolute magnitude from the period - luminosity relation was derived. Colour - colour diagram was constructed and distance of 980 pc for the variable was determined.

INTRODUCTION

The variable star W CVn belongs to the group of short period RRab Lyrae-type variables. It was discovered by Ceraski in 1907 on plates made by Blazko /Ceraski 1907/. Later was investigated by Zinner /1912, 1916/, who discovered an increase in brightness near the minimum light. She discovered similar increasing in brightness on the ascending branch and at the phase $0^{P}.47$. The last however changed its place in various cycles. Bugoslawski /1927/ discovered secondary oscillations on the light curve which recurred with a period of 0.16057 days. The period of secondary oscillations was not constant but changed during a cycle of 43.53 days. Photographic observations obtained by Jordan /1929/ and Robinson /1930/ did not confirm Bugoslawski's conclusions on periodic secondary oscillations. The light curves derived by both authors show a conspicuous wave close to the minimum. Similarly Parenago /1930/ found light curve to be smooth but the brightening before minimum escaped his attention. In the years 1931 - 1933 Detre /1934/ observed the variable by a Graff wedge photometer and collected 369 observations. According to his observations the light curve was smooth and the amplitude of the wave close to minimum was only $0^{m}.02$ which differed from the value $0^{m}.12$ previously found by Jordan /1929/. Later the star was observed visually or photographically by several observers /Radlova 1934/, /Kleissen 1938/, /Nachapkin 1940/, /Alania 1954/, /Strelkova 1960/, /Ahnert 1961/, /Satanova 1961/. Photoelectric observations are scarce with exception of those obtained at Konkoly Observatory and Skalnaté Pleso Observatory. Geyer /1961/ obtained UBV photoelectric observations in the range of the phase $0^{P}.8$ - $0^{P}.1$ and determined some photometric parameters of the variable. Sturch /1966/ obtained few UBV photoelectric observations for the program of colour indices of RR Lyrae-type stars near minimum light. The latest photoelectric observations are those obtained by Fitch et al. /1966/. Radial velocity was measured by Joy /1938/ who found a mean value of RV = + 26 km/sec. The spectrum of the variable is changing from A6 to F6 and Preston's quantity Δ S reaches a value of 7 /Woolley et al. 1965/.

OBSERVATIONAL MATERIAL AND REDUCTION

The variable was observed photographically at Konkoly Observatory in Budapest with 16-inch astrograph by the method of multiple exposures. Together 288 observations were obtained on the emulsion "Guilleminot superfulgur". No colour filter was used in the observations. The photographic material was measured and reduced by a method widely used also at other observatories. The brightnesses of the comparison stars were determined by the comparison with those from North Polar Sequence. The list of the photographic plates together with further data are given in Table I.

Table I.

J.D.	Date	Plate	N
2429373	20. Apr 1939	H 1106	43
2429401	17. May 1939	H 1147	25
2429401	17. May 1939	H 1148	40
2429401	17/18. May 1939	H 1149	30
2429425	10. June 1939	H 1164	8
2429456	11/12. July 1939	H 1182	60
2429461	16. July 1939	H 1187	27
2433453	20. June 1950	H 2124	25
2434457	21. March 1953	H 2639	30

On the basis of the photographic observations obtained at Konkoly Observatory four epochs of maxima were derived. There are included in the Table II. The variable starting from 1959 was intensively observed photoelectrically at Konkoly Observatory and at Skalnaté Pleso Observatory. Photoelectric observations in Budapest were obtained at 24-inch, f/6 reflector with a photoelectric photometer equipped with 1 P 21 photomultiplier and colour filters for the photometry in B and V region. Photoelectric observations of the variable at Skalnaté Pleso Observatory were obtained in two observational seasons in the years 1963 and 1964 with a photoelectric photometer attached at 24-inch, f/5.5 reflector. The optical part of the photometer is equipped with quarz Fabry lens which images the entrance pupil of the telescope into a form of disc of 4.3 mm in diameter on the photocathode of 1 P 21 photomultiplier. The photomultiplier was supplied from high voltage stabilizer NBZ 411 type and an electronic recorder EZ 4 type was used. The detailed description of the photometer will be done in fortcoming paper. The set of yellow observations obtained in the years 1963 - 1964 was supplied with the observations in B and U colours in the years 1967 and 1968. The standard filters for the UBV photometry were used. The observations obtained in the instrumental ubv system were converted into the standard UBV system.

THE PERIOD AND THE LIGHT CURVE

The long series of the observations over 40000 periods made possible the study of secular changes of the period. In our study we used the epochs of the maxima published by Detre /1934/ and mainly observations obtained by Detre and Tremko /this paper/. From Detre's list /Detre 1934/ we omitted two epochs derived by Jordan and we computed from Jordan's observations new epochs of maxima. We omitted from newer observations the epoch of the maximum derived by Strelkova /1960/, as it shows a very great residual from the calculated epoch. Probably there is a printing error in the original paper.

It is remarkable that the elements published by Prager /1930/ include parabolic term for the secular change of the period:

$$\mathrm{Max}_{phg} = \mathrm{J.D.}\ 2421077.977 + 0.5517622 \times E - 0.468\ 10^{-9} \times E^2 \qquad /1/$$

Later Detre /1934/ derived following elements:

$$\mathrm{Max}_{hel} = \mathrm{J.D.}\ 2421402.4206 + 0.55175981 \times E \qquad /2/$$

The last computation is that provided by Tsesevich /1966/:

$$\mathrm{Max}_{hel} = \mathrm{J.D.}\ 2421077.9868 + 0.551758775 \times E \qquad /3/$$

It is notworthy the deviation of $-0\overset{d}{.}008$ of the photoelectric epoch of maximum obtained by Geyer /1961/ from the elements /3/. Our computations give following elements:

$$Max_{hel} = J.D.\ 2421402.4270 + 0.55175834xE \qquad /4/$$

From the O - C values which are presented in the Table II. and also from the Fig. 1. it is clearly seen that the period is not constant. We did not compute the numerical value of the secular change as it is not clear whether the observed shortening is continuous or not. The latest observed epoch of the maximum /Fitch et al. 1966/ confirms our results about secular change of the period and it is shown that the statement put by Tsesevich /1966/ is not valid.

Table II.

Max. hel. J. D. 2400000+	E	O - C	Observer	Notes
15804.828	- 10145	- 0.011	Payne-Gaposchkin	pg
20251.450	- 2086	- 0.009	Zinner	v
21077.980	- 588	- 0.013	Robinson	pg
21402.427	0	000	Blazko	v
22081.6350	+ 1231	- 0.0065	Jordan	pg
22839.7576	+ 2605	+ 0.0002	Jordan	pg
24621.380	+ 5834	- 0.005	Parenago	pg
26477.504	+ 9198	+ 0.004	Detre	phm
26483.575	+ 9209	+ 0.005	Detre	phm
26488.542	+ 9218	+ 0.007	Detre	phm
26509.508	+ 9256	+ 0.006	Detre	phm
26520.545	+ 9276	+ 0.008	Detre	phm
26540.406	+ 9312	+ 0.006	Detre	phm
26556.407	+ 9341	+ 0.005	Detre	phm
26908.437	+ 9979	+ 0.013	Detre	phm
27260.457	+ 10617	+ 0.012	Detre	phm
27281.426	+ 10655	+ 0.014	Detre	phm
27311.200	+ 10709	- 0.007	Radlova	v
27543.4939	+ 11130	- 0.0034	Kleissen	pg

Table II. cont.

Max. hel. J.D. 2400000+	E	O - C	Observer	Notes
27558.390	+ 11157	- 0.005	Soloviev	v
27628.468	+ 11284	0.000	Soloviev	v
27927.516	+ 11826	- 0.005	Soloviev	v
27955.663	+ 11877	+ 0.002	Soloviev	v
28305.4779	+ 12511	+ 0.0023	Kleissen	pg
29360.431	+ 14423	- 0.007	Nachapkin	v
29456.447	+ 14597	+ 0.003	Tremko	pg
29461.422	+ 14606	+ 0.013	Tremko	pg
33453.391	+ 21841	+ 0.010	Tremko	pg
34130.377	+ 23068	- 0.011	Alania	pg
34457.580	+ 23661	- 0.001	Tremko	pg
35244.3875	+ 25087	- 0.0010	Detre	pe
35601.394	+ 25734	+ 0.018	Geyer	pg
36232.5813	+ 26878	- 0.0024	Geyer	pe
36305.4155	+ 27010	- 0.0053	Detre	pe
36343.4895	+ 27079	- 0.0016	Detre	pe
36348.4570	+ 27088	+ 0.0001	Detre	pe
36573.5685	+ 27496	- 0.0058	Detre	pe
36574.6705	+ 27498	- 0.0073	Detre	pe
36648.6094	+ 27632	- 0.0004	Detre	pe
36877.601	+ 28047	- 0.008	Satanova	pg
37025.458	+ 28315	- 0.006	Ahnert	v
38085.3844	+ 30236	- 0.0078	Tremko	pe
38448.4414	+ 30894	- 0.0078	Tremko	pe
38450.6447	+ 30898	- 0.0115	Tremko	pe
38464.4427	+ 30923	- 0.0074	Tremko	pe
38497.5455	+ 30983	- 0.0101	Tremko	pe
38789.977	+ 31513	- 0.011	Fitch	pe

The period for the interval J.D. 2436305 - J.D. 2438497 was derived from the photoelectric epochs of the mean light, obtained by Detre and Tremko /this paper/:

$$\text{Mean light}_{hel} = \text{J.D. } 2436305.3669 + 0.55175735 \times E \qquad /5/$$

The value of the period is lower as given by the equation /4/.

The epochs of the mean light on the ascending branch were tested for Blazko effect. The oscillation of the ascending branch is very small and lies within the limits of the observational errors. The heights of the maxima, the deeps of the minima and the heights of the hump at the ascending branch also do not show substantial variation. The presence or the absence of the brightening short before minimum in the observations of the different observers can be partly explained by the fact that the range of the brightening depends on wavelenght. The other couse can be longer exposures of some photographic observations.

The list of the epochs of the maxima, O - C differences and further data are collected in the Table II. The photoelectric epochs of the mean light which were used for the computation of the elements /5/ are in the Table III. and corresponding O - C differences are plotted on the Fig. 2. The photoelectric observations obtained at the Skalnaté Pleso Observatory were used for the construction of the U, B, V, light curves. The variable W CVn reaches in the V region the maximum brightness $10\overset{m}{.}065$ and in the minimum light $10\overset{m}{.}921$. Thus the amplitude of the light changes is $0\overset{m}{.}856$ which is in good agreement with the value derived from the photoelectric observations obtained by Detre in Budapest. M - m value derived from the V light curve is $0\overset{m}{.}153$ and the hump at the ascending branch is placed at the phase $0^{P}93$. The hump on the descending branch is located at the phase $0^{P}704$ and it is the most conspicuous in the B colour.

Table III.

Mean light. hel. J.D. 2430000 +	E	O - C	Observer	Notes
6305.3657	0	- 0.0012	Detre	pe
6348.4012	78	- 0.0028	Detre	pe
6574.6278	488	+ 0.0033	Detre	pe
6648.5609	622	+ 0.0009	Detre	pe
8085.3366	3226	+ 0.0005	Tremko	pe
8448.3925	3884	+ 0.0001	Tremko	pe
8450.5987	3888	- 0.0008	Tremko	pe
8497.4985	3973	- 0.0004	Tremko	pe

The colours in the maximum and in the minimum light are as follows:

	U - B	B - V
maximum	+ 0.071	+ 0.217
minimum	+ 0.070	+ 0.431

The U - B and B - V data for the minimum light differ only by 0.001 from those published by Sturch /1966/. The our observations confirm the supposition raised by Sturch /1966/ about the bluishing of the RR Lyrae-type variables with the $P > 0^{d}.5$ around the phase $0^{P}.7$. The U, B, V light curves are on the Figures 3, 4 and 5.

COLOUR - COLOUR DIAGRAM

Three colour observations of the variable make possible to construct U - B/B - V diagram. For the construction of the two colour diagram the data from the Table IV. were used. Two colour diagram for the variable W CVn is rather complicated mainly owing to the bluer colour around the phase $0^{P}.70$. The numbers at the different points of the two colour diagram on Fig. 6. denote the phase of the light changes. From the absolute magnitude and from the photometric data we can determine the distance of the variable if the interstellar absorption is known. The absolute magnitude can be derived on the basis of the period - absolute magnitude relation for the RR Lyrae-type variable with a period greater than 0.45 days /Woolley et al. 1965/:

$$M = - 0^{m}.10 - 2.5 \log P \qquad /6/$$

The distance r then can be derived from the well known equation:

$$M_V = m_V + 5 - 5 \log r - A_V \qquad /7/$$

The value A_V can be computed from the reddening. According to Woolley et al. /1965/ the stars with z coordinate higher as 100 parsecs above the galactic plane and in higher galactic latitudes are reddened by 0.05 x cosec b. The investigation performed by Sturch /1966/ has shown that the value for the reddening term for the stars with $b > 56^o$ is 0.02 x cosec b only, if the excesively reddened regions in Taurus and Ophiuchus are omitted but the stars with $b > 70^o$ are kept. Thus the reddening for the variable is very low and reaches $0^m.034$ and then the total visual absorption $A_V = 0^m.103$ if we accept the numerical value 3.03 for the ratio of total to selective absorption /Wickramasinghe N. C. 1967/. The ratio of total to selective absorption depends on the position of the star in the Galaxy relative to the Sun and can reach considerable higher value. Thus the derived total absorption can be considered as the lowest value. Woolley et al. /1965/ on the basis of the study of high galactic latitude RR Lyrae-type variables derived following relation for the determination of the visual absorption:

$$A_V = 3 \left[/B/ - /V/ - 0.24 \right] \qquad /8/$$

The mean B - V value for W CVn is $0^m.374$ and according to relation /8/ the visual absorption reaches $0^m.402$. Geyer /1961/ has found that W CVn is reddened by $0^m.08$ which leads to the visual absorption of 0^m244. The determination of the absorption according to the method derived by Woolley et al. /1965/ is very sensitive to the intrisic colour of the variable. The last term in the equation /8/ seems to be underestimated and the scatter in the B - V and mainly in U - B shows /Sturch 1966/ that even this high latitude sample of RR Lyrae-type variables is in this sense inhomogeneous. For these reasons we prefer the value of the visual absorption derived by the first method. As the median visual brightness $V = 10^m.606$ and the absolute visual magnitude computed from the equation /6/ $M_V = + 0^m.54$, the resulting distance of the variable derived with the aid of the equation /7/ is 980 pc.

Table IV.

Phase	U - B	B - V
0.00	+ 0.071	+ 0.217
0.10	+ 0.099	+ 0.272
0.20	+ 0.104	+ 0.334
0.30	+ 0.155	+ 0.322
0.40	+ 0.113	+ 0.399
0.50	+ 0.122	+ 0.420
0.60	+ 0.022	+ 0.447
0.65	+ 0.007	+ 0.474
0.70	+ 0.143	+ 0.367
0.71	+ 0.157	+ 0.331
0.73	+ 0.186	+ 0.361
0.75	+ 0.150	+ 0.409
0.77	+ 0.113	+ 0.423
0.87	+ 0.044	+ 0.457
0.93	- 0.025	+ 0.254
0.95	+ 0.012	+ 0.257

CONCLUSION

The variable star W CVn is RRab type with stabile and smooth light curve excluding the hump on the ascending branch which is most pronounced in B colour. The period is not constant and the secular shortening from the earliest observations was found but Blazko effect is not present. Two colour diagram has a rather complicated form due to the brightening at the phase $0^{p}.7$. Due to high glactic latitude of the variable the interstellar absorption is low and the adopted value is $0^{m}.10$. We determined the absolute magnitude which is $M_V = +0^{m}.54$ from the period - luminosity relation and after removing the interstellar absorption the distance of the variable r = 980 pc was found.

The author wishes to thank Prof. Dr. L. Detre for the opportunity to use the observing material of W CVn obtained at Konkoly Observatory and for many advices and stimulating discussions. He is indebted to the members of the staff of the Skalnaté Pleso observatory mainly to Messrs. L. Petrík, J. Petras and P. Zimmermann for assistance with 24-inch observing and for the help with the reductions of the photoelectric observations.

REFERENCES

Ahnert, P., 1961, MVS. 546.

Alania, I.F., 1954, Soviet Astron. Circ. 146.

Bugoslawski, N., 1927, Astron. Nachr. 229, 203.

Ceraski, W., 1907, Astron. Nachr. 176, 109.

Detre, L., 1934, Astron. Nachr. 254, 21.

Fitch, W.S., Wiśniewski, V.Z., Johnson, H.L., 1966, Commun. Lunar and Planet. Obs. 5, 71, 3.

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

Jordan, F., 1929, Publ. Allegh. Obs., VII, 44.

Joy, A., 1938, Astrophys. J. 88, 108.

Kleissen, E., 1939, Astron. Nachr. 267, 139.

Nachapkin, V.A., 1940, Tadzh. Observ. Circ. 44.

Parenago, P., 1930, Astron. Nachr. 240, 324.

Radlova, L.N., 1934, Len. Bull. 4. 28.

Robinson, V., 1930, Harv. Bull. 876.

Satanova, Eh. A., 1961, Soviet Astron. Circ. 218.

Strelkova, E.P., 1960, Soviet Astron. Circ. 209.

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

Tsesevich, V.P., 1966, Zvezdy Tipa RR Liry, Naukova Dumka, Kijev.

Wickramasinghe, N.C., 1967, Interstellar grains, CHapman and Hall, London.

Woolley Sir, R., Harding, G.A., Gassells A.I., Saunders, J., 1965, Roy. Observ. Bull, 97.

Zinner, E., 1912, Astron. Nachr. 190, 379.

Zinner, E., 1916, Astron, Nachr. 202, 233.

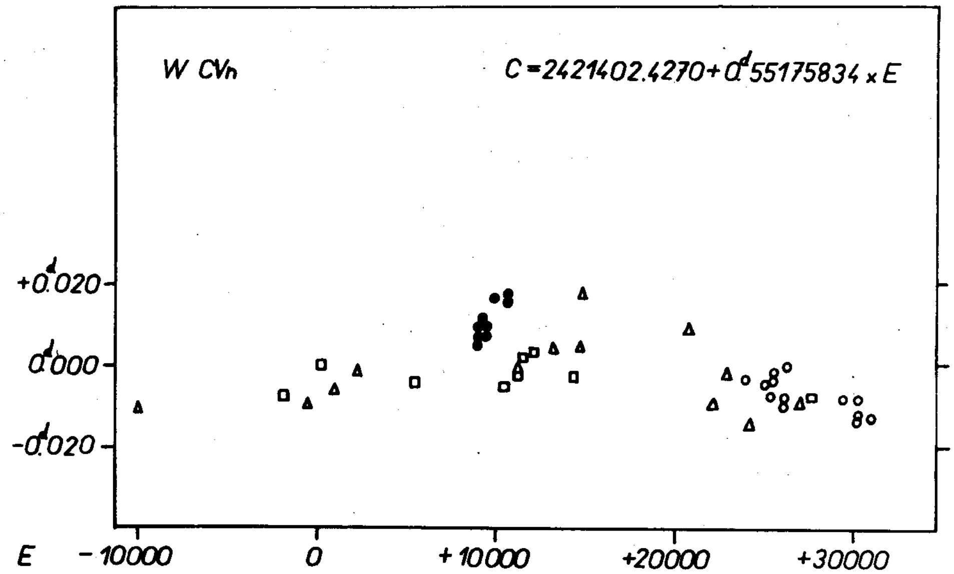

Fig. 1. O - C diagram for the epochs of maxima; squares denote visual observations, triangles photographic observations, full dots photometric observations and open circles photoelectric observations.

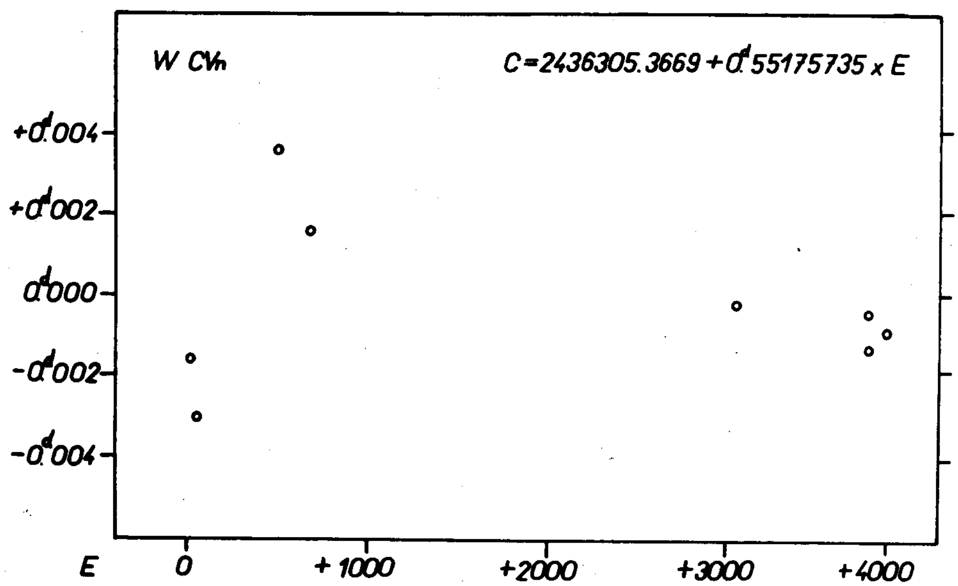

Fig. 2. O - C diagram for the epochs of the mean light from the Table III.

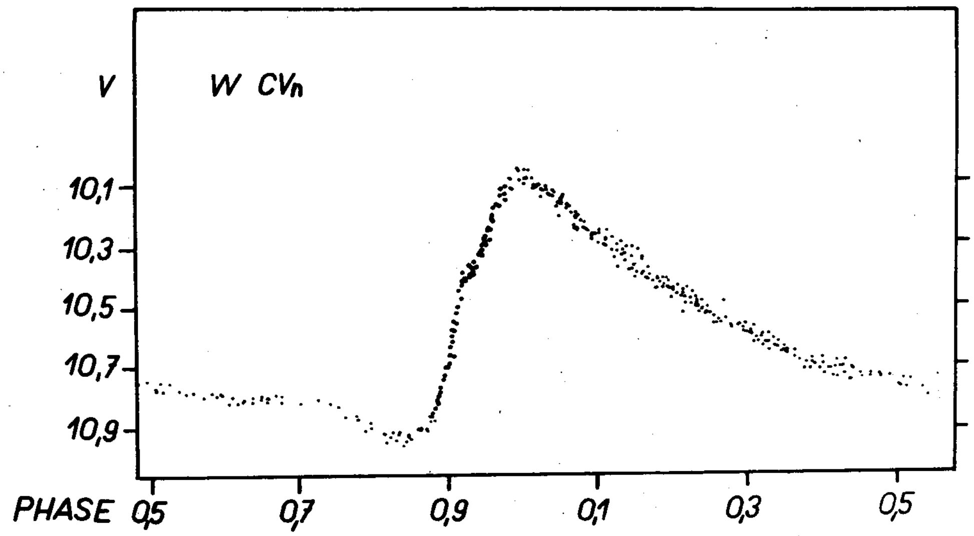

Fig. 3. V photoelectric light curve of W CVn. Full dots represent four observations, open circles represent two observations.

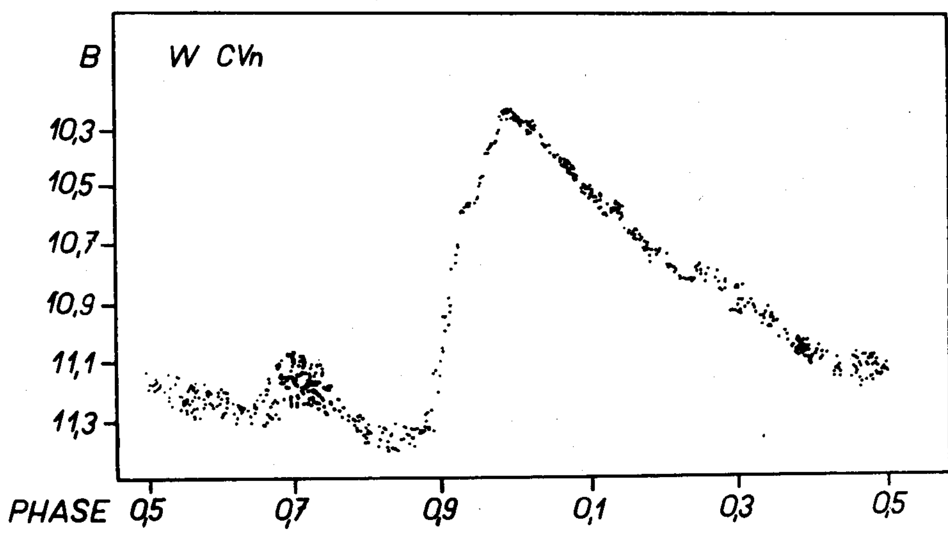

Fig. 4. B photoelectric light curve of W CVn.

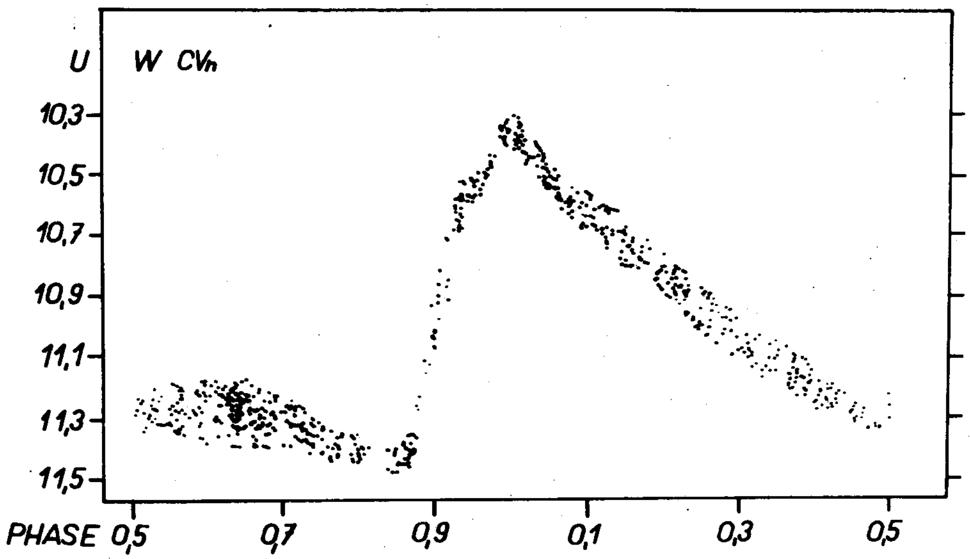

Fig. 5. U photoelectric light curve of W CVn.

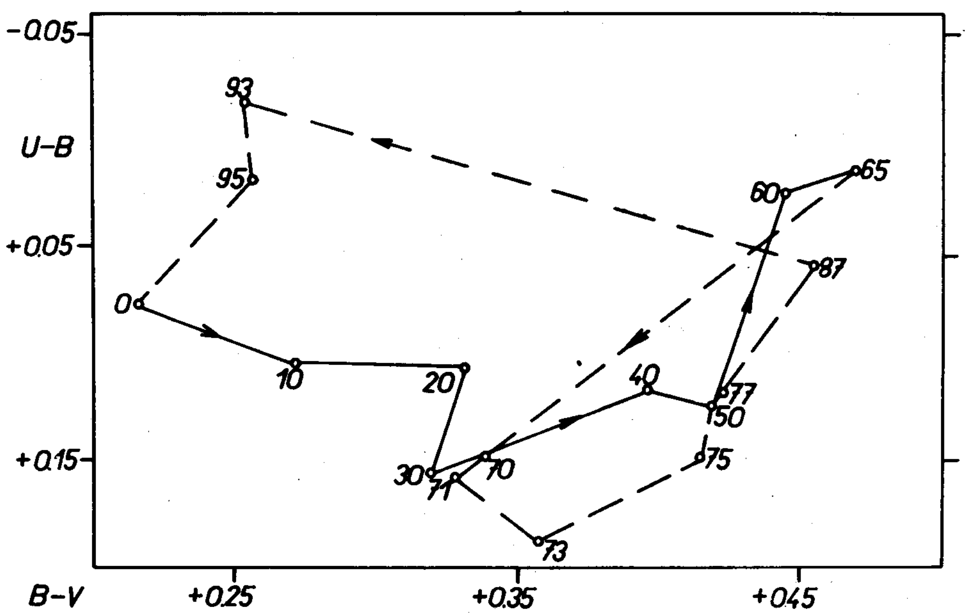

Fig. 6. Colour - colour diagram of W CVn. The numbers at the curve denote the phase.